European Commission

Supporting study for the review of the Ecodesign and Energy Labelling Regulations on ventilation units

Written Van Holsteijn en Kemna BV

July – 2020

EUROPEAN COMMISSION

Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs
Directorate C — Sustainable Industry and Mobility
Unit C.1 — Circular Economy and Construction

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European Commission
B-1049 Brussels

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Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs
Internal Market Programme
2020 EN

EN PDF ISBN 978-92-76-20667-5 doi: 10.2873/254887 ET-02-20-534-EN-N

Manuscript completed in July 2020

Final edition

Luxembourg: Publications Office of the European Union, 2020

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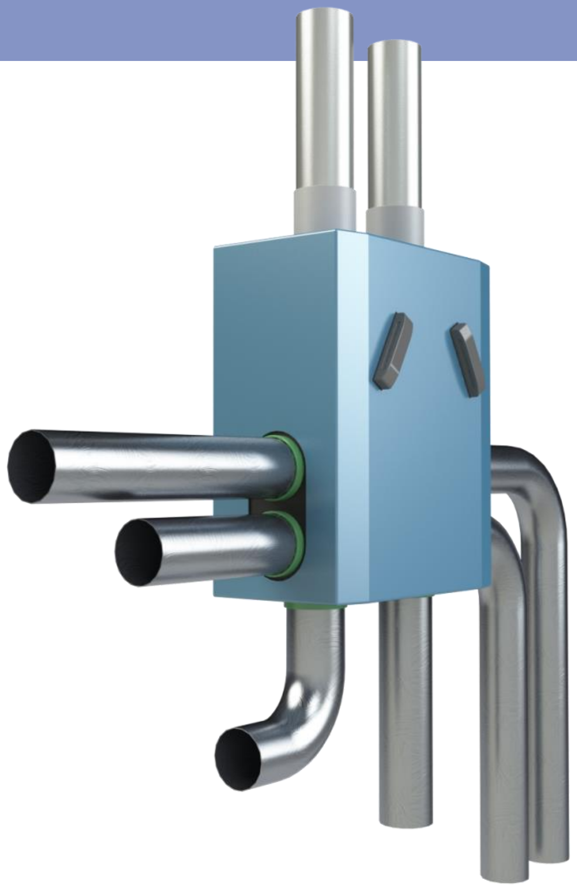

Preparatory Review Study

Phase 1.1 and phase 1.2

Final Report

TASK 1 Scope, standards & legislation

Review study on Regulations EU 1253/2014 (Ecodesign requirements for ventilation units) and EU 1254/2014 (energy labelling of residential ventilation units)

Prepared by
VHK, Delft (NL), for the
European Commission, DG GROW

March 2020

Grow

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Contract manager: VITO

Project website: www.ecoventilation-review.eu

Specific contract: No 681/PP/GRO/IMA/18/1131/10204-SI2.798223
Contract starting date: February 5th 2019

Consortium:

Cover: Ventilation unit [picture VHK 2019].

This study was ordered and paid for by the European Commission, DG Grow.

Executive summary

This is the final Task 1 report of the review study on the Ecodesign Commission Regulation (EU) No. 1253/2014 and Energy Label Commission Delegated Regulation (EU) No. 1254/2014 for ventilation units.

Task 1 includes the product scope, relevant test standards and relevant legislation, and in a sense evaluates the effectiveness of the current regulations with regards to these topics.

Chapter 1 describes the current product scope of both regulations and already addresses some items regarding the possible extension of the scope, following Article 8 of the EU 1253/2014 and Article 7 of the EU 1254/2014. It contains an initial assessment of the eligibility of proposed new products for Ecodesign legislation. The chapter also mentions the various proposals that were made for improving the text of both regulations and refers to the Annex 1, for a more detailed overview of these recommendations. Finally the chapter addresses the proposals that were done regarding additional exclusions from the scope. All proposed changes to scope and text that were presented by stakeholders were also discussed during the first stakeholder meeting of May 29th 2019 (see also related minutes).

Chapter 2 deals with the various Standards that are relevant with respect to the development of revised VU-regulations. As it is, there are transitional methods of measurement presented in the Commission communication and published in the Official Journal C 416, 11 November 2016, p. 16–30. The Commission also issued a standardisation request to the European Committee for Standardisation as regards ventilation units in support of Regulation (EU) No 1253/2014 and Delegated Regulation (EU) No 1254/2014a (Mandate M/537). The development and status of this standardization working is further discussed in this chapter and covers three main product groups: 1) Residential ventilation units (RVUs), 2) Non-residential ventilation units (NRVUs), and 3) Unidirectional ventilation units (UVUs)
The monitoring activities for these standards are at present performed by DTI[1] and look into consistency (e.g. Annex ZZ or ZA references to paragraphs in regulation), timelines of the development, possible loopholes and ambiguities.
The latest reporting of these monitoring activities are summarised below and include additional comments from VHK-side with respect to topics that may be relevant for the revision of the Regulations.
In addition to these product specific standards, the chapter also looks at EPBD-related standards, dealing amongst others, with the required performance of the ventilation units and related system. Finally, the standards that cover two related topics 'filtration' and 'material efficiency' are discussed.

Chapter 3 covers the topics dealing with legislative policies and measures affecting the performance and characteristics of ventilation units. Both generic EU legislation with relevance ventilation units as product specific legislation will be described in this chapter. The chapter reports that, especially national building regulations and national ventilation standards are governing building practices and ventilation requirements in new and existing buildings in the various member states. It is found that, *'although almost all these ventilation parameters are already defined in European Standards (and accepted in the CEN voting process by national bodies), the regulations in the*

[1] Danish Technological Institute

individual member states are different and clearly not harmonized. This inconsistency between EN standards and national regulations, as well as between member states, causes problems to designers and industry, and increases the cost. Furthermore, this practice is in contrast with the efforts of unification and standardization of the European common market'.

The Annex 1 that is attached to this Task 1 report, contains a detailed account of the recommendation stakeholders made, based on their experience with both current regulations EU 1253/2014 and EU 1254/2014.

Introduction

This final Task 1 report covers the current status of the work that has been done for Phase 1.1 and phase 1.2 of the Review Study, comprising the Technical Analysis and the update of the Preparatory studies. According to the Terms of Reference (T.o.R.) Phase 1.1 shall assess the items listed in Article 8 of Regulation 1253/2014 (Ecodesign of Ventilation Units) and Article 7 of Regulation 1254/2014 (Energy Labelling of Residential Ventilation Units), being:

a) the need to set requirements on air leakage rates in the light of technological progress
b) the possible extension of the scope of Regulation 1253/2014 to cover unidirectional units with an electric power input of less than 30 W, and bidirectional units, with a total electric power input for the fans of less than 30 W per air stream
c) the verification tolerances set out in Annex VI to Regulation 1253/2014
d) the appropriateness of taking into account the effects of low-energy consuming filters on the energy efficiency
e) the need to set a further tier with tightened Ecodesign requirements
f) the possible inclusion of other ventilation units, notably of non-residential units and of units with a total electric power input smaller than 30 W under Regulation 1254/2014,
g) the specific energy consumption calculation and classes for demand controlled unidirectional and bidirectional ventilation unit (in this respect, it would be very relevant to provide, if possible, an estimate of the efficiency and energy labelling levels of the installed base of residential and non-residential ventilation units in the European Union (EU).

According to the Terms of Reference the following additional items need to be analysed:
h) the influence of the ambient conditions and the climatic zones in the EU on the quantitative requirements for heat recovery
i) the need of specific provisions (and related formulation) on historic or listed buildings where the lack of space available can make it challenging to fit in ventilation units compliant with the two Regulations.
j) the need for (further) clarification on the nature of ‘box fans’ and ‘roof fans’, in particular concerning their compliance with the two Regulations, and the fans Ecodesign regulation 327/2011.
k) the need/feasibility to impose quantitative requirements on the maximum internal leakage for bidirectional ventilation units, as well as the need/feasibility of correction factors for the declared thermal efficiency of a residential ventilation units, based on the internal leakage rate
l) Introduction, in the text of the two Regulations (e.g. in the definitions of unidirectional and bidirectional ventilation units), of the clarifications contained in the ‘Question on a combination of a supply UVU and an exhaust UVU being considered as a BVU (11-2016)2‘
m) Improvement/increased description of the definition of ‘nominal flow rate’ of non-residential ventilation units
n) Improvements/changes in the definition of ‘ventilation unit’, with particular regard of the inclusion/exclusion of ventilation units for industrial applications (on the basis of FAQ 10 of the ‘Guidelines accompanying Regulation (EU) No 1254/2014

with regard to the energy labelling of residential ventilation units and Regulation (EU) No 1253/2014 with regard to Ecodesign requirements for ventilation units'.

o) The application and potential improvement of the requirement on the provision of instructions for the effective material recycling of the ventilation units (as in Annex IV - point 3 - of the Regulation 1253/2014).
p) Other clarification requests from stakeholder in the context of the stakeholder consultation process.

And finally, if needed, the existing 'Guidelines accompanying Regulation (EU) No 1254/2014 with regard to the energy labelling of residential ventilation units and Regulation (EU) No 1253/2014 with regard to Ecodesign requirements for ventilation units' will be updated .

In the subsequent phase 1.2 the Preparatory Studies are updated, where according to the T.o.R. at least the following additional items need to be addressed:

1) the identification of potential new functional parameters at product level, in particular concerning the indoor air quality when relevant and feasible
2) resource efficiency aspects3 - most likely disassembly, recyclability, reparability, durability and content of Critical Raw Materials (CRM), following the adoption of the Circular Economy Package in December 2015 and the new Ecodesign Working Plan 2016-2019. This includes the analysis of requirement already set (on the instruction for material recycling), their effectiveness in promoting the resource efficiency of ventilation unit, and the identification of additional and/or more ambitious requirements, when relevant (e.g. on the content of CRM in magnets).
3) the potential inclusion in the analysis of smart controls and demand control options (such as, but not limited to, solutions for building/home energy management system based on the European standards SAREF/SAREF4ENER).

The study is performed as a supplement to already existing preparatory studies for Lot 6 and Lot 10, indicating that topics that have already been addresses will not be addressed again, unless there are new elements to be reported.

This sub-report on Task 1, specifically deals with updates on topics regarding Scope, Standards and Legislation.

Acronyms and units

Acronyms

AC/DC	Alternating/Direct Current
ADCO	Administrative Co-operation
AHRI	American Air Conditioning, Heating and Refrigeration Institute
AMCA	Air Movement and Control Association
ATEX	ATmosphères EXplosibles
BC	Backward Curved
BVU	Bidirectional Ventilation Unit
CECED	European Committee of Domestic Equipment Manufacturers
CEN	European Committee for Standardization
CFD	Computer Fluid Dynamics
CIRCA	Communication and Information Resource Centre
CLP	Classification, Labelling and Packaging (Regulation)
DigitalEurope	Association representing the digital technology industry in Europe
DoC	Document of Conformity
DoE	US Department of Energy
EC	Electronically Commutating
EN	European Norm
EPEE	European Partnership for Energy and the Environment
Eurovent	Association of European refrigeration, air conditioning, air handling, heating and ventilation industry
EVIA	European Ventilation Industry Association
FC	Forward Curved
GWh	Giga Watt hour 10^9 Wh
HNL	Howden Netherlands
HRS	Heat Recovery System
ICSMS	Information and Communication System on Market Surveillance
ISO	International Standardisation Organisation
JBCE	Japan Business Council in Europe
JRAIA	Japan Refrigeration and Air Conditioning Industry Association
N	Efficiency grade
NRVU	Non-Residential Ventilation Unit
RAC	Run Around Coil
RAPEX	EU Rapid Alert System
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (Regulation)
RoHS	Restriction of Hazardous Substances (directive)
RVU	Residential Ventilation Unit
rpm	rounds per minute (unit for fan rotation speed)
TC	Technical Committee (in ISO, CEN, etc.)
TWh	Tera Watt hour 1012 Wh
UVU	Unidirectional Ventilation Unit
VU	Ventilation Unit
WEEE	Waste of electrical and electronic equipment (directive)
WG	Working Group (of a TC)
yr	year

Parameters

A	floor surface area building [m²]
cair	specific heat air [Wh/ m³.K]
Q	heat/energy [kWh]
q	hourly air exchange [$m^3.h^{-1}/ m^3$]
rec	ventilation recovery rate [-]
S	shell surface area building [m²]
SV	shell surface/volume ratio building
t	heating season hours [h]
T_{in}	Indoor temperature [°C]
T_{out}	outdoor temperature [°C]
U	insulation value in [W/K. m²]
V	heated building volume [m³]
ΔT	Indoor-outdoor temperature difference [°C]
η	efficiency [-]

Units

€	Euro
°C	degree Celsius
a	annum (year)
bn	billion (1000 million)
CO_2	carbon-dioxide (equivalent)
h	hours
K	degree Kelvin
kWh	kilo Watt hour
m	metre or million
m²	square metre
m³	cubic metre
Pa	Pascal
W	Watt

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1. Scope of the Regulation

1.1. Scope existing regulation

Table 1. Product scope following existing Ecodesign Regulation 1253/2014

<table>
<tr><td>Subject matter and Scope</td><td colspan="2">Ventilation Units (VU)
‘An electricity driven appliance equipped with at least one impeller, one motor and casing, intended to replace utilised air by outdoor air in a building or part of a building’</td></tr>
<tr><td>Exclusions</td><td colspan="2">a) Unidirectional units with electric power input < 30 W
b) Bidirectional units with electric power input < 30 W per air stream
c) Axial or centrifugal fans only equipped with a housing acc. Regulation 327/2011
d) Units exclusively specified as operating in potentially explosive atmosphere as defined in Directive 94/9/EC
e) Units exclusively specified as operating for emergency use, for short periods of time and comply with Regulation No. 305/2011
f) Unit exclusively specified as operating:
i. With temperatures of the air being moved >100°C
ii. In ambient temperatures for motor (outside airstream) > 60°C
iii. With temperatures of the air being moved, or ambient temperatures for motor (located outside airstream) < -40°C
iv. Where supply voltage > 1000 VAC or > 1500 VDC
v. In toxic, highly corrosive or flammable environments or environments with abrasive substances
g) Units that include a heat exchanger <u>and</u> a heat pump for heat recovery or allowing heat transfer or extraction being additional to that of the HRS, except heat transfer for frost protection or defrosting
h) Units classified as range hoods covered by EU 66/2016 on kitchen appliances</td></tr>
<tr><td>Distinction between RVU and NRVU</td><td>Residential Ventilation Unit (RVU) are units where:
– Qmax ≤ 250 m3/h
– Qmax is > 250 and ≤ 1000 m3/h and its declared intended use is exclusively for residential ventilation applications
– Qmax is declared at standard air conditions, using the complete unit (incl. filters, controls) installed acc. to manufact. instructions and at an external static pressure difference of
- 100 Pa for ducted RVU
- The lowest achievable ΔP selected from (10-20-100-150- 200-250 Pa) for non-ducted RVU</td><td>Non-Residential Ventilation Unit (NRVU) are units where:
a) Qmax is > 250 m3/h
b) Qmax is > 250 and ≤ 1000 m3/h and its declared intended use is <u>not</u> exclusively for residential ventilation applications</td></tr>
<tr><td>Types of RVU and NRVU</td><td colspan="2">Unidirectional Ventilation Unit (UVU)
A ventilation unit producing an airflow in one direction only (either exhaust or supply), where the mechanically induced airflow is balanced by natural air supply or exhaust.

Bidirectional Ventilation Unit (BVU)
A ventilation unit which produces an airflow between indoors and outdoors and is equipped with both exhaust and supply fans.</td></tr>
</table>

Table 2. Product scope following existing Energy Labelling Regulation 1254/2014

Subject matter and Scope	**Residential Ventilation Units (RVU)** 'An electricity driven appliance equipped with at least one impeller, one motor and casing, intended to replace utilised air by outdoor air in a dwelling or part of a dwelling'
Definition RVU	RVUs are units where: – Qmax ≤ 250 m3/h – Qmax is > 250 and ≤ 1000 m3/h and its declared intended use is exclusively for residential ventilation applications – Qmax is declared at standard air conditions, using the complete unit (incl. filters, controls) installed acc. to manufact. instructions and at an external static pressure difference of - 100 Pa for ducted RVU - The lowest achievable ΔP selected from (10-20-100-150- 200-250 Pa) for non-ducted RVU
Exclusions	a) Unidirectional units with electric power input < 30 W b) Units exclusively specified as operating in potentially explosive atmosphere as defined in Directive 94/9/EC c) Units exclusively specified as operating for emergency use, for short periods of time and comply with Regulation No. 305/2011 d) Unit exclusively specified as operating: i. With temperatures of the air being moved >100°C ii. In ambient temperatures for motor (outside airstream) > 60°C iii. With temperatures of the air being moved, or ambient temperatures for motor (located outside airstream) < -40°C iv. Where supply voltage > 1000 VAC or > 1500 VDC v. In toxic, highly corrosive or flammable environments or environments with abrasive substances e) Units that include a heat exchanger <u>and</u> a heat pump for heat recovery or allowing heat transfer or extraction being additional to that of the HRS, except heat transfer for frost protection or defrosting f) Units classified as range hoods covered by EU 66/2016 on kitchen appliances
Types of RVU	**Unidirectional Ventilation Unit (UVU)** A ventilation unit producing an airflow in one direction only (either exhaust or supply), where the mechanically induced airflow is balanced by natural air supply or exhaust. **Bidirectional Ventilation Unit (BVU)** A ventilation unit which produces an airflow between indoors and outdoors and is equipped with both exhaust and supply fans.

Main differences regarding the scope of the two regulations is the fact that the Energy Labelling Regulation only refers to residential ventilation units, where the Ecodesign Regulations relates to both residential and non-residential ventilation units.

Regarding exclusions, the main difference relates to the bidirectional units with <30watts per air stream and the axial or centrifugal fans only equipped with a housing according to Regulation 327/2011; both products types are excluded from the Ecodesign regulation but not from the Energy Labelling Delegated Regulation.
Unidirectional units with electric power input < 30 W are excluded from both Regulations. The Ecodesign regulation does however include these units where the information requirements are concerned.

Regarding the exclusion g) in the EU 1253/2014 and exclusion e) in the 1254/2014 regulation, there are ambiguities with regards to the actual meaning of this text.
Some people assume that this text only refers to multifunctional units, i.e. units that recover heat using a heat pump for additional (other than ventilation) functions like water- or space heating and cooling.
Others are of the opinion that text also refers to units that use an additional heat pump to recover energy from the exhaust air to the ventilation supply air.

If the first interpretation is correct, these BVUs with air-to-air heat pump are subject to the Regulations and could in principle be treated similarly to the HRS-only units.
In case the second interpretation is originally intended, the obvious next step is to include these BVUs with air-to-air heat pump in the regulation.

Currently, the product test standard FprEN13141-7 already covers residential BVUs with both type heat recovery solutions (i.e. units using a recuperative or regenerative air-to-air HRS, units that use an air-to-air heat pump, and units that use both). In that sense, the related test method is well underway.

In any case, both interpretations agree on the fact that BVUs that recover heat (using a HRS and a heat pump) for additional functions (other than ventilation) like water- or space heating/cooling, are excluded from the scope.

1.2. Proposed extensions to the product scope for RVUs

1.2.1. VUs with < 30 W per airstream

Article 8 of EU 1253/2014 and article 7 of EU 1254/2014 ask for an assessment of the need to extend the scope of both Regulations for ventilation units with an electric power input of less than 30 W per air stream.

For the Ecodesign Regulation this would mean an extension with both UVUs and BVUs with power inputs of < 30 watts per airstream. For energy labelling it would mean an extension with only UVUs < 30 watts.

Present market situation

Especially in the existing buildings market, decentralized ventilation units are gaining market share due to their relative easy and straightforward installation compared to centralized systems. Because decentralized units serve only one (sometimes two) rooms and do not need ductwork (only wall ducts), they generally have low power consumption per air stream (typically < 30W).
It is important to distinguish between decentralized ventilation units that are merely used for temporary extraction of humidity and odours from toilets/bathrooms/kitchens and decentralized ventilation units that are continuously running and/or monitoring the IAQ to achieve the requested air exchanges in the various rooms during presence and absence.

Although the former type VUs do not qualify as a ventilation unit in the sense that they do not comply with building code requirements regarding ventilation systems where the VUs may not be switched off, they do meet the definition of a VU and consume electricity and space heating energy (the thermal energy content of the extracted air). A quick calculation of the energy that is involved here (based on the previous preparatory studies) indicates that these temporary local exhaust UVUs in total consume around 24[2] TWh of primary energy per year, of which around 2.5 TWh relates to the power consumption of the fan and 21.5 TWh to heating energy consumption. This still is a considerable amount that equals for instance the total EU primary energy consumption for residential space cooling.

As indicated, the second type (continuously running) VUs is gaining market share. And because they continuously exchange indoor air with outdoor air, they are becoming an important product group where energy consumption is concerned. As it is, the bidirectional units (BVUs) are already covered by the current Energy Labelling Regulation, whereas the UVUs are not. This means that there is a serious gap in the existing regulations where the continuously running UVUs < 30 watts are concerned, especially considering the fact that there also is a trend towards lowering the power input of central extract UVUs (to values below 30 W).

Stakeholder positions

Some stakeholder are strongly in favour of extending the scope to VUs < 30 watts, while others are against.

[2] Around 65 million bathroom/kitchen/toilet fans in stock, operating on average 2 hours a day (estimated average occupation time in wet rooms) with an average power consumption of around 20 watts @ 100 m3/h. Average delta T between indoor and outdoor air is 10°, c_{air} = 0.000344 kWh/m^{3}K, PEF =2.5

Arguments in favour
Strong argument in favour is the fact that some manufacturers – since the regulation came into force - have developed new UVU units with power consumption below 30 watts, while previously selling similar units above 30 watts, just to be outside the scope of the regulation. No minimal efficiency and no energy label are required and because without air quality sensors these products are cheaper, they gain market share. Because of this the related energy saving potential for demand controlled units remains largely unexploited.

A French stakeholder pre-calculates that of the roughly 775.000 UVU-kits sold per year in France (new built, renovation and replacement) in the beginning, around 500.000 kits were manually controlled units above 30 watts and 275.000 kits were demand controlled (humidity, presence, VOC). In 2016 most of the actors were expecting the manually controlled kits to disappear by 2018, due to the Ecodesign and Energy Labelling Regulation. What actually happened is that some manufacturers replaced the demand controlled UVUs by manually controlled units < 30 watts and are today still supplying the largest part of this market, due to lower product cost. Aereco calculates that for this reason the saving potential in France only of around 0.5 TWh/yr that could be achieved with demand controlled UVUs, remains unaddressed.

In summary, the consequence of this 30 W limit in the Regulations is, that it becomes possible to realise UVU-systems in the residential sector (including centralized extract UVU-systems) without any need to comply with any energy efficiency regulation. This should not be possible.

Argument against
Main argument against extension of the regulation with VUs < 30 watts is that the burden related to the administrative and testing procedures as well as market surveillance, do not outweigh the energy savings than can be achieved.

Table 3 summarizes the position of the stakeholders who have taken a stand on the issue.

Table 3. Stakeholder in favour or against extension to <30 watts per air stream

In favour	Against
EUROVENT AERECO MITSUBISHI Electric, provided it is done in steps (1st step <20W, 2nd step < 15 W) EVIA, for continuous running VUs BAM: investigate its impact, then decide ALDES	EVIA, for non-continuous running UVUs

EVIA insists to exclude all incidental running units like toilet fans or single room fans, because they cannot be considered as (part of) a ventilation system. They propose the following definition for non-continuous UVUs:

Proposal EVIA for definition incidental running extract fans:
a single room exhaust ventilation unit intended to intermittently ventilate either one bathroom or one toilet (rest room) by means of an external switch (for example light switch) or built-in sensor (motion and timer, humidity, VOC, etc.)

Exemption: Special <30 W exhaust UVU for over-pressure common exhaust ducts
In case the 30 W limit will be lowered, UVUs especially designed for collective systems extracting odours and humidity from toilets and bathrooms shall be exempt from the

regulation. A particularly concerned product group relates to extract fans (UVUs) especially designed to discharge the extract air of up to 30 toilets and bathrooms of a multi-family dwelling into a common duct by means of over pressure.
Consequently these fans have to have a compact design and feature tight non-return dampers within their casing to avoid return flow of exhaust air. Furthermore to ensure a sufficient air flow for all toilets and bathrooms under all pressure conditions in the exhaust duct at any time, these special fans need to provide a constant air flow characteristic with very limited permissible deviations.
In Germany these fans are third-party certified and regularly monitored according to the DIN standard 18017-3. Because of all demands and boundary conditions of this particular application the therefore especially designed UVUs can't fulfil all eco-design requirements of EU1253 and should be exempt from requirements.

> Preliminary assessment in this Task 1 context is, that the options and related impacts of extending the scope to VU-units < 30 watts are interesting enough and will be further investigated in the following Tasks.

1.2.2. Multifunctional Residential BVUs

Multifunctional BVUs are units designed and supplied as a complete package with mount instructions, covering packages that contain at least, within one or more casing: supply and exhaust air fans, air filters, common control system, and one or more of the following three additional components: air to water heat pump; air to air heat pump; air-to-air heat exchanger, and fulfil additional heating/cooling functions next to its primary function *ventilation with heat recovery.* Residential BVUs including only an air to air heat exchanger and/or an *exhaust air* to *supply air* heat pump are covered by EN 13141-7.

Five of the leading European industry associations in the sector (EPEE, EHPA, Eurovent, EVIA and EHI) share common concerns over the approach taken to the integration of multifunctional units within the EU's framework for Energy Related Products (ERP).
In particular, they have reservations on the proposal outlined in the Task 7 Final Report1 on the revision of EU 206/2012 (Small air conditioners and comforts fans) to extend the scope to include ventilation exhaust air-to-air heat pumps and air conditioners whose rated capacity is ≤ 12 kW.
According to these European Industry Associations, *multifunctional bidirectional ventilation units* (two fans), having the primary function of ventilating the dwelling or building and delivering energy contributions to additional functions like space heating, cooling and/or domestic hot water should be included in the Regulations for ventilation units (EU 1253/2014 and EU 1254/2014) and <u>not</u> in the proposed revised scope of EU 206/2012.
Furthermore they stipulate that the multifunctional units including only one exhaust air fan, namely exhaust air heat pumps, are already covered by regulations (EU) 813/2013 and 814/2013 and shall remain in the scope of these regulations.

Definition and testing Multifunctional BVUs
According to the European Industry Associations (EPEE, EHPA, Eurovent, EVIA and EHI) the EN 16573 '*Ventilation for Buildings - Performance testing of components for residential buildings - Multifunctional balanced ventilation units for single family dwellings, including heat pumps'* can be a good starting point for defining and rating the multifunctional BVUs, because:

- It covers units than contain (within one or more casings) at least:
    - supply and exhaust air fans
    - air filters

  - control systems
  - one or more of the following components: air-to-air heat pump; air-to-water heat pump; air-to-air heat exchanger
- Its primary function is providing ventilation for single dwellings, while offering additional functions regarding hydronic heating or air heating, hydronic cooling or air cooling and/or hot water productions
- It delivers global performance indicators like EER, COP etc. and performance by functions at reference air volume flow considering the test standards EN13141-7, EN 14511 and EN 16147,

Criteria for eligibility

Products are eligible for measures if they are economically significant, have a significant environmental impact and represent a significant saving potential. Currently is it estimated that the sales figures of these multifunctional BVUs are below 15000 units a year.
Recent estimates from Eurovent for 2017 do not go beyond 4000 units.
If the related total primary energy consumption for the ventilation and heating function for these dwellings are estimated at around 50 kWh/m^2/year (5 MWh per dwelling per year), the total amount of energy on which multifunctional BVUs can achieve additional savings (when these 15000 units a year are actually achieved), are 75 GWh (15.000 x 5 MWh). Even if savings would be around 50 - 100%, we are still only talking about 0.038 - 0.075 TWh of maximum energy savings in the EU.

Preliminary assessment in this Task 1 context is, that the EU-saving potential in the short term might not be enough to justify extension of the scope per 2020/2021, but that it certainly is recommended to anticipate on future extensions by providing a proposal for a method for rating these multifunctional BVUs under the VU-Regulations EU 1253/2014 and EU 1254/2014.

Note: similar considerations as for Residential BVUs apply for non-residential BVUs.

1.3. Proposed adjustments in Regulation text

1.3.1. General remarks

As a general remark, stakeholder emphasized that, where the EVIA/EUROVENT Guidance Document can help improving/clarifying the text of the Regulations, this should be considered. Furthermore the latest status of the EN13142 and the 13141-series should be considered for any revisions of the Regulations.
It is therefore recommended to use these documents when the text of the Regulations are to be revised.

1.3.2. Definition Ventilation Unit

Another general comment relates to the definition for ventilation units (VUs) currently used in the Regulation. Stakeholders propose to use a more precise definition, explaining the primary purpose for the intended replacement of air.

Definition (see Article 2, Definitions, (1)):
'ventilation units (VU)' means an electricity driven appliance equipped with at least one impeller, one motor and a casing and intended to replace utilised air in a building or part of a building

This definition clearly defines the technical function of the ventilation unit, but it does not provide any clarification as to the purpose of exchanging the indoor air with outdoor air. This omission makes it extremely difficult to assess the performance of ventilation systems in general and to value demand controlled ventilation (DCV) systems in particular. If the purpose of the air exchange is not specified, it is not possible to indicate what air exchanges are useful and what air exchanges are not. And because pointless air exchanges involve considerable energy losses, it is very recommendable that the purpose of these air exchanges is further specified.

The current test standards EN 13141-series and EN 13053 do not contain any descriptions that can be used for further specification.
In the EN 16798-series (Energy Performance of Buildings, Input parameters for assessing the energy performance of buildings, addressing indoor air quality, thermal environment, lighting and acoustics), the section *Terms and Definitions* describes the term *ventilation* as:
The process of providing outdoor air by natural or mechanical means to a space or building

Although this definition still contains no leads for further specification of its purpose, the standard further elaborates in *section 6.3 and Informative Annex B.3* upon the aim of exchanging indoor air with outdoor air which primarily is achieving acceptable IAQ-levels.

Two pollutant sources are mentioned in this context:

a. Pollutants coming from the occupants (bio effluents)[3]
b. Pollutants coming from building materials and systems[4]

The main purpose of ventilation (exchange indoor air with outdoor air) therefore is the removal and/or dilution to acceptable concentration levels of pollutants mentioned under a) and b).

[3] It is assumed that pollutants include emissions coming from human activities in the building

[4] It is assumed that pollutants include emissions coming from decorative and interior products

With this explanation and clarification originating from FprEN 16798-1, the following adjusted definition is proposed.

Proposed new definition
'ventilation units (VU)' means an electricity driven appliance equipped with at least one impeller, one motor and a casing and intended to replace air that is utilised/polluted due to presence of human beings and their use of the building including emissions from building materials, decorative and interior product and equipment.

Stakeholders proposed something similar, but added another purpose for ventilation being the compensation or removal of internal and external heat gains. It is proposed not to include this additional function, because it serves a different purpose and a different control strategy. Furthermore, not all heat gains are useless and this function is closer to temperature control or ventilative cooling than it is to IAQ-control.

Further explanation of methods for determining the ventilation performance following this adjusted definition if given in section 2.10 dealing with this FprEN 16798-1

1.3.3. Specifically requested text adjustments

Various detailed proposals were made by stakeholders regarding adjustments and further explanation of the current text in the Regulations EU1253 and EU1254 (see also Annex 1. Stakeholder Comments to Existing Regulation, for a more detailed account of the recommendation stakeholders made in this context). These proposals were already discussed during the first stakeholder meeting in May 2019. They will be further evaluated together with de latest versions of the EVIA/Eurovent Guidance document dated February 10^{th}, 2017 and the document 'Frequently Asked Questions (FAQ) on the Ecodesign Directive', updated June 2019.

Eventually these modifications and additional clarifications will be further processed in the draft versions of the revised text of the Regulation.

1.4. Proposed revisions regarding Exclusions of the product scope

Stakeholder made various detailed proposals for further clarification of the products that are to be excluded from the scope of the Regulations EU1253 and EU1254.
(See also Annex 1, for more detailed description of the exclusions proposed by the various stakeholder).

1.4.1. AHUs primarily used for air heating/cooling with 0-10% ventilation

Stakeholder propose that AHUs, primarily used for air heating and/or cooling, having also a connection to the outdoor (i.e. a ventilation function) with a supply/exhaust air flow rate in regular heating operation (whenever using heat recovery) below 10% of the total declared air flow rate, are excluded from the scope. Such units should also be excluded when they are capable of operating with 100% outdoor air at designed airflow rate when exclusively intended for free-cooling purposes.

It has to be checked whether this proposal is feasible in the sense that it does not create a loophole and that is relates to a clear technical feature that can be checked by market surveillance.

1.4.2. VUs used for replacing old units in historic buildings

It is proposed that NRVUs that are used for replacing old worn units in construction objects having a verifiable status of the historic landmarked building, where fitting the ErP compliant unit is not feasible, are excluded.
In general, historical buildings and listed buildings may have special laws and exemptions in national or local building codes. Stakeholders suggest that on the basis of these national codes, and an investigation of the feasibility of the refurbishment by local authorities, ventilation units can be excluded from meeting minimum requirements if needed, given the architecture of the building, while still respecting the higher standard of energy efficiency.

The European Commission Regulation (EU) No 548/2014 of 21 May 2014 for power transformers already allows exemptions for such cases. Therefore Stakeholders propose to adapt the Regulation 1253 along the following lines (text based on wording included in the Transformers regulation No 548/2014). Stakeholders propose the following text,

This Regulation shall not apply to:

1. ventilation units for historic and listed buildings where the installation cannot be achieved in the available space, without changing the historic character of the building and entailing disproportionate costs associated to their transportation and/or installation,

except as regards the product information requirements and technical documentation set out in Annex V."

1.4.3. VUs exclusively for dehumidification and de-chlorination of spaces

Stakeholder propose to exclude NRVUs that are exclusively intended for dehumidification or de-chlorination of spaces not designated for human occupancy.

However, should the product be only for dehumidification/de-chlorination (e.g. in the case of a ventilation unit in a swimming pool environment used to remove the build-up of chlorine), this would also mean that the product functionality would be, specifically, dehumidification/de-chlorination, and not the replacing of utilised air; in this specific case, the product should be considered to be out of the scope of Regulation 1253/2014.

Here, it also has to be checked whether this proposal is feasible in the sense that it does not create a loophole and that is relates to a clear technical feature that can be checked by market surveillance.

1.4.4. UVUs not classified as range hoods but used in commercial kitchen hoods

It is proposed that UVUs equipped with at least one impeller, one motor and a casing, exclusively designed for operation in a commercial kitchen ventilation hood AND not covered in the scope of Commission Regulation EU 66/2014, are not included.

Again, it has to be further examined whether this '*exclusively designed for'* is a clear technical product feature that can be checked.

1.4.5. Bypass facility exception for certain BVUs

Stakeholders proposed an exclusion to Annex III, point (2) of the EU1253 regarding thermal bypass. Existing text is as follows: *'The HRS shall have a thermal bypass facility;*

It is proposed to add the following exclusion:
'except for duly justified cases (notably swimming-pool or high supply air temperature application), requiring heat recovery all year long.

It has to be checked whether this proposal is feasible in the sense that it does not create a loophole and that is relates to a verifiable technical feature.

1.4.6. Toxic environment

Stakeholder propose to add explanatory text to Exclusions *f. (v)* in Article I of the EU1253.
Current text:

> *'Units exclusively specified as operating in toxic, highly corrosive or flammable environments or environments with abrasive substances'*,

Proposed additional text:

> *'and are exclusively designed for abstract of air from such an environment without any purpose of ventilation (e.g. an extract air unit for a laboratory fume hood or a technical extraction system of a machinery)*.

Only ventilation units that are *exclusively designed* for application within production processes are excluded; not any other units (for example: a ventilation unit that also can be used for the office has to comply with the regulation).

Question that needs answering: is this exclusion feasible in the sense that is relates to a verifiable technical feature and does not create a loophole?

Regarding the exclusions in general, stakeholders propose to use the decision tree[5] displayed below, to help deciding whether a VU is covered by the regulation.

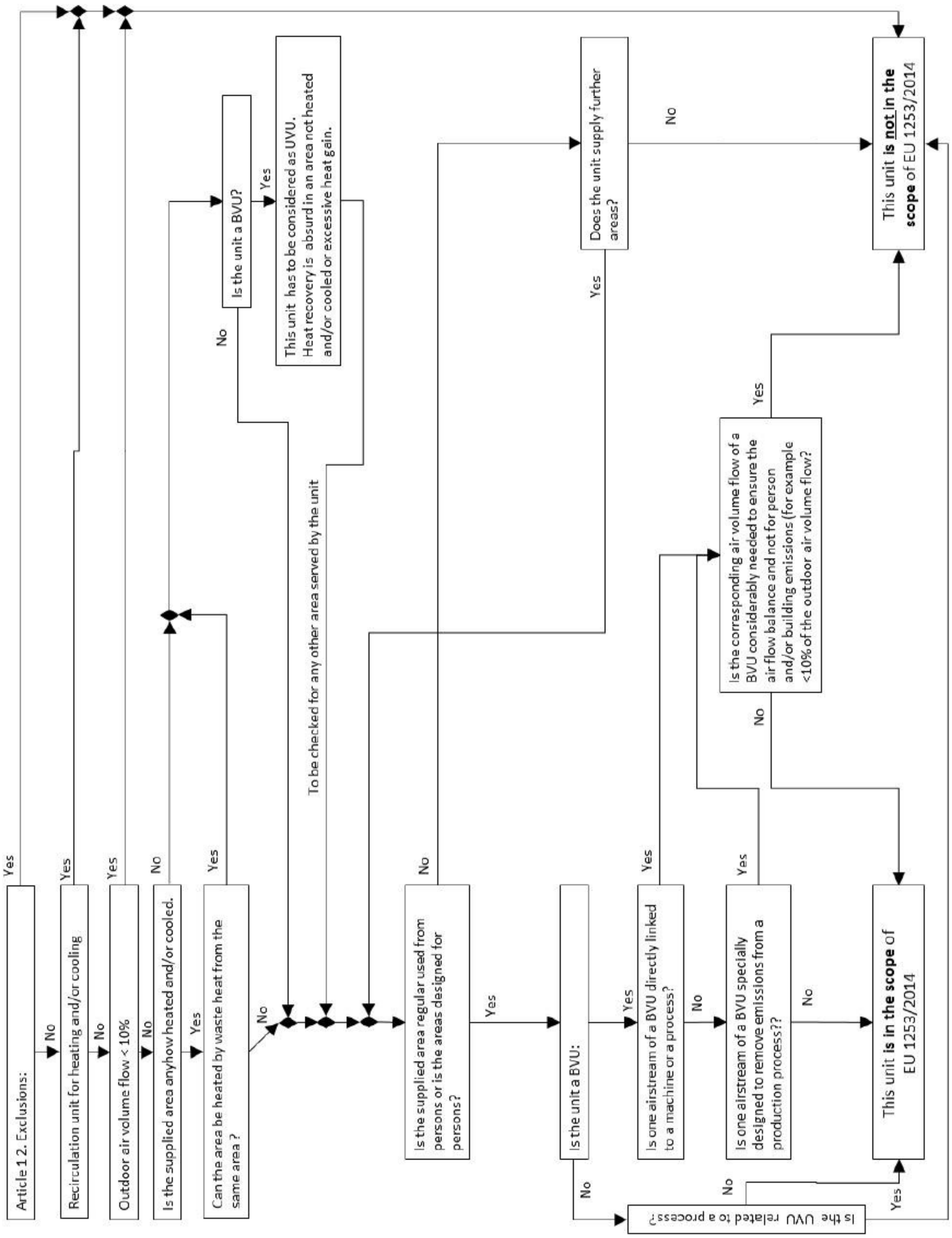


Figure 1. Decision tree for determining what VUs are excluded from the scope

[5] EVIA/Eurovent Guidance Document on Ecodesign requirements for ventilation units Release 3 – 10th Feb. 2017 - Including EVIA, Eurovent and EU Commission comments

2. Standards

This Chapter presents test standards relevant for performance assessment of ventilation units. The first section deals with the harmonisation of standards, followed by sections describing standards by product group and/or parameter.

2.1 Harmonisation of standards

Harmonisation of standards

Technical standards, laying down constructional requirements on how to assess performance or safety are normally developed by the European Standardisation Organisations (ESOs): CEN, CENELEC and ETSI.

If the Commission has issued a '*request for standardisation*' (a '*Mandate*') the standard developed by the ESOs at this request is considered *'harmonised'* when finalised and published. However, it is only after the publication of the references of these standards in the Official Journal that '*presumption of conformity*' can apply. In general terms these two distinct steps are often referred to as a single step called '*harmonisation'* (of standards).

See also Regulation (EU) No 1025/2012 of the European Parliament and of the Council of 25 October 2012 on European standardisation, Article 3.2 of Decision 768/2008/EC and CEN/CENELEC FAQ[6].

Standards harmonised for Regulation (EU) No 1253/2014 and Regulation (EU) No 1254/2014

There are currently **no** references of harmonised standards which have been published in the Official Journal of the European Union for[7] ventilation units.

2.2 Transitional Methods for ventilation units

There are transitional methods of measurement presented in the Commission communication in the framework of the implementation of Commission Regulation (EU) No 1253/2014 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for ventilation units and of the implementation of Commission Delegated Regulation (EU) No 1254/2014 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of residential ventilation units - Publication of titles and references of transitional methods of measurement and calculation - Official Journal C 416, 11 November 2016, p. 16–30

2.3 Mandate M537

M/537 COMMISSION IMPLEMENTING DECISION C(2015) 8325 final of 27.11.2015 on a standardisation request to the European Committee for Standardisation as regards ventilation units in support of Regulation (EU) No 1253/2014 and Delegated Regulation (EU) No 1254/2014

There are three main product groups:

1) Residential ventilation units (RVUs),
2) Non-residential ventilation units (NRVUs), and

[6] https://www.cencenelec.eu/helpers/Pages/FAQ.aspx
[7] https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/ecodesign_en

3) Unidirectional ventilation units (UVUs)

The related tests standards (part of M/537) are all developed within CEN Technical Committee 156 – “Ventilation for buildings”.

CEN/TC Working Group 2 “Natural and mechanical powered residential ventilation” is working on the standards related to residential ventilation units (RVU). The standards prEN13142, prEN 13141-4, 7 and 8 are still in drafting phase and have to be dispatched to CCMC for formal vote the latest on 21-01-2020. The draft standards will be discussed in more detail in the following chapters.

CEN/TC WG 5 “Air handling units” is working on the standards related to non-residential ventilation units (NRVU). FprEN13053:2018 has been approved and the date of publication was set on the CEN website for 31-07-2019[8]. This standard will be discussed in chapter 1.6.8 in more detail.

Standards for part of the non-residential ventilation units, the so-called unidirectional ventilation units (UVU), are covered by TC156 fan workgroup WG 17 “Fans”.
prEN 17291 is being prepared for the formal voting stage (last stage)[9].

The monitoring activities for these standards are at present performed by DTI[10] and look into consistency (e.g. Annex ZZ or ZA references to paragraphs in regulation), timelines of the development, possible loopholes and ambiguities.
The latest reporting of these monitoring activities are summarised below and include additional comments from VHK-side with respect to topics that may be relevant for the revision of the Regulations.

2.4 FprEN 13142[11]

Ventilation for Buildings – Components/ products for residential ventilation – Required and optional performance characteristics

Summary

prEN 13142 is a product standard with references to the EN 13141-x standards for testing procedures and includes unidirectional ventilation units (UVU) and bidirectional ventilation units (BVU)

prEN 13142 specifies and classifies the component/product performance characteristics which may be necessary for the design, rating and dimensioning, placing on the market of residential ventilation products and systems to provide the predetermined performance, comfort conditions of temperature, air velocity, humidity, hygiene and sound in the occupied zone.

prEN 13142 defines those performance characteristics (mandatory or optional) which shall be determined, measured and presented according to relevant test methods. It provides a classification scheme which leads to a full definition of product properties based on test

[8] https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_LANG_ID:62289,25&cs=1DFFE8D5442B92B48E87FCDA1833C518F
[9] Voting stage is set for 3-11-2019 https://standards.cen.eu/dyn/www/f?p=204:22:0::::FSP_ORG_ID,FSP_LANG_ID:951766,25&cs=199DED2F9023421D11C73B5DC5A8F3C88
[10] Danish Technological Institute
[11] Version date: 2019-05

methods described in various EN Standards and gives an overview of the test standards. Distinction between mandatory and optional requirement is left to European and national regulations.

The codification part in Annex A B and the classification part in Clause 8 apply to the following products:

- unidirectional mechanical supply and exhaust residential ventilation units according to prEN 13141-4
- ducted mechanical bidirectional residential ventilation units according to prEN 13141-7
- non-ducted mechanical bidirectional residential ventilation units according to prEN 13141-8

prEN13142 does not apply to other products such as filters, fire dampers, ducts, control devices and sound attenuators, which may also be incorporated in residential ventilation.

Issues related to Regulations (EU) 1253:2014 and EU1254/2014:

- A new annex ZA considering EU1253/2014 is added
- A new annex ZB considering EU1254/2014 is added
- Link and references to prEN13141-4, 7 and 8
- An informative Annex G about SEC calculation
- Proposal of temperature ratio correction at reference air volume flow

Comments to the test standard FprEN13142

Possible arrangements and the relevant standards for testing, classification and codification have been included in an informative Annex C of prEN13142.

One of the observations made by the monitoring consultants is that the temperature ratio at reference air volume flow must be corrected. As described in the prEN13141-series, the leakage, mixing and flow balance then has influence on the efficiency. Therefore, it is proposed that the temperature ratio, η_0 shall be corrected depending on relevant values. The corrections end up in a temperature ratio η_5. The corrected temperature is not in alignment with the Regulation (EU) 1253:2014.
This proposal has been reason for discussion at WG 2 meetings and in the table of comments for the prEN13142. It seems that is has been accepted by the WG 2 that η_0 is still going to be used for declaration in alignment with Regulations 1253:2014 and 1254:2014, WG 2 recommends to consider the full standard including the η correction for the revision of the regulation.

The leakage issue regarding bidirectional ventilation units is an ongoing discussion. The discussion focusses mainly on the internal leakage in RVUs with a regenerative heat exchanger.
The standard provides methods for measurements and calculations or a reference to another relevant standards is made for at least following parameters:

- The specific energy consumption (SEC)
- The specific power input (SPI)
- The thermal efficiency of heat recovery (η_t)
- Sound power level (L_{wa})

Furthermore, the test standard provides methods for measurements and calculations of following parameters related to information requirements:

- Maximum flow rate
- Reference flow rate
- Reference pressure difference

- Electric power input
- External leakage
- Air flow sensitivity
- Indoor/outdoor air tightness
- Exhaust air transfer ratio
- Indoor mixing
- Outdoor mixing

Additional comments VHK

1.
Informative Annex G, SEC calculation according to EU 1253/2014 and EU 1254/2014
Annex G (amongst others) points out a mistake in the existing Regulation EU1254 formula for AEC (Annual Electricity Consumption per 100 m^2). Current formula is:

$$AEC = q_{net} * MISC * CTRL_x * SPI + Q_{defr}$$

The Q_{defr} in this formula relates to primary energy (not electricity consumption) and needs to corrected (divided) by the *pef*-value. Furthermore the AEC-value relates to the annual electricity consumption per 100 m^2 but the formula calculates the consumption per m^2. Therefore either the definition of AEC needs to be adjusted or the formula needs to be multiplied by 100.

2.
Informative Annex F, Calculation of an extended SEC considering Infiltration
According to the Working Group, the current SEC-calculation does not consider the impact of the pressure of ventilation systems on the infiltration. Because of this, the comparison between unidirectional (over or under pressure) and balanced systems is considered not done properly. An additional correction parameter *'INF'* is proposed to compensate for this omission, resulting in an increased reference natural ventilation rate and consequently in lower SEC-value for UVU-systems.

Furthermore, this Annex F proposes a modified MISC-factor, because the existing one does not reflect the real aspects of cascading in dwellings.
MISC is an aggregated general typology factor, incorporating factors for ventilation effectiveness, duct leakages and extra infiltration. Current values are 1.1 for ducted units and 1.21 for non-ducted units.
It is proposed to change these values into 1 for all UVUs and central BVUs, and to 1.5 – 2.0 for single room BVUs.

The proposals in this Annex F is further discussed and evaluated in Task 3 and Task 6.

3.
Informative Annex E , Calculation of an extended SEC considering Infiltration
This proposal for an extended SEC-calculation is based on regulations of the Swiss Deklaration Komfortlüftung[12] and on results from a project[13] looking at defrosting in residential ventilation units.

[12] Komfortlüftung Deklariert / Comfort Ventilation Declaration, internet comparison tool for energy efficiency and other features of comfort ventilation systems; url: www.deklariert.ch

[13] Amman, Josef; Keller, Patrick: Effizienter Vereissungsschutz (VS) bei Lüftungsanlagen, insbesondere Konfortlüftungssystemen. Schlussbericht des BFE-Projekts Nr. 810001346, Bern, Verein Energie-Cluster.ch, 2015

It looks with more detail into the energy consumption for defrosting, preheating (if applicable) and the actual occurring recovery in HR-units. It is a rather extensive Annex using lots of formulas to achieve a probable improvement in accuracy.

4.
Corrected Temperature Ratio described in FprEN13142 and related EN 13141-series
The test standards apply a correction factor to the thermal efficiency (temperature ratio) where the Regulation does not. This correction is applied to compensate for:

- Internal leakages
- Outdoor mixing
- Indoor mixing
- External leakage
- Air flow sensitivity

This seems legitimate and justifiable since these unintended airflows can seriously influence the temperature ratio.

Section 5.1.4 'Correction of temperature ratio' of the FprEN13142 describes the calculation the method that is to be used to determine the corrected value.

Table 4. Temperature ratio correction at reference airflow (Table 2 in the FprEN13142)

Measure	Result	Unit	Temperature ratio correction	
			Non-ducted units	**Ducted units**
Temperature ratio on supply air side	η_0	—	—	—
Internal leakage	w	—	$\eta_1 = \eta_0 \times (1 - 0{,}7 \times (w - 0{,}02))$	$\eta_1 = \eta_0 \times (1 - 0{,}7 \times (w - 0{,}02))$
Outdoor mixing	o	—	$\eta_2 = \eta_1 \times (1 - (o - 0{,}02))$	$\eta_2 = \eta_1$ [a]
Indoor mixing	y	—	$\eta_3 = \eta_2 \times (1 - (y - 0{,}02))$	$\eta_3 = \eta_2$ [a]
External leakage	z	—	$\eta_4 = \eta_3$ [b]	$\eta_4 = \eta_3$ [b]
Air flow sensitivity	v	—	$\eta_5 = \eta_4 \times (1 - (v - 0{,}02))^{0{,}4}$	$\eta_5 = \eta_4 \times (1 - (v - 0{,}02))^{0{,}4}$

[a] The outdoor mixing depends on the duct system and not on the unit. There is no mixing in typical installations.
[b] The impact of external leakage depends on the design of the unit. No further correction shall be done.

NOTE.
To take into account the uncertainty of measurement, the corrections given in Table 2 are applied for each individual value in percentage only if the deviation for each criterion given in Table 2 is bigger than 2 %, and the correction is reduced from this percentage.

5.
Filter clogging compensation factor according to informative Annex D

Another parameter that may influence the actual temperature ratio and specified supply airflow is the fact that filters overtime will get clogged, which increases the resistance in the flow path and subsequently may reduce the supply airflow rate.

Informative Annex D of the FprEN13142/2019 proposes a method to assess the sensitivity of a ventilation unit to this filter clogging effect. Section D.2 of this Annex describes the method:

D.2. Definition and calculation of the filter compensation factor

The filter compensation factor (*FC*) is determined by adding an additional pressure drop during the test of the unit. This additional pressure is set to 1,5 times the initial pressure drop of the clean filter and is deemed representative of the clogged filter additional pressure drop.

The *FC* factor is calculated according to Formula (D.1).

$$FC = \frac{(q_{\text{vref}} - q_{\text{vfc}})}{q_{\text{vref}}} \qquad \text{(D.1)}$$

where

q_{vref} is the reference air flow according to EN 13141-4, EN 13141-6, EN 13141-7, EN 13141-8 or EN 13141-11, with clean filters;

q_{vfc} is the air flow with an additional pressure drop of 1,5 times the initial pressure drop of the filter.

For bidirectional ventilation units, FC shall be determined on both supply and exhaust sides.

The test method is the following:

a) The initial pressure drop of the filter ($\Delta p_{\text{initial}}$) is measured according to EN ISO 16890 series at reference air flow (q_{vref}).
b) The ventilation unit is set at the reference air flow (regular test) according to the relevant part of the EN 13141 series with clean filters.
c) A pressure drop Δp_{fc} corresponding to 1,5 x $\Delta p_{\text{initial}}$ is added at the outside connection of the ventilation unit.
d) The resulting air flow q_{vfc} is measured and reported.
e) The ratio *FC* (filter clogging air flow reduction) is calculated according to D.2 and reported.

As it is, this FC-factor is *optional* parameter and is not used when calculating the corrected temperature ratio η_5.

6.
<u>No correction on air volume flow and specific power input</u>

Leakage ratios that in total may be as high as 30% or more (especially for unducted units) also affect the ventilation performance of the unit, because the declared airflows will not be achieved.
This does not only ask for a correction of the temperature ratio, but also the declared flow rates need to be corrected and well as the related SPI.

As is it the new FprEN13142 does not provide for corrections of the declared airflows and related SPI-values.

2.5 FprEN 13141-4:2019[14]

Ventilation for Buildings – Performance testing of components/products for residential ventilation – Part 4 Aerodynamic, electrical power and acoustic performance of unidirectional ventilation units

Summary

FprEN13141-4:2019 specifies aerodynamic, acoustic and electrical power performance test methods for unidirectional ventilation units used in residential ventilation systems. The prEn13141-4 is applicable to ventilation units:

- installed on a wall or in a window without any duct, A category
- installed in the upstream of a duct, B category
- installed in the downstream of a duct, C category
- installed in a duct, or with duct connection upstream and downstream, D category
- with one or several inlets/outlets
- installed in a system with a heat pump for domestic hot water or water for cooling or heating
- which can be used for supply or exhaust

This standard does not apply to:

- fan assisted cowls which are tested according to EN 13141-5;
- mechanical supply and exhaust units which are tested according to prEN 13141-7 or prEN 13141-8.

Issues related to Regulation (EU) 1253:2014:

- The leakage test is included in the standard. This is in alignment with review of the Regulation (EU) 1253:2014
- Determination of the maximum air flow is added in standard and is in alignment with the Regulation (EU) 1253:2014
- Determination of the reference flow is also added and is in alignment with the Regulation (EU) 1253:2014
- The acoustic chapter has been reorganized and updated with the correct references to the relevant test standards. Following tests are added:
    - Noise radiated by casing for ducted units
    - Radiated Sound power in the indoor or outdoor space and the air airborne sound insulation of the non-ducted units

Comments to the test standard FprEN13141-4
The revision of the test standard EN13141-4 aims for alignment with the definitions and requirements in the Regulation (EU) 1253:2014.The standard included improved test methods and calculations.
In the standard the methods and test procedure are described more distinctly and sufficiently. For example, determination of the external pressure and a tolerance regarding the maximum air flow is included which is needed from a testing laboratory perspective.
The standard provides methods for measurements and calculations for at least following parameters

- Sound power level (L_{wa})

The test standard provides methods for measurements and calculations of following parameters for information requirements

- Maximum flow rate

[14] Version date: 2019-05

- Reference flow rate
- Reference pressure difference
- Electric power input
- External leakage
- Air flow sensitivity to pressure variations at -20 Pa and 20 Pa for non-ducted
- Indoor / outdoor tightness

Additional comments VHK

1.

Test method for determining indoor/outdoor airtightness

The proposed test method for determining the indoor/outdoor airtightness prescribes that if the unit is equipped with a manual of automatic shutter, the measurement shall be done with a closed shutter.
The study team is of the opinion that – for UVUs that are intended for dwelling ventilation (opposite to occasionally operating units for bathrooms and toilets) - this text provides a significant loophole, since only an automatic shutter or valve will results in a correct operation of the shutter/valve during periods no ventilation is required (DCV-controlled). A manual shutter will not be operated properly all of the time and may not provide a loophole. It is proposed to test the manually operated shutters in the open position.

2.6 FprEN 13141-7:2019[15]

Ventilation for Buildings – Performance testing of Components/products for residential ventilation – Part 7: Performance testing of ducted mechanical supply and exhaust ventilation units including heat recovery.

Summary

FprEN 13141-7:2019 specifies the laboratory test methods and test requirements for the testing of aerodynamic, thermal, acoustic and electrical performance characteristics of ducted mechanical supply and exhaust ventilation units intended for single family houses/dwellings. This standard is applicable to units that contain at least, within one or more casing:

- fans for mechanical supply and exhaust
- air filters
- air-to-air heat exchanger and/or air-to-air heat pump for air heat recovery
- control system

Such a unit can be provided in more than one assembly, the separate assemblies of which are designed to be used together.
Examples of different possible arrangements of heat recovery, heat exchangers and/or heat pumps are described in Annex A.

FprEN 13141-7 does not cover:

- ventilation units with continuous mass flows for each setting point.
- non-ducted units that are treated in EN 13141-8.
- ventilation systems that may also provide water space heating and hot water that are treated in EN 16573.

[15] Version date: 2019-05

- units including combustion engine, driven compression heat pumps and absorption heat pumps.

Electrical safety requirements are also excluded from this standard but are given in EN 60335-2-40 and EN 60335-2-80.

Issues regarding the Regulation (EU) 1253:2014:

- The leakage limits are changed in the standard.
- Determination of the maximum air flow is corrected in standard and is in alignment with the Regulation (EU) 1253:2014
- Determination of the reference flow is also corrected and is in alignment with the Regulation (EU) 1253:2014

Comments to the test standard FprEN13141-7

The revision of the test standard EN13141-7 aims for alignment with the definitions and requirements in the Regulation (EU) 1253:2014.The internal and external leakage rates are determined according to a certain volume flow. In the revised standard this reference has been changed to the reference air volume flow (as defined in Regulation 1253:2014) where in the current standard (EN13141-7:2010) the reference is the declared maximum flow. The required leakage class to allow measurements has been changed as well. For a typical RVU configuration, the fans are positioned in exhaust air and supply air respectively, which gives under pressure at both air sides of the RVU. For this configuration, the allowed class is “A3” for pressurization and “B3” for the tracer gas test. This allows an internal leakage rate, at 100 Pa and the reference flow as reference, to be up to 14%. In the current standard EN13141-7:2010, the allowed leakage rate is up to 10 % at 100 Pa and declared maximum air flow as reference. This means that the allowed leakage rate level is unchanged and aligned with the change in reference. Study of leakage test results have shown that a significant number of RVUs with recuperative heat exchangers have a leakage under 7 % (according to EN13141-7:2010) which corresponds with class A2. In other words, the allowed leakage rate may be conservative.

The leakage issue is an ongoing discussion where the focus is mostly on the internal leakage in RVUs with a regenerative heat exchanger.
In the draft standard the methods and test procedure are described more distinctly and sufficiently. For example a description of the determination of the external pressure and tolerance regarding the maximum air flow is now included which was needed.
The standard provides methods for measurements and calculations for at least following parameters

- The thermal efficiency of heat recovery (η_t)
- Sound power level (L_{wa})

The test standard provides methods for measurements and calculations of following parameters for information requirements

- Maximum flow rate
- Reference flow rate
- Reference pressure difference
- Electric power input
- Internal and external leakage rates

Additional comments VHK

1.

Terms and definitions regarding leakages

Similar to the VU-Regulations, the FprEN13141-7 uses the terms *internal leakage* and *external leakage*, but the definitions are different from the ones used in the Regulations. Also the FprEN13141-7 uses the term *transfer ratio*, which is not used in the Regulation text. Vice versa, the Regulation uses the term *carry-over*, which is not used in the standard. To make it even more confusing, the current practice for non-residential ventilation units sector is to use the terms *Outdoor Air Correction Factor (OACF)* (which represents another way of describing and measuring the *internal leakage*), and *Exhaust Air Leakage Rate (EATR)*, which is used to define and measure the fraction of exhaust air that is returned to the supply air, which term more or less corresponds to the term *carry-over* used in the Regulation text. It looks like only the term *external leakage* is consequently used and defined in the standards and the regulations and sector specific approaches.

The threshold values regarding leakage rate classes in relation to the fan positions in the BVU is given in Table 3 of Chapter 6 of the FprEN13141-7. If the unit falls in a lower leakage class, measurements and results on thermal performance are not accepted.

Table 5. Requirements on air leakage class (= table 3 in the standard)

Fan position	Minimum required leakage class
Exhaust fan upstream HE; supply fan downstream HE*	A1, B1
Exhaust fan downstream HE; supply fan upstream HE	Better or equal to A2 , B2
Other fan positions	Better or equal to A3 , B3
*not recommended for good IAQ	

This implies that a minimum performance regarding leakages is introduced.
In the view of the study team this represents a step forward in the overall quality of bidirectional ventilation units. Over time these leakage measurements results can be used for future strengthening of these minimum required leakage rates.

It is proposed to investigate whether it is possible to harmonise the terms and definitions used to define and measure the various leakages of BVUs, preferably according to the existing practice in the non-residential sector.

2.
<u>Temperature test conditions</u>

Where the regulations only look at the thermal efficiency (temperature ratio on supply air η_ϑ) and prescribe a fixed delta T of 13° to determine this efficiency at reference airflow, this standard provides more temperature conditions (see table 6) and also a test procedure for measuring the humidity ratio (η_x).

Table 6. Mandatory and optional temperature conditions in relation to HE/VU-type

Test No.	**1**	**2**	**3**
Extract air			
Temperature ϑ_{11}	20°C	20°C	20°C
Wet bulb temperature ϑ_{w11}	12°C	15°C	12°C
Outdoor air			
Temperature ϑ_{21}	7°C	2°C	-7°C
Wet bulb temperature ϑ_{w21}	-	1°C	-8°C

Test No. mandatory or optional			
Recuperative HE for T-transfer	*mandatory*	*optional*	*optional*
Recuperative HE for T & H-transfer	*mandatory*	*mandatory*	*optional*
Regenerative HE (e.g. rotary)	*mandatory*	*mandatory*	*optional*

If the VU is designed to operate at outdoor temperatures below -15 °C, an additional cold climate test shall be performed for all HE/VU-types, according to section 7.3.3.2. of the standard:

- Temperature extract air = 20 °C (wet bulb temp = 12 °C); outdoor temperature = -15 °C.
- Outdoor temperature starts at 2 °C and is gradually lowered to -15 °C within 3 hours
- Test shall run for a minimum of 6 hours up to maximum of 24 hours to a point where the airflow is stabilised
- The test is successful, if the temperatures and mass flows during the operating cycles are stabilised without harmful icing over the complete unit.

Following the cold climate test, the unit shall be visually inspected. This inspection shall be carried out immediately after the defrosting action. Observations shall be noted in the test report as to the influence of freezing and condensation on the operation of the heat recovery device and the condensation water outlet.

For all heat exchangers the temperature ratio on the supply side shall be reported (measurement and reporting of the temperature ratio on exhaust side is optional).
For heat exchangers that facilitate humidity recovery, the humidity recovery ratio on the supply side shall be reported (optional for exhaust side). In that sense the FprEN13141-7 is prepared for a possible extension of the scope to VUs that enable humidity recovery.

2.7 FprEN 13141-8: 2019[16]

Ventilation for Buildings – Performance of testing Components/products for residential ventilation – Part 8: Performance testing of non-ducted mechanical supply and exhaust ventilation units including heat recovery.

Summary

FprEN13141-8:2019 specifies the laboratory test methods and test requirements for the testing of aerodynamic, thermal, acoustic and the electrical performance characteristics of non-ducted mechanical supply and exhaust ventilation units used in single dwellings. The purpose of this document is not to consider the quality of ventilation but to test the performance of the equipment. In general, a ventilation unit contains:

- fans for mechanical supply and exhaust
- air filters
- air-to-air heat exchanger for heat and possibly humidity recovery
- control system
- inlet and outlet grilles.

Such equipment can be provided in more than one assembly, the separate assemblies of which are designed to be used together. Such equipment can contain alternating heat

[16] Version date: 2019-05

exchangers which provide separate supply and exhaust air flows. In certain cases, i.e. alternating ventilation unit, it may be declared that the equipment can be installed in such a way that it serves more than one room. For the purpose of this document, these products are assessed in a single room.

This standard does not deal with ducted units which are covered in EN 13141-7 or units with heat pumps.

Safety requirements are given in EN 60335-2-40 and EN 60335-2-80.

Issues related to Regulation (EU) 1253:2014:

- The scope has been changed and includes now non-ducted units which ventilate more than one single room.
- Determination of the maximum air flow is corrected in standard and is in alignment with the Regulation (EU) 1253:2014.
- Determination of the reference flow is also corrected and is in alignment with the Regulation (EU) 1253:2014.
- Proposal of a new test method (purge air method) for measuring the thermal characteristics of alternating units.

Comments to the test standard prEN13141-8

The revision of the test standard EN13141-8 aims for alignment with the definitions and requirements in the Regulation (EU) 1253:2014. Proposal of a method of measurement of effective airflow and disbalance of alternating units in heat recovery mode. This will for a significant number of products most likely result in different values determined in accordance to the method described in EN13141-8:2014
Proposal of a purge air test for measurement of thermal characteristics of alternating units (purge air method). A research project has compared the purge air method with the direct method which is described in EN13141-8:2014. The principle of purge air method is to mix and homogenize the outlet air of the device with the help of purge air flow without influencing the device itself. The research concluded that the purge air test resulted in more stable and reproducible results.
This proposal has been intensively discussed at WG 2 meetings and commented in the table of comments for the FprEN13141-8 because the test method can result in less satisfying temperature ratio values for some products.
The standard provides methods for measurements and calculations for at least following parameters

- The thermal efficiency of heat recovery (η_t)
- Sound power level (L_{wa})

The test standard provides methods for measurements and calculations of following parameters for information requirements

- Maximum flow rate
- Reference flow rate
- Reference pressure difference
- Electric power input
- Internal and External leakage rates
- Mixing rate
- Air flow sensitivity to pressure variations at -20 Pa and 20 Pa for non-ducted

Additional comments VHK

1.
<u>Terms and definitions regarding leakages</u>
Even more terms and definitions for leakages are used in the FprEN13141-8 to accommodate for the additional leakage and mixing airflows of the non-ducted BVUs. Table 7 gives and overview of these unintended airflow and the names they are given. The table also highlights what types of leakages and mixing is to be tested for what type of heat exchanger/ventilation unit and according which test method.

Table 7. Leakage tests that are requested for the various BVUs

Classification / Term	**Recuper. HE T-transfer**	**Recuper. HE T&H-transfer**	**Regener. HE rotary type**	**Regener. HE push/pull**	**Ref. test method**
External leakage	✓	✓	✓	✓	7.2.1.2
Internal leakage	✓	✓	-	-	7.2.1.3.1
Exhaust air transfer ratio	-	-	✓	-	7.2.1.3.2
Exhaust air transfer ratio	-	-	-	✓	7.4.2
Outdoor mixing	✓	✓	✓	✓	7.2.1.4
Indoor mixing	✓	✓	✓	✓	7.2.1.4
Indoor/outdoor airtightness	✓	✓	✓	✓	7.2.2

Also for non-ducted ventilation units threshold values regarding leakage rate classes in relation to the fan positions in the BVU are given in Chapter 6 of the standard. Requirements of the FprEN13141-8. If the unit falls in a lower leakage class than the indicated value, measurements and results on thermal performance are not accepted.

Table 8. Requirements on air leakage class (= table 3 in the standard)

Fan position	**Minimum required leakage class**
Exhaust fan upstream HE; supply fan downstream HE	U1
Exhaust fan downstream HE; supply fan upstream HE	Better or equal to U2
Other fan positions	Better or equal to U3

The leakage classes for non-ducted (local) BVUs are arranged as indicated in the table below, where the leakage class is determined by the lowest value.

Table 9. Leakage classes for non-ducted (local) BVUs

Class	Internal leakage				Outdoor mixing		Indoor mixing		External leakage	
	At 20 Pa	At 100 Pa	R_S						At 50 Pa	At 250 pa
	%	%	%		%		%		%	
U1	≤ 3	≤ 8.5	≤ 2	and	≤ 2	and	≤ 2	and	≤ 3	≤ 8.5
U2	≤ 7	≤ 21.5	≤ 5	and	≤ 5	and	≤ 5	and	≤ 7	≤ 21.5
U3	≤ 14	≤ 43	≤ 10	and	≤ 10	and	≤ 10	and	≤ 14	≤ 43
Not Classified	> 14	> 43	> 10	or	> 10	or	> 10	or	> 14	> 43

Al the leakages mentioned in Table 9 except for the last on (indoor/outdoor airtightness) are used to correct the measured temperature ratio η_0 into η_5 (see also table 4).

Leakages caused by a bad indoor/outdoor airtightness of the local VUs will decrease the airtightness of a dwelling, increase the infiltration rate and reduce the ventilation effectiveness. This should somehow or somewhere be integrated into the assessment method.

Furthermore the proposed test for determining the indoor/outdoor airtightness prescribes that if the unit is equipped with a manual of automatic shutter, the measurement shall be done with a closed shutter.
The study team is of the opinion that this text provides a significant loophole, since only an automatic shutter or valve will results in a correct operation of the shutter/valve during periods no ventilation is required. A manual shutter will not always be operated correctly. Adding a simple manual valve or shutter may not provide a loophole.
It is proposed to test the manually operated shutters in the open position.

2.
Special section in the standard on alternating units
Alternating ventilation units use regenerative heat exchangers for heat recovery. These heat exchangers are cyclically charged and discharged via flow reversal, meaning that the direction of the flow is periodically changed from exhaust to supply with a stop period in between. At least two devices working in opposite operating modes are required for a proper operating BVU that in theory could maintain a correct balance of air flows. Such a pair of alternating units meets the definition of BVU in the Ecodesign and Energy Labelling Regulations

These alternating units differ fundamentally from the ductless VUs with recuperative heat exchangers. Because these units are gaining market share, a dedicated section dealing with appropriate test conditions for these type of unit in the revised standard for determining leakages, airflows, temperature and humidity ratios of alternating units is justified.

3.
Temperature test conditions
See remarks in section 1.6.4. on this topic.

2.8 FprEN 13503[17]

Ventilation for Buildings - Air Handling units – Rating and performance for units, components and sections

FprEN 13503:2018 specifies requirements and testing for rating and performance of Non Residential Ventilation Units, NRVUs, specifically Air Handling Units (AHUs). It specifies requirements, classifications and testing of components and sections of air handling units.

This European Standard applies to tests in a laboratory and in situ. This European Standard is applicable both for mass produced air handling units and tailor-made Air Handling Units. This European Standard applies to AHU and individual sections of AHU with the designed air flow > 250 m^3/h. This European Standard applies to UVUs with additional air treatment components in addition to filtration.

This standard does not include

[17] Version date: 2018-08

- residential unidirectional and bidirectional ventilation units,
- non-residential unidirectional ventilation units which consist of only a casing, a fan with or without filter.

The standard uses the following definition for AHU:
Air Handling Unit: *factory made unit encased assembly containing a fan or fans, filtrating device(s) and other necessary equipment to perform at least one or more of the following functions: heating, cooling, heat recovery, heat transfer, humidifying, dehumidifying and mixing air*

Strangely enough, the function *ventilation* does not appear in this definition. It is the term *'mixing'* that relates to the ventilation function; *mixing* is defined as the process where an outdoor airflow and the recirculation airflow are mixed in a controlled way. Since mixing itself is not the intended function (where heating, cooling etc. is) and more importantly not always necessary (ventilation can be achieved without a mixing section), it is proposed adjust this definition and use the key term ventilation instead of mixing. By doing this, the definitions of the key component in the standards scope (AHU) at least refers to the purpose of this standard: Ventilation for buildings.

For reasons of clarity and consistency it is proposed to change this definition e.g. into:
Air Handling Unit, *factory-made encased assembly unit containing a fan or fans, filtrating device(s) and other necessary equipment, that is designed to ventilate a building with airflows > 250 m^3/h, and is able to perform at least one or more of the following additional functions: heating, cooling, heat recovery, heat transfer, humidifying, dehumidifying*

2.9 prEN 17291:2018[18]

Fans – Procedures and methods to determine and evaluate the energy efficiency of non-residential unidirectional ventilation units

This European Standard has been prepared under a Commission's standardisation request to the European Committee for Standardisation as regards ventilation units in support of Regulation (EU) No 1253/2014 and delegated Regulation EU No 1254/2014 "M/537"/"C(2015) 8325 final" to provide one voluntary means of conforming to Ecodesign requirements of Commission Regulation (EU) No [1253/2014] of [7 July 2014] implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for ventilation units.

Once this standard is cited in the Official Journal of the European Union under that EU Directive 2009/125/EC and Commission Regulation (EC) No 1253/2014, compliance with the normative clauses of this standard given in Table ZA.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding essential requirements of that EU Directive 2009/125/EC and Commission Regulation (EC) No 1253/2014, and associated EFTA Regulations.

This standard provides procedures and methods for measuring and calculating the energy efficiency and associated characteristics of non-residential unidirectional ventilation units when driven by electric motors. Unidirectional ventilation units include roof fans and box fans. This document includes unidirectional ventilation units with and without filters. Additional air treatment items are considered in this document but are excluded in the determination of the efficiency of the product. This document does not include: - residential

[18] Version date: 2018-10

unidirectional and bidirectional ventilation units, - non-residential bidirectional ventilation units.

Definition of a Non-residential ventilation unit used in this standard is based on definition Article 2 (3) of Regulation (EU) No 1253/2014.

Non-residential ventilation unit (NRVU)
ventilation unit where the maximum flow rate exceeds 250 m^3/h, excluding those between 250 m^3/h and 1 000 m^3/h where the manufacturer has declared it a residential ventilation unit only.

2.10 EN16798-1 and -2[19]

Energy performance of buildings – Part 1: indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics – Module M1-6

Summary
The first edition of this standard was published as EN 15251. The major change consists of splitting up the standard in a normative Part 1 and a Technical report as Part 2.
Part 1 includes an Annex B with tables with default values and an Annex A with similar empty tables to be used for national values. All aspects of indoor air quality and indoor environment are discussed in EN 16798-1

This standard specifies different types and categories of criteria, which may have a significant influence on the energy demand. The criteria in EN 15251 were mainly for dimensioning of building, heating, cooling and ventilation systems. Occupant expectations in natural ventilated buildings may differ from conditioned buildings, which is a part of this standard. The standard is applicable to buildings where criteria for the indoor environment are set by human occupants and where the production or process does not have major impact in the indoor environment.
The standard defines how to establish and define the main parameters to be used as an input for building energy calculation and short and long term evaluation of the indoor environment.

This standard provides default indoor environmental criteria for the design of buildings, room conditioning systems and lighting systems. The standard provides default values for the indoor environment as input to the calculation of the energy demand when the space is occupied. The standard does not specify design methods, but gives input parameters to the design of building envelope, heating, cooling, ventilation and lighting. The design criteria in clause 6 shall be used for both design of buildings (dimensioning of windows, solar shading, building mass, etc.) and HVAC systems. Local discomfort criteria at three levels are now a part of the standard (table H.3).
For buildings without mechanical cooling it shall be stated if the building design and the natural ventilation system are not adequate to meet the required temperature categories. It is not mandatory to state how much of the time the temperature is outside the required range.

A new category *Increased air velocity* has been added to the standard. It shall be evaluated if the thermal comfort during summer comfort conditions can be improved by increase of air velocity – only with personal control by the occupant.

[19] Version date: 2018-09

CEN/TR 16798-2: Technical Report – Interpretation of the requirements in EN 16798-1

This Technical Report is a guide to EN 16798-1. It can help the user in application of the standard and give additional valuable background information. The document explains how to use EN 16798-1 for specifying indoor environmental input parameters for building design and energy performance calculations.
The document explains how design criteria can be established and used for dimensioning of systems. It explains how to establish and define the main parameters to be used as input for building energy consumption and long term evaluation of the indoor environment.
The document deals with the indoor environmental parameters for the thermal environment, indoor air quality, lighting and acoustics. The document explains how values from the indoor environment (temperature, ventilation, lighting) are used as input parameters to the calculation of the energy demand. Output from measured indoor environmental parameters in existing buildings (temperature, CO2, ventilation rates, illumination levels) will enable the evaluation overall annual performance and can be used to display the indoor environmental factors together with data for the energy performance.
The document provides a method for categorization of indoor environment (chapter 10). This method can be used to integrate complex indoor environment information to simple classification for indoor environment certification.

The standard distinct between buildings with mechanically controlled cooling and buildings without mechanical cooling. Criteria for the thermal environment in mechanically cooled/heated buildings are based on the thermal indices PMV-PPD with assumed typical levels of activity and typical values of thermal insulation for clothing.
For buildings without mechanical cooling the adaptive criteria can be applied for the temperature during spring, autumn and summer. During the winter season the same temperature limits should be applied as presented for buildings with mechanical cooling. The adaptive criteria are based on data from office buildings, but could possibly be used for other buildings of similar type used mainly for human occupancy, with mainly sedentary activity and easy access to operable windows.

Design for indoor air quality (also named *ventilation rates*).
Source control strategy together with ventilation, placement of air intakes and filtration and air cleaning technologies all contribute to improve the indoor air quality. The source control strategy is very important since air pollutants often are generated indoors. For residential buildings indoor sources will often be the predominant source of air pollutants. The main priority in residential buildings is to ensure a healthy indoor environment, and a secondary priority is to prevent damages to the building from excess of moisture. To limit the indoor concentration and ingress of outdoor air pollutants appropriate air filtration, placement of intake and/or air cleaning should be considered.
The humidity criteria depend partly on the requirements for thermal comfort and indoor air quality and partly on the physical requirements of the building. Light is a necessary part to people's health and wellbeing. For reasons of comfort and energy in most cases the use of daylight is preferred.
The noise level is described as the continuous sound level ($L_{eq,A}$) which is a good descriptor of noise due to sources active under operating conditions in a medium-long time span. It is widely used in most of the regulations and national standards.
The input values for the energy calculations are based on the same concepts as the criteria for design. The criteria presented in 16798-1 are then also reflected in the occupant's schedule.
In order to control the indoor environmental quality calculations can be performed according to the listed criteria. For existing buildings measurements can be performed to check if the criteria are met. To control the indoor air quality measurements of the ventilation rates can be performed. However, the indoor air quality depends as well on the presence of specific indoor pollutants that can decrease the perception of the indoor air quality for the occupant. In addition to the measurements of the ventilation rates investigation and/or measurements

of specific pollutants will be needed to identify the actual indoor air quality. WHO provides guideline values for indoor and outdoor air pollutants.

Additional comments VHK

1.

IAQ-categories

The FprEN 16798-1 and 2 provide practical leads for further assessment of the ventilation performance.

First of all, the standard identifies four categories of IAQ-levels:

Table 10. IAQ-categories

Category	Level of expectation
I	High
II	Medium
III	Moderate
IV	Low

The standard proposes three different methods to determine the IAQ-category that is applicable for a ventilation system in a specific building. The first method is based perceived air quality, using a predefined airflow rate per non adapted person combined with a predefined airflow rate per m2 of building surface that increases depending on the polluting level of the building (LPB-1 to LPB-3). The second method is based on the use of limit values of substance concentrations (e.g. CO_2). And the third method on predefined airflow rates.

The standard allows individual member states to define their own, national specific, values for the three different methods. For instance, regarding method 2, country *x* may use a value of 800 ppm for the allowed CO_2-concentration above outdoors to achieve category II, while another country *y* can use a much higher value, e.g. 1200 ppm. This implies that double standards are used for determining the IAQ and not an unambiguous EU-wide reference, which would be more appropriate since the CO_2 emissions of the average occupant does not vary per member state.

Next to the option of using national values, the standard also provides default values for the various methods.

2.

Default design ventilation rates and IAQ-categories for non-residential buildings

The default ventilation rates for the three different methods are further explained in the section below.
Due to health reasons the minimum total airflow rate during occupancy expressed as l/s per person should never be below 4 l/s/pp which should also be sufficient to comply with the WHO Guideline values for pollutant concentrations (see table B.21 of this EN 16798-1 standard).

Method 1: Method on perceived air quality

The design ventilation rate is calculated from the two pollutant components, a) ventilation to dilute/remove pollution coming from the occupants and b) ventilation to remove/dilute pollution coming from the buildings and systems. The total ventilation rate is the sum of these two components (see formula below) and is indicative for the resulting IAQ-category

$$q_{tot} = n * q_p + A_R * q_B \qquad \text{in l/s}$$

where

q_{tot} = total ventilation rate for the breathing zone, in l/s
n = design value for the number of persons in the room
q_p = ventilation rate of occupancy per person, in l/s/pp
A_R = floor area, in m^2
q_B = ventilation rate for emissions from building, in $l/(s.m^2)$

The default design ventilation rate values for occupants (q_p) are listed in Table 11.

Table 11. Design ventilation rates for sedentary, adults, non-adapted persons for diluting emissions (bio effluents) from people for different categories (Table B.6 in standard)

Category	Expected percentage dissatisfied	Airflow per non-adapted person l/(s per person)
I	15	10
II	20	7
III	30	4
IV	40	2.5

The ventilation rates (qB) for the building emissions are given in Table 12.

Table 12. Design ventilation rates for diluting emissions from different type of buildings (table B.7 in the standard)

Category	Very low polluting building LPB-1	Very low polluting building LPB-2	Very low polluting building LPB-3
	$l/(s*m^2)$	$l/(s*m^2)$	$l/(s*m^2)$
I	0.5	1.0	2.0
II	0.35	0.7	1.4
III	0.2	0.4	0.8
IV	0.15	0.3	0.6

When the design ventilation rates are calculated for a single-person office of 10 m2 in a low polluting building for a non-adapted person, the resulting design airflow rates for the various categories for IAQ are given in the table below.

As seen from Table 13 the total ventilation rate is never lower than 4 l/s per person. The ventilation rate should always be higher than 4 l/s per person (minimum 4 l/s per person for human emissions and a part for building and activity related emissions).

Table 13. Example of default design ventilation air flow rates for a single-person office of 10 m² in a low polluting building (un-adapted person) (table B.8 in standard)

Category	Low-polluting building	Airflow per non-adapted person	Total design ventilation air flow rate for the room expressed in different ways		
	l/(s*m²)	l/(s per person)	l/s	l/(s per person)	l/(s*m²)
I	1.0	10	20	20	2
II	0.7	7	14	14	1.4
III	0.4	4	8	8	0.8
IV	0.3	2.5	5.5	5.5	0.55

Method 2, using limit values for individual substance concentrations

Default limit values for CO_2 concentrations can be found in table B.9 section B.3.1.3. of the standard, and in section B.7 for other substances; table B.21 in section B.7 gives suggested guideline values for indoor and outdoor air pollutants as formulated by WHO. For some pollutants no indoor air requirements have been defined yet by the WHO.

Table 14. Default design CO2 concentrations above outdoors, assuming standard CO2 emission of 20 l/h/pp (Table B.9 in the standard)

Category	**Corresponding CO_2 concentration above outdoors** (in ppm for non-adapted persons)
I	550
II	800
III	1350
IV	1350

The design ventilation rate required to dilute an individual substance shall be calculated with the formula below:

$$Q_h = \frac{G_h}{C_{h,i} - C_{h,o}} * \frac{1}{\varepsilon v}$$

Where

Q_h is the ventilation rate required for dilution, in m3 per second;

G_h is the generation rate of the substance, in micrograms per second;

$C_{h,i}$ is the guideline value of the substance, in micrograms per m^3;

$C_{h,o}$ is the concentration of the substance of the supply air, in micrograms per m3;

εv is the ventilation effectiveness

Method 3, based on pre-defined ventilation airflow rates

This method is based estimates of minimum ventilation airflow rates that are necessary to meet the requirements on perceived air quality and health in the occupied zone. These pre-defined ventilation airflow rates shall be expressed by one or more of the following parameters:

q_{tot} : total design ventilation for people and building components
q_{m2} : design ventilation per unit floor area
q_{p} : design ventilation per person
ach : design air change rates
q_{room} : design air flow rates by room and building type

The default pre-defined design ventilation rates following this method, are given in the table below.

Table 15. Default pre-defined design ventilation airflow rates for an office for an un-adapted person

Category	Total design ventilation airflow rate for the room	
	in l/s/pp	in l/s/m^2
I	20	2
II	14	1.4
III	8	0.80
IV	5.5	0.55

If the pre-defined default design airflow rates are given both perp person and per m^2, the higher ventilation airflow rate should be used for design.

Ventilation air flow rate during unoccupied periods

In case the ventilation is shut off, the minimum amount of air to be delivered prior to occupation is by default: 1 volume within 2 hours of the zone to be ventilated.

In case the ventilation is lowered for un-occupied periods, the total air flow rate for diluting emissions from building should be minimum 0,15 l/s.m^2 of floor area in all rooms.

3.
Default design ventilation rates and IAQ-categories for residential buildings

Design ventilation air flow rates shall be specified as an air change per hour for each room, and/or outdoor air supply per person and/or required extract rates (bathroom, toilets, and kitchens), given as an overall required air-change rate or design air flow rates by room and building type (q_{room}) and design opening areas.

NOTE Design opening areas (A_{tot}) for residential buildings can be considered as predefined air flow rates but need specific data on local climate and building characteristics (see EN 16798–7).

Predefined ventilation air flow rates can be given based on one or more of the following components:

a) total air exchange rate for the dwelling;
b) extract airflow rates for specific rooms;
c) supply airflow rates for specific rooms;
d) design opening areas for natural ventilation.

Both the total air flow rate for the entire dwelling and the extract air flow rate from wet rooms shall be calculated. Either one of the criteria can be used in the design.

In residential buildings, the occupants can in most cases be considered as adapted to the perceived air quality as they occupy the house for a longer time. Unlike other types of buildings, there is no need to maintain a situation where the indoor air quality is perceived as fresh by non-adapted persons entering the building, as this is an unusual situation for everyday use of the residential building. But it is of course also possible to design the ventilation rate in residential buildings for non-adapted people. The main priority in residential buildings is to ensure a healthy indoor environment, and a secondary priority is to prevent damages to the building from excess of moisture.

Default design supply airflow rates

Table 16 gives the default pre-defined design supply airflow values for three criteria. It is assumed that air is supplied in living rooms and extracted from wet rooms.

Table 16.Criteria based on pre-defined supply ventilation air flow rates: Total ventilation (1), Supply air flow (2) and (3); (table B.11 in the standard)

Category	Total ventilation including air infiltration (1)		Supply air flow per person (2)	Supply air flow based on perceived IAQ for adapted persons (3)	
	l/s,m²	ach	l/s[a] per	q_P l/s*per	q_B l/s,m²
I	0.49	0.7	10	3.5	0.25
II	0.42	0.6	7	2.5	0.15
III	0.35	0.5	4	1.5	0.1
IV	0.23	0.4			

[a] Supply air flow for Method 3 based on Formula (1) from 6.3.2.2.

Default design CO_2-concentrations above outdoors

The values in Table 17 assume that supply air is outdoor air, or unused air transferred from other rooms. These values may be converted to l/(s m²) of floor area at national level depending on the average number of occupants in dwellings.

Table 17.Default design CO_2-concentrations above outdoors (table B.12 in standard)

Category	Design ΔCO_2 concentration for living rooms (ppm above outdoors)	Design ΔCO_2 concentration for bedrooms (ppm above outdoors)
I	550	380
II	800	550
III	1350	950
IV	1350	950

NOTE 1 The above values in Table 17 correspond to the equilibrium concentration when the air flow rate is 10, 7, 4 l/s per person for cat. I, II, III respectively and the CO2 emission is 20 l /h per person and 13,6 l/h per person for living rooms and bedrooms respectively.

NOTE 2 For a 10 m2 room (room height 2,5 m, volume 25 m3) 4; 7 and 10 l/s per person correspond, with two persons in the room, to an air change rate of 1,2; 2,0 and 2,9 ACH.

Default design extract airflow rates

This section gives default values for the design extract air flow rate based on air flow rates by room and building type (q_{room}). See table 18 and 19.

Table 18. Design airflow rates by room & building type (q_{room}) for category II IAQ (table B.13 in the standard)

Number of main rooms in the dwelling	Design extract air flow rates in l/s				
	Kitchen	Bathroom or shower with or without toilets	Other wet room	Toilet	
				Single in dwelling	Multiple (2 or more in dwelling)
1	20	10	10	10	10
2	25	10	10	10	10
3	30	15	10	10	10
4	35	15	10	15	10
5 and more	40	15	10	15	10

Table 19 gives the multipliers for the other IAQ-categories.

Table 19. Categories for predefined extract air flow rates (table B.14 in standard)

Category	Airflow rates defined in Table 18 multiplied by
I	1.4
II	1.0
III	0.7
IV	0.5

Category IV can only be used if there is an additional range hood in the kitchen.

Ventilation air flow rates during non-occupied periods

The total air flow rate needed to deal with building materials emissions and humidity reduction during non-occupied hours is between 0,1 and 0,15 l/(s*m^2) of floor area, depending on the size and occupancy of the dwelling.

2.11 EN16798-3 and 4

Energy performance of buildings – Ventilation for buildings – Part 3: For non-residential buildings – Performance requirements for ventilation and room-conditioning systems (Modules M5-1, M5-4)

The abstract describing the status and content of this EU standard is taken from a paper in the REHVA journal in April 2018[20]

This standard has been produced to meet the requirements of Directive 2010/31/EU 19 May 2010 on the energy performance of buildings (recast), referred to as "recast EPDB", while the substituted EN 13779:2007 was produced to meet the requirements of previous Directive 2002/91/EC 16 December 2002 on energy performance of buildings referred to as "EPBD".
The latest recast of the energy performance buildings directive (see section 1.7.2) should not have a significant influence on this specific standard at least for other ten years.
Because EPB standards like this one, have been produced with the aim of supporting the recast EPBD and its application at national level, a certain degree of freedom in their application was a mandatory request. Thus, these standards provide a certain flexibility regarding the methods, the required input data and references to other EPB standards, by the introduction of a normative template in Annex A and Annex B with informative default choices.
The normative annex A is just an empty format that has to be filled at the national level to customize the standard in a way of complying to national legal requirements.
Nevertheless, although the main goal of this standard is the energy performance of ventilation systems, EN 16798-3 also provides requirements especially for designers, installers, manufacturers, building owners and users, on ventilation, air-conditioning and room-conditioning systems in order to achieve a comfortable and healthy indoor environment in all seasons with acceptable installation and running costs.
It focuses on the system-aspects for typical applications and covers the following:

- Important aspects to achieve and maintain a good energy performance in the systems without any negative impact on the quality of the indoor environment.
- Definitions of design and performances data.

<u>Changes with respect to EN 13779</u>
The new EN 16798-3:2017, and its supporting technical report: CEN/TR 16798-4:2017, is the revision of EN 13779:2007 and covers the same items. Main changes in this revised version are:

- The document was split in a normative part, containing all the normative aspects and a supplementary technical report containing additional information and informative annexes, i.e. CEN/TR 16798-4:2017;
- The standard allows a normative national annex;
- New structure to clarify designing and calculation aspects;
- Clear coordination with FprEN 16798-1:2015, outdoor air volume flows have been shifted to FprEN 16798-1:2015;
- All indoor air quality aspects have been deleted and reference is made to prEN 16798-1:2015, supply air quality have been introduced;
- Update of definitions of systems;
- Update of SFP definitions and links to EU 327/2014 regulation;
- Update of heat recovery aspects;
- Update of filtration aspects;
- Update of leakages aspects;

[20] Mazzarella, L., Hogeling, J., CEN Standard EN 16798-3:2017 on ventilation for non-residential buildings: PERFORMANCE REQUIREMENTS, Rehva Journal, April 2018.

- Aspects of energy performance have been updated;
- The standard was supposed to be updated to cover hourly/monthly/seasonal time-step, but this is not actually done.

Update of definitions of systems

In the 16798-3:2017 the ventilation system paragraph has been improved including definitions for basic system types of ventilation systems (see Table 20) as unidirectional ventilation system (UVU), bidirectional ventilation systems (BVU), natural ventilation system and hybrid ventilation systems.
The EN 13779:2007 "pressure conditions in the room" paragraph is now more clearly renamed as "design air flow balance" and explicitly refers to balanced mechanical ventilation system (BUV type), where the extract airflow rate is given as function of the supply airflow rate and the air balance class needed.
Another comprehensive table (see Table 21) is added to classify ventilation or air-conditioning systems based on ventilation and thermal functions.
A clear definition of cooling is also given as "any component in the unit or the room lowering the supply air or room air enthalpy (for example cooling coil with chilled water, cooling water or ground source water or brine)".

Table 20. Basic system types of ventilation systems

Description	Name of the system type
Ventilation system with a fan assisted air volume flow in only one direction (either supply or exhaust) which is balanced by air transfer devices in the building envelope.	Unidirectional ventilation system (UVU)
Ventilation system with a fan assisted air volume flow in both directions (supply and exhaust)	Bidirectional ventilation system (BVU)
Ventilation relying on utilization of natural driving forces	Natural ventilation system
Ventilation relying on natural and mechanical venitaltion in the same part of a building, subject to control selecting the ventilation principle appropriate for the given situation (either natural or mechanical driving forces or a combination thereof).	Hybrid ventilation system

Table 21. Types of Ventilation-, Air-conditioning-, and Room Conditioning-Systems based on functions

System	x equipped with (x) equipped with, but function might be limited; - not equipped with; O may or may not be equipped with depending on requirements	Supply air fan	Extract air fan	Secondary fan	Heat recovery	Waste heat pump	Filtration	Heating	Cooling	Humidification	Dehumidification
Unidirectional supply air ventilation system (Positive pressure ventilation)		x	-	-	-	-	○	○	-	-	-
Unidirectional exhaust air ventilation system		-	x	-	-	○	-	-	-	-	-
Bidirectional ventilation system		x	x	-	x	○	x	○	-	-	-
Bidirectional ventilation system with humidification		x	x	-	x	○	x	○	-	x	-
Bidirectional air-conditioning system		x	x	-	x	○	x	○	(x)	○	(x)
Full air-conditioning system		x	x	-	x	○	x	x	x	x	x
Room air condtitioning system (Fan-Coil, DX-Split-system, VRF, local water loop heat pumps, etc.)		-	-	x	-	-	○	○	x	-	(x)
Room air-heating systems		-	-	x	-	-	○	x	-	-	-
Room conditioning system		-	-	-	-	-	-	○	x	-	-

Update of SFP topics

The SFP-classification has been extended with respect to EN 13779:2007 by adding a SPF 0 category for less than 300 W/(m³/s)) and its definition is now clearly stated through a formula:

$$P_{SFP} = \frac{P}{q_V} = \frac{\Delta P_{tot}}{\eta_{tot}} = \frac{\Delta P_{stat}}{\eta_{stat}} \left[\frac{W}{m^3/s}\right]$$

(for the meaning of the symbols refer to the standard).

Paragraphs have been added to provide normative formulas and calculation methodologies for calculating:

- the power demand of the fan;
- Specific Fan Power of an entire building;
- Specific Fan Power of Individual Air Handling Units (I-AHU);
- AHU related PSFP values.

(Similar formulas and calculation methodologies were also reported in the superseded EN 13779-2007, but only as informative options in the informative Annex D).

Update of heat recovery aspects

The heat recovery paragraph has been completely rewritten, updated and extended. The “dry” recovery efficiency has been introduced, as stated in EN 308 and EN 13053. Some information is then reported on transfer of humidity, icing and defrosting, transfer of pollutants.

Update of filtration aspects

The filtration paragraph is entirely new and gives guidance in filters selection. In fact, depending on outdoor particle pollution level and desired supply air quality, different levels of filtration are required. The filtering of outdoor air shall be chosen to meet the requirements of the indoor air in the building, taking into consideration the category of outdoor air. Tables are given to define the minimum required filtration efficiency according to the selected outdoor air (ODA) quality and the supply air (SUP) class (Table 22) and to indicate when optional gas filtration is recommended or required (Table 23).

Table 22. Minimum filtration efficiency based on particle outdoor air quality

Outdoor air quality	Supply air class				
	SUP 1	SUP 2	SUP 3	SUP 4	SUP 5
ODA (G) 1	88 %[a]	80 %[a]	80 %[a]	80 %[a]	Not specified
ODA (G) 2	96 %[a]	88 %[a]	80 %[a]	80 %[a]	60%
ODA (G) 3	99 %[a]	96 %[a]	92 %[a]	80 %[a]	80%

[a] Combined average filtration efficiency over a single or multiple stage filtration in accordance to average filtration efficiency specified in EN 779.

Table 23. Application of gas filter as complement to particle filtration based on gaseous outdoor air quality

Outdoor air quality	Supply air class				
	SUP 1	SUP 2	SUP 3	SUP 4	SUP 5
ODA (G) 1	recommended				
ODA (G) 2	required	recommended			
ODA (G) 3	required	required	recommended		

G = Gas filtration; should be considered if design SUP quality category is above design ODA quality category. Dimensioning should be done in accordance with EN ISO 10121-1 and EN ISO 10121-2.

The formula to calculate the combined filtration efficiency when different filters are used in series is given as:

$$E_t = 100 * \left(1 - \left(\left(1 - \frac{E_{s,1}}{100}\right) * \left(1 - \frac{E_{s,2}}{100}\right) * \ldots * \left(1 - \frac{E_{s,n+1}}{100}\right)\right)\right)$$

where

E_t : is the total filter efficiency

$E_{s,j}$: is the efficiency of each j filter step

Update of leakages aspects

The leakages in ventilation system paragraph is completely new. This paragraph was added because leakages of the air distribution or the AHU casing affect energy efficiency and function, as well as hygiene aspects (e.g. condensation). Thus, it is important to minimize leakages.

This paragraph specifically deals with leakages in heat recovery section (HRS) (internal leakages), leakages of the AHU casing (external leakages) and leakages of the air distribution (ducts) including components.

For leakages in heat recovery section, two new quantities are defined to quantify them:

1. Exhaust Air Transfer ratio (EATR) [%]
   ratio of the supply air mass flow rate leaving the HRS originated by air internal recirculation due to HRS internal leakages and the supply air mass flow rate leaving the HRS;
2. Outdoor Air Correction Factor (OACF) [-]:
   ratio of the entering supply mass airflow rate and the leaving supply mass airflow rate.

With these two values, the leakage situation is fully defined. EATR and OACF shall be calculated by the heat recovery manufacturer for the nominal design condition of the air handling unit.

Based on the OAC Factor a classification is given as reported in Table 24.

Table 24. Classification of outdoor air correction factor (internal leakage)

	OACF	
Class	**Outdoor to exhaust air**	**Extract to supply air**
1	1,03	0,97
2	1,05	0,95
3	1,07	0,93
4	1,01	0,9
5	Not classified	

For leakages of the AHU casing, reference is made to EN 1886:2007 - Ventilation for buildings. Air handling units. Mechanical performance, which specifies test methods, test requirements and classifications for air handling units.

For leakages of the air distribution, ducts mainly, a classification is given based on EN 12599 - Ventilation for buildings - Test procedures and measurement methods to hand over air conditioning and ventilation systems, as reported in Table 25.

Table 25. Classification of system air tightness class

Air tightness class		Air leakage limit (f_{max}) $m^3\ s^{-1} * m^{-2}$
Old	New	
	ATC 7	Not classified
	ATC 6	$0.0675 \times p_t^{0.65} \times 10^{-3}$
A	ATC 5	$0.027 \times p_t^{0.65} \times 10^{-3}$
B	ATC 4	$0.009 \times p_t^{0.65} \times 10^{-3}$
C	ATC 3	$0.003 \times p_t^{0.65} \times 10^{-3}$
D	ATC 2	$0.001 \times p_t^{0.65} \times 10^{-3}$
	ATC 1	$0.00033 \times p_t^{0.65} \times 10^{-3}$

Update of energy performance aspects

The major update to the air volume flows calculations is the explicit introduction of the ventilation effectiveness, ϵ_V , when calculating the ventilation air volume flow (i.e. outdoor air flow to dilute indoor contaminants) starting from normalized standard requirements as in the referred prEN 16798-1:2015.

Another update is the calculation of the required ventilation rate for humidifying or dehumidifying, if such services are provided by the ventilation systems.
What is not reported is a procedure or a criterion for selecting the effective supply airflow rate, when the ventilation air volume flow, the air volume flow required for balancing heating and cooling loads and, eventually, required ventilation rate for humidifying or dehumidifying have to be contemporary or not satisfied.

The new paragraph is on the energy rating of ventilation system. The new quantities herewith introduced, but already defined in the EN 13053 standard in a bit different way (in terms of powers instead of annual energies), are:

Annual heat recovery efficiency

$$\eta_e = 1 - \frac{Q_{H;V;in;req}}{Q_{H;V;tot}}$$

Annual coefficient of performance

$$\varepsilon_{HRS} = \frac{Q_{hr}}{E_{V;hr;gen;in;el}}$$

where

$Q_{H;V;in,req}$	is annual heating energy of ventilation supply (or/and intake) air including defrosting, in kWh
$Q_{H;V;tot}$	is annual heating energy of supply (or/and intake) air without heat recovery, in kWh
Q_{hr}	is annual heat transferred by heat recovery, in kWh
$E_{V;hr;gen,in;el}$	is annual electric energy of the heat recovery section required by fans and auxiliaries, in kWh.

Finally, a section is added that deals with primary energy use of ventilation in kWh/(m³/h)/a.

2.12 EN 16573:2017

Ventilation for Buildings. Performance testing of components for residential buildings. Multifunctional balanced ventilation units for single family dwellings, including heat pumps

This European Standard specifies the laboratory test methods and test requirements for aerodynamic, energy rating and acoustic performance, of multifunctional balanced units intended for use in a single dwelling. In the case of units consisting of several parts, this standard applies only to those designed and supplied as a complete package with the mount instructions. It covers units that contain at least, within one or more casing: - supply and exhaust air fans; - air filters - common control system; and one or more of the additional components: - air to water heat pump; - air to air heat pump; - air-to-air heat exchanger. Units including only an air to air heat exchanger and/or an exhaust air to supply air heat pump are covered by EN 13141-7. A non-exhaustive list of possible configurations of multifunctional units covered by this standard is given in Clause 5. The standard does not cover the thermal aspects of humidity transfer in the air-to-air heat exchanger. This standard does not deal with non-ducted units on supply and extract air side. This standard does not deal with collective units (centralized or semi-centralized systems) These multifunctional balanced units can be connected to ground heat exchanger for air preheating, solar collector or other heating systems. This standard does not cover the testing with these additional components. This standard does not cover units including combustion engine driven compression heat pumps and sorption heat pump.

2.13 EN 308

Heat exchangers - Test procedures for establishing performance of air to air and flue gases heat recovery devices

This European Standard specifies methods to be used for laboratory testing of air-to)air heat recovery devices or those recovering heat from flue gases of heating appliances in buildings (except process-process applications) to obtain rating data. It gives test requirements and procedures for performing such tests and specifies input criteria required for tests to verify performance data given by the manufacturer. For the purposes of this standard, the term exhaust air may also be taken to mean the products of combustion. This European Standard is intended to be used as a basis for testing heat recovery devices for HVAC-systems, which as specific in prEn 247 consist of the heat exchanger itself installed in a casing having the necessary air duct connecting elements and in some cases the fans and pumps, but without any additional components of the HVAC-system.

2.14 FprEN 17166:2019

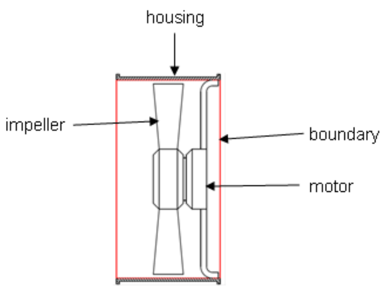
Fans - Procedures and methods to determine the energy efficiency for the electrical input power range of 125 W up to 500 kW.

This standard provides procedures and methods for measuring and/or calculating the energy efficiency and associated characteristics of fans when driven by electric motors. It provides procedures and methods to evaluate the compliance of the fan efficiency against minimum efficiency requirements. This standard does not include Uni-Directional Ventilation Units (these are included in EN 17291).

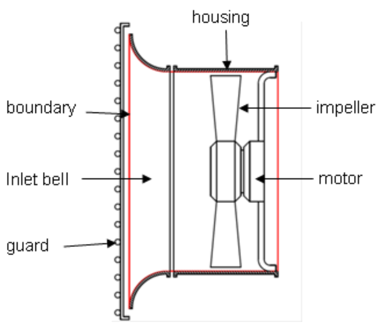
This standard includes stand-alone fans and fans that are integrated in other products. It gives guidance to manufacturers in providing information to surveillance authorities to describe the full extent of the fan by describing boundaries, significant elements and additional parts.

The term “housing” is described in detail as a casing around the impeller that guides the gas stream toward, through and from the impeller. The housing may include an inlet bell, an inlet guide vane, an outlet guide vane or an outlet diffuser. For examples of boundaries for different fan types (in line with the working draft), see sketches (a) to (f) in figure 2. A fan can be with or without housing. Protective guards are not included in the measurements of fans (guards are removed for testing).

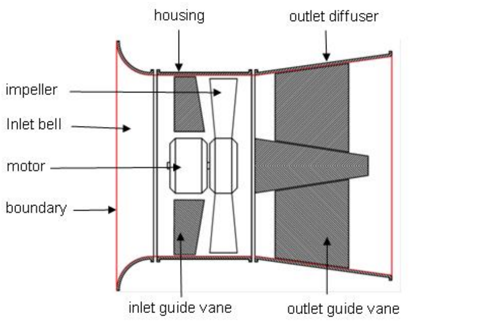
Ventilation units are by definition equipped with a casing (Article 2 (1)), which, according to the above, is additional to the housing in terms of Regulation 327/2011. This implies that the casing is defined as all parts of the ventilation unit that interfere with the airflow, in addition to the housing. For a ventilation unit including a fan without a housing, there will only be the casing interfering with the airflow. Products that would normally be called ‘box-fans’ or ‘roof-fans’ are considered ventilation units. For examples of ventilation units within the scope of Regulation 1253/2014, see sketches (g) and (h) in figure 2.



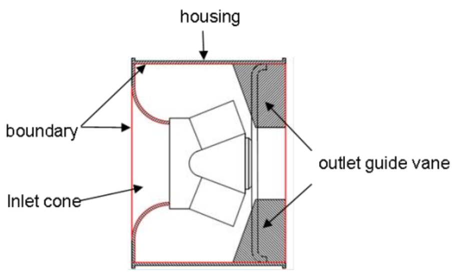
(a) Tube-axial



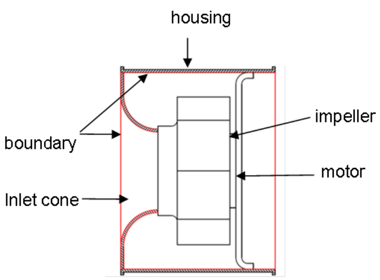
(b) Tube-axial with bell (guard not in boundary



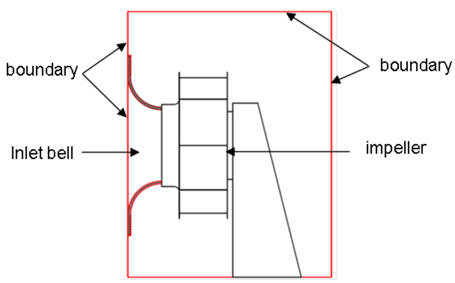
(c) Vane-axial with inlet bell, inlet guide vane, outlet diffuser & vane.



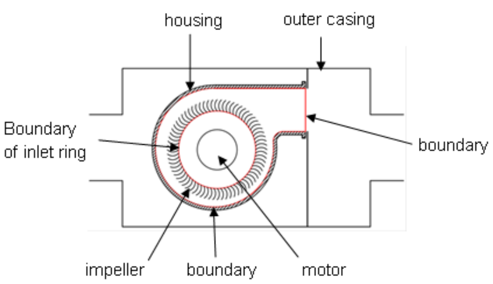
(d) Mixed-flow with inlet cone and outlet guide vanes



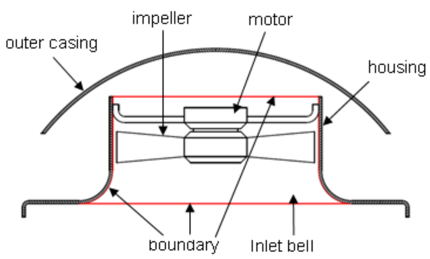
(e) Centrifugal fan with housing



(f) Centrifugal fan without housing (plenum fan)



(g) Boundaries of centrifugal fan inside a box-fan



(h) Boundaries of an axial fan with bell, inside a rooftop-fan

Figure 2: Sketches of some fan types and ventilation unit types with indications for 'housing' and 'casing'. The term 'boundary' is used to indicate the practical boundary for the testing of fans.

Source: CEN TC 156 WG 17 Working draft (figures are taken from Guidelines accompanying Regulation (EU) No 1254/2014 with regard to the energy labelling of residential ventilation units and Regulation (EU) No 1253/2014 with regard to Ecodesign requirements for ventilation units).

2.15 EN ISO 12759

Fans — Efficiency classification for fans

ISO 12759:2010 specifies requirements for classification of fan efficiency for all fan types driven by motors with an electrical input power range from 0,125 kW to 500 kW. It is applicable to (bare shaft and driven) fans, as well as fans integrated into products. Fans integrated into products are measured as stand-alone fans.

It is not applicable to fans for smoke and emergency smoke extraction; fans for industrial processes; fans for automotive application, trains, planes, etc.; fans for potentially explosive atmospheres; box fans, powered roof ventilators and air curtains or jet fans for use in car parks and tunnel ventilation

2.16 EN ISO 16890 Air filters for general ventilation

This test method shifts the focus on filtration performance to the classes of particulate matter size (PM) and is a more realistic test criteria than the theoretical EN 779:2012. EN 779 tests arrestance of only one particulate size (0.4 µm). ISO 16890 determines arrestance over a spectrum of particulate sizes (see also below). A simple 'translation' of classes ISO 16890 to EN779:2012 is not possible because of the very different measurement and assessment methods.

EN ISO 16890:2016 consists of the following parts, under the general title Air filters for general ventilation:
Part 1: Technical specifications, requirements and classification system based upon particulate matter efficiency (ePM)
Part 2: Measurement of fractional efficiency and air flow resistance
Part 3: Determination of gravimetric efficiency and the air flow resistance versus the mass of test dust captured
Part 4: Conditioning method to determine the minimum fractional test efficiency.

Particulate matter in the context of ISO 16890 series describes a size fraction of the natural aerosol (liquid and solid particles) suspended in ambient air. The symbol ePM_x describes the efficiency of an air cleaning device to particles with an optical diameter between 0.3 µm and x µm. The following particle size ranges are used in the ISO 16890 series for the listed efficiency values.

Table 26: Optical particle diameter size ranges for the definition of the efficiencies ePM_x

Efficiency	Size range, µm	Classification Criterium
ePM_{10}	$0.3 \leq x \leq 10$	Average efficiency ≥ 50 %
$ePM_{2.5}$	$0.3 \leq x \leq 2.5$	Minimum efficiency ≥ 50 %
ePM_1	$0.3 \leq x \leq 1$	Minimum efficiency ≥ 50 %

Part 1: Technical specifications, requirements and classification system based upon particulate matter efficiency (ePM)

This part of ISO 16890 establishes an efficiency classification system of air filters for general ventilation based upon particulate matter (PM). It also provides and overview of the test procedures, and specifies general requirements for assessing and marking the filters, as well as for documenting the test results. It is intended for use in conjunction with ISO 16890-2, ISO 16890-3 and ISO 16890-4.

The test method described in this part of ISO 16890 is applicable for air flow rates between 0.25 m3/s (900m^3/h) and 1.5 m^3/s (5400 m^3/h), referring to a test rig with a nominal face area of 610 mm x 610 mm.

ISO 16890 (all Parts) refers to particulate air filter elements for general ventilation having an ePM_1 efficiency less than or equal to 99% when tested according to the procedures defined within ISO 16890-1, ISO 16890-2, ISO 16890-3 and ISO 16890-4. Air filter elements with a higher initial efficiency are evaluated by other applicable test methods (see ISO 29463-1, ISO 29463-2, ISO 29463-4 and ISO 29463-5)

This test method shifts the focus on filtration performance to the classes of particulate matter size (PM) and is therefore a much more realistic test criteria than the theoretical EN779:2012.

Part 2: Measurement of fractional efficiency and air flow resistance

This part of ISO 16890 specifies the aerosol production, the test equipment and test methods used for measuring fractional efficiency and air flow resistance of air filters for general ventilation.

It is intended for use in conjunction with ISO 16890-1, ISO 16890-3 and ISO 16890-4.

The test method described in this part of ISO 16890 is applicable for air flow rates between 0.25 m^3/s (900m^3/h) and 1.5 m^3/s (5400 m^3/h), referring to a test rig with a nominal face area of 610 mm x 610 mm.

ISO 16890 (all Parts) refers to particulate air filter elements for general ventilation having an ePM_1 efficiency less than or equal to 99% and an ePM_{10} efficiency greater than 20% when tested as per the procedures defined within ISO 16890 (all parts)

Part 3: Determination of gravimetric efficiency and the air flow resistance versus the mass of test dust captured

This part of ISO 16890 specifies the test equipment and the test methods used for measuring the gravimetric efficiency and resistance to air flow of air filter for general ventilation.

It is intended for use in conjunction with ISO 16890-1, ISO 16890-2 and ISO 16890-4.

The test method described in this part of ISO 16890 is applicable for air flow rates between 0.25 m^3/s (900 m^3/h) and 1.5 m^3/s (5400 m^3/h), referring to a test rig with a nominal face area of 610 mm x 610 mm.

ISO 16890 (all Parts) refers to particulate air filter elements for general ventilation having an ePM_1 efficiency less than or equal to 99% and an ePM_{10} efficiency greater than 20% when tested as per the procedures defined within ISO 16890 (all parts).

Part 4: Conditioning method to determine the minimum fractional test efficiency.

This part of ISO 16890 establishes a conditioning method to determine the minimum fractional test efficiency

It is intended for use in conjunction with ISO 16890-1, ISO 16890-2 and ISO 16890-3 and provides the related test requirements for the test device and conditioning cabinet as well as the conditioning procedure to follow.

The conditioning method described in this part of ISO 16890 is referring to a test device with a nominal face area of 610 mm x 610 mm.

ISO 16890 (all Parts) refers to particulate air filter elements for general ventilation having an ePM_1 efficiency less than or equal to 99% and an ePM_{10} efficiency greater than 20% when tested as per the procedures defined within ISO 16890 (all parts)

NOTE the lower limit for this test procedure is set at a minimum of ePM_{10} efficiency of 20% since it will be very difficult for a test filter element below this level to meet the statistical validity requirements of this procedure.

2.17 Material efficiency standards

In December 2015 the Commission issued a standardisation request to the European Standardization organisations regarding Ecodesign requirements on material aspects for energy-related products. The standardisation work is performed in CEN-CLC/J WG 10 under M/543[21].

The Technical Boards of CEN and CENELEC established a joint technical body to prepare standards that cover both electro technical and non-electro technical matters.

CEN- CENELEC Technical Committee 10, known as 'Energy-related products – Material Efficiency Aspects for Ecodesign', has created 6 Working Groups that are responsible for the development of the standardisation deliverables:

- WG 1 'Terminology'
- WG 2 'Durability'
- WG 3 'Ability to repair, reuse and upgrade energy-related products'
- WG 4 'Ability to remanufacture and method for determining the proportion of reused components in products'
- WG 5 'Ability to recycle and recover energy-related products, recycled material content of energy-related products'
- WG 6 'Documentation and/or marking regarding information relating to material efficiency of the product'

WG 1 is developing a technical report TR 45550 which gives a glossary of definitions related to material efficiency. The next draft will be prepared once all the other relevant standards developed under M/543 have been finalised for Formal Vote (FV) by the Working Groups.

The other relevant standards part under M/543 are under development or published are:

prEN 45552 ,General method for the assessment of the durability of energy related products.

The standard prEN 45552 focuses on durability and reliability of parts and products, including software. Reliability is an element of durability, representing the assessment of the time from first use to first failure or in-between failures, whilst durability is the whole assessment from production to end of life.

The standard requires an analysis of functions and operating conditions (including environmental conditions) (Clause 5) followed by a reliability analysis of failure modes, failure sites and frequency of failure, to be assessed using specific standards (clause 6). Assessment of durability (clause 7) shall follow EN 62308:2006, possibly involving accelerated tests according EN 62506:2013. Depending on the specific subject, repair and

[21] https://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=564

maintenance can be included in the durability assessment or not. Reporting is described in clause 8. The publication is expected for March 2020.

FprEN 45553, General method for the assessment of the ability to re-manufacture energy related products
The standard provides a general method for assessing the ability of an energy-related product to be remanufactured. It identifies seven general process steps which are crucial to the remanufacturing process. Each of the seven steps is linked to several product attributes of the energy-related product.

These process steps, which can occur more than once and in a different order than presented below, are:

- Inspection
- Disassembly
- Cleaning
- Reprocessing
- Assembly
- Testing
- Storage

The relevant parameters to assess remanufacturability (ease of: locating access points and fasteners; identification and verification; access; disassembly and reassembly; and wear resistance). The remanufacturability can be expressed using a scoring system (not yet described). The publication of this standard is expected for 2020.

FprEN 45554, General methods for the assessment of the ability to repair, reuse and upgrade energy related products
The standard focuses on three aspects: Reparability, Reusability and Upgradeability (RRU). After having explained the use of the standard for qualitative / semi-quantitative and quantitative assessment of RRU (clause 4) and general considerations (clause 5) the standard describes (in clause 6) the product related criteria and (in clause 7) an overview of the support-related criteria is given and Reporting reparability, re-useability and upgradeability aspects are discussed in clause 8. The publication of this standard is expected for 2020.

EN 45555:2019, General methods for assessing the recyclability and recoverability of energy related products
This standard defines generic methods and parameters which are applicable for the development of product-specific standards in order to calculate product-specific recyclability and recoverability rates. The standard covers recyclability, recoverability (includes incineration with energy recovery, or backfilling), and the ability to remove certain parts and/or (parts containing) critical raw materials during end-of-life, and recognises that recyclability/recoverability are determined by both the product characteristics and the waste treatment processes, and their interplay.

The general assessment describes the following factors
• the design characteristics of the product such as the structure, material composition, size, weight mass;
• the techniques, combination or sequence of techniques used to recycle or recover a given waste stream.

The end-of-life treatment scenario and criteria to assess the compatibility of the product with this scenario are discussed in clause 5. When defining the EOL the representativeness of the product, technology and temporal and geographical boundaries must be considered.

Design related criteria affecting recyclability and recoverability, assessment of the recyclability and recoverability of an energy-related product and Assessment of the recyclability and recoverability of critical raw materials have a more general, approach uses simple yes/no factors in determining the recyclability/recoverability of materials.

EN 45556:2019, General method for assessing the proportion of re-used components in an energy-related product
The standard provides formulae for determining a reuse index one either or all of three bases: by mass, number or value of reused component using a simple proportion. An important assumption is that suitable audit trail exists to correctly identify reused components from new.

prEN 45557, General method for assessing the proportion of recycled material content in energy-related products
This European Standard is currently under development (expected publication date 2020). The aim is to ensure a general method for assessing the proportion of recycled material content in energy related products. This standard relates to the physical characteristic of the materials and manufacturing history of all the parts in the product. The standard includes:
• Methods for calculating the recycled material content
• Specific guidelines per material type
• Traceability
• Reporting

Guidelines for accounting and reporting recycled content will contribute to avoid potentially unsubstantiated and misleading claims on recycled content for which it is not clear how they are determined. This standard enables requirements of recycled content in products as these claims can be controlled by market surveillance authorities

EN 45558:2019, General method to declare the use of critical raw materials in energy-related products
Topics covered are linked to the following material efficiency aspects:

- Extending product lifetime;
- Ability to re-use components or recycle materials from products at end-of-life;
- Use of re-used components and/or recycled materials in products.

This standard distinguishes between regulated and non-regulated CRMs and assist users (manufacturers and their suppliers) to make CRM declarations, giving the supply chain some level of certainty regarding what to report, how to report and a standardised mechanism to communicate the data throughout the supply chain.

EN 45559:2019, Methods for providing information relating to material efficiency aspects of energy-related products
This document establishes a common method for the provision of information related to the material efficiency (ME) aspects of ErP. It has two key intentions:

- it requires generic or horizontal ME topic publications to include a clause with an overview of the specific topic-related content to be reported; and
- it includes a generic method on how to create a communication strategy which will be used when preparing product-specific, or product-group, publications.

3. Legislation

3.1 Introduction

The aim of this section is to describe which policies and measures affect the performance and characteristics of ventilation units.

Both generic EU legislation with relevance ventilation units as product specific legislation will be described in this chapter.

3.2 Ecodesign - 2009/125/EC (ex. 2005/32/EC)

Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 (recast of Directive 2005/32/EC on energy using products) establishes a framework for the setting of eco-design requirements for energy related products which have to be met before they can be placed on the EU market. It does not apply to transport used to carry people or goods.[22]

The Ecodesign Directive aims to remove disparities between the laws or administrative measures adopted by the Member States in relation to the Ecodesign of energy-related products as these may impact the establishment and functioning of the internal market. The Directive refers in particular to Article 95 of the Treaty establishing the European Community.

Key points of the Directive are:

- Eco-design requirements cover all stages of a product's life: from raw materials, manufacturing, packaging and distribution to installation, maintenance, use and end-of life. The requirements can be:
  - **specific** e.g. minimum energy efficiency requirements or maximum emission limit values, or criteria related to circular economy (product durability);
  - **generic**, e.g. requiring the provision of relevant product information and may extend to producing an overview of life cycle impacts.
- Products which satisfy the requirements bear the CE marking and may be sold anywhere in the EU.

The Directive is a New Approach Directive and requires[23] the use of CE marking and harmonised standards to show conformity with essential requirements. The essential requirements and conformity assessment procedures are specified by the implementing measures and usually leave to manufacturers the choice between the internal design control set out in Annex IV to this Directive (Module A of Council Decision 768/2008/EC) and the management system set out in Annex V to this Directive (the management system

[22] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC Text with EEA relevance, OJ L 315, 14.11.2012, p. 1–56

[23] Article 3 of Directive 2009/125/EC specifies that "Member States shall ...ensure that products covered by implementing measures may be placed on the market and/or put into service only if they comply with those measures and bear the CE marking in accordance with Article 5." Article 5 states that a CE marking shall be affixed before the products is placed on the market and/or put into service.

assessment includes, besides the same elements as the internal design control, additional elements regarding a management system aimed at improving the environmental performance of products and the organisation; describing policies, planning, implementation and documentation, checking and corrective action).
Other modules as described in Annex II to Decision No 768/2008/EC (Module A to G) are in principle possible, where duly justified and proportionate to the risk.

3.3 Energy Labelling – 2017/1369/EU

The former Energy Labelling Directive 2010/30/EU has been replaced by the Energy Labelling Regulation (EU) 2017/1369 on 28 July 2017 [24].

Like the old directive the new regulation sets out obligations for suppliers and dealers of energy-related products for the labelling of those products and the provision of standard product information regarding energy efficiency, the consumption of energy and of other resources by products during use and supplementary information concerning products, thereby enabling customers to choose more efficient products in order to reduce their energy consumption. Two new elements are that the scope specifically includes 'systems' and that there is an obligation for suppliers to provide data-input for a product database.

The new regulation also presents new rules for the introduction of new labels and introduces a procedure to rescale existing labels. New labels shall no longer allow additional classes above A (A+ etc.), and class A shall be empty when a label is introduced on the market, to avoid too frequent rescaling of labels (class A and B empty if the pace of product change is quick).

3.4 Directive (EU) 2018/844 of May 2018

Amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency

The EPBD was revised in 2018 as part of the Clean energy for all Europeans package. Several of these revisions relate to ventilation and IAQ topics.

The revised Directive advises MS to ensure that the measures to improve energy performance do not focus only on the building envelope but include all relevant elements and technical systems. When buildings undergo major renovations, MS shall encourage that technical building systems are replaced or upgraded to high efficiency ones as far as technically and economically feasible. Technical building systems play an important role in reducing costs and maintaining or improving the *Indoor Environmental Quality* in our buildings.
In that sense, national renovation strategies should also address the fact that evidence based knowledge will be necessary to estimate not only the expected energy savings, but also wider benefits, such as those related to health, safety and air quality.

Inspection stand-alone ventilation systems
The revised Directive also mandates the Commission to conclude, by 2020, a feasibility study about the possibilities and timeline to introduce the inspection of stand-alone ventilation systems and an optional building renovation passport complementary to Energy Performance Certificates (EPCs) providing long-term, step-by-step renovation roadmap for specific buildings to improve energy performance (see Article 19a of the Directive). This can

[24] Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling and repealing Directive 2010/30/EU (Text with EEA relevance). OJ L 198, 28.7.2017, p. 1–23

support the development of a possible Indoor Environmental Quality declaration as part of the EPCs.

Voluntary smart readiness indicator

The Council has also agreed on the establishment of a voluntary Smart Readiness Indicator (SRI) promoting digitalisation and smart technologies. The Commission shall adopt a delegated act by 31 December 2019 establishing an optional common European Union scheme for rating the smart readiness of buildings. This rating shall be based on assessment of the buildings' or building units' capabilities to adapt its operation to the needs of the occupant, and the grid, and to improve its energy efficiency and overall performance, including indoor comfort and health.

The SRI shall cover features for enhanced energy savings, benchmarking and flexibility, enhanced functionalities and capabilities resulting from more interconnected and intelligent devices. The methodology shall consider features such as smart meters, building automation and control systems, self-regulating devices for indoor temperature, built-in home appliances, recharging points for electric vehicles, energy storage and detailed functionalities and the interoperability of these features, as well as benefits for the indoor climate condition, energy efficiency, performance levels and enabled flexibility. Three key functionalities are listed:

- the ability to use energy from renewable sources in a flexible way,
- the ability to adapt its operation mode in response to the needs of the occupant in a user-friendly way, to maintaining healthy indoor climate conditions and to report on energy use,
- the flexibility of a building's overall electricity demand, including demand-response in relation to the grid.

A consortium of consultants was contracted by DG Energy and is working on a study defining the criteria and a calculation methodology based on related international and European standards, and on a feasibility study about the SRI indicator.

Health aspects and IEQ

Supported by the European Parliament, stakeholders have been advocating for strengthened Indoor Environmental Quality (IEQ) requirements and health aspects in the EPBD. The compromise legislation contains some improvements, although it doesn't set binding European IEQ criteria. The IEQ related relevant point of the directive are the following:

- For new buildings and buildings undergoing major renovations, MS should encourage high-efficiency alternatives while also addressing healthy indoor climate conditions. MS should support that energy performance upgrades of existing buildings contribute to achieving a healthy indoor environment.
- The directive refers to the 2009 WHO guidelines concerning indoor air quality, and better performing buildings that provide higher comfort levels and wellbeing and improve health.
- The Annex I of the directive indirectly mandates MS-s to define comfort and indoor air quality levels to safeguard the health of the building users by requiring that the energy needs for space heating, space cooling, domestic hot water, lighting, ventilation and other technical building systems shall be calculated in order to optimise health, indoor air quality and comfort levels defined by Member States at national or regional level.
- Long-term renovation strategies shall contain evidence-based estimate of expected energy savings and wider benefits, such as those related to health, safety, and air quality.

- The feasibility study on the inspection of stand-alone ventilation systems that shall be carried out by the EC before 2020 can support the development of a possible Indoor Environmental Quality declaration as part of the EPCs.

3.5 LVD – 2014/35/EU

Directive 2014/35/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits is a directive which requires CE marking. It repeals Directive 2006/95/EC with effect from 20 April 2016.
The directive creates uniform safety conditions for the placing on the market of electrical equipment designed for use within certain voltage limits. It applies to electrical equipment designed for use with a voltage rating of between 50 and 1 000 V for alternating current and between 75 and 1 500 V for direct current.

It covers all health and safety risks, thus ensuring that electrical equipment is used safely and for the applications for which it was made.

The relevance for ventilation units is that electric products are covered by the LVD.

3.6 EMC – 2014/30/EU

Directive 2014/30/EU[25] of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (recast) is a Directive which requires CE marking. It repeals Directive 2004/108/EC.

The directive defines the responsibilities of manufacturers, importers and distributors in regard to the sale of electromagnetic equipment.

The Directive aims to ensure that electrical and electronic equipment complies with an adequate level of electromagnetic compatibility by laying down uniform rules to ensure protection against electromagnetic disturbance so as to guarantee the free movement of electrical and electronic equipment within the EU's internal market. The equipment covered by this directive includes both apparatus and fixed installations.

The relevance for ventilation units is that certain products, that may be very susceptible to, or may affect other equipment through electromagnetic energy, may be covered by the EMC Directive. This may apply to certain variable speed motor drives incorporated into equipment.

3.7 PD – Packaging Directive 2015/720

The Packaging directive (EU) 2015/720 amends the original packaging directive 94/62/EC. The initial document sets measures and limitations on the production of packaging waste. It furthermore promotes recycling, re-use and waste recovery in general. All is focussed on using final disposal as a last resort.
The directive applies to all packaging placed on the European market, regardless their source or sector. In includes packaging at industrial, commercial, office, shop, household or

[25] OJ L 96, 29.3.2014, p.79-106

any other level and material. The directive sets requirements on the amount waste that needs to be recovered. The amendment of 2015 focuses specifically on the use and distribution of lightweight plastic bags, which is not directly relevant for ventilation units. The essential requirements for packaging are:

- to limit the weight and volume of packaging to a minimum in order meet the required level of safety, hygiene and acceptability for consumers;
- to reduce the content of hazardous substances and materials in the packaging material and its components;
- to design reusable or recoverable packaging.

3.8 CPD – 89/106/EEC & CPR 305/2011

The Construction Products Directive 89/106/EEC of 1989 has been replaced by the Construction products Regulation (EU) No 305/2011(CPR). The aim of the regulations is to lay down the essential requirements regarding safety of construction products and works. In doing so, it tries to eliminate technical barriers to trade between member States.

The essential requirements relate to mechanical safety, fire safety, hygiene, health and environment, safety in use, protection against noise and energy economy and heat retention. The actual values or thresholds to be achieved by products are laid down in harmonised standards. European technical Approval applies in cases no harmonised standards nor a recognized national standard exists and is based on ETA guidelines or issued upon common agreement of the approval bodies.
Due to the enormous diversity of construction products and works, the Regulation has various mechanisms for implementation, that take not account the specifics of the many SMEs active in the construction industry (both as supplier of products or as constructor of works).

The relevance of the CPR in this study is that certain products may be mentioned in the scope of CPR and in Annex 1 (6).

Following the publication of the July 2016 implementation report, the Communication Clean Energy for all Europeans announced a possible revision of the Construction Products Regulation in November 2016. An external study was carried out to collect evidence for the evaluation of the CPR and the impact assessment of future potential options in 2018[26].

3.9 MD – 2006/42/EC

The "Machinery" Directive 2006/42/EC of 17 May 2006 (recast of Directive 95/16/EC.) introduces essential requirements regarding health and safety for machinery, in order for them to move freely throughout the EU. The Directive promotes harmonisation through a combination of mandatory health and safety requirements and voluntary harmonised standards and applies to products when they are first placed on the EU market.
The directive covers machinery, interchangeable equipment, safety components, lifting accessories, chains, ropes and webbing, removable mechanical transmission devices and partly completed machinery. It does not cover other types of machinery, such as machinery used in fairgrounds, the nuclear industry, laboratories and mines or by the military or police.

[26] https://ec.europa.eu/growth/sectors/construction/product-regulation/review_en

3.10 RoHS (2)– 2011/65/EU & 2015/863/EU

In February 2003 the first RoHS Directive 2002/95/EC entered into force, restricting the use of hazardous substances in electrical and electronic products. The legislation requires heavy metals such as lead, mercury, cadmium, and hexavalent chromium and flame retardants such as polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE) to be substituted by safer alternatives.

In 2011 this Directive was repealed by Directive 2011/65/EU[27] (RoHS 2) which clarified certain terms, introduced new definitions and introduced a wider scope of products (open ended scope). The list of restricted substances was widened in 2015 by an amendment (Commission Delegated Directive (EU) 2015/863 of 31 March 2015) that added four phthalate types (DEHP, BBP, DBP and DIBP) to the list.
The RoHS requires demonstration of compliance by affixing the CE marking, plus related documentation.

The list of products exempted from substance bans is continuously revised and updated. Frequently Asked Questions have been answered in the RoHS 2 FAQ document. Furthermore, consolidated guidance for exemptions applicants and related application format pursuant to RoHS 2 Article 5(8) have been drafted.

In January 2017, the Commission adopted a legislative proposal under the Article 24(1) mandate to introduce adjustments in the scope of the Directive, including clarification on the conditions for exempting the reuse of spare parts, supported by the impact assessment. The proposal was adopted in first reading in the European Parliament on 3 October 2017 and in the Council on 23 October 2017. The final act was signed on 15 November 2017 and was published in the EU Official Journal on 21 November 2017 as Directive (EU) 2017/2102.

3.11 WEEE – 2012/19/EU

The first WEEE Directive (Directive 2002/96/EC) entered into force in February 2003. The Directive provided for the creation of collection schemes where consumers return their WEEE free of charge. These schemes aim to increase the recycling of WEEE and/or re-use.
In December 2008, the European Commission proposed to revise the Directive in order to tackle the fast-increasing waste stream. The new WEEE Directive 2012/19/EU entered into force on 13 August 2012 and became effective on 14 February 2014. This revised WEEE introduced an open-ended scope.

The FAQ document for the WEEE[28] of 2014 explains that the scope is for products that are ‘dependent on electric currents or electromagnetic fields in order to work properly’. This could mean that equipment that needs electric currents or electromagnetic fields (e.g. not petrol or gas) to fulfil their basic function (i.e., when the electric current is off, the equipment cannot fulfil its basic function) are within scope. If electrical energy is used only for support or control functions, this type of equipment is not covered by the Directive. Examples of equipment that does not need electricity to fulfil its basic function, (but only requires, for example, a spark to start), include petrol lawn mowers and gas stoves with electronic ignition only (see also Appendix, Part 2). Most ventilation units rely on electricity to function as intended (to run the fan(s), controls etc.)

On 4 February 2013, the Commission issued a request for standardisation M/518 to the European Standardization Organizations to develop European standards for the treatment of WEEE. These standards have been developed following the preparatory work under the

[27] OJ L 174, 1.4.2011, p.88-110
[28] http://ec.europa.eu/environment/waste/weee/pdf/faq.pdf

WEEELABEX project, by the so-called WEEE-forum. European standards (EN) and technical Specifications (precursor for possible EN) relevant for WEEE include the following:

Table 27: Standards for treatment of WEEE

Standard reference	Title or contents
EN 50419:2006	Marking of electrical and electronic equipment in accordance with Article 11(2) of Directive 2002/96/EC (WEEE) This standard applies to the application of the "wheelie bin" mainly – Requirements, design and location of the marking
EN 50574	Collection, logistics & treatment requirements for end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons
TS 50574-2	Collection, logistics & treatment requirements for end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons - Part 2: specification for de-pollution
EN 50614	Requirements for the preparing for re-use of waste electrical and electronic equipment (not yet published)
EN 50625-1	Collection, logistics & treatment requirements for WEEE - Part 1: General treatment requirements
TS 50625-3-2	Collection, logistics & treatment requirements for WEEE -- Part 3-2: Specification for de-pollution – Lamps
EN 50625-2-2	Collection, logistics & treatment requirements for WEEE -- Part 2-2: Treatment requirements for WEEE containing CRTs and flat panel displays
TS 50625-3-3	Collection, logistics & treatment requirements for WEEE -- Part 3-3: Specification for de-pollution- WEEE containing CRTs and flat panel displays (not yet published)
EN 50625-2-3	Collection, logistics & treatment requirements for WEEE -- Part 2-3: Treatment requirements for temperature exchange equipment (not yet published)
TS 50625-3-4	Collection, logistics & treatment requirements for WEEE -- Part 3-4: Specification for de-pollution- temperature exchange equipment (not yet published)
EN 50625-2-4	Collection, logistics & treatment requirements for WEEE -- Part 2-4: Treatment requirements for photovoltaic panels (not yet published)
TS 50625-3-5	Collection, logistics & treatment requirements for WEEE -- Part 3-5: Specification for de-pollution- photovoltaic panels (not yet published)
TS 50625-4	Collection, logistics & treatment requirements for WEEE -- Part 4: Specification for the collection and logistics associated with WEEE (not yet published)
TS 50625-5	Collection, logistics & treatment requirements for WEEE -- Part 5: Specification for the end-processing of WEEE fractions- copper and precious metals (not yet published)

3.12 Ecodesign Fan Regulation

The Ecodesign Commission Regulation 327/2011 on Fans >125 W (hereafter '*Fan Regulation*'), covers fans with rated electric motor input power between 125 W and 500kW.

It uses the fan system efficiency as a parameter for Minimum Efficiency Performance Standards (MEPS).

It is based on the ISO 5801 standard for the performance assessment.

The Fan Regulation uses 4 different *measurement categories*, depending on whether the fan inlet and outlet are both free (category A), ducted on the outlet side (B), on the inlet side (C) or ducted on both sides. ISO 5801 defines the standard airways (ducts) that allows fans to be tested with harmonized test set-ups. A fan adaptable to more than one measurement category will have more than one performance characteristic.

The Fan Regulation then distinguishes, depending on measurement category, an *efficiency category* which may be based on either *static pressure*[29] or *total pressure*[30], resulting in either *static efficiency* or *total efficiency*. The Fan Regulation proposes an assessment at the *Best Efficiency Point (BEP)*.

The nominal rated motor efficiency ηm should be determined in accordance with Regulation 640/2009 whenever applicable. If the motor is not covered by Regulation 640/2009 or in case no motor is supplied a default ηm is calculated for the motor using empirical equations given in the regulation. Note: a new motor Regulation will be published soon.

As regards the use of Variable Speed Drives, the Fan Regulation recognises that –although in a standard test it may cost some energy - in practice this is an efficient feature and it has introduced a *part load compensation factor* C_c in the equation for the fan system efficiency. *The drive efficiency* η_T is 100% for a direct-drive, 89% for a 'low-efficiency drive' and 94% for a 'high efficiency drive'.

In case the fan is not placed on the market as a *'final assembly'* –not relevant for products in the scope of ENTR Lot 6 but mentioned to complete the picture—there is a *compensation factor* C_m in the equation (default 0.9) that accounts for matching of components.
All in all, the generic equation for fan system efficiency in the Fan Regulation, using the notation from the Fan Regulation is

$$\eta_e = \eta_r \cdot \eta_m \cdot \eta_T \cdot C_m \cdot C_c \text{ , where:}$$

η_e is the overall efficiency;
η_r is the fan impeller efficiency according to $P_{u(s)} / P_a$,where:

$P_{u(s)}$ is fan gas power determined at the point of optimal energy efficiency for the impeller;
P_a is the fan shaft power at the point of optimal energy efficiency of the impeller;

η_m is the nominal rated motor efficiency in accordance with Regulation 640/2009 whenever applicable. If the motor is not covered by Regulation 640/2009 or in case no motor is supplied a default η_m is calculated for the motor using the following values:

[29] 'Fan static pressure' (p_{sf}) means the fan total pressure (pf) minus the fan dynamic pressure corrected by the Mach factor; 'Mach factor' means a correction factor applied to dynamic pressure at a point, defined as the stagnation pressure minus the pressure with respect to absolute zero pressure which is exerted at a point at rest relative to the gas around it and divided by the dynamic pressure; 'Stagnation pressure' means the pressure measured at a point in a flowing gas if it were brought to rest via an isentropic process;
[30] 'Fan total pressure' (p_f) means the difference between the stagnation pressure at the fan outlet and the stagnation pressure at the fan inlet;

if the recommended electric input power 'Pe' is ≥ 0.75 kW,
$\eta_m = 0.000278*(x^3) - 0.019247*(x^2) + 0.104395*x + 0.809761$
where $x = Log(P_e)$
and P_e is as defined in 3.1.(a);

if the recommended motor input power 'Pe' is < 0.75 kW,
$\eta_m = 0.1462*\ln(P_e) + 0.8381$
and P_e is as defined in 3.1.(a), where the electric input power Pe recommended by the manufacturer of the fan should be enough for the fan to reach its optimum energy efficiency point, taking into account losses from transmission systems if applicable;

η_T is the efficiency of the driving arrangement for which the following default values must be used:
for direct drive $\eta_T = 1.0$;

if the transmission is a low-efficiency drive then
$P_a \geq 5$ kW, $\eta_T = 0.96$ or 1 kW < P_a < 5 kW, $\eta_T = 0.0175 * Pa + 0.8725$ or
$P_a \leq 1$ kW, $\eta_T = 0.89$

if the transmission is a high-efficiency drive then
$P_a \geq 5$ kW, $\eta_T = 0.98$ or 1 kW < P_a < 5 kW, $\eta_T = 0.01 * Pa + 0.93$ or
$P_a \leq 1$ kW, $\eta_T = 0.94$

C_m is the compensation factor to account for matching of components, with value 0.9 for fans without housing and 1 for fans with housing;

C_c is the part load compensation factor:
for a motor without a variable speed drive $C_c = 1.0$
for a motor with a variable speed drive and $P_{ed} \geq 5$ kW then $C_c = 1.04$
for a motor with a variable speed drive and $P_{ed} <$ 5 kW then

$C_c = -0.03 \ln(P_{ed}) + 1.088$.

In its target efficiency the Fan Regulation also implicitly uses the new ISO 12759 and AMCA 205 [31]standard on FMEG, because it sets a different target for units up to 10 kW electric motor power input and units above 10 kW. Target values for category A,C seem less ambitious than for category B,D , but it must be taken into account that these are efficiencies based on total pressure[32], i.e. generally 10-15%-points higher than the efficiency values based on static pressure.

The table below gives a summary of the Fan Regulation and examples of minimum efficiency targets for several values of the electric motor power P (in kW).

[31] AMCA 205. Energy efficiency classification for fans
[32] Dynamic pressure (in Pa) is the pressure derived from the mass flow rate, the average gas density at the outlet and the fan outlet area.

Table 28: Ecodesign Fan Regulation 327/2011, summary and examples

						EXAMPLES (P in kW)					
fan type	**cat.**	**press.**	**range P in kW**	**ηtarget =**	**N 15**	**P =**	**0.5**	**1**	**2.2**	**7.5**	**32**
Axial	A, C	static	P ≤ 10	2.74 · ln(P) − 6.33 + N							
			10 < P	0.78 · ln(P) − 1.88 + N	40		31	34	36	39	41
	B, D	total	P ≤ 10	2.74 · ln(P) − 6.33 + N							
			10 < P	0.78 · ln(P) − 1.88 + N	58		49	52	54	57	59
FC and radial*	A, C	static	P ≤ 10	2.74 · ln(P) − 6.33 + N	44						
			10 < P	0.78 · ln(P) − 1.88 + N			35	38	40	43	45
	B, D	total	P ≤ 10	2.74 · ln(P) − 6.33 + N	49						
			10 < P	0.78 · ln(P) − 1.88 + N			40	43	45	48	50
BC without housing**	A, C	static	P ≤ 10	4.56 · ln(P) − 10.5 + N	62						
			10 < P	1.1 · ln(P) − 2.6 + N			48	52	55	61	64
BC with housing ***	A, C	static	P ≤ 10	4.56 · ln(P) − 10.5 + N							
			10 < P	1.1 · ln(P) − 2.6 + N	62		48	52	55	61	64
	B, D	total	P ≤ 10	4.56 · ln(P) − 10.5 + N							
			10 < P	1.1 · ln(P) − 2.6 + N	64		50	54	57	63	66
Mixed flow	A,C	static	P ≤ 10	4.56 · ln(P) − 10.5 + N	50						
			10 < P	1.1 · ln(P) − 2.6 + N			47	47	48	50	52
	B,D	total	P ≤ 10	4.56 · ln(P) − 10.5 + N	62						
			10 < P	1.1 · ln(P) − 2.6 + N			59	59	60	62	64
Cross flow	B, D	total	P ≤ 10	1.14 · ln(P) − 2.6 + N	21						
			10 < P	N			17	18	19	21	21

*=Centrifugal forward curved fan and centrifugal radial bladed fan

**=Centrifugal backward curved fan without housing

***=Centrifugal backward curved fan with housing

Compare:

	0.5	1	2.2	7.5	32
Sales 2010 (total; cat. B,D)	18	63	54	58	61
Stock 2010 (total; cat B,D)	17	56	45	50	52

cat. A,C= measurement with free in/outlets or duct inlet
cat. B, D=with duct outlet or both duct in/outlet
press. static= static efficiency

press. total= total efficiency

ηtarget = minimum efficiency (in %) , equation as function of P (in kW) and N
N= efficiency grade; '15'=applies to tier 2 in 2015.

The Commission expects an electricity saving potential of 5% in 2020 from this generic fan measure (34 TWh/a on a total of 560 TWh/a in baseline 2020).
Although the Ecodesign Fan Regulation promises to be a valuable generic instrument to eliminate the least efficient fans from the market, it is by no means a substitute for the regulation of energy consumption inside a specific application such as the mechanical ventilation unit, because

- It does not cover the role of controls and heat recovery, thus missing out on very important saving potential related to mechanical ventilation;
- Even when related on electricity consumption alone, the ambition level of a generic fan measure is governed by the economics of the "weakest application" in terms of payback-time and Life Cycle Costs, in order to avoid a "negative impact on the industry" (boundary condition of directive 2009/125/EC). In contrast, when the application is known –as is the case with mechanical ventilation—the ambition level can be specific and in this case much higher. For the application in non-residential

ventilation units, where usually the category B,D (with outlet ducts) applies and cross-flow fans are not suitable, it seems that 5% is a conservative estimate. The potential could be increased by excluding forward curved and radial fans for this application.

- A generic fan measure uses generic test conditions. A specific application uses its own measurement standards, which take into account the specific design and (selection of) components used. For instance, using the same fan, there may be up to 50% electricity saving of the ventilation unit depending on the internal pressure drop of the casing, fan in/outlet, filters and the heat recovery unit.
- Last but not least, the selection of the right fan, motor and drive in relation to the load profile of a ventilation unit may give a very different design than is evident from generic fan specifications. This is related to the so-called 'fan-laws', describing the non-linear relationship of the energy use, fan impeller and fan speed, i.e. showing that the best efficiency point (bep) of a generic fan test (usually at 70% of nominal pressure and flow rate) is often not the bep in operation. Depending on the application, it may e.g. be advantageous to choose a large impeller with a smaller (lower rpm) motor and fitting variable speed drive, especially if the fan is to operate in part load. According to the fan laws, a 10% increase of impeller diameter results in a 41% energy saving (fiftht power correlation, c.p.). The fan rotational speed decrease of 20% leads to an almost 50% decrease in absorbed power (third power correlation, c.p.). These effects will often not show from a fan manufacturer's catalogue, where the priority is usually to show a fan with the highest nominal flow rate at the lowest price.

3.13 Ecodesign Electric Motor Regulation No. 640/2009

The Ecodesign Commission Regulation No. 640/2009 on Motors > 750 W (and < 375 kW) was published d.d. 23.7.2009. Regulation No. 640/2009 stipulates that (brushless squirrel cage) fan motors have to reach IE2 level on the 16th of July 2011 and meet either the IE3 level or be equipped with a variable speed drive by 1 January 2015 (large motors 7.5-375 kW) respectively 1 January 2017 (all motors 0.75-375 kW).

Motors in ventilation units or ventilation fans are not part of the exemptions, and thus the regulation will apply in general. However, it applies only to electric single speed, three-phase 50 Hz or 50/60 Hz, squirrel cage induction motor that:
— has 2 to 6 poles,
— has a rated voltage of U N up to 1 000 V,
— has a rated output P N between 0.75 kW and 375 kW,
— is rated on the basis of continuous duty operation.

These single speed motors are rare in ventilation unit applications and thus the impact of the measure will be very limited omn the products in scope.

3.14 Ventilation rates and IAQ in National Legislation

National building regulations and national ventilation standards are governing building practices and ventilation requirements in new and existing buildings in the various member states. In Work Package 5 of the HealthVent project (supported by the EC) is was found

that the national ventilation rate values used the various member states vary considerably.[33]
Large differences were found in both local exhaust rates and air changes per hour over the entire dwelling, with factor of almost 1 to 6.

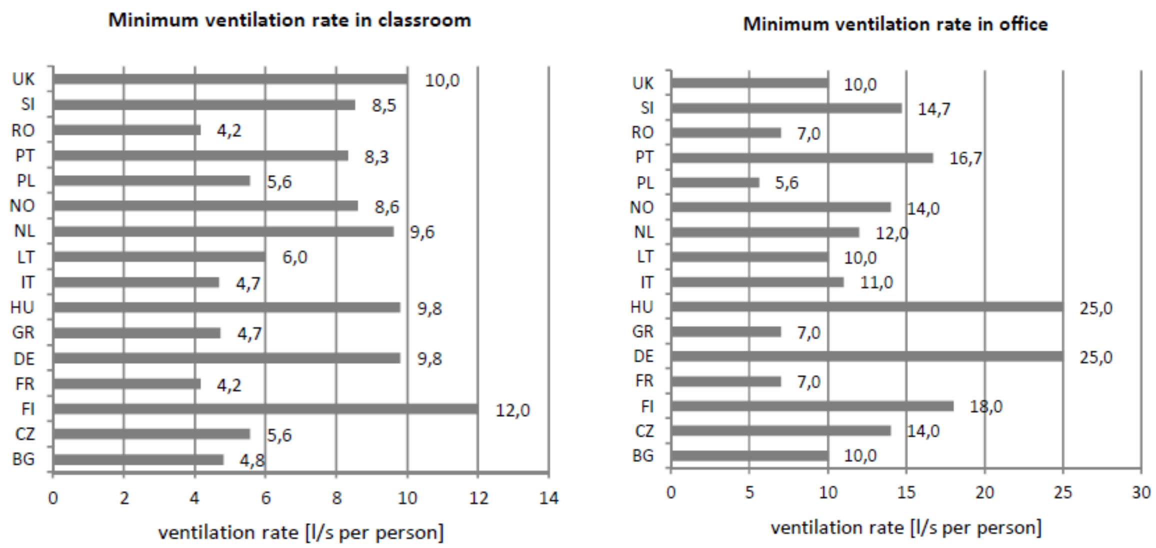


Figure 3 . Examples of the variations in minimum requested ventilation rates in various national standards for non-residential buildings

[33] Brelih,N., Seppänen, O., Ventilation rates and IAQ in European standards and national regulations, 32nd AIVC Conference, Brussels, October 2011.

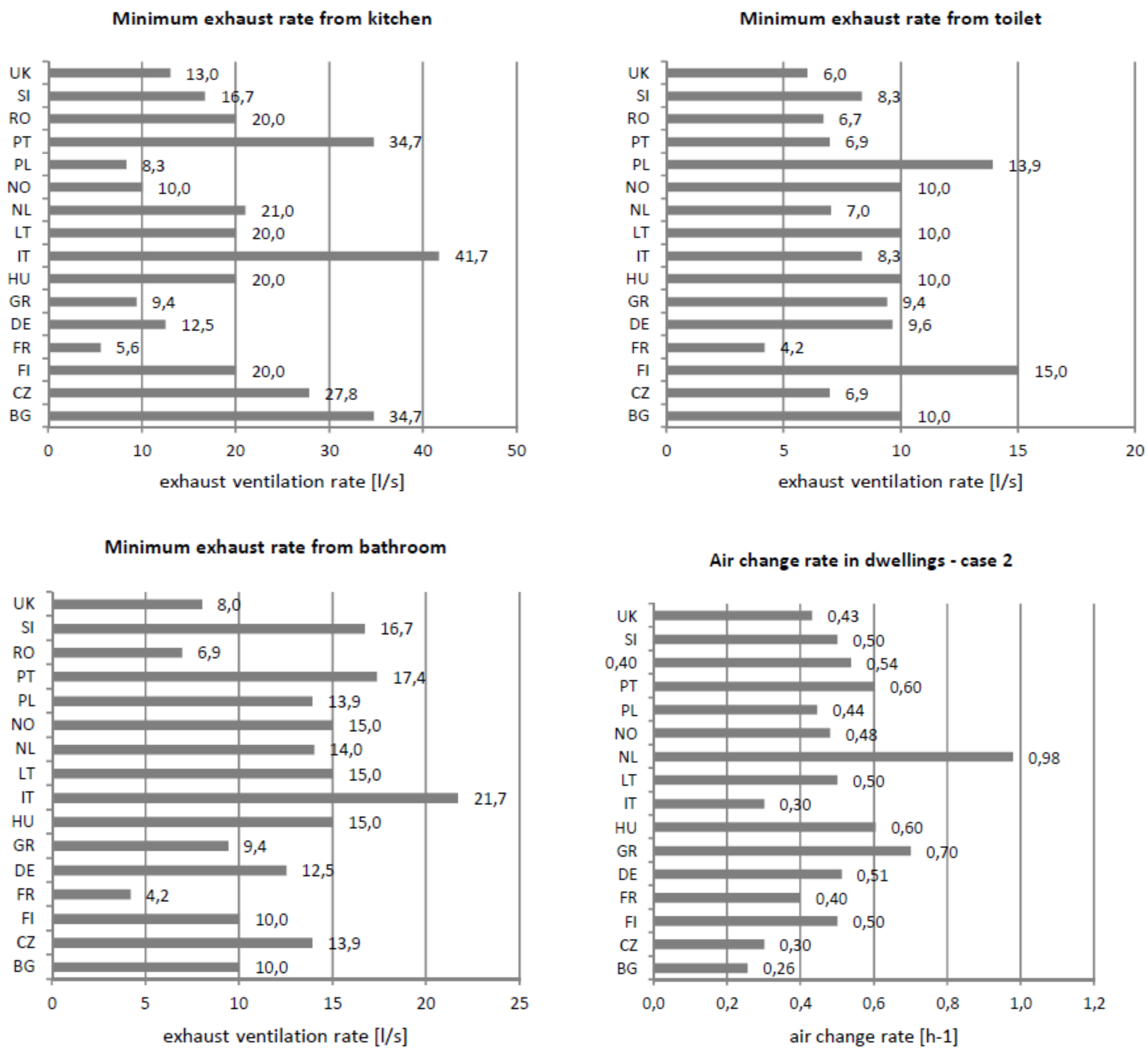


Figure 4. Examples of the variations in minimum requested ventilation rates in various national standards for residential buildings

The paper[7] concludes that '*although almost all these ventilation parameters are already defined in European Standards (and accepted in the CEN voting process by national bodies), the regulations in the individual member states are different and clearly not harmonized. This inconsistency between EN standards and national regulations, as well as between member states, causes problems to designers and industry, and increases the cost. Furthermore, this practice is in contrast with the efforts of unification and standardization of the European common market. Clearly, a common European guideline is needed, which would serve as a basis for national European regulations. The guide-line should include ventilation rates, technical properties, and other parameters related to the performance of ventilation*'

In march 2015, the Buildings Performance Institute Europe (BPIE) published an analysis report on residential buildings regulation in eight EU member states.[34] In the executive summary the background and main findings of these analyses are described.

[34] Kunkel, S., and others, Indoor Air Quality, Thermal Comfort and Daylight, Analysis of Residential Building Regulations in Eight EU Member States, ISBN:9789491143106, published March 2015 by BPIE

Background
'Air quality - be it indoors or outdoors - is one of the major environmental health concerns for Europe1. For this reason, and since people spend 60-90% of their life in indoor environments (homes, offices, schools, etc.), indoor air quality plays a very important role in the health of the population, particularly for vulnerable groups such as babies, children and the elderly. According to the World Health Organization3, 99 000 deaths in Europe and 19 000 in non-European high income countries were attributable to household (indoor) air pollution in 2012.

Indoor air quality (IAQ) refers to the quality of the air inside buildings and is related to people's health, comfort and ability to work. To define IAQ, parameters such as ventilation rate and exposure to mould or chemicals should be taken into account. Indoor air pollutants are emitted from sources inside the building but can also come from outside. For instance, pollutants are emitted when cleaning or when burning fuel for cooking and heating. But even furniture and construction materials, as well as dampness, lack of or improper ventilation or contaminated outdoor air, can be responsible for poor indoor air quality.

The building sector in the EU is responsible for more than a third of the energy consumption and a similar share of the CO_2 emissions associated with human activities. Building policies are thus becoming more demanding in respect to the improvement of energy performance and the reduction of CO_2 emissions. Consequently, buildings are being better insulated and made more airtight so as to prevent heat loss via transmission and uncontrolled airflows. To ensure a good indoor climate and air exchange in buildings, a ventilation control system is required (for which both natural and mechanical solutions exist). Therefore, the evolution towards meeting the requirements for energy performance in existing buildings should impose appropriate minimum requirements to secure a good indoor air quality for the occupants.

The Energy Performance of Buildings Directive (EPBD, 2010/31/EU) clearly states that minimum energy performance requirements "shall take account of general indoor climate conditions, in order to avoid possible negative effects such as inadequate ventilation". However, within the EU legislation there are currently no clear requirements describing how this can be achieved. Therefore, it is important to have a better understanding of the role of indoor climate requirements in national regulations in order to compare them with the European technical standards and to create evidence for potential future improvements. The assessment focuses on the respective building codes for new and existing residential buildings in selected MS: Belgium (Brussels Region), Denmark, France, Germany, Italy, Poland, Sweden and the UK (England and Wales)

Main findings new residential buildings
Ventilation is included in the building regulations of all surveyed MS. In Denmark, France, Sweden and Brussels-Capital Region (BE), there are clear minimum requirements, while in Germany, Italy, Poland and the UK there is only a recommendation for minimum ventilation rates. The indicators for minimum ventilation rates vary from one country to another and are generally different from EU standards (e.g. EN 13779 and EN 15251).

The most commonly used units are litres per second and cubic meters per hour while the air exchange rate is regulated based on the assumed number of occupants (e.g. Poland: 20 m3/h per occupant), or on the type of room (e.g. UK: Kitchen 13-60 l/s and WC 6 l/s), or on the floor area (e.g. 0.35 l/s per m2). Even though the use of the same metrics is less important, it seems that there is a need for further European harmonisation in order to facilitate a proper comparison across MS and an easier transfer of knowledge and practices among countries.
Mandatory mechanical ventilation is in effect in two cases, i.e. for multi-family (DK) and high-rise (PL) buildings. For the other cases, there are recommendations for mechanical ventilation in two countries (Br-Region in BE, DE), while in Italy, especially in warmer regions, natural ventilation is encouraged.

It is worth mentioning the fact that the Danish regulation specifically requires ventilation systems to be easy to maintain, even by the occupants. This should be considered as a good practice since ventilation systems need periodical maintenance to operate correctly over their lifetime. Maintenance of ventilation systems should be undertaken systematically and should therefore be an easy and affordable procedure. Last but not least, it seems that most surveyed countries have to further improve their calculation tools to address adequately hybrid and demand-controlled ventilation in order to have comprehensive calculation methods which can ensure that the ventilation needs are met.

Minimum efficiency requirements for *heat recovery systems* are in place in some countries (Sweden, Poland, Italy) when new mechanical ventilation systems are installed. *Airtightness* requirements differ largely across the EU. Six of the surveyed MS already have precise requirements in place. Similar to ventilation, indicators for airtightness requirements vary throughout Europe (e.g. volume per hour, litres per second per m2).

Random airtightness tests are required in Denmark and France, but are voluntary in the rest of the surveyed countries and are usually required only when applying for financial subsidies or energy certification in the high classes. Regulations for heat recovery and airtightness, mainly introduced for energy efficiency reasons, have to be completed by relevant ventilation requirements in order to secure proper indoor living conditions.

The *CO_2 concentration* in fully occupied buildings – where inhabitants are the main pollutants – in relation to outdoor concentration is indicated by the European standard EN 15251. Requirements to limit CO_2 levels in residential buildings are in place in France, while in the UK there are recommended levels. Limitations for *nitrogen oxide* are also in place in some countries (e.g. Denmark).

Five countries within this survey (Brussels-Capital Region-Belgium, Denmark, France, Germany and the UK) have *overheating* limitations (either mandatory or recommended), where overheating indicators differ by temperature and time limit. The extremes are found in Brussels-Capital Region (> 25°C for 5%/yr) and the UK (> 28°C for 1%/yr), but only as a recommendation in the latter case. Passive systems to avoid overheating are common in southern climates, but minimum requirements are mainly limited to solar shades while others such as ventilative cooling, the use of building mass, natural ventilation and night time ventilation are rarely considered. In Sweden, the building codes explicitly ask for consideration of some passive solutions and, in Brussels-Capital Region, a minimum share of 50% for passive systems is recommended for new buildings.

Maximum *relative air velocity* limits are inconsistent in Europe; they range from 0.15 to 0.40 m/s (in summer) and from 0.15 to 0.25 m/s (in winter). Maximum values for air velocity in order to avoid draughts are required in Sweden and recommended in Denmark, Italy, Poland, the UK and Brussels (from 2015).

Main findings existing residential buildings

For existing buildings, **indoor air quality** related requirements, such as minimum ventilation rates, airtightness or limitation of pollutants, can hardly be found in the analysed building codes. Only recommendations on IAQ aspects can be found in most of the building codes. Energy efficiency improvements do often apply without mandatory consideration of the influences in terms of building physics or indoor air quality. This lack of proper IAQ requirements to accompany the thermal and energy performance requirements has to be further considered as a priority.

Among the surveyed countries, the Swedish building codes are unique at the moment by underlining potential conflicts between energy saving requirements and good indoor air quality in existing buildings, stipulating that in such cases priority should be given to the latter. Generally, renovation measures resulting in more airtight buildings are not accompanied by a compulsory assessment of the ventilation needs. Therefore, in such situations, air change rates below the required values are reported. This is a serious shortcoming in building codes which has to be addressed through an improvement of the regulatory framework for renovation. Potentially, this aspect should be considered in the future recast of EU-related legislation such as the EPBD.

When major renovation is undertaken, the most common requirement across surveyed countries concerns the *thermal transmittance* of buildings' elements (U-Values), as required by the EPBD. Among the countries surveyed, only the southern ones (France and Italy) include shading requirements in the event of refurbishment.

Increased thermal comfort is often considered as a main driver for the decision of an owner-occupier to invest in renovation. However, thermal comfort resulting from improved energy performance is rarely captured by national and/or European legislations.

As in the case of new buildings, compliance checks are only done on structural analysis and energy performance aspects, while no indoor air quality or thermal comfort verification procedures have been identified. Indoor air quality and other aspects of thermal comfort have to be seriously considered when strengthening the energy performance requirements for buildings and building elements. Today, as identified in the eight focus countries of this study, *there are no clear and strict requirements in place for indoor air quality and thermal comfort*.

Recommendations

The following recommendations concerning ventilation and indoor air quality are provided in the BPIE report.

1.

Indoor health and comfort aspects should be considered to a greater extent in European building codes than current practice. When planning new nZEBs or nZEB refurbishments, requirements for a healthy and pleasant indoor environment should be included. While indoor climate is mentioned in the EPBD, the importance of indoor air quality, thermal comfort and daylight have to be strengthened in a future recast. Such requirements should also be reflected in national renovation strategies as developed under Articles 4 and 5 of the Energy Efficiency Directive.

2.

In EU and national legislation, stricter energy performance requirements should be completed with appropriate requirements and recommendations to secure proper indoor air quality, daylight and thermal comfort. For instance, requirements for stricter insulation and airtightness should be complemented by appropriate minimum requirements for indoor air exchange and ventilation. As there are several ways to obtain significant savings in energy consumption in buildings while at the same time improving the indoor climate, clear legislative provisions for conflicting situations will create certainty for planners and architects. At the same time legislation should be technology-neutral.

3.

Unused potentials for energy savings should be further exploited in European and national legislation taking a system-approach to the building. This means that the building's envelope and its insulation, use of daylight, demand-controlled ventilation, heat recovery through mechanical ventilation systems, installations to avoid overheating such as ventilative cooling and solar shading (e.g. by overhangs, louvers and awnings) should be analysed and optimised in a systematic way in order to achieve the highest energy saving possible.

4.

Indoor air quality, thermal comfort and daylight indicators should be integrated in the Energy Performance Certification as relevant information regarding the actual living conditions in the building.

5.
The development of a proper cost indicator and calculation formula to estimate the benefits of a healthy indoor environment should be considered and further integrated in the European methodology to calculate cost-optimal levels at macroeconomic level.
6.
Co-benefits of a healthy indoor environment should be taken into account when assessing the macroeconomic impact of energy renovation measures (e.g. reduction of health service costs).
7.
Passive systems to avoid overheating are common in southern climates, but minimum requirements are mainly limited to solar shades. Additional measures, such as the management of glazing areas of the building envelope, dynamic external shading, consideration of solar gains and the use of building mass, natural and night time ventilation strategies, etc. have to be further covered within national and European legislation.
8.
The mandatory compliance tools to evaluate energy performance according to national EPBD transposition should to a larger extent reward and facilitate the use of energy efficient ventilation solutions and measures to prevent overheating.

ANNEX 1 : STAKEHOLDER COMMENTS TO EXISTING REGULATION

1. Comments EUROVENT

The following comments/proposals has been put forward by Eurovent:

1.1. Comments and clarifications related to regulatory Text & Scope

EUROVENT 1.1

Add text to definition of Ventilation Units (VU)

'An electricity driven appliance equipped with at least one impeller, one motor and casing, intended to replace utilised air by outdoor air in a building or part of a building', *where utilized air refers to polluted air due to the presence of human beings in and their use of the building, including emissions from materials, equipment, internal and external heat gains.*

EUROVENT 1.2

Further explanation on BVUs

Configuration that should also be considered as a BVU:

- *Two or more units (UVUs) combined with a run-around Heat Recovery System (HRS)*
- *Two or more units (UVUs) directly (without building sided ductwork) connected with a mixing chamber*

EUROVENT 1.3

Add text to Exclusions f. v)

'Units exclusively specified as operating in toxic, highly corrosive or flammable environments or environments with abrasive substances', *and are exclusively designed for abstract of air from such an environment without any purpose of ventilation. This can be for example an extract air unit for a laboratory fume hood or a technical extraction system of a machinery.*

EUROVENT 1.4

Add text for further clarification

Unit, consisting of single components that are used for exchanging similar old components (replacement of components) or adding components.

EUROVENT 1.5

New (additional) exclusion

Units that are used for replacing old worn units in construction objects having a verifiable status of the historic landmarked building, where fitting the ErP compliant unit is not feasible.

EUROVENT 1.6

New (additional) exclusion

Units that are exclusively intended for dehumidification or de-chlorination of spaces not designated for human occupancy.

EUROVENT 1.7

Add text for further clarification

Units equipped with at least one impeller, one motor and a casing, intended exclusively to operate as a commercial kitchen ventilation hood AND not covered in the scope of Commission Regulation EU 66/2014, are included.

EUROVENT 1.8

New (additional) exclusion

Units that have a connection to the outdoor with a supply/exhaust air flow rate in regular heating operation (whenever using heat recovery) below 10% of the total declared air flow rate, nevertheless capable of operating with 100% outdoor air at designed airflow rate exclusively for free-cooling purposes.

EUROVENT 1.9

Lift existing exclusion g)

NRVUs including a heat exchanger AND a heat pump for heat recovery or allowing heat transfer or extraction being additional to that of the heat recovery system, shall be covered in the scope of the reviewed Regulation 1253/2014.

Minimum requirements for this kind of units should allow for energy impact of the heat pump and additional pressure drop over an evaporator and a condenser.

EUROVENT 1.10

Proposed text amendments regarding NRVUs with recirculation

Existing text, Annex 1, section 2, point (9):
'internal pressure drop of ventilation components ($\Delta ps,int$)' (expressed in Pa) means the sum of the static pressure drops of a reference configuration of a BVU or an UVU at nominal flow rate;

Proposed text amendment: For the BVU including recirculation air and with outdoor air flow rate between 10% and 100% of nominal flow rate, static pressure drops of the reference configuration are considered for maximum declared outdoor air flow rate under winter heating conditions (whenever heat recovery is used).

Existing text, Annex 1, section 2, point (11):
'thermal efficiency of a non-residential HRS (η_{t_nrvu})' means the ratio between supply air temperature gain and the exhaust air temperature loss, both relative to the outdoor temperature, measured under dry reference conditions, with balanced mass flow, an indoor-outdoor air temperature difference of 20 K, excluding thermal heat
gain from fan motors and from internal leakages;

Proposed text amendment: For a BVU including recirculation air and with outdoor air flow rate between 10% and 100% of the nominal flow rate, the maximum declared outdoor air flow rate under winter heating conditions (whenever heat recovery is used) is considered.

New point in Information Requirements for NRVUs (Annex IV) as referred to in Article 4 (2)

Declared maximum outdoor air flow for a BVU operating with recirculation under winter heating conditions (whenever heat recovery is used).

New Definition for NRVU in Annex 1, section 2:

Declared maximum outdoor air flow for a BVU operating with recirculation air, means the maximum designed flow rate of outdoor air between 10% and 100% of the nominal flow rate, under winter conditions, whenever heat recovery is used.

EUROVENT 1.11

Proposed text amendments regarding declaration NRVUs when design point is not known

Proposed text amendment to Annex V, Information requirements for NRVUs
If the working point is not specified by the customer, the manufacturer can declare the 'flow rate — external pressure' performance graph showing an area in which the min. requirements are met. The area is circumscribed by at least five points indicating all cross sections. (An example of graphical representation of the area is shown in the EU FAQ document — figure 6). For each of this point information required in (f), (g), (j) and (k) must be specified.

EUROVENT 1.12

Proposed text amendments to Article 2. Definitions, point (5) UVU
Existing text :
'unidirectional ventilation unit' (UVU) means a ventilation unit producing an air flow in one direction only, either from indoors to outdoors (exhaust) or from outdoors to indoors (supply), where the mechanically produced air flow is balanced by natural air supply or exhaust;
Proposed text amendment:
Components to be considered is only fan including casing without any other accessories. Filters as part of the unit have to be considered according reference design described in ANNEX IX

EUROVENT 1.13

Proposed text amendments to Annex III, point (2) regarding thermal by-pass
Existing text :
'The HRS shall have a thermal by-pass facility;
Proposed text amendment:
'except for duly justified cases (notably swimming-pool or high supply air temperature application), requiring heat recovery all year long.

EUROVENT 1.14

Proposed text amendments for further clarification of thermal efficiency NRVUs

Existing text, Annex I, section 2, point (11):
'thermal efficiency of a non-residential HRS (ηt_nrvu)' means the ratio between supply air temperature gain and the exhaust air temperature loss, both relative to the outdoor temperature, measured under dry reference conditions, with balanced mass flow, an indoor-outdoor air temperature difference of 20 K, excluding thermal heat gain from fan motors and from internal leakages;

Proposed text amendments:
'thermal efficiency of a non-residential HRS (η_{t_nrvu})' means the ratio between supply air temperature gain and the exhaust air temperature loss, both relative to the outdoor temperature, measured under dry reference conditions, with balanced mass flow, at the highest designed outdoor air flow rate through HRS when the thermal by-pass facility is not in use, an indoor outdoor air temperature difference of 20 K, excluding thermal heat gain from fan motors and from internal leakages;

Thermal efficiency of a run-around HRS allowing for heat transfer (injection) being additional to that of the heat recovery system shall be declared under condition when this additional heat transfer is active. The negative impact of heat injection on the thermal *efficiency of the round-around HRS shall be considered. At the same time the positive impact of heat (or cooling energy) injection on the electrical power consumption should be also considered.*

Thermal efficiency of run-around HRS shall be declared for a system filled with a mixture of water and antifreeze fluid as defined by a manufacturer for the design conditions. If nothing is specified it is considered that the brine in the HRS is a mixture with 25 % ethylene glycol and 75% water.

For a HRS of which design does not enable operation with balanced mass flow, and for a combined run-around HRS comprising multiple coils, the thermal efficiency shall be calculated as explained in ANNEX IX

EUROVENT 1.15

Proposed amendments for calculating thermal efficiency NRVUs that do not enable balanced mass flow

Existing text, Annex IX, point (1):
THERMAL EFFICIENCY OF A NON-RESIDENTIAL HEAT RECOVERY SYSTEM
The thermal efficiency of a non-residential heat recovery system is defined as

$$\eta_{t\_nrvu} = (t_2'' - t_2') / (t_1' - t_2')$$

where: …….

Proposed amendments:
For an HRS of which design does not enable operation with balanced mass flow, the thermal efficiency at balanced conditions is calculated as:

$$\eta_{t\_nrvu} = \frac{1}{1+\frac{1}{NTU}}$$

With

$$NTU(z{\neq}1) = \frac{1}{z-1} * \ln\left(\frac{1-\eta_{tt}}{1-z*\eta_{tt}}\right)$$

$$Z = \frac{qm_{sup}}{qm_{eta}}$$

where:
η_{tt} = *thermal efficiency at unbalance mass flows*
qm_{SUP} = *mass flow of supply air*
qm_{ETA} = *mass flow of extract air*

If supply and/or exhaust air side consists of more than one air stream (e.g. run around coils systems), then the $SFP_{int.air\_side}$ shall be calculated for each side by using the following formula (ref. EN 13053:

$$SFP_{\mathrm{int,air\_side}} = \frac{P_{\mathrm{el,int,1}} + P_{\mathrm{el,int,2}} + \cdots + P_{\mathrm{el,int,n}}}{q_{\mathrm{v,1}} + q_{\mathrm{v,2}} + \cdots + q_{\mathrm{v,n}}}$$

SFP_{int} is the sum of SFP_{int}, supply and SFP_{int}, exhaust if both supply and exhaust air side exist.

1.2. Include effects of filters on Energy Efficiency

Currently the energy impact of filters is not included in the Regulation for RVUs.
For NRVUs, filters are taken into account when determining the SPF, but only based on fixed and default correction values in case medium and/or fine filters are missing when the test is performed. When a filter is present, its initial pressure drops (clean filter) is the basis for the SPF-measurement. Eurovent proposes the following approach:

Regarding RVUs

EUROVENT 2.1

Provide information on filters in the information request:

- *Filter classes (for supply and exhaust)*
- *Velocity to the filter media*
- *Clean pressure drops*
- *Recommendation on filter exchange intervals*

EUROVENT 2.2

Provide information on filter class in a clear visible form (label)

- *Filter class*
- *Type of filter*

EUROVENT 2.3

Set the reference filter class, when determining the SPI of the unit. For supply RVU an ISO ePM1 50% filter is proposed, and for exhaust (bidirectional RVU only) an ISO Coarse 60% filter.

EUROVENT 2.4

Provide information on the filter by-pass leakage rate in the information request

EUROVENT 2.5

Limit the velocity on the filter media for all filters inside a RVU:

- *0.2 m/s for ISO ePM1 / ePM2.5 / ePM10 filters*
- *0.5 m/s for ISO coarse filters*

Regarding NRVUs

EUROVENT 2.6

Introduce the parameter filter-velocity and set a limit to the maximum velocity.
Eurovent proposes to limit the velocity on the filter media for all filters inside the unit (so not only reference configurations) to 0.2 m/s for filter classes according to EN ISO 16890 and EN 1822.

EUROVENT 2.7

Define the maximum final pressure difference for filters. As per EN 13053-2018 the following maximum final pressure differences for filters are suggested:

Table 29. Proposal Eurovent final pressure difference for filters

Filter class	Final pressure difference
ISO coarse	The smaller value of either adding 50 Pa to the clean filter pressure difference or three times the pressure difference of clean filters
ISO ePM1 ISO ePM2.5 ISO ePM10	The smaller value of either adding 100 Pa to the clean filter pressure difference or three times the pressure difference of clean filters

EUROVENT 2.8

Strengthen information requirements

Expand Annex V of the existing Regulation with the following additional information:

- *Velocity filter media*
- *Filter classes*
- *Clean pressure drops*
- *Maximum final pressure differences for filters*

EUROVENT 2.9

Provide information regarding the filter section in a clear visible form (label)

- *Filter classes*
- *Type of filter*
- *Final pressure drop*

EUROVENT 2.10

Introduce a filter correction factor

Eurovent recommends changing the formula of the SFP-limit requirement and make the limit dependent on the filtration level of the filter used (applicable to both BVUs and UVUs).

Proposed SPF-values

	2018 requirements							
Filter class EN 779	ISO ePM_1	SFP	ISO $ePM_{2,5}$	SFP	ISO ePM_{10}	SFP	ISO Coarse	SFP
G4							≥ 60%	90
M5					≥ 50%	150		
M6			≥ 50%	170				
F7	≥ 50%	190						
F8	≥ 70%	230						
F9	≥ 80%	260						

	Tier 1 of the future Regulation							
Filter class EN 779	ISO ePM_1	SFP	ISO $ePM_{2,5}$	SFP	ISO ePM_{10}	SFP	ISO Coarse	SFP
G4							≥ 60%	**70**
M5					≥ 50%	**120**		
M6			≥ 50%	**135**				
F7	≥ 50%	**150**						
F8	≥ 70%	**185**						
F9	≥ 80%	**210**						

1.3. Adjust definitions and requirements regarding BVU leakages

Regarding Residential BVUs

EUROVENT 3.1

*Eurovent proposes to introduce limit values for the maximum internal leakage rate in residential BVUs. Following the upcoming harmonised EN 13141-7:2019 it is recommended to limit the internal leakage rate to class **A2** for BVUs with recuperative HRS and to class **C3** for BVUs with regerative HRS.*

EUROVENT 3.2

Eurovent points out that the internal leakage measurement methods (pressure for recuperative and tracer gas for regenerative HRS) differ considerable and that their results are not comparable at all. It is recommended to define a consistant measurement method for both type of HRS, preferably based on the pressure method, considering the pressure difference (inside-outside) at reference air flowrates.

EUROVENT 3.3

The declared thermal efficiency of residential BVUs should be corrected, depending on the internal leakage rates, following the upcoming harmonised EN 13141-7:2019.

Regarding Non-Residential BVUs

According to Eurovent, current Regulation text regarding NRVUs is not clear enough where the definitions concerning *leakages* and *nominal flow rate* are concerned. It is recommended to adjust these definitions:

Current Definition '*Nominal flow rate'*

Nominal flow rate (q_{nom}, expressed in m3/s) is the *declared design flow rate* of an NRVU, at standard air conditions (20°C and 101.325 Pa), whereby the unit is installed complete (e.g. including filters) and according to the manufacturer instructions.

EUROVENT 3.4

Proposed adjustment for definition of 'Nominal flow rate'

Nominal flow rate (q_{nom}, expressed in m^3/s) is the declared design flow rate of an NRVU distributed to and/or extracted from the building, including any leakages or any pressure balancing flow, at standard air conditions (20°C and 101.325 Pa), whereby the unit is installed complete (e.g. including filters) and according to the manufacturer instructions.

EUROVENT 3.5

Additional, new definition: 'Required supply flow rate'

Required supply flow rate (q_{req}, expressed in m^3/s) is the required design outdoor flow rate of an non-residential BVU, at standard air conditions (20°C and 101.325 Pa), whereby the unit is installed complete (e.g. including filters) and according to the manufacturer instructions.

Text adjustments concerning leakages

Current Definition '*Internal leakage rate'*

Internal leakage rate is the fraction of extract air present in the supply air of ventilation units with HRS as a result of leakage between extract and supply air flows inside the casing when the unit is operated at reference air flow, measured at the ducts; The test shall be performed for RVUs at 100 Pa, and for NRVUs at 250 Pa.

EUROVENT 3.6

Proposed adjustment for definition of 'Internal leakage rate'

Internal leakage rate is the air leakage inside the casing between supply and exhaust air flows when the unit is operated at nominal flow rate and designed pressure relations. The 'Internal leakage rate' is quantified with the Outdoor Air Correction Factor (OACF[35]), defined as the Ratio of outdoor air flow measured in the outdoor duct – to the supply air flow measured in the supply air duct, where the internal leakage rate is defined as OACF-1.

Current Definition '*Carry over*'

Carry over is the percentage of the exhaust air which is returned to the supply air for a regenerative heat exchanger according to the reference flow.

EUROVENT 3.7

Proposed adjustment: change parameter 'Carry over' into 'Exhaust Air Leakage Rate'

Definition: 'Exhaust Air Leakage Rate' is the percentage of the exhaust air which is returned to supply air for a heat exchanger when the BVU is operated at nominal flow rate, measured at the supply air duct. The exhaust air leakage is calculated or measured at actual design pressure conditions and reference air flow.

'Exhaust Air Leakage' is quantified with the Exhaust Air Transfer Ratio (EATR)[36].

Eurovent further explains the problems that occur when leakage rates are becoming too high (exhaust air leakages can be as high as up to 20 – 30%):

Indoor Air Quality

Internal and external leakages may contaminate the supply air. The standard EU 16798-3 states that "The outdoor air rates shall be specified in the design of the system. If supply air also contains recirculation air, this shall be noted in the design documentation as well. Only extract air of category ETA1 can be recirculated to other rooms. Extract air of category ETA2 may be recirculated to the same room"

According to Eurovent this can be handled by one of the following three options:

1. If AETR and external leakage at design conditions are both less than 1%, the non-residential BVU is acceptable without further actions
2. If extract air and surrounding air fulfils category ETA1, and AETR and/or external leakages are higher than 1% at design conditions, the supply air shall be compensated to include the required amount of outdoor air.
3. If extract air does not fulfils category ETA1 and AETR is higher than 1% and/or

surrounding air does not fulfils category ETA1 and external leakage is higher than 1%, at design conditions, the non-residential BVU cannot be used without correcting the leaks.

Transparency and Fair competition

A manufacturer can gain benefits by not addressing leaks. Printouts of properties and data of an non-residential BVU must contain OACF and EATR values at design conditions. Construction and maintenance ensuring good air tightness and minimal internal leakages of AHUs are costly. Therefore, all internal, external and HRS leakages and their impacts must be handled and communicated in related documentation. This topic also needs to be addressed in market surveillance.

[35] Formula for OACF = $q_{m,21} / q_{m,22}$ = supply outdoor air mass flow at the inlet divided by supply air mass flow at the outlet (Source: Eurovent 17/11-2015, Guidelines for Heat Recovery).

[36] Formula for EATR = $1 - q_{m,22,net} / q_{m,22} = 1$ – mass flow of the net outdoor air supply at the outlet divided by the mass flow of the supply air at the outlet (Source: Eurovent 17/11-2015, Guidelines for Heat Recovery).

Energy Efficiency

Internal leakages need to be compensated with increased air flow through the AHU, which increases the pressure drops over all components along its path, which will increase the fan power consumption. Internal leakages can also influence the efficiency of the HRS depending on where the leakages passes the barrier between supply air side and exhaust air side and in what direction. All relevant parts and impacts, at design conditions, must be handled and be shown in printouts. Ignorance of leakage treatment has a negative impact on ErP compliance and market surveillance.

In order to avoid above problems with leakages, Eurovent proposes to introduce and implement the following measures in the next ErP regulation:

EUROVENT 3.8

Set limits on external leakages rates for all NRVUs

The external leakage rate for a Non-Residential Ventilation Unit (NRVU) must be limited, depending on the unit's operating pressure conditions:

- *For negative pressure to: 1.32 l/s/m2 at 400 Pa negative test pressure*
- *For positive pressure to:1.90 l/s/m2 at 700 Pa positive test pressure*

The square meters relate to the outer surface of the NRVU

EUROVENT 3.9

Set limits on EATR for all Non-Residential BVUs expect for BVUs with RAC

- *Maximum EATR at design conditions: < 5%*

EUROVENT 3.10

Set limits on OACF for all Non-Residential BVUs

- *At design conditions OACF must be within the range 0.9 to 1.1*

EUROVENT 3.11

Set limits on EATR for Non-Residential BVUs including RAC

- *Maximum EATR at design conditions: < 0,1% (if there is a common wall between supply- and extract air)*

EUROVENT 3.12

Further clarification on SFP_{int} for NRVU

SFP_{int} for NRVU shall include all impacts of internal (OACF and EATR) and external leakages at nominal conditions to ensure that the required supply flow rate (q_{req}) will be delivered. The impacts include increased air flow and pressure losses.

EUROVENT 3.13

Corrections of airflows due to internal leakages

The actual outdoor supply air flow must be increased to ensure that the required supply flow rate (q_{req}) is delivered.

Also corrections for balancing the two air flows over the building may be needed. As a result the power consumption of the supply fan may increase and the heat recovery temperature efficiency may decrease.

- *For EATR < 1% at design conditions, no additional compensation action required*
- *For 1% ≤ EATR ≤ 5%, nominal supply flow rate shall be increased with EATR-percentage to compensate for the exhaust air leakage at design conditions and ensure that the required supply flow rate (q_{req}) is delivered.*

- *For 1% ≤ EATR ≤ 5%, the flow rate extracted from the building shall contain the required design extract flow rate added with required air flow rate multiplied with EATR*

1.4. Including ambient conditions in requirements energy recovery

Energy transferred in exhaust air comprises both the sensible part (temperature) and the latent part (moisture content). Some types of heat exchangers enable recovery of both sensible and latent energy.
Recovery of latent energy is by far more relevant in warm climate countries since it leads to further reduction of cooling energy demand compared to sole sensible heat recovery. This in turn, is particularly important in the light of EPBD requirements tending to turn buildings across Europe into nZEBs and addressing the increasing role of cooling energy demand in the total energy consumption balance of a building. A considerable part of this energy is related to ventilation systems.
Moreover, the latent energy recovery facilitates maintaining better Indoor Environment Quality (IEQ). In many applications, indoor humidity control is necessary and required due to comfort or technological reasons. This entails a need to use heat exchangers offering not only the sensitive heat recovery, but recovery of moisture as well. It should be also noted that recovery of moisture, aside from reducing the cooling demand, results in lowering the risk of exchanger freezing, what again leads
to considerable energy savings.
However, exchangers for moisture recovery feature higher pressure drops compared to exchangers for sensitive heat recovery only. Since the current Ecodesign benchmarks consider only the thermal efficiency, units which must be equipped with moisture recovery exchangers (sorption rotors, enthalpy plate exchangers) due to system design requirements, are at a disadvantage.

For the reasons explained above, Eurovent proposes to introduce separate minimum requirements for HRS featuring only recovery of sensible heat and for HRS offering both the sensible heat recovery and the moisture recovery under summer conditions.

For **Non-Residential BVUs** Eurovent proposes the following modifications.

EUROVENT 4.1

Maintain current requirements for minimum thermal efficiency $\eta_{t\ nrvu}$ for sensible HRS

η_{t_nrvu} = *73% for all HRS expect run-around HRS (RACs)*

η_{t_nrvu} = *68% for run-around HRS*

EUROVENT 4.2

Add new requirements for minimum energy recovery efficiency $\eta_{e\ nrvu}$ for HRS that enable both sensible and latent energy recovery

η_{e_nrvu} = *75%*

With

$$\eta_{e\_nrvu} = \eta_{t\_nrvu} + c * \eta_{x\_c}$$

Where

η_{t_nrvu} = *thermal efficiency*

c = *conversion factor of humidity efficiency to thermal efficiency*

η_{x_c} = *humidity efficiency for cooling conditions defined as per prEN308 (exhaust air 25°C DB/ 18°C WB, outdoor air 35°C DB/ 25°C WB*

EUROVENT 4.3
Set a specific efficiency bonus E for HRS that enable both sensible and latent energy recovery:

$E \quad = (\eta_{e\_nrvu} - 0.73) * 3000$

For **Residential BVUs** no modifications are proposed regarding the inclusions of ambient conditions.

1.5. Include information energy consumption for defrosting HRS

The current methodology of the energy efficiency assessment for NRVUs does not distinguish a type of HRS applied in a ventilation unit in terms of its sensitivity to freezing. This could lead to confusing conclusions, particularly when comparing ventilation units operating in cold climate countries.
To ensure continuous, undisturbed operation of the exchanger in cold climate conditions, additional energy for defrosting might need to be supplied. This is not covered in the current Ecodesign benchmark for NRVUs.
To provide for level-playing field for all manufacturers, Eurovent suggest including in the information request (Annex V of the Regulation) an indication of annual energy consumption for defrosting, attributable to applied HRS, most preferably expressed in kWh/a.

Proposal Eurovent regarding **Non-Residential BVUs**

EUROVENT 5.1
Calculate and display defrosting energy
The displayed defrosting energy should be determined based on a simplified calculation method for common reference conditions (climate zone, operating time, temperature and moisture content of extract air)

EUROVENT 5.2
Consider climate zones in the calculation of defrosting energy
Considered climate zones should be the same as already applied in the assessment for RVUs (Cold, Average, Warm)

EUROVENT 5.3
Consider controls in the calculation of defrosting energy
The calculation method should take into consideration the defrosting strategy and control logic (either offered by an integrated control system or provided in a manufacturer's manual)

Figures calculated separately for each climate zone should be presented in the information requirements.

For **Residential BVUs** the following is proposed:

The information requirements of the current Regulation differentiate only the type of heat recovery system (recuperative, regenerative, none) and do not address at all the technology for defrosting standing behind (in case of units with recuperative heat exchangers). In the opinion of Eurovent members, this is an overreaching simplification. In practice, there are numerous defrosting strategies available on the market.
Moreover, each of these strategies can be controlled in a simplified on/off mode or advanced modulating mode. Depending on the applied defrosting strategy and the control mode, the effective consumption of energy for defrosting - notably in cold climate — might considerably vary.

EUROVENT 5.4

Include description of defrosting strategy in Information Requirements / Fiche

A non-exclusive list of possible defrosting strategies includes:

- *Lowering the supply air flow rate*
- *Increasing exhaust air flow rate*
- *Bypass for defrosting*
- *Electric and hot water coil preheating*
- *Ground heat exchanger*

EUROVENT 5.5

Modify SEC calculations to better reflect energy consumption for defrosting

Eurovent suggests modifying in a simple and easy-to-adopt way the calculation of the Specific Energy Consumption factor (SEC) to consider the impact of defrosting strategy. The corrected SEC should regard the actually applied strategy (and not the best available in the VU control system). As a base for developing a consistent method for correcting SEC, the approach outlined in the Annex 'Calculation of an extended SEC' of the upcoming harmonised standard EN 13142:2019 might be used. This method, developed based on in-depth study of various defrosting strategy options, provides for feasible consideration of defrosting strategy impact on the energy efficiency of RVUs.

Eurovent members believe, that the appropriate consideration of the defrosting strategy effect will be a powerful driving force for eliminating non-effective technologies from the market.

Besides the energy issue, the indoor comfort in served spaces could be compromised when using the simplest defrosting strategy. Not all available defrosting strategies secure undisturbed functioning of the ventilation system. Besides reducing energy consumption, the correct operation involves continuous and balanced air flows in any conditions and the acceptable limit for minimum supply air temperature. These features have a crucial impact on heat losses of modern, air-tight buildings (pressure balance) and hygienic aspects (condensation and mould problem inside/outside air ducts at too low supply temperature).
For these reasons, Eurovent suggest straightening the mandatory information requirements and to include a detailed description of the applied defrosting strategy in order to provide complete information to the end user and to eliminate from the market technologies which do not guarantee correct operation of the system during defrosting.

1.6. Consider actual working point in energy efficiency assessment RVU

Assumedly, the objective of the energy labelling for RVUs is to encourage end-users to purchase energy-efficient products, taking for grounded that professional planners do not participate in the selection of these products.
The SEC factor is calculated based on the Specific Power Input (SPI) for the reference air flow rate. For ducted units, the considered reference air flow rate corresponds to at least 70% of the maximum air flow rate and 50 Pa of external pressure difference. However, the Eurovent members hold that the performance of the ducted RVU always depend on the characteristic of ductwork the unit is installed in. Usually, the actual duty point (air flow — pressure) considerably differs from the Ecodesign reference air flow point. Moreover, out of Eurovent members experience, the ventilation system design is oftentimes performed by professional HVAC planners (typical projects of single-family homes or project of the multi-family house) and a selection of RVUs in not left to customers (end-users).

Eurovent claims that the product selection driven only by declared energy class does not always contribute to the optimal matching of a unit performance to the system, and frequently is just misleading (e.g. unit rated in 'A' class operates effectively in 'B' class zone or vice versa).

Eurovent acknowledges the positive impact of energy labelling on energy savings. However, given that system planners are also involved in product selections, we put forward for consideration two alternative proposals of additional measures providing for further improvements.

EUROVENT 6.1

Extend SEC-values to entire working range of the RVU

Eurovent's proposal is to extend the information on SEC (or similar SEC-related) value across the entire working range of the unit, instead of focusing on the reference flow rate only. This information would be addressed to system planners who know the actual working point of the unit and could select a more energy-efficient product.

Thus, Eurovent suggests including in the information requirements for the documentation provided with the product (Annex IV or Regulation 1253/2014 and Annex IV or Regulation 1254/2014) a tabular or graphical collation of SEC value across the product working range (see Table 30 for an example).

Table 30. Example tabular representation SEC-values

Flow	SEC 50 Pa	SEC 100 Pa	SEC 150 Pa
100	-36.6 A	-33.8 B	-31.1 B
110	-36.8 A	-34.2 A	-31.8 B
120	-36.9 A	-34.5 A	-32.3 B
130	-36.9 A	-34.8 A	-32.8 B
140	-36.9 A	-34.9 A	-33.1 B
150	-36.9 A	-35.1 A	-33.2 B
160	-37.0 A	-35.2 A	-33.2 B
170	-37.0 A	-35.4 A	-33.2 B
180	-37.2 A	-35.6 A	-33.2 B
190	-37.2 A	-35.6 A	-33.3 B
200	-37.2 A	-35.4 A	-33.2 B
210	-37.2 A	-35.2 A	-33.2 B
220	-37.2 A	-35.0 A	-33.1 B
230	-37.1 A	-34.8 A	-33.0 B
240	-36.9 A	-34.6 A	-32.9 B
250	-36.6 A	-34.4 A	-32.8 B
260	-36.2 A	-34.2 A	-32.7 B
270	-35.9 A	-34.1 A	-32.5 B
280	-35.6 A	-33.7 B	-32.3 B
290	-35.2 A	-33.6 B	-32.0 B
300	-35.0 A	-33.3 B	-31.7 B
310	-34.7 A	-33.1 B	-31.3 B
320	-34.3 A	-32.7 B	-30.8 B
330	-33.8 B	-32.2 B	-30.3 B
340	-33.4 B	-31.6 B	-29.7 B
350	-33.0 B	-31.1 B	-29.3 B
360	-32.6 B	-30.7 B	-29.0 B

EUROVENT 6.2

Or alternatively, allow SEC-calculations using higher external ΔP for units with a q_{max} between 250 – 1000 m^3/h

If proposal 7.1 could not be accepted, the alternative Eurovent proposal is to modify the definition of the nominal air flow rate for VUs of the maximum flow rate between 250 m^3/h and 1000 m^3/h and declared by the manufacturer as intended for exclusive use in a residential ventilation application.
The Eurovent members' expertise shows that for RVUs operating at a flow rate above 250 m^3/h, the corresponding external pressure difference generally exceeds 50 Pa and, in most cases, amounts to much higher values (typically 150 Pa). This means, the SEC evaluation referring to 50 Pa might be not accurate and misleading for larger Residential Ventilation Units.
Thus, we propose introduction in the revised regulation of an additional model for calculation of SEC (referring to higher than 50 Pa external pressure difference) for RVUs of maximum airflow rate exceeding a certain value (most preferably 250 m^3/h)

1.7. Consider controls in the assessment of NRVUs

Increasing minimum energy efficiency levels along the lines of the current Regulation in place has its physical and practical limits, as can be specifically observed in warmer climate zones of Southern Europe. A pure focus on, for instance, heat recovery has led to units being applied in some regions that do not make economic sense and are not justifiable over a product's life cycle.
Thus, instead of solely focussing on increasing minimum efficiency levels, Eurovent strongly recommends the European Commission and study consultants to have a closer look at control systems, which have a significant impact on the energy efficient and secure functioning of a NRVU.

A unit can be well structured and include high quality fans, heat exchangers, filters, and the like. Yet, without a proper control system, which can dynamically manage and react to all kinds of scenarios, positive aspects of a unit can easily diminish.
Only with a high-quality controller, it can be ensured that NRVUs are performing in the most energy efficient and secure manner, while at the same time reducing subsequent changes to a unit — bearing risks in terms of warranty, hygiene, corrosion, tightness, and related issues.
Strengthening controller requirements within the future Regulation would also support evolutions within the latest revision of the Energy Performance of Buildings Directive (EPBD), which strongly promotes Building Management Systems (BMS), and the use of smart technologies in buildings in general.

Minimum requirements
To further increase the energy efficiency, safety, and quality of ventilation units, Eurovent asks the European Commission that the following minimum requirements concerning control systems should be met by each Bidirectional Ventilation Unit (BVU) placed on the European market.
Eurovent and its members have defined the following requirements in a manner open to all types of technologies. In some cases, requirements are being applied over two Tiers to allow the market sufficient time to adapt.

EUROVENT 7.1

Set minimal requirements regarding the controls

The control system shall – at minimum – be able to:

- *Communicate with Building Management System by either receiving analogue and/or digital systems*
- *Manage the fresh air supply through demand control*
    - *Tier 1: at least by time or presence*
    - *Tier 2: through an automatic control linked to the air quality determined by a sensor*
- *Speed control the fans*
    - *This is already a requirement in the current Regulation*
- *Monitor filter dust*
    - *This is already a requirement in the current Regulation*
- *Continuously control the heat recovery efficiency depending on the actually demanded supply air temperature*
    - *Thermal by pass requirements are already being dealt with within the current Regulation*
- *Monitor core information*
    - *Tier 1: Malfunctions concerning the fan(s) and heat recovery system(s)*
    - *Tier 2: Instantaneous technical data (e.g. airflows, temperatures, power consumption)*

By incorporating these minimum requirements in the future Regulation, it would be ensured that all ventilation units placed on the European market meet essential quality criteria. Furthermore, and most importantly, it would make it much more likely that a unit performs as envisaged by the Ecodesign regulation not only on paper, but also in real-life conditions.

The verification of minimum controller requirements by market surveillance authorities can be easily ensured through a documentation review. All controller functions have to be described in the documentation of a ventilation unit.

1.8. Other

EUROVENT 8.1

Include revised requirements Ecodesign Regulation on Fans

Being currently under revision Commission Regulation (EU) 327/2011 implementing Ecodesign requirements for fans is expected to introduce new, higher target energy efficiencies reflecting fan technology progress. The Eurovent members are of an opinion, that in the revised regulation for ventilation units, the maximum internal specific fan power factors (SFP_{int_limit}) should be adjusted accordingly to requirements of revised Regulation 327/2011.

EUROVENT 8.2

Proposal to use same reference point for information declared on RVU Energy Label

As per current Regulation 1254/2014, the energy label includes information on the sound power level (L_{WA}) and the maximum flow rate. However, the sound power level refers the reference air flow rate and not the maximum flow rate, which is not clearly stated on the label. Eurovent members hold, this way of presenting data might be highly confusing to the end user and propose to unify the reference point for these two values. Proposal: Use same reference point for declaration q_{max} and sound power level on label

2. Comments EVIA

2.1 General aspects

EVIA 1.1

EVIA proposes to use the Declaration of **Intended Use** issued by the manufacturer (in analogy with Machine Directive) to identify the valid ErP regulation for the products.

This is a simple way to deal with multi-usage and various applications whilst allowing market surveillance to react in the correct way. Furthermore, manufacturers shall specify the correct way to assess the conformity based on regulations and standards.

EVIA proposes to modify the following definitions as follows: *Article 2* ***Definitions***

In addition to the definitions set out in Article 2 of Directive 2009/125/EC, the following definitions shall apply for the purpose of this Regulation:

(1) 'Ventilation unit (VU)' means an appliance equipped with at least a fan, motor and casing intended to replace utilised air by fresh air in a building or part of a building;

(2) 'Residential ventilation unit (RVU)' means a ventilation unit where the nominal (maximum) *outdoor air volume flow does not exceed 1.000 m3/h and the manufacturer does not declare it as a NRVU;*

(3) 'Non-residential ventilation unit (NRVU)' means a ventilation unit where the nominal (maximum) *outdoor air volume flow*
a. exceeds 1.000 m3/h or
b. the manufacturer declares it only for a non-residential ventilation application

EVIA 1.2

EVIA suggests that the European Commission refers back to EVIA and Eurovent's Guidance Document.

This Guidance Document is intended to contribute to a better understanding of EU Regulations 1253 and 1254/2014 and a more uniform and coherent implementation across different sectors and product groups within the EU Common Market. Overall, we call on the European Commission to harmonize definitions where and when possible.

EVIA 1.3

EVIA recommends to consider the current status of EN 13142 and the EN 13141-series as basis for future revisions of the Regulations

These standards have been developed to clarify current regulation and also include further options.

2.2 Comments and clarifications related to regulatory Text & Scope

EVIA 2.1

Include Multifunctional Ventilation Units in the Scope

EVIA as well as other industry representatives have called the European Commission to include multifunctional bidirectional ventilation units in the revision of the Ecodesign Regulation (EU) 1253/2014 (Ventilation).

EVIA 2.2

Exclude repair, refurbishment and replacement of existing **NRVU** in Historic listed building from the scope.

EVIA would like to point out that in some specific cases of refurbishment, especially for historically listed buildings, the Ecodesign requirements applied to new ventilation units are in most cases not adapted to the actual building architecture. Indeed, these ventilation units which aim at replacing old/existing ventilation systems often face limited space in the installation rooms. The existing installation rooms in historical buildings are in most cases too small for ventilation units that have the same operation point and fulfil all Ecodesign regulation.
In general, historical buildings and listed buildings have special laws and exemptions in national or local building codes (see Annex 1 for Italian examples). EVIA suggests that on the basis of these codes, and an investigation of the feasibility of the refurbishment by local authorities, Air Handling Units (AHU) can be excluded from meeting minimum requirements if needed, given the architecture of the building, while still respecting the higher standard of energy efficiency.

The European Commission Regulation (EU) No 548/2014 of 21 May 2014 already allows exemptions for power transformers in these cases. Therefore EVIA proposes to adapt the Regulation 1253 along the following proposal, based on wording included in the Transformers regulation No 548/2014.

Proposal: "2. This Regulation shall not apply to ventilation units specifically designed and used for the following applications:
- *ventilation units which are meant for **replacements** in the same physical location/installation for existing ventilation units, where this replacement cannot be achieved without entailing disproportionate costs associated to their transportation and/or installation,*
- *ventilation units for **historic and listed buildings** where the installation cannot be achieved in a limited space and without changing the historic character of the building and entailing disproportionate costs associated to their transportation and/or installation, except as regards the product information requirements and technical documentation set out in Annex V."*

EVIA 2.3

Clarification on 'Toxic and highly abrasive substances

EVIA would like to highlight the need to harmonise and clarify the definitions of what is a "toxic or highly corrosive" substance, by using the following standards for example: REACH EU/1907/2006, prEN 17166 Annex B, EU / 2011 / 327, prEN 17166 Annex B.

EVIA 2.4

Clarification on definition of NRVU

The current regulation is not clear yet on process ventilation application and mixing air, the FAQ clarifies these aspects and EVIA suggests to use the decision tree included in the FAQ to clarify this issue (E125, E135). Any new requirements included in the revision of the Regulation should consider the decision tree and clarify first.

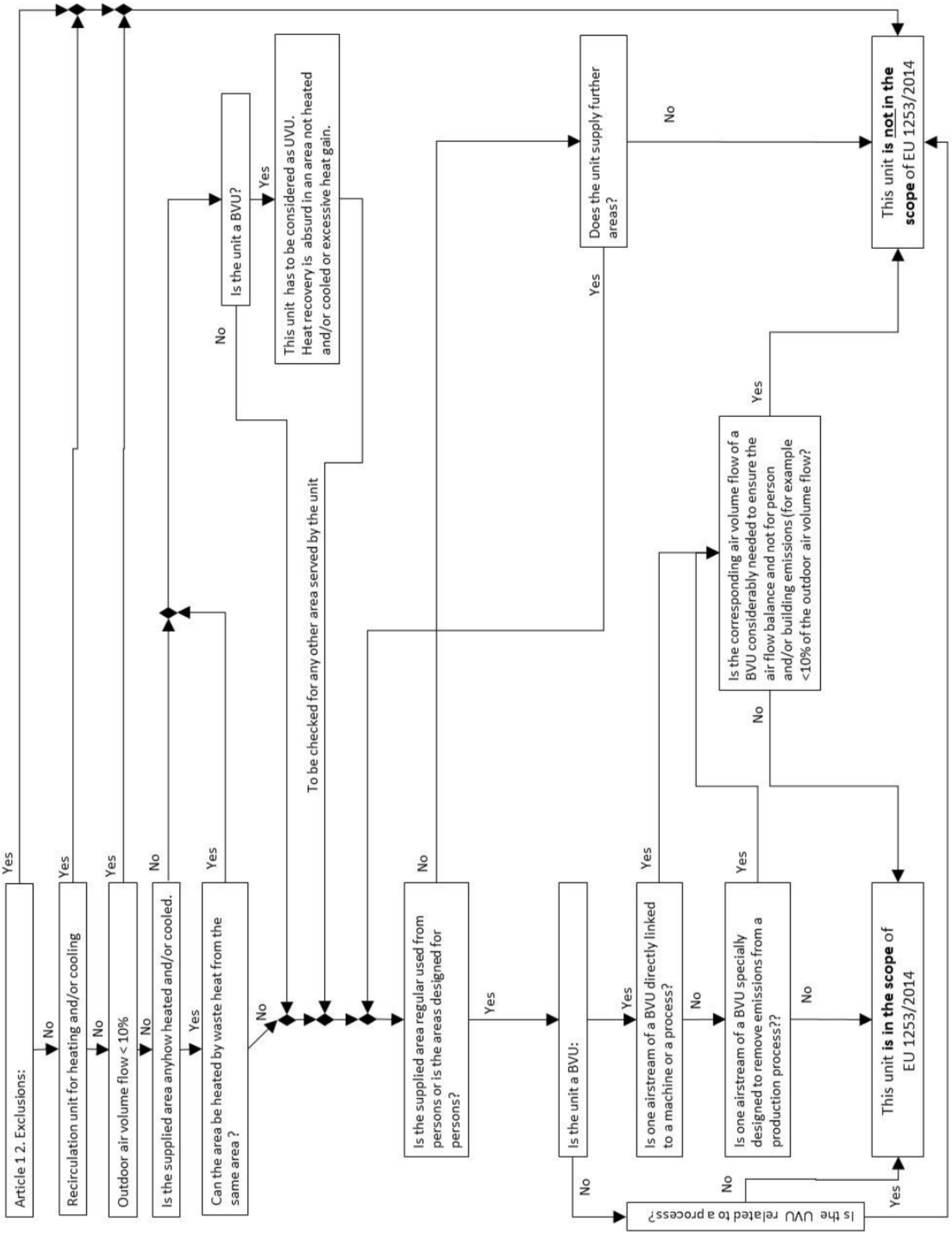


Figure 5. Decision tree Ventilation Units

EVIA 2.5

Harmonization terminology p_{static}, p_{total} $p_{static,ext}$

The harmonization of the terminology is in progress at the CEN level (draft standards under the current mandate). The review of Regulation 1253 will have to align with these standards and especially use pu and pus as pressure reference parameter instead of Δps,ext.

EVIA 2.6

Adjust definition for UVU in NRVUs

Article 2 item 5 is defining:

(5) 'unidirectional ventilation unit' (UVU) means a ventilation unit producing an air flow in one direction only, either from indoors to outdoors (exhaust) or from outdoors to indoors (supply), where the mechanically produced air flow is balanced by natural air supply or exhaust;

This definition is valid for residential ventilation systems, where units generally are sold as a "system package".

In Non-Residential applications, however a UVU can be balanced in different ways, and normally not by natural means, because the airflows are too high. Additionally, these units are not sold as a package, and the manufacturer does not know anything about the balancing. These units might be balanced for example by:

- Process air flows
- Disbalanced BVU
- Other corresponding UVU
- Etc.

EVIA proposes to correct the definition by deleting the last part.

(5) 'unidirectional ventilation unit' (UVU) means a ventilation unit producing an air flow in one direction only, either from indoors to outdoors (exhaust) or from outdoors to indoors (supply).

EVIA 2.7

Clarification concerning Dual Use NRVUs

When specific exemptions are planned in component legislation, such as the Fans & Motors Regulations, it is important for these to also be reflected in related product regulations, such as the Ventilation Unit Regulation. If ventilation units contain fans or motors that are exempt from meeting energy efficiency requirements, then exemptions and arrangements should also be put in place to ensure that the overall unit should not have to respect its usual energy efficiency requirements.

For instance, some claim that motors above 0.75 kW have to be equipped with a VSD is an issue for motors in smoke extraction fans because they work only in case of emergency at its maximum speed or possibly a few minutes a year for maintenance purposes, the requirement of equipping those fans with a VSD is actually not logical.

This is not precisely right because those motors not only can be used in emergency use only fans (only a few minutes a year only for maintenance purposes) but they can also be used (and are the majority of applications) in dual use fans and ventilation units (working several hours a day. Emergency use only fans are excluded from both Regulations 327/2011 (fans) and from draft fan regulation, since the importance of the use phase on the overall environmental impact of emergency use only fans is minimum. There are no energy gains to achieve due to its few hours of operation through its lifetime. This exclusion cannot be extended to motor regulation as there is no distinction between emergency only motors and dual use motors.

Therefore a request for an exclusion for motors in smoke extraction fans makes no sense. ErP Directive aims to minimize expected life-cycle costs. Production costs of emergency only fans are for far the highest on the life cycle cost impact. Therefore minimizing those costs is a must. Since VSD is useless in those applications, IE3 motor is the mandatory which is even cheaper than using IE2+VSD.
The problem appear with the use of VSD. Current motor regulation requirement accept the use of IE2 motors+VSD, but this is not accepted in fan and ventilation unit regulations for dual use products due to maximizing safety aspects: what would happen in a dual use product when it has to shift to emergency operation when it had been run for several year through VSD.

EVIA proposes to keep the current motor regulation and draft fan regulations as they are:

Draft motors regulation lot 30 that will repeal regulation 640/2009

- from 1 January 2021: motors above 0,75kW up to 375 kW will met IE3 efficiency level
- from 1 January 2022: motors above 0,12 kW up to 0,75 kW will met IE2 efficiency level
- excluded motors specified to operate exclusively in maximum operating temperature above 400 °C

According to the draft fan regulation that will repeal regulation 327/2011

- excluding fans designed for emergency use only, at short-time duty of 1 hour or more with regard to fire safety requirements for temperatures of 300°C and above set out I Regulation (EU) No 305/201 and keep the exclusion of equipping VSD with dual use units in the future ventilation unit regulation.

2.3 Include effects of filters on Energy Efficiency

In some cases, it is not clear how filter correction should apply, for instance how should one proceed when the filter delivered has a lower efficiency than the one in the reference configuration.
In order to deal with these issues, EVIA suggests an option which would lead to changing the formula of the SFPlimit requirement to make the limit dependant on the filtration level. For this, a typical value of filter SFP for each class of Filter should be proposed. If the Regulation goes in that direction, there would be no need down the line for any corrections.

Principles

- EVIA suggests that clear reference should be made to ISO 16890 principles which give a clear definition of a filter.
- EVIA proposes to change the formula of the SFP limit requirement to make the limit dependent on the filtration level of the used filter.
- For this, a typical value of filter SFP for each filter classified acc to EN ISO 16890 from ISO Coarse ≥ 60% (G4) to ISO ePM1 ≥ 80% (F9) has to be identified.
- If there are several filter stages (*2 options proposed – we will have to fix the EVIA preferred option later*):
    - Option 1: they are all considered in ventilation components. We apply the filter SFP value to each filter.

- Option 2: only the highest efficiency filter acc to EN ISO 16890 is considered. Other filters are considered in non-ventilation components (additional SFP)
- This procedure shall be used for BVUs as well as for UVUs

Proposed SFP values per Filter Type
Based on 2018 requirements. To be adapted for further tiers

	Based on EVIA recommendation							
Filter class EN 779	ISO ePM1	SFP ***F***	ISO ePM2,5	SFP ***F***	ISO ePM10	SFP ***F***	ISO Coarse	SFP ***F***
G4							≥ 60%	**90**
M5					≥ 50%	**150**		
M6			≥ 50%	**170**				
F7	≥ 50%	**190**						
F8	≥ 70%	**230**						
F9	≥ 80%	**260**						

Example of SFP requirement (based on 2018 requirements)

The Current requirements for Non Residential BVU
For Run around coil HRS:

$$\mathrm{SPF}_{\text{int-limit}} = 1600 + E - 300 * qnom/2 - \quad qnom \leq 2\ m3/s \ \ and$$

$$\mathrm{SPF}_{\text{int-limit}} = 1300 + E - F\ if\ qnom \geq 2\ m3/s$$

All others HRS

$$\mathrm{SPF}_{\text{int-limit}} = 1100 + E - 300 * qnom2 - F\ if\ qnom \leq 2\ m3/s \quad and$$

$$\mathrm{SPF}_{\text{int-limit}} = 800 + E - F\ if\ qnom \geq 2\ m3/s$$

UVU intended to be used with filters

$$\mathrm{SPF}_{\text{int-limit}} = 230$$

F = 150 if medium filter is missing
F = 190 if fine filter is missing

EVIA 3.1
Proposed New Requirements

For Run around coil HRS:

$$\mathrm{SPF}_{\text{int-limit}} = \mathbf{1260} + E - 300 * q_{nom}2 + \boldsymbol{F_{sup}} + \boldsymbol{F_{exh}}\ if\ q_{nom} \leq 2\ m_3/s \quad and$$

$$\mathrm{SPF}_{\text{int-limit}} = \mathbf{960} + E + \boldsymbol{F_{sup}} + \boldsymbol{F_{exh}}\ if\ q_{nom} \geq 2\ m_3/s$$

All others HRS

$$SPF_{int\text{-}limit} = \mathbf{760} + E - 300 * q_{nom} 2 + \boldsymbol{F_{sup}} + \boldsymbol{F_{exh}}\ if\ q_{nom} \leq 2\ m^3/s \quad and$$

$$SPF_{int\text{-}limit} = \mathbf{460} + E + \boldsymbol{F_{sup}} + \boldsymbol{F_{exh}}\ if\ q_{nom} \geq 2\ m^3/s$$

UVU intended to be used with filters

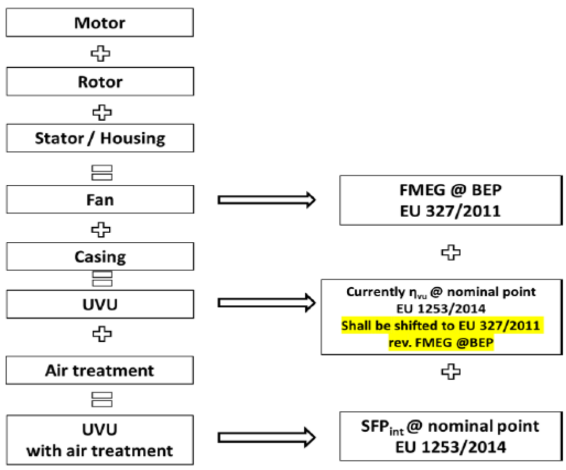
$$SPF_{int\text{-}limit} = \cancel{230} + \boldsymbol{F_{sup}} (\boldsymbol{or\ F_{exh}})$$

Fsup and Fexh: values from table above

EVIA 3.2
Distinction in Filter Corrections to be used for UVUs

Filters in UVUs should be treated in the same way as filters in BVUs, as the function remains the same. EVIA suggests to include filter correction factor F in SFPint requirements for UVUs intended to be used with filters. This should be done in the same way that is suggested above for NR BVUs.

In addition, important distinctions are to be made between:
- UVU with air treatment (filtration and/or additional heating, cooling, etc.) which should be considered as a ventilation unit (AHU);
- UVU without any air treatment which should be considered as a fan (see EVIA/Eurovent FAQ Document for clarification)



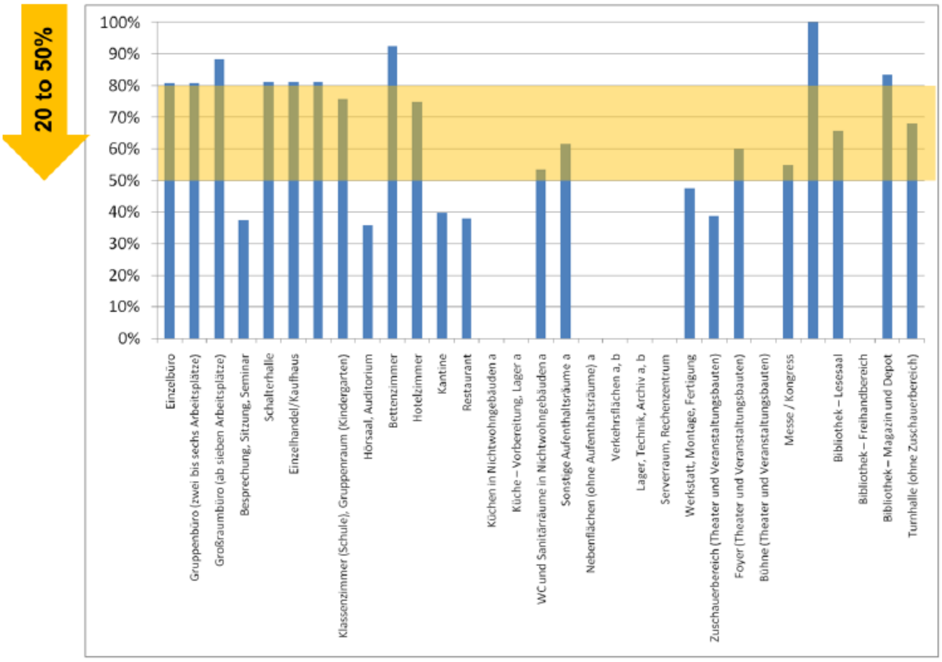
2.4 Consider Demand Control options for NRVU

Demand control systems are suitable solutions to optimize energy demand of ventilation systems. There are a wide range of Non-Residential applications for ventilation units and a simplified approach, similar to the one applied for the residential sector is just not possible or feasible. The reasons are:

- In general, the application of a non-residential ventilation unit is not known by the manufacturer
- Key elements of demand control is not part of the AHU delivery (i.e. VAV controller, dampers, and diffusors).

- A high percentage of AHUs are not equipped with any control system, because this is part of the installer's work or the customer specifies his needs according their individual BACS needs and the manufacturer has no choice in installing a control system in the product.
- Even units with their own control systems might not have an impact on Demand Control Ventilation (DCV) elements in the field.

Considering the aspects above, *EVIA would like to propose a simple bonus system on the minimum requirement of SFPint*. If the unit is equipped (by the manufacturer) with a controls system covering a function level 3 or higher (EN 15232) or IDA-C5 /C6 (EN 16798-3), allowed to have an additional bonus on the SFPinternal value, which would make it higher.
The following chart shows the impact of DCV in different applications considering EN 16798-3 on the air volume flow according to German EPBD implementation (EnEV and DIN V 18599). The average reduction of air volume flow over all comfort applications can be considered to 35% and a minimum of 20%. Therefore a conservative approach to consider DCV system in AHU with controls could be 20% bonus on SFPint.
The relative impact of air flow on heat recovery is low so there is no need to correct heat recovery requirements by considering DCV. Therefore we are not proposing to attribute a bonus scheme applying to heat recovery requirements when there is a DCV, because the impact is only limited.



Graph originating from DIN V 18599

2.5 Consider Heat Recovery, Enthalpy Recovery & Life cycle cost

EVIA 5.1

Increasing HR-efficiency not always economically feasible

For heat recovery systems, some studies highlight that higher energy efficiency requirements are not always the best way to deliver energy savings, as these requirement should take into account other factors, such as the big differences in climatic conditions in which heat recovery systems operate in Europe. More detailed studies can be provided on this point.

EVIA 5.2

Enthalpy recovery can increase economic feasibility

Enthalpy recovery describes the function of heat recovery and moisture recovery from the extract air to the supply air. Enthalpy recovery systems provide a better energy performance for AHU in the following cases:

1. Humidifying or dehumidifying the air
2. Cold recovery
3. Frost protection in cold climates

Considering items 1 and 2, the calculation of the energy performance of the enthalpy recovery is a very complex process and even EPBD calculation considers these aspects at a lower level, EPBD does not calculate the whole range of the enthalpy recovery. The building model is purely based on temperature.

EVIA is proposing a simple bonus system on heat recovery based on the humidity ratio of heat recovery component. In case enthalpy recovery or humidity recovery, then give a bonus for the temperature ratio for minimum heat recovery rates depending on a humidity ratio of 8%, based on a calculated average.

$$\eta = \eta t + 0{,}08 * \eta x$$

EVIA 5.3

Consider life cycle costs

Several studies show, that the impact of ventilation heat recovery and fan consumption in Non-Residential buildings is highly dependent on:

- Building performance
- Building use and application
- Occupation times
- Thermal loads
- Climatic data

In some applications and user scenarios, regulation that imposes high efficiency requirements is actually not providing realistic energy savings. For example, when high efficiency heat recovery systems are used in bypass in trade fare halls or shopping malls, their operating time is at 100% therefore leading to fans using a lot more energy than what is necessary. Also, *EVIA suggests that when a ventilation unit is running less than 500 hours/year, it should benefit from a different treatment and requirements on its efficiency*, given its usage.

Revised requirements for ventilation units must take into account some individual application cases to ensure that the regulations do not conflict with their original ambition and actually provides energy savings in all scenarios.

2.6 Recommendations regarding calculations NRVU

EVIA 6.1

Reduce Ecodesign Requirements NR UVUs to one parameter

As long as box and roof fans without air treatment are in the scope of Lot 6, fans without air treatment should follow only $SPF_{internal}$, and not in parallel η_{VU} as the efficiency of the fan inside is already in the scope of the Fans Regulation 327/2011.

EVIA 6.2

Recommendation to use SFP_{global}

EVIA is facing ongoing discussions on SFP internal, global and other versions. EVIA recommends a consistent development of the electrical requirements for the ventilation functions either by keeping current procedure or by changing into an equivalent SFP global approach. Any change of the view must be discussed carefully on all implications and must keep the principle of excluding external or additional components impact.

Considering the above, the following approach based on SFP global instead of SFP internal might be a metric for characterization of aerodynamic performance of NRVU. The ErP limit on SFP global would take into account the design external pressure: higher design external pressure => higher SFP global allowed.

- SFPint is difficult to measure (often impossible to measure onsite). EVIA highlights that different approaches should considered for tailor made and mass products, given that the measurements may produce different results and create a risk of non-compliance for manufacturers.
- SFPglobal is easy to measure onsite: one just needs the power and the airflow. It has been used for long in building codes and standards in some countries. It may be applicable to all units, including box and roof fans, with adjusted parameters

Requirements can be easily derived from target fan efficiency and current SFPint limit and can take into account the design external pressure.

Formulas and propositions are listed below (from prEN 16798-3, §9.5.6)

$$SFPg = \frac{\Delta p_{s,fan}}{\eta_{s,fan}}$$

$$SFPg = \frac{\Delta p_{s,ext}}{\eta_{s,fan}} + \frac{\Delta p_{s,int}}{\eta_{s,fan}} + \frac{\Delta p_{s,add}}{\eta_{s,fan}}$$

$$SFPg = SFPext + SFPint + SFPadd$$

The only parameters the manufacturer is accountable for are $\eta_{s,fan}$ and $\Delta p_{s,int}$

$\Delta p_{s,ext}$ is <u>not</u> under the responsibility of the manufacturer

$\Delta p_{s,add}$ is <u>partly</u> under the responsibility of the manufacturer

$$SFPg = \frac{\Delta p_{s,ext}}{\eta_{s,fan}} + \frac{\Delta p_{s,int}}{\eta_{s,fan}} + \frac{\Delta p_{s,add}}{\eta_{s,fan}}$$

Thus, a requirement on global SFP should be related to the design external pressure and the additional components (it is already the case).

The requirement formula would be of this type for BVU:

$$SFPg, lim = \frac{\Delta p_{s,ext}}{6.2 \times \ln(P_{unit}) + X} + Y + E - 300 \times qnom/2$$

X, Y to be adjusted for each Tier
Example for 2018, (heat exchanger other than run around coil):

$$SFPg, lim = \frac{\Delta p_{s,ext}}{6.2 \times \ln(P_{unit}) + X} + 1100 + E - 300 \times qnom/2$$

Proposed values: X= 52

It can also be made simpler by removing the $qnom/2$ factor since the size effect is already taken into account with the logarithm.

$$SFPg, lim = \frac{\Delta p_{s,ext}}{6.2 \times \ln(P_{unit}) + X} + 1100 + E$$

Proposed values: X= 58

2.7 Recommendation related to the Energy Label of RVUs

EVIA 7.1

Consider climatic zones when calculating Energy Label

The thermal aspect of ventilation is based on climatic conditions. The use of average climate only can be misleading.
The principle of SEC calculation for three different climate zones is already implemented in the calculation procedure, but a label schematic has not been developed of all climate zones.

EVIA 7.2

Recommendation to put filter and IAQ information on the label.

The additional advantages of better filtration is not yet visible. A filter has a direct impact on SEC value.
An information of filter performance shall be added on the label.
Furthermore an information about IAQ controls options shall be given.

EVIA 7.3
Recommendation to use different label for UVUs and BVUs
When considering the current minimum requirements (SEC < -20) there is limited space for unidirectional ventilation units to differentiate in the label class better performing products. This would lead to a low interest of customer to invest in better performing UVU system especially if we look and the market for refurbishments.
EVIA is requesting a different label for UVU and BVU based on a common calculation scheme in analogy with the boiler.

2.8 Recommendation regarding SEC Calculation RVUs

EVIA 8.1
Recommendation to add a control factor CTRL=0.5

The Energy Labelling shall provide a simple and fair comparison between the products within the same group and in relation to other products.
The deletion of the "full local demand control" with the CTRL factor of 0,5 in the development of the current regulation was never understood and lead to a dramatic change of the relation between unidirectional ventilation units (UVU) and bidirectional ventilation units (BVU) which is unfounded.
For that reason, the room by room control option was specified in EN 13142 table A.3 and shall be used for the review.

Table 31. Declaration of control factor (Table A3 in EN 13142:2018)

Criteria	Grading (optionnal)	Properties	Declaration	Corresponding ecodesign value CTRL	
				Ducted units	Non-ducted units
CTRL Control Factor	N	None	Declaration	1	1
	M	Manual control (no DCV)[a]	Declaration	1	1
	C	Clock control (no DCV)[b]	Declaration	0,95	0,95
	CDC	Central demand control (one sensor)[c d]	Declaration	0,85	—
	LDC	Local demand control (at least two sensors for ducted unit one sensor for non-ducted units)[c e]	Declaration	0,65	0,65
	RDC	Room by room control one sensor in each room[c f]	Declaration	0,5	0,5

[a] Manual control: any control type that does not use demand control.

[b] Clock control: a clocked (daytime-controlled) human interface to control the fan speed/flow rate of the ventilation unit, with at least seven weekday manual settings of the adjustable flow rate for at least two setback periods, i.e. periods in which a reduced or no flow rate applies.

[c] Demand control: a device or set of devices, integrated or as a separate delivery, that measures a control parameter and uses the result to regulate automatically the flow rate of the unit and/or the flow rates of the ducts.

[d] Central demand control: a demand control of a ducted ventilation unit that continuously regulates the fan speed(s) and flow rate based on one sensor (type O or I) for the whole ventilated building or part of the building at central level.

[e] Local demand control: a demand control for a ventilation unit that continuously regulates the fan speed(s) and two flow rates (for example one sensor related to supply air and one sensor for extract air or 2 sensors related to supply or extract air with dampers) based on more than one sensor (type O or I) for a ducted ventilation unit or one sensor for a non-ducted unit.

[f] Room by room control (not considered in EU 1253/2014): a demand control for a ventilation unit that continuously regulates the fan speed(s) and the air volume flow to/from the rooms in minimum 80 % of the total number of rooms (or area or air volume flow) based on measurements in these rooms.

EVIA 8.2

Recommendation to apply Filter Compensation (FC) factor

EVIA proposes to use Annex D of EN 13142 to assess the sensibility of a residential ventilation unit to pressure changes caused by filter clogging.

D.1 General

In a ventilation unit equipped with filters, dust accumulates on the filter media and tends to clog the filter overtime. A regular change of the filter is therefore needed. However, between two filter replacements the progressive clogging of the filter will increase the pressure drop of the filter and may result in a change in the air flow/pressure characteristic of the unit, it may decrease the ventilation air flow and have adverse effects on indoor air quality and on thermal performance of the building. Annex E provides guidance on how to assess the sensitivity of a ventilation unit to this filter clogging effect.

D.2 Definition and calculation of the filter compensation factor

The filter compensation factor (*FC*) is determined by adding an additional pressure drop during the test of the unit. This additional pressure is set to 1,5 times the initial pressure drop of the clean filter and is deemed representative of the clogged filter additional pressure drop.

The *FC* factor is calculated according to Formula (D.1).

$$FC = (q\mathrm{ref} - q\mathrm{vfc})/q\mathrm{ref} \qquad \text{(D.1)}$$

where

qref is the reference air flow according to EN 13141-4, EN 13141-6, EN 13141-7, EN 13141-8 or EN 13141-11, with clean filters;

qvfc is the air flow with an additional pressure drop of 1,5 times the initial pressure drop of the filter.

For bidirectional ventilation units, FC shall be determined on both supply and exhaust sides.

D.3 Classification of the filter compensation factor

The classification of the filter compensation factor is given in Table D.1.

Table 32. Classification of filter compensation factor (Table D1 in EN 13142:2018)

Type	Class	Filter compensation factor %
Fully compensated	1	≤ 3 %
Not fully compensated	2	≤ 8 %
	3	≤ 12 %
	4	≤ 20 %
	Not classified	> 20 %

For further description of test method and test set up, see informative Annex D of prEN 13142:2018.

EVIA 8.3

Recommendation to include '*infiltration*' and adjust the '*MISC-factor*' in an extended SEC calculation

Current definition of MISC factor is wrong and confusing. EVIA is proposing to use the original procedure, already discussed and presented in the first drafts of the current regulation. Informative Annex F of EN 13142 prepared a full set of equations and default values to be used.

F.1 General

The current SEC calculation used in EU 1253/2014 and EU 1254/2014 does not consider the impact of the pressure of ventilation systems on the infiltration. This leads to the principle problems when comparing unidirectional ventilation systems (over or under pressure in the building) with balanced system (neutral pressure in the building).

The simplified approach developed in Annex F introduces a parameter for the infiltration to correct the influence of the pressure of ventilation systems on the infiltration.

F.2 Extended SEC calculation

The extended SEC is calculated using Formula (F.1).

$$SEC = \frac{8\,760}{1000} \times PRI_{el} \times SPI \times 1{,}3 \times CTRL^{x} \times MISC - t_h \times \Delta T_h \times \frac{344}{10^6} \times PRI_h \times \left(2{,}2 + INF - 1{,}3 \times CTRL \times MISC \times (1 - HR)\right)$$

The parameter *INF* in Formula (F.1) is defined in Table F.1.

Table 33. Infiltration INF parameter (Table F1 in EN13142:2018)

Climate	t_h	Δt_h	*INF*	
			Exhaust Supply	Balanced
Cold	6 552	14,5	0,10	0
Average	5 112	9,5	0,18	0
Warm	4 392	5	0,36	0

The current approach of MISC in EU 1253/2014 and EU 1254/2014 does not reflect the real aspects of cascading in dwellings. The modified MISC parameter is defined in Table F.2.

Table 34. Modified MISC parameter (Table F2 in EN13142:2018)

Unit	Overflow MISC
Exhaust ventilation unit	1
Supply ventilation unit	1
Balanced ventilation unit (single dwelling)	1
Balanced ventilation unit (single room)	1,5 to 2,0

EVIA 8.4

Recommendation to improve calculations for defrosting / frost-prevention, following the extended SEC calculations of informative Annex E of the prEN13142:2018

Current correction of defrosting controls and strategies are far to simplified. The revision shall consider more detailed aspects. Informative Annex E of EN 13142 was provided to consider each detail, typically effects the defrosting and might be used to specify a more targeting correction in the review.

Paragraph E.2.5 Annual electricity consumption for defrosting of this This Annex E describes a calculation method for determining the annual electricity consumption for defrosting / frost-prevention.

E.2.5 Annual energy consumption for defrosting

E.2.5.1 Annual Electricity consumption for defrosting

Annual electricity consumption for defrosting is calculated using Formula:

$$E_{defr} = E_{\Delta p,ext,defr} + E_{\Delta p,int,defr} + E_{preh} + E_{pump,defr}$$

where

E_{defr} is the annual electricity consumption per m2 heated floor area for defrosting, in kWh/m2·a;

$E_{\Delta p,ext,defr}$ is the annual electricity consumption use due to external pressure losses of external defrosting devices per m2 heated floor area in kWh/m2·a;

$E_{\Delta p,int,defr}$ is the annual electricity consumption due to internal pressure loss during frost growing per m2 heated floor area in kWh/m2·a;

E_{preh} is the annual electricity consumption for an electric preheater per m2 heated floor area in kWh/m2·a;

$E_{pump,defr}$ is the annual electricity consumption use for defroster pump per m2 heated floor area in kWh/m2·a.

See Annex E of the prEN13142:2018 sections E.2.5.2 to E.2.5.5 for further explanation on how to calculate these parameters

E.2.5.6 Annual heating energy consumption for defrosting

The annual heating energy consumption for defrosting per m^2 heated floor is calculated as:

$$\Delta E_{AH,defr} = \Delta E_{h,preh} + \Delta E_{by} + \Delta E_{su} + \Delta E_{ex} - \Delta E_{vent} - \Delta E_{el,preh} - \Delta E_{earth}$$

where

$\Delta E_{AH,defr}$ is the annual heating energy consumption for defrosting per m2 heated floor area in kWh/m2·a;

$\Delta E_{h,preh}$ is the annual heating energy consumption for preheating (by space heating generation) per m2 heated floor area in kWh/m2·a;

ΔE_{by} is the annual heating energy consumption for bypassing the heat recovery per m2 heated floor area in kWh/m2·a;

ΔE_{su} is the annual heating energy consumption for lowering of the supply air flow rate per m2 heated floor area in kWh/m2·a;

ΔE_{ex} is the annual heating energy consumption for increasing of the exhaust air flow rate per m2 heated floor area in kWh/m2·a;

ΔE_{vent} is the annual heating energy reduction by ventilator heat per m2 heated floor area in kWh/m2·a;

$\Delta E_{el,preh}$ is the annual heating energy reduction by an electric preheater per m2 heated floor area, in kWh/m2·a;

ΔE_{earth} is the annual heating energy reduction by an earth to air heat exchanger per m2 heated floor area in kWh/m2·a.

See Annex E of the prEN13142:2018 sections E.2.5.7 to E.2.5.12 for further explanation on how to calculate these parameters

Proposed Default values for calculation and classification

Table 35. General typology RVU (Table E.3 in prEN13142:2018)

Type of ventilation units	**general typology factor *MISC***
Ducted ventilation units	1.1
Non-ducted ventilation units	1.21

Table 36. Ventilation control factor CTRL (table E.4 in prEN13142:2018)

Type of ventilation control	**Ventilation control factor *CTRL***
Manual control (no DCV)	1.00
Clock control (no DCV)	0.95
Central demand control	0.85
Local demand control	0.65

Table 37. Exponent 'x' for not-linearity motor and drive (table E.5 in prEN13142)

Type of motor and drive	**exponent for non-linearity *x***
on/off & single speed	1.0
2-speed	1.2
3-speed	1.5
variable speed	2.0

Table 38. General defaults for SEC calculation (table E.6 in prEN131452)

Description	**Symbol**	**Unit**	**Value**
specific heat capacity of air	c_{air}	kWh/(m³K)	0.000344
net ventilation requirement per m² heated floor area	q_{net}	m³/h.m²	1.3
reference natural ventilation rate per m² heated floor area	q_{ref}	m³/h.m²	2.2
annual operating hours	*ta*	h	8760
primary energy factor electric power generation and distribution	*pef*	-	2.5
space heating efficiency	η_h	%	75

Table 39. Climate related defaults for defining heating season (table E.7 in prEN13142)

Climate	Description	Symbol	Unit	Value
cold	total hours heating season	t_h	h	6446
	average difference indoor and outdoor temperature	ΔT_h	K	14.53
Average	total hours heating season	t_h	h	4910
	average difference indoor and outdoor temperature	ΔT_h	K	10.94
warm	total hours heating season	t_h	h	3590
	average difference indoor and outdoor temperature	ΔT_h	K	5.21

Table 40. Climate related defaults for defrosting (table E.8 in prEN13142)

Description	Symbol	Unit	Climate	Defrosting mode setpoint θ_{idefr} in °C			
				-2	-3	-4	-5
Operating time in defrosting mode	t_{defr}	h/a	cold	1814	1434	1142	905.5
			average	430.5	303.5	216.5	134
			warm	0	0	0	0
Average difference between the outdoor temperature and defrost mode setpoint during the defrosting period	ΔT_{defr}	K	cold	5.15	5.14	5.29	5.32
			average	2.94	2.61	2.48	2.49
			warm	-	-	-	-

Table 41. Technology related defaults for defrosting in average climate (table E.9 in prEN13142)

Cat.	Description	Value	Unit	Defrosting set point °C - 2	- 3	- 4	- 5	Note
N	**None**			Shall be declared like E1				
E	**Electric preheating**							
E1	1 stage, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	4,16	4,46	4,74	5,04	
E2	2 stage, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	2,63	2,78	2,95	3,08	
E3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	1,00	1,00	1,00	1,00	
E4	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	$f_{ctrl,defr}$	—	0,80	0,80	0,80	0,80	
M	**Mixing air**			(Not available yet)				
Cat.	**Description**	**Value**	**Unit**	Temperature ratio η_t 0,6	0,7	0,8	0,9	**Note**
L	**Lowering supply air flow rate (or shut off)**							
L1	Ventilator shut off	$\Delta\eta_{t,low}$	—	0,012	0,038	0,057	0,095	
L2	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	$\Delta\eta_{t,low}$	—	0,003	0,007	0,013	0,023	
L3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	$\Delta\eta_{t,low}$	—	0,002	0,006	0,011	0,018	
I	**Increasing exhaust air flow rate**							
I1	Ventilator shut off	$\Delta\eta_{t,dec}$	—	0,012	0,038	0,057	0,095	
I2	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	$\Delta\eta_{t,dec}$	—	0,009	0,018	0,031	0,045	
Cat.	**Description**	**Value**	**Unit**	Defrosting set point °C - 2	- 3	- 4	- 5	**Note**
I3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	$\Delta\eta_{t,dec}$	—	0,007	0,014	0,025	0,036	
B	**Bypass for defrosting**							
B1	Bypass full open	$\Delta\eta_{t,by}$	—	0,012	0,038	0,057	0,095	
B2	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	$\Delta\eta_{t,by}$	—	0,003	0,007	0,013	0,023	
B3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	$\Delta\eta_{t,by}$	—	0,002	0,006	0,011	0,018	

S	**No freezing risk**							
S1	In warm climate until – 25 °C							no additional energy use
S2	In average climate until – 15 °C							
S3	In cold climate until 0 °C							
X	**External frost protection**							defined by supplier
XE1	1 stage, controlled by outdoor temperature inlet in ventilation unit	*f*ctrl,defr	—	4,16	4,46	4,74	5,04	
XE2	2 stages, controlled by outdoor temperature inlet in ventilation unit	*f*ctrl,defr	—	2,63	2,78	2,95	3,08	
XE3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	*f*ctrl,defr	—	1,00	1,00	1,00	1,00	
XE4	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	*f*ctrl,defr	—	0,80	0,80	0,80	0,80	
XW2	External water based preheater, controlled by outdoor temperature inlet in ventilation unit. Stepless variable controlled pump	*f*ctrl,defr	—	1,00	1,00	1,00	1,00	by space heating generation
XB1	External brine air preheater, controlled by outdoor temperature inlet in ventilation unit. 1-stage pump	*f*ctrl,defr	—	1,00	1,00	1,00	1,00	heat supply from earth
XB2	External brine air preheater, controlled by outdoor temperature inlet in ventilation unit. Stepless variable controlled pump	*f*ctrl,defr	—	0,75	0,75	0,75	0,75	heat supply from earth
XG	External earth-to-air heat exchanger							

Table 42. Technology related defaults for defrosting in cold climate (table E.10 in prEN13142)

Cat.	Description	Value	Unit	Defrosting set point °C				Note
				- 2	- 3	- 4	- 5	
N	**None**			Shall be declared like E1				
E	**Electric preheating**							
E1	1 stage, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	5,04	4,74	4,46	4,16	
E2	2 stages, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	2,69	2,64	2,46	2,36	
E3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	1,00	1,00	1,00	1,00	
E4	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	$f_{ctrl,defr}$	—	0,80	0,80	0,80	0,80	
M	**Mixing air**			(Not available yet)				
Cat.	**Description**	**Value**	**Unit**	Temperature ratio η_t				**Note**
				0,6	0,7	0,8	0,9	
L	**Lowering supply air flow rate (or shut off)**			Not applicable in cold climate				
L1	Ventilator shut off	$\Delta\eta_{t,low}$	—	NA	NA	NA	NA	
L2	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	$\Delta\eta_{t,low}$	—	NA	NA	NA	NA	
L3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	$\Delta\eta_{t,low}$	—	NA	NA	NA	NA	
I	**Increasing exhaust air flow rate**			Not applicable in cold climate				
I1	Ventilator shut off	$\Delta\eta_{t,dec}$	—	NA	NA	NA	NA	
I2	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	$\Delta\eta_{t,dec}$	—	NA	NA	NA	NA	
I3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	$\Delta\eta_{t,dec}$	—	NA	NA	NA	NA	
B	**Bypass for defrosting**			Not applicable in cold climate				
B1	Bypass full open	$\Delta\eta_{t,by}$	—	NA	NA	NA	NA	
B2	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	$\Delta\eta_{t,by}$	—	NA	NA	NA	NA	

Cat.	Description	Value	Unit	Defrosting set point °C				Note
				- 2	- 3	- 4	- 5	
B3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	$\Delta\eta_{t,by}$	—	NA	NA	NA	NA	
S	**No freezing risk**							no additional energy use
S1	In warm climate until – 25 °C							
S2	In average climate until – 15 °C							
S3	In cold climate until 0 °C							
X	**External frost protection**							defined by supplier
XE1	1 stage, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	5,04	4,74	4,46	4,16	
XE2	2 stage, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	2,69	2,64	2,46	2,36	
XE3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	1,00	1,00	1,00	1,00	
XE4	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	$f_{ctrl,defr}$	—	0,80	0,80	0,80	0,80	
XW2	External water based preheater, controlled by outdoor temperature inlet in ventilation unit. Stepless variable controlled pump	$f_{ctrl,defr}$	—	0,75	0,75	0,75	0,75	by space heating generation
XB1	External brine air preheater, controlled by outdoor temperature inlet in ventilation unit. 1-stage pump	$f_{ctrl,defr}$	—	1,00	1,00	1,00	1,00	heat supply from earth
XB2	External brine air preheater, controlled by outdoor temperature inlet in ventilation unit. Stepless variable controlled pump	$f_{ctrl,defr}$	—	0,75	0,75	0,75	0,75	heat supply from earth
XG	External earth-to-air heat exchanger							

3. Combined Position paper EHI–EHPA–EPEE–EUROVENT-EVIA

3.1 Inclusion multifunctional BVUs in Revision of EU 1253/2016

Five of the leading European industry associations in the sector (EPEE, EHPA, Eurovent, EVIA and EHI) share common concerns over the approach taken to the integration of multifunctional units within the EU's framework for Energy Related Products (ERP).
In particular, they have reservations on the following proposal outlined in the Task 7 Final Report1 on the revision of EU 206/2012 (Small air conditioners and comforts fans) to extend the scope to include ventilation exhaust air-to-air heat pumps and air conditioners whose rated capacity is ≤ 12 kW.

As the functions of ventilation, heating and hot water production may be combined in one multifunctional product (see EN 16573), overlapping with the scopes of (EU) 813/2013 and 814/2013 and 1253/2014 is arising. Whilst we recognise the concept of multifunctional units as valid, we also note that the definition of the possible technical parameters and scope of multifunctional units is, as of yet, to be clarified.
Multifunctional units may include only one exhaust air fan or may include both exhaust air and supply air fans. In addition, multifunctional units include one or several additional functions, such as heating and/or cooling and/or domestic hot water production etc. Multifunctional units including only one exhaust air fan, namely exhaust air heat pumps, are already covered by regulations (EU) 813/2013 and 814/2013 and shall remain in the scope of these regulations.

As multifunctional bidirectional ventilation units may include any combination of additional functions there are multiple types and architectures of multifunctional bidirectional ventilation units. Among them, ventilation is the only common function. For that reason, in order to gather all the multifunctional bidirectional units in a single regulation to make it possible the comparison among them, we propose to include these units in (EU) 1253/2014, and not in (EU) 206/2012.
Including them in (EU) 1253/2014 will also allow to consider them independently on their capacity range (as EU 206/2012 is limited to 12kW units).
Today, products are included in the different ERP regulations according to their function. However, typically multifunctional units are not optimised to perform a function in isolation, but to provide a combination aimed at achieving the highest overall performance and benefit for the consumer.
Including multifunctional bidirectional ventilation units in the revision of regulation (EU) 1253/2014 will allow to assess the energy efficiency of the ventilation function. However, as these units offer functions other than ventilation only, all additional functions of a unit having energy and environmental impacts shall be considered in the revised regulation. So, energy efficiencies of heating and/or cooling and/or DHW shall be addressed as well as sound power level. This will also allow a fair comparison of these units with products already covered by existing regulations addressing the impact of a specific function (heating, cooling, DHW), such as regulation 206/2012, 813/2013 and 814/2013.

DEFINITION AND TESTING OF "MULTIFUNCTIONAL BIDIRECTIONAL VENTILATION UNITS"
EN 165732 was intended to cater specifically for these kinds of units. The rating basis is the reference flow for the ventilating function plus one or more additional functions. It references a wide range of multifunctional units as examples.
The definitions and procedures of this standard would be a good starting point:

- EN 16573 covers units that contain at least, within one or more casing:

    - supply and exhaust air fans;
    - air filters;
    - common control system;
    - and one or more of the additional components:
        - Air-to-water heat pump;
        - Air-to-air heat pump;
        - Air-to-air heat exchanger.

- A multifunctional bidirectional ventilation unit provides ventilation for single dwellings as a primary function. The additional functions that may be provided by the units are:
    - Hydronic heating/air heating;
    - Hydronic cooling/air cooling;
    - Hot water production.

- EN 16573 delivers global performance, EER, COP etc. and performance by functions at reference air volume flow considering the test standards EN 13141-7, EN 14511 and EN 16147 in the applicable combination.

CONCLUSION

In consideration of the aspects outlined above, our industry associations, which represent multifunctional units, request that multifunctional bidirectional ventilation units are removed from the scope of EU 206/2013 revision and are instead covered within EN 1253/2014 revision. Multifunctional units including only one exhaust air fan are already in the scope of regulations 813/2016 and 814/2013.

Further, we suggest that EN 16573 provides a ready-made foundation for facilitating the implementation of a change that will assist in delivering a measurable improvement in the energy efficiency delivered to European consumers, whilst providing a level playing field for the uptake and future development of the technology.

Representatives of the Platform trust that the proposal outlined in this letter will be given thorough consideration in the context of the revisions of (EU) 206/2012 and (EU) 1253/2014 and would be delighted to address clarifications in person.
Currently, the market for multifunctional bidirectional ventilation units including heat pumps is relatively small. Indeed, we estimate that no more than 15,000 units per year are placed on the market for residential applications. The units for residential applications that are available on the market are optimised for very low energy buildings providing predominately ventilation and, depending on the function, space heating/cooling and hot water capabilities. We estimate similar numbers for non-residential applications. Nevertheless, we welcome the European Commission's efforts to integrate multifunctional units within the ERP framework with a view to shaping the development of the marketplace.

4. Comments ALDES

4.1 General Comments

ALDES 1.1
Apply longer periods between two revisions (at least 5 years)

ALDES 1.2
Synchronize publication, revision of Regulations regarding Motors, Fans, Ventilation units.

ALDES 1.3
Notice the industry in advance and ensure an incompressible period of 2 year between publication and entry into force

Rationale
Industry needs time to adapt. The sector of HVAC equipment has relatively low annual sales quantities per model, models are kept several years on the market and therefore payback periods are long for fan and ventilation units Industry are much longer, compared to consumer goods industry. For instance TV manufacturers launch new models every year, thus facing new sets of requirements every two year is perhaps not an issue. In our industry some products are sold during more than 10 years.
Too frequent changes in regulatory framework creates uncertainty and instability. Both of them are clearly enemies of investment and therefore of industrial jobs. Too frequent changes in regulatory framework endanger the wealth of European Market. That is why long term perspectives and objectives are requested.
In the same way, ventilation products are facing two or more regulations (cascading), each one having its own schedule making them very complex to handle for manufacturers. Regulations affecting the same products shall be synchronized.

ALDES 1.4
No stacking (cascading) of regulations

Components used in a product put on the market complying with requirements from an Ecodesign Regulation covering that product, shall be excluded from Ecodesign regulations.

Rationale
Ventilation units face 3 requirements: motors, fan, and ventilation units.
Each additional requirement adds costs and burdens while limiting the freedom of manufacturers in designing their products. Only the last requirement is useful and adds value to the customer and makes sense from an Ecodesign performance perspective.

ALDES 1.5
Enforce market surveillance.

Rationale
Market surveillance is the key to success for Ecodesign Regulations. There is no or too few market surveillance about application of Regulations 1253/2014 and 1254/2014. Without market surveillance, some competitors take advantage of non-applying these Regulations properly. This leads to a situation where compliant manufacturers have invested a lot of

money to make their products compliant. Therefore, these products more efficient including speed control are more expensive.
The European Commission has to enforce Market Surveillance. Otherwise it isn't worth to have these Ecodesign Regulations.
The European Commission should work on several scenarios in order to strengthen the effectiveness of the Market surveillance.

ALDES 1.6

Do not put requirements that are impossible or difficult to assess

Rationale

There are some requirements that are too difficult to assess in the current regulation 1253/2014. For instance, SFPint is very difficult to check onsite. The requirements on VSD are also difficult to check when delivered separately from the ventilation unit.

ALDES 1.7

Do not put requirements that need additional interpretation. Improve the quality of the regulation in order to make it self-sufficient.

Rationale

There are too many aspects that are poorly written in the current regulation and makes the application tricky (lack of precise definitions for example). They are not clear enough and need extra interpretation.
Examples:

– a distinction between "fans" (covered by Regulation 327/2011) and "ventilation units (UVU, BVU)" (covered by 1253/2014) shall be made by clear definitions and borders (define clearly what are "housings" and "casings")
– the definition of local demand control is too poor.

4.2 Comments regarding setting additional requirements NRVUs

ALDES 2.1

Do not set higher requirements

Rationale

- Higher requirements may be counterproductive for products sold in some areas where currently there is no real Market surveillance then, it wouldn't make sense to have higher requirements.
- Current Ecodesign Regulations have somehow increased product prices and it has been difficult to explain and justify it to a big majority of customers.
- Higher requirements would endanger some European SMEs.

ALDES 2.2

Do not make different requirements according to project data (climate, type of building…)

Rationale

- Current Ecodesign Regulations shall ensure free circulation of goods for which too specific parameters (e.g. climate) would deeply disturb.
- Mass produced RVUs can't be designed with climate parameters because manufacturers don't know where these products will be installed.

ALDES 2.3

No need to take into account defrosting aspects

Rationale

- It would make Ecodesign Regulations more complicated to apply.
- **The verification of defrosting performance is tricky.**

ALDES 2.4

Proposal to communicate a compliance area instead of a single nominal point for SFP:

- Selection software would inform about the Ecodesign compliancy of SFP at the working point
- Printed aerodynamic performance diagrams would show the compliancy area of SFP
- No compliance area for UVU without filters (only a declaration and no requirement for SFP).
- Compliancy area of SFP for UVU and BVU with filters.

Rationale

- Today, products are often used at lower pressure / airflow than the nominal point, because nominal data are design data and include security coefficient. Furthermore, lot of units are operated with sensors and work most of the time at part load (demand control ventilation). It is counterproductive to check compliancy only on the maximum duty point.
- Communicate compliancy on all points would let the customer designing a ventilation installation to check the compliancy of the most typically used working points.
- Communication of compliancy of all points would harmonize practices in the ventilation area.

ALDES 2.5

No compliancy area for η_{eff} (thermal efficiency of heat exchanger) for BVUs and for ηvu of UVU

Rationale

Mixing compliancy areas for SFP and efficiencies would lead to not acceptable too high requirements for products without saving significant energy for the final use of products.

ALDES 2.6

No requirements on leakage

Rationale

- Leakage of a NRVU is something difficult to assess, thus the market surveillance is quite impossible on that point.
- Information on the leakage level is sufficient.

- Keep a possible requirement at national building code level.

4.3 Comments regarding improvement of the Regulation for NRVUs

ALDES 3.1

Promote Demand Controlled Ventilation and rising pressure fans

Rationale

- DCV is a very effective way to reduce energy consumption of ventilation products.
- Requirements must be softened for DCV products.
- Performance shall be checked at average duty point, not maximum design duty point.

ALDES 3.2

Adapt current requirement on 3 speed or VSD:

- Remove the obligation for NRVU < 1000 m3/h
- Make it mandatory to deliver a mounted VSD for VU > 1000 m3/h (no separate delivery)
- VSD should be defined in a way to make voltage regulation non-compliant

Rationale

Many products are sold without variable speed even if the Ecodesign data is established with a variable speed. The same rules for the game are not ensured today because some manufacturers sell their units with 3S or VSD and some other without. It is therefore better to remove the requirement, at least for small units. For larger units, ventilation units shall be factory equipped with a VSD.
Some products are equipped with very cheap non efficient voltage graduator. Those variable speed shall be simply forbidden.

ALDES 3.3

Use SFPglobal instead of SFPinternal

- Requirements can be easily derived from target fan efficiency and current SFPint limit. The requirement would also take into account the design external pressure (higher pressure => higher allowed SFP)
- SFPglobal required for both BVU and UVU with filters
- Declaration (no requirements) of SFPglobal for UVU without filters.

Rationale

- SFPint is difficult to measure (often impossible to measure onsite). We need different approaches for tailor made and mass products, that may produce different results and this situation creates a risk of non-compliance for manufacturers.
- SFPglobal is easy to measure onsite: one just needs the power and the airflow. It has been used for long in building codes and standards in some countries. It may be applicable to all units, including box and roof fans, with adjusted parameters.

ALDES 3.4

UVU type "box fans" and "roof fans" (with or without filters) shall remain under Regulation 1253/2014

Rationale

- If these products are considered as "fans", with which efficiency limit (N grade) will the requirement be defined?
- These products can't be considered as "fans" because they are equipped with "casings" and not "housings" and then it would create a "loophole" as requiring a performance adapted to "fans" to a "ventilation unit"
- EN Standards have now been developed by TC 156 WG 17 to clarify definitions of "ventilation units" (EN 17291) and "fans" (EN 17166). Therefore, it will create a new confusion on the market by moving these products from a Regulation to another one.

ALDES 3.5

No Energy Label for NRVUs

Rationale

Use case of NRVU are diverse and make it difficult to build a consistent label. Eurovent has one but neither it helps in choosing between an AHU with higher heat recovery efficiency and an AHU with a lower fan consumption nor it takes into account DCV.

ALDES 3.6

Avoid cascading and consider intended use

All fans or UVU which intended use is ventilation: lot 6 / Other intended use: lot 11

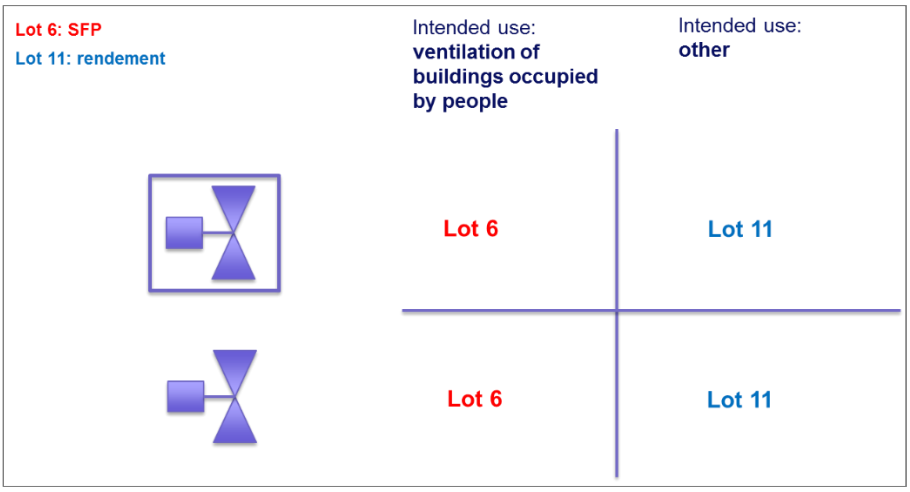


Figure 6. Regulation based on intended use

Rationale

Lot 11 only considers the BEP (Best Efficiency Point). For products being in use for ventilation, BEP is not relevant. Products may operate at other points, especially if they are equipped with DCV.

Furthermore, there shouldn't be any distinction between the uses of regulations only based on too slight technical details. All products having the same function and same final use must be covered by the same regulation. Therefore, fans used for ventilation of buildings occupied by people must be covered by Regulation 1253 (lot 6).

4.4. Comments regarding requirements for RVU

ALDES 4.1

Do not set higher requirements

Rationale

- As far as there is no real Market surveillance, it would make no sense to have higher requirements
- Ecodesign Regulation has somehow increased product prices and that it has been difficult to explain and justify it to customers.
- Higher requirements would endanger some European SMEs.

ALDES 4.2

Revised Regulation 1253/2014 shall cover all RVUs without the limit of 30W (start at 0W)

Rationale

- Covering all RVU without a limit of power will clarify the market offer of RVU without a risk of "loophole" with products having a declared power consumption of 29, 99 W but currently consuming more.
- Consequently, the current situation creates a market distortion 30 W makes it possible to have CMEV out of Ecodesign regulation. If the limit is lowered, this possibility decrease the level of the market being filled with not efficient small fans or duct fans not compliant with Ecodesign requirements.
- To ensure the same playing rules, all fans have to be in the scope, whatever the value of power they are equipped with.

ALDES 4.3

No need to take defrosting aspects into account

Rationale

- It would make Ecodesign more difficult to apply
- The verification of defrosting performance is expensive

ALDES 4.4

Add requirement on leakage for BVU but only if effective market surveillance is done

Rationale

- Having a requirement on leakages for residential BVU makes sense. Leakages can artificially increase the measured efficiency while being negative from an energy and IAQ perspective
- For residential BVU, the test is done for the efficiency requirement. It doesn't add costs

ALDES 4.5

Remove the possibility of 3 speed for RVU > 30 W

- All RVU > 30 W shall be equipped with VSD

- VSD should be defined in a way to make voltage regulation non-compliant

Rationale
They are already all equipped with variable speed drive

4.5. Comments regarding Indoor Air Quality RVUs

ALDES 5.1
Add IAQ performance information next to the Energy performance on the label

Rationale
- Giving the energy efficiency without any information on the performance of the core function of the ventilation unit is worthless and misleading

ALDES 5.2
Don't penalize RVUs with efficient filters

Rationale
- RVU with efficient shall not be penalized. The use of such filters shall be neutral in the SEC calculation. But the calculation shall be kept simpler.

5. Comments AGORIA Naventa

About Agoria Naventa
Agoria Naventa is a belgian professional organisation that groups manufacturers of natural ventilation systems (systems 2 & 3) in residential (homes) and non-residential buildings. This organisation is an integral part of Agoria, the federation of the technological industry in Belgium.

5.1. Separate Energy Label for residential UVUs and BVUs

When considering the current minimum requirements (SEC < -20) there is limited space for unidirectional ventilation units to differentiate in the label class better performing products. This would lead to a low interest of customers to invest in better performing UVU system both for new buildings and the market for refurbishments.

By putting both UVU and BVU in one calculation and one label, the UVUs are discriminated and put at a disadvantage. When considering the labels, BVUs can reach an A+ label, while the best UVUs with demand control can maximum reach a B-label (without the prospect of ever going beyond this label). This situation gives a competitive advantage for the Heat Recovery manufacturers, consequently going against the basic Ecodesign-principle that says: "Ecodesign should avoid a distorted competition".

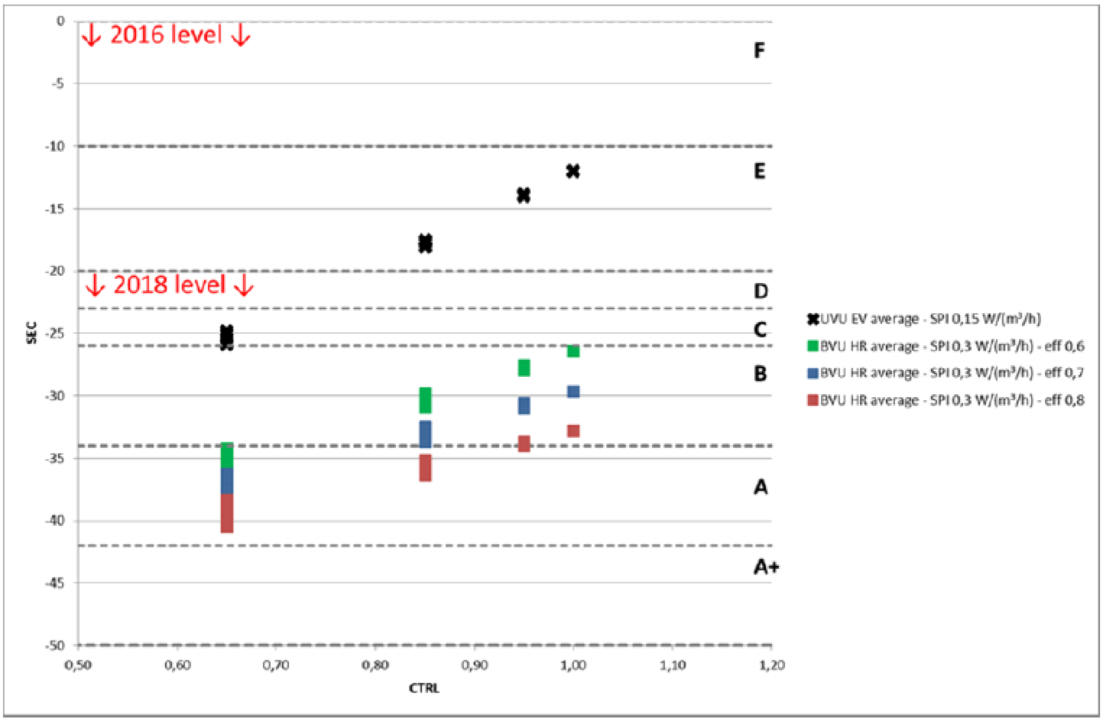


Figure 7. Typical Labels for typical RVUs

Moreover, this does not reflect the real performance of demand controlled UVUs.
With the strong EPBD rules in the different member states, the UVU manufacturers have searched for a way to become more competitive with BVUs with HR. They achieved this

through a series of innovations in Demand Control. At this point there is a level-playing field and the best UVUs with DCV are at the same energy-efficiency as BVUs with HR1[37].

In the scientific article "*Heat recovery ventilation operation traded off against natural and simple exhaust ventilation in Europe*", it is clearly mentioned : "*The results presented here demonstrate that, unless low specific fan power is achieved, for the moderate climate region of middle Europe, natural ventilation, simple exhaust mechanical ventilation and heat recovery ventilation have no clear advantage over each other as far as operating energy and associated ecologic (CO2) and economic (Household consumer price) effects are concerned. The choice between the different systems should be made based on building specific characteristics, investment and maintenance cost*" [38]

More recently, extensive monitoring results have become available on the European CONCERTO ECO-Life project, in which an existing social housing neighbourhood (274 dwellings) 'Venning' in Kortrijk was transformed into a zero-carbon neighbourhood. "*Combining the available data on the energy consumption for heating and auxiliary energy (electricity), allows to calculate the real performance in detail. Contrary to what is usually expected from existing simulations/calculations, the monitoring results demonstrate that the total energy consumption is very similar for both ventilation systems (Table 16)*."[39]

Table 43. Yearly mean space heating and fan consumption for DCMEV and MVHR

	DCMEV	MVHR
Space heating consumption (kWh)	6592	5826
Fan consumption (kWh)	186	853
Total energy use (kWh)	6778	6679

Therefore Agoria Naventa urges a strengthening of the distinction between the two labels and strongly requests further development of two independent labels for UVUs and BVUs To accomplish this, the calculation method should be split UVU/BVU and a seperate SEC-table for the labelling. While the equation to calculate the SEC (Specific Energy Consumption) is not fundamentally flawed, the range of certain calculation-factors is either too big or too small, causing the final SEC-result to be advantageous for one system and disadvantageous for other systems.
One of the reasons why the calculation should be also split is that DCV has a different effect on the energy performance of both UVU and BVU, not taken into account today. When a Demand controlled UVU (local sensors + valve control) detects an increase of a CO2/RH/VOC in a certain room of the house, the extraction will be increased ONLY for that room until the pollution is gone. When a demand controlled BVU detects a pollution in a room, then the extraction in ALL rooms increase AND the supply in alle rooms, because it is a balanced system. This is why Demand Control is much more energy efficient for UVUs than for BVUs.

[37] Performance of a demand controlled mechanical extract ventilation system for dwellings: simulations and in-situ measurements, CIBSE Technical Symposium, Liverpool, April 2013

[38] Heat recovery ventilation operation traded off against natural and simple exhaust ventilation in Europe by primary energy factor, carbon dioxide emission, household consumer price and exergy, Laverge/Janssens, Elsevier 2012

[39] Energy performance of demand controlled mechanical extract ventilation systems vs mechanical ventilation systems with heat recovery in operational conditions : Results of 12 months in situ-measurements at Kortrijk ECO-Life community, Derycke/Bracke/Laverge/Janssens, UGent 2018

5.2. Climate zones must be considered in the Energy Label

The Ecodesign approach as used for household appliances like TVs is suitable for standalone products, of which the energy performance will be the same whatever living-room it is placed in, whether it be London or Berlin.
Technical building systems like ventilation however, are not standalone, they need to be designed, installed and maintained correctly to achieve the energy-efficiency published by the manufacturer. Therefore, their actual energy performance is in most cases very different from the theoretical performance.
The energy performance of heat recovery units (BVU) is very different depending on the location and should be based on climatic conditions.
The use of average climate only is very misleading and supposes that the energy performance of a ventilation system is the same for the north of Sweden and the south of Italy.
Figure 8 clearly shows that this is not the case. In northern countries the efficiency of Heat recovery systems is much higher than in the moderate of warm climate zone.

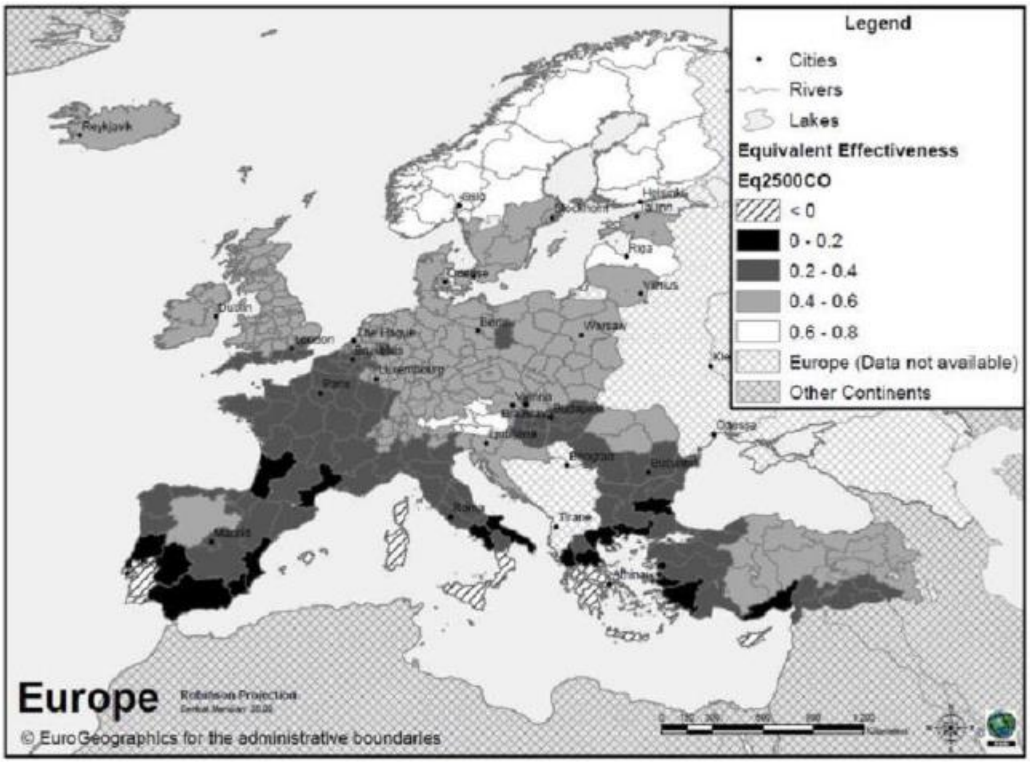


Figure 8. Nett Efficiencies of HR systems in Europe[40]

The principle of SEC calculation for three different climate zones is already implemented in the calculation procedure (needs correction), but a label schematic has not been developed for all climate zones.

[40] Nett Efficiency of Heat Recovery systems in Europe, PHD "Design Strategies for Residential Ventilation systems", University of Gent(Belgium), Jelle Laverge, 2013

5.3. Additional control factor for room by room control: CRTL =0.5

The Energy Labelling shall provide a simple and fair comparison between the products within the same group and in relation to other products.
The deletion of the "full local demand control" with the CTRL factor of 0,5 in the development of the current regulation was never understood and lead to a dramatic change of the relation between unidirectional ventilation units (UVU) and bidirectional ventilation units (BVU), which is unfounded.
For that reason, the room by room control option was specified in EN 13142 table A.1 and should be used for the review, considering the following aspects:

1. **Occupancy or presence sensors**, or sensors for other parameters that are representative for the ventilation demand (but not IAQ sensor):
   A measurable parameter or set of measurable parameters that are assumed to be representative of the ventilation demand and are not an IAQ sensor. For example
   a. Detection of presence
   b. Detection of motion or occupancy from infrared body heat or from reflection of ultrasonic waves
   c. Electrical signals from human operation of lights or equipment
   d. Other parameters that are representative of the ventilation demand

•

2. **IAQ sensor** (CO2, VOC, humidity, etc.) : (Type IDA-C6 according to prEN16798-3:2014) A measurable parameter or set of measurable parameters that are assumed to be representative of the ventilation demand and that can measure the concentration of gas or humidity or other "pollutant" which have an impact on the indoor air quality. For example :
   a. Detection of the level of relative humidity (RH),
   b. Detection of the level of carbon dioxide (CO2),
   c. Detection of the level of volatile organic compounds (VOC)
   d. Detection of the level of other gases or other parameters that influence the well human being.

•

3. **Demand control** : A device or set of devices, integrated or as a separate delivery, that measures a control parameter and uses the result to regulate automatically the flow rate of the unit and/or the flow rates of the ducts.

The CTRL factors shall be specified by the manufacturer based on the following aspects:

Table 44. Control factor

Criteria	Grading (optionnal)	Properties	Declaration	Corresponding ecodesign value CTRL	
				Ducted units	Non-ducted units
CTRL Control Factor	N	None	Declaration	1	1
	M	Manual control (no DCV)[a]	Declaration	1	1
	C	Clock control (no DCV)[b]	Declaration	0,95	0,95
	CDC	Central demand control (one sensor)[c d]	Declaration	0,85	—
	LDC	Local demand control (at least two sensors for ducted unit one sensor for non-ducted units)[c e]	Declaration	0,65	0,65
	RDC	Room by room control one sensor in each room[c f]	Declaration	0,5	0,5

[a] Manual control: any control type that does not use demand control.

[b] Clock control: a clocked (daytime-controlled) human interface to control the fan speed/flow rate of the ventilation unit, with at least seven weekday manual settings of the adjustable flow rate for at least two setback periods, i.e. periods in which a reduced or no flow rate applies.

[c] Demand control: a device or set of devices, integrated or as a separate delivery, that measures a control parameter and uses the result to regulate automatically the flow rate of the unit and/or the flow rates of the ducts.

[d] Central demand control: a demand control of a ducted ventilation unit that continuously regulates the fan speed(s) and flow rate based on one sensor (type O or I) for the whole ventilated building or part of the building at central level.

[e] Local demand control: a demand control for a ventilation unit that continuously regulates the fan speed(s) and two flow rates (for example one sensor related to supply air and one sensor for extract air or 2 sensors related to supply or extract air with dampers) based on more than one sensor (type O or I) for a ducted ventilation unit or one sensor for a non-ducted unit.

[f] Room by room control (not considered in EU 1253/2014): the airflow to the individual rooms/zones is regulated according to the local demands measured by the sensors in/to/from the room/zone. The local flow to/from the room/zones is regulated by dampers/valves serving an individual room in minimum 80 % of the total number of rooms (or area or air volume flow).

REMARK: It is important that the choice of sensors for LOCAL demand control is limited to IAQ-sensors alone (except toilets). For instance, installing a presence sensor in a bedroom will not guarantee a good IAQ. Only sensors from category IDA C6 can be used to ensure that local demand control ensures good IAQ at all times.

5.4. Reducing the gap between theoretical and actual HR-efficiency

In many countries who have experience with ventilation systems, practice has shown that the theoretical performance of a HR-system (BVU) differs strongly from the actual performance. Therefore many legislations have included correction factors to come closer to reality.

Reasons for this lower efficiency:
- Not all the air passes heat recovery unit: air leakages in envelope, open windows
- Not all the heat passes heat recovery unit:
- Heat losses through ducts to and from the unit to outside
- Heat extraction from less heated spaces as laundry/storage
- Heat exchange in unit is lower: condensation in unit, poor maintenance, flow unbalance, …

Solutions:

a.

Correction factor on thermal Heat efficiency.

In Belgium, the Netherlands, UK, Norway and other countries correction factors are included in local Energy Performance legislation, ranging from 0,7 to 0,9.

PROPOSAL FOR ANNEX I and V (RVUs):

Include a correction factor on the thermal efficiency of 0,8 to take into account the difference between the efficiency of a heat recovery unit measured in the laboratory and the unit in practice + formula

b.

Correction factor on the SPI (Specific Power Input)

The draft working document specifies a flow rate of 50Pa including clean filters for the residential VUs. This is again theory, in reality a filter and heat exchanger are loaded with dust particles within a few months (CETIAT-research), thus increasing the pressure drop and consequently, the energy consumption of the BVU.

PROPOSAL FOR ANNEX I and V (RVUs):

- *Include and specify the type of filters for testing SPI (cfr NRVU)*
- *take into account an average filter contamination by measuring SPI at 75-100Pa instead of 50 Pa OR multiply the SPI at 50Pa with 1,25 to 1,5 + formula*

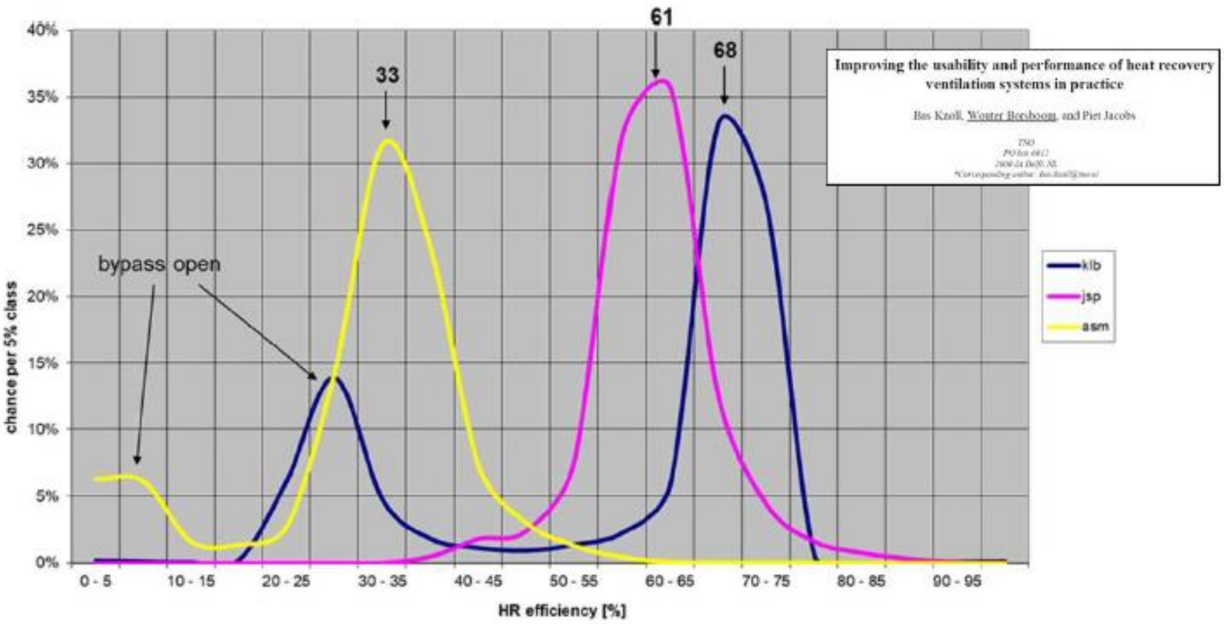


Figure 9. Measured HR-recovery efficiency for three dwellings

6. Comments UNICLIMA

Uniclima is the French association of heating, ventilation, air conditioning and refrigeration Industries. The manufacturers represented by this association are French companies for half of them or come from different European Member States as Spain, Sweden, Germany and Italy.
The French market is one of the most important in Europe with 800 000 residential ventilation units and 110 000 non-residential ventilation units sold each year.

6.1. General aspects

UNICLIMA 1.1
Regulate only the final product (no cascading)

The most efficient components do not necessarily lead to the most efficient product: This is only possible if the components are designed to work together. Over-regulation imposes a rhythm and an accumulation of requirements that hinder coherence of equipment. Moreover regulations relating to sub-assemblies and equipment are neither coordinated in terms of requirements nor on the implementation dates. For instance ventilation units face 3 Ecodesign regulations that are not synchronized: motor, fan and ventilation units.

Uniclima asks the European Commission to regulate only the final product. Spare parts used, in a product put on the market complying with Ecodesign requirements, shall be excluded from Ecodesign requirements.

UNICLIMA 1.2
Enhance Market Surveillance

A Product regulation is effective when it is easily understood and applicable for all actors especially manufacturers and supervisors. In Europe, market surveillance for ventilation unit is very heterogeneous.

Before strengthening technical requirements, Uniclima suggest to strengthen the effectiveness of the market surveillance.

6.2. Proposals for further clarification of the Regulation

UNICLIMA 2.1
Avoid adding new requirements before clarifying the regulation

In principle, Uniclima is generally opposed to the introduction of new requirements in the revision of the ventilation units Ecodesign regulation. On the other hand clarification of the definitions of the Regulation is necessary in the revision of the Regulation.
Moreover the Ecodesign regulation is an energy efficiency regulation for the put on market products and not a commercial selection tool.

UNICLIMA 2.2

Adjust definition of nominal point

The definition of the nominal point used for NRVU measures must be clarified for a better application. A tailor made NRVU is designed for specific working points. A mass-produced compacts NRVU is typically used for a wide range of working points. To check the conformity of the product on one nominal point, we propose to define the nominal point for mass produced NRVU as following:

It is the point on the maximum speed where:
- SFP < SFPlimit and
- Thermal efficiency of a non-residential HRS (ηt_nrvu) < ηt_nrvu Ecodesign

On the figure below, the blue dot corresponds to the nominal point (obtained at maximum speed).

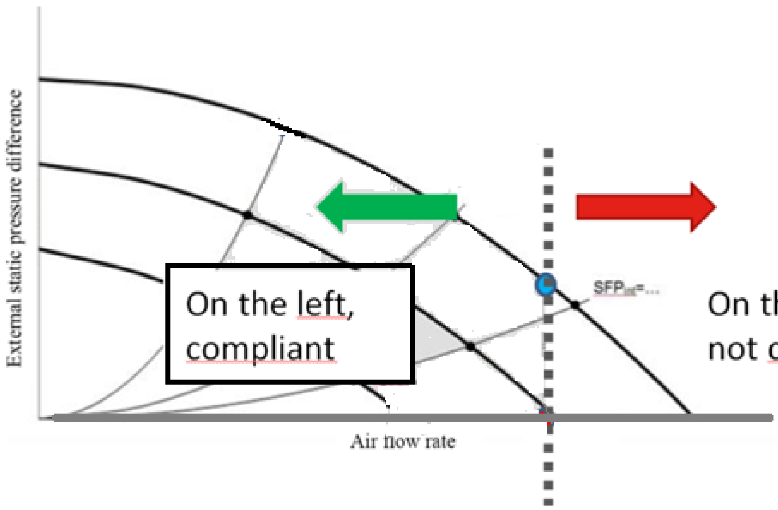


Figure 10. Example of declaration nominal point of mass produced VUs

UNICLIMA 2.3

Use SFP global instead of SFP internal

SFPint is difficult to measure (and often impossible to measure onsite). Different approaches are followed for tailor made and mass products, that may produce different results and this situation creates a risk of non-compliance for manufacturers.

SFPglobal is easy to measure onsite: one just needs the power and the airflow. It has been used for long in building codes and standards in some countries. It may be applicable to all units, including box and roof fans, with adjusted parameters.

UNICLIMA 2.4

Introduce a bonus for SFP_{limit} for smart controls

Uniclima proposes to integrate in the calculation of the SFPlimit criteria that strongly impact the real electrical consumption of the ventilation unit. In fact a ventilation unit never permanently works to its maximum flow rate.

So, it would make sense to introduce SFPlimit bonuses for the following functions:
- Integrated serial controller (to make sure that the performance is reported with electrical engine controller which is tested and validated by the manufacturer)
- Airflow modulation by presence detection or by CO2 level
- Time schedule programming
-

This list of functions should be further investigated.

UNICLIMA 2.5

The possible use of VU-compliance area must remain optional

Uniclima is opposed to the introduction of a new requirement on the compliance area of the ventilation unit.
Eurovent / EVIA FAQ already offers today the optional declaration of a range of conformity for mass-produced units. According to us, if mandatory, a compliancy area is difficult to apply by manufacturers and is hardly controllable by market surveillance. This mapping would require a lot of testing for mass-produced vs. taylor made ventilation unit.
Moreover many questions arise regarding this issue:
- How many points should be measured and verified in the laboratory?
- How many points can be simulated by calculation?
- Who controls the calculation methods?
- How to ensure that the compliance ranges are sufficiently precise in the documentation?
- In case of market surveillance, what will be controlled? All 5 points or only the nominal point?

UNICLIMA 2.6

No differentiated requirements for climatic zones

The proposal to modulate the requirements according to the climatic zones is too complex. Mass produced VUs can't be designed with climate parameters because manufacturers don't know where these products will be installed.

Moreover current Ecodesign Regulations shall ensure free circulation of goods.

UNICLIMA 2.7

No requirements on internal leakage

Information on the leakage level is sufficient. Regarding the choice of type of leakage test, it must remain free for the manufacturer (no generalization of tracer gases tests).

UNICLIMA 2.8

No additional requirements regarding filtration

For NRVU, the energy performance of the filter is taken in the SFPint. For us, any new requirement means must be avoided, so as not to constitute a brake on innovation and a barrier to competition.
For example, new requirement like filter media velocity threshold does not appear to be relevant for energy calculation and it blocks the innovation of the filters.

UNICLIMA 2.9

No additional requirements regarding defrosting

Unicli9ma is against the introduction of defrosting specifications. Moreover the verification of defrosting performance is considered tricky.

UNICLIMA 2.10

No additional requirements regarding defrosting

Uniclima proposes to exclude clearly in the text regulation Residential BVU equipped with a heat pump for heat recovery only.

The following adjustment on the scope is proposed:

Article 1 : Subject matter and scope
2. This Regulation shall not apply to ventilation units which:
(g) include a heat exchanger and a heat pump ***or a heat pump alone*** *for heat recovery or allowing heat transfer or extraction being additional to that of the heat recovery system, except heat transfer for frost protection or defrosting.*

7. Comments ROSENBERG

7.1. Comments regarding Non-Residential UVUs without air treatment

Non-Residential UVUs without air treatment (roof fans, duct fans, tube fans,so-called 'box fans') are only conveying air, the same as fans regulated under EU/327/2011 are doing. They only have an additional housing for e.g. directing the air or reduce sound emission. For this, they only need their own efficiency requirements within the LOT 11 – regulation.
Furthermore, UVUs without air treatment are tested exactly the same way as the fans within scope of LOT 11: in its final stage of assembling directly mounted on a test stand: Testing can easily reproduced after placing the product on the market.

Examples for fan tests in different installation situations on ISO 5801 standardised test bench:

a) Roof fan connected on top of a suction-side chamber test bench
b) Duct fan connected to an suction-side chamber test bench
c) Isolated "Box" fan
d) Examples for axial and centrifugal LOT 11 fans

So-called 'box fans' are from application side and from testing side much more similar to products from scope of LOT 11 than to "ventilation products" from LOT 6.

Figure 11. Test roof fan

Figure 12. Test duct fan

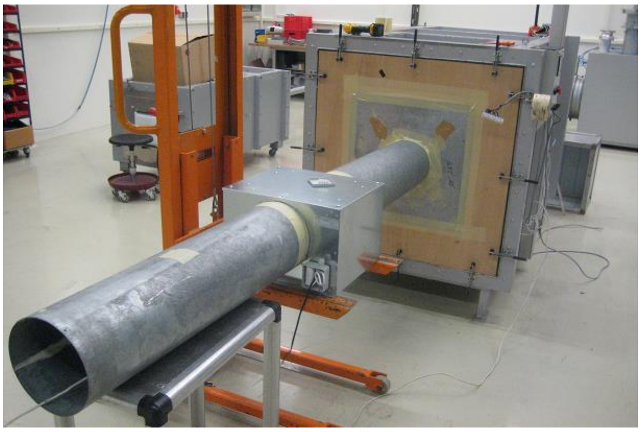


Figure 13. Test isolated box fan

Figure 14. Test axial fan

Proposal is to leave the Non-Residential UVUs without air treatment to the LOT11 –Regulation and exempt them from Regulation 1253/2014.

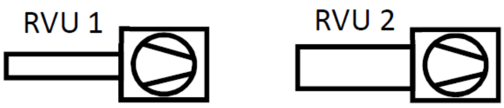
8. Comments HELIOS

8.1. Introduction of new reference pressure parameters VUs

The Issue
In the current regulation EU 1253/2014 the "external static pressure difference" Δps,ext is used as pressure reference parameter for the efficiency assessment of both RVUs and NRVUs.
The external static pressure difference however doesn't consider the dynamic pressure at inlet and/or outlet of the unit as part of its energy transformation from electric energy (input) to flow energy (output). This can lead to a distorted picture of the energy efficiency particularly for ventilation units providing pressure and kinetic flow energy to a duct system.
A closer examination makes obvious that Δps,ext is not in all cases suitable to ensure a correct evaluation of the energy efficiency of a ventilation unit and following the current regulation EU 1253/2014 units performing with identical energy efficiency can reveal different eco-design performance data. Finally this can mislead users comparing ventilation units with regard to energy efficiency.

Example for a Residential Ventilation Unit (RVU)
Example: RVU-UVU - roof fan intended to be installed with ducted inlet

Given:
Two RVUs with identical energy and flow performance but featuring different inlet cross-section areas



$A_{inlet,1} < A_{inlet,2}$
A_{inlet} = duct cross-section area at inlet

$p_{us,1}(q_v) = p_{us,2}(q_v)$
p_{us} = difference between static pressure at unit outlet and total pressure at unit inlet
q_v = air volume flow
$P_{el,1}(q_v) = P_{el,2}(q_v)$
P_{el} = electrical power input

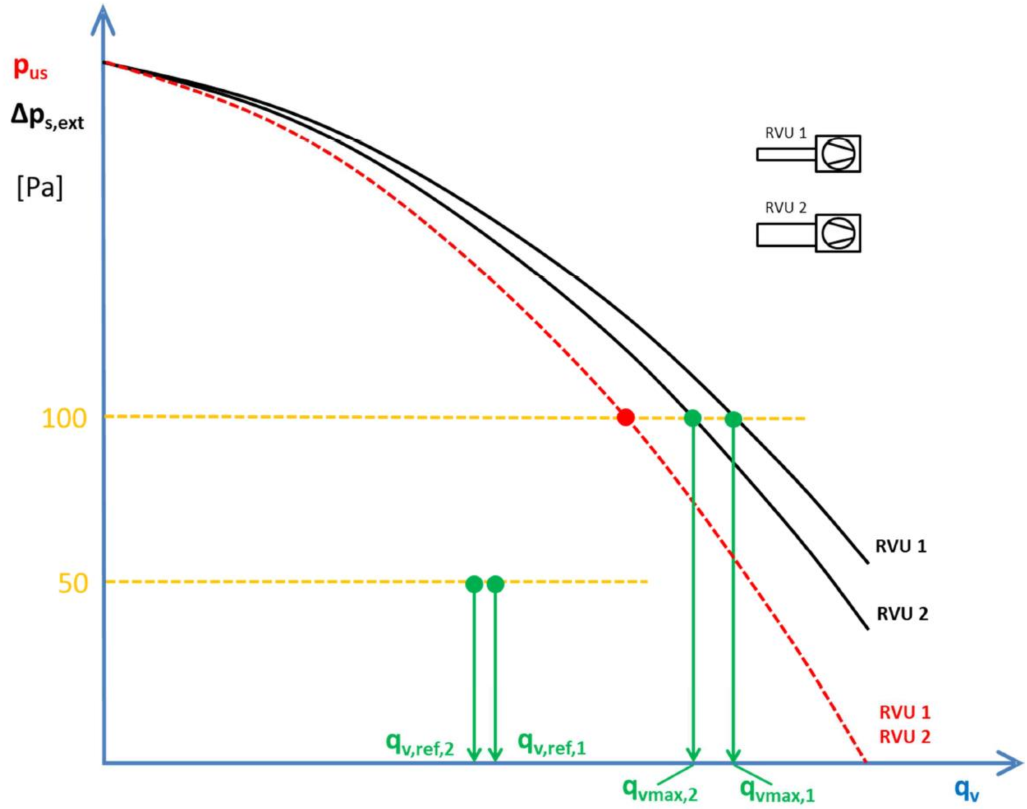


Figure 15. h/q diagram for RVU1 and RVU2

The external static pressure difference Δps,ext depends on the inlet dimension. The two RVUs with different cross-section areas at inlet have to be assessed at different flow rates qv,ref , because the reference point according to EU 1253/2014 is set at a fixed pressure level (Δps,ext = 50 Pa).
Depending on the efficiency characteristic of the integrated fan the electrical power input of both RVUs will differ, e.g. with the result: SPI,1 < SPI,2 .
The specific power input SPI, used to calculate the SEC value which is the eco-design requirement for RVUs and also relevant for their energy labelling, is different for both units and might lead to different SEC classes, although the flow and energy efficiency performance of both units are the same.

The described situation is in principle valid for ducted units in general.

Example for a Non-Residential Ventilation Unit (NRVU)
According to regulation EU 1253/2014 the energy efficiency requirement for NRVU-UVUs is ηvu. As corresponding actual unit parameter the Commission Communication specifies the fan efficiency ηfan which in case of UVUs without filter shall be understood as external static efficiency and determined in line with ISO 5801.

$$\eta_{fan} = \frac{q_v \, . \, \Delta p_{s,ext}}{P_{el}}$$

Although the energy efficiency requirement of NRVUs is linked to an air flow rate (not to a fixed pressure value like for RVUs) using the external static pressure difference Δps,ext for calculating the external fan efficiency ηfan can create a similar distortion as described in 1.1.

Example: NRVU-UVU – box fan (without filter) intended to be installed with ducted outlet

Given:
Two NRVUs with identical energy and flow performance but featuring different outlet cross- section areas

$A_{outlet,1} < A_{outlet,2}$
A_{outlet} = duct cross-section area at outlet

$p_{u,1} (q_{v,nom}) = p_{u,2} (q_{v,nom})$
p_u = difference between total pressure at unit outlet and total pressure at unit inlet
$q_{v,nom}$ = nominal air volume flow
$P_{el,1} (q_{v,nom}) = P_{el,2} (q_{v,nom})$
P_{el} = electrical power input

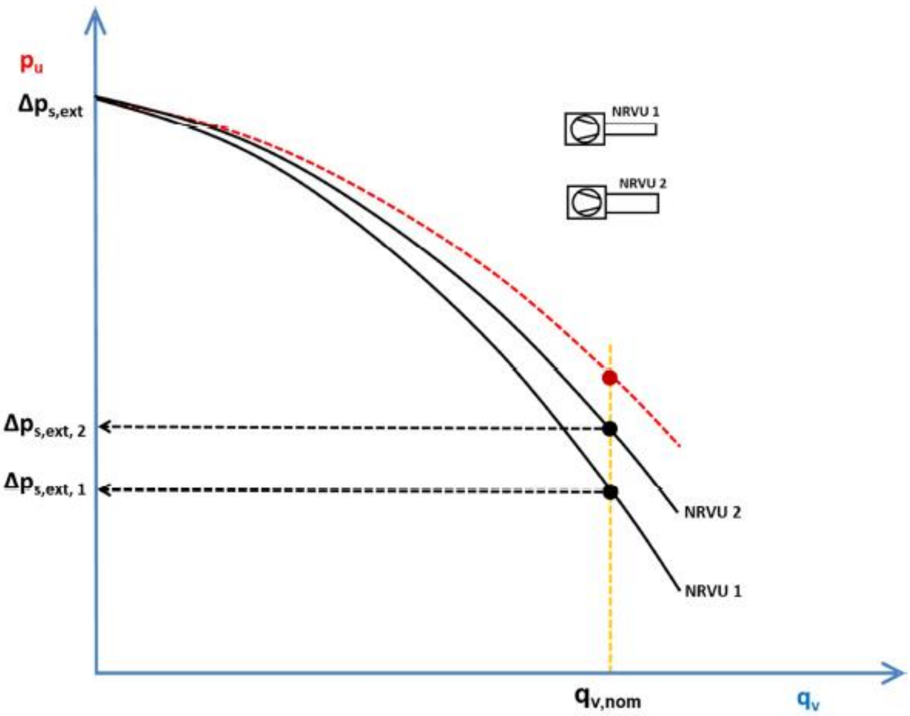


Figure 16. q/h diagram for NRVU1 and NRVU2

The two NRVUs with different cross-section areas at outlet can be assessed at the same nominal flow rate qv,nom . The corresponding external static pressure difference Δps,ext

however is different, because it depends on the outlet dimension, i.e. on the dynamic pressure at outlet.
As result of the different external static pressure curves and identical electric power input at the same nominal air volume flow the external static fan efficiency ηfan is different for both units, although their flow performance and energy efficiency are the same.
The described situation is in principle valid for ducted units in general.

With regard to SFPint, which is another energy efficiency requirement to be applied for UVUs with filter and BVUs, the explained problem does not occur, because SFPint at a certain duty point is not dependent on the type of pressure parameter used to specify the duty point. However it is confusing when units with equal flow performances and energy efficiencies show different nominal external pressure values in the ErP information data sheet caused by the use of Δps,ext as pressure reference parameter.

Proposed solution

Both examples described above prove that the external static pressure difference Δps,ext is not in all cases a suitable reference parameter to evaluate the energy efficiency of ventilation units. Furthermore it becomes obvious that the dynamic pressure in all existing duct connections has to be considered when a correct energy efficiency rating shall be made.

As a conclusion the following pressure parameters shall be introduced in the EU regulation for ventilation units und used to determine the reference point for the energy efficiency assessment:

1. Unit static pressure pus as difference between static pressure at unit outlet and total pressure at unit inlet
2. Unit pressure pu as difference between total pressure at unit outlet and total pressure at unit inlet

These pressure parameters lead to a single and unambiguous reference point (see red dot in the diagrams above). The pressure parameters are in full analogy to the pressure parameters pf and pfs for fans according to ISO 5801 and shall be linked to the intended installation category of the ventilation unit as follows (see table 18):

Table 45. Proposed pressure parameters for energy efficiency assessment

Installation category			Example (ventilation unit)	Pressure parameter RVU, NRVU	Pressure parameter Fans *)
A	free inlet / free outlet		wall fan with casing	p_{us}	p_{fs}
B	free inlet / ducted outlet		„toilet fan" (box fan)	p_u	p_f
C	ducted inlet / free outlet		roof fan	p_{us}	p_{fs}
D	ducted inlet / ducted outlet		duct fan, air handling unit	p_u	p_f

*) acc. to EU 327/2011, resp. ISO 5801

Benefits

- Comparable ventilation units (same installation category) with identical flow and energy efficiency performances reveal equal ErP data.
- With the new reference pressure parameters the same systematic approach for eco-design assessment is used for RVUs, NRVUs and fans. This leads to a synchronised procedure and common understanding of eco-design (energy efficiency) assessment of all types of ventilation units and fans.
- The regulation becomes more transparent and clear for all involved – manufacturers,designers, end-users and MSAs.
- All current draft standards EN13141-4, -7, -8, EN13053 and prEN17291, relevant for the ecodesign assessment of various ventilation units are prepared for the proposed solution as the new pressure parameters and the link to the installation category are already implemented.
- The described approach is derived from physical laws. The proposed reference pressure parameters describe the correct characteristic curves to be used when the design duty point is calculated based on (total) pressure losses (ζ coefficients used for all components including inlet and outlet terminals of the duct system).

  Remark: It is also possible to calculate the design duty point based on the static pressure drop of the duct system. In this case the external static pressure difference Δps,ext is the relevant pressure parameter of the unit. But for the purpose of energy efficiency assessment only the pressure parameters pu und pus are generally correct. The mentioned draft standards describe how the new pressure parameters and the external static pressure difference Δps,ext of a unit are related.

- The use of the new reference pressure parameters will not affect the ErP data of ventilation units which are ducted on both sides (cat D) and featuring the same areas at inlet and outlet. Also the ErP data for non-ducted units (cat A) will remain the same. Thus a large majority of ventilation units on the market doesn't have to be re-assessed in terms of eco-design, when the proposed pressure parameters are implemented in the revised regulation EU 1253/2014.

Additional remarks

- The introduction of the proposed pressure parameters requires different efficiency limits (η_{vu}) for the installation categories A/C and B/D (analogue to fans).
- Currently A, B and C units are often discriminated compared to Cat D units because the casing of A, B, C units often incorporates e.g. a non-removable protection grid which is part of the duct system in case of D units and not considered there. EU1253/2014 is a product regulation for ventilation units and unit integrated parts of the duct system should not affect the unit's energy efficiency assessment in a negative way. Therefore those functional components which are part of the duct system in category D units shall not be considered for the energy efficiency assessment of all unit types.

9. Other comments

9.1. JACOBS: Regulation NRVU counterproductive for certain applications

For clean spaces and supporting mechanical utility spaces with moderate-to-high heat loads and/or high air exchange rates and low OA percentages—the analysis presented by Jacobs shows that the regulation does not appear to reduce energy consumption and carbon footprint as intended.
The capital cost of installing code-compliant energy-recovery systems can be significant and includes:
• Additional building footprint and volume
• Increased engineering
• Added equipment
• More complex systems and controls
• Associated test and balance work

These systems also require additional care in design, installation, and commissioning, plus annual maintenance costs such as equipment maintenance, filter replacement, and instrumentation calibration. The added equipment and system complexity may increase the risk of potential system failure. These costs were not factored into the analysis.
As this regulation applies to many HVAC systems used in the pharmaceutical industry, it can drive higher energy consumption and greater carbon footprint than would be necessary if an air-side economizer were recognized as an alternative energy-conservation measure for low-to-moderate OA rates, as identified in Table B.

An airside economizer can be a low cost addition to a new air handling system requiring the outdoor and relief air duct be sized for 100% airflow and for a controls addition to modulate outdoor air and relief airflows to meet cooling demands. This is much less expensive than having to add heat recovery to both the outdoor air and
relief air streams and added fan sizing to accommodate this added pressure drop.

For units that will be designed with less than 10% OA heat recovery is not required by the regulation. However, if an air side economizer is installed, then the unit will sometimes run above 10% outdoor air and heat recovery will be required as currently being interpreted by the regulators. This leaves the owner of the systems with a
decision;
1) Install the air handling system with no heat recovery and no air side economizer driving up energy cost and carbon footprint, or
2) taking on the cost of Installing both even though heat recovery on systems
below 21%-70% outdoor air, depending on the area being served, will see no benefit of significance from the heat recovery portion of the installation.

Some owners are deciding to install systems with less than 10% outdoor air without either system which is driving up energy consumption and carbon footprint, which is the opposite impact the regulation is striving for.

9.2. 2VV: Alternative proposal impact internal leakage on ηt

For the actual proposal, reference is made to Doc. Number N935 of the CEN/TC 156/WG2, Natural and mechanical powered residential ventilation.

9.3. HEATEX: Drawbacks of higher ηt requirements for heat exchangers

Article 8 of Regulation 1253/2014 states that the Commission shall review this Regulation in the light of technological progress and assess the need to set a further tier with tightened Ecodesign requirements.

With the current requirement of 73% thermal efficiency it is possible to find solutions with good energy recovery and at the same time keeping electrical consumption of the fans within reasonable limits. For an end user this is a goof balance between energy saving and investment cost.

Development of heat exchangers in recent years have not led to significant technological leaps. Instead, fine tuning of thermal efficiency vs pressure drop has been done to adapt to the levels of requirements. Furthermore a lot of development has been done on material efficiency, resulting in the production of heat exchangers with the same thermal performance but with reduced material usage. This itself has had a positive impact on energy efficiency and the environment. Higher thermal efficiency requirements will work against this trend. Adding a new tier with higher requirements will have the following impact:

- Heat exchangers need to be bigger to deliver this thermal efficiency. This leads to higher material usage and an increased environmental impact. Larger heat exchangers will also result in larger AHUs and higher complexity in buildings, demanding larger space and making refurbishment more complicated.
- Alternative heat exchanger modification is to decrease the air channel size. This will not only increase efficiency but also the pressure drop, resulting in higher electricity consumption of the fans.
- High efficiency plate heat exchangers will condense air humidity if ambient temperature is low. This condensate could result in problems with freezing. Freezing in the heat exchanger require bypass without any heat recovery which needs to compensated by a heater before the air enters the building. The gain in heat exchanger efficiency could thus be erased by increased operation in defrost mode.

Heatex welcomes the focus on energy efficiency within the EU. Higher requirements on heat exchanger efficiency could however result in higher material usage, higher electricity consumption, increased defrost operating times and in some regions lack of economic benefit. Heatex therefore suggests to maintain the thermal efficiency requirement at 73%.

9.4. Discussions on Market surveillance

In the context of discussion on market surveillance, an issue emerged concerning the FAQ 3 of the 'Guidelines accompanying Regulation (EU) No 1254/2014 with regard to the energy labelling of residential ventilation units and Regulation (EU) No 1253/2014 with regard to Ecodesign requirements for ventilation units – October 2016 (see at https://ec.europa.eu/energy/sites/ener/files/documents/implementation_guide_-_ventilation_units_with_cover.pdf):

Who is responsible for the CE marking when the ventilation unit is delivered without a control system: the manufacturer of the ventilation unit, or the individual who connects the control system? How should an RVU sold without a control system be labelled? How should one deal with separately-delivered components and/or installed units?

Some stakeholders are of the view that in case a ventilation unit needs sensors (to benefit from a certain value of CTRL factor), but the sensors are not permanently integrated in the product, the manufacturer should deliver the (non permanently integrated) sensors with the ventilation unit.

The review study shall clarify/modify the legal text from this point of view.

9.4 Mez-Technik: Including airtightness of ductwork

Airtightness class C has to become a minimum standard for complete ventilation systems in Europe in order to generate a maximum of energy savings and CO_2 reduction. This has to be part of the European legislation and controlled by an independent organisation.

Ductwork is the foundation for energy efficiency improvements of ventilation systems and units in the very first place and their role was therefore very underestimated in the past such as tightness of building envelopes as well.
The ventilation industry accepted leakage of 15% - 40% and much more in the past which lead to an excessive energy consumption for fan energy, as well as cooling and heating energy, because there was no technological solution to reduce these leakages in an efficient way. So everybody tried to hide and not talk about this huge problem.

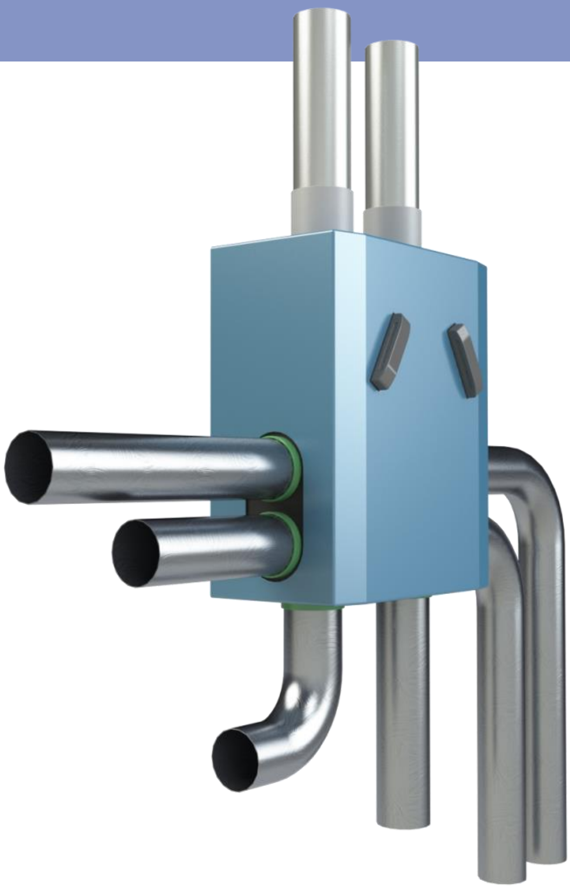
Products and measurment technologies and or now in place that can solve this leakage problem in order to reduce these leakages to nearly zero and save 50% of fan energy consumption in average - plus cooling/heating energy.

Mez-Technik therefore recommends to integrate airtightness of ductwork into a study in the very first place.

European Commission

Ventilation Units

Ecodesign and Energy Labelling



Preparatory Review Study

Phase 1.1 and phase 1.2

Final Report

TASK 2 Markets

Review study on Regulations EU 1253/2014 (Ecodesign requirements for ventilation units) and EU 1254/2014 (energy labelling of residential ventilation units)

Prepared by
VHK, Delft (NL), for the
European Commission, DG GROW

Revision September 2020

Grow

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Contract manager: VITO

Project website: www.ecoventilation-review.eu

Specific contract: No 681/PP/GRO/IMA/18/1131/10204-SI2.798223
Contract starting date: February 5th 2019

Consortium:

Cover: Ventilation unit [picture VHK 2019].

This study was ordered and paid for by the European Commission, DG Grow.

Executive summary

This Task 2 report regards the market data for Ventilation Units (VUs), i.e. sales, stock and consumer expenditure.

ProdCom and ComExt data on production, export and import

Chapter 1 presents the production, import and export data potentially related to VUs, as extracted from the Eurostat PRODCOM and COMEXT databases. However, there are no specific ProdCom- or CN8-categories for VUs. Ventilation units/systems are classified either as '*fans*' or as '*Air conditioning machines not containing a refrigeration unit; central station air handling units; vav boxes and terminals, constant volume units and fan coil units*'.

For '*fans*' this means that Eurostat's data regard a very heterogeneous mix of ventilation units intended for end-users with OEM-fans intended to be built into e.g. boilers (combustion fans), chillers (e.g. condenser fans), laundry driers, ovens, fan-coils, etc.. E.g., for '*fans*' the Eurostat data indicate an apparent consumption in EU-28 of 106 mln units > 125 W and 48 mln units < 125 W, but total sales of Ventilation Units in 2017 estimated in this study are only around 4.5 mln units[1].

For *'Air conditioning machines not containing a refrigeration unit'*, it means that ventilation devices (Air-Handling Units, AHUs) are mixed up with large quantities of non-ventilation devices (most fan-coils, terminals, etc.). E.g., the Eurostat data indicate a 2017 production in EU-28 of 1.5 mln units of *'Air conditioning machines not containing a refrigeration unit'*, but EuroVent for 2017 reports sales quantities of AHUs of only 179 thousand units.

Consequently the Prodcom and ComExt data are of limited use for the review study. At best, they provide upper limits for the amount of VUs sold and for their market value, and they can show trends.

In general, possibly after a dip in crisis years 2008-2009, the trend is positive for sales of '*Fans*', '*Air conditioning machines not containing a refrigeration unit', 'Parts for air conditioning machines',* and '*Installation and Repair and Maintenance of non-domestic cooling and ventilation equipment*'.

Available sales and stock data for Ventilation Units

Chapter 2 first presents the publicly available data on the sales and stock of Ventilation Units. Most of these data are fragmentary, e.g. for one Member State, for one year, limited to certain types of VUs, or only for a specific sector.

Complete time-histories and projections on sales and stock of ventilation units are available from previous Ecodesign studies, and summarized in the Ecodesign Impact Accounting. Up to year 2010 for the residential sector, and up to year 2015 for the non-residential sector, these existing sales and stock estimates have essentially been maintained in the current study, but they have been scaled down from EU-28 to EU-27

[1] 4.5 mln counting also non-continuous operating 'ventilation units' for wet rooms, which are not in the scope of the regulations. Counting only ventilation units in scope, the total EU28 sales in 2017 are around 2 mln.

(excl. UK) by subtracting 14% of the sales. In addition the distribution of sales over the AHU size classes had to be adapted to obtain a realistic share of non-residential building area covered by VUs.

However, the existing data are typically based on information from 2008 or before, and they do not fully reflect:

- the strong decrease in new-built residential dwellings in the period 2008-2014,
- the slow-down in growth, and decrease from 2040, of the EU population and households,
- the provisions of the 2018 recast of the Energy Performance of Buildings Directive (EPBD), i.e. all new-built to be NZEB (Nearly-Zero Energy Building) by 2020, and the entire EU-28 stock of buildings to be NZEB by 2050.

Buildings-Ventilation Model (BVM)

Therefore, in particular for the future projection of the sales and stock of ventilation units, the study team developed a Buildings-Ventilation Model (BVM), **linking the sales of VUs to the number of new-built and renovated residential dwellings and non-residential buildings**. This model takes into account the points listed above, and the fragmentary data on sales and stock of VUs where available.

Considering the different ventilation habits and needs in the EU Member States, the development aim was to diversify the model per country. This has been done for the residential sector, but for the non-residential sector insufficient data were available for a breakdown per Member State. **Stakeholders are invited to verify the data for their country** (and the overall European total as far as possible) and send their corrections and comments to the study team so that the model can be improved.

The description of the BVM in the second part of chapter 2 clarifies the assumptions made for:

- the number of new-built dwellings / buildings,
- the number of dwellings / buildings to be renovated by 2050,
- the implementation of VUs in new-built dwellings / buildings,
- the implementation of VUs in renovated dwellings / buildings.

BVM main assumptions

The most important model assumptions are:

- 60% of the 2015 residential dwelling stock will be renovated by 2050. This % varies per country, from 46% to 69%. The EU average annual renovation rate necessary to reach this is 0.6% in 2015, 1.6% in 2030 and 2.6% in 2050.
- 45% of the 2015 non-residential building stock will be renovated by 2050. The EU average annual renovation rate necessary to reach this is 0.7% in 2015, 1.4% in 2030 and 1.4% in 2050.

- The share of new-built or renovated residential dwellings installing a certain type of VU in the period 2025-2050 is given per country by Table 1.
- For the non-residential sector, the distribution share of new-built or renovated non-residential building area covered by the various VU-types is given by Table 2. In addition to these distribution shares it is assumed that 80% of new-built building area will install a VU, and 60% of the renovated building area.

Table 1. Share of new-built and renovated Residential Dwellings implementing a certain type of mechanical ventilation in the period 2025-2050.

	New-Built dwellings						Renovated dwellings				
	CBVU	LBVU	CUVU	LUVUc	sum		CBVU	LBVU	CUVU	LUVUc	sum
Austria	45%	25%	10%	0%	80%		35%	20%	15%	5%	75%
Belgium	45%	10%	25%	0%	80%		30%	10%	30%	5%	75%
Bulgaria	45%	25%	10%	0%	80%		30%	25%	3%	7%	65%
Croatia	20%	10%	30%	10%	70%		15%	5%	20%	10%	50%
Cyprus	20%	10%	30%	10%	70%		15%	5%	20%	10%	50%
Czech Rep.	45%	25%	10%	0%	80%		30%	25%	3%	7%	65%
Denmark	70%	20%	10%	0%	100%		60%	15%	15%	5%	95%
Estonia	45%	30%	25%	0%	100%		30%	15%	10%	10%	65%
Finland	100%	0%	0%	0%	100%		67%	23%	5%	0%	95%
France	40%	10%	50%	0%	100%		25%	10%	50%	10%	95%
Germany	35%	25%	10%	0%	70%		30%	25%	3%	7%	65%
Greece	20%	10%	30%	10%	70%		15%	5%	20%	10%	50%
Hungary	45%	25%	10%	0%	80%		30%	25%	3%	7%	65%
Ireland	40%	20%	20%	0%	80%		30%	20%	20%	5%	75%
Italy	20%	10%	30%	10%	70%		15%	5%	20%	10%	50%
Latvia	45%	30%	25%	0%	100%		30%	15%	10%	10%	65%
Lithuania	45%	30%	25%	0%	100%		30%	15%	10%	10%	65%
Luxembourg	40%	10%	30%	0%	80%		30%	10%	30%	5%	75%
Malta	20%	10%	30%	10%	70%		15%	5%	20%	10%	50%
Netherlands	55%	20%	25%	0%	100%		35%	30%	20%	10%	95%
Poland	45%	30%	25%	0%	100%		30%	15%	10%	10%	65%
Portugal	20%	10%	30%	10%	70%		15%	5%	20%	10%	50%
Romania	45%	25%	10%	0%	80%		30%	25%	3%	7%	65%
Slovakia	45%	25%	10%	0%	80%		30%	25%	3%	7%	65%
Slovenia	20%	10%	30%	10%	70%		15%	5%	20%	10%	50%
Spain	20%	10%	30%	10%	70%		15%	5%	20%	10%	50%
Sweden	70%	20%	10%	0%	100%		65%	25%	5%	0%	95%
United Kingdom	40%	20%	20%	0%	80%		30%	10%	30%	5%	75%

Table 2. Average building area covered by a NRVU/AHU, and distribution share of new-built or renovated non-residential building area covered by VU-types.

		Area share of 1st time NRVU/AHU installation					
	m^2/VU	2010	2015	2020	2030	2040	2050
AHU-L (> 14500 m3/h)	7000	8.8%	9.2%	9.2%	9.2%	9.2%	9.2%
AHU-M (5500-14500 m3/h)	2500	36.1%	37.8%	37.8%	37.8%	37.8%	37.8%
AHU-S (2500-5500 m3/h)	1050	26.2%	29.6%	29.6%	29.6%	29.6%	29.6%
CHRV (1000-2500 m3/h)	500	8.9%	7.6%	8.8%	10.5%	11.0%	11.6%
CHRV (250-1000 m3/h)	200	7.2%	6.2%	7.1%	8.5%	9.0%	9.4%
CUVU / CEXH (> 1000 m3/h)	400	6.3%	4.7%	3.7%	2.1%	1.7%	1.2%
CUVU / CEXH (250- 1000 m3/h)	200	6.4%	4.8%	3.8%	2.2%	1.7%	1.2%

Sales of Ventilation Units for residential dwellings

In 2015, a total of 1.2 mln VUs intended for continuous operation were sold for the EU-27 residential sector. Of these, 0.3 mln (25%) were for new-built dwellings, 0.3 mln (23%) for renovated dwellings and 0.6 mln (52%) were replacement sales. The large majority were Central Unidirectional (CUVUs, 0.8 mln units, 72%), followed at distance by Local Bidirectional (LBVUs, 0.2 mln units, 14%), Local Unidirectional (LUVUs, 0.1 mln units, 7%), and Central Balanced (CBVUs, 0.1 mln units, 7%).

Starting from 2020, due to the measures in the EPBD, a strong increase in sales of VUs is projected. This increase is driven primarily by the sales for renovated dwellings. The increase in sales mainly regards BVUs (with heat recovery), that pass from 0.2 mln in 2015 to 2.4 mln in 2030 and 5.3 mln in 2050. Sales for UVUs are projected to remain relatively stable: between 0.9 and 1.2 mln per year over the entire period.

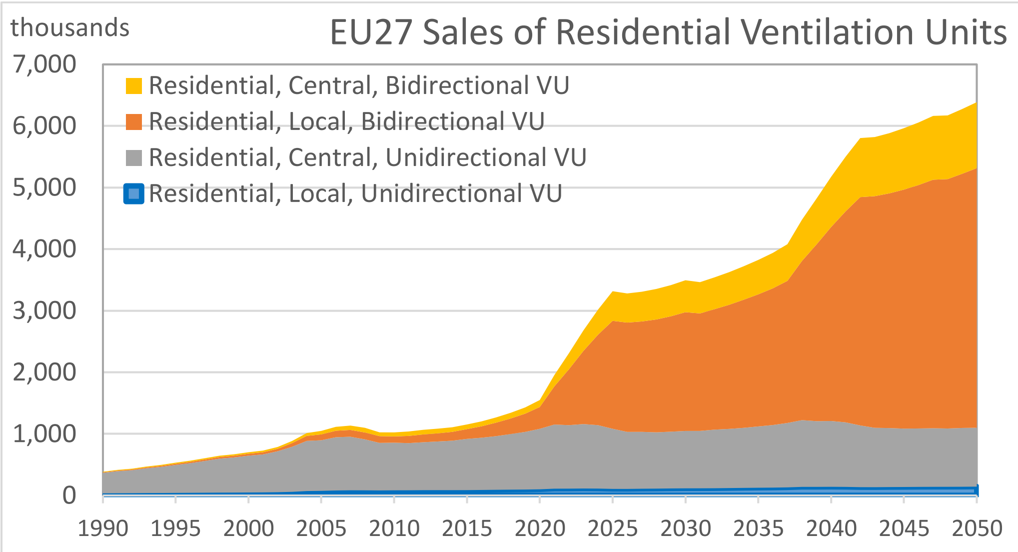


Figure 1. Sales of Ventilation Units intended for continuous operation in residential dwellings, in thousands of units for EU-27, total sales (for new-built + for renovated + replacements)

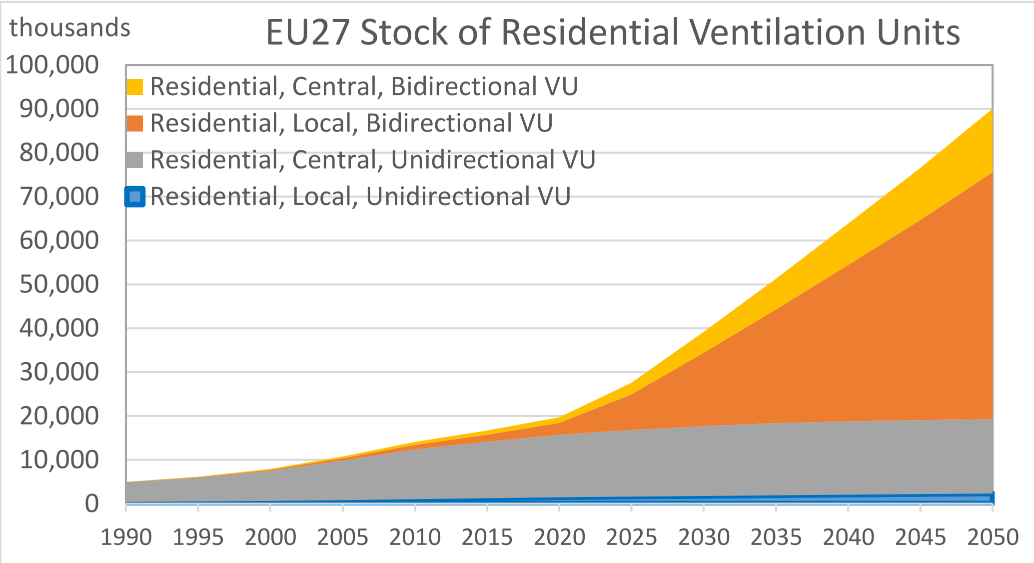
Stock of Ventilation Units for residential dwellings

In 2015, the total stock of VUs for continuous operation used in the residential sector amounted to 16.6 mln units. The large majority were UVUs (14.1 mln units, 85%), mainly Central UVUs > 100 m3/h (12.9 mln, 77%). BVUs represented 15% of the stock (2.5 mln units), mainly Local BVUs < 100 m3/h (1.6 mln, 9.5%).

In 2015, 20% of the total EU-27 area of permanently occupied dwellings used a CUVU, and 2% a CBVU. The share of area covered by continuously operating Local VUs was less than 1%. Overall, around 23% of the dwelling area used some kind of mechanical ventilation. This implies that 77% had no mechanical ventilation (except non-continuous local UVU for toilet, bathroom, kitchen, etc.).

Due to the increase in sales, the share of permanently occupied dwelling area using CBVUs is projected to increase from 2% in 2015 to 7% in 2030 and 22% in 2050. Local BVUs are projected to increase their covered area share from 0.3% in 2015 to 10% in

2050[2]. CUVUs slightly increase their share of covered dwelling area from 20% in 2015 to 25% in 2050. As a result, 34% of permanently occupied residential dwelling area uses some kind of mechanical ventilation in 2030, and in 2050 this is projected to further increase to 58%.



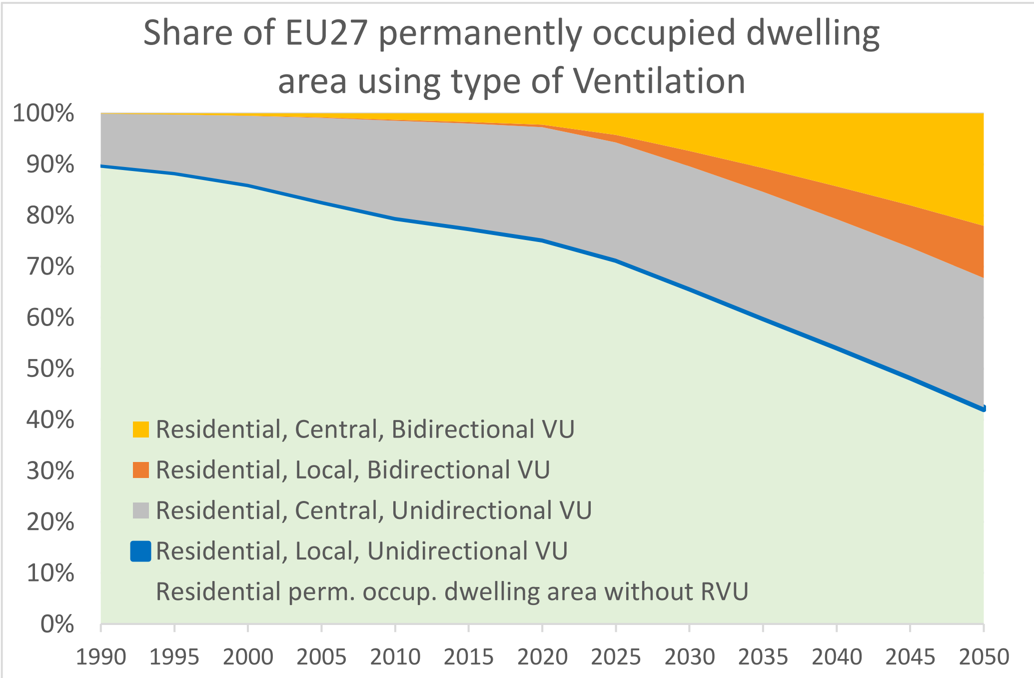


Figure 2. Total EU27 stock of residential ventilation units and share of EU27 residential dwelling area using a certain type of ventilation

[2] Local BVUs have a reference covered dwelling area of 33 m^2 (3 LBVUs used per dwelling of 100 m^2). The large increase in LBVU sales and stock quantities thus corresponds to a more modest increase in the share of dwelling area covered by LBVUs.

Sales of Ventilation Units for non-residential buildings

In 2015, a total of 487 thousand VUs intended for continuous operation were sold for the EU-27 non-residential sector. Of these, 122 thousand (25%) were for new-built buildings, 85 thousand (18%) for renovated buildings and 280 thousand (57%) were replacement sales. Central Unidirectional (CUVU, CEXH) represented 49% of the market (236 thousand units) and Central Balanced solutions (CBVU, CHRV) 21% (104 thousand units). Air Handling Units covered the remaining 30% (148 thousand units).

Starting from 2020, due to the measures in the EPBD, a strong increase in sales of VUs is projected. This increase is driven both by new-construction and by renovation. In particular the sales of CBVUs are expected to increase from 104 thousand units in 2015 to 177 thousand in 2030 and 270 thousand units in 2050. Sales of CUVUs are expected to remain relatively stable: between 216 and 248 thousand units per year over the entire 2015-2050 period, with a decreasing tendency after 2035. Sales of AHUs are projected to increase from 148 thousand units in 2015 to 188 thousand in 2030 and 247 thousand in 2050.

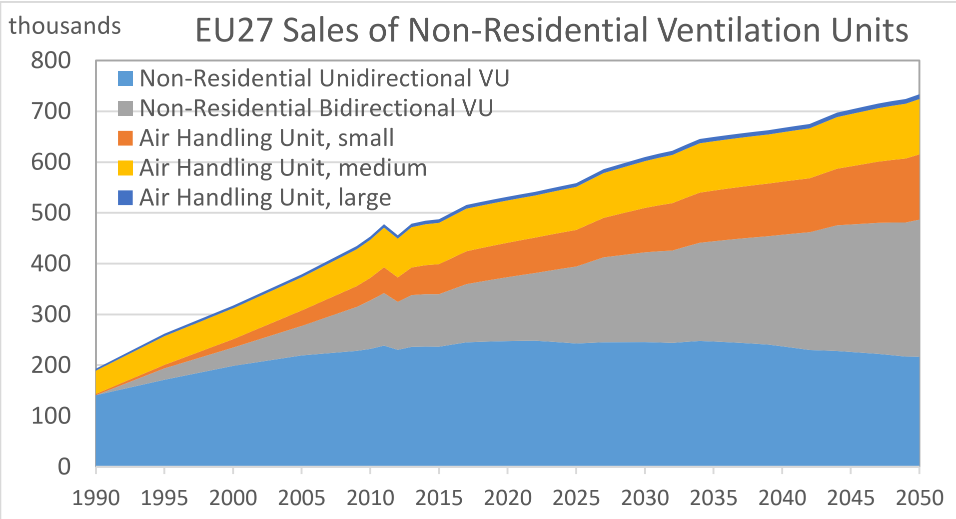


Figure 3. Sales of Ventilation Units intended for continuous operation in non-residential buildings, in thousands of units for EU27, total sales (for new-built + for renovated + replacements)

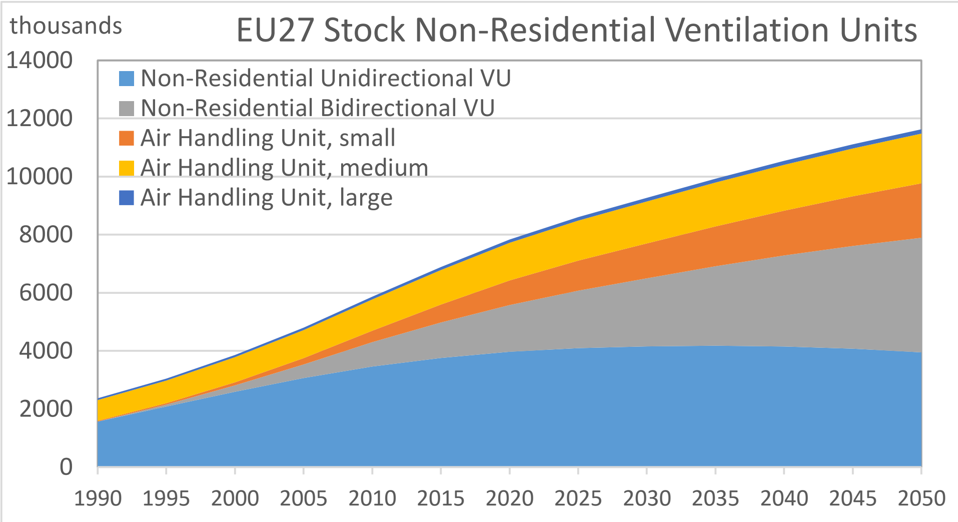
Stock of Ventilation Units for non-residential buildings

In 2015, the total EU-27 stock of VUs for continuous operation in the non-residential sector amounted to 6.9 mln units. Of these, 3.8 mln (55%) were Central Unidirectional units (CUVU/CEXH) and 1.2 mln (18%) Central Balanced units (CBVU/CHRV). Air Handling Units represented 27% of the stock (1.9 mln units).

In 2015, 15% of the non-residential building area used a CUVU and another 5% a CBVU, while 43% used an Air Handling Unit. Overall, 64% of the non-residential building area used some kind of mechanical ventilation. This implies that 36% of the building area had no continuously operating mechanical ventilation.

Due to the increase in sales of VUs, the share of non-residential building area using CBVUs is projected to increase to 9% in 2030 and to 14% in 2050. In parallel, the share of area covered by AHUs increases from 43% in 2015, to 53% in 2030 and 62% in 2050.

The share of non-residential building area using CUVUs is projected to slightly decrease over the 2015-2050 period, from 15% to 13%. As a result, 78% of non-residential building area uses some kind of mechanical ventilation in 2030, and this is projected to further increase to 90% in 2050.



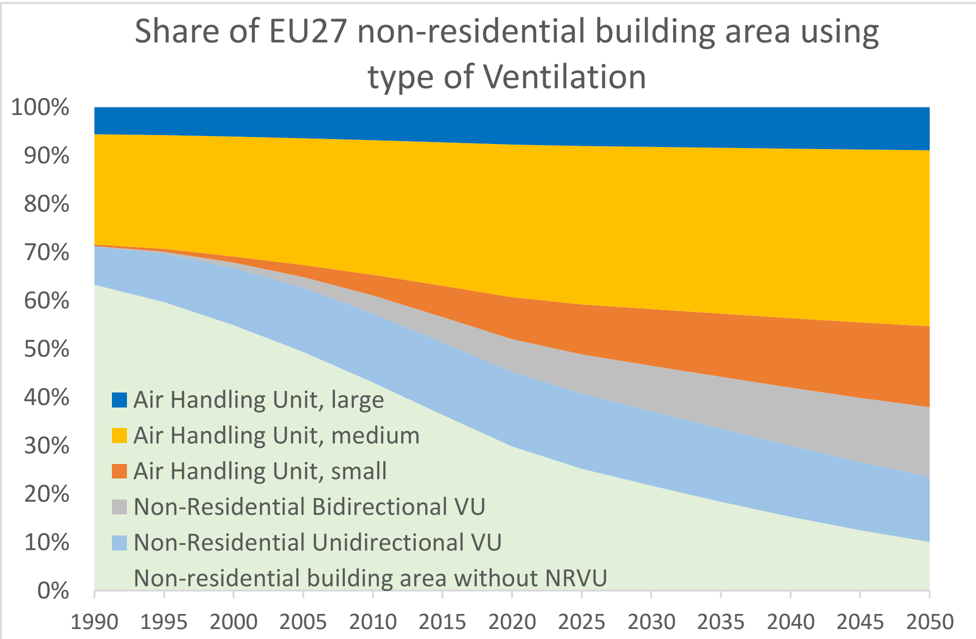


Figure 4. Total EU27 stock of non-residential ventilation units and share of EU27 non-residential building area using a certain type of ventilation

(source: VHK 2019, BVM model)

Prices of Ventilation Units

New data on prices of Ventilation Units have been collected (e.g. from internet sales sites), and compared with existing data from the 2014 Impact Assessment study and from the 2018 Ecodesign Impact Accounting. The data are reported in chapter 4 and Annex VI.

Introduction

This final Task 2 report covers the current status of the work that has been done for Phase 1.1 and phase 1.2 of the Review Study, comprising the Technical Analysis and the update of the Preparatory studies. According to the Terms of Reference (T.o.R.) Phase 1.1 shall assess the items listed in Article 8 of Regulation 1253/2014 (Ecodesign of Ventilation Units) and Article 7 of Regulation 1254/2014 (Energy Labelling of Residential Ventilation Units), being:

a) the need to set requirements on air leakage rates in the light of technological progress
b) the possible extension of the scope of Regulation 1253/2014 to cover unidirectional units with an electric power input of less than 30 W, and bidirectional units, with a total electric power input for the fans of less than 30 W per air stream
c) the verification tolerances set out in Annex VI to Regulation 1253/2014
d) the appropriateness of taking into account the effects of low-energy consuming filters on the energy efficiency
e) the need to set a further tier with tightened Ecodesign requirements
f) the possible inclusion of other ventilation units, notably of non-residential units and of units with a total electric power input smaller than 30 W under Regulation 1254/2014,
g) the specific energy consumption calculation and classes for demand controlled unidirectional and bidirectional ventilation unit (in this respect, it would be very relevant to provide, if possible, an estimate of the efficiency and energy labelling levels of the installed base of residential and non-residential ventilation units in the European Union (EU).

According to the Terms of Reference the following additional items need to be analysed:
h) the influence of the ambient conditions and the climatic zones in the EU on the quantitative requirements for heat recovery
i) the need of specific provisions (and related formulation) on historic or listed buildings where the lack of space available can make it challenging to fit in ventilation units compliant with the two Regulations.
j) the need for (further) clarification on the nature of 'box fans' and 'roof fans', in particular concerning their compliance with the two Regulations, and the fans Ecodesign regulation 327/2011.
k) the need/feasibility to impose quantitative requirements on the maximum internal leakage for bidirectional ventilation units, as well as the need/feasibility of correction factors for the declared thermal efficiency of a residential ventilation units, based on the internal leakage rate
l) Introduction, in the text of the two Regulations (e.g. in the definitions of unidirectional and bidirectional ventilation units), of the clarifications contained in the 'Question on a combination of a supply UVU and an exhaust UVU being considered as a BVU (11-2016)2'
m) Improvement/increased description of the definition of 'nominal flow rate' of non-residential ventilation units
n) Improvements/changes in the definition of 'ventilation unit', with particular regard of the inclusion/exclusion of ventilation units for industrial applications (on the basis of FAQ 10 of the 'Guidelines accompanying Regulation (EU) No 1254/2014 with regard to the energy labelling of residential ventilation units and Regulation (EU) No 1253/2014 with regard to Ecodesign requirements for ventilation units'.

o) The application and potential improvement of the requirement on the provision of instructions for the effective material recycling of the ventilation units (as in Annex IV - point 3 - of the Regulation 1253/2014).
p) Other clarification requests from stakeholder in the context of the stakeholder consultation process.

And finally, if needed, the existing 'Guidelines accompanying Regulation (EU) No 1254/2014 with regard to the energy labelling of residential ventilation units and Regulation (EU) No 1253/2014 with regard to Ecodesign requirements for ventilation units' will be updated .

In the subsequent phase 1.2 the Preparatory Studies are updated, where according to the T.o.R. at least the following additional items need to be addressed:

1) the identification of potential new functional parameters at product level, in particular concerning the indoor air quality when relevant and feasible
2) resource efficiency aspects3 - most likely disassembly, recyclability, reparability, durability and content of Critical Raw Materials (CRM), following the adoption of the Circular Economy Package in December 2015 and the new Ecodesign Working Plan 2016-2019. This includes the analysis of requirement already set (on the instruction for material recycling), their effectiveness in promoting the resource efficiency of ventilation unit, and the identification of additional and/or more ambitious requirements, when relevant (e.g. on the content of CRM in magnets).
3) the potential inclusion in the analysis of smart controls and demand control options (such as, but not limited to, solutions for building/home energy management system based on the European standards SAREF/SAREF4ENER).

The study is performed as a supplement to already existing preparatory studies for Lot 6 and Lot 10, indicating that topics that have already been addresses will not be addressed again, unless there are new elements to be reported.

This sub-report on Task 2, specifically deals with updates on topics regarding generic economic data, market and stock data, and consumer expenditure.

Acronyms and units

Acronyms

AC/DC	Alternating/Direct Current
ADCO	Administrative Co-operation
AHRI	American Air Conditioning, Heating and Refrigeration Institute
AHU	Air-Handling Unit
AMCA	Air Movement and Control Association
ATEX	ATmosphères EXplosibles
BC	Backward Curved
BVU	Bidirectional Ventilation Unit
CBVU	Central BVU
CHRV	Central Heat-Recovery Ventilation
CUVU	Central UVU
CVU	Central VU
CECED	European Committee of Domestic Equipment Manufacturers
CEN	European Committee for Standardization
CEXH	Central Exhaust VU
CFD	Computer Fluid Dynamics
CIRCA	Communication and Information Resource Centre
CLP	Classification, Labelling and Packaging (Regulation)
Digital Europe	Association representing the digital technology industry in Europe
DoC	Document of Conformity
DoE	US Department of Energt
EC	Electronically Commutating
EN	European Norm
EPEE	European Partnership for Energy and the Environment
Eurovent	Association of European refrigeration, air conditioning, air handling, heating and ventilation industry
EVIA	European Ventilation Industry Association
FC	Forward Curved
GWh	Giga Watt hour 109 Wh
HNL	Howden Netherlands
HR(S)	Heat Recovery (System)
ICSMS	Information and Communication System on Market Surveillance
ISO	International Standardisation Organisation
JBCE	Japan Business Council in Europe
JRAIA	Japan Refrigeration and Air Conditioning Industry Association
LBVU	Local BVU
LHRV	Local Heat-Recovery Ventilation
LVU	Local VU
LUVU	Local UVU
LUVUc	LUVU for continuous operation
LUVUnc	LUVU for non-continuous operation
msp	Manufacturer selling price
N	Efficiency grade
NRVU	Non-Residential Ventilation Unit
RAC	Run Around Coil
RAPEX	EU Rapid Alert System
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (Regulation)
RoHS	Restriction of Hazardous Substances (directive)
RVU	Residential Ventilation Unit
rpm	rounds per minute (unit for fan rotation speed)
TC	Technical Committee (in ISO, CEN, etc.)
TWh	Tera Watt hour 1012 Wh
UVU	Unidirectional Ventilation Unit
VAT	Value added tax
VU	Ventilation Unit
WEEE	Waste of electrical and electronic equipment (directive)
WG	Working Group (of a TC)
yr	year

Parameters

A	floor surface area building [m²]
cair	specific heat air [Wh/ m³.K]
Q	heat/energy [kWh]
q	hourly air exchange [$m^3.h^{-1}$/ m³]
rec	ventilation recovery rate [-]
S	shell surface area building [m²]
SV	shell surface/volume ratio building
t	heating season hours [h]
T_{in}	Indoor temperature [°C]
T_{out}	outdoor temperature [°C]
U	insulation value in [W/K. m²]
V	heated building volume [m³]
ΔT	Indoor-outdoor temperature difference [°C]
η	efficiency [-]

Units

€	Euro
°C	degree Celsius
a	annum (year)
bn	billion (1000 million)
CO_2	carbon-dioxide (equivalent)
h	hours
K	degree Kelvin
kWh	kilo Watt hour
m	metre or million
m²	square metre
m³	cubic metre
Pa	Pascal
W	Watt

Table of Contents

1. Generic economic data

1.1. Introduction

This section intends to present the production, import and export data as extracted from the Eurostat PRODCOM [3] and COMEXT [4] databases [5].

Official statistics on the production, sales and trade for 'ventilation units' or 'ventilation systems' do not exist, i.e. there are no specific ProdCom- or CN8-categories for these products. Eurostat and the national statistics offices classify ventilation units/systems either as '*fans*', characterized by their technical typology (axial, centrifugal, etc.) or a size characteristic (>125 W/<125 W; >300 Pa/<300 Pa), or as '*Air conditioning machines not containing a refrigeration unit; central station air handling units; vav boxes and terminals, constant volume units and fan coil units*' (ProdCom 28251270).

For 'fans' this means that Eurostat's data regard a very heterogeneous mix of ventilation units intended for end-users with OEM-fans intended to be built into boilers (combustion fans), chillers (e.g. condenser fans), laundry driers, ovens, fan-coils, etc.. For the Prodcom 28251270 category, the ventilation devices (AHUs) are mixed up with large quantities of non-ventilation devices (most fan-coils, terminals, etc.).

In the tables with Eurostat production data presented in this chapter, country-specific data are often missing for all or for some years. These data are not available or they are confidential and have been suppressed by Eurostat. In these cases Eurostat anyway presents an EU28 total, but this total may be less accurate, being rounded (sometimes quite roughly) and/or including estimates. These totals typically differ from the sum of country-contributions (incomplete in case of missing data; not reported in the tables).

In the tables with Eurostat import and export data, country-specific data always refer to import to and export from that country. This includes imports from and exports to other countries of the EU28. The EU28 totals for import and export regard only the trade with extra-EU28 countries (not the intra-EU28 trade), and consequently these totals are not the sum of the country-contributions.

Due to the above, and other, limitations and imperfections in the Eurostat data, and the mix of ventilation- and non-ventilation-products, the usefulness of the data for the present study

[3] PRODCOM provides statistics on the production of manufactured goods. The term comes from the French "PRODuction COMmunautaire" (Community Production) for mining, quarrying and manufacturing: sections B and C of the Statistical Classification of Economy Activity in the European Union (NACE 2). Prodcom uses the product codes specified on the Prodcom List, which contains about 3900 different types of manufactured products. Products are identified by an 8-digit code of which the first four digits correspond to the NACE code, the first six correspond to the CPA code (Classification of Products by Activity), and the remaining two digits specify the product in more detail.

[4] COMEXT is Eurostat's reference database for detailed statistics on international trade in goods. Products are identified by the CN8 code. The Combined Nomenclature (CN) is a tool for classifying goods, set up to meet the requirements both of the Common Customs Tariff and of the EU's external trade statistics. The CN is also used in intra-EU trade statistics. The first six digits of the code are based on the chapter, heading and subheading of the World Customs Organization's Harmonized System (HS) nomenclature. The last two digits of the CN8 code provide an EU-specific subdivision.

[5] The databases are available at https://ec.europa.eu/eurostat/data/database.

For ProdCom select: 'database by themes' => 'Industry, trade and Services' => 'Statistics on the production of manufactured goods (prom)' => 'Sold production, exports and imports by PRODCOM list (NACE Rev.2)-annual data (DS-066341).

For ComExt select: : 'database by themes' => 'International trade' => 'International trade in goods' => International trade in goods – detailed data' => EU trade since 1988 by CN8 (DS-016890).

is limited. Therefore, details have been moved to Annex I, and the main text reports only the most relevant information.

1.2. AHUs and CHRV units

Products/systems

As mentioned, the production of air handling units (AHUs) and probably also of central heat recovery ventilation (CHRV) units is expected to be included in Prodcom category 28251270: '*Air conditioning machines not containing a refrigeration unit; central station air handling units; vav boxes and terminals, constant volume units and fan coil units*'.

The Eurostat production statistics per EU Member State are given in Annex I, Table 36 (production volume in 000 units) and Table 37 (value of production in M euros) for the available period 1995-2017. As regards the number of units produced, Italy is by far the largest producer, covering 42% of the total EU28 production in 2017. Considering the value of the production, the largest contributions come from Germany, Italy and Sweden.

In 2017, around 1.5 mln units were produced in EU28 for a total value of 1.8-1.9 bn euros. This implies an average unit price around 1230 euros, but the variation is large, from 16 euros/unit for smaller products from Estonia to more than 10,000 euros/unit for the production from Austria and the Netherlands.

For comparison (see par.2.2.5): Eurovent reports 179 thousand sales of AHUs in 2017, with a market value of 1.7 bn euros.

As shown in Figure 5, following a strong decrease in produced units in the period 2006-2009 (economic crisis), the trend in both units produced and value of production is positive since 2009.

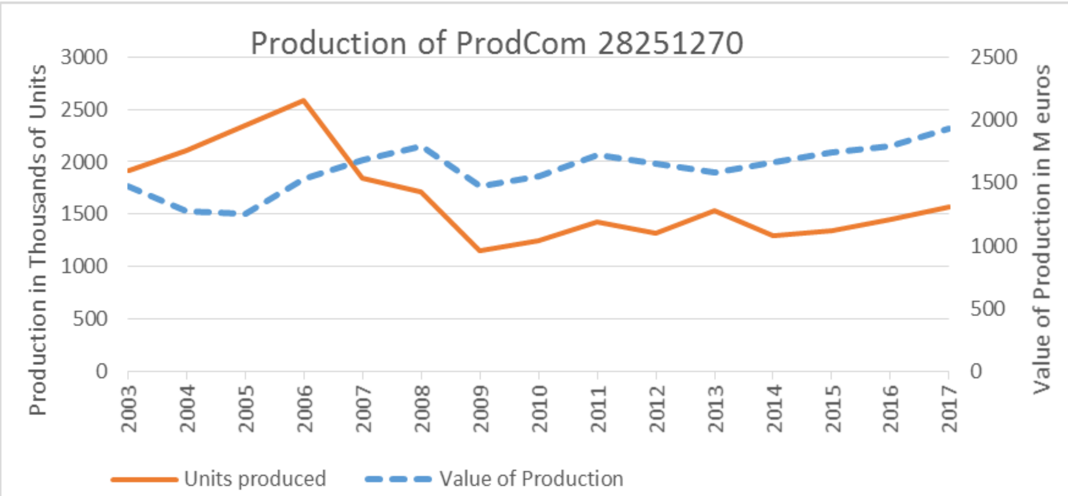


Figure 5. EU28 total Production Volume (000 units) and Value (M euros) of non-cooling AC units, AHUs, VAV Boxes, CAV boxes and FCUs

(Source: Eurostat 2019, ProdCom 28251270)

As regards import and export, only monetary data (values) are available, not quantities in number of units. Import and Export data are shown in Annex I, Table 38 and Table 39.
In 2017, the total value of exports towards extra-EU28 was 0.5 bn euros, while the total value of imports from extra-EU28 was 0.18 bn euros.

The combined results of EU28 production and extra-EU28 imports and exports in the period 1995-2017 are given in Table 3, also providing a calculation of the apparent consumption (production + imports - exports), expressed in millions of euros. As unit values for production, import and export may be different, and not directly comparable, the resulting value for the apparent consumption is indicative only and should be used with care.

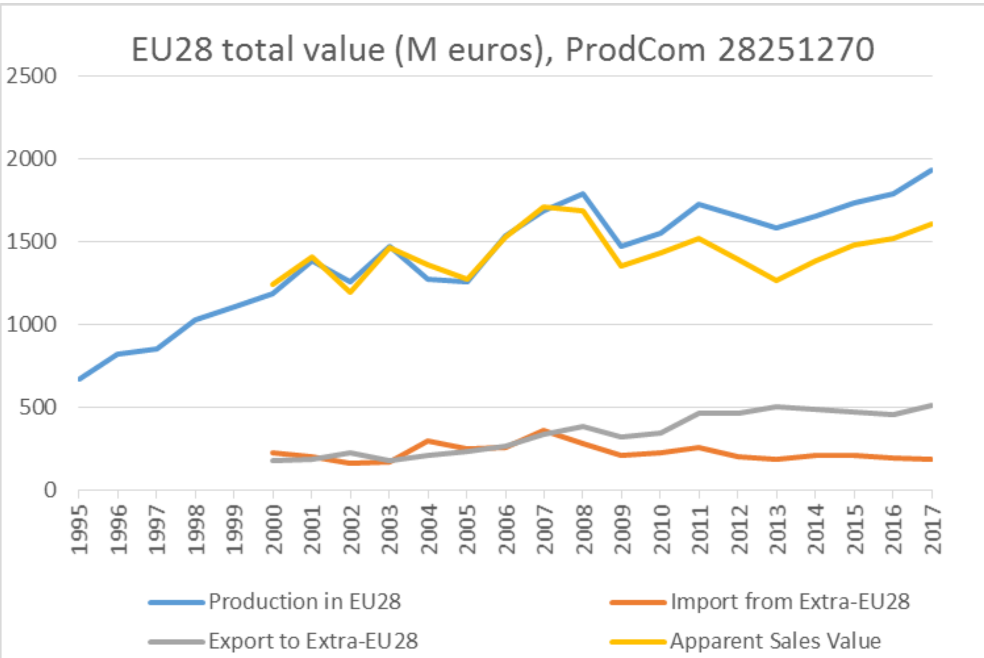
As shown in Figure 6, until 2007 export and import value are similar so that the value of apparent consumption equals the value of production. In later years, the export value exceeds the import value. As order of magnitude, import and export value are around one quarter of the production value.

After a minimum of 1.3 bn euros in 2013, in 2017 the value of apparent consumption is around 1.6 bn euros, which is more or less the same as before the economic crisis, in 2007.

Table 3. EU28 summary in M euros for Production, Extra-EU28 Imports, and Extra-EU28 Exports of non-cooling AC units, AHUs, VAV Boxes, CAV boxes and FCUs. Value of apparent consumption (production + import – export) computed by VHK

(Source: Eurostat 2019, ProdCom code 28251270 and ComExt CN8 codes 84158300 and 84158390)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28	672	821	856	1030	1107	1190	1389	1259	1475	1272	1255	1535	1685	1792	1469	1550	1726	1654	1581	1658	1738	1788	1935
Import from Extra-EU28						224	203	158	166	292	250	255	359	276	207	224	259	198	185	209	211	189	180
Export to Extra-EU28						175	184	222	177	204	234	261	332	380	323	340	466	459	504	484	468	458	508
Apparent consumption						**1239**	**1408**	**1195**	**1463**	**1359**	**1272**	**1529**	**1712**	**1689**	**1354**	**1435**	**1519**	**1393**	**1262**	**1383**	**1480**	**1519**	**1607**



The Figure 6. EU-28 Production, Export, Import and Apparent Consumption of non-cooling AC units, AHUs, VAV Boxes, CAV boxes and FCUs

Conclusion is that the EU-industry holds a relatively strong position in the above mentioned product groups, with Italy (mostly Fan Coil Units, FCUs) and Germany (mostly Air Handling Units, AHUs) accounting for a major part of the production.

As mentioned, the usefulness of the presented figures for the study on Ventilation Units is limited, due to the very heterogeneous nature of the product group. They constitute a maximum value.

Parts

Other relevant Eurostat statistics in this context relate to AHU modules that are manufactured as Prodcom category 28253010: '*Parts for air conditioning machines (including condensers, absorbers, evaporators and generators)*' and that are traded as CN8 categories 84159000 and 84159090: '*Parts of air conditioning machines, comprising a motor-driven fan and elements for changing the temperature and humidity, n.e.s.*'.

Monetary production statistics per EU Member State are given in Annex I, Table 41. The countries with largest production value in recent years are Germany, Czech Republic and Slovakia. The total EU28 production value of these parts in 2017 is around 2.7 bn euros.

This production value is higher than that of complete airco units without refrigeration ProdCom 28251270 (€ 1.9 bln. in 2017), discussed in the previous section. Even when extending the latter with the production value of complete airco units with refrigeration ProdCom 28251250 (€ 2.4 bln. in 2017), the value of the parts production is still more than 50% of the value of complete systems/products. The main reason behind this is probably that air-conditioning systems rarely get replaced as a whole. As mentioned in the AC Task 2 study, their product life 'as a system' may be as long as 30-35 years. But the product life of individual components, such as ventilation modules and heat exchanger modules in an AHU, is typically only 15-20 years [6]. One might classify this as 'repairs', but actually 'replacement sales' would be more appropriate.

Import and Export data are shown in Annex I, Table 42 and Table 43. In 2017, the total value of extra-EU28 exports was 1.3 bn euros, of the same order of magnitude as the extra-EU28 imports of 1.4 bn euros.

The combined results of EU28 production and extra-EU28 imports and exports in the period 1995-2017 are given in Table 4, also providing a calculation of the apparent consumption (production + imports - exports), expressed in millions of euros. As unit values for production, import and export may be different, and not directly comparable, the resulting value for the apparent consumption is indicative only and should be used with care.

As shown in Figure 7, export and import values are similar so that the value of apparent consumption equals the value of production. As order of magnitude, import and export value are around half the production value. In 2017, the value of apparent consumption is around 2.8 bn euros. Trends are positive.

[6] The FGK supplementary study 2010 on ventilation systems <125 W mentions 17 years as an overall average.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28	497	667	686	776	824	905	993	1287	1363	1449	1569	1855	1865	2105	1800	2082	2358	2228	2153	2215	2625	2658	2687
Import from Extra-EU28						535	500	429	437	496	428	519	631	678	556	765	897	904	949	1036	1074	1330	1402
Export to Extra-EU28						413	449	440	434	498	480	567	636	640	632	774	889	978	1061	1083	1097	1250	1296
Apparent consumption						**1027**	**1044**	**1276**	**1366**	**1447**	**1517**	**1807**	**1860**	**2143**	**1724**	**2073**	**2366**	**2154**	**2041**	**2168**	**2602**	**2738**	**2793**

Table 4. EU28 summary in M euros for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Parts for Air Conditioning machines. Value of apparent consumption (production + import – export) computed by VHK

(Source: Eurostat 2019, ProdCom 28253010 and ComExt CN8 codes 84159000 and 8415900)

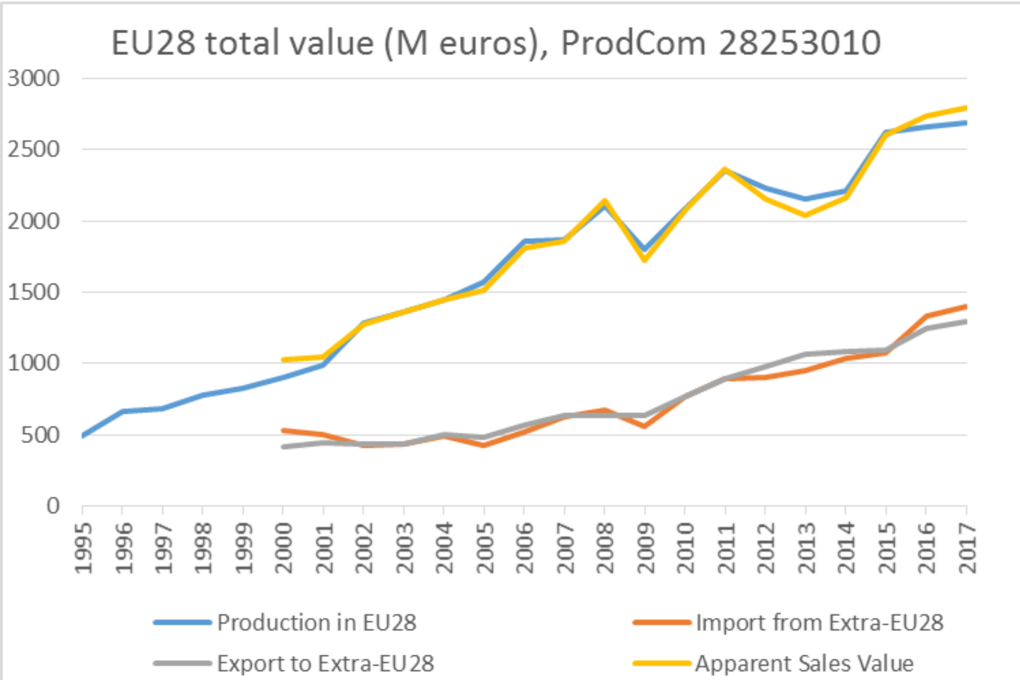


Figure 7. EU28 total value in M euros for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Parts for Air Conditioning machines. Value of apparent consumption (production + import – export) computed by VHK

(Source: Eurostat 2019, ProdCom 28253010 and ComExt CN8 codes 84159000 and 8415900)

The value of these statistics for the purpose of the underlying study is again very limited, given the mix with non-ventilation products, but at the moment it is the best that Eurostat can offer.

Note that the above parts cover only a small part of the extra installation materials. The most important materials, also in money terms, are in the air duct-system. Unfortunately, Eurostat PRODCOM does not specify, e.g. within section 24, which tubes and sheets are produced as air ducts and therefore no figures can be presented here. The same can be said about other parts of the duct system: vibration isolators (a.k.a. attenuators, 'isolating' AHU from ducts), take-offs (first divider after AHU), plenums (dividers further downstream), risers/stacks (vertical thin and wide or oval ducts), dampers, terminal units (e.g. VAV boxes), grills and diffusers. The part that deals specifically with ventilation controls is also not shown in PRODCOM.

1.3. Central exhaust or supply units

Central exhaust or supply ventilation units > 125 W are included in Prodcom categories (NACE Rev. 2) [7]:

- 28252030 Axial fans >125W;
- 28252050 Centrifugal fans >125 W or
- 28252070 Other fans >125 W.

Larger CHRV units are wholly or partly included in the last category.

Eurostat production statistics per EU Member State for the available period 1995-2017 are given in Annex I , Table 45 thru Table 50, respectively for axial, centrifugal and other fans > 125 W, and for production volume (in thousands of units) and production value (in millions of euros). The largest producers are Germany and Italy, and Sweden for the other fans category. The large production of axial 'fans' in Hungary probably regards impellers, and not complete fans. This can also be derived from the low value of around € 2,- /unit.

Not counting the Hungarian contribution of axial 'fans', a total of 44 million fans > 125W were produced in EU28 in 2017, of which 21 mln axial, 15 mln centrifugal and 8 mln other type. This production represented a value of 3.5 bn euros, of which 1.3 bn euros for axial fans (€ 62 /unit), 1.5 bn euros for centrifugal fans (€ 97 /unit), and 0.7 bn euros for other fans (€ 88 /unit).

For comparison (see par. 2.6 and 2.8): the total sales of Ventilation Units in 2017 estimated in this study are around 8 mln units (including also residential VUs < 125 W and non-continuously operating LUVUs).

As shown in Figure 8, for centrifugal and other fans the trend in production volumes is increasing. For axial fans, the production volume remained more or less constant over the last ten years (except for a dip in crisis years 2008 and 2009 and an anomalous peak in Eurostat data in 2014). After a dip in crisis year 2009, the trend in production value is also positive.

[7] 28252030-Axial fans (excluding table, floor, wall, window, ceiling or roof fans with a self-contained electric motor of an output <=125 W). Corresponding ComExt CN8 codes are 84145930, 84145920 and 84145925, valid for different year ranges.

28252050-Centrifugal fans (excluding table, floor, wall, window, ceiling or roof fans with a self-contained electric motor of an output <= 125 W). Corresponding ComExt CN8 codes are 84145950, 84145940 and 84145935, valid for different year ranges.

28252070-Fans (excluding table, floor, wall, ceiling or roof fans with a self-contained electric motor of an output <= 125 W, axial fans, centrifugal fans). Corresponding ComExt CN8 codes are 84145990, 84145980 and 84145995, valid for different year ranges.

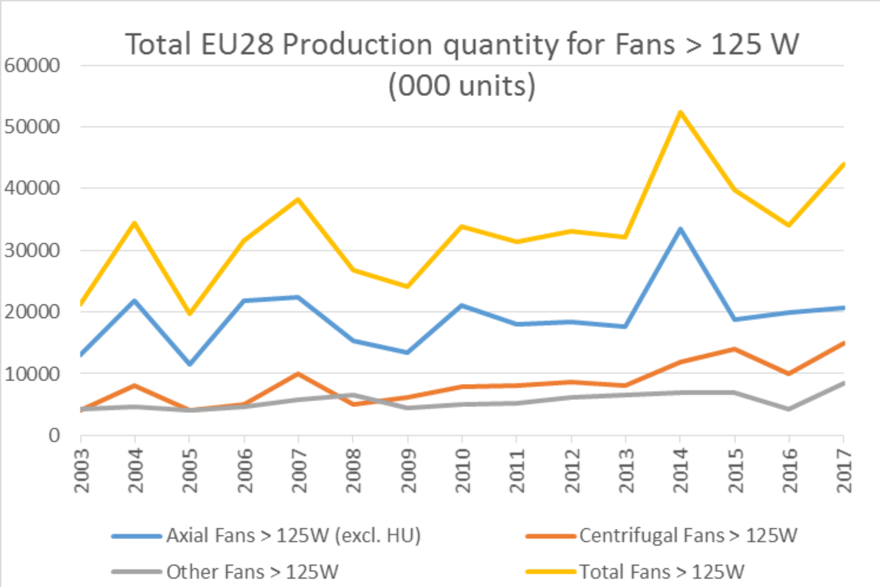


Figure 8. EU28 total Production Volume of Axial, Centrifugal and Other fans > 125W, in units x 1000

(Source: Eurostat 2019, ProdCom codes 28252030, 28252050, 28252070)

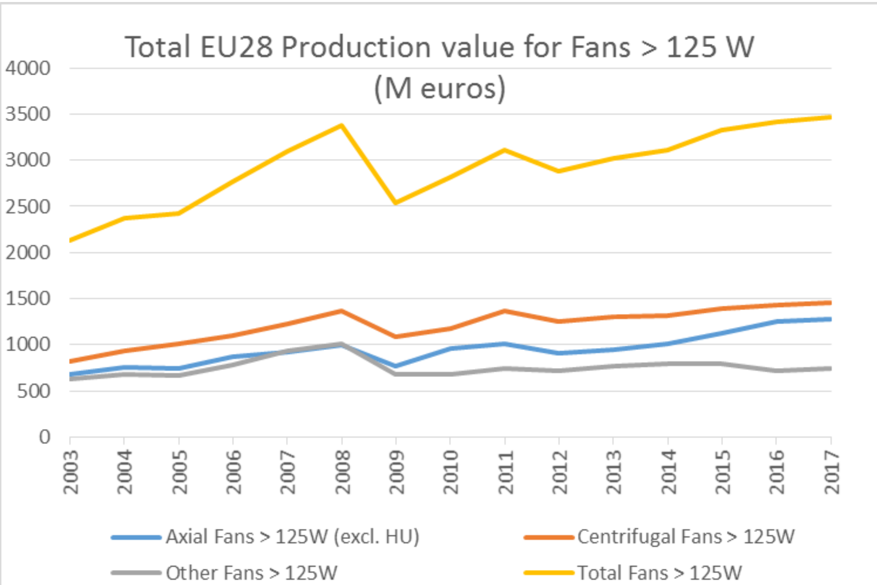


Figure 9. EU28 total Production Value of Axial, Centrifugal and Other fans > 125W, in M euros

(Source: Eurostat 2019, ProdCom codes 28252030, 28252050, 28252070)

Import and Export data are shown in Annex I, Table 51 through Table 62, respectively for axial, centrifugal and other fans >125 W, and for production volume (in thousands of units) and production value (in millions of euros). Germany is by far the largest exporter of axial and centrifugal fans >125W. For 'other' fans the German position is less dominant.

The total EU28 export of fans >125W to extra-EU28 countries in 2017 was 33 mln units, of which 15 mln axial, 11 mln centrifugal and 7 mln other type. This export represented a value of 1.7 bn euros, of which 0.7 bn euros for axial fans (€ 48 /unit), 0.7 bn euros for centrifugal fans (€ 63 /unit), and 0.3 bn euros for other fans (€ 45 /unit).

The total EU28 import of fans >125W from extra-EU28 countries in 2017 was 94 mln units (nearly 3 times the exported quantity), of which 64 mln axial, 9 mln centrifugal and 22 mln other type. This import represented a value of 0.7 bn euros, of which 0.36 bn euros for axial fans (€ 6 /unit), 0.09 bn euros for centrifugal fans (€ 10 /unit), and 0.25 bn euros for other fans (€ 11 /unit).

The difference in unit price between imported and exported products indicates that especially smaller, maybe partial, products are imported, while larger, probably more complex, products are exported.

For axial and centrifugal fans >125W the trend in export volumes is increasing. For other fans the export volumes remained more or less constant since 2010. The dip in exports in crisis year 2009 is clearly visible (graphs in Annex I.3).
The same trend exists for imports, showing an increase for axial and centrifugal fans and a decrease or stable situation for other fan types.

The combined results of EU28 production and extra-EU28 imports and exports in the period 2000-2017 are given in Table 5 and Table 6, also providing a calculation of the apparent consumption (production + imports - exports), with quantity expressed in thousands of units and value in millions of euros. As unit values for production, import and export may be different, and products not directly comparable, the results for the apparent consumption are indicative only and should be used with care.

Considering Table 5 and Figure 10 the position of EU-industry in the production of fans > 125W seems rather weak because imported quantities dominate the scene, possibly with the exception of centrifugal fans. However, considering the associated monetary values of Table 6 and Figure 11 the picture changes, showing a low relative value of the imports. As also remarked before, the data seem to indicate that EU-industry produces and exports fans that are relatively large and complex, with a high unit value, while the EU imports much larger quantities of smaller, more simple fans, with a low unit value.

In 2017, the apparent 'consumption' of fans >125W in EU28 is around 106 mln units, of which 69 mln are axial, 13 mln centrifugal and 24 mln other type. The 106 mln results from a production in EU28 of 44 mln units and an import-export balance with extra-EU28 countries of 62 mln units. The corresponding value of the 106 mln units is 2.5 bn euros, consisting of a value of production of 3.5 bn euros and an import-export balance with extra-EU28 countries of -1.0 bn euros.

Table 5. EU28 Quantity summary in 000 units for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Fans >125W. Value of apparent consumption (production + import – export) computed by VHK

(Source: Eurostat 2019, ProdCom codes 28252030, 28252050, 28252070 and ComExt CN8 codes 841459xx)

Axial fans > 125W, ProdCom 28252030 (excl. Hungary)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28				13066	21773	11601	21905	22484	15265	13508	20995	18027	18368	17557	33480	18727	19880	20626
Import from Extra-EU28	32196	36587	32986	30011	36694	38611	41837	50410	49173	42325	56041	58145	45202	54000	56518	59840	67475	63694
Export to Extra-EU28	9735	8247	6181	9231	9687	9730	10127	10196	11237	8222	11789	13395	15488	13427	12951	12717	13713	15049
Apparent consumption				**33846**	**48780**	**40482**	**53615**	**62698**	**53201**	**47611**	**65247**	**62777**	**48082**	**58130**	**77047**	**65850**	**73642**	**69271**

Centrifugal fans > 125W, ProdCom 28252050

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28				4000	8004	4003	5000	10000	5000	6120	7825	8000	8601	8000	12000	14000	10000	15000
Import from	1145	663	1137	749	825	1036	1723	2316	3041	2095	3266	3838	4075	7176	9296	8719	8784	8672

Centrifugal fans > 125W, ProdCom 28252050

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Extra-EU28																		
Export to Extra-EU28	2106	2052	2499	2296	3309	4586	6578	6682	6409	5087	7216	7805	7597	7902	9309	8754	9428	11000
Apparent consumption	**1366**	**599**	**558**	**2453**	**5520**	**453**	**145**	**5634**	**1632**	**3128**	**3875**	**4033**	**5079**	**7274**	**11987**	**13965**	**9356**	**12672**

Other fans > 125W, ProdCom 28252070

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28				4200	4620	4161	4645	5718	6475	4440	5032	5306	6127	6637	6871	7020	4252	8411
Import from Extra-EU28	20064	26809	25274	30141	33995	30036	26412	25727	23111	15474	19267	19454	15976	14833	17528	14794	16266	21988
Export to Extra-EU28	3725	4295	5279	6818	7537	8768	10237	8426	6789	4668	6255	6002	6360	6451	6608	6369	7689	6767
Apparent consumption				**27523**	**31078**	**25429**	**20820**	**23019**	**22797**	**15246**	**18044**	**18758**	**15743**	**15019**	**17791**	**15445**	**12829**	**23632**

All fans > 125W, sum of ProdCom 28252030, 28252050, 28252070

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28				21266	34397	19765	31551	38202	26740	24069	33851	31333	33096	32194	52351	39747	34132	44037
Import from Extra-EU28	53405	64059	59397	60901	71514	69683	69972	78453	75325	59894	78574	81437	65253	76009	83342	83353	92525	94354
Export to Extra-EU28	15566	14594	13959	18345	20533	23084	26942	25304	24435	17977	25260	27202	29445	27780	28868	27840	30830	32816
Apparent consumption				**63822**	**85378**	**66364**	**74581**	**91351**	**77630**	**65986**	**87165**	**85568**	**68904**	**80423**	**106825**	**95260**	**95827**	**105575**

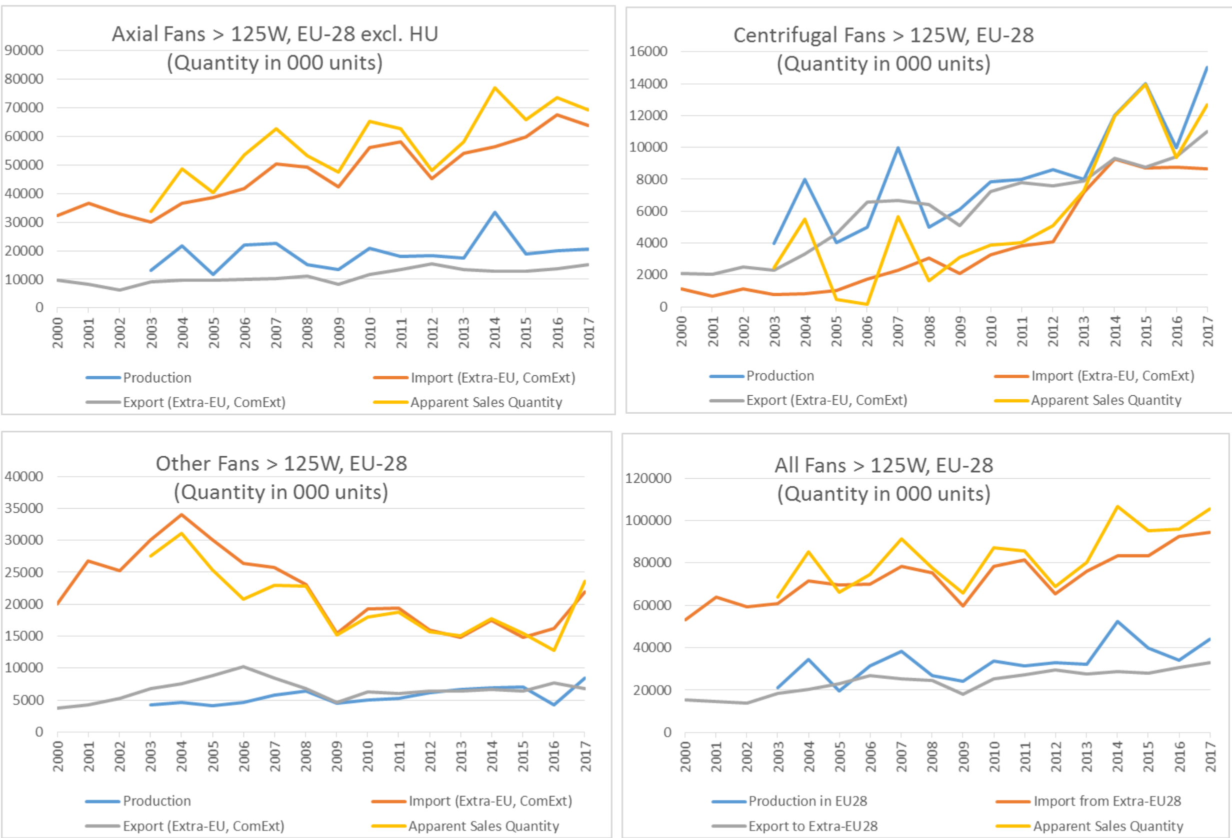


Figure 10. EU28 total quantity in 000 units for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Fans > 125W. Value of apparent consumption (production + import – export) computed by VHK

(Source: Eurostat 2019, ProdCom codes 28252030, 28252050, 28252070 and ComExt CN8 codes 841459xx)

Table 6. EU28 Value summary in M euros for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Fans >125W. Value of apparent consumption (production + import – export) computed by VHK

(Source: Eurostat 2019, ProdCom codes 28252030, 28252050, 28252070 and ComExt CN8 codes 841459xx)

Axial fans > 125W, ProdCom 28252030 (excl. Hungary)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28				674	753	748	875	926	993	765	962	1004	912	951	1005	1131	1257	1272
Import from Extra-EU28	163	187	172	143	153	162	186	204	207	167	217	240	245	254	296	360	399	356
Export to Extra-EU28	227	208	177	209	256	259	306	345	383	294	443	512	524	537	570	624	691	725
Apparent consumption				**607**	**651**	**651**	**755**	**785**	**817**	**637**	**736**	**732**	**633**	**667**	**731**	**868**	**965**	**904**

Centrifugal fans > 125W, ProdCom 28252050

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28				817	940	1006	1104	1230	1369	1085	1173	1363	1255	1298	1320	1393	1436	1460
Import from Extra-EU28	16	13	13	11	12	13	24	35	45	35	45	44	57	69	88	106	111	88
Export to Extra-EU28	105	106	101	133	168	185	247	274	305	275	397	435	486	646	576	637	586	688
Apparent consumption				**695**	**784**	**834**	**881**	**991**	**1109**	**845**	**821**	**972**	**826**	**721**	**832**	**862**	**961**	**860**

Other fans > 125W, ProdCom 28252070

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28				634	680	668	784	937	1016	685	682	746	715	769	790	798	723	739
Import from Extra-EU28	177	197	177	176	185	166	166	183	171	136	163	181	186	166	173	169	187	249
Export to Extra-EU28	151	173	189	199	217	243	291	299	293	249	235	283	281	301	299	317	295	306
Apparent consumption				**611**	**648**	**591**	**659**	**821**	**894**	**572**	**610**	**644**	**620**	**634**	**664**	**650**	**615**	**682**

All fans > 125W, sum of ProdCom 28252030, 28252050, 28252070

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28				2125	2374	2422	2763	3093	3379	2536	2817	3113	2882	3018	3114	3322	3416	3471
Import from Extra-EU28	356	397	362	330	350	341	376	422	423	338	425	465	488	489	557	635	697	693
Export to Extra-EU28	483	487	467	541	641	687	844	918	981	818	1075	1230	1291	1484	1445	1578	1572	1719
Apparent consumption				**1914**	**2083**	**2076**	**2295**	**2596**	**2821**	**2055**	**2166**	**2348**	**2079**	**2022**	**2226**	**2380**	**2541**	**2446**

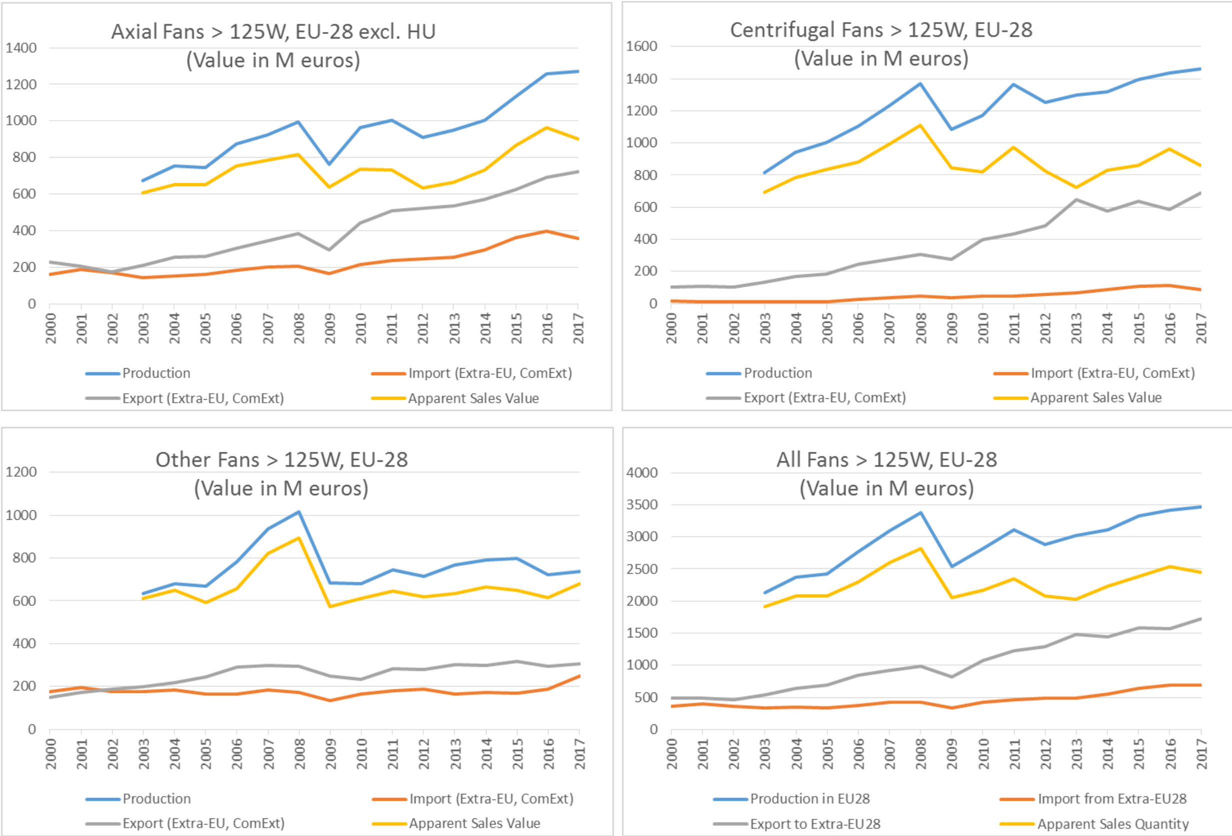


Figure 11. EU28 total value in M euros for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Fans > 125W. Value of apparent consumption (production + import – export) computed by VHK

(Source: Eurostat 2019, ProdCom codes 28252030, 28252050, 28252070 and ComExt CN8 codes 841459xx)

1.4. Installation repair and maintenance

Eurostat's ProdCom database provides statistics on the installation, repair and maintenance of non-domestic cooling and ventilation appliances, respectively in ProdCom categories 33202950 and 33121800.

Corresponding 'production' values in M euros are presented in Annex I, Table 65 and Table 66. In 2017, a total of 4.7 bn euros was spent in EU28 for installation of non-domestic cooling and ventilation equipment, and 3.5 bn euros for their repair and maintenance. A noteworthy large contribution comes from France where between 2007 and 2009 the expenses for these activities seem to have tripled, notwithstanding the economic crisis.

Trends are positive, even when taking into account inflation: For Installation, the increase is from 2.9 bn euros in 2003 to 4.7 bn euros in 2017 (+64%), and for Repair and Maintenance from 2.1 bn euros in 2003 to 3.5 bn euros in 2017 (+71%), compared to an inflation over the 2003-2017 period of 28%.

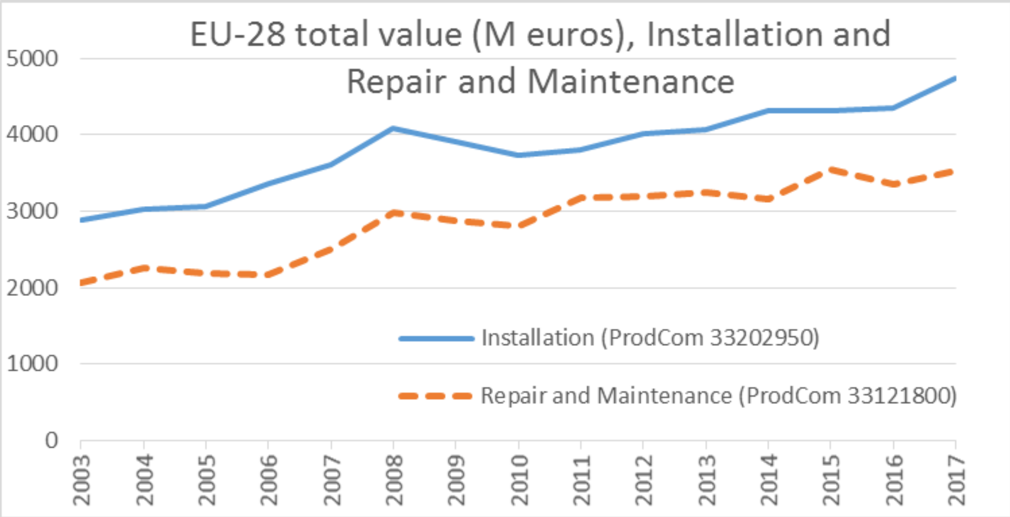


Figure 12. EU28 total value in M euros for Installation and Repair and Maintenance of non-domestic cooling and ventilation equipment

(Source: Eurostat 2019, ProdCom codes 33202950 and 33121800)

An additional investigation of ProdCom data, see Annex I.4 and Figure 13, shows that, in monetary terms, repair and installation activities are more significant than the part manufacture.

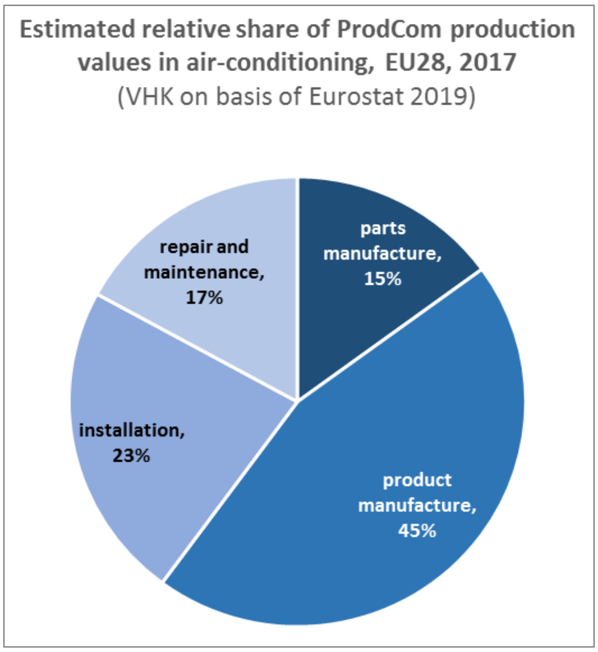


Figure 13. ProdCom figures on air conditioning and ventilation (excluding trade)

1.5. Ventilation Units ≤ 125W

ProdCom category 27511530 covers '*Table, floor, wall, window, ceiling or roof fans, with a self-contained electric motor of an output <= 125 W*'. The corresponding ComExt CN8 codes are 84145100 and 84145190, valid for different year ranges.

The Eurostat production statistics per EU Member State are given in Annex I, Table 68 (production volume in 000 units) and Table 69 (value of production in M euros) for the available period 1995-2017. Germany and the United Kingdom are the major producers, followed by Italy and Poland. The major value of production is also found in Germany and United Kingdom, while e.g. the value for Poland is low considering the quantity produced.

In 2017, around 13 mln units are produced in EU28 for a total value of 0.4 bn euros. This implies an average unit price around 32 euros, but variation is from € 8 /unit in Poland to € 136 /unit in Finland.

Import and Export data (quantity in thousands of units and value in millions of euros) are shown in Annex I, Table 70 thru Table 73.

In 2017, the total exports from EU28 towards extra-EU28 countries were 2.8 mln units with a value of 86 mln euros, implying an average € 31 /unit.

In 2017, the total imports to EU28 from extra-EU28 countries were 37 mln units with a value of 341 mln euros, implying an average € 9 /unit.

The combined results of EU28 production and extra-EU28 imports and exports in the period 2000-2017 are given in Table 7 and Table 8, also providing a calculation of the apparent consumption (production + imports - exports), with quantity expressed in thousands of units and value in millions of euros. As unit values for production, import and export may be different, and products not directly comparable, the results for the apparent consumption are indicative only and should be used with care.

As regards quantities of fans ≤ 125 W, imports into EU28 are dominant and generally much higher than the EU28 production. The imports show a dip in crisis years 2008 and 2009 and only recently the imported quantities are back to the 2007 level. Produced and exported quantities remain more or less on the same level. Exports are low. The value of production exceeds the value of imports. Imported products have a much lower unit value and must on average be smaller and less complex.

In 2017, the apparent 'consumption' of fans ≤ 125W in EU28 is around 48 mln units, which is less than half of the 106 mln fans > 125 W reported in Annex I.3. The 48 mln result from a production in EU28 of 13 mln units and an import-export balance with extra-EU28 countries of 35 mln units. The corresponding value of the 48 mln units is 680 mln euros, consisting of a value of production of 420 mln euros and an import-export balance with extra-EU28 countries of 260 mln euros.

For comparison (see par. 2.6): the total sales of Ventilation Units for the residential sector in 2017 estimated in this study are around 7 mln units (including also non-continuously operating LUVUs).

Table 7. EU28 Quantity summary in 000 units for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Fans ≤ 125W. Value of apparent consumption (production + import – export) computed by VHK

(Source: Eurostat 2019, ProdCom code 27511530 and ComExt CN8 codes 84145100 and 84145190).

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28	4961	6597	7235	12000	15000	12732	14288	16463	12269	11009	12729	11559	10306	10529	11482	11332	11958	13436
Import from Extra-EU28	13721	11921	17731	25832	40282	28837	24347	32727	18311	11279	15274	22054	16664	17047	21955	19129	30117	37374
Export to Extra-EU28	1914	1643	1785	2150	2439	2749	2907	2876	2754	2196	3822	2654	3063	2989	2989	2751	2695	2808
Apparent consumption	**16768**	**16875**	**23181**	**35682**	**52843**	**38820**	**35728**	**46314**	**27826**	**20092**	**24181**	**30959**	**23907**	**24587**	**30448**	**27710**	**39380**	**48002**

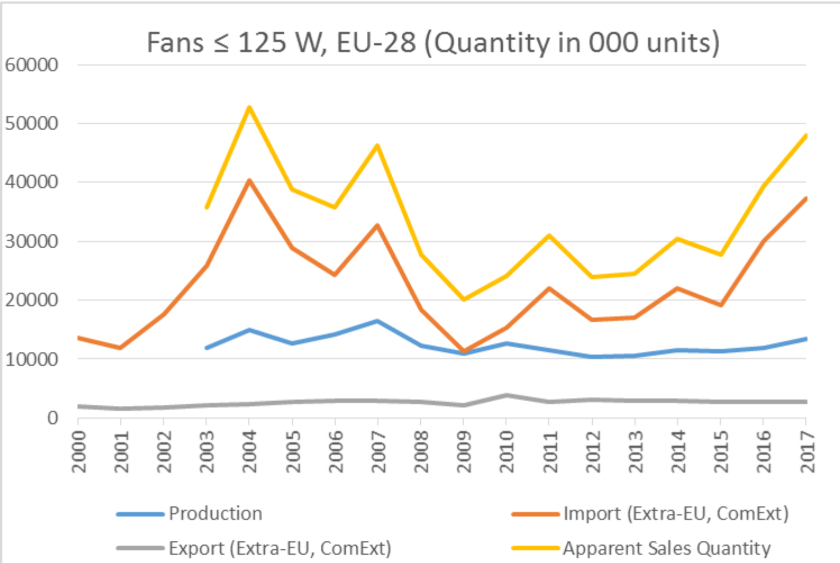


Figure 14. EU28 Quantity summary in 000 units for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Fans ≤ 125W. Value of apparent consumption (production + import – export) computed by VHK

(Source: Eurostat 2019, ProdCom code 27511530 and ComExt CN8 codes 84145100 and 84145190)

Table 8. EU28 Value summary in M euros for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Fans ≤ 125W. Value of apparent consumption (production + import – export) computed by VHK

(Source: Eurostat 2019, ProdCom code 27511530 and ComExt CN8 codes 84145100 and 84145190).

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28	358	357	336	340	351	322	369	393	358	296	361	372	338	359	388	404	392	426
Import from Extra-EU28	135	129	143	159	261	206	182	254	143	101	140	196	163	162	204	227	320	341
Export to Extra-EU28	63	55	59	54	61	65	73	67	75	64	73	86	91	85	84	92	80	86
Apparent consumption	**430**	**431**	**420**	**445**	**551**	**463**	**478**	**580**	**426**	**333**	**428**	**482**	**410**	**436**	**508**	**539**	**632**	**681**

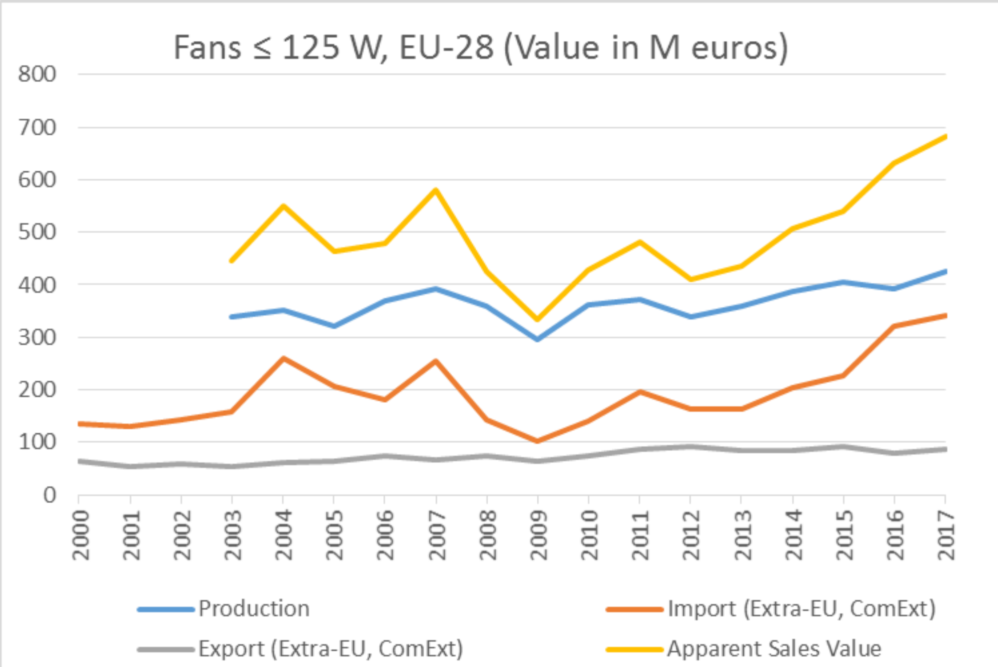


Figure 15. EU28 Value summary in M euros for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Fans ≤ 125W. Value of apparent consumption (production + import – export) computed by VHK

(Source: Eurostat 2019, ProdCom code 27511530 and ComExt CN8 codes 84145100 and 84145190)

2. Market and stock data

2.1 Introduction

Data availability and quality on sales and stock of ventilation units in the residential and non-residential sector was poor at the time the previous preparatory studies were performed (2010). In the meantime various market research companies have been building knowledge and expertise in this particular sector, amongst which:

- BSRIA (Countries: France, Germany, the Netherlands, Sweden, UK, USA, China; Years: 2015, 2016, 2017 with forecasts to 2021)
- BRG (Countries: Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Poland, Russia, Spain, Sweden, Switzerland, UK, Canada, USA)
- IC (Countries: Austria, France, Germany, Switzerland, Nordics, Italy, Benelux, UK, Poland)
- EMI (Countries: EU28, Middle East countries and Africa)

These are commercial data and therefore not available in the public domain.

For this study, alternative data sources are used (with thanks to stakeholders who provided data) to update the 'top-down / bottom-up' approach VHK employed in the previous preparatory studies on ventilation and in the Ecodesign Impact Accounting (EIA). A survey of these data is presented in paragraph 2.2, while additional details and references can be found in Annex II.

To gain further insight in the sales and stock of ventilation units, the study team developed a model (Building-Ventilation Model, BVM) to link the VU sales to the activities in the building sector, i.e. to the number of new-built and renovated residential dwellings and non-residential buildings. This model takes into account the provisions of the Energy Performance of Buildings Directive (EPBD), i.e. all new-built to be Nearly-Zero Energy Building (NZEB) by 2020, and the entire EU-27 stock of buildings to be NZEB by 2050. Although NZEB does not necessarily imply the use of balanced ventilation units (BVU) with heat recovery (HR), the provisions of the EPBD are expected to lead to a strong increase in the sales of BVUs. The residential part of the model is presented in paragraphs 2.3 (dwellings), 2.6 (sales) and 2.7 (stock); the non-residential part in paragraphs 2.5 (buildings), 2.8 (sales) and 2.9 (stock).

2.2 Reference data for Sales and Stock of Ventilation units

This paragraph provides a survey of available data on the sales and stock of ventilation units. These data have been used as a reference to calibrate the Building-Ventilation Model.

2.2.1 Uniclima data for France

Uniclima provides data on the French market for ventilation units in the period 2004-2018, covering UVUs and BVUs for individual residential dwellings, UVUs and BVUs for collective residential dwellings (multi-family) and tertiary sector, and tailor-made Air Handling Units (AHUs). Details, graphs and sources are provided in Annex II.1 and show:

For individual residential solutions:

- UVU sales increasing from 550 thousand units in 2004 to 800 thousand units in 2018;

- BVU sales initially increasing from 5 thousand units in 2004 to over 35 thousand units in 2011, but since then decreasing to 21 thousand in 2018;
- Sales of 440 thousand small local fans and decentralized BVU with a flow rate < 400 m3/h. This quantity is more or less constant since 2013.

For collective residential and tertiary sector:

- UVU sales of 100 thousand units in 2018. This quantity is more or less constant over the 2004-2018 period, although there was a peak of 110 thousand units around 2007;
- BVU sales increasing from less than 1000 units in 2004 to nearly 11 thousand in 2011. Since then fairly constant, slightly increasing to 12,500 units in 2018.

For tailor-made AHUs:

- Sales decreasing from 11,500 units in 2008 to 6,100 units in 2018. Of the latter, slightly over one-third uses heat recovery.

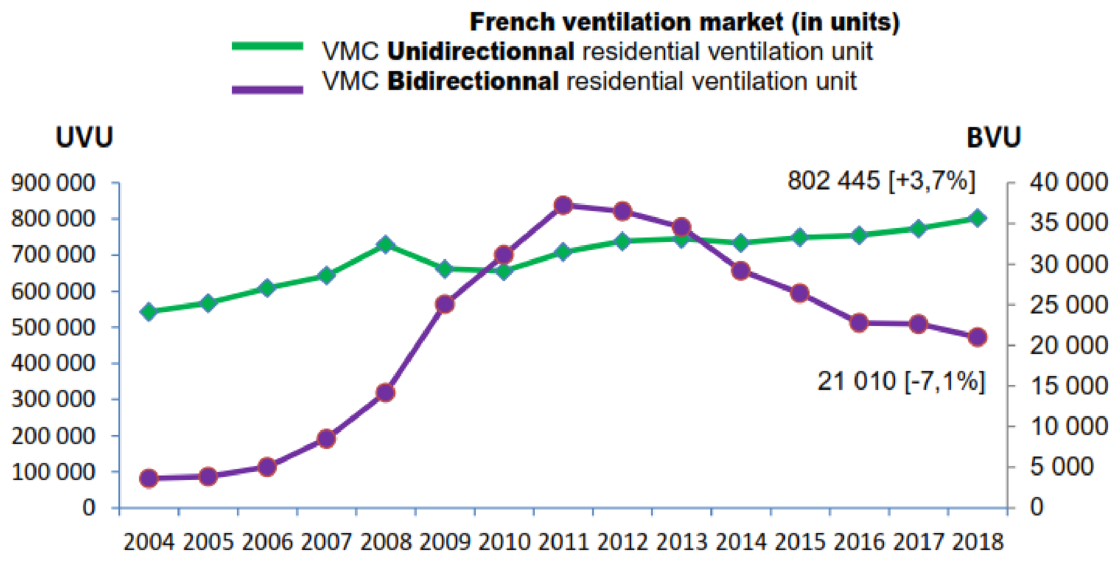


Figure 16 Market for Ventilation Units for individual dwellings in France
(source: Uniclima; see Annex II.1 for additional information)

2.2.2 FGK-BDH-IKZ data for Germany

Documents from FGK, BDH and IKZ (details, graphs and sources in Annex II.2) provide the sales of Ventilation Units with Heat Recovery in Germany (split in central and local) over the period 2013-2018 and compare these sales with the number of new-built dwellings.
Main conclusions:

- In 2018, 257 thousand residential dwellings were built in Germany;
- Sales of central BVU with HR in 2018 were 50 thousand, or 20% of the new-built dwellings;
- Sales of local BVU with HR in 2018 were 198 thousand. Counting on average 4.5 LBVU per dwelling, this corresponds to 44 thousand dwellings, or 17% of the new-built.

- Consequently 63% of the new-built dwellings in 2018 did not use BVU with HR [8]. This share is more or less constant over the 2013-2018 period.
- The share of central BVU in new-built has decreased from 26% in 2013 to 20% in 2018 while the share of local BVU has increased, from 10% in 2013 to 17% in 2018.

2.2.3 Hasselaar for The Netherlands

The dissertation of Hasselaar (details and source in Annex II.3) estimates the following distribution of ventilation systems for the 2006 Dutch housing stock:

- Of the total building stock of 2006 in The Netherlands (around 6.9 million houses), 43% had a natural ventilation system, which includes vertical natural exhaust canals to the roof in the kitchen (traditionally separated from the living room), in the bathroom and often also in the toilet, in combination with windows that can be opened.
- About 53% was equipped with a central exhaust fan (CUVU) that extracts air from the kitchen, bathroom and toilet, in combination with natural inlet through (more modern) grates and windows.
- Since 1998, many new houses are equipped with balanced-flow (BVU) heat-recovery ventilation systems, and in 2006 the number amounted to approximately 280,000 houses, which is about 4% of the stock in 2006.

2.2.4 BRG for Finland

The study team had access to BRG data on the use of ventilation systems in Finland. These data are confidential and cannot be included in this report, but they were elaborated and have been used to calibrate the Building-Ventilation Model.
The main conclusion is that starting from 2003 practically all new dwellings in Finland use Balanced Ventilation Units with Heat Recovery.

2.2.5 Eurovent sales data

Eurovent's EMI provides a dataset containing the EU-28 total sales figures for residential BVU (with heat recovery) and non-residential AHUs for year 2017 (details in Annex II.4).

The document mentions a total of 460,859 residential BVUs sold in 2017, of which 33% has an airflow ≤ 100 m^3/h, 29% between 101-250 m^3/h, 34% between 251-500 m^3/h and 4% with higher maximum airflow capacities. 7% had energy class A+, 79% class A and 14% class B. Total market value: 347.5 million euro, leading to an average ex-works price of around € 760,-.

As regards non-residential AHUs, total sales in 2017 were 179,395 units with a market value of 1712 million euros and an average ex-works price of around € 9.500,-.
Biggest AHU markets in numbers are Germany, France, UK, Sweden and Italy.

[8] The documents even suggest that 63% of the new dwellings in Germany are not equipped with mechanical ventilation systems (KWL-anlagen) (not even UVU?), but apply natural ventilation methods (Fensterlüftung or Quer-/Schachtlüftung).

2.2.6 Public data from Interconnection Consulting (IC)

In their press release [9], Interconnection Consulting (IC) published aggregated data on the development of Europe's residential ventilation market. According to IC, indicators suggest that the market for residential ventilation systems in the markets analysed (Germany, Austria, Switzerland, France, the UK, Italy, Poland, and the Benelux countries) will increase at an annual rate of 2.7% to 2021. France is the largest market, with a share of 32.3% of the countries analysed, followed by Germany (22.9%) and the Benelux region (21.6%).
Looking at the numbers and values, these data most probably refer to all residential ventilation units, both extract UVUs and BVUs with heat recovery, both centralised and decentralised (the manually operated and temporarily functioning bathroom and toilet fans are not in these figures).

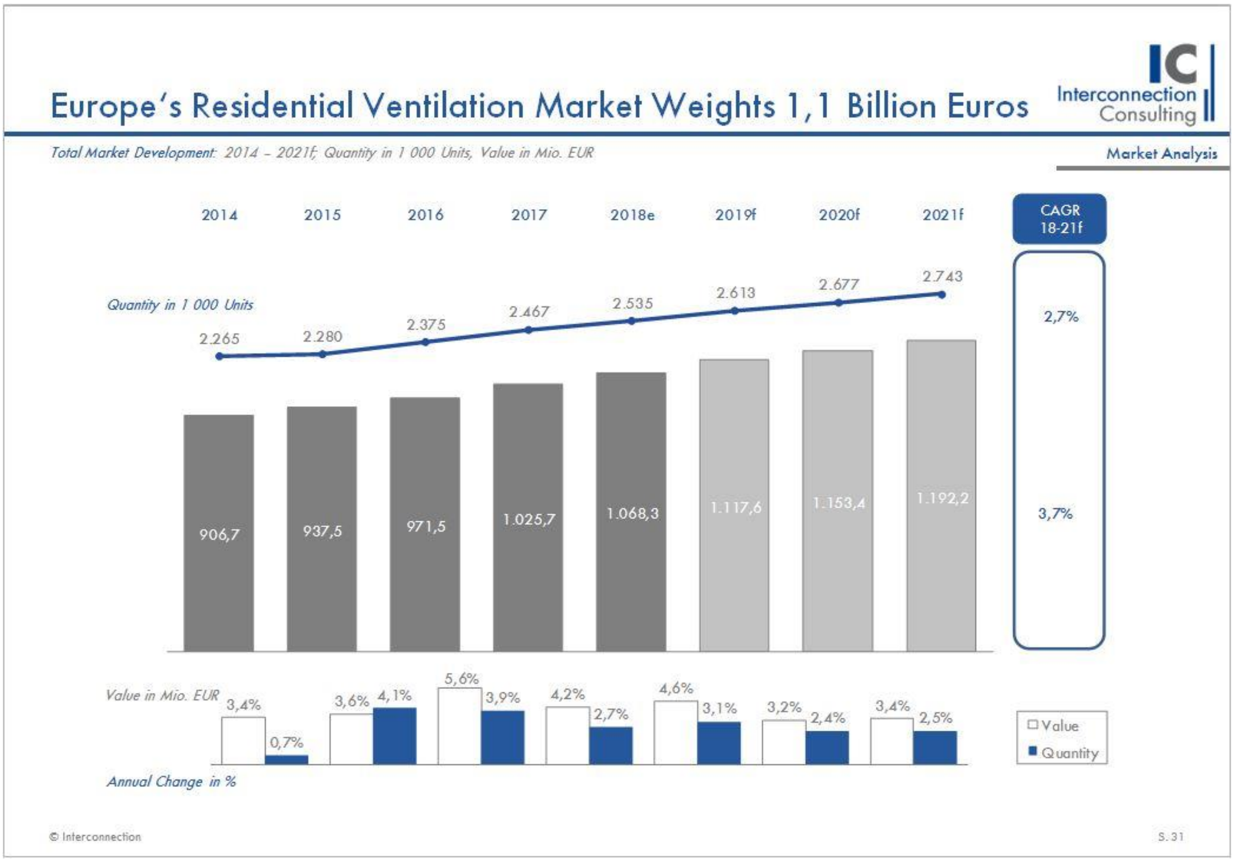


Figure 17. Market for residential ventilation systems according to IC (09-2018) [9]

Other data from a 2015 IC research (limited to the same countries) have been discussed by MarktMeinungMensch [10]:

- In 2015 around 210 thousand central BVUs with Heat Recovery were sold.
- In 2015, sales of local BVUs with HR increased by 10.6% compared to 2014.
- In 2015, almost 2 mln UVUs without heat recovery were sold, for a value of M€ 508.7, representing 60% of the market. Market share of UVUs was 65.5% in 2011 and is expected to decrease to 55.8% in 2018.

[9] https://www.interconnectionconsulting.com/news/kwl-2/

[10] http://www.marktmeinungmensch.de/news/markt-fuer-wohnraumlueftungssysteme-wird-kraeftig-/

- Largest increase in market share of central BVU with HR is found in the Benelux and the United Kingdom. Largest increase in market share of local BVU with HR is found in Germany, Austria and Italy.
- 87% of Central BVU with HR are used in new-built because they need extensive duct works.
- 60% of the UVUs are used in renovation.

2.2.7 BVU market data published by Daikin based on BRG source

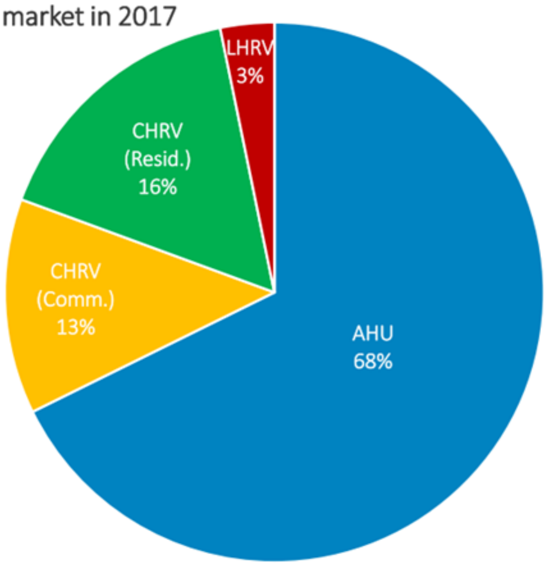
Kranenberg (Daikin) reports BRG-data on the European heat recovery ventilation market in 2017 [11]. For 2017 the market is reported to be worth M€ 2910, and expected to increase to M€ 3317 (+14%) by 2020. The data include AHUs and CHRVs for use in the tertiary sector. Single exhaust fans (UVUs) are not included. The country breakdown clarifies that not all EU-28 countries are included, while e.g. Norway, Russia and Switzerland are included in the figures.

[11] Ventilation and climate control - Market and product development trends - Henk Kranenberg, Daikin Europe NV, 13/11/2018, https://www.rehva.eu › fileadmin › events › eventspdf › Kranenberg

EUROPEAN MARKET VALUE AND FORECAST*

*Single exhaust fan not included

European heat recovery ventilation market in 2017



TECHNOLOGY	MARKET VALUE (M€)		GROWTH RATE 2017 - 2020
	2017	2020	
AHU	1 971 €	2 207 €	12%
Centr. HRV (Comm.)	375 €	413 €	10%
Centr. HRV (Resid.)	471 €	570 €	21%
Local HRV	93 €	127 €	36%
TOTAL	*2 910 €*	*3 317 €*	*14%*

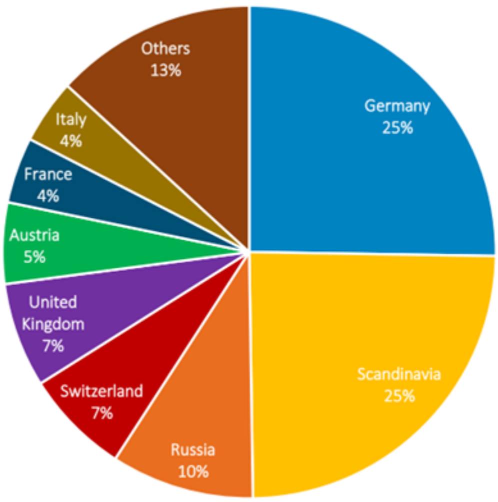
Source: BRG study "The European Ventilation Product Markets", November 2015

- Huge potential **all over Europe**, for both new construction and refurbishment.
- **Double digit growth** (2017 to 2020) for all types of ventilation solutions and applications: residential, light commercial and industry.

5 DAIKIN

VENTILATION MARKET VALUE PER COUNTRY

European heat recovery ventilation market in 2017



MARKET	MARKET VALUE (M€)		GROWTH RATE 2017 - 2020
	2017	2020	
Austria	155 €	179 €	15%
Belgium	97 €	111 €	15%
Czech Republic	47 €	56 €	19%
Denmark	143 €	162 €	13%
Finland	177 €	186 €	5%
France	126 €	147 €	17%
Germany	735 €	887 €	21%
Italy	123 €	147 €	19%
Netherlands	113 €	147 €	30%
Norway	122 €	129 €	6%
Poland	59 €	66 €	11%
Russia	273 €	219 €	-20%
Spain	67 €	81 €	21%
Sweden	271 €	325 €	20%
Switzerland	201 €	232 €	15%
United Kingdom	200 €	242 €	21%
TOTAL	*2 910 €*	*3 317 €*	*14%*

Source: BRG study "The European Ventilation Product Markets", November 2015

6 DAIKIN

Figure 18. Market for Balanced Ventilation Units with Heat Recovery (11-2018) [11]

2.2.8 Sales of Ventilation Units in the Ecodesign Impact Accounting

The Ecodesign Impact Accounting (EIA) [12] collects data from the impact assessments and preparatory studies for all products with an ecodesign and/or energy labelling regulation and combines them inside a common calculation methodology. For Ventilation Units, the sales and stock data in EIA are the same as those in the 2014 impact assessment [13], which on their turn are based on the preparatory studies [14] [15] and supplementary study [16] of 2009-2012. The latter studies are generally based on data from 2008 or before. The EIA Sales and Stock over the period 1990-2050 are shown in Figure 19 and Figure 20. See Annex II.5 for table values.

The Building-Ventilation Model (BVM) that is developed in the current study has been calibrated in such a way that the EIA sales and stock up to 2010 are approximately maintained. The average lifetime of Ventilation Units used in EIA (17 years) is also maintained in the current study.

As will be shown in the next paragraph, the number of new-built dwellings in the period 2000-2014 is irregular, showing a peak around 2006-2007 and a strong decrease (-50%) in the period 2008-2014. Although this decrease in new-built dwellings is mitigated by an increase in number of renovated dwellings, this effect of the 2008-2009 economic crisis is probably not completely reflected in the data underlying EIA. For this reason it has been accepted that starting from around 2010 the BVM gives lower VU sales than EIA. As an example, EIA projected BVU sales of 940 thousand in 2017, while Eurovent data (par. 2.2.5) indicate 460 thousand, less than half.

As regards the projection for 2020-2050, the BVM makes new assumptions for the effect of the EPBD provisions on the sales of Ventilation Units (see following paragraphs). In general these assumptions lead to higher sales in the BVM than in EIA.

Note that EIA (and underlying studies) used the limit of 125 W per fan to distinguish between residential (RVU < 125 W) and non-residential (NRVU > 125 W). This reflects the subdivision used in ProdCom data for fans. However, Ecodesign regulation 1253/2014 and energy labelling regulation 1254/2014 use an RVU-NRVU subdivision based on maximum flow rate. For the regulations, a VU is 'residential' if the maximum flow rate does not exceed 250 m3/h or if the maximum flow rate is between 250 and 1000 m3/h and the manufacturer declares its intended use as being exclusively for a residential ventilation application. Otherwise the VU is 'non-residential' for the purposes of the regulations. Following the regulation, in this study it has been preferred to use a subdivision of base cases based on maximum flow rate.

Note that VUs that are 'residential' for the regulations can also be used in the non-residential sector, e.g. in small shops or offices. Vice versa, VUs that are 'non-residential' for the regulations could also be used in residential applications, e.g. in collective solutions for multi-family dwellings. As the current study attempts to link the number of VUs to the number of dwellings/buildings, this becomes relevant for the model.

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[12] https://ec.europa.eu/energy/en/studies/ecodesign-impact-accounting-0

[13] COMMISSION STAFF WORKING DOCUMENT, IMPACT ASSESSMENT, Accompanying the document 'Commission Regulation implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for ventilation units' and 'Commission Delegated Regulation implementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of ventilation units', , {SWD(2014) 222 final}, European Commission 2014

[14] Preparatory study on the environmental performance of residential room conditioning appliances (airco and ventilation), Study on residential ventilation - Final report, February 2009, co-ordinator: Philippe RIVIERE, ARMINES, France

[15] Sustainable Industrial Policy – Building on the Ecodesign Directive – Energy-Using Product Group Analysis - Lot 6: Air-conditioning and ventilation systems, Final Report, prepared by Armines, VHK and BRE, June 2012.

[16] Supplements to Preparatory Study on Residential Ventilation LOT 10 (i.e. mechanical ventilation units with fans < 125 W), Fachinstitut Gebäude-Klima e.V., Contact : Claus Händel, final draft July 2010

EIA does not report data on small local UVUs. The reason for this is probably that these small VUs are assumed to be below 30 W and thus exempted from the regulations. The current study has to take into account these small UVUs, to evaluate the opportunity to include them in the regulation. In the BVM they are split in UVUs for continuous operation (traditionally counted as ventilation units) and UVUs for non-continuous operation (for temporary use in bathroom, toilet, kitchen, laundry; traditionally not counted as ventilation units)[17].

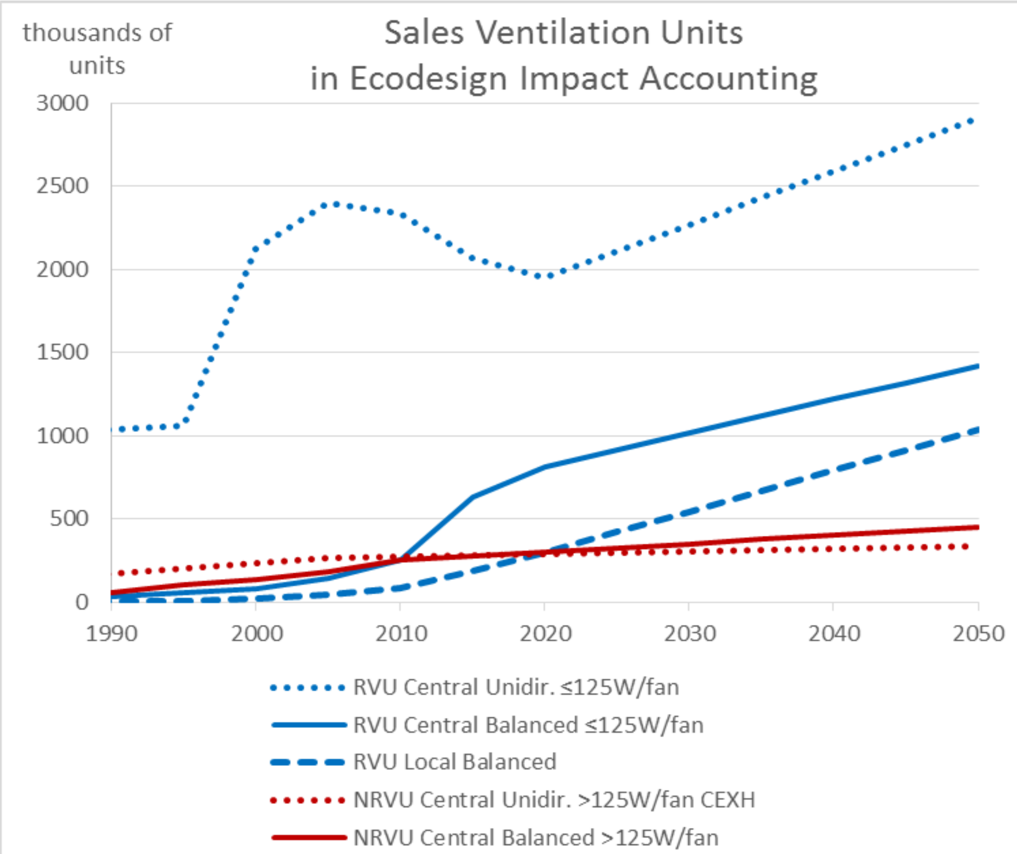


Figure 19. Annual sales of Ventilation Units in the Ecodesign Impact Accounting (EU-28)

[17] UVUs for non-continuous use are not taken into account in the final scenario analysis in Task 7, because it is not proposed to include them in the regulation. In addition, the final scenario analysis does not consider the use of local VUs in the non-residential sector, because they are considered to have negligible impacts.

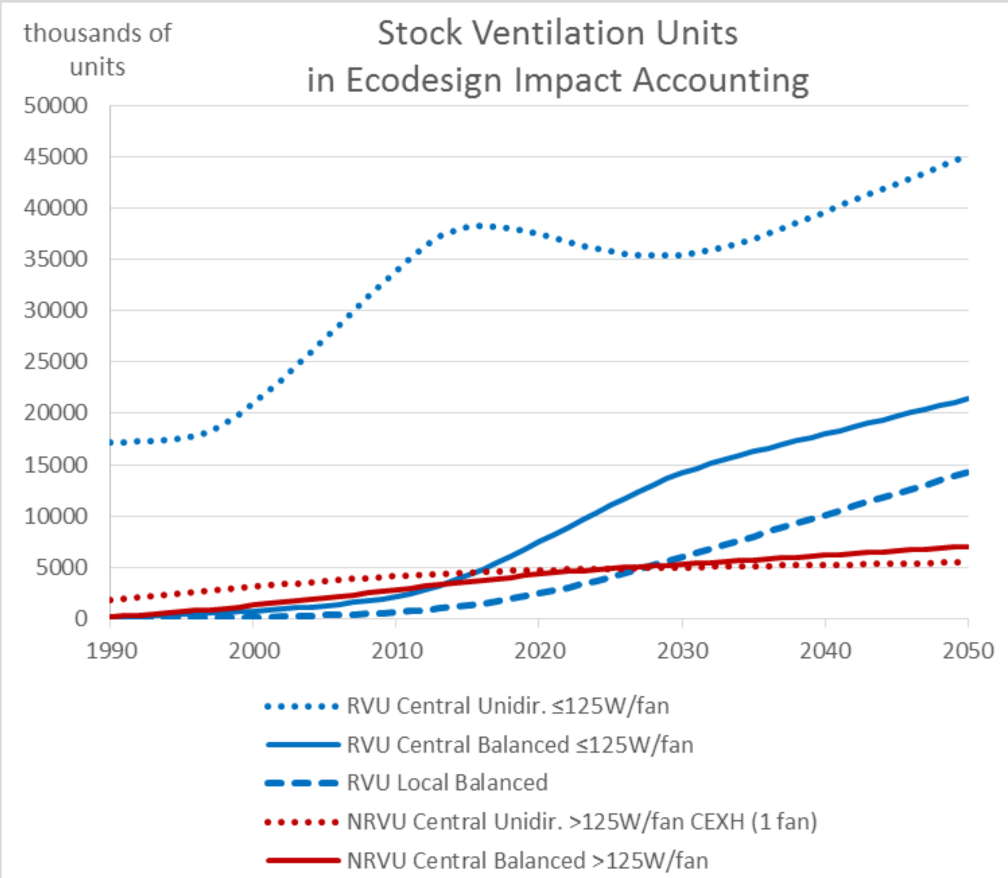


Figure 20. Installed stock of Ventilation Units in the Ecodesign Impact Accounting (EU-28)

2.2.9 EU Building Heat Demand report

The 2014 Building Heat Demand report provides data on residential dwellings, their ventilated volume, and the types of ventilation used, for year 2010. Details and reference in Annex II.6. Elaborating these data, 69% of the residential dwellings in 2010 used natural ventilation. This percentage is higher in single family dwellings (SFD, 75%) and lower in multi-family dwellings (MFD, 63%). Unidirectional ventilation (exhaust or supply) was used in 29% of the dwellings (23% of SFDs and 35% of MFDs). Only 1.6% of the dwellings used balanced ventilation, of which 75% with heat recovery.

2.2.10 Lot 10 Supplementary study

The 2010 supplementary study on Lot 10 by FGK [18] provides a detailed estimate of the 2003 sales and stock of residential Ventilation Units (< 125 W), including the distribution over 27

[18] Supplements to Preparatory Study on Residential Ventilation LOT 10 (i.e. mechanical ventilation units with fans < 125 W), Fachinstitut Gebäude-Klima e.V., Claus Händel, FINAL DRAFT 01-07-2010, (in particular Appendices 2 and 3), https://www.eup-network.de/updates/preparatory-studies-news/news-detail/lot-10-residential-room-conditioning-appliances-additional-report-on-residential-ventilation/

Member States (Croatia not included) and including the assumptions made to derive the distribution from the number of dwellings and from anecdotal market data.
This distribution over the Member States has largely been maintained over the period 1990-2015 (except for countries where more recent data was available), but applying scale factors depending on the years to approximately match the EU totals from e.g. Ecodesign Impact Accounting and Eurovent sales data. The distribution is reflected in the tables of Annex IV.

2.2.11 Lot 6 preparatory study

The 2012 Lot 6 preparatory study [19] in the Task 7 report provides sales and stock data for non-residential ventilation units over the period 1990-2050. These data are identical to those in the 2014 Impact Assessment [20] and in the Ecodesign Impact Accounting (par. 2.2.8). The sales in 2015 amount to 560 thousand units of which approximately half are CEXH (CUVUs) and the other half AHUs and CHRVs (CBVUs).

The study subdivides the Air-handling Units (AHUs) in three maximum flow rate categories:
AHU-L (> 14500 m3/h)
AHU-M (5500-14500 m3/h)
AHU-S (2550-5500 m3/h)

Central Heat Recovery Ventilation (CHRV) units are reported to have maximum flow rates from 300 to 2250 m3/h.

Table 9. Sales and Stock of Non-Residential Ventilation Units (in millions) from previous studies

(source: 2012 preparatory study [34])

Table 7- 6. SALES of Energy-related Product (in mln. units/yr)

Category >	year--	1990	1995	2000	2005	2010	2015	2020	2025	2030	2050
CEXH		0.168	0.205	0.237	0.262	0.276	0.282	0.290	0.297	0.304	0.304
CHRV		0.000	0.027	0.043	0.070	0.112	0.124	0.137	0.151	0.166	0.203
AHU-S		0.000	0.009	0.014	0.023	0.038	0.041	0.044	0.047	0.051	0.058
AHU-M		0.029	0.033	0.039	0.045	0.052	0.056	0.060	0.065	0.070	0.081
AHU-L		0.032	0.037	0.043	0.049	0.054	0.057	0.060	0.063	0.066	0.073
TOTAL		**0.229**	**0.311**	**0.376**	**0.449**	**0.532**	**0.560**	**0.590**	**0.623**	**0.658**	**0.646**

The sales quantities reported in Table 9 for CEXH/CUVU and CHRV/CBVU for the period 1990-2015 have essentially been maintained in the current study, although 14% has been subtracted to scale quantities down from EU28 to EU27 (excl. UK). The same is true for the sum of the AHU-sales, but the subdivision of sales over the S, M and L sizes had to be changed, to obtain a reasonable share of total non-residential building area covered by VUs. As an illustration of the need for this change, the AHU-L annual sales of 0.054-0.060 mln, together with a lifetime of 17 years, imply an AHU-L stock of almost 1 mln units. The reference building area covered by an AHU-L was originally estimated to be close to 10 000 m^2 (nominal

[19] Sustainable Industrial Policy – Building on the Ecodesign Directive – Energy-Using Product Group Analysis/2 - Lot 6: Air-conditioning and ventilation systems - Final Report Task 7 - Policy- and scenario analysis - Prepared by VHK - 14 June 2012, Main contractor: ARMINES, France, Project leader: Philippe RIVIERE

[20] COMMISSION STAFF WORKING DOCUMENT, IMPACT ASSESSMENT, Accompanying the document 'Commission Regulation implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for ventilation units' and 'Commission Delegated Regulation implementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of ventilation units', {C(2014) 4517 final}, {SWD(2014) 223 final}

flow of 35 000 m^3/h). This would imply that AHU-Ls alone cover close to 10 000 Mm^2 of non-residential building area. Estimates for the total EU-27 non-residential building heated floor area in 2015 range from 7 000 to 11 000 Mm^2. Hence, using the sales quantities from the 2012 preparatory study, the non-residential building area covered by all NRVUs and AHUs would be more than twice the total building area. To resolve this discrepancy, AHU-L sales were drastically reduced, and AHU-S and AHU-M sales correspondingly increased (as said: the sum of AHU sales from the 2012 study was maintained, also because this sum is compatible with Eurovent's total AHU sales for 2017, see section 2.2.5). In parallel, the reference flow rates and corresponding building areas covered by a VU have been reduced, e.g. for AHU-L the final value taken is 7 000 m^2.

In the same 2012 report in Task 2, additional data are presented for the 2008 sales and stock, but these are for the collective residential and non-residential sectors together, and in general the quantities are higher than the final non-residential values presented in Task 7. The Task 2 data (details in Annex II.7) also include the ventilated volumes and the shares covered by each type of ventilation. In addition a number of LHRV and 'local fans' is reported, that do not appear in the final Task 7 table, nor in the Impact Assessment or the Ecodesign Impact Accounting, probably because these VUs are below 250 m^3/h and thus have been considered to be 'residential'.

2.3 EU Population and Households

The number of persons living in EU-27 (EU-28 excl. UK) and the number of households are relevant for the projection of the number of residential dwellings (next paragraph).

Data on EU-27 population have been taken from Eurostat, including the projection up to 2050 (details in Annex III.1).

In 2015 there were 444 million persons living in EU-27. This number is projected to increase to 449 mln by 2040. From 2040 onwards, total EU population is projected to slightly decrease.

Data on EU-27 households have been taken from Eurostat where available. For earlier and later years, trends in the number of persons per household were used to compute the number of households from the population (details in Annex III.2).

In 2015 there were 191 million households in EU-27, on average consisting of 2.30 persons. This is projected to increase to 200 mln households by 2030 and 202 mln by 2040, with 2.24 persons on average. From 2040 onwards, the number of households is projected to remain stable or decrease.

The slow-down in growth of the number of households, and the projected decrease from 2040, are relevant for the projection of the number of new-built dwellings.

2.4 EU Buildings model: residential dwellings

Purpose
The purpose of creating a model for the EU-27 stock of dwellings is to develop a projection for the number of new-built dwellings and for the number of renovated dwellings. The construction and renovation of dwellings are the moments where energy-related measures can be taken, such as the implementation of ventilation units.

In the Building-Ventilation Model (BVM) the projection of the sales of ventilation units has therefore been linked to the number of new-built and renovated dwellings. This model takes into account the provisions of the EPBD, i.e. all new-built to be NZEB by 2020, and the entire EU-27 stock of buildings to be NZEB by 2050. Although NZEB does not necessarily imply the use of balanced ventilation units (BVU) with heat recovery (HR), the provisions of the EPBD are expected to lead to a strong increase in the sales of BVUs.

Obviously, it would have been much easier to 'just' make an educated guess of the rate of increase in the sales of BVUs over the 2020-2050 period, but the study team preferred to try to make it more explicit what the EPBD actually means for ventilation units. The approach clarifies:

- The assumptions made for the number of new-built dwellings,
- The target set for the number of dwellings to be renovated by 2050,
- The assumptions made for the implementation of VUs in new-built dwellings,
- The assumptions made for the implementation of VUs in renovated dwellings.

Considering the different ventilation habits and needs in the EU Member States, the approach is diversified per country. **Stakeholders are invited to verify the data for their country (and the overall European total as far as possible) and send their corrections and comments to the study team so that the model can be improved**.

Data sources and elaboration
Data on the residential dwelling stock and its composition have mainly been taken from the EU Building Stock Observatory (BSO) database. These data are available for the period 2000-2014 or a shorter period. Data are not always complete, and errors and inconsistencies were also encountered. The study team corrected evident errors and estimated missing data. Before 2000 and after 2014, the data have been extrapolated, mainly based on the relation between the number of dwellings and the number of households. Details and references are provided in the notes in Annex III, points 3 - 8.

Number of dwellings
In 2015 there were 223 mln residential dwellings in EU-27 (i.e. EU-28 excl. UK). This is interpreted to include around 15% secondary dwellings (holiday homes). Similar to the population and the number of households, the total number of residential dwellings is projected to almost stabilize by 2030 (235 mln) and decrease from 2040. Details in Annex III.3.

The number of permanently occupied residential dwellings in 2015 was 187 mln. This is 85% of all residential dwellings, and in good approximation equal to the number of households (0.98 permanently occupied dwellings per household). Around 46% of the dwellings are single family houses (detached-, semi-detached- or terraced houses) and 54% are apartments in multi-family buildings (city-blocks, low-rise or high-rise apartment buildings). Similar to the population and the number of households, the number of permanently occupied residential dwellings is projected to almost stabilize by 2030 (198 mln) and decrease from 2040. Details in Annex III.4.

Size of dwellings
In the EU Buildings database, data on the size of dwellings are available for years 2000-2014 (when integrating some missing year/country data by estimation). For later years, the EU-27 total dwelling area has been estimated from the number of dwellings, assuming that the average dwelling size remains the same as in 2014. For earlier years, the 2010=>2000 backwards and downwards trend in average dwelling size has been extrapolated until 1990.

In 2015, the EU-27 total dwelling area was 20 034 Mm^2 with an average size of 90.0 m^2 per dwelling. For permanently occupied dwellings the area was 17 510 Mm^2 with an average of 93.6 m^2 per dwelling.

The total EU-27 area of permanently occupied dwellings is projected to increase to 18 519 Mm^2 in 2030 and to remain almost stable in later years.

The total EU-27 area of permanently occupied dwellings was used as a reference in the study when performing scenario analysis calculations for ventilation units based on dwelling area. This excludes the area of empty dwellings and secondary dwellings (holiday homes) where VUs are less frequent, and used for a very limited time, or not used at all.

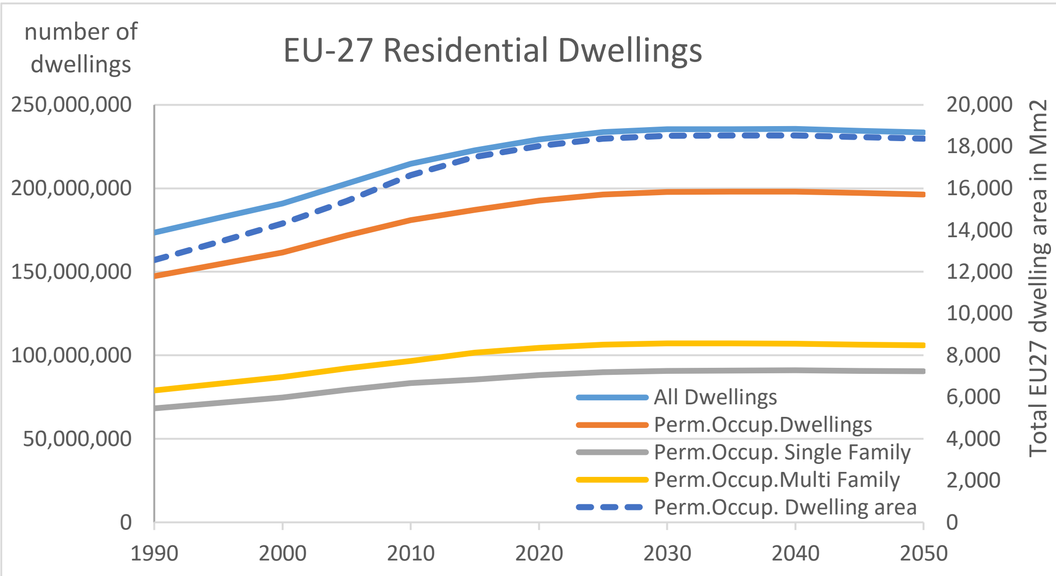


Figure 21. EU-27 Number of residential dwellings: all, permanently occupied, single family and multi-family, and total EU-27 area of permanently occupied dwellings in Mm^2.

(source: EU Buildings Observatory 2000-2014; VHK elaboration and extrapolation)

Number of new-built dwellings

Available data from the EU BSO database, and their elaboration by VHK, show a strong variation in number of new-built residential dwellings. In the period 1990-2000, annually around 2.0 mln dwellings were built in EU-27, but this gradually increased to a peak of 2.7 mln dwellings in 2006 (mainly in multi-family dwellings). Due to the economic crisis, starting from 2008, the annual number of new-built dwellings decreased to a minimum of 1.2 mln in 2014, less than half of the 2006 value.

The share of new-built dwellings in the total stock was around 1% before 2000, with peaks of 1.2% around 2006-2007, and decreasing to 0.6% in 2014.

The number of new-built dwellings is projected to increase again to 1.6 mln (0.7% of stock) by 2020, compensating for the deficit of new-built in earlier years. After 2020 the number is expected to gradually decrease to 0.9 mln (0.4% of stock) in 2050, reflecting the slowdown in growth, and later the decrease, in population and in number of households.

The future projection assumes that, from 2025, the share of new-built dwellings is identical to the annual increase in total dwelling stock plus an assumed share of dwellings being demolished. In absence of data, the latter share is estimated to increase from 0.1% in 2015 to 0.3% in 2030 and later years. For many countries, the number of households is projected to decrease from 2040, and this is reflected in the variation of the dwelling stock and thus in the number of new-built dwellings. For these countries / years the new-built dwellings replace the demolished dwellings. Details in Annex III.5.

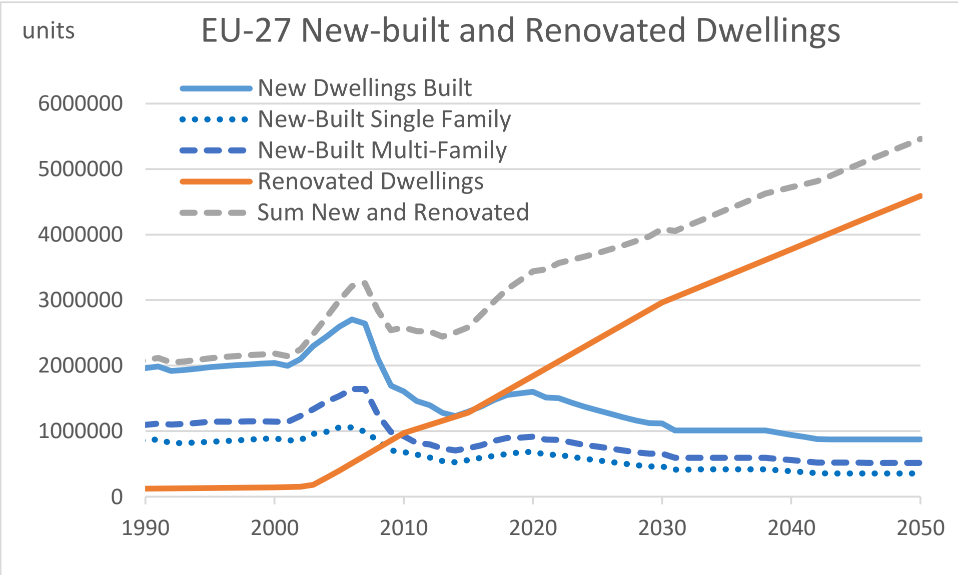


Figure 22. EU-27 Number of New-built and Renovated residential dwellings. New-built subdivided in single family dwellings and multi-family dwellings. Sum of New-Built and Renovated dwellings also shown.

Number of renovated dwellings

The number of dwellings that has been renovated up to 2015 is uncertain. This is due to scarcity of data and to a lack of clarity of what the available data actually mean: different countries use different definitions for 'light', 'medium' or 'deep' 'renovation'. This problem was also encountered by the ZEBRA project, which introduced a 'major renovation equivalent rate' (Annex III.6) and by the Impact Assessment study for the recast of the EPBD, which defined a 'full thermal renovation rate' (Annex III.7).

The current study uses the annual renovation rates reported by ZEBRA and by the IA for the EPBD as a reference and consequently accepts their rather vague definitions of which level of renovation is intended. For this study it is sufficient to conceive renovation as an occasion to install or upgrade ventilation units in a dwelling. This does not mean that every renovated dwelling is assumed to install a ventilation unit: the share of renovated dwellings that installs a certain type of VU is defined separately. The number of VUs sold for renovated dwellings depends both on the renovation rate (part of the 2015 dwelling stock being renovated) and on the share of renovated dwellings installing a VU.

The number of dwellings being renovated in a year is computed multiplying the permanently occupied dwelling stock by an annual renovation rate. For years before 2015 the rates refer to the stock of that year; for 2015 and later the rates refer to the 2015 dwelling stock. The annual renovation rates have been determined as explained in the notes in Annex III.8. Main points:

- For countries where data are available, the 2015 renovation rates are based on ZEBRA information. For other countries a rate of 0.1% is used in 2015. The average EU renovation rate is then 0.61%, which is the value used in the IA for EPBD for 2015.
- In 2003 a renovation rate of 0.05% has been used, as suggested in the 2010 supplementary report on Lot 10 by FGK.
- In 1990 and earlier years the renovation rate has been set to 0.02%.

- As regards the projection for 2015-2050, the model sets a target for the part of the 2015 dwelling stock that will have to be renovated by 2050. This part is derived by subdividing the 2015 dwelling stock in dwellings built before 1990 (78%) and dwellings built between 1990 and 2015 (22%). For the latter group it is assumed that 30% will be renovated by 2050 (same % for all countries). For the former group it is assumed that 20% has already been renovated in 2015 and will not be renovated again before 2050 (this % varies per country from 15% to 25%). In addition it is assumed that 9% of the 2015 dwelling stock will have been demolished by 2050, and thus needs not be renovated. Overall, this gives a **target of 60% of the 2015 dwelling stock to be renovated by 2050**. This % varies per country, from 46% to 69%, depending on the average age of the 2015 dwelling stock and on the part of that stock that was already renovated in or before 2015 (see Table 105 in Annex III.8).

  Based on the renovation target for 2050, annual renovation rates for the 2015-2050 period have been derived. The 2030 renovation rates have been scaled in such a way that the overall EU renovation rate of 1.6% used in the IA for the EPBD is obtained.

As a result, it is estimated that in 2015 around 1.3 mln dwellings were renovated in EU-27. This is 0.61% of the 2015 permanently occupied dwelling stock. Stimulated by the EPBD, it is projected that renovations will gradually increase to 3.0 mln in 2030 (1.6% of the 2015 stock) and to 4.6 mln in 2050 (2.6% of the 2015 stock). Cumulatively this means that 60% of the 2015 dwelling stock will be renovated between 2015 and 2050. See Figure 22 for a graph and Annex III.8 for details.

2.5 EU Buildings model: non-residential buildings

Data on the EU non-residential building stock are available from e.g. the EU Building Stock Observatory (BSO) database, the ZEBRA-project, the 2014 EU Buildings Heat Demand report and a 2011 Ecofys report. Details and references in Annex V. These data are not complete and not always reliable. This situation has been recognized by the European Commission, and work is ongoing to improve the data accessibility, availability and quality [21].

Number of non-residential buildings

The **total number of non-residential buildings in EU-27** reported in the EU BSO database for years 2010-2013 (14.2 to 14.5 mln) has been accepted for use in this study, although for many countries this stock does not seem to be complete (Annex V.1). The average annual increase in number of buildings over the 2010-2013 period has been assumed to remain the same up to 2050, implying an increase in non-residential building stock varying from 0.5% in 2015 to 0.42% in 2050. This leads to 16.0 mln buildings in 2030 and 17.8 mln in 2050 (in EU-27, excl. UK).

The limited available data indicate an annual new-construction rate around 1% of the building stock for years 2010-2013 (Annex V.4). Considering that the annual increase in stock is around 0.5%, this implies a demolition rate of also around 0.5%. This demolition rate has been assumed to slightly decrease to 0.35% in 2050, leading to a new construction rate varying from 1% in 2015 to 0.77% in 2050. The annual **number of new-built non-residential buildings in EU-27** then varies from 146 thousand in 2015 to 130 thousand in 2030 and 138 thousand in 2050.

The renovation rate suggested by the Impact Assessment for the EPBD recast (Annex III.7) for 2015 (0.7%) has been copied for the current study, but the suggested value for 2030

[21] See e.g. EU Building Stock Observatory Workshop 2, 31st January 2019, https://aldren.eu › uploads › 2019/02 › EU-BSO-Workshop_2_-2019

(1.7%) has been reduced to 1.4% (see notes on building area below). Linear interpolation is used in intermediate years. For the period 2031-2050 a constant value of 1.4% has been set. For all years, these rates are applied to the 2015 non-residential building stock, and cumulatively lead to 45% of the 2015 stock being renovated between 2015 and 2050. The annual **number of renovated non-residential buildings in EU-27** is then 103 thousand in 2015 and increases to 206 thousand in 2030 and later years.

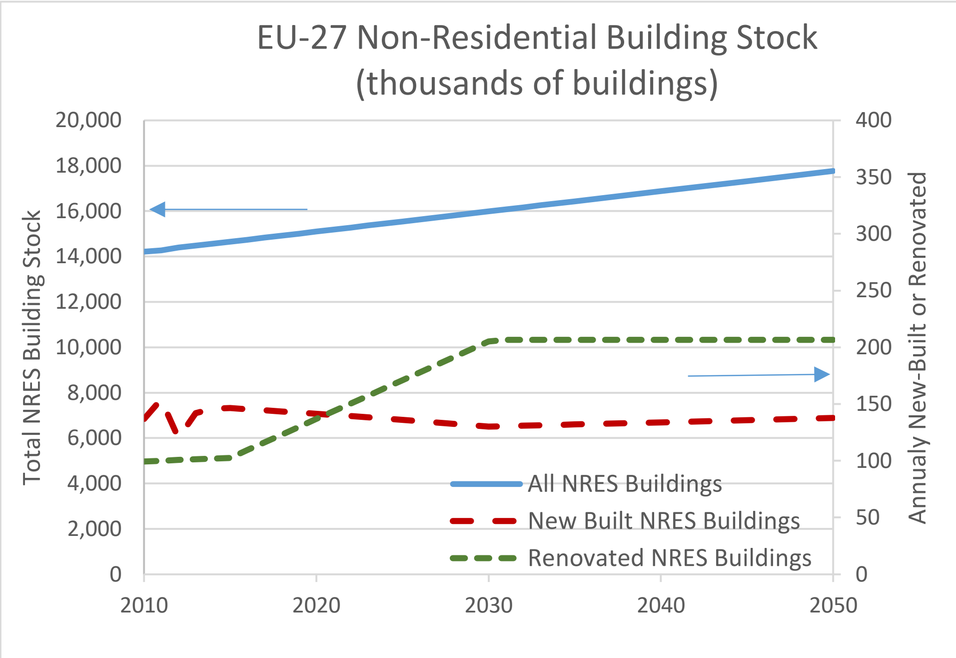


Figure 23. EU-28 Non-Residential Building Stock used in this study (thousands of buildings): total stock (left axis), annual new built and annual renovated (right axis)

(source: BVM model, VHK 2020)

Table 10. EU-27 Non-Residential Building Stock (thousands of buildings)

(source: BVM model, VHK 2020)

EU-27	2010	2011	2012	2013	2014	2015	2020	2025	2030	2040	2050
Total Stock	14,209	14,271	14,398	14,476	14,565	14,654	15,098	15,543	15,987	16,876	17,765
New-built	137	154	120	142	146	146	141	136	130	134	138
Renovated	99	100	101	101	102	103	137	171	206	206	206
Share New-built	0.96%	1.08%	0.83%	0.98%	1.00%	1.00%	0.94%	0.88%	0.81%	0.79%	0.77%
Share Renovated	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.93%	1.17%	1.40%	1.40%	1.40%

Size of non-residential buildings

For calculations on ventilation units in non-residential buildings, the number of buildings reported above is not an adequate parameter, because the various types of NRVUs differ considerably in the reference building area covered by a single device, ranging from 200 m^2 for the smallest NRVU models (250-1000 m^3/h) to 7000 m^2 or more for the largest AHUs. In particular, the stocks (and related sales) of the various types of NRVU should be established in such a way (see sections 2.8 and 2.9) that multiplying these stocks by the corresponding reference building area per NRVU, all NRVUs together cover a reasonable share of the total non-residential building area.

Unfortunately, the total size of non-residential buildings in EU-27, and its distribution over building size classes, is uncertain. The EU BSO database reports values for EU-28 (incl. UK) around 7 000 Mm^2 for years 2011-2013. These values seem to be compatible with those reported in the IA for the EPBD [22] for 2023 (7 507 Mm^2) and for 2030 (7 862 Mm^2). However, a 2011 Ecofys study [23] estimates between 10 625 Mm^2 and 13 291 Mm^2 (depending on which building types are taken into account) and the 2014 VHK Building Heat Demand (BHD) study [24] reports an EU-28 total of 11 773 Mm^2. Most likely, the EU BSO values are without industrial, agricultural and 'other' types of buildings. In addition, studying the underlying country data, a part of the tertiary sector buildings might also be missing. Consequently, values from the EU BSO database seem too low to be used as a reference in this study. Considering that the 2014 BHD study was commissioned by the European Commission with the aim to create a single reference for all studies requiring building heat demand data, these data have been used as reference in this study. This also ensures compatibility with the recent review study on central heating boilers, where the same reference was used.

For the EU-27 this leads to a total (heated floor) area of non-residential buildings of 10 016 Mm^2 in 2015. This area is assumed to vary with the years in the same way as assumed above for the total number of buildings. The shares new-built and renovated applied above to the number of buildings have been assumed to apply also to the building area.

Table 11. EU-27 Non-Residential Building Stock area (million m^2)

(source: BVM model, VHK 2020, based on 2014 VHK Building Heat Demand study)

EU-27, in Mm^2	2010	2015	2020	2025	2030	2040	2050
Total Stock Mm^2	9,685	10,016	10,264	10,513	10,761	11,258	11,756
New-built	93	100	96	92	88	89	91
Renovated	68	70	96	123	151	158	165
Share New-built	0.96%	1.00%	0.94%	0.88%	0.81%	0.79%	0.77%
Share Renovated	0.7%	0.7%	0.93%	1.17%	1.40%	1.40%	1.40%

2.6 Sales of Ventilation Units for residential dwellings

Methodology, first step

In a first step, the BVM model determines sales for four main residential VU types:

- **CBVU**: Balanced Ventilation Units with maximum flow > 100 m^3/h, mainly for Central use, i.e. ventilating an entire dwelling. Typically expected to have an air to air heat exchanger (recuperative or regenerative, with or without humidity recovery).

[22] COMMISSION STAFF WORKING DOCUMENT, IMPACT ASSESSMENT, Accompanying the document Proposal for a Directive of the European Parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings. {COM(2016) 765} {SWD(2016) 415}, non-residential sum in Table 19

[23] Ecofys, 2011, Panorama of the European non-residential construction sector, table 13: 10,625, excluding 'other' buildings, but including industrial; 12,357 including also 'other'. However, in table 16 total value is 13,291.

[24] Average EU building heat load for HVAC equipment, final report, René Kemna, VHK, Prepared for the European Commission DG ENER C.3, August 2014. Further elaboration by VHK reported in: Preparatory study on lighting systems , 'Lot 37', VITO / VHK / Kreios / P.Waide for the European Commission DG ENER C3, December 2016. Data assumed valid for year 2014

- **LBVU**: Balanced Ventilation Units with maximum flow ≤ 100 m^3/h, mainly for Local use, i.e. ventilating a single room or a part of a dwelling. Typically expected to have an air to air heat exchanger (recuperative or regenerative, with or without humidity recovery).

- **CUVU**: Unidirectional Ventilation Units with maximum flow > 100 m^3/h, mainly for Central use, i.e. ventilating an entire dwelling. With or without air-to-water heat pump for e.g. DHW.

- **LUVUc**: Unidirectional Ventilation Units with maximum flow ≤ 100 m^3/h and intended for continuous (c) operation (basis/DCV ventilation when absence, nominal/DCV ventilation when presence), mainly for Local use, i.e. ventilating a single room or a part of a dwelling. With or without air-to-water heat pump for e.g. DHW.

For each of these four main VU types, the sales are determined per Member State and separately for new-built dwellings, renovated dwellings and like-for like replacements. Member State contributions are then summed to a EU-27 (excl. UK) or EU-28 total.

Sales of a VU-type for new-built or renovated dwellings in a Member State are computed multiplying the number of new-built or renovated dwellings in that Member State by the country-specific share of those dwellings installing the VU-type, and by the average number of VUs installed per dwelling (which can be higher than 1 if a single dwelling uses several local VUs, or less than 1 if the same central VU services several dwellings).

Replacement sales of a VU-type in a Member State are taken as a share (90-100%) of the VUs reaching End-of-Life (EoL), which are the total sales of lifetime years ago (17 years). Note that not all VUs reaching EoL will actually be replaced like-for-like:

- some will be replaced by a VU of a different type (e.g. BVU substituting UVU), but this is counted under renovation and should not be double-counted as replacement sale,
- some will be repaired, substituting parts, without a complete replacement,
- some dwellings with VUs reaching EoL will be demolished,
- some dwellings with VUs reaching EoL may remain vacant.

Summarizing, the sales for ventilation units of type XVU in a given year (y) for a Member State (M) are determined as:

Sales XVU (y,M) =				
New Dwellings (y,M)	x	Share of New Dwellings using XVU (y,M)	x	XVU per Dwelling +
Renovated Dwellings (y,M)	x	Share of Renovated Dwellings using XVU (y,M)	x	XVU per Dwelling +
Sales XVU (y-lifetime, M)	x	Share of EoL XVU actually being replaced		
XVU: CBVU, LBVU, CUVU or LUVUc				

The number of dwellings (new-built or renovated) is presented in section 2.4 and Annex III.

The number of VUs per dwelling depends on the ratio between the average dwelling size (93 m^2) and the reference dwelling area covered by a single VU. For local VUs the reference area is 33 m^2, resulting in 2.79 LVUs per dwelling. For central VUs the average reference area is 270 m^2, resulting in 0.344 CVUs per dwelling [25].

The shares of new-built or renovated dwellings using CBVU, LBVU, CUVU or LUVUc, are defined in the model in 8 tables, each covering the years from 1970 to 2050 and all Member States. These tables are included in Annex IV.2.

[25] The average of 270 m^2 derives from 43% sales of VUs with 100-250 m^3/h (reference 100 m^2) and 57% sales of VUs with 250-1000 m^3/h (reference 400 m^2)

For years up to 2015, the distribution of shares over the VU-types and over the Member States is mainly based on the 2010 supplementary study on Lot 10 by FGK [26], which provides a detailed estimate of the 2003 sales and stock of residential Ventilation Units (< 125 W), including the distribution over 27 Member States (Croatia not included) and including the assumptions made to derive the distribution from the number of dwellings and from anecdotal market data.
The distribution has been adapted for countries where more recent data are available. In addition, scale factors depending on the year have been applied to approximately match the EU total sales from e.g. Ecodesign Impact Accounting and Eurovent data (see paragraph 2.2).

For years 2025-2050 a 'target' distribution of shares has been set, separately for new-built dwellings and for renovated dwellings, depending on the ventilation 'culture' and 'needs' of the various countries. These distributions are presented in Table 12. Linear interpolation is used between 2015 and 2025.

Table 12. Shares of new-built and renovated dwellings implementing a certain type of mechanical ventilation; 'target' values used for the period 2025-2050

	New-built dwellings						Renovated dwellings				
	CBVU	LBVU	CUVU	LUVUc	sum		CBVU	LBVU	CUVU	LUVUc	sum
Austria	45%	25%	10%	0%	80%		35%	20%	15%	3%	73%
Belgium	45%	10%	25%	0%	80%		30%	10%	30%	3%	73%
Bulgaria	45%	25%	10%	0%	80%		30%	25%	3%	5%	63%
Croatia	20%	10%	30%	5%	65%		15%	5%	20%	10%	50%
Cyprus	20%	10%	30%	5%	65%		15%	5%	20%	10%	50%
Czech Rep.	45%	25%	10%	0%	80%		30%	25%	3%	5%	63%
Denmark	70%	20%	10%	0%	100%		60%	15%	15%	3%	93%
Estonia	45%	30%	25%	0%	100%		30%	15%	10%	10%	65%
Finland	100%	0%	0%	0%	100%		67%	23%	5%	0%	95%
France	40%	10%	50%	0%	100%		25%	10%	50%	10%	95%
Germany	35%	25%	10%	0%	70%		30%	25%	3%	5%	63%
Greece	20%	10%	30%	5%	65%		15%	5%	20%	10%	50%
Hungary	45%	25%	10%	0%	80%		30%	25%	3%	5%	63%
Ireland	40%	20%	20%	0%	80%		30%	20%	20%	3%	73%
Italy	20%	10%	30%	5%	65%		15%	5%	20%	10%	50%
Latvia	45%	30%	25%	0%	100%		30%	15%	10%	10%	65%
Lithuania	45%	30%	25%	0%	100%		30%	15%	10%	10%	65%
Luxembourg	40%	10%	30%	0%	80%		30%	10%	30%	3%	73%
Malta	20%	10%	30%	5%	65%		15%	5%	20%	10%	50%
Netherlands	55%	20%	25%	0%	100%		35%	30%	20%	10%	95%
Poland	45%	30%	25%	0%	100%		30%	15%	10%	10%	65%
Portugal	20%	10%	30%	5%	65%		15%	5%	20%	10%	50%
Romania	45%	25%	10%	0%	80%		30%	25%	3%	5%	63%
Slovakia	45%	25%	10%	0%	80%		30%	25%	3%	5%	63%
Slovenia	20%	10%	30%	5%	65%		15%	5%	20%	10%	50%
Spain	20%	10%	30%	5%	65%		15%	5%	20%	10%	50%
Sweden	70%	20%	10%	0%	100%		65%	25%	5%	0%	95%
United Kingdom	40%	20%	20%	0%	80%		30%	10%	30%	3%	73%

[26] Supplements to Preparatory Study on Residential Ventilation LOT 10 (i.e. mechanical ventilation units with fans < 125 W), Fachinstitut Gebäude-Klima e.V., Claus Händel, FINAL DRAFT 01-07-2010, (in particular Appendices 2 and 3), https://www.eup-network.de/updates/preparatory-studies-news/news-detail/lot-10-residential-room-conditioning-appliances-additional-report-on-residential-ventilation/

Methodology, second step

In a second step, the CBVU and CUVU sales quantities derived in the first step have been further subdivided in two flow rate categories, but this is done only at EU-level (not per country) and using the same percentage subdivision for all years:

- CBVU or CUVU 251-1000 m^3/h (57% of sales)
- CBVU or CUVU 101-250 m^3/h (43% of sales)

Sales for a third flow rate category, for CUVU > 1000 m^3/h and CBVU 1000-2500 m^3/h, for collective residential use, are added as a share (10%) of the non-residential sales for these VU-types.
The split of CBVU and CUVU in three maximum flow rate categories is based on information from the VHK 2014 Building Heat Demand report (par. 2.2.9) and on information from Eurovent (par. 2.2.5). For details, see Annex IV.**Error! Reference source not found.**.

Also in a second step, LUVUc ≤ 100 m^3/h are further subdivided in those used for Extract Spaces (ES) and those used for Habitable Spaces (HS). The latter start to appear around 2020 and are assumed to increase their share of LUVUc-sales to 10% in 2030 and 20% in 2050.

In addition, only at EU-level, sales for **LUVUnc** are added in a second step. These are Unidirectional Ventilation Units with maximum flow ≤ 100 m3/h but intended for **non-continuous (nc) operation**. These are mainly exhaust fans for toilets, bathrooms, kitchens, laundries, etc., operating for short intervals of time. The reported quantities of LUVUnc are intended to be without range hoods covered by Commission Delegated Regulation (EU) No 65/2014 and Commission Regulation (EU) No 66/2014.
The reasons for separately treating these LUVUncs are:
- They are normally not taken into account when defining the share of dwellings that uses mechanical ventilation, i.e. a dwelling that has only LUVUnc is still considered to be without (controlled) mechanical ventilation.
- Most of the LUVUnc would be expected to be below 30 W and in that case they are exempted from the current regulations. For that reason they were also not inserted in the Ecodesign Impact Accounting.

The estimate for sales of LUVUnc is mainly based on the 2010 Supplementary report by FGK-Händel (par. 2.2.10). For details, see Annex IV.3.

Data for non-continuously operating LUVUs are reported here for reference only; they have not been used for the final scenario analysis in Task 7.

Table 13. EU-28 Total Sales estimate for non-continuously operating LUVUs, for reference only (not used in scenario analysis) (source: VHK 2020, BVM model)

thousands of units (for EU-28)	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
LUVUnc ≤ 100 m3/h, non-continuous operation	3628	3715	3802	3855	3855	3855	3855	3904	3953	4002	4052	4101	4150

Sales of Ventilation Units for residential dwellings

The results of the Building-Ventilation Model in terms of annual sales of ventilation units for the residential sector over the 1990-2050 period are reported below. The sales are split in sales for new-built dwellings, sales for renovated dwellings, and like-for-like replacement sales, and summed up to the EU-27 total sales for the residential sector.

In 2015, a total of 1.2 mln VUs were sold for the EU-27 residential sector. Of these, 0.3 mln were for new-built dwellings, 0.3 mln for renovated dwellings and 0.6 mln were replacement sales. The large majority were CUVUs (0.8 mln units, 72%). BVUs represented 20% of the sales: 0.23 mln units of which 0.08 mln CBVU (> 100 m3/h) and 0.15 mln LBVU (< 100 m3/h). Continuously operating LUVUs represented 7% of the market (0.09 mln units).

Starting from 2020, due to the measures in the EPBD (all new-built dwellings NZEB by 2020; entire EU dwelling stock NZEB by 2050), a strong increase in sales of VUs is projected. This increase is driven mainly by the sales for renovated dwellings that are projected to continue to increase up to 2050. Sales for new-built dwellings show a temporary increase until 2025, but then stabilize or decrease due to the gradual reduction of the number of new-built dwellings. Given the increase in sales from 2020, and the assumed average lifetime of VUs of 17 years, starting from 2037 there is a strong increase in replacement sales. The increase in sales mainly regards BVUs (with heat recovery), that pass from 0.23 mln in 2015 to 2.4 mln in 2030 and 5.3 mln in 2050. In comparison, sales for CUVUs are projected to remain relatively stable: around 1 mln units per year over the entire period.

Table 14. EU-27 Total Sales of Ventilation Units for residential dwellings (thousands), for new-built dwellings, for renovated dwellings, like-for-like replacement sales, and overall total

(source: VHK 2020, BVM model)

thousands of units	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
VU Sales for New-Built Dwellings													
UVU ≤ 100 m3/h ES	12	17	21	29	16	11	10	4	3	2	2	3	3
UVU ≤ 100 m3/h HS	0	0	0	0	0	0	0	1	1	1	1	1	1
BVU ≤ 100 m3/h for HS	3	8	10	15	16	34	80	655	578	514	487	457	456
UVU 100-250 m3/h	52	93	136	215	129	90	85	52	45	41	38	34	34
BVU 100-250 m3/h	4	7	9	19	14	15	20	80	71	63	59	55	55
UVU 250-1000 m3/h	68	122	179	281	169	118	112	68	58	54	50	45	45
BVU 250-1000 m3/h	5	9	12	25	19	20	26	105	93	83	77	72	72
UVU > 1000 m3/h	2	2	2	2	1	1	1	1	0	0	0	0	0
BVU 1000-2500 m3/h	0	0	1	1	2	1	1	1	1	1	1	2	2
Sum new-built	**146**	**259**	**370**	**586**	**366**	**291**	**335**	**966**	**851**	**761**	**716**	**668**	**667**
VU Sales for Renovated Dwellings													
UVU ≤ 100 m3/h ES	3	4	5	16	30	31	36	21	23	24	28	35	40
UVU ≤ 100 m3/h HS	0	0	0	0	0	0	0	4	9	12	14	11	11
BVU ≤ 100 m3/h for HS	4	12	20	75	72	100	219	995	1226	1393	1560	1726	1893
UVU 100-250 m3/h	6	6	7	17	38	50	60	69	84	95	107	118	129
BVU 100-250 m3/h	0	0	1	2	7	8	14	96	122	140	159	178	196
UVU 250-1000 m3/h	8	8	9	22	49	65	79	90	111	125	140	154	169
BVU 250-1000 m3/h	0	1	1	3	9	10	19	126	159	184	208	233	257
UVU > 1000 m3/h	1	1	1	1	1	1	1	1	1	1	1	0	0
BVU 1000-2500 m3/h	0	0	1	1	1	1	1	1	2	2	2	2	2
Sum renovated	**24**	**33**	**45**	**138**	**207**	**265**	**430**	**1404**	**1736**	**1977**	**2217**	**2457**	**2697**
VU Sales for like-for-like Replacements													
UVU ≤ 100 m3/h ES	18	19	21	29	36	43	52	70	68	69	72	58	51
UVU ≤ 100 m3/h HS	0	0	0	0	0	0	0	0	0	0	3	8	12
BVU ≤ 100 m3/h for HS	0	0	1	5	14	25	55	104	124	239	1104	1700	1868
UVU 100-250 m3/h	84	94	112	121	165	217	276	298	271	291	315	255	247
BVU 100-250 m3/h	0	0	0	3	6	8	13	30	30	36	132	196	209
UVU 250-1000 m3/h	110	123	147	158	216	284	362	391	355	381	412	334	324
BVU 250-1000 m3/h	0	0	1	3	8	11	17	39	39	47	173	257	274
UVU > 1000 m3/h	1	2	3	4	5	6	7	7	7	7	7	7	7
BVU 1000-2500 m3/h	0	0	0	0	0	1	2	2	3	4	4	5	6
Sum replacements	**214**	**239**	**286**	**323**	**450**	**595**	**784**	**941**	**897**	**1073**	**2223**	**2820**	**2999**
Total VU Sales for Residential sector													
UVU ≤ 100 m3/h ES	33	40	47	73	82	85	98	100	104	110	121	116	118
UVU ≤ 100 m3/h HS	0	0	0	0	0	0	0	5	10	14	18	20	24
BVU ≤ 100 m3/h for HS	8	19	32	95	102	159	355	1753	1929	2146	3151	3883	4217
UVU 100-250 m3/h	142	194	256	353	331	357	422	419	400	427	459	407	411
BVU 100-250 m3/h	4	8	10	24	27	31	47	206	222	239	350	428	460
UVU 250-1000 m3/h	186	254	335	462	434	468	553	549	524	560	602	533	538
BVU 250-1000 m3/h	5	10	13	31	35	41	62	270	291	313	458	561	603
UVU > 1000 m3/h	5	6	7	7	8	8	8	8	8	8	8	8	7
BVU 1000-2500 m3/h	0	1	1	2	3	4	4	5	6	7	7	9	9
Sum overall	**384**	**531**	**700**	**1047**	**1023**	**1152**	**1549**	**3316**	**3494**	**3825**	**5174**	**5965**	**6387**

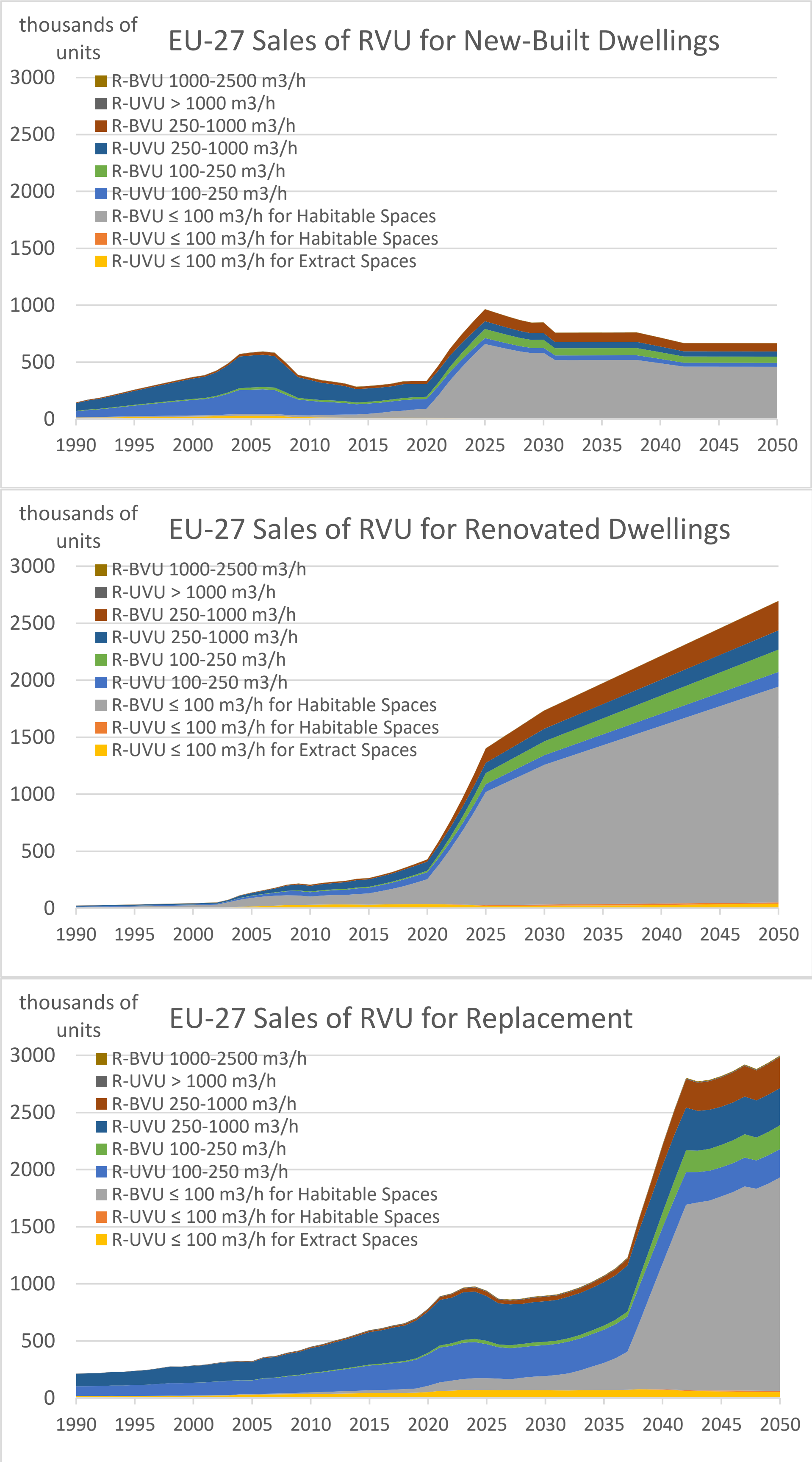


Figure 24. EU-27 Sales of Ventilation Units for residential dwellings (thousands), split in VU for new-built dwellings, VU for renovated dwellings and like-for-like replacement sales
(source: VHK 2020, BVM model)

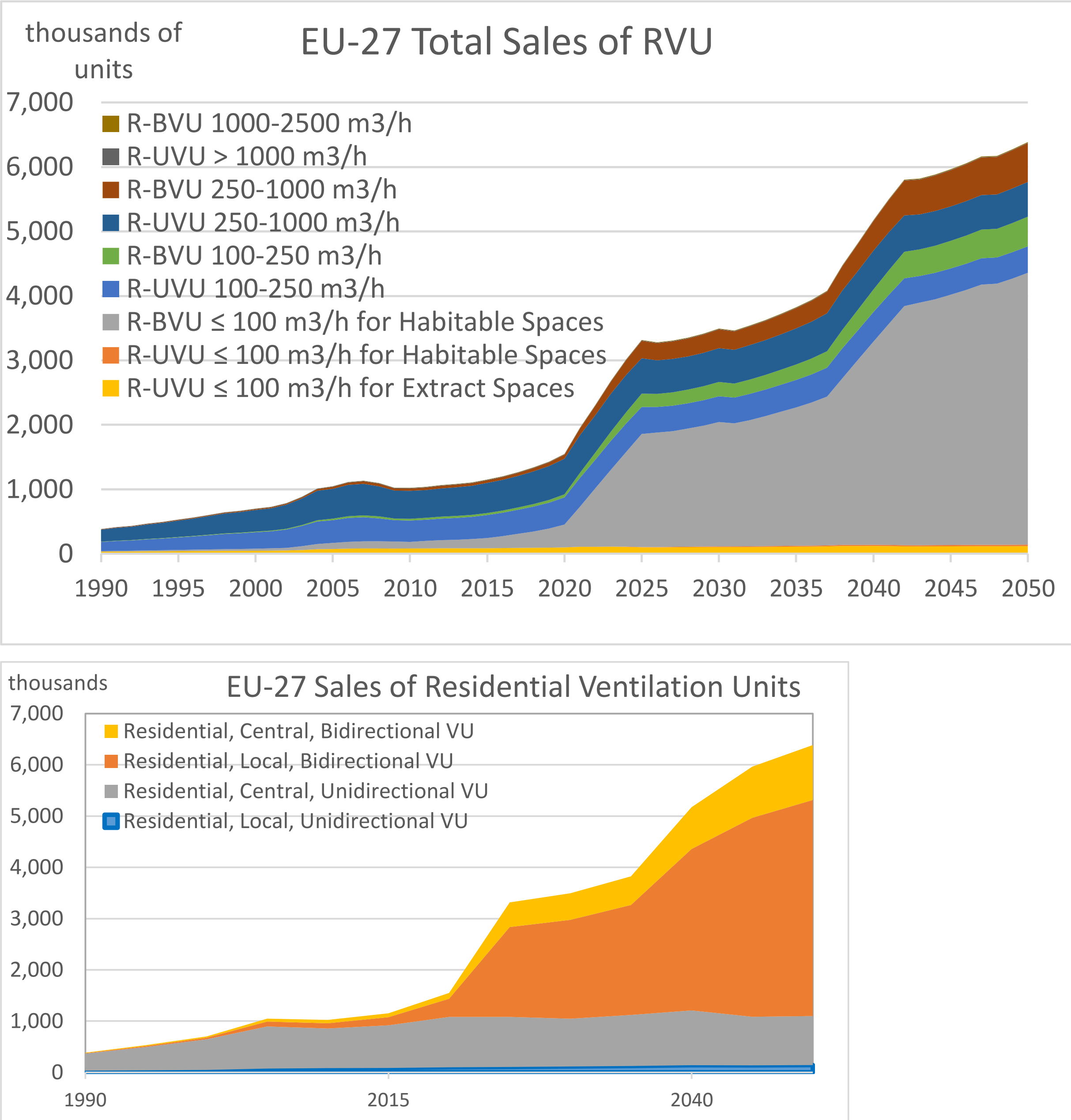


Figure 25. EU-27 Total Sales of Ventilation Units for residential dwellings (thousands) (new-built + renovated + replacements)

(source: VHK 2020, BVM model)

2.7 Stock of Ventilation Units for residential dwellings

The stock of ventilation units is calculated from the sales using the same method as in the Ecodesign Impact Accounting (EIA), i.e. summing for a given year the sales of the lifetime preceding years. An average lifetime of 17 years is assumed for all types of VU. This corresponds to the lifetime used in EIA and in underlying studies.

In 2015, the total stock of VUs used in the residential sector amounted to 16.7 mln units. The large majority were CUVUs (13 mln units, 77%). BVUs represented 15% of the stock: 2.5 mln units of which 0.9 mln CBVU (> 100 m3/h) and 1.6 mln LBVU (< 100 m3/h). Continuously operating LUVUs represented 7% of the stock (1.2 mln units).

In 2015, 23% of the residential permanently occupied dwelling area was covered by a continuously operating mechanical ventilation unit. This implies that 77% of the dwelling area had no mechanical ventilation (except non-continuous LUVU for toilet, bathroom, kitchen, etc.).

Due to the increase in sales of VUs (previous paragraph), the share of permanently occupied dwelling area using mechanical ventilation is projected to increase to 34% in 2030 and 58% in 2050. This increase is mainly due to BVUs (with heat recovery); the stock of UVUs is projected to remain more or less stable.

Table 15. Total EU-27 stock of Ventilation Units for residential dwellings, in thousands of units (top) and in million m² of dwelling area covered (bottom)

(source: VHK 2020, BVM model)

thousands of units	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
UVU ≤ 100 m3/h ES	394	481	598	770	1,003	1,217	1,432	1,573	1,667	1,759	1,832	1,904	1,969
UVU ≤ 100 m3/h HS	0	0	0	0	0	0	0	16	56	118	194	259	316
BVU ≤ 100 m3/h HS	32	105	238	533	1,022	1,590	2,702	8,137	16,757	25,906	35,676	45,646	56,349
UVU 100-250 m3/h	1,928	2,321	2,929	3,866	4,863	5,527	6,113	6,513	6,831	7,072	7,178	7,244	7,272
BVU 100-250 m3/h	17	48	92	163	279	394	533	1,113	2,028	2,996	4,033	5,084	6,217
UVU 250-1000 m3/h	2,527	3,042	3,838	5,066	6,372	7,242	8,010	8,534	8,951	9,267	9,406	9,493	9,529
BVU 250-1000 m3/h	22	63	120	214	366	517	699	1,459	2,657	3,925	5,284	6,662	8,147
UVU > 1000 m3/h	53	71	88	104	118	128	135	140	142	143	142	139	135
BVU 1000-2500 m3/h	0	2	8	16	29	42	55	68	80	93	107	121	135
Sum overall	**4,973**	**6,133**	**7,910**	**10,733**	**14,050**	**16,658**	**19,679**	**27,552**	**39,169**	**51,279**	**63,850**	**76,552**	**90,068**

Mm2 dwelling area covered by RVU	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
UVU ≤ 100 m3/h ES	13	16	20	26	33	41	48	52	56	59	61	63	66
UVU ≤ 100 m3/h HS	0	0	0	0	0	0	0	1	2	4	6	9	11
BVU ≤ 100 m3/h HS	1	4	8	18	34	53	90	271	559	864	1,189	1,522	1,878
UVU 100-250 m3/h	193	232	293	387	486	553	611	651	683	707	718	724	727
BVU 100-250 m3/h	2	5	9	16	28	39	53	111	203	300	403	508	622
UVU 250-1000 m3/h	1,011	1,217	1,535	2,026	2,549	2,897	3,204	3,414	3,581	3,707	3,762	3,797	3,812
BVU 250-1000 m3/h	9	25	48	85	146	207	279	583	1,063	1,570	2,114	2,665	3,259
UVU > 1000 m3/h	44	59	74	87	98	107	113	116	118	119	118	116	112
BVU 1000-2500 m3/h	0	3	9	20	36	52	69	84	100	117	134	151	168
Sum dwelling area covered by VU	**1,273**	**1,560**	**1,996**	**2,665**	**3,411**	**3,948**	**4,467**	**5,285**	**6,363**	**7,445**	**8,505**	**9,555**	**10,654**
EU-27 area perm. occup. dwellings	**12,562**	**13,430**	**14,309**	**15,385**	**16,627**	**17,510**	**18,027**	**18,378**	**18,519**	**18,525**	**18,531**	**18,453**	**18,375**
Share covered by VU	**10%**	**12%**	**14%**	**17%**	**21%**	**23%**	**25%**	**29%**	**34%**	**40%**	**46%**	**52%**	**58%**

Table 16. EU-28 Total Stock of non-continuously operating local 'Ventilation Units'. Estimate for reference only; not used in scenario analysis. (source: VHK 2020, BVM model)

thousands of units (for EU-28)	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
(L)UVUnc ≤ 100 m3/h, non-continuous oper.	59,292	60,777	62,263	63,695	64,744	65,355	65,530	65,678	66,072	66,711	67,538	68,375	69,211

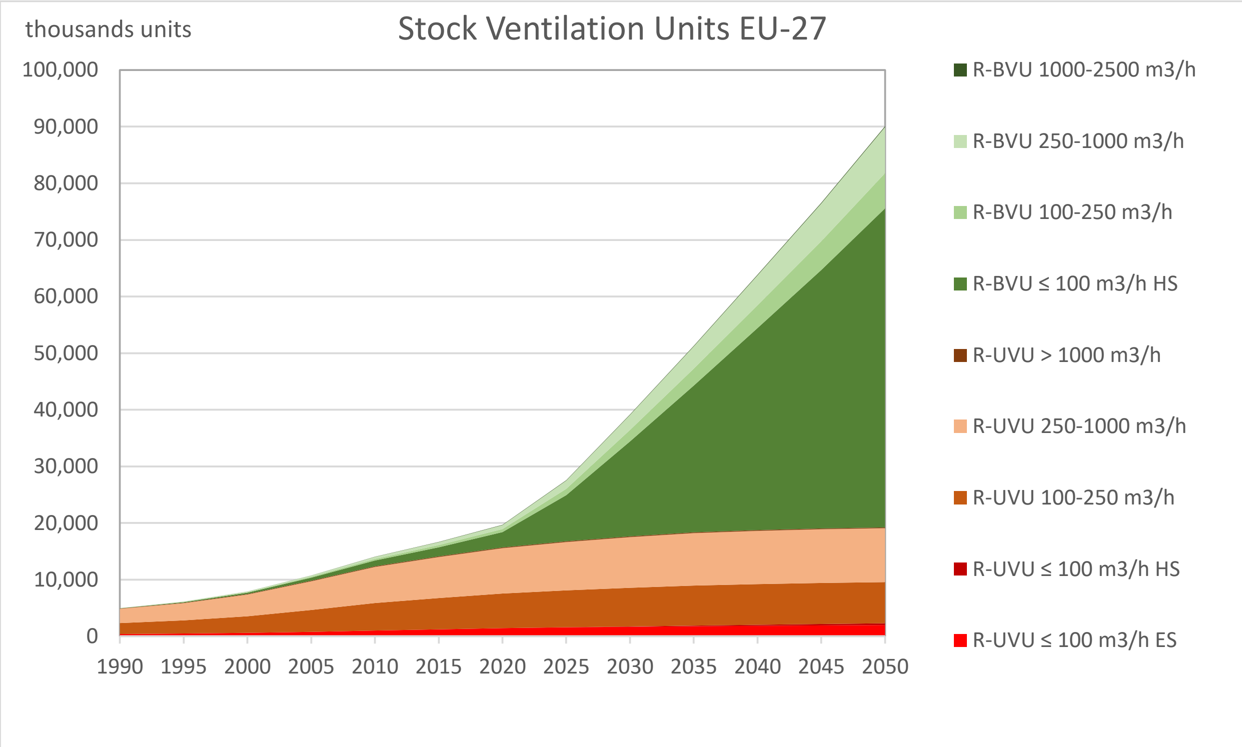


Figure 26. EU-27 Stock of Ventilation Units for residential dwellings, in thousands of units
(source: VHK 2020, BVM model)

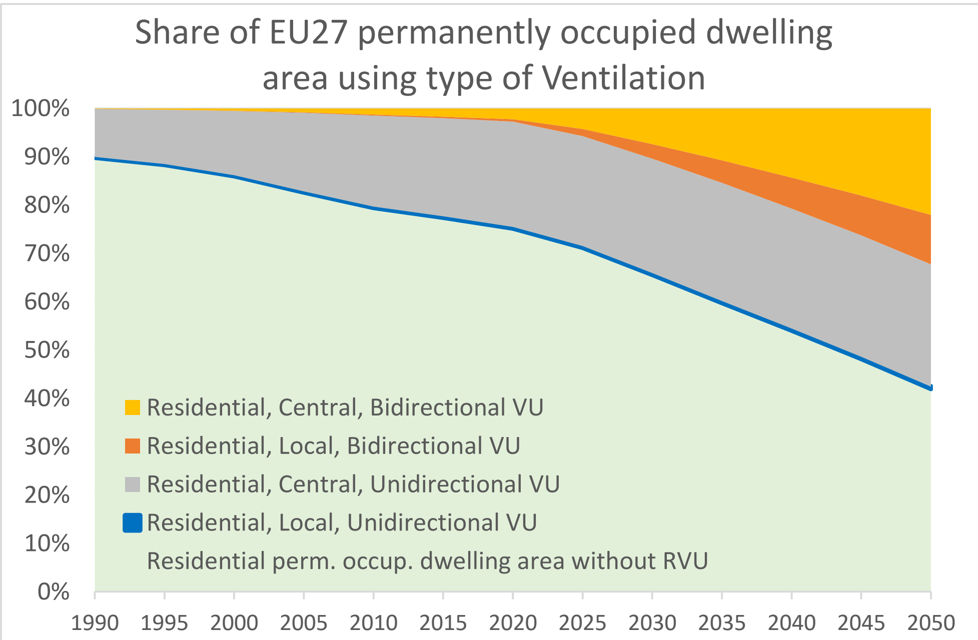


Figure 27. Share of EU-27 residential permanently occupied dwelling area using a certain type of ventilation
(source: VHK 2020, BVM model)

2.8 Sales of Ventilation Units for non-residential buildings

Methodology for sales up to year 2015

Different from the residential sector, for the non-residential sector the sales of ventilation units have been determined directly for the EU-27 as a whole. Insufficient data were available for a subdivision by Member State.

Until year 2015 the total sales of VUs for the non-residential sector from preceding studies have been accepted for use in the current study. These sales are reported in the Ecodesign Impact Accounting (par. 2.2.8) and compatible with those reported in the 2012 Lot 6 preparatory study (par. 2.2.11 and Annex II.7) and in the 2014 Impact Assessment. However, as anticipated in section 2.5, the distribution of the total AHU sales over the size classes -S, -M and –L had to be adjusted, reducing the share of large AHUs. In parallel, the reference mechanical air flow for the AHUs, and the corresponding reference building area covered, had to be reduced. Both changes had to be applied to obtain a reasonable share of total non-residential building area covered by NRVUs (incl. AHUs). As an illustration of these changes, for 2010 the previous studies subdivided sales as 37.8% AHU-L, 36.1% AHU-M and 26.1% AHU-S. This had to be adapted to 5.2% AHU-L, 59.8% AHU-M and 35.0% AHU-S. The reference mechanical air flow for AHU-L used in previous studies was 35 000 m^3/h, corresponding to 9722 m^2 building area (3.6 $m^3/h/m^2$ assumed). The present study had to reduce this to 25 200 m^3/h, or 7000 m^2.

The 2012 study subdivides the Air-Handling Units (AHUs) in three maximum flow rate categories, and this subdivision is maintained here:
AHU-L (> 14500 m^3/h)
AHU-M (5500-14500 m^3/h)
AHU-S (2550-5500 m^3/h)

The same study specifies the Central Heat Recovery Ventilation (CHRV/CBVU) units as having maximum flow rates from 300 to 2250 m^3/h. Considering that the existing regulations separately consider VUs between 250 and 1000 m^3/h and above 1000 m^3/h, the CHRVs have been subdivided in these two categories, preliminarily estimating a 67% / 33% subdivision of sales quantities. The same subdivision, with the same percentages, has been applied for CUVUs (called CEXH, Central Exhaust in the 2012 study) between 250 and 1000 m^3/h and above 1000 m^3/h.

The studies on non-residential ventilation do not consider the use of small local VUs, probably because these are considered to be 'residential' by the existing regulations. The amounts of small VUs (LBVU, LUVUc, LUVUnc) taken into account for the residential sector are intended to cover only their use in residential dwellings. It is reasonable to assume that many small shops, offices, bars, restaurants etc. that are counted as non-residential buildings are using such local VUs, but compared to the larger NRVUs and AHUs their environmental impact has been considered to be negligible for this study. The 2012 study (details in Annex II.7) reports sales of 30 thousand LHRVs and 6 million local fans in 2008 for the collective residential and non-residential sector together, but for a (very) large part these numbers probably overlap with those already considered for the residential dwellings. For the moment, more as a place-holder, it is estimated that the use of local VUs in non-residential buildings is 10% of that in residential dwellings (for the period up to 2015).

Methodology for share of buildings using VU-type

The like-for-like replacement sales for years 2010-2015 are taken as a share (95-100%) of the VUs assumed to reach end-of-life in these years, which are the total sales of 17 years before (considering an average lifetime of 17 years for all VU-types). Subtracting these sales from the total sales in the period 2010-2015, the quantity of sales for first-time installation in new-built or renovated buildings, and the corresponding building area coverage are

obtained. For the years 2010-2015 this provides for each NRVU/AHU-type the 1st time installation area share in the total non-residential 1st time installation area (Table 17). For AHUs, this share has been assumed to remain constant in years after 2015. For CEXH/CUVU the share is assumed to decrease with the years and for CHRV/CBVU it is assumed to correspondingly increase. The same share is applied for new-built and for renovation. Multiplying this share by the non-residential new-built or renovated area (Table 11), by the assumed shares of these areas installing an NRVU/AHU, and dividing by the reference building area coverage per VU, gives the number of NRVU/AHUs sold for new-built and renovation. Adding the replacement sales then provides the total sales projection.
The share of new-built non-residential building area installing an NRVU/AHU has been taken 80%. For renovated non-residential building area this share is 60%. These values are applied from 2025 [27]. For years between 2015 and 2025 linear interpolation is used.

Summarizing, sales quantities for NRVU and AHU from 2025 are determined in a year 'y' as:

Sales XVU (y) =

New Building Area (y) x Share of 1st time Area using XVU (y) x
Share of New Built installing NRVU / Reference Building Area for XVU +

Renovated Building Area (y) x Share of 1st time Area using XVU (y) x
Share of Renovated installing NRVU / Reference Building Area for XVU +

Sales XVU (y-lifetime) x Share of EoL XVU actually being replaced

XVU: CHRV/CBVU, CEXH/CUVU, AHU-S, -M, -L

Table 17. Average building area covered by a NRVU/AHU, and area share of 1st time installation per VU-type in the total of 1st time non-residential installation. These shares are multiplied by the new-built and renovated building area of Table 11 to get the sold area coverage per VU-type.

(Source: VHK 2020, BVM model)

		Area share of 1st time NRVU installation					
	m2/VU	2010	2015	2020	2030	2040	2050
AHU-L (> 14500 m3/h)	7000	8.8%	9.2%	9.2%	9.2%	9.2%	9.2%
AHU-M (5500-14500 m3/h)	2500	36.1%	37.8%	37.8%	37.8%	37.8%	37.8%
AHU-S (2500-5500 m3/h)	1050	26.2%	29.6%	29.6%	29.6%	29.6%	29.6%
CHRV (1000-2500 m3/h)	500	8.9%	7.6%	8.8%	10.5%	11.0%	11.6%
CHRV (250-1000 m3/h)	200	7.2%	6.2%	7.1%	8.5%	9.0%	9.4%
CUVU / CEXH (> 1000 m3/h)	400	6.3%	4.7%	3.7%	2.1%	1.7%	1.2%
CUVU / CEXH (250- 1000 m3/h)	200	6.4%	4.8%	3.8%	2.2%	1.7%	1.2%

Sales of VU for non-residential

The results of the Building-Ventilation Model in terms of annual sales of ventilation units for the non-residential sector over the 1990-2050 period are reported below. The sales are split in sales for new-built buildings, sales for renovated buildings, and like-for-like replacement sales, and summed up to the EU-27 total sales for the non-residential sector.

[27] Considering the procedure used to derive the sales projection, the additional application of the 80% or 60% shares from 2025 is not logical, but this reduction is necessary to limit the total building area covered by NRVU/AHUs to a reasonable quantity.

In 2015, a total of 487 thousand VUs were sold for the EU-27 non-residential sector. Of these, 122 thousand (25%) were for new-built buildings, 85 thousand (17%) for renovated buildings and 280 thousand (57%) were replacement sales. Central Balanced solutions (CBVU; AHU and CHRV) represented 52% of the market (251 thousand units) and Central Unidirectional (CUVU, CEXH) another 48% (236 thousand units).

Due to the measures in the EPBD (entire EU building stock NZEB by 2050), a continuing increase in sales of NRVUs is projected. This increase is driven both by new-construction and by renovation. In particular the sales of BVUs and AHUs (most with heat recovery) are expected to increase from 251 thousand units in 2015 to 365 thousand in 2030 and 517 thousand in 2050. Sales of CUVUs are expected to remain relatively stable: between 216 and 247 thousand units per year over the entire 2015-2050 period.

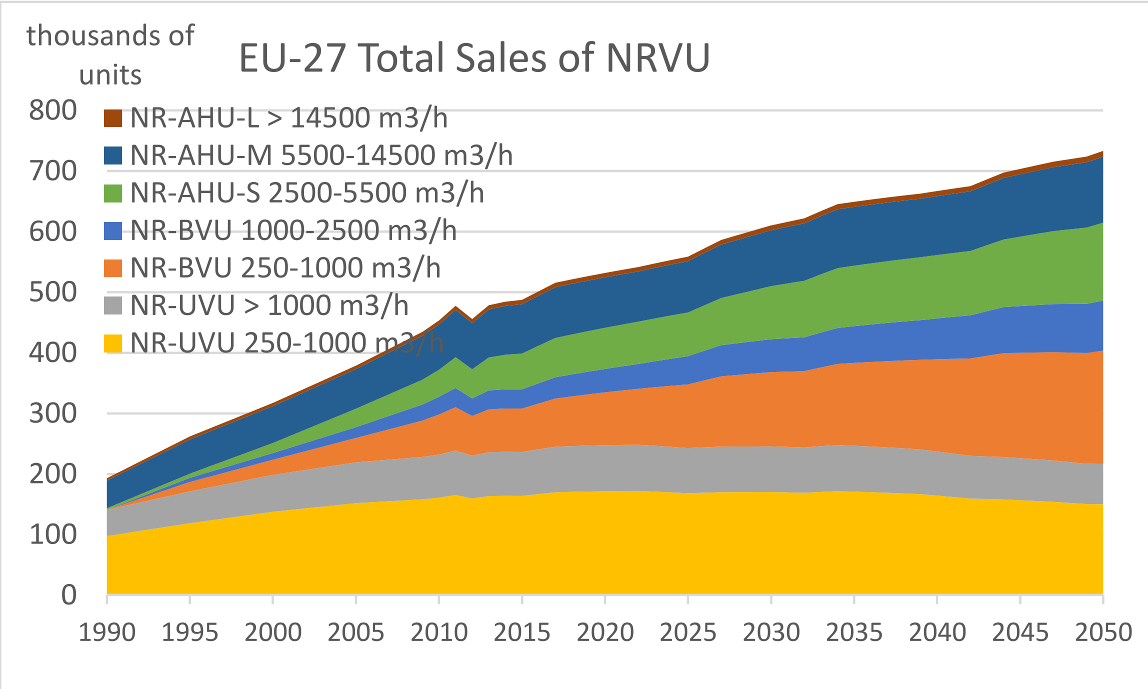


Figure 28. EU-27 Total Sales of Ventilation Units for non-residential buildings (thousands) (new-built + renovated + replacements)

(source: VHK 2020, BVM model)

Table 18. EU-27 Total Sales of Ventilation Units for non-residential buildings (thousands), for new-built buildings, for renovated buildings, like-for-like replacement sales, and overall total

(source: VHK 2020, BVM model)

thousands of units	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
VU Sales for New-Built Buildings													
UVU 250-1000 m3/h	42	42	40	36	29	24	18	11	9	8	7	6	5
BVU 250-1000 m3/h	0	9	14	23	33	30	30	28	28	29	30	31	33
UVU > 1000 m3/h	18	18	18	16	13	10	8	5	4	4	3	3	2
BVU 1000-2500 m3/h	0	4	6	10	15	13	13	13	12	13	13	14	14
AHU-S 2500-5500	1	3	9	16	23	28	24	19	18	19	19	19	20
AHU-M 5500-14500	4	10	11	12	13	15	13	10	10	10	10	10	10
AHU-L > 14500 m3/h	0	1	1	1	1	1	1	1	1	1	1	1	1
Sum new-built	**66**	**87**	**99**	**115**	**127**	**122**	**107**	**87**	**83**	**83**	**84**	**85**	**86**
VU Sales for Renovated Buildings													
UVU 250-1000 m3/h	30	30	29	26	21	17	17	14	15	13	12	10	8
BVU 250-1000 m3/h	0	7	11	17	24	21	26	26	33	34	35	36	37
UVU > 1000 m3/h	13	13	13	12	9	7	8	6	7	6	5	4	4
BVU 1000-2500 m3/h	0	3	5	8	11	9	11	12	15	15	16	16	17
AHU-S 2500-5500	1	2	6	12	17	19	20	18	22	22	22	22	22
AHU-M 5500-14500	3	7	8	9	10	10	11	10	12	12	12	12	12
AHU-L > 14500 m3/h	0	1	1	1	1	1	1	1	1	1	1	1	1
Sum renovated	**48**	**63**	**72**	**84**	**92**	**85**	**94**	**87**	**103**	**103**	**103**	**102**	**102**
VU Sales for like-for-like Replacements													
UVU 250-1000 m3/h	26	47	68	89	110	123	136	143	146	149	145	140	136
BVU 250-1000 m3/h	0	0	0	0	9	20	32	50	62	74	87	106	117
UVU > 1000 m3/h	11	21	30	39	49	55	60	64	65	66	64	62	60
BVU 1000-2500 m3/h	0	0	0	0	4	9	14	22	27	33	39	47	52
AHU-S 2500-5500	0	1	2	2	5	12	23	35	48	59	64	73	87
AHU-M 5500-14500	38	40	42	45	52	56	59	65	71	75	75	81	86
AHU-L > 14500 m3/h	3	3	4	4	5	5	5	6	6	7	7	7	8
Sum replacements	**79**	**112**	**146**	**179**	**234**	**280**	**331**	**385**	**424**	**463**	**480**	**517**	**546**
Total VU Sales for Non-Residential sector													
UVU 250-1000 m3/h	97	119	137	152	161	164	171	168	170	171	164	157	150
BVU 250-1000 m3/h	0	16	25	40	66	72	87	105	123	137	152	174	187
UVU > 1000 m3/h	43	53	61	67	71	73	76	75	75	76	73	69	66
BVU 1000-2500 m3/h	0	7	11	18	29	32	39	47	54	61	67	77	83
AHU-S 2500-5500	3	7	17	30	44	59	68	72	88	100	105	115	129
AHU-M 5500-14500	46	57	61	65	75	81	83	85	92	97	97	103	109
AHU-L > 14500 m3/h	4	5	5	6	7	7	7	7	8	8	8	9	9
Sum overall	**193**	**262**	**317**	**379**	**453**	**487**	**532**	**559**	**610**	**649**	**667**	**704**	**733**

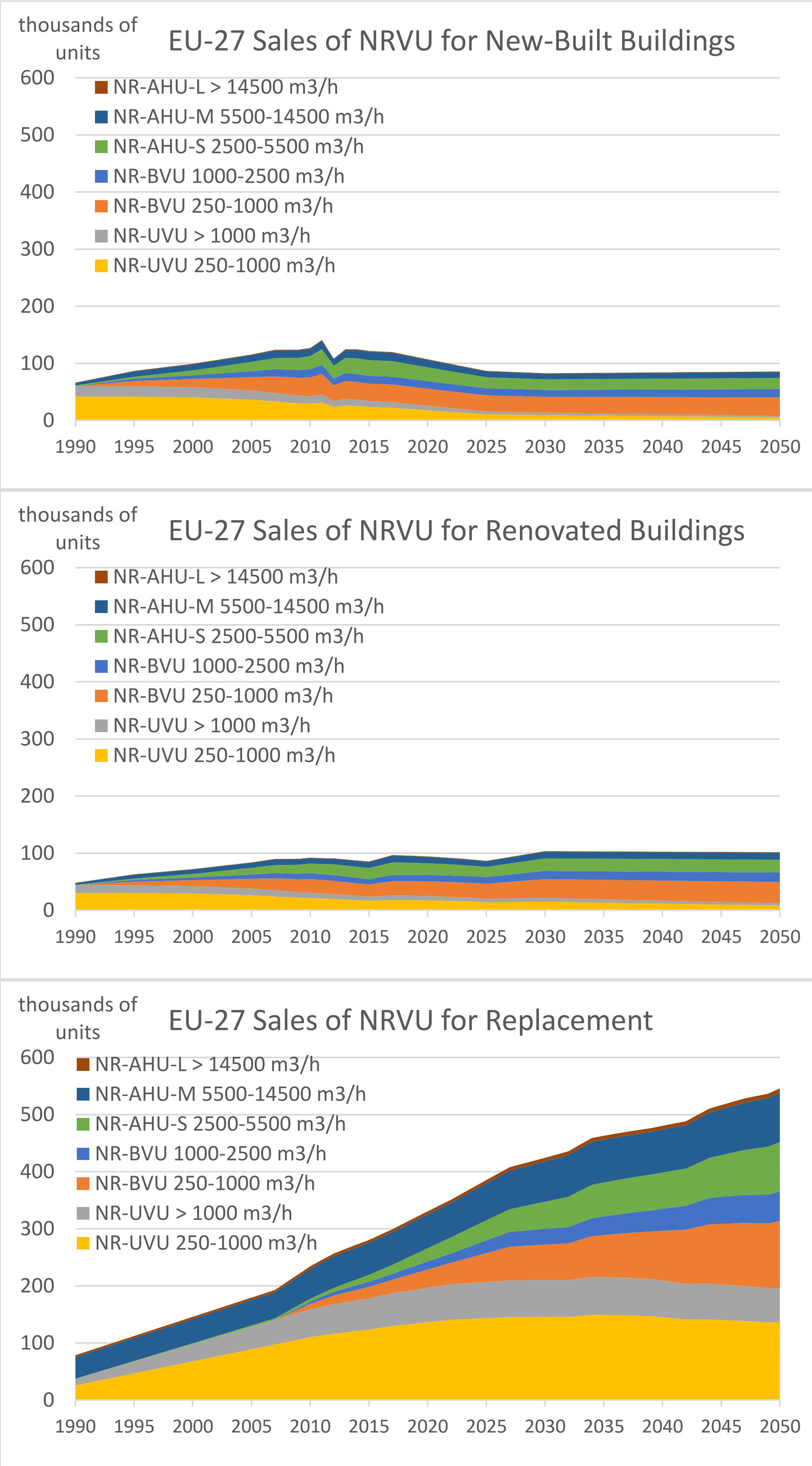


Figure 29. EU-27 Sales of Ventilation Units for non-residential buildings (thousands), split in VU for new-built buildings, VU for renovated buildings and like-for-like replacement sales

(source: VHK 2020, BVM model)

2.9 Stock of Ventilation Units for non-residential buildings

The stock of ventilation units is calculated from the sales using the same method as in the Ecodesign Impact Accounting (EIA), i.e. summing for a given year the sales of the lifetime preceding years. An average lifetime of 17 years is assumed for all types of VU. This corresponds to the lifetime used in EIA and in underlying studies.

In 2015, the total stock of VUs used in the non-residential sector amounted to 6.9 mln units. Of these, 3.8 mln (55%) were Central Unidirectional units (CUVU/CEXH) and 3.1 mln (45%) Central Balanced units (CBVU; AHU and CHRV).
All NRVUs and AHUs together are estimated to cover 64% of the total non-residential building area in 2015 [28].

Due to the increase in sales of VUs (previous paragraph), the share of CBVUs in the stock is projected to increase from 45% in 2015 to 55% in 2030 and to 66% in 2050. The stock of CUVUs remains relatively stable over the 2015-2050 period, between 3.8 and 4.2 mln units, implying that the share of CUVUs in the total stock decreases to 34% in 2050. As a result, 78% of non-residential building area uses some kind of mechanical ventilation in 2030, and in 2050 this is projected to further increase to 90%.

Table 19. Total EU-27 stock of Ventilation Units for non-residential buildings, in thousands of units (top) and in million m² of building area covered (bottom)

(source: VHK 2020, BVM model)

thousands of units	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
UVU 250-1000 m3/h	1,083	1,442	1,794	2,121	2,396	2,600	2,749	2,835	2,877	2,894	2,875	2,822	2,735
BVU 250-1000 m3/h	0	47	153	323	581	847	1,114	1,371	1,625	1,896	2,173	2,451	2,734
UVU > 1000 m3/h	480	639	795	940	1,062	1,153	1,218	1,257	1,275	1,283	1,274	1,251	1,212
BVU 1000-2500 m3/h	0	21	68	143	258	375	494	608	720	841	963	1,086	1,212
AHU-S 2500-5500	27	48	105	219	393	617	848	1,035	1,203	1,372	1,542	1,711	1,875
AHU-M 5500-14500	714	779	867	965	1,079	1,189	1,297	1,379	1,445	1,512	1,580	1,647	1,713
AHU-L > 14500 m3/h	62	68	75	84	94	103	113	120	126	131	137	143	149
Sum overall	**2,365**	**3,043**	**3,856**	**4,797**	**5,864**	**6,885**	**7,833**	**8,606**	**9,272**	**9,929**	**10,544**	**11,112**	**11,629**

Mm2 building area covered by NRVU	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
UVU 250-1000 m3/h	433	577	718	849	959	1,040	1,099	1,134	1,151	1,158	1,150	1,129	1,094
BVU 250-1000 m3/h	0	19	61	129	232	339	446	549	650	758	869	980	1,093
UVU > 1000 m3/h	192	256	318	376	425	461	487	503	510	513	510	500	485
BVU 1000-2500 m3/h	0	10	34	72	129	188	247	304	360	420	482	543	606
AHU-S 2500-5500	28	51	110	229	413	648	890	1,087	1,263	1,441	1,619	1,797	1,969
AHU-M 5500-14500	1,784	1,946	2,167	2,414	2,698	2,973	3,243	3,448	3,613	3,779	3,949	4,118	4,282
AHU-L > 14500 m3/h	434	474	527	588	657	724	790	839	880	920	962	1,003	1,043
Sum building area covered by VU	**2,872**	**3,332**	**3,934**	**4,657**	**5,512**	**6,373**	**7,202**	**7,864**	**8,427**	**8,990**	**9,540**	**10,070**	**10,571**
EU-27 area non-residential buildings	**7,822**	**8,270**	**8,730**	**9,201**	**9,685**	**10,016**	**10,264**	**10,513**	**10,761**	**11,010**	**11,258**	**11,507**	**11,756**
Share covered by VU	**37%**	**40%**	**45%**	**51%**	**57%**	**64%**	**70%**	**75%**	**78%**	**82%**	**85%**	**88%**	**90%**

[28] For comparison, in the 2012 Lot 6 preparatory study (Annex II.7) it was estimated for year 2008 that 45% of the ventilated volume for the collective and non-residential sector was covered by mechanical ventilation units (except non-continuously operating local fans). In the 2014 Building Heat Demand report (Annex II.6) it is estimated that 47% of the ventilated volume of non-residential buildings in 2014 was provided by mechanical ventilation units of which 16% by unidirectional units (CUVUs) and 31% by balanced units (CBVUs).

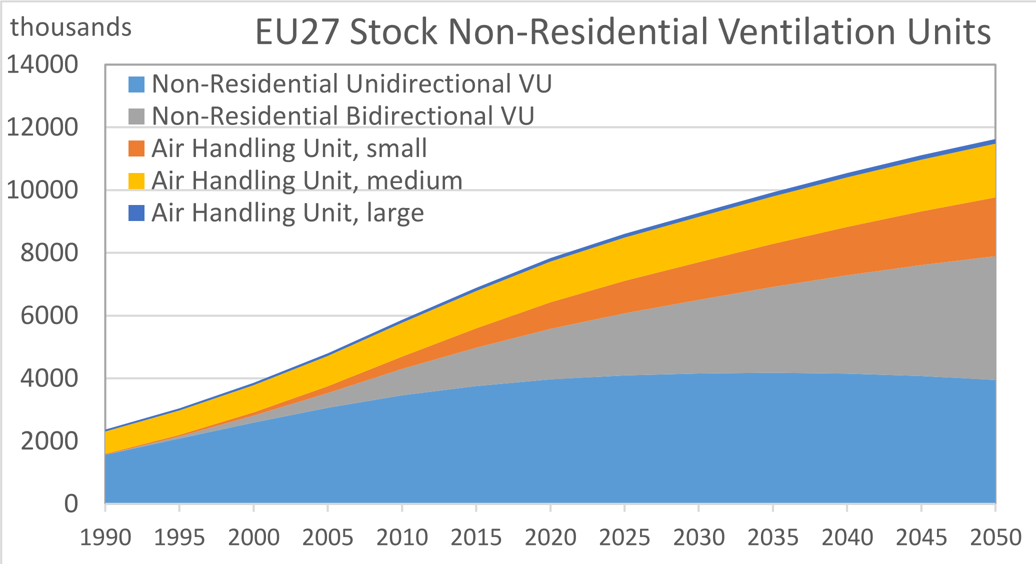


Figure 30. EU-27 Total Stock of Ventilation Units for non-residential buildings, in thousands of units

(source: VHK 2020, BVM model)

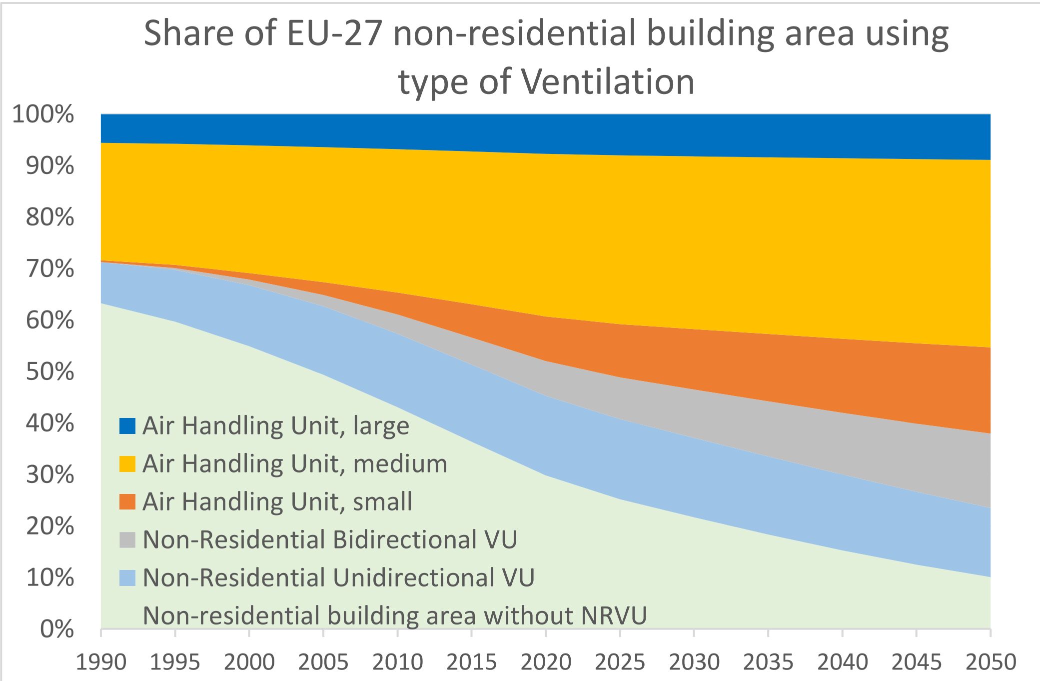


Figure 31. EU-27 Non-residential building area using a certain type of ventilation

(source: VHK 2020, BVM model)

3. Barriers and trends in VU-market

3.1 Construction production

New built

The construction of new buildings has a strong impact on the market for ventilation units. In the period 1990-2000, around 2.0 mln dwellings were built in EU-27 each year, gradually increasing to a peak of 2.7 mln dwellings in 2006-2007 (mainly in multi-family dwellings). The economic crisis, decreased the annual number of new-built dwellings to a minimum of 1.2 mln in 2014 (half of the 2006 value).

The number of new-built dwellings is projected to increase again to around 1.6 mln (0.7% of stock) by 2020, compensating for the deficit of new-built in earlier years. After 2020 the number is expected to gradually decrease to 0.9 mln (0.4% of stock) in 2050, reflecting the slowdown in growth, and later the decrease, in population and in number of households.

Renovation of buildings

Renovation of buildings, especially when this renovation aims at minimising the energy consumption of dwellings, can be a strong impetus for the VU-market. Improving building insulation and airtightness without renovating the ventilation system is not really an option, since it may lead to very poor IAQ-levels, affecting people's health and performance. It is therefore expected that the renovation market will also affect the VU-market.

According to the Energy Performance of Buildings Directive (EPBD), all new-built buildings need to be Nearly-Zero Energy Building (NZEB) by 2020, and the entire EU stock of buildings need to be NZEB by 2050. Although NZEB does not necessarily imply the use of balanced ventilation units (BVU) with heat recovery (HR), the provisions of the EPBD are expected to lead to a strong increase in the sales of BVUs.

If member states implement these EPBD-directives as planned and construct new buildings as projected, the VU-market will annually show double digit growth figures.

3.2 National building codes lagging behind

Despite the fact that harmonised EU-standards have been developed, presenting guidelines with respect to ventilation capacities to be installed and actual real-life performance of ventilation systems, most of the national building codes do not (yet) adopt these standards. This observation was already made by Mr. Seppänen in the final report of Work Package 5 of the HealthVent project[29] (2012). The situation has not substantially improved since then. Building codes however, are governing building practices and to a large extent determine the type of ventilation system that is being selected. As long as building codes allow the application of rudimentary ventilation systems without setting any requirements for its performance levels, these generally cheap solutions will be applied.

National buildings codes have a long history, displaying country's building- and ventilation culture over the years. Most of these buildings codes are of prescriptive nature, indicating to what physical requirements the ventilation provisions need to comply (type of supply- and exhaust provisions that are allowed), ventilation capacity that need to be installed as a minimum, including ways to determine the actual installed capacity. As an example, some member states still consider 'windows' in combination with a passive stack a suitable ventilation provision with which the requested continuous ventilation rates in rooms can be achieved, while others do not (windows may be used for incidental airing but not as

[29] https://webgate.ec.europa.eu/chafea_pdb/assets/files/pdb/20091208/20091208_d05_oth5_en_ps.pdf

continuous ventilation provision) and prescribe ventilation grids or trickle-vents as the minimum required natural ventilation provision.

What practically all building codes have in common is the fact that they do not refer to the actual ventilation performance in practice. It is generally assumed that when ventilation systems are designed and installed according to building codes (applying the correct installed ventilation capacities per m^2 and/or per person), these ventilation rates are actually achieved when needed. This is not the case. Various monitoring studies in the residential sector demonstrate that, although total air exchanges over the dwelling could in theory be enough to achieve acceptable IAQ-levels, the air exchange rate in the occupied spaces is often too low. Higher pollutant concentrations cannot always be detected and people adapt to gradually changing IAQ-levels. Unless in extreme cases, the occupant's sensory system is not a reliable control mechanism for operating the ventilation provisions. As a result, the occupants are often exposed to higher pollutant concentrations than can be considered healthy by any standard.

This omission in national building regulations can result in even worse indoor air quality levels when the new EPBD regulation (with its focus on energy performance) is going to be implemented in building codes without giving increased attention to the required ventilation performance in practice. Building codes should preferably be amended by adding specific requirements regarding ventilation performance and by promoting ventilation provisions that are actually capable of achieving the requested minimum design ventilation rates during presence. In the end, national building codes should also seek to pursue the objective that ventilation systems induce the right air exchanges in the right place at the right time in order to reduce exposure to higher pollutant concentrations.

Some member states are working on ways to implement additional requirements regarding ventilation performance to the already existing prescriptive approach in the building codes. Implementing changes or amendments in building codes can however be difficult due to the strong vested interest of local organisations.

These buildings code regulations and their future modifications will have a significant impact both on the total market for VUs and on the product trends, i.e. preference for certain VUs and related ventilations system types.

3.3 No awareness

In most cases, people are not aware of poor IAQ-levels. Apart from the fact that many pollutants are not perceptible by humans, there is also the fact that people adapt to gradually changing IAQ-levels. Individual interviews with inhabitants may prove that people are quite happy with their ventilation systems and IAQ-levels, while monitoring data actually reveals that the CO_2-concentrations in their bedrooms frequently rises above 3000 ppm and the air exchanges were far too low. So unless in extreme cases, the occupants sensory system is not a reliable control mechanism for operating ventilation provisions and assessing the IAQ-levels.

There is also a lack of awareness on both the health and energy aspects of ventilation. Few people are aware that one-third or even half of their space heating bill is due to 'ventilation'. Fewer people are aware that the ventilation heating energy losses can be tackled with heat recovery systems. Only a handful of occupants are aware of the fact that poor IAQ can have significant impact on their health, well-being and even on their performance levels

Lack of knowledge. Even if all decision-makers were aware of the need for sufficient ventilation and the ventilation energy saving potential, it is very difficult to find advisors and installers that are well-informed and properly trained. This does not only concern small electrical installers being unfamiliar with the actual ventilation performance levels.

For many of the big installation firms dealing with larger commercial buildings, ventilation is mainly considered as a part of air-conditioning, i.e. cooling and air heating. Design calculations and lay-outs that provide best price/quality for 'ventilation only' are therefore rare. This is especially true for retrofitting existing buildings where there are significant opportunities for heat recovery ventilation linked with renovation of the facades or even simple retrofitting with the latest decentralized heat recovery ventilation products.

The unfortunate fact that poor indoor air quality cannot be recognized and ventilation heat losses are barely conceived, very much complicates things. Contrary to e.g. heating comfort (temperature level in the room), there are no direct drivers that spur occupants to the desired conduct in this matter. Poorly functioning ventilation provisions are hardly recognized, indicating that there is no self-correcting mechanism in force in this sector, making it even more difficult to put ventilation high on the agenda.

3.4 Split responsibilities and budgets

This topic remains an important barrier, especially in multi-family buildings and commercial buildings. Builders, installers and users of ventilation systems are not the same entities and do not have the same budgetary priorities. Builders and developers want to cut down on building costs. Because the ventilation systems is a low-interest product for the future occupant of the building, it is a perfect item for cost saving. Builders will look for the cheapest solution that still complies with building regulations.
Buyers of the building and building authorities increasingly value low energy buildings, but commercially it is often more attractive to boost some sort of 'high visibility' renewable installation (solar, heat pump) than highlighting a good performing ventilation system.
The users of the buildings have to pay the energy bill, but very often have no say (and expertise) in how the buildings' installations should be improved.

3.5 Centralised ventilation / decentralised air conditioning

As already stated in the previous preparatory study, ventilation is more and more decoupled from air conditioning, not only in the perception of the general public but also physically.
The market share for traditional central air-based installations, where the same AHU handles both the requirements of air cooling/heating and the ventilation, is in decline as far as new buildings is concerned (replacement market is still very big).
With these 'newer' systems, the central 'air handling unit' (or rather just a ventilation unit) takes care of the ventilation, while the fan coils and VRF units –helped by recirculation fans— just handle the air cooling/heating. This configuration reduces the traditional over-sizing of fan capacity, allows independent control of the various spaces and lowers distribution losses.
In summary, the main benefits are:

- Compact design of the central VU (AHU)
- Lower procurement costs compared with a centralised HVAC
- Minimal ductwork, minimal space requirement,
- Reduced duct losses
- Reduced pressure losses
- Improved decentralised temperature control
- High energy savings

3.6 Smart controls and monitoring

Another trend regards the increasing use of smart controls in ventilation systems, gradually moving away from rudimentary systems and controls, to systems that are capable of adjusting the ventilation airflows per room, using appropriate actuators (dampers, valves, local fans, etc.) and intelligent controls (occupancy sensors, CO_2 and TVOC-sensors and –for wet rooms—humidity sensors. The benefits of his development are substantial:

1.
First and foremost, these smart controls can ensure that the requested ventilation rates are actually achieved in the right places at the right time, leading to a verifiable ventilation performance and to the intended reduction of exposure to indoor pollutants.

2.
Smart controls also enable the monitoring of actual IAQ-levels in the various rooms, making the indoor air quality visible and the inhabitant aware of their actual situation. Monitoring systems compensate for the inadequate sensory systems of the occupants, and can become a strong driver in the assessment of the real-life performance of ventilation systems.

3.
Finally, smart controls will have a strong impact on the further reduction of energy consumption related to ventilation, without jeopardizing the IAQ-levels. Compared to rudimentary controlled ventilation systems, they can reduce the air exchange rates considerably.

3.7 More attention for HRV

As a result of EPBD and Ecodesign regulations, heat recovery ventilation systems are gaining market share in the new built sector but also in the renovation rector. In the latter, the local heat recovery ventilation systems with in- and outlets through the façade, show strong growth rates. This is particularly true for the regenerative alternating units that require limited installation work and are relatively affordable. This VU-type has a strong market in the German speaking regions and is enjoying a growing interest from countries like UK, Baltic states and some other east European countries. These non-ducted local heat recovery ventilation units are further discussed in the Task 4 report, describing the recent technological developments.

4. Consumer expenditure

For further elaboration of the price information in this chapter, see also the Task 5 and Task 7 reports.

4.1 Sources for VU prices

Information on product prices has been collected in Annex VI. The following sources have been considered:

- Interconnection Consulting market value data (Annex VI.1)
- Eurovent market value data (Annex VI.5)
- Daikin / BRG market value data (Annex VI.6)
- Price data from the 2014 Impact Assessment (Annex VI.7)
- Price data from the 2018 Ecodesign Impact Accounting (Annex VI.8)
- List price data from a VU manufacturer (Annex VI.9)
- Prices from on-line (internet) sales sites (Annex VI.10)

This paragraph summarizes the data availability from each source.
Paragraph 4.2 summarizes the data per VU-type.

Price data in the sources are valid for different years (ranging from 2003 to 2020) and expressed in different euro-levels (2003-, 2010-, 2015-, 2019-euros). Data from before 2015 have been converted to 2015-euros by the study team. Some sources present manufacturer selling prices, while others are consumer street prices, with or without VAT, or manufacturer list prices. Some prices are for VUs with a specific design flow rate, while others are an average over the entire range of flow rates. Some sources include installation costs (material and labour) in the product price, while others do not. There is also a difference between prices for base cases and increased prices for products with higher energy efficiency. This makes comparison of prices from various sources not straightforward.

4.1.1 Interconnection Consulting market value data

Interconnection Consulting (IC) published aggregated data on the development of Europe's residential ventilation market (par. 2.2.6, Annex VI.1). The derived average market value per residential ventilation unit varies from € 400 in 2014 to € 435 in 2021 (Table 20). These prices are considered to be ex-works, manufacturer selling prices (msp).
Using additional data from MarktMeinungMensch concerning the subdivision of the 2015 sales between UVUs and BVUs, a unit msp of € 254 for UVUs and € 1531 for BVUs can be estimated.

Table 20. Estimate of average market value per Residential Ventilation Unit

(Source: VHK elaboration of public data from Interconnection Consulting)

	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Units (thousands)	2265	2280	2375	2467	2535	2613	2677	2743
Market value (M€)	906.7	937.5	971.5	1025.7	1068.3	1117.6	1153.4	1192.2
RVU Unit value (€)	400	411	409	416	421	428	431	435
variation		2.7%	-0.5%	1.6%	1.4%	1.5%	0.7%	0.9%
UVU units (thousands)		2000						
UVU value (M€)		508.7						
UVU Unit value (€)		**254**						
BVU units (thousands)		280						
BVU value (M€)		428.8						
BVU Unit value (€)		**1531**						

4.1.2 Eurovent market value data

Eurovent's EMI provides a dataset containing the EU-28 total sales figures for residential BVU (with heat recovery) and non-residential AHUs for year 2017 (par.2.2.5, Annex II.4).

The document mentions a total of 460,859 residential BVUs with heat recovery sold in 2017, with a total market value of 347.5 million euro, leading to an average ex-works price (msp) of € 754. This includes LBVU and CBVU of all sizes up to 1000 m3/h. 79% has energy class A.

As regards non-residential AHUs, total sales in 2017 were 179,395 units with a market value of 1712 million euros and an average ex-works price (msp) of around € 9,500. The average price per Member State varies from below € 3000 in Estonia and Lithuania to between € 13,000 and 15,000 in Croatia, Germany, Malta and United Kingdom.

4.1.3 BVU market data published by Daikin based on BRG source

Kranenberg (Daikin) published market data deriving from BRG (par. 2.2.7, Annex VI.6). These data have been elaborated by the study team, leading to the estimated unit prices of Table 21 (ex-works prices, msp).

For AHUs, the estimated msp per unit is € 8600 - 9500.

For residential BVUs, the estimated msp is € 1190 – 1380 for CBVU and € 375 for LBVU, with a sales weighted average of € 875-930.

For non-residential CHRV, an average market value of € 2090-2050 is estimated.

Table 21. Estimate of average market value (ex-works, manufacturer selling price) for AHU, CHRV and BVU (2015 euros per unit)

(Source: VHK elaboration of data from Daikin / BRG)

	2017	2020
AHU	8649	9503
CHRV non-residential	2089	2048
CBVU residential	1186	1384
LBVU residential	376	375
sales weighted average all residential BVU	*875*	*929*

4.1.4 Price data from the 2014 Impact Assessment

The 2014 Impact Assessment (IA) presents price breakdowns per type of ventilation unit (Annex VI.7). The information is based on the preparatory studies for Lot 10 and Lot 6. The Lot 10 data for residential VUs are valid for year 2003; the Lot 6 data for non-residential VUs for year 2010. The data have been converted to 2015 euros and are presented in the tables below.

Note that for non-residential units, the end-consumer unit prices for replacement are lower than those for 1st time installation during new-built or renovation (builder mark-up on the price).

Table 22. Price breakdown for Residential Ventilation Units in year 2003, as reported in the 2014 Impact Assessment

prices converted to 2015 euros by the study team

Unit price in 2015 euros	local exhaust (LUVU)	central exhaust (CUVU)	central HR (CBVU)	local HR (LBVU)
design flow rate m3/h	80	250	250	115
Manufacturing selling price, VAT excl. (msp)	63	208	1596	766
Wholesale price, VAT excl. (msp+20%)	75	249	1915	920
Installer price, VAT excl. (wholesale+20%)	92	298	2298	1103
Consumer street price, VAT included	**109**	**356**	**2735**	**1312**

Table 23. Price breakdown for Non-Residential Ventilation Units in year 2010, as reported in the 2014 Impact Assessment

prices converted to 2015 euros by the study team

Unit price in 2015 euros	CEXH	CHRV	AHU-S	AHU-M	AHU-L
design flow rate (m3/h)	1500	2250	4000	10000	35000
manufacturer labour	49	540	734	1296	2160
manufacturer materials	162	1080	1641	3024	6479
manufacturer overhead	113	1080	1944	4320	12959
manufacturer selling price (msp)	**324**	**2700**	**4320**	**8639**	**21598**
wholesale price	421	3510	5184	9503	22678
installer price [1]	527	4388	6220	10454	24492
builder price [2]	**685**	**5703**	**8086**	**13590**	**31840**

[1] end-consumer unit price for replacements (excl. VAT)
[2] end-consumer unit price for new-built / retrofit (excl. VAT)

4.1.5 Price data from the 2018 Ecodesign Impact Accounting

In the Ecodesign Impact Accounting (EIA, details in Annex VI.8), prices of ventilation units are defined by means of three price-efficiency pairs, respectively for a base case (BC), for an average improvement option (MID, typically corresponding to LLCC) and for the best-available technology option (BAT).

In the case of VUs, the efficiency parameter considered is the kWh primary energy consumed (kWhprim), which is the sum of the electricity consumption by the VU (multiplied by 2.5 to convert to primary energy) and the space heating primary energy losses (at 75% average efficiency) due to the ventilation heat losses associated with the VU.

Depending on the scenario, the electric efficiency and thermal efficiency of the VUs increase with the years, leading to a decrease of the kWh primary energy consumed. The price of the VU in a given year is determined in EIA using the kWhprim of that year, interpolating between the three price-efficiency pairs. This price is then decreased (for ECO-scenarios after 2010) by 0.4-0.9 % per year, to account for the decrease of the price over time due to the learning effect and due to the increase in sales quantities.

The EIA price includes the acquisition costs for the VU itself (unit), costs for installation materials (kit) and installation labour costs (install). The unit-price is further split in shares for industry, wholesale, retail and VAT, and used in EIA to compute the revenues per sector. For the residential VUs, the EIA price includes 20% VAT. For non-residential VUs, the EIA price is without VAT.
In addition, EIA specifies the maintenance and repair costs, in euros per year.

In general, EIA data are based on data from the 2014 Impact Assessment (previous paragraph) and from the preparatory studies underlying that IA.

The acquisition costs for the VU itself (unit) are presented in the tables below for a 2010 base case version (BAU scenario) and a 2015 version with improved energy efficiency (ECO scenario).

Table 24. Price data for residential ventilation units from the 2018 Ecodesign Impact Accounting in function of primary energy consumption, for a base case 2010 (BAU) version and an improved 2015 (ECO) version

prices in €/unit (excl. installation, incl. VAT, 2015 euros)

	2010 (BAU)			2015 (ECO)	
	Unit €	kWh prim		Unit €	kWh prim
CUVU	349	4625		589	2545
CBVU	2389	1830		2899	837
LBVU	1305	1057		1336	446

Table 25. Price data for non-residential ventilation units from the 2018 Ecodesign Impact Accounting in function of primary energy consumption, for a base case 2010 (BAU) version and an improved 2015 (ECO) version

prices in €/unit (excl. installation, excl. VAT, 2015 euros)

	2010 (BAU)			2015 (ECO)	
	Unit €	kWh prim		Unit €	kWh prim
CEXH	685	24659		689	22207
CHRV	5988	8072		6005	5519
AHU-S	8418	28958		8549	17203
AHU-M	13988	80945		14004	50915
AHU-L	32476	305010		32261	197967

4.1.6 List price data from a VU manufacturer

List price data (2019) from a manufacturer are presented in Annex VI.9.
Actual street prices (excl. VAT) are assumed to be around 30% lower [30].

For CBVU with heat recovery and maximum flow rate below 250 m3/h, an average street price excl. VAT around € 1750 can be estimated. For models of 300-400 m3/h this increases to € 2000 – 2600, where models with higher thermal efficiency cost around 7% more than comparable models with lower efficiency. A model with enthalpy heat exchanger costs 70% more than the same model with standard heat exchanger.

For LBVU with heat recovery and maximum flow rate 70 m3/h, a street price excl. VAT of € 917 can be estimated.

For CUVU roof-top extract units, estimated street prices excl. VAT vary from € 1500 at 2000 m3/h to € 3700 at 13000 m3/h.

4.1.7 Prices from on-line (internet) sales sites

Prices for on-line sales of Ventilation Units have been collected from e.g. the following sites:

- https://www.amazon.de
- https://www.acsalesdirect.co.uk
- https://sks24.at
- https://www.gamma.nl
- https://www.ventilatieland.nl
- https://www.idealo.it/

The collection is certainly not exhaustive, but is believed to give a good idea of the 2019 street prices for several types of VUs (details and remarks in Annex VI.10).

The on-line prices are presented per VU-type (with or without heat recovery, central or local, continuous operation or not) in paragraph 4.2, excluding VAT and including delivery costs. Where different prices for the same VU-model were available on different sites, the lowest offered price has been considered.

[30] Some internet sales' sites for Ventilation Units show both an original price and a discounted price, and it is not uncommon for the latter to be around 30% lower than the former. Differences between 15 and 30% are also mentioned in earlier ecodesign studies on ventilation units.

The prices are presented per type of VU, in function of the declared maximum flow rate. However, the flow rate is not the only parameter influencing the price, and especially for the smaller VUs not even the main parameter. Parameters that influence the VU-price are e.g.:

- Type of VU, i.e. with or without heat recovery, central or local, continuous or not
- Maximum flow rate
- Electric efficiency
- EC-motor or AC-motor
- 1-phase 230 V or 3-phase 400 V supply
- Thermal efficiency (for models with heat recovery)
- Type of heat exchanger (for models with heat recovery)
- Noise level
- Number of inlets (mainly for CUVUs)
- Presence of filters and type of filter (mainly for BVUs)
- Suitability of the model to optionally add certain types of sensors or controls
- Number of control speed settings (1,2,3,5,7,..) or continuous control or fully automatic
- Accessibility of fans / filters for maintenance and cleaning
- Presence or not of a timer (with or without delay function)
- Presence or not of sensors (humidity, CO2, presence/movement, odour, light)
- User control interface (on/off switch, pull-cord, multiple-button control panel, touch-screen control display, dedicated remote control unit, app-control from mobile phone, tablet or computer (WiFi, blue tooth)
- Presence of closure grills, guards, automatic no-return valves, power supply cable with plug, type of plug, other installation-related components,
- Suitability for high air temperatures; including grease collection (for kitchen exhaust)
- Aesthetics / design, e.g. material (plastic, glass, metal), colour and shape of the room-inlet valve, display of e.g. humidity and temperature, presence of LED-lights on or around the supply valve.

4.2 Prices per VU-type

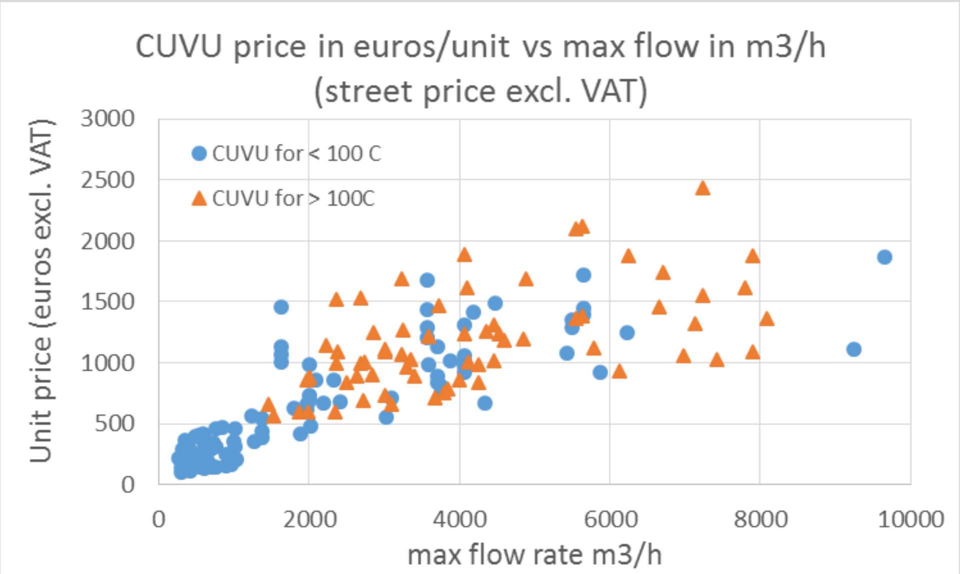
4.2.1 Prices for central unidirectional ventilation units, CUVU

On-line prices (par. 4.1.7) were collected for 166 central unidirectional ventilation unit (CUVU) models (Figure 32).

For the 41 CUVU models with a maximum flow rate between 250 and 1000 m3/h, the average declared maximum flow rate is 551 m3/h with a price of € 248 (excl. VAT).

For the 125 models with a maximum flow rate above 1000 m3/h, the average declared flow rate is 4142 m3/h with a price of € 1102 (excl. VAT).
Excluding the 67 models suitable for kitchen exhaust (air temperature > 100°C; grease collection), that would be exempted from current regulations, the average declared flow rate is 3903 m3/h with a price of € 994 (excl. VAT).

In the online search, no CUVU models were found with maximum flow rate below 250 m3/h. This does not mean that they do not exist, but it is an indication that a one-size-fits-all approach is often used for CUVUs. I.e. a CUVU with maximum flow rate above 250 m3/h is used also where a lower maximum flow rate would be sufficient, appropriately setting the dip-switches during installation.



Online prices 2019, excl. VAT	Number	Average flow m3/h	Average Price €
Entire sample	166	3255	891
of which ≤ 250 m3/h	0		
of which 250-1000 m3/h	41	551	248
of which > 1000 m3/h	125	4142	1102
of which for T < 100 °C	58	3903	994

Figure 32. Collection of on-line (Internet) price data, for central unidirectional ventilation units (CUVU), in function of maximum flow rate.

In 2019 euros, incl. delivery, excl. VAT. Models suitable for kitchen exhaust (air temperature above 100°C; grease collection) separately indicated (source: VHK 2019)

Table 26 compares the residential CUVU-prices from different sources (details in par. 0 and Annex VI). The average on-line price of € 248 for a 551 m3/h VU (extrapolated < € 200 for

250 m3/h) is low when compared to the other sources. In particular the ECO-price from EIA for models with improved efficiency seems rather high.
The average maximum flow rate from models found on internet is higher (550 m3/h) than used in the analyses of IA and EIA (250 m3/h).

Table 27 compares the non-residential CUVU-prices from different sources. The average on-line price of € 994 for a 3900 m3/h VU (interpolated € 530 for 1500 m3/h) matches the price for replacement from the Impact Assessment (without builder mark-up). Note that EIA used the price for 1st time installation from the IA, including the builder mark-up.

Table 26. Comparison of prices for residential CUVUs (source: VHK 2019)

	year	Max flow rate m3/h	Street Price € / unit (excl. VAT)	MSP € / unit
Internet for 250-1000 m3/h	2019	551	248	
Internet for 250 m3/h	2019	250	< 200 [2]	
2014 IA	2003	250	297 [1]	208
2018 EIA	2010 BAU	250	291 [1]	
2018 EIA	2015 ECO	250	491 [1]	
IC (all residential UVUs)	2015			254

[1] in 2015 euros
[2] extrapolating data for VUs with higher flow rates

Table 27. Comparison of prices for non-residential CUVUs
(source: VHK 2019)

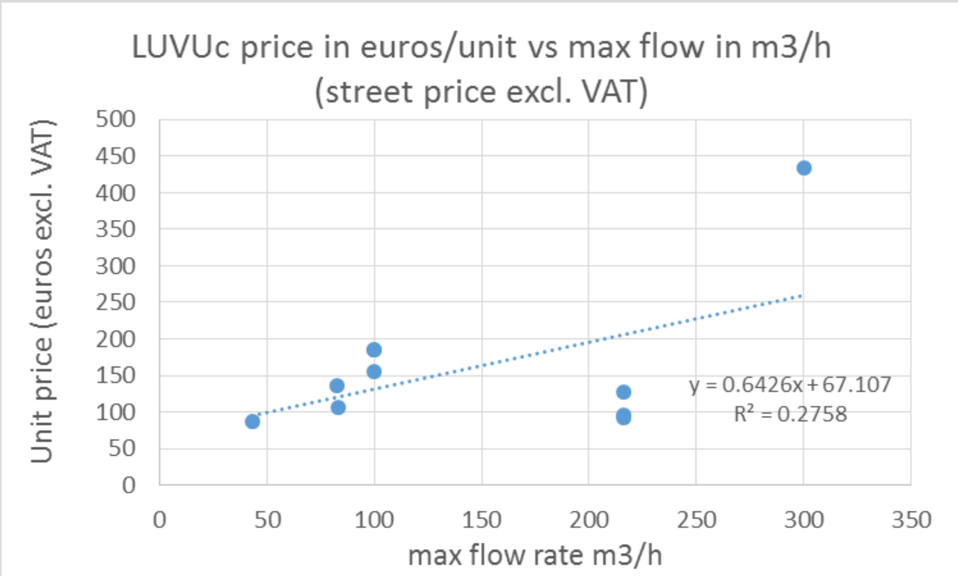
	year	Max flow rate m3/h	Street Price € / unit (excl. VAT)	MSP € / unit
Internet for > 1000 m3/h	2019	3903	994	
Internet for 1500 m3/h	2019	1500	530 [2]	
2014 IA for replacement	2010	1500	527 [1]	324
2014 IA for new / renovate	2010	1500	685 [1]	324
2018 EIA	2010 BAU	1500	685 [1]	
2018 EIA	2015 ECO	1500	689 [1]	
Manufacturer – roof fan	2019	2000	1477 [3]	

[1] in 2015 euros
[2] estimate from linear trend in dataset
[3] list prices minus 30%

4.2.2 Prices for continuous local unidirectional ventilation units, LUVUc

On-line prices (par. 4.1.7) were collected for 10 local unidirectional ventilation unit models intended for continuous operation (LUVUc) (Figure 33). The average price is € 161 (excl. VAT) for an average maximum flow rate of 146 m3/h.

Considering the trend in the data, an 80 m3/h LUVUc would cost € 118, which compares well to the € 91 reported in the Impact Assessment for year 2003.



	Number	Average flow m3/h	Average price €
Entire sample	10	146	161

Figure 33. Collection of on-line (Internet) price data, for continuously operating LUVUc, in function of maximum flow rate

In 2019 euros, incl. delivery costs, excl. VAT. (source: VHK 2019)

Table 28. Comparison of prices for LUVUcs for continuous operation

(source: VHK 2019)

	year	Max flow rate m3/h	Street Price € / unit (excl. VAT)	MSP € / unit
Internet	2019	146	161	
Internet for 80 m3/h	2019	80	118 [2]	
2014 IA	2003	80	91 [1]	63

[1] in 2015 euros
[2] estimate from linear trend in dataset

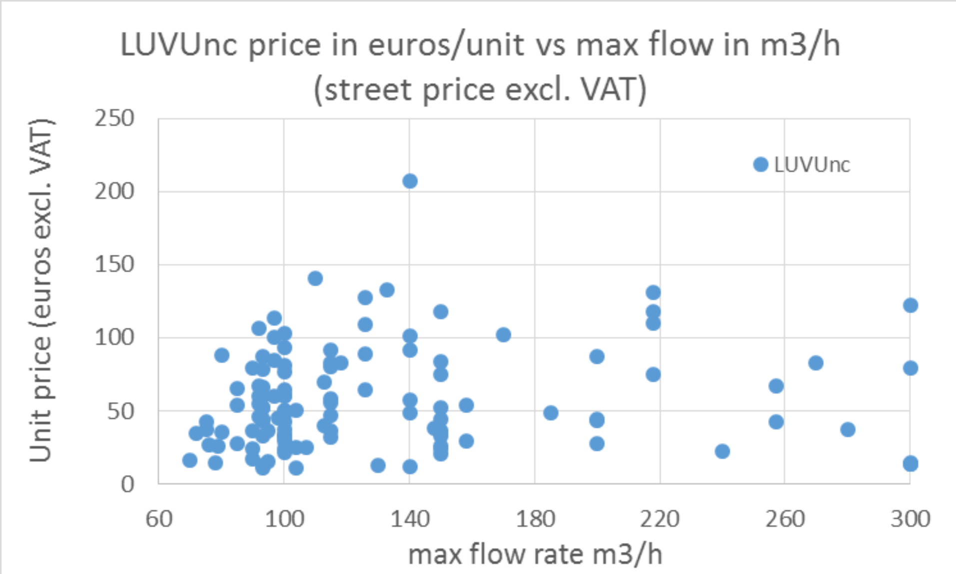
4.2.3 Prices for non-continuous local unidirectional ventilation units, LUVUnc

On-line prices (par. 4.1.7) were collected for 121 local unidirectional ventilation unit models intended for non-continuous operation (LUVUc). These VUs are mainly intended for use in e.g. toilets, bathrooms, laundries, kitchens as intermittently used exhaust fans.

For 59 models with a maximum flow rate below 100 m3/h, the average declared flow rate is 92 m3/h with a price of € 51 (excl. VAT).

For 53 models with a maximum flow rate between 100 and 250 m3/h, the average declared flow rate is 147 m3/h with a price of € 65 (excl. VAT).

For 9 models with a maximum flow rate above 250 m3/h, the average declared flow rate is 285 m3/h with a price of € 52 (excl. VAT).
No information is available from other sources for comparison.



	Number	Average flow m3/h	Average price €
Entire sample	121	130	57
of which ≤ 100 m3/h	59	92	51
of which 100-250 m3/h	53	147	65
of which > 250 m3/h	9	285	52

Figure 34. Collection of on-line (Internet) price data, for non-continuously operating LUVUnc (bathroom / toilet exhaust fans), in function of maximum flow rate

In 2019 euros, incl. delivery, excl. VAT (source: VHK 2019)

4.2.4 Prices for central bidirectional ventilation units, CBVU

On-line prices (par. 4.1.7) were collected for 68 central bidirectional ventilation units (CBVU) (Figure 35).

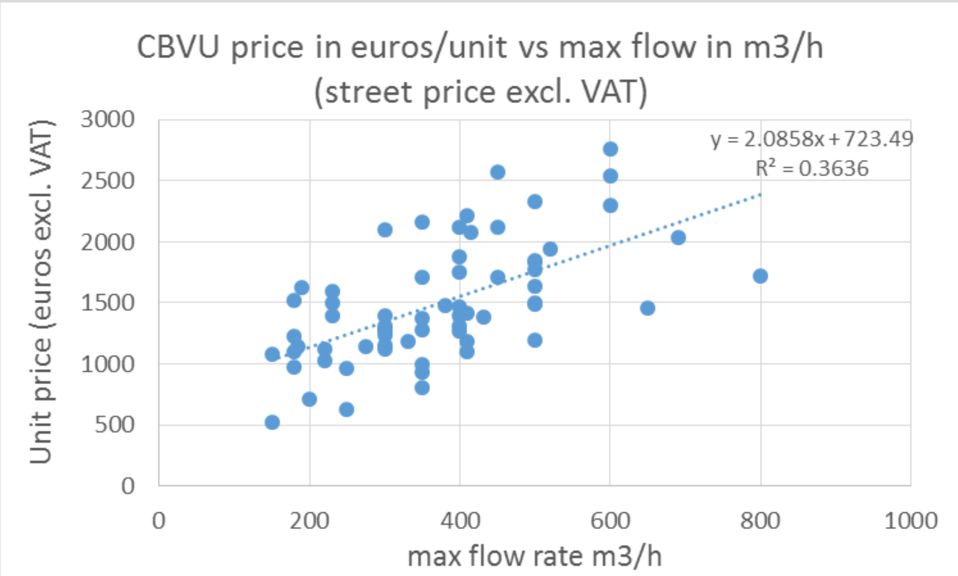
For 14 models of central bidirectional ventilation units (CBVU) with a maximum flow rate below 250 m3/h, the average declared maximum flow rate is 202 m3/h with a price of € 1134 (excl. VAT).

For 50 CBVU models with a maximum flow rate between 250 and 1000 m3/h, the average declared maximum flow rate is 439 m3/h with a price of € 1625 (excl. VAT).

For 2 models with a maximum flow rate above 1000 m3/h, the average declared flow rate is 1750 m3/h with a price of € 3471 (excl. VAT).

Table 29 compares the residential CBVU-prices from different sources (details in par. 0 and Annex VI). The average on-line price of € 1245 for a 250 m3/h VU is low when compared to the other sources. In particular the ECO-price from EIA for models with improved efficiency seems rather high.

Table 30 compares the non-residential CBVU/CHRV-prices from different sources. The average on-line price of € 4500 for a 2250 m3/h VU (extrapolated from dataset) matches the price for replacement from the Impact Assessment (without builder mark-up). Note that EIA used the price for 1st time installation from the IA, including the builder mark-up. Comparing manufacturer selling prices, Daikin / BRG data seem to indicate a downward trend in prices for non-residential CBVU / CHRV.



	Number	Average flow m3/h	Average price €
Entire sample	68	421	1562
of which ≤ 250 m3/h	14	202	1134
of which 250-1000 m3/h	50	439	1625
of which > 1000 m3/h	2	1750	3471

Figure 35. Collection of on-line (Internet) price data, for central bidirectional ventilation units (CBVUs), in function of maximum flow rate

In 2019 euros, incl. delivery, excl. VAT. (source: VHK 2019)

Table 29. Comparison of prices for residential CBVUs (source: VHK 2019)

	year	Max flow rate m3/h	Street Price € / unit (excl. VAT)	MSP € / unit
Internet for < 250 m3/h	2019	202	1134	
Internet for 250-1000 m3/h	2019	439	1625	
Internet for 250 m3/h	2019	250	1245 [2]	
2014 IA	2003	250	2297 [1]	1596
2018 EIA	2010 BAU	250	1991 [1]	
2018 EIA	2015 ECO	250	2416 [1]	
Manufacturer	2019	244	1942 [3]	
Daikin / BRG	2017			1186 [1]
Daikin / BRG	2020			1384 [1]
IC (all residential BVUs)	2015			1531

[1] in 2015 euros
[2] estimate from linear trend in dataset
[3] list prices minus 30%

Table 30. Comparison of prices for non-residential CBVUs / CHRVs (source: VHK 2019)

	year	Max flow rate m3/h	Street Price € / unit (excl. VAT)	MSP € / unit
Internet for > 1000 m3/h	2019	1750	3471	
Internet for 2250 m3/h	2019	2250	4500 [2]	
2014 IA for replacement	2010	2250	4388 [1]	2700
2014 IA for new / renovate	2010	2250	5703 [1]	2700
2018 EIA	2010 BAU	2250	5988 [1]	
2018 EIA	2015 ECO	2250	6005 [1]	
Daikin / BRG	2017			2089 [1]
Daikin / BRG	2020			2048 [1]

[1] in 2015 euros
[2] extrapolated from linear trend in dataset

4.2.5 Prices for local bidirectional ventilation units, LBVU

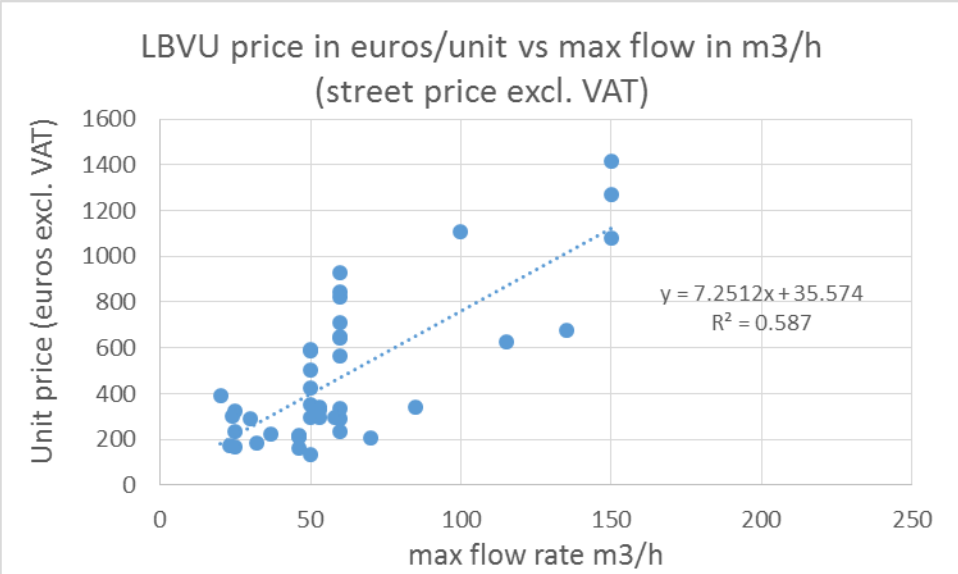
On-line prices (par. 4.1.7) were collected for 45 local bidirectional ventilation units (LBVU).

For 37 LBVU models with a maximum flow rate below 100 m3/h, the average declared maximum flow rate is 50 m3/h with a price of € 403 (excl. VAT).

For 5 LBVU models with a maximum flow rate between 100 and 250 m3/h, the average declared maximum flow rate is 140 m3/h with a price of € 1013 (excl. VAT).

For 3 LBVU models with a maximum flow rate above 250 m3/h, the average declared flow rate is 383 m3/h with a price of € 2122 (excl. VAT).

Table 31 compares the LBVU-prices from different sources (details in Annex VI). The average on-line price of € 869 for a 115 m3/h VU is slightly lower than the prices used in IA and EIA and the price derived from a manufacturer price list. The price estimate derived from Daikin / BRG data (for msp) is the lowest of all prices, even when considering that it is a manufacturer selling price.



	Number	Average flow m3/h	Average price €
Entire sample	45	82	565
of which > 250 m3/h	3	383	2122
of which 100-250 m3/h	5	140	1013
of which ≤ 100 m3/h	37	50	403

Figure 36. Collection of on-line (Internet) price data, for local bidirectional ventilation units (LBVUs), in function of maximum flow rate

In 2019 euros, incl. delivery, excl. VAT. (source: VHK 2019)

Table 31. Comparison of prices for LBVUs

(source: VHK 2019)

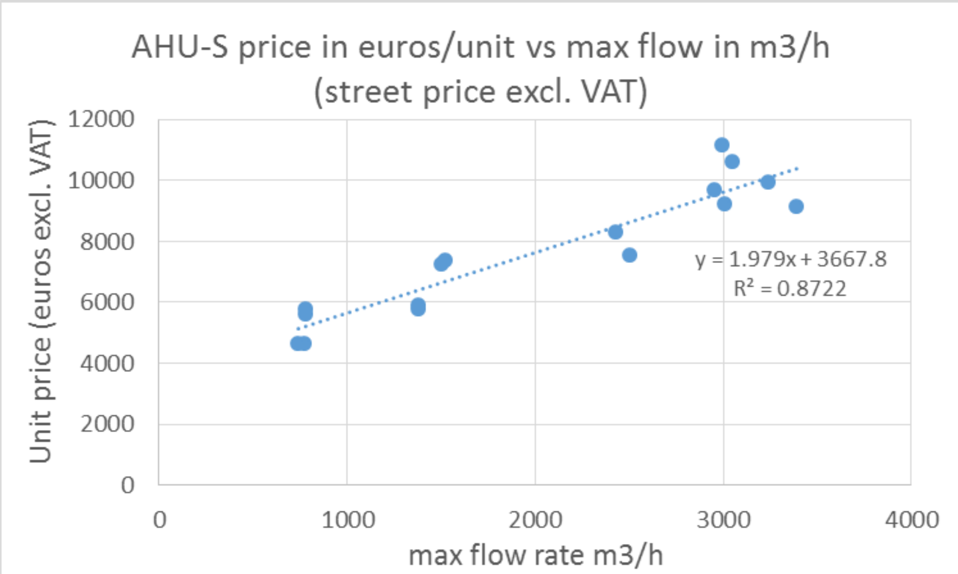
	year	Max flow rate m3/h	Street Price € / unit (excl. VAT)	MSP € / unit
Internet for < 100 m3/h	2019	50	403	
Internet for 100-250 m3/h	2019	140	1013	
Internet for 115 m3/h	2019	115	869 [2]	
2014 IA for replacement	2010	115	1093 [1]	766
2018 EIA	2010 BAU	115	1088 [1]	
2018 EIA	2015 ECO	115	1113 [1]	
Manufacturer	2019	70	917 [3]	
Daikin / BRG	2017			376 [1]
Daikin / BRG	2020			375 [1]

[1] in 2015 euros
[2] estimate from linear trend in dataset
[3] list prices minus 30%

4.2.6 Prices for air-handling units < 5500 m3/h (AHU-S)

For a sample of 16 air-handling units with maximum flow rate below 5500 m3/h (AHU-S), an average price of € 7674 (excl. VAT) and an average maximum flow rate of 2024 m3/h are derived from on-line sales data Figure 37.

Table 32 compares the AHU-S-prices from different sources (details in par. 0 and Annex VI). The average on-line price of € 11600 for a 4000 m3/h VU (extrapolated from dataset) is high compared to the prices used in IA and EIA, but seems compatible with the manufacturer selling prices derived from Eurovent and Daikin/BRG data (for all AHUs).



	Number	Average flow m3/h	Average price €
Entire sample	16	2024	7674

Figure 37. Collection of on-line (Internet) price data, for Air-Handling Units ≤ 5500 m3/h (AHU-S), in function of maximum flow rate

In 2019 euros, incl. delivery, excl. VAT. (source: VHK 2019)

Table 32. Comparison of prices for AHU-S

(source: VHK 2019)

	year	Max flow rate m3/h	Street Price € / unit (excl. VAT)	MSP € / unit
Internet for 4000 m3/h	2019	4000	11600 [2]	
2014 IA for replacement	2010	4000	6220 [1]	4320
2014 IA for new / renovate	2010	4000	8086 [1]	
2018 EIA	2010 BAU	4000	8418 [1]	
2018 EIA	2015 ECO	4000	8549 [1]	
Eurovent (all AHUs)	2017			9500
Daikin / BRG (all AHUs)	2017			8649 [1]
Daikin / BRG (all AHUs)	2020			9503 [1]

[1] in 2015 euros
[2] extrapolated from linear trend in dataset

4.2.7 Prices for air-handling units > 5500 m3/h (AHU-M, AHU-L)

No new price information has been collected for AHUs with a maximum flow rate above 5500 m3/h (AHU-M and AHU-L). Prices for these large installations are typically available on request only, for a specific situation.

This means that the price data from the 2014 Impact Assessment and from the 2018 Ecodesign Impact Accounting remain as reference (Table 23, Table 25):

- AHU-M: € 14000 for new-built / renovation; € 10500 for replacement; 10000 m3/h;
- AHU-L: € 32000 for new-built / renovation; € 24500 for replacement; 35000 m3/h.

4.3 VU-Price built-up

No new information has been collected as regards the price built-up.

The data from the 2014 Impact Assessment remain as reference, see Table 22 and Table 23.

4.4 Installation costs

Installation costs have been defined in the 2014 Impact Assessment (Annex VI.7), subdivided in costs for installation materials and labour costs for installation. Installation costs are also being considered in the 2018 Ecodesign Impact Accounting (Annex VI.8).

Installation materials include e.g. ducts, grills, controls, supply or overflow provisions. These materials are assumed to be necessary only during first installation (new-built or renovation), not during like-for-like replacement of a VU.

Except for small local ventilation units, installation labour costs are lower for new-built than for renovation (additional installation complexity in existing buildings).

In the tables below, the costs have been converted to 2015 euros.

Table 33. Installation costs for residential ventilation units in 2003, converted to 2015 euros per unit

(source: 2014 Impact Assessment; 2018 Ecodesign Impact Accounting; conversion to 2015 euros by VHK 2019)

2015-euros / unit	local exhaust	central exhaust	central HR	local HR
design flow rate (m3/h)	80	250	250	115
Installation materials				
Installation kit, VAT included	0	377	755	126
Supply/overflow provisions, VAT included	0	377	189	0
Sum installation materials	0	755	944	126
Installation labour costs				
installation costs new-built, VAT included)	69	415	1661	138
installation costs renovation, VAT included)	69	1038	2768	138
Installation costs total				
total costs new-built, VAT included)	69	1170	2605	264
total costs renovation, VAT included)	69	1793	3712	264
Compare EIA 2018 (BAU, 2010)		*1212*	*2308*	*218*
Compare EIA 2018 (ECO, 2015)		*2045*	*2800*	*223*

Table 34. Installation costs for non-residential ventilation units in 2010, converted to 2015 euros per unit

(source: 2014 Impact Assessment; 2018 Ecodesign Impact Accounting; conversion to 2015 euros by VHK 2019)

2015-euros / unit	CEXH	CHRV	AHU-S	AHU-M	AHU-L
design flow rate (m3/h)	1500	2250	4000	10000	35000
Installation materials [1]	**2100**	**7700**	**37200**	**106000**	**414000**
Installation labour costs					
installation labour, new-built	2900	11200	55800	159000	621000
installation labour, renovation	4100	13500	67000	191000	745000
installation labour, replacement	260	2200	3100	5200	12250
Installation costs total					
total installation, new-built	5000	18900	93000	265000	1035000
total installation, renovation	6200	21200	104200	297000	1159000
total installation, replacement	260	2200	3100	5200	12250
Compare EIA 2018 (BAU, 2010)	*5400*	*20500*	*97000*	*272000*	*942000*
Compare EIA 2018 (ECO, 2015)	*5430*	*20600*	*98500*	*272500*	*935000*

[1] not for replacement, only for new-built or renovation

4.5 Maintenance and Repair costs

Annual maintenance and repair costs have been defined in the 2018 Ecodesign Impact Accounting (Annex VI.5), and are already in 2015 euros in the source. Maintenance includes e.g. filter replacement, cleaning of fans, ducts, valves and grills, and small repairs.

Table 35. Annual maintenance and repair costs for ventilation units, in 2015 euros per unit per year

(source: 2018 Ecodesign Impact Accounting)

2015-euros / unit / year	Annual maintenance and repair costs per unit
Residential	
CBVU	52
LBVU	22
CUVU	10
LUVUc	2*
LUVUnc	2*
Non-residential	
CEXH / CUVU	72
CHRV / CBVU	135
AHU-S	191
AHU-M	652
AHU-L	2739

* First estimate, not in EIA

Annex I: ProdCom data related to Ventilation Units

Note: EU total data in this Annex are for EU-28, incl. UK

1. AHUs and CHRV units, products / systems

The production of air handling units (AHUs) and probably also of central heat recovery ventilation (CHRV) units is expected to be included in Prodcom category 28251270: ‘Air conditioning machines not containing a refrigeration unit; central station air handling units; vav boxes and terminals, constant volume units and fan coil units’.

The Eurostat production statistics per EU Member State are given in Table 36 (production volume in 000 units) and Table 37 (value of production in M euros) for the available period 1995-2017.

As regards the number of units produced, Italy is by far the largest producer, covering 42% of the total EU28 production in 2017. Considering the value of the production, the largest contributions come from Germany, Italy and Sweden.

In 2017, around 1.5 mln units are produced in EU28 for a total value of 1.8-1.9 bn euros. This implies an average unit price around 1230 euros, but the variation is large, from 16 euros/unit for smaller products from Estonia to more than 10,000 euros/unit for the production from Austria and the Netherlands.

Table 36. EU28 Production Volume of non-cooling AC units, AHUs, VAV Boxes, CAV boxes and FCUs, in units x 1000

(Source: Eurostat 2019, ProdCom code 28251270)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	68			91		119				132	111			22	49	133	62	26	39	20		41	23
Netherlands									0		3	4				4			1	5		1	2
Germany	139	137	150	118	101	74	80	75	70	69	81	94	88	99	77	92	96	96	88	89	91	84	87
Italy	245	525	282	309	540	740	696	687	767	861	1050	1208	1119	986	571	551	685	589	538	517	572	547	652
Un. Kingdom	46	49	59	77	68	72	73	44	32	23	22	34	32	29	26	32	32	23	20	29	25	37	29
Ireland	7	28	34	38	117	75	47	86					48										
Denmark							17	50	34	15	62	72	79	53	45	61	63	41	37	30	34	43	61
Greece																			0	0	0	0	0
Portugal						9	17		1	1	1					1						1	
Spain	17	23	36	35	65	59	60	47	61	81	71	29	27	18	36	36	34	31	29	29	21	13	16
Belgium																							
Luxemburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden		7	2	3	3	3	4	4			23	18	64	66	54	51	47	58	60	58	71	87	95
Finland					58	60	78	60	71		83			104	76	64	62	62	57	58	60	72	84
Austria											3	3	3	3	3	4	5	7					6
Malta								0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia						0	0	0	0	0				0		0	0	0	0	0	0	210	109
Latvia							0		0	0	0	0	0	0	0	0	0	0	0			0	0
Lithuania						0	0		0	0	0	5	5	6	4	5	48	34	26	38	42	47	57
Poland									16	17		4			36	59	67	176					
Czech Rep.										222	260		160	185	124	107	121	110	124	110			221
Slovakia					0	0		0						0							3	3	2
Hungary							39	211	8	8	7	8	11	11	8	13	45	1	1	2	2	1	
Romania						0	0			0	0	0	0	0		0	0	0	0	0	0	0	0
Bulgaria							0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0
Slovenia																							
Croatia							0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1
Cyprus								0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 TOTAL									**1919**	**2110**	**2342**	**2582**	**1845**	**1719**	**1146**	**1252**	**1421**	**1317**	**1531**	**1294**	**1341**	**1455**	**1569**

Table 37. EU28 Production Value of non-cooling AC units, AHUs, VAV Boxes, CAV boxes and FCUs, in M euros

(Source: Eurostat 2019, ProdCom code 28251270)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	72	65	87	82	88	88	99	99	94	122	103	84	79	55	95	74	84	62	48	40	42	40	34
Netherlands									0							47				45			27
Germany	263	312	345	396	489	524	623	503	645	352	340	397	416	480	429	470	520	530	512	537	561	547	567
Italy	99	181	157	172	189	239	264	263	236	240	267	474	478	515	340	330	426	336	304	284	317	315	351
Un. Kingdom	131	137	142	180	144	155	153	136	107	92	93	99	99	86	75	83	73	79	77	111	115	132	105
Ireland		21	29	42	40	15	14	18	20	19	19	21	12	21									
Denmark	48	42	42	51	47	46	56	80	68	90	85	110	121	93	79	99	94	70	65	59	56	73	106
Greece																			0	0	0	0	0
Portugal						3	4		2	2	2					6						5	
Spain	26	28	23	28	38	45	56	50	51	54	46	28	30	27	36	31	29	20	18	19	20	17	20
Belgium																							
Luxemburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden		0	0	22	26	24	31	33	72	72	83	104	179	197	158	183	196	225	238	236	244	260	269
Finland	33	34	30	57	45	51	73	62	60	62	66	72	93	79	64	58	47	55	47	49	52	51	63
Austria											36	38	45	49	44	44	51	59					59
Malta								0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia						0	0	0	0	0				0		0	0	0	0	0	0	2	2
Latvia							0		0	0	0	0	0	0	0	0	0	0	0			0	0
Lithuania						0			0	0	0	3	4	5	3	3	15	12	21	51	59	67	81
Poland									12	11	12	7	20	52	38	44	53	68	71	65	60	60	81
Czech Rep.							13	12	14	22	30	28	33	41	29	30	33	29	32	30	34	36	43
Slovakia					0	0		0					0										
Hungary							3	3	1	3	3	2	9	9	9	7	11	15	14	15	17	14	
Romania						0	0			0	0	0	0	0		0	0	0	0	0	0	0	0
Bulgaria							0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1
Slovenia																							
Croatia							0	0	1	2	2	3	3	5	4	3	4	5	4	5	6	6	6
Cyprus								0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 TOTAL									**1475**	**1272**	**1255**	**1535**	**1685**	**1792**	**1469**	**1550**	**1726**	**1654**	**1581**	**1658**	**1738**	**1788**	**1935**

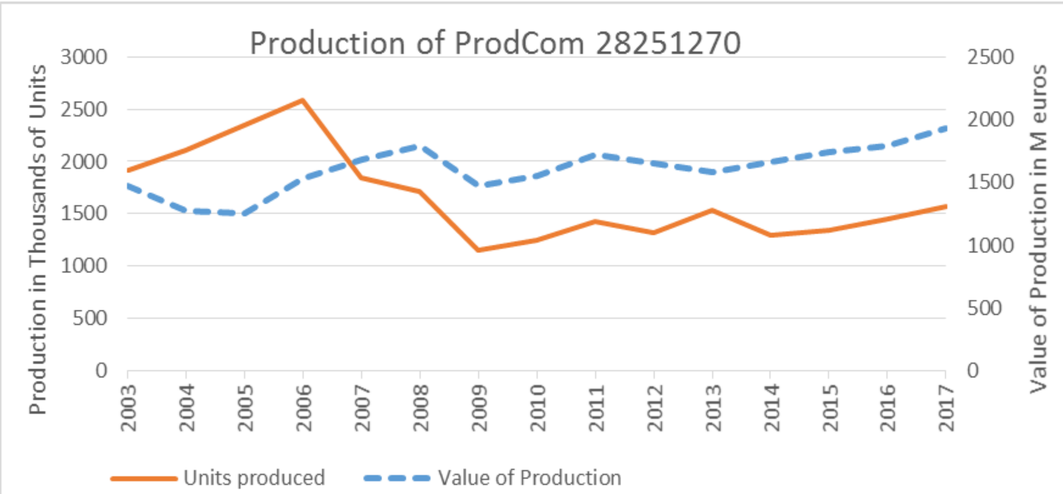


Figure 38. EU28 total Production Volume (000 units) and Value (M euros) of non-cooling AC units, AHUs, VAV Boxes, CAV boxes and FCUs

(Source: Eurostat 2019, ProdCom 28251270)

Country data for import and export have been taken from ProdCom for code 28251270. These data include intra-EU28 trade. EU28 totals for Extra-EU trade have been taken from ComExt for CN8 categories 84158300 (from 2006 onwards) and 84158390 (until 2006), with description '*Air conditioning machines comprising a motor-driven fan, not incorporating a refrigerating unit but incorporating elements for changing the temperature and humidity (excl. of a kind used for persons in motor vehicles, and self-contained or "split-systems")*'. These totals do not include intra-EU28 trade and consequently are not the sum of the country-data. Only monetary data (values) are available for import and export, not quantities in number of units. Import and Export data are shown in Table 38 and Table 39.

In 2017, the total value of exports towards extra-EU28 was 0.5 bn euros. In the same year, the total value of imports from extra-EU28 was 0.18 bn euros.

Table 38. EU Export value of non-cooling AC units, AHUs, VAV Boxes, CAV boxes and FCUs, in M euros

(Source: Eurostat 2019, ProdCom code 28251270 and ComExt CN8 codes 84158300 and 84158390)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	69	75	87	76	110	103	87	72	63	58	57	41	61	63	61	47	40	34	37	34	28	47	48
Netherlands	13	21	12	10	10	12	18	35	31	30	26	35	48	53	55	85	95	93	83	78	77	89	60
Germany	58	65	73	75	68	101	106	117	114	126	148	175	230	250	221	212	314	253	242	250	265	239	281
Italy	100	143	137	165	189	222	223	240	216	210	226	226	289	287	199	219	256	270	297	246	237	263	284
Un. Kingdom	35	40	42	28	44	65	66	54	53	58	55	72	69	60	49	50	53	70	62	63	89	89	89
Ireland	10	13	20	22	12	7	4	4	3	5	6	6	7	4	3	4	4	4	5	6	6	9	14
Denmark	11	13	13	14	20	26	35	32	26	40	32	41	57	49	41	41	49	36	38	33	33	36	44
Greece	1	1	2	2	3	1	2	4	2	2	2	1	2	2	1	1	1	1	1	0	1	1	1
Portugal	0	0	1	2	2	3	3	3	1	1	0	1	1	1	1	0	0	1	1	4	2	2	2
Spain	12	6	5	6	5	9	6	6	6	12	18	38	27	17	14	16	16	22	49	48	46	41	39
Belgium	7	10	9	15	14	22	19	14	14	22	15	10	14	20	19	19	17	10	11	12	14	8	12
Luxemburg					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	20	15	19	21	26	23	27	26	33	34	36	53	74	94	77	96	111	135	126	121	93	96	107
Finland	6	7	6	10	6	6	6	7	6	5	5	12	16	18	16	3	3	4	5	4	2	3	2
Austria	31	43	53	48	45	48	52	55	53	54	52	45	49	49	36	25	18	17	19	26	24	20	22
Malta								0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Estonia						0	0	0	0	0	1	1	0	1	0	1	1	1	0	0	1	1	1
Latvia							0	0	0	0	0	0	0	1	1	2	3	4	4	3	3	2	2
Lithuania						0	0	1	1	2	3	5	7	13	14	26	36	49	56	62	64	64	80
Poland								15	16	19	29	11	20	30	22	29	39	47	51	45	39	41	46
Czech Rep.							7	7	6	22	30	35	40	52	37	37	54	59	62	65	68	91	94
Slovakia					8	20	13	22	25	10	5	6	25	17	10	15	43	49	46	42	40	37	48
Hungary								0	1	1	1	45	86	100	94	84	87	12	13	11	13	12	15
Romania						0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	0
Bulgaria							0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Slovenia							0	1	2	2	3	3	7	5	4	2	4	6	6	6	7	6	14
Croatia								0	0	0	0	0	0	1	1	1	2	6	6	5	8	9	9
Cyprus								0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 Total for Extra EU						**175**	**184**	**222**	**177**	**204**	**234**	**261**	**332**	**380**	**323**	**340**	**466**	**459**	**504**	**484**	**468**	**458**	**508**

Table 39. EU Import value of non-cooling AC units, AHUs, VAV Boxes, CAV boxes and FCUs, in M euros

(Source: Eurostat 2019, ProdCom code 28251270 and ComExt CN8 codes 84158300 and 84158390)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	89	97	129	113	151	89	96	98	97	93	97	104	102	102	89	85	100	102	93	99	92	90	103
Netherlands	32	32	37	28	23	30	25	30	39	43	40	41	64	56	51	58	64	64	50	52	46	55	56
Germany	32	29	38	28	35	37	54	52	56	71	85	124	172	177	152	149	172	98	93	98	115	131	142
Italy	46	64	48	56	103	111	104	116	136	194	153	98	178	100	63	67	59	34	28	36	47	40	40
Un. Kingdom	47	60	49	80	80	95	91	71	54	79	93	126	195	176	125	133	156	153	143	152	154	143	142
Ireland	6	11	14	17	15	22	18	15	13	17	20	27	20	15	11	6	2	4	7	10	10	10	18
Denmark	4	4	4	5	4	5	8	7	7	8	7	8	14	12	6	7	9	10	8	10	13	11	7
Greece	4	3	6	5	6	7	6	3	5	4	3	3	4	6	4	3	5	7	3	5	4	5	4
Portugal	5	3	4	6	8	11	13	9	12	11	15	17	21	22	19	23	19	16	15	14	17	16	18
Spain	12	18	13	18	25	33	35	27	33	65	59	60	47	28	25	28	22	15	10	8	9	14	15
Belgium	16	23	23	15	11	17	16	16	18	21	24	24	31	37	31	34	37	39	45	45	45	43	46
Luxemburg					3	2	7	3	4	5	6	3	4	4	4	6	6	5	5	7	6	8	13
Sweden	7	8	8	5	9	34	26	46	37	25	25	36	27	21	15	23	29	18	15	16	14	13	16
Finland	8	7	8	10	10	13	16	14	12	13	11	8	10	11	8	6	10	10	10	10	11	11	11
Austria	13	17	16	21	25	23	24	24	16	17	26	34	34	38	37	35	40	49	48	45	37	47	51
Malta								0	0	0	0	1	1	1	1	1	1	1	1	3	2	2	1
Estonia						3	3	4	4	4	3	3	3	5	2	2	4	5	3	4	5	8	10
Latvia							2	3	3	3	1	2	3	4	3	3	6	6	5	4	5	3	4
Lithuania						2	2	3	4	4	4	5	7	9	10	5	7	8	9	11	13	12	14
Poland								19	19	23	20	24	36	35	23	31	40	35	36	36	51	47	44
Czech Rep.							19	16	19	20	23	19	28	26	13	11	13	14	17	17	16	16	21
Slovakia					3	7	8	6	8	7	10	11	16	12	11	13	9	8	7	8	11	12	14
Hungary								18	0	0	11	17	17	25	15	15	12	9	10	18	21	17	16
Romania						3	2	5	3	5	7	12	15	18	8	9	10	10	9	10	13	16	13
Bulgaria							2	3	3	4	6	6	8	7	4	3	4	3	3	3	5	3	4
Slovenia							3	3	3	4	5	5	10	9	6	6	5	7	7	5	4	5	6
Croatia								0	6	6	6	5	8	9	5	4	3	3	4	3	4	5	5
Cyprus								0	2	2	1	1	2	1	1	1	1	1	0	0	0	0	1
EU28 Total for Extra EU						**224**	**203**	**158**	**166**	**292**	**250**	**255**	**359**	**276**	**207**	**224**	**259**	**198**	**185**	**209**	**211**	**189**	**180**

The combined results of EU28 production and extra-EU28 imports and exports in the period 1995-2017 are given in Table 40, also providing a calculation of the apparent consumption (production + imports - exports), expressed in millions of euros. As unit values for production, import and export may be different, and not directly comparable, the resulting value for the apparent consumption is indicative only and should be used with care.

As shown in Figure 39, until 2007 export and import value are similar so that the value of apparent consumption equals the value of production. In later years, the export value exceeds the import value. As order of magnitude, import and export value are around one quarter of the production value. In 2017, the value of apparent consumption is around 1.6 bn euros.

Table 40. EU28 summary in M euros for Production, Extra-EU28 Imports, and Extra-EU28 Exports of non-cooling AC units, AHUs, VAV Boxes, CAV boxes and FCUs.

Value of apparent consumption (production + import – export) computed by VHK (Source: Eurostat 2019, ProdCom code 28251270 and ComExt CN8 codes 84158300 and 84158390)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28	672	821	856	1030	1107	1190	1389	1259	1475	1272	1255	1535	1685	1792	1469	1550	1726	1654	1581	1658	1738	1788	1935
Import from Extra-EU28						224	203	158	166	292	250	255	359	276	207	224	259	198	185	209	211	189	180
Export to Extra-EU28						175	184	222	177	204	234	261	332	380	323	340	466	459	504	484	468	458	508
Apparent consumption						**1239**	**1408**	**1195**	**1463**	**1359**	**1272**	**1529**	**1712**	**1689**	**1354**	**1435**	**1519**	**1393**	**1262**	**1383**	**1480**	**1519**	**1607**

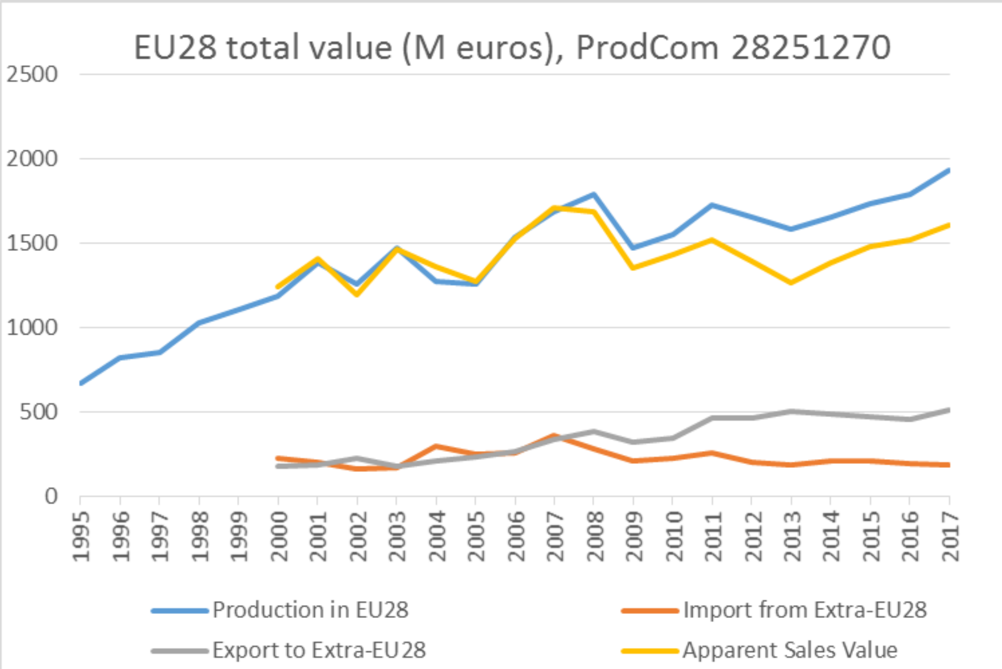


Figure 39. Production, Export, Import and apparent Consumption EU28

The conclusion is that the EU-industry holds a relatively strong position in the above mentioned product groups, with Italy (mostly Fan Coil Units, FCUs) and Germany (mostly Air Handling Units, AHUs) accounting for a major part of the production.

As mentioned, the usefulness of the presented figures for the study on Ventilation Units is limited, due to the very heterogeneous nature of the product group. They constitute a maximum value.

2. AHUs and CHRV units, parts

Other relevant Eurostat statistics in this context relate to AHU modules that are manufactured as Prodcom category 28253010: '*Parts for air conditioning machines (including condensers, absorbers, evaporators and generators)*' and that are traded as CN8 categories 84159000 and 84159090: '*Parts of air conditioning machines, comprising a motor-driven fan and elements for changing the temperature and humidity, n.e.s.*'.

Monetary production statistics per EU Member State are given in Table 41. The countries with largest production value in recent years are Germany, Czech Republic and Slovakia. The total EU28 production value of these parts in 2017 is around 2.7 bn euros.

This production value is higher than that of complete airco units without refrigeration ProdCom 28251270 (€ 1.9 bln. in 2017), discussed in the previous section. Even when extending the latter with the production value of complete airco units with refrigeration ProdCom 28251250 (€ 2.4 bln. in 2017), the value of the parts production is still more than 50% of the value of complete systems/products. The main reason behind this is probably the fact that air-conditioning systems rarely get replaced as a whole. As mentioned in the AC Task 2 study, their product life 'as a system' may be as long as 30-35 years. But the product life of individual components, such as ventilation modules and heat exchanger modules in an AHU, is typically only 15-20 years [31]. One might classify this as 'repairs', but actually 'replacement sales' would be more appropriate.

Table 41. EU Production value for Parts of Air Conditioning machines, in M euros

(Source: Eurostat 2019, ProdCom 28253010)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	12	15	6	5	6	22	13	9	7	7	7				23	15		18	20	19	23	21	24
Netherlands					10						15												
Germany	151	182	181	211	196	212	230	480	459	708	641	694	737	771	603	681	769	663	625	627	599	611	598
Italy	25	139	36	36	44	48	30	30	44	65	57	76	102	185	112	135	176	124	124	101	134	153	143
Un. Kingdom	90	124	168	180	187	190	152	143	140	116	113	117	124	73	86	81	60	63	60	76	112	74	67
Ireland	5	8	11	20	20	25	19	21	19	17	12	11	13	14	4	8	10	5	5	3	6		2
Denmark	4	7	6	6	7	7	9	9	10	8	17	7	9	9	6	4	4	6	12	17	18	18	20
Greece	5	5	3	4	3	0	0	4	2	5	4	4	4	1	4	6	2	2	9	8	9	7	6
Portugal	4		0	0	24	4	7	7	7	7	5	5	3	2	2	2	2	1				0	
Spain	191	176	238	253	274	328	366	387	473	173	180	205	174	127	112	109	106	151	170	191	171	200	203
Belgium	3	5	4	4			13	18	24	30	29												
Luxemburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden		0	0	17	16	19	25	13	8	7	8				124	127	155	149	147		140	140	145
Finland	4	7	33	37	37	47	99	110	91	105	87	91	103	116	91	91	106	106	91	86	108	88	90
Austria	4							13	16	25	15			25	19								
Malta									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia								0	0	1	1	1	1	1	1	1	1	2	0	3	3	4	4
Latvia							0	0	0	0	1	0	0										
Lithuania								3			2	2	2	1	2	4	7	8	9	11	11	12	13
Poland								1	1	6			16	15		25	81	22	52	56	122	98	101
Czech Rep.							16	19	35	119	303	404	204	339	257	317	364	365	344	360	541	571	630
Slovakia				3	0	0	0	8	8	14	12	14	24	53	61	244	212	252	271	263	331	337	354
Hungary							9	9	9	15	42	48	66	70	61	81	96	119	26	45	57	57	52
Romania						1	1				0		0				4		5	7	7	7	9
Bulgaria							0	0	0	0	3	4	4	8	34	9	12	10	6	7	7	10	11
Slovenia							4	4	3		3	1					2	2	3	3	4	4	6
Croatia									3	5	6	5	12	19	16	16	16	9	20	18	25	37	15
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 TOTAL									**1363**	**1449**	**1569**	**1855**	**1865**	**2105**	**1800**	**2082**	**2358**	**2228**	**2153**	**2215**	**2625**	**2658**	**2687**

[31] The FGK supplementary study 2010 on ventilation systems <125 W mentions 17 years as an overall average.

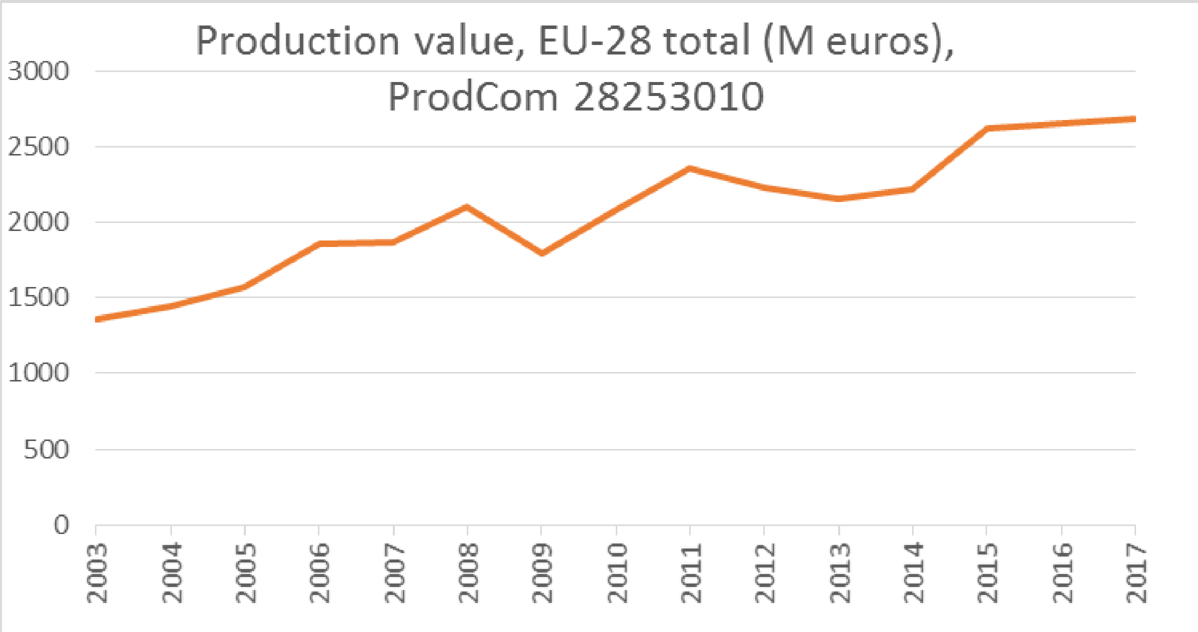


Figure 40. EU28 Total Production value for Parts of Air Conditioning machines, in M euros
(Source: Eurostat 2019, ProdCom 28253010)

Country data for import and export have been taken from ProdCom for code 28253010. These data include intra-EU28 trade. EU28 totals for Extra-EU trade have been taken from ComExt for CN8 categories 84159000 (from 2006 onwards) and 84159090 (until 2006), with description '*Parts of air conditioning machines, comprising a motor-driven fan and elements for changing the temperature and humidity, n.e.s.*'.. These totals do not include intra-EU28 trade and consequently are not the sum of the country-data. Only monetary data (values) are available for import and export, not quantities in number of units. Import and Export data are shown in Table 42 and Table 43.

In 2017, the total value of extra-EU28 exports was 1.3 bn euros. In the same year, the total value of extra-EU28 imports was 1.4 bn euros.

Table 42. EU Export value for Parts of Air Conditioning machines, in M euros

(Source: Eurostat 2019, ProdCom 28253010 and ComExt CN8 codes 84159000 and 84159090)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France									298	279	242	220	232	208	151	149	176	202	274	303	325	316	232
Netherlands									89	101	115	130	139	188	145	169	196	220	224	225	239	373	489
Germany									368	443	414	363	350	373	323	458	556	579	660	716	724	725	680
Italy									232	251	237	275	325	312	314	298	291	331	370	367	420	434	513
Un. Kingdom									104	169	161	98	102	101	129	157	145	132	119	127	166	174	141
Ireland									8	3	4	6	6	11	9	13	11	9	6	11	4	12	8
Denmark									12	13	15	19	19	25	25	27	34	44	36	32	29	37	35
Greece									4	3	3	5	5	5	3	4	6	2	2	2	3	3	4
Portugal									14	11	14	16	15	16	14	14	17	15	24	19	23	20	28
Spain									177	172	153	178	194	138	120	122	141	148	142	150	141	131	163
Belgium									117	130	131	131	155	179	702	679	706	627	652	629	607	656	669
Luxemburg									0	0	0	0	1	0	1	1	0	0	1	0	0	1	0
Sweden									61	60	68	77	82	90	77	92	89	102	98	101	105	95	82
Finland									17	16	19	12	19	16	9	10	8	6	5	5	5	4	4
Austria									38	48	56	65	64	72	72	72	85	71	75	65	61	68	79
Malta									0	0	1	0	1	1	1	0	1	0	1	0	1	0	0
Estonia									0	0	1	1	1	1	1	4	5	4	4	5	5	7	6
Latvia									0	0	0	0	1	2	1	1	1	5	19	27	39	34	36
Lithuania									2	3	3	3	3	3	5	8	12	14	16	18	18	18	20
Poland									25	53	68	72	102	102	67	99	111	132	118	109	116	106	125
Czech Rep.									240	313	429	479	519	575	467	514	579	575	578	642	918	1046	1000
Slovakia									5	7	11	11	19	18	17	39	43	42	52	61	77	86	137
Hungary									88	80	0	97	108	90	65	105	166	176	203	193	243	262	266
Romania									1	1	19	32	42	42	44	61	68	81	94	108	114	136	131
Bulgaria									0	0	1	1	7	15	27	4	2	3	4	5	3	2	3
Slovenia									1	1	1	2	4	3	3	2	3	6	9	12	12	7	7
Croatia									0	0	1	1	1	2	2	1	2	1	2	2	3	4	7
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 Total for Extra EU						**413**	**449**	**440**	**434**	**498**	**480**	**567**	**636**	**640**	**632**	**774**	**889**	**978**	**1061**	**1083**	**1097**	**1250**	**1296**

Table 43. EU Import value for Parts of Air Conditioning machines, in M euros

(Source: Eurostat 2019, ProdCom 28253010 and ComExt CN8 codes 84159000 and 84159090)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France									215	265	253	243	250	283	451	442	418	417	450	448	475	516	575
Netherlands									100	106	91	96	127	133	126	168	200	230	233	266	230	286	312
Germany									538	495	605	607	688	607	554	706	818	756	778	831	854	864	788
Italy									183	203	191	183	244	271	208	388	407	360	419	409	353	491	527
Un. Kingdom									306	347	311	305	374	469	286	344	390	372	362	371	386	381	387
Ireland									16	16	20	18	15	13	9	12	12	11	11	17	16	20	24
Denmark									46	41	32	33	41	39	29	29	38	36	40	39	42	43	38
Greece									20	27	19	17	24	26	45	37	28	25	25	27	32	37	43
Portugal									34	27	30	31	32	31	55	63	60	48	52	48	47	54	58
Spain									164	187	149	167	207	191	264	317	330	263	315	367	412	482	459
Belgium									202	227	226	186	219	234	304	316	354	313	357	362	330	395	407
Luxemburg									7	6	5	7	7	7	7	8	9	7	6	8	9	10	12
Sweden									37	38	51	73	71	73	58	67	71	77	79	94	92	72	56
Finland									15	15	19	21	21	26	19	20	26	23	22	33	40	40	42
Austria									75	103	85	91	103	109	88	80	99	83	92	94	99	106	130
Malta									6	3	4	4	4	4	4	10	3	3	5	3	5	5	4
Estonia									3	3	5	5	5	5	2	2	4	4	4	6	6	5	5
Latvia									4	4	4	4	5	4	2	2	3	8	18	30	35	30	35
Lithuania									3	4	5	4	4	5	2	3	4	6	8	11	11	12	14
Poland									25	42	58	84	93	120	77	117	117	106	114	120	122	145	158
Czech Rep.									81	79	104	128	140	168	93	121	175	190	187	198	235	278	326
Slovakia									12	16	18	24	42	35	28	45	38	63	51	58	64	96	107
Hungary									23	33	60	44	70	78	50	91	106	118	125	158	190	219	206
Romania									12	11	19	28	46	56	56	60	61	68	65	59	57	52	61
Bulgaria									6	6	7	10	18	22	26	28	23	28	29	28	37	45	48
Slovenia									3	3	2	4	6	6	6	6	7	12	16	18	18	15	17
Croatia									5	5	7	7	7	9	7	9	8	8	6	8	11	14	21
Cyprus									1	2	2	2	2	5	3	3	2	2	1	1	2	2	3
EU28 Total for Extra EU						**535**	**500**	**429**	**437**	**496**	**428**	**519**	**631**	**678**	**556**	**765**	**897**	**904**	**949**	**1036**	**1074**	**1330**	**1402**

The combined results of EU28 production and extra-EU28 imports and exports in the period 1995-2017 are given in Table 44, also providing a calculation of the apparent consumption (production + imports - exports), expressed in millions of euros. As unit values for production, import and export may be different, and not directly comparable, the resulting value for the apparent consumption is indicative only and should be used with care.

As shown in Figure 41, export and import values are similar so that the value of apparent consumption equals the value of production. As order of magnitude, import and export value are around half the production value. In 2017, the value of apparent consumption is around 2.8 bn euros.

Table 44. EU28 summary in M euros for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Parts for Air Conditioning machines

Value of apparent consumption (production + import – export) computed by VHK (Source: Eurostat 2019, ProdCom 28253010 and ComExt CN8 codes 84159000 and 8415900)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28	497	667	686	776	824	905	993	1287	1363	1449	1569	1855	1865	2105	1800	2082	2358	2228	2153	2215	2625	2658	2687
Import from Extra-EU28						535	500	429	437	496	428	519	631	678	556	765	897	904	949	1036	1074	1330	1402
Export to Extra-EU28						413	449	440	434	498	480	567	636	640	632	774	889	978	1061	1083	1097	1250	1296
Apparent consumption						**1027**	**1044**	**1276**	**1366**	**1447**	**1517**	**1807**	**1860**	**2143**	**1724**	**2073**	**2366**	**2154**	**2041**	**2168**	**2602**	**2738**	**2793**

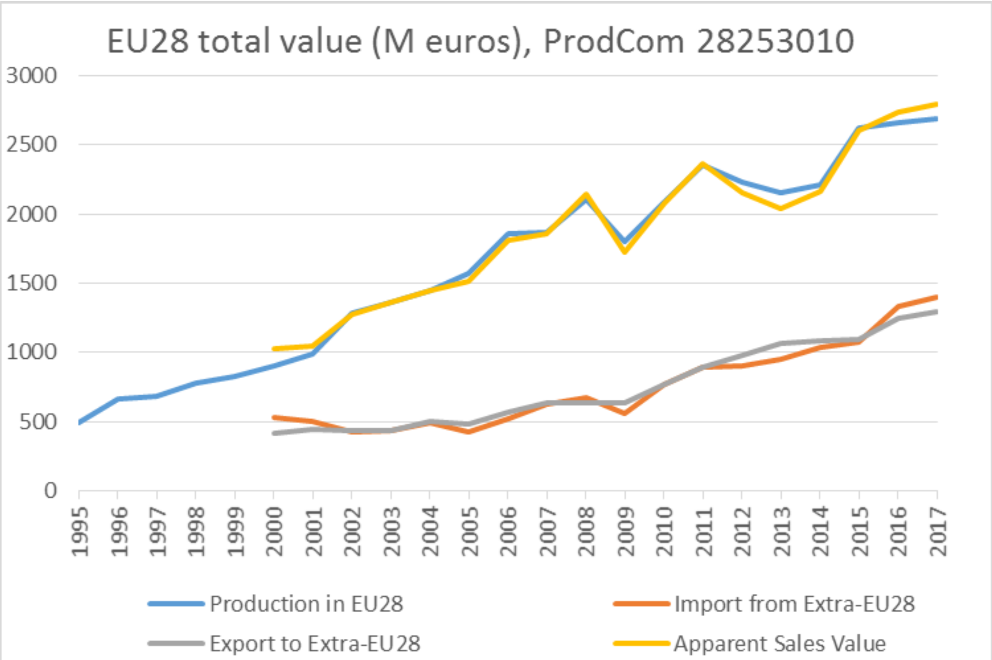


Figure 41. EU28 total value in M euros for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Parts for Air Conditioning machines

Value of apparent consumption (production + import – export) computed by VHK (Source: Eurostat 2019, ProdCom 28253010 and ComExt CN8 codes 84159000 and 8415900)

The value of these statistics for the purpose of the underlying study is again very limited, given the mix with non-ventilation products, but at the moment it is the best that Eurostat can offer.

Note that the above parts cover only a small part of the extra installation materials. The most important materials, also in money terms, are in the air duct-system. Unfortunately, Eurostat PRODCOM does not specify, e.g. within section 24, which tubes and sheets are produced as air ducts and therefore no figures can be presented here. The same can be said about other parts of the duct system: vibration isolators (a.k.a. attenuators, 'isolating' AHU from ducts), take-offs (first divider after AHU), plenums (dividers further downstream), risers/stacks (vertical thin and wide or oval ducts), dampers, terminal units (e.g. VAV boxes), grills and diffusers. The part that deals specifically with ventilation controls is also not shown in PRODCOM.

3. Central exhaust or supply units

Central exhaust or supply ventilation units > 125 W are included in Prodcom categories (NACE Rev. 2) [32]:

- 28252030 Axial fans >125W;
- 28252050 Centrifugal fans >125 W or
- 28252070 Other fans >125 W.

Larger CHRV units are wholly or partly included in the last category.

Eurostat production statistics per EU Member State for the available period 1995-2017 are given in Table 45 thru Table 50, respectively for axial, centrifugal and other fans > 125 W, and for production volume (in thousands of units) and production value (in millions of euros).

The largest producers are Germany and Italy, and Sweden for the other fans category. The large production of axial 'fans' in Hungary probably regards impellers, and not complete fans. This can also be derived from the low value of around € 2,- /unit.

Not counting the Hungarian contribution of axial 'fans', a total of 44 million fans > 125W were produced in EU28 in 2017, of which 21 mln axial, 15 mln centrifugal and 8 mln other type. This production represented a value of 3.5 bn euros, of which 1.3 bn euros for axial fans (€ 62 /unit), 1.5 bn euros for centrifugal fans (€ 97 /unit), and 0.7 bn euros for other fans (€ 88 /unit).

As shown in Figure 42, for centrifugal and other fans the trend in production volumes is increasing. For axial fans production volume remained more or less constant over the last ten years (except for a dip in crisis years 2008 and 2009 and an anomalous peak in Eurostat data in 2014).

[32] 28252030-Axial fans (excluding table, floor, wall, window, ceiling or roof fans with a self-contained electric motor of an output <=125 W). Corresponding ComExt CN8 codes are 84145930, 84145920 and 84145925, valid for different year ranges.

28252050-Centrifugal fans (excluding table, floor, wall, window, ceiling or roof fans with a self-contained electric motor of an output <= 125 W). Corresponding ComExt CN8 codes are 84145950, 84145940 and 84145935, valid for different year ranges.

28252070-Fans (excluding table, floor, wall, ceiling or roof fans with a self-contained electric motor of an output <= 125 W, axial fans, centrifugal fans). Corresponding ComExt CN8 codes are 84145990, 84145980 and 84145995, valid for different year ranges.

Table 45. EU28 Production Volume of Axial fans > 125W, in units x 1000

(Source: Eurostat 2019, ProdCom code 28252030). EU28 total reported including and excluding Hungary, see note

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	138			167		207				188	191			167	166	203	195	224	298	367	292	239	190
Netherlands	123	141	221	209					161	188	190	183	351	156	103	132	450	222	210	198	186	174	162
Germany	9883	10380													12347	19291	17932	16572	15875	15178	14480	15346	15645
Italy		799	381	391	898	479	429	424	555	669	609	635	585	671	437	803	487	311	2607	3092	3355	3646	4036
Un. Kingdom	266	253	649	818	768	865	2340	2559	524	359	241	353	275	315	133	132	151	121	126	123	125	159	254
Ireland		0									13									0			
Denmark				26	82		19	52	16				36	42	27	44	31	23	217	27	30	31	28
Greece	2		1	2	1	0																	
Portugal			1	1			2	2	2	2	2	1	2	3	4	2	2	1	2	1	1	1	1
Spain	40	74	56	55	66	79	110	85	82	80	344	223	235	300	215	237	267	213	154	166	186	170	193
Belgium																						1	1
Luxemburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	0	0	0	0	0	0	0			0	0	0											
Finland			0	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	
Austria																			0	0		0	0
Malta									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia						0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0
Latvia							0				0	0			0	0	0	0	0	0	0	0	0
Lithuania						0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0
Poland								54	51	68	76	109	150	71	41	39	24			16	18	18	38
Czech Rep.																98	117	123	101	108	98	71	69
Slovakia								0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hungary							6886	5263	7935	8252	8447	10312	9517	8736	5202	9301	8974	7734	6443	6520	6283	6820	6920
Romania						1	1			1	0	1	1				3	2					
Bulgaria							0	0	0	23	47		3	3		2	2		2	2	2	1	2
Slovenia																							
Croatia									0	1	1	0	1	1	1	1	1	1	1	3	3	5	4
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 TOTAL									**21000**	**30025**	**20048**	**32217**	**32001**	**24001**	**18710**	**30296**	**27001**	**26101**	**24000**	**40000**	**25010**	**26700**	**27545**
EU28 TOTAL excl. HU									**13066**	**21773**	**11601**	**21905**	**22484**	**15265**	**13508**	**20995**	**18027**	**18368**	**17557**	**33480**	**18727**	**19880**	**20626**

Note: Unit values for production in Hungary are very low (around 2 euros/unit) and probably relate to OEM-production of axial propellers only and not to complete fans. The EU28 total is therefore reported both with and without the quantities produced in Hungary.

Table 46. EU28 Production Volume of Centrifugal fans > 125W, in units x 1000

(Source: Eurostat 2019, ProdCom code 28252050)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	430			454		585				576	585	529		541	99	133	148	137	208	171	228	204	129
Netherlands	132	125				196			51	132	59	102	107	133	126	167		135		74	77		
Germany															4562	5851		6161					
Italy		1042	2301	2516	1527	1035	1204	1178	467	724	571	695	1034	1190	456	506	985	797	1793	1821	2893	3172	3623
Un. Kingdom	194	184	192	167	123	112	158	162	132	143	116	142	93	129	122	113	120	108	118	132	151	166	268
Ireland																							
Denmark	30	26	35	34	35	41	34	30	32	31	35	36	37	35	26	24	30	98	46	14	16	17	35
Greece	1	1	1	1	1	0	1	1	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1
Portugal	0		0	0	1	1	1	1	1	1	1	2	1	1	1	1	1	11	12	13	16	13	10
Spain	264	209	228	239	297	358	354	394	367	410	591	599	642	524	400	464	507	421	365	389	388	328	291
Belgium		100					235	122								89	102	102	98	88		80	77
Luxemburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden		37										14	22	32	30								
Finland			0	0	0	0	0	0	0	0	0		1	1	1	1	1	1	1	1	9	1	1
Austria														29	28	23	29	28		32	30		
Malta									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia						0	0	0	0	0	0	0				1	1	1	1	1	1	1	1
Latvia							0	0	0	0	0			0									
Lithuania						0	0				0	38	50	47	20	33	45	58	54	54	37	48	40
Poland								30	104	136	107	106	66	68	46	50	59	151	136	67	64	50	42
Czech Rep.														56	50	50	63	79	103	118	122	123	100
Slovakia										0	0	0	0			0	0	0	0	0	0	0	
Hungary							2	1	1	1	1	1	1	0	0			0			0	0	0
Romania										1	1	2			47	90	91	120					
Bulgaria							0	0	0	3	2	2	3	4	2	2	2	2	2	2	2	2	3
Slovenia									112											4	5	3	4
Croatia							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 TOTAL									**4000**	**8004**	**4003**	**5000**	**10000**	**5000**	**6120**	**7825**	**8000**	**8601**	**8000**	**12000**	**14000**	**10000**	**15000**

Table 47. EU28 Production Volume of Other fans > 125W, in units x 1000

(Source: Eurostat 2019, ProdCom code 28252070)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France				141		287				699	1053			119	23	16	18	21	15	11	53	28	
Netherlands									115	42	27	54	43	53	31	48		2	1	1			
Germany			811	1195	1938	2668	1961	1780	1978	2066	1733	2100	2403		2737	3614	4180	3684	3703	3537	3185	2828	3083
Italy		73				60	76	73	92	122	94	100	696	1043	416	439	287	207	177	218	198	186	458
Un. Kingdom	79	117	556	585	483	641	835	256	174	174	115	57	91	106	49	45	32	30	35	40	25	30	13
Ireland	0	0											0			0	0						
Denmark								85	160	94	161		293	399	329	162	110	88	192	199	221	108	182
Greece						0	0	0			0	0	0	0	0	0	0	0					
Portugal		0	1	0	0	1	1	0	0	1	1	1	0	1	0	0	0	0	0	0		0	0
Spain	14	74	68	124	57	67	59	54	678	499	73	117	91	106	122	119	82	71	110	215	362	289	273
Belgium																							
Luxemburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden			924	805	972	1046	903	934		698	722	990			479		312	1752	2174	2407	2712	491	
Finland			27	35	16	18				43	21	19	24	19	25	21	56	16	11	12	10	6	6
Austria	12	11	15				10		7	3										2			
Malta									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia						1						3	4	0	0	0	0	0	0	0	0	0	0
Latvia																						0	
Lithuania						0	0		0		0	0	0	0	0	0	0	0	1	2	2	1	2
Poland								29	2	7	7	8	8	28	30	21	10	16	15		15	19	18
Czech Rep.												14	13	11	8	6	43				13	11	13
Slovakia					0													0		0	0	0	
Hungary							1	1	1	1	1	1	1	1	1				0		0	0	0
Romania						0	0					0	0			0		0	0	0			
Bulgaria							0	0	0	0				4	3	2	2	2	3	3		5	
Slovenia							2		66														
Croatia							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 TOTAL									**4200**	**4620**	**4161**	**4645**	**5718**	**6475**	**4440**	**5032**	**5306**	**6127**	**6637**	**6871**	**7020**	**4252**	**8411**

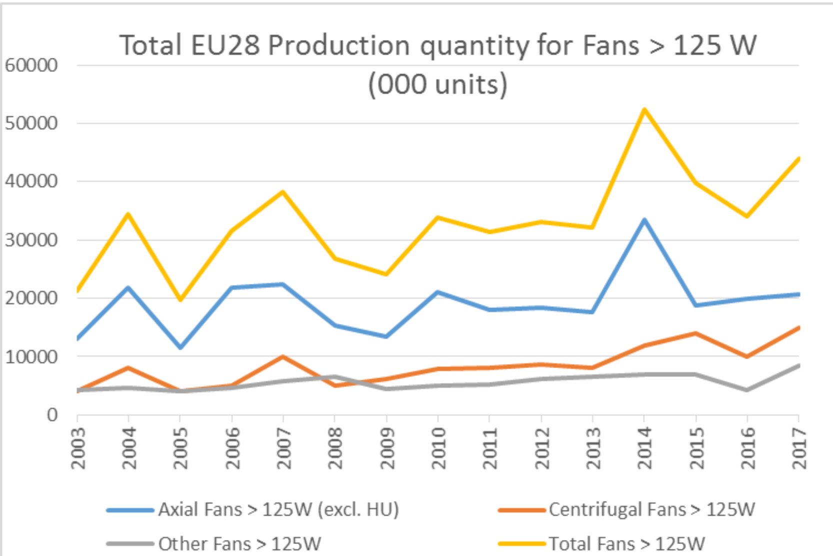


Figure 42. EU28 total Production Volume of Axial, Centrifugal and Other fans > 125W, in units x 1000

(Source: Eurostat 2019, ProdCom codes 28252030, 28252050, 28252070)

Table 48. EU28 Production Value of Axial fans > 125W, in M euros

(Source: Eurostat 2019, ProdCom code 28252030). EU28 total reported including and excluding Hungary, see note

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	31	33	32	32	38	47	44	47	44	44	47	59	64	51	62	76	68	82	81	83	104	100	77
Netherlands	36	33	33	32	28	34	42	32	30	34	54	59	69	65	44	55	63	65	58	58	61	73	67
Germany	267	257	274	298	325	381	333	319	348	401	378	451	480	495	408	521	525	473	490	535	612	719	717
Italy		48	38	39	93	78	83	81	102	121	104	88	87	115	83	115	134	81	117	132	157	186	207
Un. Kingdom	82	93	89	109	88	93	80	95	81	82	78	114	112	113	71	92	100	101	110	100	98	84	92
Ireland																				0			
Denmark	19	18	22	21	23	24	22	23	23	16	17	18	19	20	13	12	14	18	19	21	22	21	26
Greece	0		0	0	0	0																	
Portugal			0	0			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Spain	10	12	15	14	17	21	27	27	25	28	46	55	67	82	57	67	72	64	50	47	50	46	57
Belgium																						1	1
Luxemburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	0	0	0	0	0	0	0	0		0	0	0											
Finland			0	0	0	0	0	4	1	1	1	1	1	1	0	1	1	0	0	0	0	0	0
Austria																			0	0		0	0
Malta									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia						0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0
Latvia							0				0	0			0	0	0	0	0	0	0	0	0
Lithuania						0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0
Poland								4	5	5	5	8	15	33	19	16	14	16	15	18	17	13	15
Czech Rep.																2	3	4	4	4	4	4	6
Slovakia								0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hungary	0	0	0	0	0	0	11	9	13	14	15	18	20	18	10	18	15	19	9	9	9	11	12
Romania						1	1	2		0	0	1	1		1	1							
Bulgaria							0	0	0	1	1	1	1	1	0	1	1	0	0	1	1	1	1
Slovenia																							
Croatia									1	1	1	1	1	1	1	0	1	1	1	2	2	4	3
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 TOTAL									**687**	**768**	**763**	**893**	**946**	**1012**	**775**	**980**	**1020**	**931**	**960**	**1014**	**1140**	**1268**	**1284**
EU28 TOTAL excl. HU									**674**	**753**	**748**	**875**	**926**	**993**	**765**	**962**	**1004**	**912**	**951**	**1005**	**1131**	**1257**	**1272**

Note: Unit values for production in Hungary are very low (around 2 euros/unit) and probably relate to OEM-production of axial propellers only and not to complete fans. The EU28 total is therefore reported both with and without the quantities produced in Hungary.

Table 49. EU28 Production Value of Centrifugal fans > 125W, in M euros

(Source: Eurostat 2019, ProdCom code 28252050)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	117	141	136	152	154	160	160	149	140	144	151	137	151	131	77	75	83	71	85	91	106	99	61
Netherlands	30	38	42	60	38	33	34	42	47	50	33	43	43	54	52	38	47	50	34	32	32	32	25
Germany			113	118	160	179	146	166	195	238	278	348	390	441	395	476	586	537	592	610	611	692	741
Italy		216	230	252	194	180	229	225	194	265	233	262	330	390	277	244	274	194	189	221	230	238	230
Un. Kingdom	74	72	108	112	100	84	101	110	95	100	90	111	80	96	86	106	109	120	131	135	157	143	167
Ireland																							
Denmark	29	32	30	33	42	44	36	37	36	38	40	42	45	55	41	40	40	44	37	31	33	32	38
Greece	0	0	1	1	1	0	0	0	0	0	0	1	1	0	0	2	2	2	2	2	2	2	2
Portugal	0		0	1	1	1	5	3	3	4	5	6	2	2	3	1	2	4	6	7	8	5	5
Spain	27	24	25	31	37	41	45	52	54	56	79	84	102	91	71	79	78	72	67	61	68	69	65
Belgium	9	15					29	26			68		24			31	37	36	36	34		32	30
Luxemburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden		0	0	7	7	8	10	9				5	8	8	6								
Finland			0	0	0	0	0	0	0	0	0	8	7	12	6	6	25	36	34	9	16	10	10
Austria														5	5	5	5	4		6	6		
Malta									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia						0	0	0	0	0	0	0				2	3	3	3	4	4	3	4
Latvia							0	0	0	0	0			0									
Lithuania											0	4	5	4	2	3	5	5	5	5	4	4	3
Poland								3	7	9	12	18	18	25	18	19	24	31	27	34	41	26	31
Czech Rep.												4	5	7	5	4	6	5	8	9	10	10	11
Slovakia										0	0	0	0			0	0	0	0	0	0	0	
Hungary							2	1	1	1	2	1	1	1	1			0			0	0	0
Romania										1	1	2			3	6	4	7					
Bulgaria							0	0	0	1	1	1	1	2	0	1	1	1	1	1	2	2	2
Slovenia									3											6	6	4	4
Croatia							0	1	1	1	1	2	1	1	0	0	0	0	0	0	0	0	0
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 TOTAL									**817**	**940**	**1006**	**1104**	**1230**	**1369**	**1085**	**1173**	**1363**	**1255**	**1298**	**1320**	**1393**	**1436**	**1460**

Table 50. EU28 Production Value of Other fans > 125W, in M euros

(Source: Eurostat 2019, ProdCom code 28252070)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France		26	30	37	44	56		56	63	61	92	86	96	127	64	44	38	29	31	17	18	14	
Netherlands	15	15	12	13	11	13	14	18	33	16		23	24	26		22						48	72
Germany			233	231	279	313	299	296	312	354	335	408	471	478	373	403	470	476	519	520	530	432	454
Italy		33				22	28	28	37	50	34	43	95	109	51	54	38	27	27	41	37	34	34
Un. Kingdom	23	36	51	46	52	64	49	32	33	40	34	25	42	49	22	20	15	15	17	20	14	14	4
Ireland													0			6	7						
Denmark	7	9	13	12	12	14	10	10	9	12	15	14	20	26	20	18	34	25	39	40	42	38	23
Greece						0	0	0			0	0	0	0	0	0	0	0					
Portugal		3	4	2	2	3	3	2	2	2	3	4	1	1	0	0	0	0	0	0		0	0
Spain	5	6	6	9	7	7	7	9	32	33	18	26	18	15	14	16	21	19	15	30	40	39	36
Belgium																							
Luxemburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	0	0	0	80	87	89	109	82	60	59	69	77			50		38	40	38	37	32	25	
Finland			32	35	19	22	22	22	24	21	25	29	36	38	32	19	7	3	3	27	17	11	6
Austria	16	14	12				11		13	10										15			
Malta									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia						1						3	2			0	0	0	0	0	0	0	2
Latvia																						0	
Lithuania						0			0		0	0	0	0	0	0	0	0	0	0	0	0	0
Poland								4	2	3	4	11	12	23	16	11	11	22	18	5	13	13	13
Czech Rep.									8	7	8	10	12	15	10	12	18	20	24	20	23	21	19
Slovakia				0	0													0		0	0	0	
Hungary							0	0	0	1	0	0	0	0	0				0		0	0	0
Romania						0	0					0	0			0		0	0	0			
Bulgaria							0	0	0	0		0	1	1	1	1	1	1	1	1			
Slovenia							1		2														
Croatia							0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 TOTAL									634	680	668	784	937	1016	685	682	746	715	769	790	798	723	739

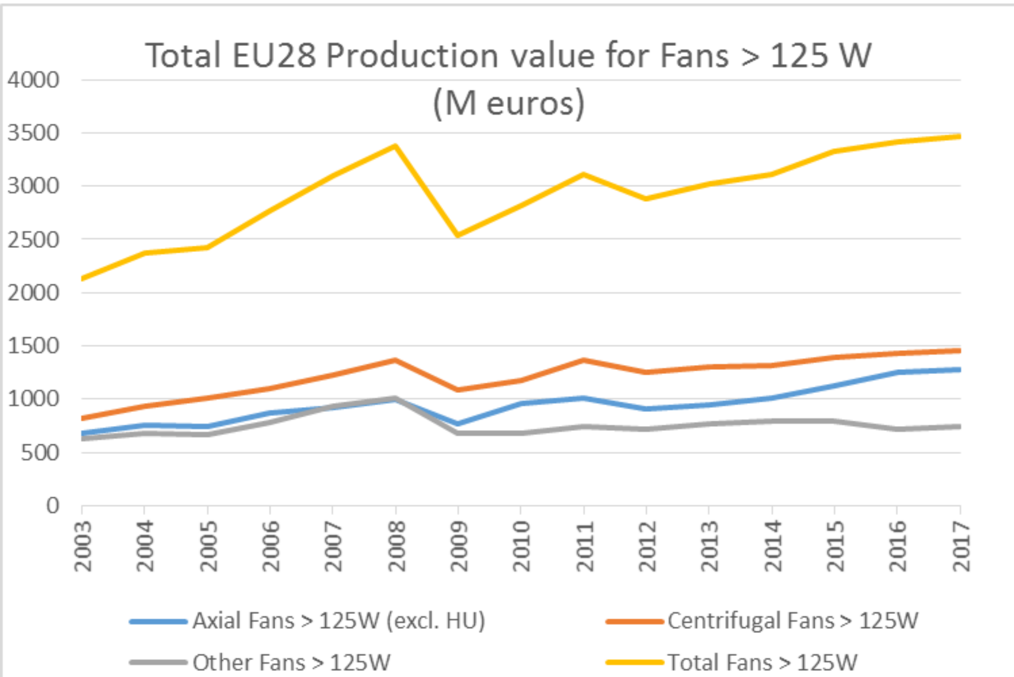


Figure 43. EU28 total Production Value of Axial, Centrifugal and Other fans > 125W, in M euros

(Source: Eurostat 2019, ProdCom codes 28252030, 28252050, 28252070)

Country data for import and export have been taken from ProdCom, for the same categories as used for production above. These data include intra-EU28 trade. EU28 totals for Extra-EU trade have been taken from ComExt for CN8 categories 841459xx [7]. These totals do not include intra-EU28 trade and consequently are not the sum of the country-data. Import and Export data are shown in Table 51 thru Table 62, respectively for axial, centrifugal and other fans >125 W, and for production volume (in thousands of units) and production value (in millions of euros).

Germany is by far the largest exporter of axial and centrifugal fans >125W. For 'other' fans the German position is less dominant. Note that in 2017, the German production of axial fans is around 16 mln units, while a larger quantity, 29 mln units, are reported to be exported. Most likely, a large part of the 40 mln imported units is again exported, maybe after additional elaboration.
The large production of axial 'fans' in Hungary (probably impellers, not complete fans) amounts to nearly 7 mln units in 2017, and additional 5 mln units are imported. However, export from Hungary is reported to be around 14 mln units, exceeding the sum of production and imports. Hungarian export to extra-EU28 is low (not shown in the tables), and it hardly makes any difference if the Hungarian contribution to the total EU28 export to extra-EU28 countries is included or not.
These examples show that Eurostat data are sometimes difficult to interpret, especially at the level of single countries.

The total EU28 export of fans >125W to extra-EU28 countries in 2017 was 33 mln units, of which 15 mln axial, 11 mln centrifugal and 7 mln other type. This export represented a value of 1.7 bn euros, of which 0.7 bn euros for axial fans (€ 48 /unit), 0.7 bn euros for centrifugal fans (€ 63 /unit), and 0.3 bn euros for other fans (€ 45 /unit).

The total EU28 import of fans >125W from extra-EU28 countries in 2017 was 94 mln units, of which 64 mln axial, 9 mln centrifugal and 22 mln other type. This import represented a value of 0.7 bn euros, of which 0.36 bn euros for axial fans (€ 6 /unit), 0.09 bn euros for centrifugal fans (€ 10 /unit), and 0.25 bn euros for other fans (€ 11 /unit).

The difference in unit price between imported and exported products seems to indicate that especially smaller, maybe partial, products are imported, while larger, probably more complex, products are exported.

As shown in Figure 44 for axial and centrifugal fans >125W the trend in export volumes is increasing. For other fans export volumes remained more or less constant since 2010. The dip in exports in crisis year 2009 is clearly visible.

As shown in Figure 46, the same trend exists for imports, showing an increase for axial and centrifugal fans and a decrease or stable situation for other fan types.

Table 51. EU28 Export Volume of Axial fans > 125W, in units x 1000

(Source: Eurostat 2019, ProdCom code 28252030 and ComExt CN8 codes 841459xx). EU28 total reported including and excluding Hungary, see note

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	402	322	455	640	730	941	646	556	528	570	659	1385	1505	1770	1226	2074	1436	3830	1094	1737	1946	1970	597
Netherlands	771	790	1320	1967	1131	876	2293	3691	3710	6925	6835	6301	9991	9032	3431	2806	3179	3242	2659	3025	2750	3350	3800
Germany	11897	14289	20362	24660	28652	26840	21710	18347	19730	22090	21025	21524	19429	19802	15515	23606	24997	23208	23878	26318	27356	29375	29028
Italy	762	768	805	719	1068	1686	1622	1687	2131	2567	3623	4200	4138	4014	1865	3756	4219	6192	6398	7253	7638	8382	8851
Un. Kingdom	656	766	1151	1168	1185	723	676	520	571	623	555	1061	842	995	823	910	1029	2115	1122	1139	1249	1612	728
Ireland	0	0	1	1	2	1	1	8	14	17	16	16	25	27	21	21	14	30	4	11	6	13	19
Denmark	21	24	22	19	17	23	21	34	61	37	34	132	122	195	651	92	49	47	59	47	53	71	124
Greece	0	0	1	0	0	0	0	0	0	1	3	0	7	9	5	10	3	2	1	6	3	6	8
Portugal	0	1	0	0	2	1	0	0	0	1	1	3	1	1	2	1	3	7	14	9	15	46	5
Spain	763	362	474	788	623	1090	1060	876	662	914	526	395	486	473	306	358	393	794	747	500	745	793	611
Belgium	54	62	139	164	76	46	92	267	321	460	483	508	285	282	231	434	386	422	421	472	478	563	491
Luxemburg					169	402	27	0	18	1	14	1	2	2	2	8	11	13	14	20	18	19	41
Sweden	96	80	154	108	184	192	107	149	248	136	253	222	241	406	381	568	451	494	395	427	611	680	315
Finland	2	10	11	3	14	12	44	37	50	43	110	189	124	165	152	75	48	49	56	76	89	145	42
Austria	20	70	32	31	33	102	69	84	109	98	88	92	310	305	389	411	431	261	335	456	487	956	551
Malta									0	0	0	0	0	0	0	0	2	9	21	4	1	0	0
Estonia						0	1	0	0	0	4	20	14	13	13	12	46	54	76	50	41	62	22
Latvia							0	0	0	1	1	2	19	10	11	35	22	43	35	29	11	17	13
Lithuania						10	2	0	3	3	6	2	2	7	9	30	262	233	127	187	84	84	200
Poland								36	105	137	234	354	468	567	428	485	644	860	1174	881	1073	1276	1698
Czech Rep.							62	150	373	115	881	578	1323	724	471	535	459	440	338	430	485	569	448
Slovakia					4	2	3	9	7	2	8	9	7	24	63	33	50	57	171	128	97	199	122
Hungary							10811	8835	13600	7711	6184	9985	15636	17756	9427	16351	17350	12995	13659	16048	13478	13704	14331
Romania						0	0	1	0	0	24	0	167	179	123	242	389	586	712	520	593	465	553
Bulgaria							0	1	0	3	3	6	3	16	0	8	6	6	4	6	11	65	59
Slovenia							1	8	2	2	4	119	172	135	187	579	977	1788	1939	592	71	1260	1549
Croatia									1	0	0	1	1	1	1	1	0	3	2	4	9	8	8
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 Total for Extra EU						**9743**	**8249**	**6543**	**9233**	**9689**	**9737**	**10162**	**10215**	**11244**	**8242**	**12479**	**14342**	**15611**	**13468**	**13022**	**12781**	**13795**	**15074**
EU28 Total for Extra EU excl. HU						**9735**	**8247**	**6181**	**9231**	**9687**	**9730**	**10127**	**10196**	**11237**	**8222**	**11789**	**13395**	**15488**	**13427**	**12951**	**12717**	**13713**	**15049**

Note: Unit values for production in Hungary are very low (around 2 euros/unit) and probably relate to OEM-production of axial propellers only and not to complete fans. The EU28 total is therefore reported both with and without the quantities produced in Hungary.

Table 52. EU28 Export Volume of Centrifugal fans > 125W, in units x 1000

(Source: Eurostat 2019, ProdCom code 28252050 and ComExt CN8 codes 841459xx)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	116	215	88	182	72	71	58	70	113	78	127	262	145	167	113	103	82	68	62	62	58	73	427
Netherlands	81	111	120	197	229	106	181	76	128	93	153	124	185	122	61	84	125	252	259	613	484	690	679
Germany	3835	3991	4419	4199	4650	6310	6825	6536	7787	11098	13583	16805	16748	15519	13074	17374	18158	17938	18479	20246	20715	20798	23736
Italy	1535	474	410	524	877	1271	1132	1096	1295	1747	1636	1805	1842	2051	1308	3044	3520	2835	3105	3065	2846	3458	4282
Un. Kingdom	151	173	177	178	226	306	391	379	150	334	281	429	460	551	627	724	740	677	684	633	552	547	509
Ireland	6	7	13	10	16	27	16	13	6	3	4	2	3	5	3	4	2	10	3	2	1	1	2
Denmark	31	24	38	30	37	45	32	30	24	29	35	29	57	44	73	41	23	24	44	44	61	81	45
Greece	0	0	0	1	7	4	0	7	1	4	1	6	8	9	3	35	13	4	14	14	10	7	3
Portugal	0	0	3	0	0	0	0	2	0	14	14	1	1	2	4	0	5	2	17	4	5	7	9
Spain	101	91	94	130	148	199	195	327	349	299	417	276	327	405	238	537	325	321	302	464	338	402	430
Belgium	33	63	84	100	99	101	84	66	68	45	45	36	69	70	36	33	55	105	131	125	58	85	56
Luxemburg					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	233	444	509	791	666	471	697	581	466	242	52	46	51	56	57	53	408	1117	2041	1459	159	173	146
Finland	2	6	38	5	10	32	16	10	12	17	51	38	42	51	29	56	52	43	41	36	38	45	51
Austria	3	5	3	6	5	4	6	10	25	34	28	54	18	19	20	51	37	31	81	94	145	58	415
Malta									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia						0	1	0	0	0	3	1	4	3	1	2	25	16	14	12	22	18	10
Latvia							4	4	1	4	11	8	14	13	11	20	13	28	13	10	7	8	11
Lithuania						1	2	3	3	11	27	33	42	47	27	42	46	54	60	52	45	52	55
Poland								10	11	35	37	54	108	127	40	173	359	630	539	636	911	759	1008
Czech Rep.							10	37	28	41	56	71	63	222	370	366	401	319	311	719	391	369	403
Slovakia					0	0	2	3	2	1	0	0	0	0	0	0	0	29	1	33	41	4	114
Hungary							0	0	2	445	1419	1650	1604	1497	1162	2028	2203	2418	2405	3448	3440	3709	2919
Romania						0	0	0	0	0	0	45	59	73	74	1296	1433	1059	1023	1407	1402	1313	1088
Bulgaria							0	0	0	0	0	3	0	0	1	2	1	1	1	1	1	2	2
Slovenia							2	3	4	39	66	263	1803	1530	892	743	3559	3551	3787	5546	5909	4760	5054
Croatia									0	0	0	0	0	0	0	0	1	0	1	0	1	1	1
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 Total for Extra EU						**2106**	**2052**	**2499**	**2296**	**3309**	**4586**	**6578**	**6682**	**6409**	**5087**	**7216**	**7805**	**7597**	**7902**	**9309**	**8754**	**9428**	**11000**

Table 53. EU28 Export Volume of Other fans > 125W, in units x 1000

(Source: Eurostat 2019, ProdCom code 28252070 and ComExt CN8 codes 841459xx)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	350	1237	1166	1035	950	1131	1034	1039	1127	1150	1731	3145	2015	1903	1008	1568	1750	1684	988	868	967	963	1909
Netherlands	341	774	674	565	598	451	808	1863	2208	3338	2604	2304	1263	741	590	1003	1400	1134	974	1632	1353	1435	3056
Germany	1358	1532	1485	1612	2314	3460	4390	5527	6848	7000	6093	6209	5859	4025	2757	3743	4046	4113	5084	6222	5067	4198	4793
Italy	9647	9923	10821	11345	9141	12078	13374	13712	17612	15946	15854	9526	6472	4704	3043	3443	2335	2221	3831	2835	2666	4117	2636
Un. Kingdom	1326	792	689	680	500	663	617	732	1377	701	764	572	619	542	218	363	1604	1485	563	436	566	794	824
Ireland	7	4	1	3	105	1	3	10	10	5	9	2	13	4	16	3	9	25	19	17	26	46	22
Denmark	13	9	10	19	10	21	23	14	60	46	51	173	634	572	817	208	22	10	13	71	209	204	79
Greece	1	5	4	0	3	1	3	3	8	16	27	9	47	37	12	6	10	22	20	13	131	73	203
Portugal	8	15	6	29	20	4	5	5	10	17	55	121	99	38	19	38	36	120	54	23	27	18	16
Spain	735	108	169	199	164	181	202	216	383	709	1006	673	790	1197	681	983	939	851	829	914	1054	1287	627
Belgium	211	294	730	2133	1098	697	659	430	370	539	563	271	361	289	235	387	466	643	706	772	521	338	327
Luxemburg					47	12	3	9	49	41	35	17	15	67	15	3	3	4	6	5	61	47	52
Sweden	373	468	492	496	447	656	860	1383	833	612	612	685	716	614	464	608	373	329	343	317	379	462	220
Finland	6	22	25	54	79	109	73	80	82	79	74	102	147	91	38	46	34	35	37	25	18	15	15
Austria	68	75	66	178	297	255	280	225	318	243	402	424	235	150	63	195	236	152	147	138	120	132	211
Malta									0	0	0	1	0	2	11	3	5	30	1	13	12	0	0
Estonia						1	1	0	1	1	3	27	28	48	14	22	19	18	16	19	2	1	2
Latvia							0	0	1	1	0	6	3	3	3	22	13	13	1	1	1	1	7
Lithuania						1	1	2	1	5	7	13	22	17	10	11	16	25	26	16	17	22	44
Poland								276	923	526	440	853	1405	1293	893	672	640	619	303	385	384	866	1339
Czech Rep.							349	591	382	324	348	404	456	1817	848	991	824	864	786	807	628	513	567
Slovakia					3	2	12	4	6	22	6	17	45	36	31	14	97	67	56	67	92	656	329
Hungary							1118	0	16	29	0	98	31	37	518	727	122	81	124	195	235	138	126
Romania						0	0	1	0	0	0	0	3769	3097	2676	1639	1748	1935	1294	1839	1948	2172	2475
Bulgaria							0	0	1	0	2	8	3	7	27	7	18	15	24	44	46	24	138
Slovenia							26	142	813	1486	1824	1710	1768	1244	1329	1643	1408	1341	1427	1959	1421	2021	1913
Croatia									5	10	6	4	8	5	2	2	3	2	4	4	8	16	66
Cyprus									1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
EU28 Total for Extra EU						**3725**	**4295**	**5279**	**6818**	**7537**	**8768**	**10237**	**8426**	**6789**	**4668**	**6255**	**6002**	**6360**	**6451**	**6608**	**6369**	**7689**	**6767**

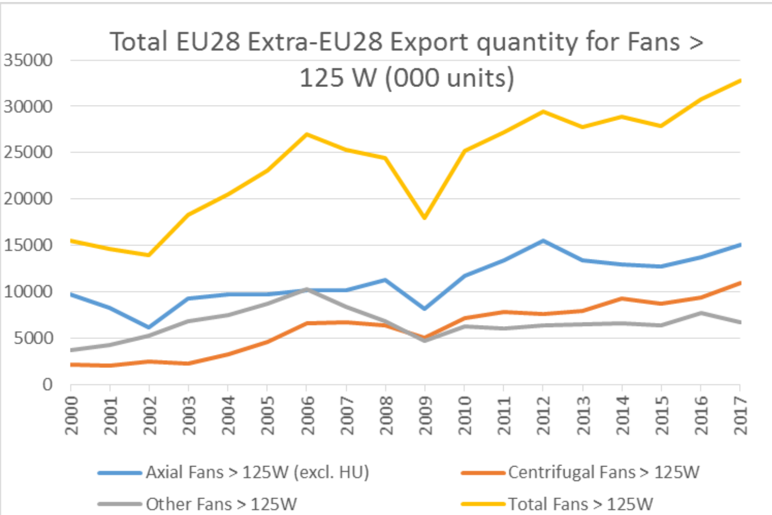


Figure 44. EU28 total Extra-EU28 Export Volume of Axial, Centrifugal and Other fans > 125W, in units x 1000

(Source: Eurostat 2019, ComExt CN8 codes 841459xx)

Table 54. EU28 Export Value of Axial fans > 125W, in M euros

(Source: Eurostat 2019, ProdCom code 28252030 and ComExt CN8 codes 841459xx). EU28 total reported including and excluding Hungary, see note

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	9	6	7	8	9	12	9	14	10	11	13	22	22	31	22	26	26	30	36	38	44	66	47
Netherlands	23	27	27	31	23	38	43	50	51	72	67	85	98	79	59	66	74	73	69	68	81	101	95
Germany	249	261	306	347	400	481	443	420	474	555	535	583	637	627	472	654	719	699	714	764	874	924	986
Italy	8	10	12	11	29	40	39	41	48	57	68	83	81	85	58	87	110	114	117	138	160	197	205
Un. Kingdom	38	44	72	73	62	64	50	45	55	61	63	77	30	31	38	28	30	34	35	43	46	40	35
Ireland	0	0	0	0	0	0	0	3	4	6	5	3	3	4	3	3	2	1	0	0	1	2	1
Denmark	13	10	12	10	7	9	8	8	11	10	11	11	17	19	15	9	11	12	11	13	14	18	25
Greece	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Portugal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2
Spain	14	15	11	13	13	32	39	39	31	31	27	27	34	43	31	43	54	58	54	51	61	64	69
Belgium	1	1	2	3	2	3	3	4	6	7	8	11	12	12	10	16	17	18	26	24	26	28	33
Luxemburg					1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Sweden	7	10	10	9	14	18	10	8	9	22	13	11	11	10	8	11	15	15	14	15	20	22	14
Finland	0	1	1	2	1	1	1	2	1	2	3	4	3	5	3	3	4	5	4	4	5	5	5
Austria	1	2	2	2	3	3	3	4	5	4	4	5	6	8	6	9	10	8	11	12	11	15	12
Malta									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia						0	0	0	1	0	0	0	1	0	0	0	2	1	2	1	1	2	1
Latvia							0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1
Lithuania						0	0	0	0	0	1	2	4	4	2	5	5	6	3	3	2	3	6
Poland								1	1	2	2	4	5	7	5	7	8	14	18	18	25	32	46
Czech Rep.							3	3	5	4	18	13	19	17	10	11	15	15	14	12	16	19	14
Slovakia					0	0	0	0	0	0	0	0	0	1	0	1	0	1	1	2	2	3	2
Hungary							34	28	46	88	124	149	167	168	97	173	175	145	97	118	97	109	133
Romania						0	0	0	0	0	1	2	3	3	2	6	13	19	20	15	18	14	10
Bulgaria							0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0
Slovenia							0	0	0	0	0	1	1	1	1	2	5	8	9	4	2	7	7
Croatia									0	0	0	0	0	0	0	0	0	1	1	1	1	2	2
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 Total for Extra EU						**227**	**208**	**178**	**209**	**256**	**259**	**307**	**345**	**384**	**295**	**444**	**513**	**525**	**538**	**571**	**626**	**694**	**726**
EU28 Total for Extra EU excl. HU						**227**	**208**	**177**	**209**	**256**	**259**	**306**	**345**	**383**	**294**	**443**	**512**	**524**	**537**	**570**	**624**	**691**	**725**

Note: Unit values for production in Hungary are very low (around 2 euros/unit) and probably relate to OEM-production of axial propellers only and not to complete fans. The EU28 total is therefore reported both with and without the quantities produced in Hungary.

Table 55. EU28 Export Value of Centrifugal fans > 125W, in M euros

(Source: Eurostat 2019, ProdCom code 28252050 and ComExt CN8 codes 841459xx)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	5	10	5	8	4	5	5	6	8	7	8	12	14	16	12	13	14	12	14	14	14	21	36
Netherlands	7	6	7	11	8	7	8	7	7	7	7	8	10	9	7	9	15	25	28	24	27	34	35
Germany	142	149	162	164	195	244	249	237	294	362	387	490	517	529	471	616	688	667	747	794	820	837	905
Italy	38	43	42	50	60	72	70	72	85	107	92	103	119	123	104	133	137	165	284	192	239	227	318
Un. Kingdom	7	9	14	13	12	14	16	13	18	19	20	54	61	67	55	61	67	80	83	80	85	68	28
Ireland	1	1	2	2	2	2	2	2	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1
Denmark	12	12	13	14	15	20	17	21	17	15	17	16	20	23	23	23	24	25	25	26	30	36	30
Greece	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Portugal	0	0	0	0	0	0	0	0	0	1	1	0	1	0	1	0	1	1	1	2	2	1	1
Spain	8	9	10	12	13	18	19	22	20	25	27	28	32	40	31	33	35	36	43	46	51	57	51
Belgium	4	7	14	13	13	14	14	12	12	9	9	7	8	8	9	9	10	14	14	13	13	20	18
Luxemburg					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	11	16	18	20	15	13	15	14	13	12	11	13	11	10	9	11	24	29	26	24	26	23	24
Finland	1	1	1	2	2	2	2	2	2	2	5	6	8	9	5	20	21	22	20	21	22	22	23
Austria	0	0	1	1	1	1	1	2	2	4	4	4	4	4	4	4	4	6	6	9	10	9	14
Malta									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia						0	0	0	0	1	1	2	2	3	2	3	4	4	4	4	5	4	4
Latvia							0	0	0	0	0	0	2	3	1	2	2	5	4	2	1	1	1
Lithuania						0	0	0	1	2	3	4	5	5	3	4	4	8	8	7	5	6	4
Poland								1	1	4	4	7	10	10	7	11	15	20	23	28	39	39	39
Czech Rep.							2	5	4	5	7	8	8	12	9	7	14	19	20	23	26	30	25
Slovakia					0	0	0	0	0	0	0	1	1	1	2	1	1	2	1	3	4	1	2
Hungary							0	0	1	19	24	41	24	22	12	23	27	28	18	29	26	29	35
Romania						1	0	0	0	0	2	2	3	3	3	8	10	10	11	14	14	14	11
Bulgaria							0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
Slovenia							0	1	1	2	2	3	9	10	7	6	19	24	28	35	36	33	38
Croatia									0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 Total for Extra EU						**105**	**106**	**101**	**133**	**168**	**185**	**247**	**274**	**305**	**275**	**397**	**435**	**486**	**646**	**576**	**637**	**586**	**688**

Table 56. EU28 Export Value of Other fans > 125W, in M euros

(Source: Eurostat 2019, ProdCom code 28252070 and ComExt CN8 codes 841459xx)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	30	38	34	41	36	42	41	55	49	42	45	51	58	62	47	54	65	58	60	60	70	67	65
Netherlands	19	27	29	23	28	30	36	42	34	45	54	36	41	36	29	34	43	41	44	44	41	48	46
Germany	97	101	114	101	117	133	145	153	175	186	168	212	227	210	184	180	211	209	244	232	213	198	193
Italy	128	130	137	137	113	127	142	144	185	168	172	140	105	92	66	59	66	63	90	106	133	140	72
Un. Kingdom	27	29	37	35	24	26	26	23	24	27	34	42	29	29	14	24	28	32	32	39	36	25	28
Ireland	0	0	0	1	1	0	0	4	1	0	1	0	0	0	1	1	1	1	2	1	2	3	1
Denmark	2	2	3	3	1	2	3	2	5	4	6	16	10	6	9	16	16	10	10	11	12	13	17
Greece	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	4
Portugal	0	0	0	0	0	0	0	1	1	1	3	8	3	1	2	2	1	3	6	4	5	3	3
Spain	9	8	7	7	5	7	6	4	6	8	11	12	16	16	25	14	15	12	12	14	13	17	24
Belgium	11	15	17	18	13	12	12	11	14	13	14	11	14	14	15	15	20	19	22	26	27	26	16
Luxemburg					0	0	0	0	1	1	2	2	3	2	2	2	2	2	3	3	3	3	3
Sweden	27	30	39	38	36	43	54	50	48	47	53	61	70	67	43	46	38	31	30	30	28	26	24
Finland	7	7	7	8	10	12	11	14	13	11	16	18	25	21	16	10	13	15	16	23	10	9	4
Austria	8	9	10	10	9	12	11	17	11	12	11	11	13	13	11	12	12	13	14	15	15	13	12
Malta									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia						0	0	0	0	0	1	3	3	5	1	2	2	1	0	0	0	0	1
Latvia							0	0	0	0	0	0	0	1	0	1	1	1	0	0	0	0	1
Lithuania						0	0	0	0	1	1	2	2	2	2	2	3	3	3	2	2	2	4
Poland								5	7	5	5	7	10	16	10	7	8	12	16	10	9	13	21
Czech Rep.							7	7	6	9	11	8	10	20	13	26	26	25	23	22	20	17	17
Slovakia					0	0	0	0	0	1	2	1	1	2	1	1	1	1	1	1	2	2	1
Hungary							2	0	2	1	0	2	1	1	2	2	3	1	1	4	6	3	2
Romania						0	0	0	0	0	0	2	14	12	9	7	8	8	8	11	13	18	24
Bulgaria							0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	4
Slovenia							2	3	6	11	15	17	19	16	14	18	19	20	19	16	15	16	19
Croatia									0	0	0	0	1	0	0	0	0	0	0	0	0	1	3
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 Total for Extra EU						**151**	**173**	**189**	**199**	**217**	**243**	**291**	**299**	**293**	**249**	**235**	**283**	**281**	**301**	**299**	**317**	**295**	**306**

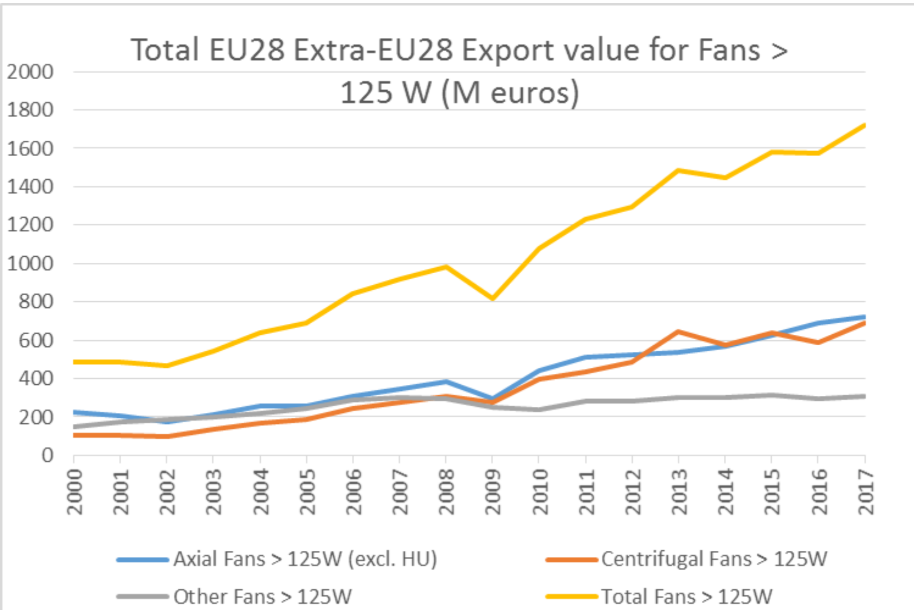


Figure 45. EU28 total Extra-EU28 Export Value of Axial, Centrifugal and Other fans > 125W, in M euros

(Source: Eurostat 2019, ComExt CN8 codes 841459xx)

Table 57. EU28 Import Volume of Axial fans > 125W, in units x 1000 *(Source: Eurostat 2019, ProdCom code 28252030 and ComExt CN8 codes 841459xx).*

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	2092	1940	3789	3687	4644	5489	4898	4334	4864	5680	5119	5224	4406	4868	3723	5527	3902	3252	3792	4191	4109	3947	3102
Netherlands	1536	2301	2787	3590	3060	7495	12965	9858	8693	8931	7639	8126	7834	8776	9605	9576	15514	5937	12032	8717	6421	7827	5655
Germany	6768	8331	13684	20406	19877	25289	25539	21315	15998	24645	25764	32818	32007	29986	24613	38657	38162	33316	35112	39963	38939	42661	40080
Italy	2278	2131	2389	3917	3296	5190	4727	3833	3478	6858	8142	7690	14218	8564	5983	6141	6752	8534	8679	8572	10128	9774	10380
Un. Kingdom	4926	6157	6104	6046	4365	9528	8117	7124	4639	5007	4633	5962	7967	6150	3818	5098	5020	4465	5138	4876	5025	6744	5303
Ireland	733	553	152	126	287	539	389	313	295	363	553	295	192	398	122	165	128	145	286	563	785	772	163
Denmark	489	607	692	698	711	840	871	871	911	974	980	1430	1233	1452	737	1260	1068	1103	896	1114	1162	926	1009
Greece	44	47	22	36	45	85	56	47	42	54	59	96	98	106	122	161	110	342	135	983	935	218	186
Portugal	150	219	208	345	317	339	150	86	93	122	188	549	839	709	1444	924	1229	776	622	756	1366	2939	3899
Spain	491	1385	2011	2003	1527	1955	2185	2127	2012	1980	2050	2746	2098	1584	1613	1839	2456	2466	3074	3022	3448	4270	5362
Belgium	159	151	626	1079	655	599	755	1038	858	936	861	786	772	915	710	897	1108	1065	1165	1229	829	1087	929
Luxemburg					233	1394	11	2	6	12	32	20	37	29	14	29	49	38	37	38	45	44	32
Sweden	855	746	756	665	722	1088	1014	987	1368	1802	1640	1866	2033	2226	1508	2061	2183	2145	2031	1911	1826	1860	1099
Finland	518	356	496	640	806	945	821	628	788	898	1220	919	627	751	599	653	621	706	519	654	530	662	577
Austria	477	661	825	779	718	799	667	624	804	871	862	857	1235	1419	1220	1325	1395	1688	1817	2000	1894	2614	1898
Malta									18	6	6	12	7	15	9	13	34	38	45	32	41	30	54
Estonia						9	16	21	42	61	51	165	251	311	103	333	573	908	732	694	499	400	232
Latvia							7	28	25	12	4	4	6	12	7	24	41	89	190	174	230	225	27
Lithuania						7	13	23	41	44	43	27	38	44	43	74	133	237	154	230	223	316	415
Poland								397	924	1655	1546	1853	2146	2402	1864	3490	3345	3464	4727	4288	5073	5048	4622
Czech Rep.							1633	2241	2567	5667	4940	6786	10453	9115	4934	6063	6509	5142	5384	6880	35585	8759	9801
Slovakia					322	396	415	457	606	358	329	217	1138	2555	3298	2659	1379	1239	1137	1527	2081	3252	2385
Hungary							1241	2028	828	1137	1863	1757	3232	1305	1352	4156	2988	2285	3751	3171	5422	5685	5030
Romania						0	0	467	0	0	649	0	614	496	852	1430	1360	914	1549	1060	838	1982	2623
Bulgaria							21	13	18	87	72	68	267	223	182	408	350	196	327	328	339	539	447
Slovenia							76	121	187	334	429	553	614	558	415	997	1144	1246	1179	1125	1408	1778	2399
Croatia									13	16	27	48	35	67	39	111	0	53	75	88	95	119	129
Cyprus									2	6	4	9	12	12	12	8	7	6	10	3	14	10	2
EU28 Total for Extra EU						**32196**	**36587**	**32986**	**30011**	**36694**	**38611**	**41837**	**50410**	**49173**	**42325**	**56041**	**58145**	**45202**	**54000**	**56518**	**59840**	**67475**	**63694**

Table 58. EU28 Import Volume of Centrifugal fans > 125W, in units x 1000 *(Source: Eurostat 2019, ProdCom code 28252050 and ComExt CN8 codes 841459xx)*

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	768	898	825	780	894	1005	884	892	1252	1567	1471	1670	1191	1284	1020	1256	1206	1283	1378	1455	1412	1405	1222
Netherlands	516	758	791	716	683	530	396	745	462	397	365	364	594	474	306	276	307	368	328	1017	1266	1639	1457
Germany	548	792	1288	1999	1706	2195	2199	2131	1750	3137	3505	6728	6267	7130	5800	7485	8441	10762	12875	15828	15653	14114	15338
Italy	883	774	665	532	577	1169	1027	1092	1327	1608	1513	2150	2549	2170	2049	3527	3903	2187	2112	1898	1899	2019	1971
Un. Kingdom	1363	2879	3548	1679	1440	1558	1355	1065	1213	1907	3031	2276	2457	2112	1361	1965	2317	1620	1633	1410	1009	1536	866
Ireland	218	174	94	94	82	128	189	344	262	353	322	65	42	21	36	22	53	17	27	42	94	78	28
Denmark	184	140	155	169	165	271	189	194	228	255	267	340	324	298	177	173	171	119	157	194	188	275	196
Greece	141	146	125	165	239	266	219	372	344	430	447	547	305	168	422	697	191	267	428	464	537	465	600
Portugal	34	53	39	26	98	129	161	243	883	751	860	478	424	843	236	259	116	94	143	199	208	277	358
Spain	83	125	103	86	93	124	129	132	192	363	444	354	342	234	242	374	555	537	369	455	513	1209	792
Belgium	192	210	165	149	206	122	124	123	114	175	167	191	274	194	153	193	255	280	271	274	239	659	224
Luxemburg					1	1	1	2	2	1	1	2	3	1	2	1	1	2	3	2	3	5	3
Sweden	103	119	114	143	178	324	436	529	369	400	426	732	411	400	392	544	482	341	356	320	410	464	469
Finland	86	77	91	129	166	188	190	150	196	215	437	586	700	767	467	395	362	456	630	626	625	583	565
Austria	138	90	69	56	58	36	46	48	60	56	79	584	605	613	568	534	570	565	551	835	763	786	696
Malta									18	37	74	48	25	16	32	42	45	35	61	41	39	28	26
Estonia						2	2	3	3	9	31	11	6	11	10	39	102	158	196	149	112	126	76
Latvia							5	2	4	8	7	8	8	15	7	7	26	44	29	54	31	38	20
Lithuania						16	22	29	33	29	43	58	60	53	33	55	121	129	69	72	104	96	632
Poland								283	290	340	402	403	366	329	327	463	437	456	796	754	1287	1275	1661
Czech Rep.							137	134	229	395	447	499	849	1056	842	768	972	935	1013	894	805	946	982
Slovakia					38	57	82	118	151	117	2692	13	28	45	56	55	51	106	181	220	295	416	647
Hungary							93	124	90	75	89	90	190	448	699	1887	2320	2828	3172	3164	2795	3706	4116
Romania						0	0	35	0	0	0	32	196	289	288	1004	1884	1383	2194	2100	1542	531	128
Bulgaria							4	4	6	8	13	21	26	33	22	51	77	88	66	86	108	126	113
Slovenia							12	13	38	31	22	55	51	103	255	273	395	387	516	600	515	707	222
Croatia									4	5	11	0	29	38	14	17	17	21	19	26	29	25	39
Cyprus									3	2	5	4	6	8	6	4	4	2	2	6	3	4	2
EU28 Total for Extra EU						**1145**	**663**	**1137**	**749**	**825**	**1036**	**1723**	**2316**	**3041**	**2095**	**3266**	**3838**	**4075**	**7176**	**9296**	**8719**	**8784**	**8672**

Table 59. EU28 Import Volume of Other fans > 125W, in units x 1000 *(Source: Eurostat 2019, ProdCom code 28252070 and ComExt CN8 codes 841459xx)*

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	4456	5296	5083	6389	7137	7544	6450	6343	6375	4585	3484	3870	5076	4478	2909	2786	2907	3020	2717	2620	2779	3427	3117
Netherlands	623	2474	2197	2990	5156	2838	7140	6181	6900	4422	3683	2639	1994	1548	1144	1568	1518	1923	1947	4155	2364	3326	5087
Germany	5746	4924	4091	4286	3862	4274	5121	5029	8006	10304	8412	6114	6112	6773	4835	7579	7402	5497	4979	5875	4302	4712	4669
Italy	4855	4006	3810	3890	3455	4424	5077	4909	7513	7308	7054	6367	9739	8179	6096	6789	6709	4182	4441	4181	3701	3954	6112
Un. Kingdom	4590	6790	6624	10408	8522	9262	11988	8436	6467	9619	7918	7010	6061	4515	2681	4186	4421	3404	3105	3900	4295	4924	4488
Ireland	338	177	237	424	2498	2288	3098	984	555	620	492	1070	630	914	759	88	82	118	274	274	210	256	143
Denmark	181	359	345	476	324	473	458	532	734	329	292	398	442	272	195	111	78	93	121	460	581	474	331
Greece	220	244	218	225	206	235	169	231	335	386	444	396	428	1162	283	196	216	222	188	172	138	221	183
Portugal	302	477	473	721	804	658	693	608	524	544	398	448	307	231	1143	342	593	667	604	698	328	277	421
Spain	3878	2784	3498	6427	5151	7818	15947	9443	5087	4635	4508	5445	3877	2520	1462	1785	1863	1569	1756	1880	2300	1818	1456
Belgium	772	838	1553	2360	2046	1267	1136	878	858	1040	1305	1263	1305	919	718	951	957	986	1010	1205	876	1505	1402
Luxemburg					70	25	19	27	15	15	26	15	14	22	20	25	24	25	50	33	86	60	49
Sweden	796	892	901	724	553	791	803	952	935	891	851	1185	1203	1344	822	873	776	524	482	539	765	609	868
Finland	206	533	613	740	570	294	372	504	506	523	421	332	400	387	198	465	402	230	239	272	338	311	168
Austria	452	429	423	592	1028	1449	1894	1967	1627	1820	2061	1845	1821	1580	632	847	591	444	504	583	516	643	489
Malta									25	95	110	117	110	40	42	34	13	1799	16	5	24	11	3
Estonia						18	20	25	25	29	53	92	49	29	15	104	120	49	30	34	51	18	13
Latvia							15	17	21	35	41	88	51	32	25	39	45	34	17	19	15	18	32
Lithuania						11	22	29	38	61	54	85	166	285	87	232	173	72	83	85	133	137	142
Poland								1316	1891	3155	2807	3190	3550	2777	3120	2547	2281	2629	2184	2163	1575	1798	2095
Czech Rep.							1766	1070	1293	2030	2231	3904	2853	4152	2287	1557	1755	2154	1833	1241	1529	2152	2403
Slovakia					36	28	57	106	208	834	1092	1644	1128	1961	1531	1283	1505	1280	1408	1755	1447	1802	2164
Hungary							288	545	1373	2536	1451	1572	2379	2206	1506	2131	1169	1015	870	1260	1215	959	780
Romania						0	0	57	0	0	0	0	481	400	449	399	409	331	369	446	249	954	393
Bulgaria							18	21	84	70	83	179	249	149	58	67	61	60	93	93	118	182	356
Slovenia							69	83	83	111	104	128	98	83	59	55	57	46	56	41	69	122	566
Croatia									159	190	112	103	146	94	69	56	67	65	67	55	68	89	144
Cyprus									21	29	22	14	10	26	23	16	64	41	9	12	7	10	27
EU28 Total for Extra EU						**20064**	**26809**	**25274**	**30141**	**33995**	**30036**	**26412**	**25727**	**23111**	**15474**	**19267**	**19454**	**15976**	**14833**	**17528**	**14794**	**16266**	**21988**

Figure 46. EU28 total Extra-EU28 Import Volume of Axial, Centrifugal and Other fans > 125W, in units x 1000 *(Source: Eurostat 2019, ComExt CN8 codes 841459xx)*

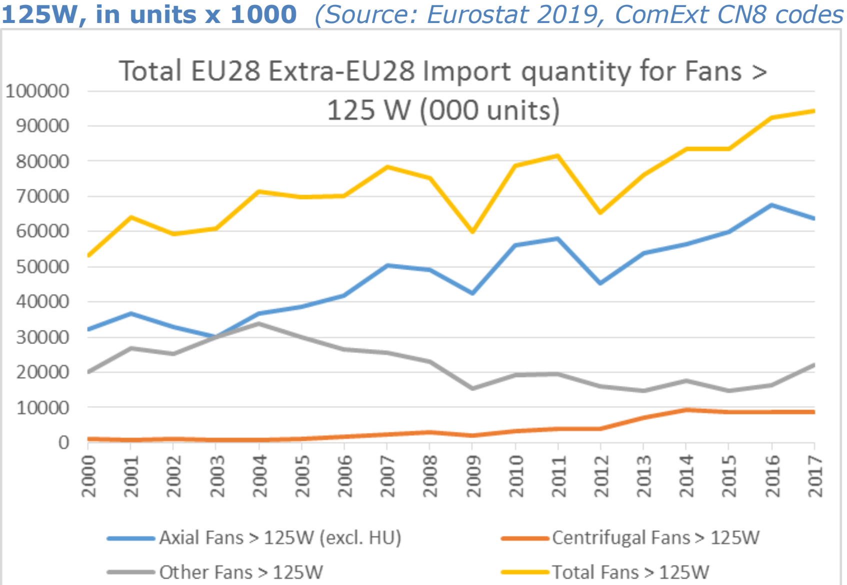


Table 60. EU28 Import Value of Axial fans > 125W, in M euros *(Source: Eurostat 2019, ProdCom code 28252030 and ComExt CN8 codes 841459xx).*

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	19	19	31	33	43	48	44	44	49	57	49	50	55	55	39	51	62	58	66	73	82	89	79
Netherlands	14	17	19	30	25	47	75	58	43	48	45	60	62	58	56	53	73	67	61	58	62	78	81
Germany	52	66	92	115	105	139	160	144	164	178	189	224	229	216	181	248	265	242	272	315	329	368	368
Italy	35	36	42	48	59	74	78	65	66	81	76	79	85	80	58	71	75	88	94	81	107	112	119
Un. Kingdom	43	50	55	56	55	78	76	68	53	49	56	68	89	74	60	79	85	74	77	85	97	98	91
Ireland	3	4	4	3	3	5	4	9	10	11	12	12	6	7	4	4	3	4	4	7	8	8	5
Denmark	4	4	6	7	8	7	7	7	9	9	10	11	14	14	10	12	11	12	10	12	12	11	11
Greece	1	1	1	1	2	4	2	1	3	4	4	3	3	5	3	2	3	2	2	3	3	3	4
Portugal	3	4	4	6	6	7	5	5	4	5	7	9	9	11	11	10	12	10	9	11	14	17	19
Spain	14	24	25	25	22	22	22	20	23	25	22	29	32	26	25	28	32	27	40	50	62	61	71
Belgium	5	5	24	27	20	21	31	25	23	23	21	19	29	33	23	24	27	26	33	30	26	33	36
Luxemburg					1	4	0	0	0	0	1	0	1	1	0	1	1	1	1	1	1	1	1
Sweden	16	15	16	17	19	28	22	24	35	51	41	46	51	45	34	36	43	40	38	38	40	39	25
Finland	10	9	10	12	13	15	15	14	15	16	21	16	16	19	15	15	19	14	17	16	15	16	16
Austria	12	12	13	14	13	17	18	18	21	20	23	19	21	22	18	21	24	25	26	26	27	28	27
Malta									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia						0	0	0	1	1	1	2	3	4	2	6	11	14	15	13	11	8	6
Latvia							0	0	0	0	0	0	1	1	0	1	1	2	2	2	2	2	1
Lithuania						0	1	0	1	1	1	2	2	2	1	2	4	7	6	6	7	8	12
Poland								9	19	36	17	25	29	32	22	34	34	37	47	55	51	55	51
Czech Rep.							20	23	37	53	40	56	60	55	34	38	43	49	51	62	74	82	63
Slovakia					7	8	6	8	8	6	6	5	7	10	9	10	12	11	7	9	11	36	33
Hungary							14	20	16	20	30	25	30	23	21	26	29	38	48	47	55	56	49
Romania						1	2	3	5	4	4	6	6	7	5	6	8	10	11	11	13	15	21
Bulgaria							1	1	1	1	1	1	2	2	3	4	5	4	5	5	5	7	6
Slovenia							1	2	3	5	6	9	10	9	6	11	13	11	7	5	6	7	7
Croatia									2	1	2	2	2	3	2	4	3	1	2	2	2	3	3
Cyprus									0	0	0	0	0	0	2	0	0	0	0	0	6	0	0
EU28 Total for Extra EU						**163**	**187**	**172**	**143**	**153**	**162**	**186**	**204**	**207**	**167**	**217**	**240**	**245**	**254**	**296**	**360**	**399**	**356**

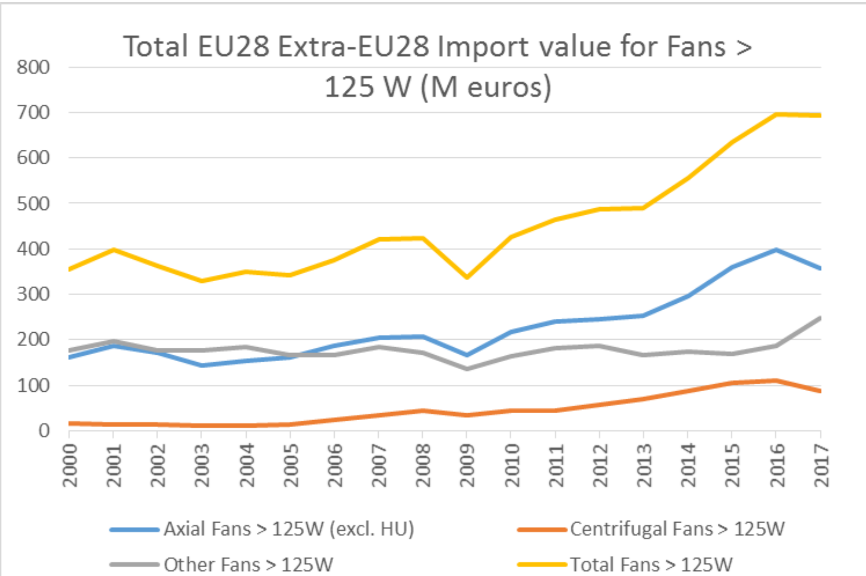
Table 61. EU28 Import Value of Centrifugal fans > 125W, in M euros *(Source: Eurostat 2019, ProdCom code 28252050 and ComExt CN8 codes 841459xx)*

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	23	25	27	28	32	30	30	31	43	45	47	56	54	58	48	56	63	68	72	79	77	79	86
Netherlands	20	20	18	19	20	16	13	17	19	23	16	16	18	20	19	18	33	51	53	53	63	75	74
Germany	17	21	24	29	32	39	39	37	34	44	52	75	78	87	69	80	85	106	125	153	163	163	174
Italy	23	20	19	18	23	29	29	28	36	40	43	61	67	68	57	72	75	68	71	63	67	76	82
Un. Kingdom	21	19	22	25	27	30	25	25	29	34	40	43	61	43	32	40	44	46	49	50	50	65	51
Ireland	3	2	3	3	2	3	3	4	4	4	5	2	2	2	1	1	2	2	3	3	5	6	5
Denmark	9	8	10	12	10	17	14	13	17	18	16	18	21	19	15	15	17	14	18	19	20	31	24
Greece	3	2	2	3	3	4	5	4	4	5	6	6	6	5	5	3	3	3	3	4	5	5	4
Portugal	2	3	3	3	4	5	5	5	7	7	8	5	7	9	5	8	7	6	8	10	10	11	11
Spain	2	3	3	3	4	5	5	6	8	9	9	10	13	12	11	13	17	14	15	17	23	28	32
Belgium	7	7	8	9	9	9	10	10	9	13	13	14	16	20	16	14	17	20	22	25	25	48	20
Luxemburg					0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	2
Sweden	7	11	14	12	13	18	21	23	18	20	24	27	25	29	27	33	44	41	45	44	44	50	47
Finland	4	4	5	6	7	9	11	10	12	13	25	23	25	28	17	20	25	25	24	27	29	29	31
Austria	5	5	4	4	5	5	6	6	6	6	7	16	18	21	16	20	23	27	27	32	34	38	35
Malta									1	1	2	2	1	1	1	1	1	1	1	1	0	1	1
Estonia						0	0	0	1	1	1	1	1	1	1	3	5	5	7	5	5	4	2
Latvia							0	0	1	1	1	1	1	3	1	1	2	6	5	2	2	2	2
Lithuania						1	1	1	2	2	4	5	5	4	3	4	8	8	7	7	8	7	12
Poland								9	9	15	8	14	15	17	14	14	21	23	27	31	43	42	45
Czech Rep.							8	9	10	15	15	18	19	21	14	16	22	25	27	28	30	33	37
Slovakia					1	3	3	5	6	5	3	1	1	3	3	4	7	9	9	11	11	19	13
Hungary							3	5	5	2	4	4	7	7	8	13	16	22	28	19	19	21	21
Romania						1	1	3	2	2	3	5	4	4	5	4	8	12	7	8	8	6	8
Bulgaria							2	1	1	1	2	4	3	3	2	3	2	3	2	3	3	3	4
Slovenia							1	2	2	1	1	2	3	4	3	3	4	4	5	4	4	5	4
Croatia									1	1	2	2	2	3	3	3	2	3	3	3	4	4	5
Cyprus									0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
EU28 Total for Extra EU						**16**	**13**	**13**	**11**	**12**	**13**	**24**	**35**	**45**	**35**	**45**	**44**	**57**	**69**	**88**	**106**	**111**	**88**

Table 62. EU28 Import Value of Other fans > 125W, in M euros *(Source: Eurostat 2019, ProdCom code 28252070 and ComExt CN8 codes 841459xx)*

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	42	44	47	49	50	55	60	55	55	52	63	62	59	56	45	51	55	53	54	45	51	55	62
Netherlands	14	25	18	26	33	27	45	41	37	34	30	27	30	23	19	25	29	37	35	36	34	50	57
Germany	69	56	61	70	69	81	93	97	104	105	93	87	84	80	74	102	120	107	100	100	96	98	112
Italy	44	35	34	34	32	43	47	43	49	46	46	45	63	60	55	59	63	50	42	40	46	44	49
Un. Kingdom	38	58	71	78	71	73	66	62	58	64	55	60	68	62	37	50	59	73	77	78	102	119	138
Ireland	3	3	4	12	21	25	28	22	8	8	11	13	8	10	7	3	3	4	6	6	6	6	3
Denmark	7	7	8	11	9	9	7	7	7	6	5	7	12	8	6	9	9	12	9	12	14	14	16
Greece	3	3	2	3	2	3	5	2	3	3	3	8	5	3	4	2	3	2	2	2	2	2	3
Portugal	6	11	13	17	17	12	10	8	9	9	8	8	9	9	16	8	10	9	7	7	6	5	5
Spain	48	40	44	53	48	50	47	37	34	35	40	47	49	39	22	27	29	20	19	24	27	28	23
Belgium	22	26	27	29	29	38	35	33	32	32	35	46	42	40	30	42	46	40	40	46	42	51	32
Luxemburg					2	2	1	2	1	2	2	2	3	2	2	2	3	5	5	6	7	5	5
Sweden	23	25	22	16	14	19	20	25	19	26	18	25	26	29	18	22	22	21	22	18	17	17	21
Finland	7	8	9	9	10	8	12	14	13	11	10	10	10	10	8	10	9	9	8	10	11	11	10
Austria	20	21	21	21	25	34	37	35	31	33	34	31	36	37	26	27	26	24	25	26	25	27	19
Malta									1	1	1	1	0	0	0	0	0	0	0	0	0	1	0
Estonia						1	1	1	1	2	2	2	1	3	1	1	1	2	2	1	1	1	1
Latvia							1	1	1	1	1	3	3	3	1	1	2	1	1	2	1	1	1
Lithuania						1	1	2	1	3	3	3	7	10	4	8	6	4	4	4	3	4	3
Poland								17	29	30	35	39	40	40	33	31	26	31	28	26	31	36	41
Czech Rep.							25	22	24	26	26	39	54	46	27	23	28	30	30	25	23	27	29
Slovakia					2	2	3	3	4	5	6	21	19	27	21	23	24	25	23	26	21	22	22
Hungary							6	8	9	15	11	9	12	15	13	13	12	9	8	10	9	10	9
Romania						4	6	6	6	9	8	12	9	9	6	7	6	6	11	10	7	8	7
Bulgaria							1	1	2	2	4	3	3	3	1	2	2	2	3	2	2	3	3
Slovenia							2	2	2	3	4	5	4	3	3	2	3	3	4	3	3	3	6
Croatia									4	4	3	5	4	4	2	2	2	2	2	2	2	2	6
Cyprus									1	1	1	0	0	1	0	0	1	0	0	0	0	0	0
EU28 Total for Extra EU						177	197	177	176	185	166	166	183	171	136	163	181	186	166	173	169	187	249

Figure 47. EU28 total Extra-EU28 Import Value of Axial, Centrifugal and Other fans > 125W, in M euros *(Source: Eurostat 2019, ComExt CN8 codes 841459xx)*



The combined results of EU28 production and extra-EU28 imports and exports in the period 2000-2017 are given in Table 63 and

Table 64, also providing a calculation of the apparent consumption (production + imports - exports), with quantity expressed in thousands of units and value in millions of euros. As unit values for production, import and export may be different, and products not directly comparable, the results for the apparent consumption are indicative only and should be used with care.

Considering Table 63 and Figure 48 the position of EU-industry in the production of fans > 125W seems rather weak because imported quantities dominate the scene, possibly with the exception of centrifugal fans. However, considering the associated values of Table 64 and Figure 49 the picture changes, showing a low relative value of the imports. As also remarked before, the data seem to indicate that EU-industry produces and exports fans that are relatively large and complex, with a high unit value, while the EU imports much larger quantities of smaller, more simple fans, with a low unit value.

In 2017, the apparent 'consumption' of fans >125W in EU28 is around 106 mln units, of which 69 mln are axial, 13 mln centrifugal and 24 mln other type. The 106 mln results from a production in EU28 of 44 mln units and an import-export balance with extra-EU28 countries of 62 mln units. The corresponding value of the 106 mln units is 2.5 bn euros, consisting of a value of production of 3.5 bn euros and an import-export balance with extra-EU28 countries of -1.0 bn euros.

Table 63. EU28 Quantity summary in 000 units for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Fans >125W. Value of apparent consumption (production + import – export) computed by VHK *(Source: Eurostat 2019, ProdCom codes 28252030, 28252050, 28252070 and ComExt CN8 codes 841459xx)*

Axial fans > 125W, ProdCom 28252030 (excl. Hungary)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28				13066	21773	11601	21905	22484	15265	13508	20995	18027	18368	17557	33480	18727	19880	20626
Import from Extra-EU28	32196	36587	32986	30011	36694	38611	41837	50410	49173	42325	56041	58145	45202	54000	56518	59840	67475	63694
Export to Extra-EU28	9735	8247	6181	9231	9687	9730	10127	10196	11237	8222	11789	13395	15488	13427	12951	12717	13713	15049
Apparent consumption				**33846**	**48780**	**40482**	**53615**	**62698**	**53201**	**47611**	**65247**	**62777**	**48082**	**58130**	**77047**	**65850**	**73642**	**69271**

Centrifugal fans > 125W, ProdCom 28252050

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28				4000	8004	4003	5000	10000	5000	6120	7825	8000	8601	8000	12000	14000	10000	15000
Import from Extra-EU28	1145	663	1137	749	825	1036	1723	2316	3041	2095	3266	3838	4075	7176	9296	8719	8784	8672
Export to Extra-EU28	2106	2052	2499	2296	3309	4586	6578	6682	6409	5087	7216	7805	7597	7902	9309	8754	9428	11000
Apparent consumption	**1366**	**599**	**558**	**2453**	**5520**	**453**	**145**	**5634**	**1632**	**3128**	**3875**	**4033**	**5079**	**7274**	**11987**	**13965**	**9356**	**12672**

Other fans > 125W, ProdCom 28252070

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28				4200	4620	4161	4645	5718	6475	4440	5032	5306	6127	6637	6871	7020	4252	8411
Import from Extra-EU28	20064	26809	25274	30141	33995	30036	26412	25727	23111	15474	19267	19454	15976	14833	17528	14794	16266	21988
Export to Extra-EU28	3725	4295	5279	6818	7537	8768	10237	8426	6789	4668	6255	6002	6360	6451	6608	6369	7689	6767
Apparent consumption				**27523**	**31078**	**25429**	**20820**	**23019**	**22797**	**15246**	**18044**	**18758**	**15743**	**15019**	**17791**	**15445**	**12829**	**23632**

All fans > 125W, sum of ProdCom 28252030, 28252050, 28252070

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28				21266	34397	19765	31551	38202	26740	24069	33851	31333	33096	32194	52351	39747	34132	44037
Import from Extra-EU28	53405	64059	59397	60901	71514	69683	69972	78453	75325	59894	78574	81437	65253	76009	83342	83353	92525	94354
Export to Extra-EU28	15566	14594	13959	18345	20533	23084	26942	25304	24435	17977	25260	27202	29445	27780	28868	27840	30830	32816
Apparent consumption				**63822**	**85378**	**66364**	**74581**	**91351**	**77630**	**65986**	**87165**	**85568**	**68904**	**80423**	**106825**	**95260**	**95827**	**105575**

Figure 48. EU28 total quantity in 000 units for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Fans > 125W. Value of apparent consumption (production + import – export) computed by VHK *(Source: Eurostat 2019, ProdCom codes 28252030, 28252050, 28252070 and ComExt CN8 codes 841459xx)*

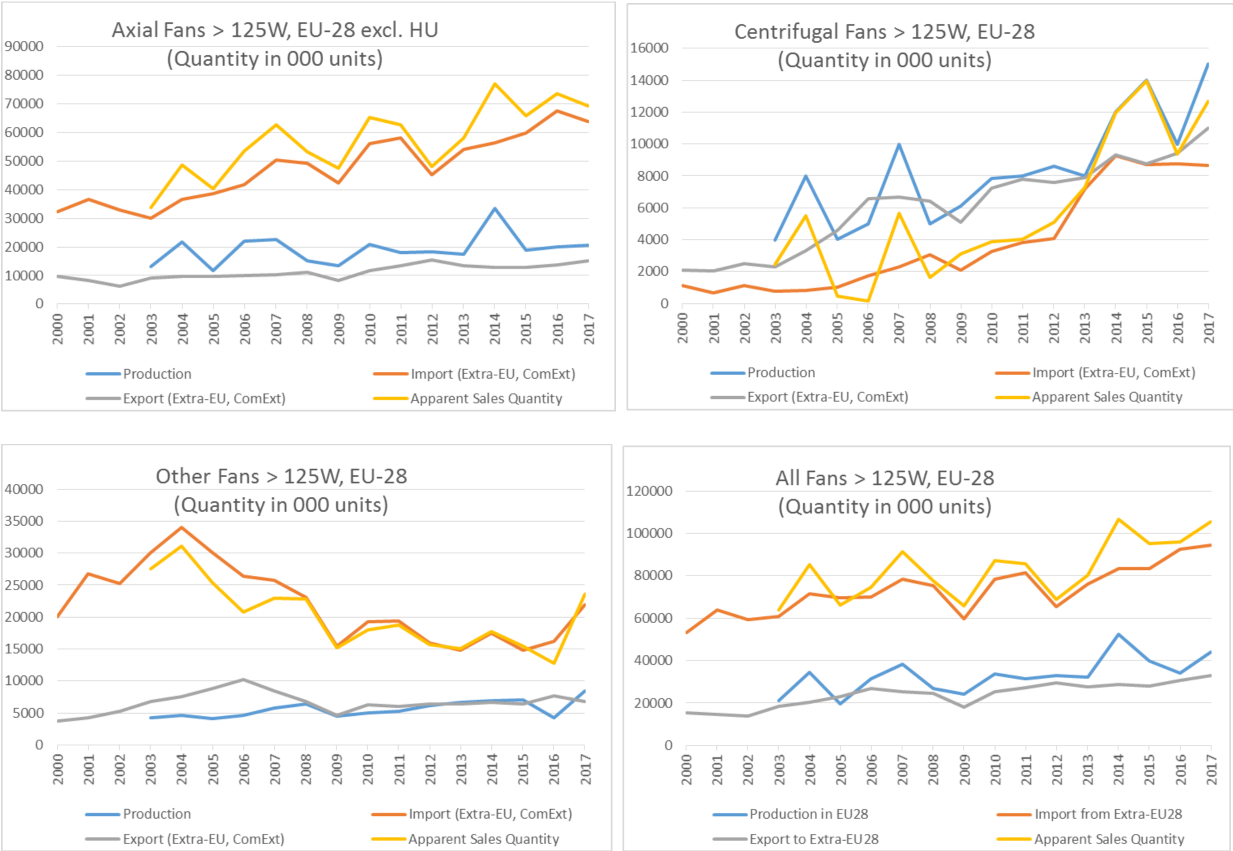


Table 64. EU28 Value summary in M euros for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Fans >125W. Value of apparent consumption (production + import – export) computed by VHK *(Source: Eurostat 2019, ProdCom codes 28252030, 28252050, 28252070 and ComExt CN8 codes 841459xx)*

Axial fans > 125W, ProdCom 28252030 (excl. Hungary)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28				674	753	748	875	926	993	765	962	1004	912	951	1005	1131	1257	1272
Import from Extra-EU28	163	187	172	143	153	162	186	204	207	167	217	240	245	254	296	360	399	356
Export to Extra-EU28	227	208	177	209	256	259	306	345	383	294	443	512	524	537	570	624	691	725
Apparent consumption				**607**	**651**	**651**	**755**	**785**	**817**	**637**	**736**	**732**	**633**	**667**	**731**	**868**	**965**	**904**

Centrifugal fans > 125W, ProdCom 28252050

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28				817	940	1006	1104	1230	1369	1085	1173	1363	1255	1298	1320	1393	1436	1460
Import from Extra-EU28	16	13	13	11	12	13	24	35	45	35	45	44	57	69	88	106	111	88
Export to Extra-EU28	105	106	101	133	168	185	247	274	305	275	397	435	486	646	576	637	586	688
Apparent consumption				**695**	**784**	**834**	**881**	**991**	**1109**	**845**	**821**	**972**	**826**	**721**	**832**	**862**	**961**	**860**

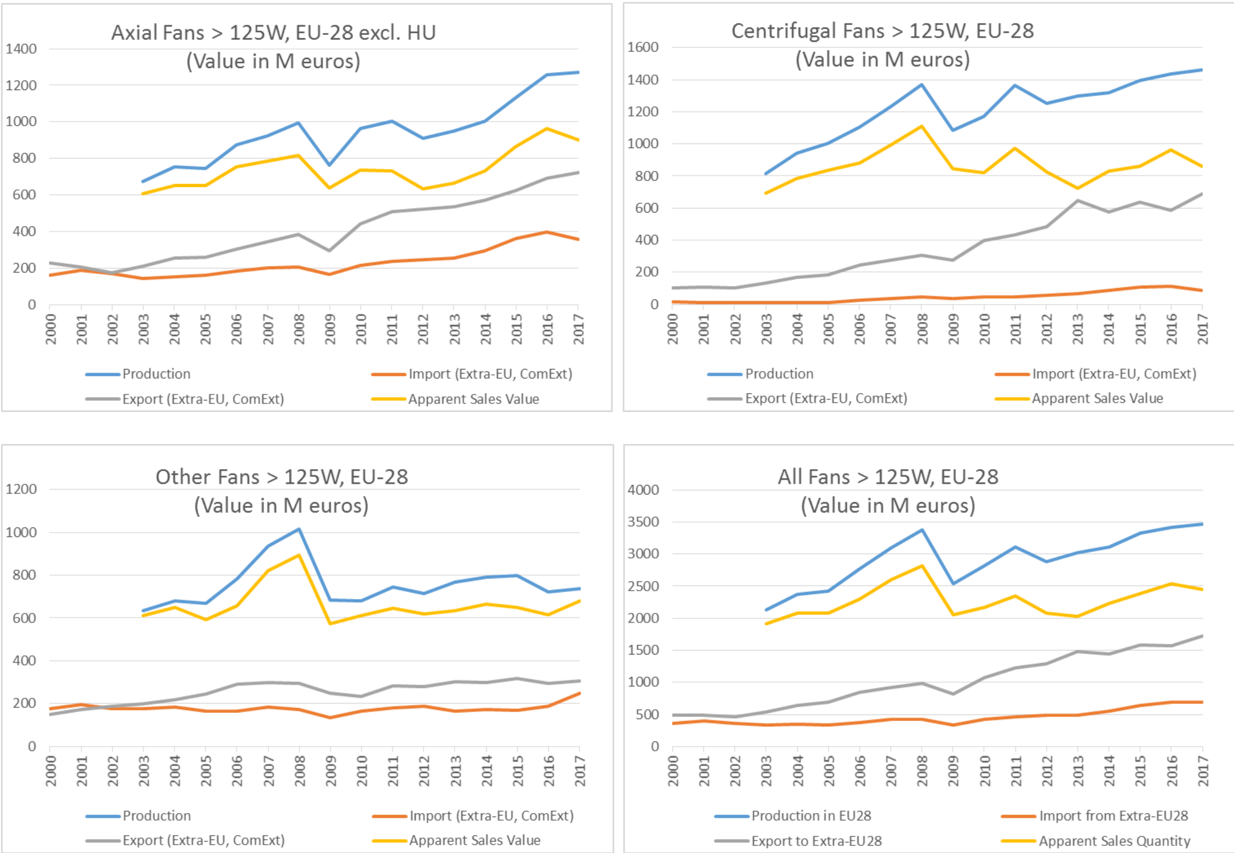
Other fans > 125W, ProdCom 28252070

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28				634	680	668	784	937	1016	685	682	746	715	769	790	798	723	739
Import from Extra-EU28	177	197	177	176	185	166	166	183	171	136	163	181	186	166	173	169	187	249
Export to Extra-EU28	151	173	189	199	217	243	291	299	293	249	235	283	281	301	299	317	295	306
Apparent consumption				**611**	**648**	**591**	**659**	**821**	**894**	**572**	**610**	**644**	**620**	**634**	**664**	**650**	**615**	**682**

All fans > 125W, sum of ProdCom 28252030, 28252050, 28252070

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28				2125	2374	2422	2763	3093	3379	2536	2817	3113	2882	3018	3114	3322	3416	3471
Import from Extra-EU28	356	397	362	330	350	341	376	422	423	338	425	465	488	489	557	635	697	693
Export to Extra-EU28	483	487	467	541	641	687	844	918	981	818	1075	1230	1291	1484	1445	1578	1572	1719
Apparent consumption				**1914**	**2083**	**2076**	**2295**	**2596**	**2821**	**2055**	**2166**	**2348**	**2079**	**2022**	**2226**	**2380**	**2541**	**2446**

Figure 49. EU28 total value in M euros for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Fans > 125W. Value of apparent consumption (production + import – export) computed by VHK *(Source: Eurostat 2019, ProdCom codes 28252030, 28252050, 28252070 and ComExt CN8 codes 841459xx)*



Since 2017, a new ProdCom category 28252010 presents data for '*Fans of a kind used solely or principally for cooling microprocessors, telecommunication apparatus, automatic data processing machines or units of automatic data processing machines*'. The corresponding ComExt CN8 code is 84145915.

Different from the other codes for fans, the description does not include a power limit. Considering the mentioned applications, the major part of these fans would be expected to be below 125 W, but the use in ComExt suggests differently. For example, with the introduction of CN8 code 84145915, the definition for axial fans >125 W has been changed to: '*84145925-Axial Fans (excl. table, floor, wall, window, ceiling or roof fans, with a self-contained electric motor of an output ≤125 W, and fans for cooling IT equipment of 8414 59 15*)'. The CN8 definition for fans ≤125 W has not been updated with a similar exception for fans cooling IT equipment.

Eurostat data for these fans cooling IT equipment are still scarce, so that no detailed data are presented here. The sum of exports from EU28 countries (including intra-EU28 trade) in 2017 is 19 mln units (mainly from Germany) for a value of 146 mln euros. The EU28 export to extra-EU28 is 1.3 mln units with a value of 40 mln euros. The EU28 import from extra-EU28 is 9.9 mln units with a value of 73 mln euros. Data on production includes only an estimate of the EU28 total of 600 thousand units in 2017, with a corresponding value of 95 mln euros.

4. Installation repair and maintenance

Eurostat’s ProdCom database provides statistics on the installation, repair and maintenance of non-domestic cooling and ventilation appliances, respectively in ProdCom categories 33202950 and 33121800.

Corresponding ‘production’ values in M euros are presented in Table 65 and Table 66. In 2017, a total of 4.7 bn euros was spent in EU28 for installation of non-domestic cooling and ventilation equipment, and 3.5 bn euros for their repair and maintenance. A noteworthy large contribution comes from France where between 2007 and 2009 the expenses for these activities seem to have tripled, notwithstanding the economic crisis.

Trends are positive, even when taking into account inflation: For Installation, the increase is from 2.9 bn euros in 2003 to 4.7 bn euros in 2017 (+64%), and for Repair and Maintenance from 2.1 bn euros in 2003 to 3.5 bn euros in 2017 (+71%), compared to an inflation over the 2003-2017 period of 28%.

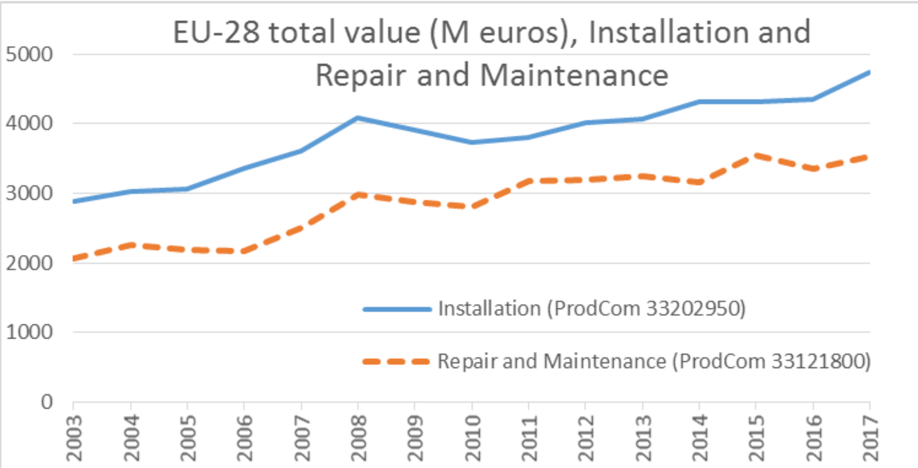
Table 65. EU28 ‘Production’ Value for Installation of non-domestic cooling and ventilation equipment, in M euros *(Source: Eurostat 2019, ProdCom code 33202950).*

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	52	106	191	225	306	319	282	372	380	351	361	308	360	889	1107	1114	1249	1238	1267	1287	1387	1429	1432
Netherlands	172	170	179	185	205	201	192	216	197	178	164	227	252	204	180	178	193	231	222	215	221	198	240
Germany			439	408	377	455	362	433	409	448	442	507	602	705	577	544	582	650	661	777	788	823	932
Italy	76	618	320	325	488	449	531	514	590	677	649	738	657	577	656	446	452	465	425	462	299	365	357
Un. Kingdom	393	295	432	466	381	566	504	530	414	406	518	504	563	572	442	443	369	478	448	462	563	378	400
Ireland	8	12	10	11	14				2	1										1			10
Denmark	28	32	38	40	45	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greece						0	0	14	11	17	18	15	14	5	5	0	0	0	0	0	0	0	0
Portugal	20	25	36	45	49	58	47	55	70	60	58	59	77	62	53	57	48	69	48	62	33	36	46
Spain	133	161	148	148	220	257	364	368	423	442	373	429	503	454	365	352	301	240	253	270	323	339	432
Belgium	128	137	137	151	124	131	116	160	144	198	211	251	278	209	199	197	197	225	285	297	190	188	234
Luxemburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden		0	0	11	26	29	40	49	40	30	29	21	27	32	36	42	36	40	37	39	35	39	47
Finland				7	7	8	7	10	9	15	17	25	27	12	16	13	14	13	18	22	22	17	23
Austria	66	75	63	73	90	104	87	104	80	84	85	76	86	103	95	138	123	163	185	176	178	181	226
Malta									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia											0	2	1	5	3	3	4	2	5	7	4	5	1
Latvia															0	0							
Lithuania						0			1		1	3	5	5	3	1	1	1	1	1	2	1	1
Poland									38	49	50	86	86	97	43	79	113	97	119	136	135	148	164
Czech Rep.							34	33	47	20	31	41	79	60	54	48	56	35	31	37	52	72	86
Slovakia				0	0	0	0	4		4	5		14	40	28	29	24	24	26	42	47	48	58
Hungary							28	28	18	22	21	20	16	24	24	14	12	10	9	5	5	8	8
Romania									2		0									0			0
Bulgaria							0	0	0	8	16	20	25	18	9	17	16	17	13	15	14	17	19
Slovenia																					9	34	11
Croatia							2	2	4	4	3	5	8	9	6	3	4	5	4	3	5	6	5
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 TOTAL									**2886**	**3019**	**3056**	**3352**	**3608**	**4091**	**3912**	**3727**	**3801**	**4010**	**4064**	**4320**	**4315**	**4341**	**4735**

Table 66. EU28 'Production' Value for Repair and Maintenance of non-domestic cooling and ventilation equipment, in M euros *(Source: Eurostat 2019, ProdCom code 33121800).*

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	56	54	70	91	141	161	147	196	200	223	232	229	225	539	652	674	773	808	848	876	862	892	911
Netherlands	76	77	82	84	92	110	113	117	111	113	94	106	121	256	208	218	226	241	245	271	283	236	236
Germany	135	150	174	152	181	193	256	249	271	249	277	310	381	382	402	413	509	497	512	472	538	473	504
Italy	7	63	261	265	251	294	380	371	299	299	311	368	402	435	420	367	628	591	624	488	731	616	651
Un. Kingdom	349	328	533	583	666	768	842	846	717	855	783	577	612	605	533	434	380	389	371	387	409	329	373
Ireland	0		1	1	1	1	2		1	2	0	0	1	4	3	2	2	4	4	4	5	5	8
Denmark	15	19	16	15	18	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greece	0			0	0	0	0			17	3	5	2	0	0		0		3	3	3	5	5
Portugal	4	5	5	10	12	22	19	26	27	31	31	27	28	17	18	20	13	12	8	12	8	10	9
Spain	77	86	78	97	111	90	118	140	177	203	153	205	272	275	219	213	162	150	164	160	171	207	223
Belgium	63	64	73	79	94	113	125	132	142	155	168	178	198	223	238	236	264	253	227	233	241	241	252
Luxemburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden		0	0	6	7	9	48	8	9	10	11	17	7	4	6	6	9	8	7	12	12	13	12
Finland			6	10	4	8	10	28	14	7	8	13	18	12	10	19	25	24	23	20	20	20	19
Austria	23	26	25	26	25	25	25	22	23	27	34	44	46	62	63	90	80	84	85	94	119	123	136
Malta									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia									1	2	1	2	2	2	1	1	2	4	3	4	2	5	2
Latvia							2	4	2	1	1						2	3	4	4	5	6	7
Lithuania						0	0				1	1	1	1	1	1	1	2	1	1	1	4	3
Poland									32	16	27	18	31	79	49	47	51	58	47	51	57	76	86
Czech Rep.							5	6	10	13	10	19	16	24	17	23	19	21	28	22	30	33	36
Slovakia				2	0	0	0	4	4	5	12	18	12	19	12	10	10	10	10	12	12	14	14
Hungary							7	9	9	16	17	18	15	13	15	11	10	13	13	14	15	15	20
Romania											0			1	1	1	0	0	2	1	4	4	4
Bulgaria							0	0	0	5	4	4	9	14	6	5	5	5	5	5	6	6	7
Slovenia							1					1	0	1	1	1	1	1	1	1		6	6
Croatia							0	1	1	1	2	1	2	3	5	4	4	4	5	6	7	8	8
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 TOTAL									**2071**	**2254**	**2179**	**2169**	**2502**	**2973**	**2882**	**2799**	**3178**	**3185**	**3240**	**3151**	**3543**	**3345**	**3533**

Figure 50. EU28 total value in M euros for Installation and Repair and Maintenance of non-domestic cooling and ventilation equipment *(Source: Eurostat 2019, ProdCom codes 33202950 and 33121800)*



In order to get a better impression on how important these items are with respect of the total economic picture for air-conditioning, Table 67 gives an estimate for 2017 of the production value of '*non-domestic cooling and ventilation products*' that are typically subject to the repair and installation costs mentioned above.

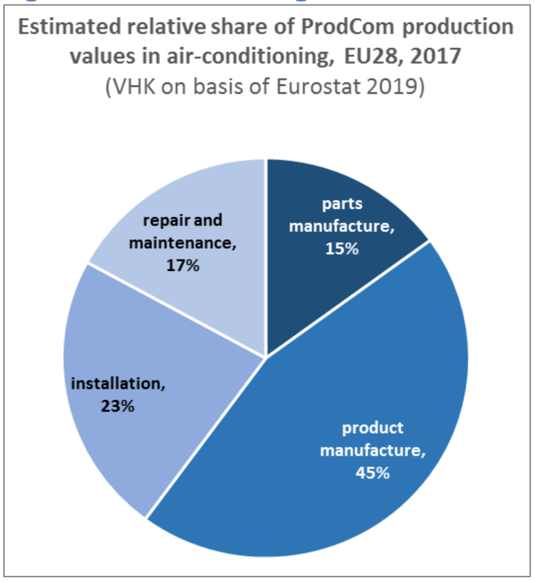
The table shows selected production values from ProdCom 2825…, and in the last column an estimate of the relevant share is made which would make it comparable to non-domestic air-conditioning systems. In this estimate, air-conditioning units are counted for 100%, and ventilation fans for 50%. The commercial refrigeration –based on the relative share of the parts production— was set at 30%. The resulting figure of € 12.5 bn, of which € 3.1 bn in parts manufacture and € 9.4 bn in products manufacture, was compared to the installation and repair and maintenance results from Table 65 and Table 66. This is expressed in Figure 51, which is by definition incomplete because the manufacturing value only includes manufacturer selling prices (msp) and not the margins of wholesale and retail. Nonetheless, it already brings together all the figures that could be extracted from the Eurostat ProdCom. The conclusion is that the repair and installation activities are indeed more significant than the part manufacture.

Table 67. Estimated EU28 production value of 'non-domestic cooling and ventilation products' *(Source: VHK elaboration of Eurostat 2019, ProdCom data).*

ProdCom	Description	EU28 total mln euros	included* mln euros
28251130	Heat Exchange Units	5481	
28251150	Machinery for liquefying air or other gases	2100	
28251220	Window or wall air conditioning systems, self-contained or split-systems	916	229
28251240	Air conditioning machines of a kind used in motor vehicles	2065	
28251250	Air conditioning machines with refrigeration unit (excluding those used in motor vehicles, self-contained or split-systems machines)	2390	2390
28251270	Air conditioning machines not containing a refrigeration unit; central station air handling units; vav boxes and terminals, constant volume units and fan coil units	1993	1993
28252030	Axial fans >125W	1263	632
28252050	Centrifugal fans >125 W	1515	758
28252070	Other fans >125 W	765	383
28251333	Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator for frozen food storage	726	218
28251335	Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator (excluding for frozen food storage)	1704	511
28251360	Refrigerating furniture with a refrigerating unit or evaporator (excluding combined refrigerator-freezers, with separate external doors, household refrigerators, refrigerated show-cases and counters)	1457	437
28251380	Heat pumps other than air conditioning machines of HS 8415	1800	1800
28251390	Other refrigerating or freezing equipment	4200	
28253010	Parts for air conditioning machines (including condensers, absorbers, evaporators and generators)	2721	2721
28253050	Parts for non-domestic refrigerating equipment (including evaporators and condensers)	382	382
	TOTAL	31478	12453
	of which Parts manufacture		*3103*
	of which Products/Systems manufacture		*9350*

* Equivalent value for air conditioning units. For 28251220 around 25% was taken into account as 'non-domestic'; for 28251333 to - 1360, installation and repair effort is set at 30% as compared to air conditioning (based on the proportion in parts manufacture); for 'fan' categories (28252..) at 50%.

Figure 51. ProdCom figures on air conditioning and ventilation (excluding trade)



5. Ventilation Units ≤ 125W

ProdCom category 27511530 covers '*Table, floor, wall, window, ceiling or roof fans, with a self-contained electric motor of an output <= 125 W*'. The corresponding ComExt CN8 codes are 84145100 and 84145190, valid for different year ranges.

The Eurostat production statistics per EU Member State are given in Table 68 (production volume in 000 units) and Table 69 (value of production in M euros) for the available period 1995-2017.

Germany and the United Kingdom are the major producers, followed by Italy and Poland (but note that for e.g. Spain no recent data are being reported). The major value of production is also found in Germany and United Kingdom, while e.g. the value for Poland is low considering the quantity produced.

In 2017, around 13 mln units are produced in EU28 for a total value of 0.4 bn euros. This implies an average unit price around 32 euros, but variation is from € 8 /unit in Poland to € 136 /unit in Finland.

Table 68. EU28 Production Volume of Fans ≤ 125W, in units x 1000 *(Source: Eurostat 2019, ProdCom code 27511530).*

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France									0	0	0	0	0	0									
Netherlands									92			0				0					58		
Germany	794	695									3859			4060	4482	4593	4192	3379	3663	3809	3811	3574	3744
Italy				1350		1716	1928	2062	2339	2338	2192	2542	2983	2847	1909	3066	2310	1438	1306	1430	1413	1396	1779
Un. Kingdom	906	1050	1255	2996	2619	3074	3014	2848	3896	3790	2882	3211	4816	2471	2436	2157	2524	2725	2990	3344	3418	3616	3649
Ireland	0	0																					
Denmark	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	5	0	0	0	0	0	4	1
Greece										0	0	0	0	0	0	0	0	0	0	0			
Portugal	0						18	23	26	25	24	24	27	24	24	38	32	19	9	59		41	
Spain	983	1231	1320				1470	1484	1671	1641	1923	2020											
Belgium		0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0		0	0
Luxemburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	547	128	185	176	168	171	168	182					244										
Finland				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	22
Austria																							
Malta									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Latvia							0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0
Lithuania						0	0		0		0	0	0	0	43	130	123	83	0	0	0	0	0
Poland								637	1059	1423							452	1026	849	889	919	932	1541
Czech Rep.												0	0						0	0			
Slovakia									44		0	0	0	0	0	0	0	0	0	0	0	0	0
Hungary								0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Romania																							
Bulgaria							0	0	0		0	0											
Slovenia															0	0	0	0	0	0	0	0	0
Croatia							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 TOTAL									**12000**	**15000**	**12732**	**14288**	**16463**	**12269**	**11009**	**12729**	**11559**	**10306**	**10529**	**11482**	**11332**	**11958**	**13436**

Table 69. EU28 Production Value of Fans ≤ 125W, in M euros *(Source: Eurostat 2019, ProdCom code 27511530).*

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	10								0	0	0	0	0	0									
Netherlands												0				0					14		
Germany	65	67	169	168	159	198	175	151	140	130	116	134	130	124	104	127	130	115	122	125	129	130	134
Italy				38	38	39	46	48	46	52	47	63	76	73	52	86	65	41	38	42	40	37	49
Un. Kingdom	61	69	82	102	93	105	101	95	97	105	96	102	107	98	88	83	100	114	130	145	159	125	134
Ireland					2	2									3	5	6						6
Denmark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greece										0	0	0	0	0	0	0	0	0	0	0			
Portugal	0						4	5	6	5	6	6	7	6	6	9	8	5	2	7		4	
Spain	10	12	11				19	20	18	20	20	20											
Belgium		0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0		0	0
Luxemburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	0	0	0	12	12	13	13	14					22										
Finland				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Austria																							
Malta									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Latvia							0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0
Lithuania									0		0	0	0	0	0	1	2	1	0	0	0	0	0
Poland								4	7	8				3	2	2	3	10	10	9	8	10	12
Czech Rep.												0	0						0	0			
Slovakia									1		0	0	0	0	0	0	0	0	0	0	0	0	
Hungary								0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Romania																							
Bulgaria							0	0	0		0	0											
Slovenia															0	0	0	0	0	0	0	0	0
Croatia							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 TOTAL									**340**	**351**	**322**	**369**	**393**	**358**	**296**	**361**	**372**	**338**	**359**	**388**	**404**	**392**	**426**

Country data for import and export have been taken from ProdCom for code 27511530. These data include intra-EU28 trade. EU28 totals for Extra-EU trade have been taken from ComExt for CN8 categories 84145100 and 84145190. These totals do not include intra-EU28 trade and consequently are not the sum of the country-data. Import and Export data (quantity in thousands of units and value in millions of euros) are shown in Table 70 Table 70 thru Table 73.

In 2017, the total exports from EU28 towards extra-EU28 countries were 2.8 mln units with a value of 86 mln euros, implying an average € 31 /unit.

In 2017, the total imports to EU28 from extra-EU28 countries were 37 mln units with a value of 341 mln euros, implying an average € 9 /unit.

Table 70. EU28 Export quantity of Fans ≤ 125W, in 000 units *(Source: Eurostat 2019, ProdCom code 27511530 and ComExt CN8 codes 84145100 and 84145190).*

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France			305	380	362	440	563	583	715	849	1049	429	449	178	175	229	251	153	164	142	140	160	202
Netherlands			817	445	325	378	533	552	1224	2063	1500	1749	1668	485	467	737	988	923	916	1343	1498	2009	2603
Germany			3093	3407	4196	2612	1284	1324	1498	2196	2593	2040	1757	1614	1040	1119	1629	1482	1591	1630	1506	2067	2167
Italy			1086	1091	864	1182	1388	1669	2073	2517	2580	2510	2213	2184	1329	1001	955	1172	960	920	998	1009	1365
Un. Kingdom			433	367	370	693	562	694	883	575	591	728	697	518	653	747	430	391	515	405	811	1576	1180
Ireland			5	5	9	5	13	13	3	7	11	3	6	1	3	1	1	3	3	4	5	11	23
Denmark			57	35	20	19	16	22	49	41	77	132	47	61	33	57	35	42	28	37	104	46	103
Greece			14	21	15	55	97	102	78	122	108	81	113	50	24	30	51	84	114	123	257	244	403
Portugal			12	12	6	5	10	20	42	73	104	204	20	8	11	9	70	39	24	29	56	104	94
Spain			1139	1553	1713	2192	2027	1866	1946	2369	2253	2466	2658	2085	1512	2905	2065	1719	2038	2270	2306	2041	2231
Belgium			415	356	593	372	279	369	800	2046	1792	1095	1543	452	331	605	902	511	590	780	931	1291	1524
Luxemburg					1	1	1	1	1	1	5	3	9	46	5	9	12	12	11	47	21	45	35
Sweden			143	158	115	112	125	122	166	172	138	154	127	126	142	144	251	244	174	176	210	194	184
Finland			32	31	23	20	36	38	30	40	14	17	17	17	15	33	22	24	24	31	47	47	46
Austria			38	65	87	93	53	93	109	98	131	199	398	330	205	405	345	234	317	257	286	227	207
Malta									0	0	0	0	0	0	0	0	0	1	26	8	1	1	1
Estonia						1	1	1	0	1	3	2	3	8	12	11	13	8	12	15	7	6	1
Latvia							0	1	1	10	8	6	23	47	160	310	333	379	347	353	337	363	344
Lithuania						1	2	3	5	7	5	12	6	4	8	24	28	59	135	143	36	42	46
Poland								521	644	736	1073	1145	1551	1056	793	850	923	1531	1297	1338	1155	982	1145
Czech Rep.							48	45	48	64	107	131	185	254	115	128	242	158	226	351	354	576	567
Slovakia					15	15	17	18	108	36	3	21	11	257	204	209	380	193	445	782	292	431	444
Hungary									65	23	0	17	31	46	43	51	120	40	72	33	25	49	60
Romania						0	0	4	0	5	0	0	32	27	241	354	274	340	378	164	55	21	33
Bulgaria							2	9	21	41	0	0	15	17	8	24	55	26	21	19	21	35	53
Slovenia							55	52	69	81	78	125	194	210	142	131	120	110	157	132	129	167	334
Croatia									0	15	0	0	1	9	4	5	0	1	7	10	11	26	31
Cyprus									0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
EU28 TOTAL						1914	1643	1785	2150	2439	2749	2907	2876	2754	2196	3822	2654	3063	2989	2989	2751	2695	2808

Table 71. EU28 Export value of Fans ≤ 125W, in M euros *(Source: Eurostat 2019, ProdCom code 27511530 and ComExt CN8 codes 84145100 and 84145190).*

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	9	10	9	12	11	13	15	17	18	18	21	15	9	9	8	11	10	9	8	8	11	11	12
Netherlands	11	12	13	9	7	12	10	18	21	29	20	17	21	14	15	15	14	13	15	19	31	40	49
Germany	46	50	53	59	70	56	41	38	38	44	52	51	48	49	40	44	59	61	64	66	70	83	93
Italy	29	33	25	25	24	25	31	35	39	47	45	40	39	39	29	27	28	21	25	23	26	21	32
Un. Kingdom	14	13	17	15	20	23	20	17	17	20	21	20	19	15	14	14	18	24	19	20	27	20	21
Ireland	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	1	1
Denmark	2	3	3	3	3	4	3	2	3	2	3	2	2	2	2	3	2	4	1	2	2	1	1
Greece	0	1	1	2	1	3	3	3	3	4	4	3	4	3	2	3	3	4	4	4	4	4	2
Portugal	0	0	0	0	0	0	1	0	1	1	3	3	0	0	0	0	3	3	1	1	1	2	2
Spain	19	24	23	29	31	39	42	36	39	47	51	54	58	51	39	43	51	46	53	55	63	56	62
Belgium	6	12	5	6	9	5	4	5	9	23	19	10	16	7	5	7	13	12	14	16	18	23	26
Luxemburg					0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	1	1
Sweden	9	7	6	6	5	6	6	6	7	7	8	5	4	6	6	6	8	7	6	5	6	6	6
Finland	1	1	1	2	1	1	1	1	1	1	2	1	1	1	1	2	2	2	2	2	2	2	2
Austria	3	3	2	2	3	3	2	2	2	4	3	4	6	4	4	6	7	6	7	7	8	8	7
Malta									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Latvia							0	0	0	0	0	0	0	1	1	2	2	3	3	4	4	5	5
Lithuania						0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	1	1	1
Poland								3	4	5	6	7	9	7	5	6	5	10	10	10	8	8	10
Czech Rep.							1	1	1	2	2	2	3	5	3	3	4	4	4	7	8	9	9
Slovakia					0	0	0	0	1	0	0	0	1	2	1	5	4	3	1	2	2	2	3
Hungary									0	0	0	0	0	1	0	1	2	1	1	1	0	1	1
Romania						0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0
Bulgaria							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Slovenia							1	1	1	2	2	3	3	4	3	3	2	2	2	2	3	3	4
Croatia									0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cyprus									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EU28 TOTAL						63	55	59	54	61	65	73	67	75	64	73	86	91	85	84	92	80	86

Table 72. EU28 Import quantity of Fans ≤ 125W, in 000 units *(Source: Eurostat 2019, ProdCom code 27511530 and ComExt CN8 codes 84145100 and 84145190).*

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France			2806	2250	2063	2092	2084	2336	3186	7864	6033	4585	5568	2567	1678	3038	3944	2386	2692	3809	3363	4683	5783
Netherlands			1871	1211	1289	1198	1663	5147	5513	3232	2558	2301	2221	1135	998	1253	2038	1888	1435	2215	2500	3220	3917
Germany			4402	3046	2768	2928	3368	2996	6208	10816	5008	3521	4881	3449	1756	1743	3767	2666	2592	3471	3302	5366	5334
Italy			1557	954	3141	3045	2138	2164	3485	6417	3649	3555	3606	2457	2716	2743	3773	2849	3293	3586	1366	4166	8350
Un. Kingdom			4298	5214	3063	4019	2748	4859	5567	7737	8434	7499	9982	3007	1538	3353	2634	2228	2635	3931	4881	5329	6499
Ireland			139	287	325	291	337	194	208	257	176	173	204	128	75	88	77	90	154	208	272	298	316
Denmark			405	453	224	280	216	308	288	391	351	315	446	362	267	266	347	284	239	273	330	414	417
Greece			392	479	814	844	714	644	881	835	616	507	830	1342	1045	400	628	749	895	440	503	845	1228
Portugal			347	347	346	382	372	318	234	649	1002	512	628	428	337	441	553	277	329	517	364	447	684
Spain			1642	1958	1695	2613	2114	2405	2272	4727	5001	3615	5310	3509	2154	3211	4127	2130	2404	2740	2595	4896	5607
Belgium			1039	833	1163	1272	1092	1066	1531	2978	2719	1949	2423	1132	875	1174	1605	1009	1097	1274	1520	1844	2273
Luxemburg					18	24	25	36	27	55	55	38	51	27	22	34	39	38	40	40	134	46	75
Sweden			476	632	459	506	360	368	580	888	671	560	686	620	416	604	824	735	380	534	767	757	683
Finland			165	167	137	182	164	220	278	365	311	240	256	216	97	156	536	637	261	203	365	185	200
Austria			253	229	276	282	386	439	475	948	461	350	687	782	325	489	653	617	652	692	577	683	561
Malta									68	97	75	69	61	47	75	62	50	85	127	86	49	93	81
Estonia						21	23	20	29	43	55	41	138	173	30	46	58	51	22	40	89	28	35
Latvia							36	50	72	121	127	151	203	173	178	212	273	389	279	407	257	237	237
Lithuania						34	34	50	70	77	84	106	171	135	51	66	130	166	158	232	171	159	137
Poland								822	905	953	715	862	1612	1289	414	628	1584	1156	1073	1500	1287	1872	2216
Czech Rep.							293	352	557	824	537	596	761	928	363	279	514	408	530	784	791	1350	926
Slovakia					88	93	155	201	455	614	295	143	222	411	305	409	650	455	761	1097	498	1045	1199
Hungary									1084	396	368	302	556	624	376	371	593	354	401	454	269	544	834
Romania						0	0	83	0	124	1	0	687	831	432	545	1206	626	744	473	280	457	552
Bulgaria							97	144	206	151	211	178	321	518	194	124	197	223	258	230	148	258	336
Slovenia							69	69	101	142	82	140	211	252	156	107	118	128	185	176	126	230	344
Croatia									232	204	117	145	171	254	92	73	29	147	170	149	90	198	234
Cyprus									95	89	110	85	84	179	118	71	133	101	121	101	100	140	154
EU28 TOTAL						**13721**	**11921**	**17731**	**25832**	**40282**	**28837**	**24347**	**32727**	**18311**	**11279**	**15274**	**22054**	**16664**	**17047**	**21955**	**19129**	**30117**	**37374**

Table 73. EU28 Import value of Fans ≤ 125W, in M euros *(Source: Eurostat 2019, ProdCom code 27511530 and ComExt CN8 codes 84145100 and 84145190).*

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
France	38	54	37	28	27	29	28	31	34	74	64	49	59	30	24	39	51	40	44	55	57	74	85
Netherlands	30	44	32	20	24	24	25	43	45	48	40	39	43	38	35	39	31	20	20	28	42	48	53
Germany	71	106	41	26	27	28	30	28	35	52	37	36	48	41	26	30	49	44	40	51	60	88	82
Italy	33	44	20	14	35	33	28	24	33	51	34	29	32	22	25	28	35	29	32	36	20	44	56
Un. Kingdom	32	53	45	54	36	45	39	43	38	48	47	53	74	25	16	30	29	28	34	42	59	53	60
Ireland	2	3	3	5	5	6	7	5	5	4	2	3	4	4	2	4	3	3	4	5	7	7	10
Denmark	5	6	6	8	6	6	5	7	5	6	6	4	6	6	6	7	9	11	6	7	6	7	7
Greece	5	7	6	6	9	9	8	5	7	7	6	5	9	13	10	5	6	8	10	5	5	8	12
Portugal	4	6	5	5	6	6	5	5	4	8	11	7	9	6	5	6	8	4	5	6	5	6	9
Spain	18	27	18	15	22	36	30	28	23	43	46	33	38	23	22	32	42	27	28	30	38	65	72
Belgium	18	25	13	17	20	21	18	17	16	26	26	19	24	16	12	15	20	17	24	24	29	32	38
Luxemburg					1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	3
Sweden	9	10	9	11	9	10	6	6	7	8	7	8	8	9	7	10	11	10	6	8	12	11	10
Finland	2	4	3	3	3	3	3	4	5	5	5	4	5	5	4	6	8	15	10	6	8	6	7
Austria	11	13	7	7	8	8	8	7	10	11	9	8	10	10	6	8	10	10	11	13	13	15	12
Malta									1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Estonia						0	0	0	0	1	2	1	1	2	0	1	1	1	0	1	1	1	1
Latvia							1	1	1	1	1	2	2	2	1	1	2	4	3	6	3	3	3
Lithuania						0	1	1	1	1	1	1	2	2	1	1	2	2	2	3	2	2	2
Poland								5	7	10	9	9	13	13	7	9	15	14	14	17	18	23	25
Czech Rep.							5	6	7	10	7	7	9	10	6	6	8	7	8	13	14	20	15
Slovakia					1	1	2	2	3	3	2	3	4	5	3	9	8	6	7	8	10	13	9
Hungary									6	4	4	4	6	6	4	3	5	3	5	5	3	6	8
Romania						1	1	1	1	1	2	3	6	7	3	2	3	4	4	3	3	4	6
Bulgaria							1	1	1	1	2	2	3	3	2	1	2	2	2	2	1	2	3
Slovenia							1	1	1	2	1	1	2	2	2	1	1	1	2	2	2	3	4
Croatia									2	2	2	1	2	3	1	1	2	2	2	2	1	2	3
Cyprus									1	1	2	1	2	3	2	1	2	2	2	2	2	2	3
EU28 TOTAL						**135**	**129**	**143**	**159**	**261**	**206**	**182**	**254**	**143**	**101**	**140**	**196**	**163**	**162**	**204**	**227**	**320**	**341**

The combined results of EU28 production and extra-EU28 imports and exports in the period 2000-2017 are given in Table 74 and

Table 75, also providing a calculation of the apparent consumption (production + imports - exports), with quantity expressed in thousands of units and value in millions of euros. As unit values for production, import and export may be different, and products not directly comparable, the results for the apparent consumption are indicative only and should be used with care.

As regards quantities of fans ≤ 125 W, imports into EU28 are dominant and generally much higher than the EU28 production. The imports show a dip in crisis years 2008 and 2009 and only recently the imported quantities are back to the 2007 level. Produced and exported quantities remain more or less on the same level. Exports are low. As regards value, the value of production exceeds the value of imports. Imported products have a much lower unit value and must on average be smaller and less complex.

In 2017, the apparent 'consumption' of fans ≤ 125W in EU28 is around 48 mln units, which is less than half of the 106 mln fans > 125 W reported at Annex I.3. The 48 mln result from a production in EU28 of 13 mln units and an import-export balance with extra-EU28 countries of 35 mln units. The corresponding value of the 48 mln units is 680 mln euros, consisting of a value of production of 420 mln euros and an import-export balance with extra-EU28 countries of 260 mln euros.

Table 74. EU28 Quantity summary in 000 units for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Fans ≤ 125W. Value of apparent consumption (production + import – export) computed by VHK *(Source: Eurostat 2019, ProdCom code 27511530 and ComExt CN8 codes 84145100 and 84145190).*

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28	4961	6597	7235	12000	15000	12732	14288	16463	12269	11009	12729	11559	10306	10529	11482	11332	11958	13436
Import from Extra-EU28	13721	11921	17731	25832	40282	28837	24347	32727	18311	11279	15274	22054	16664	17047	21955	19129	30117	37374
Export to Extra-EU28	1914	1643	1785	2150	2439	2749	2907	2876	2754	2196	3822	2654	3063	2989	2989	2751	2695	2808
Apparent consumption	**16768**	**16875**	**23181**	**35682**	**52843**	**38820**	**35728**	**46314**	**27826**	**20092**	**24181**	**30959**	**23907**	**24587**	**30448**	**27710**	**39380**	**48002**

Figure 52. EU28 Quantity summary in 000 units for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Fans ≤ 125W. Value of apparent consumption (production + import – export) computed by VHK *(Source: Eurostat 2019, ProdCom code 27511530 and ComExt CN8 codes 84145100 and 84145190).*

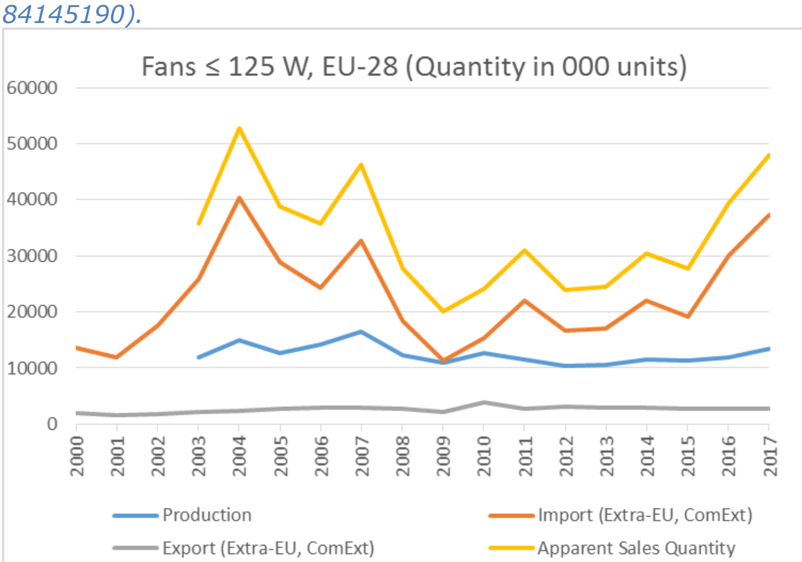
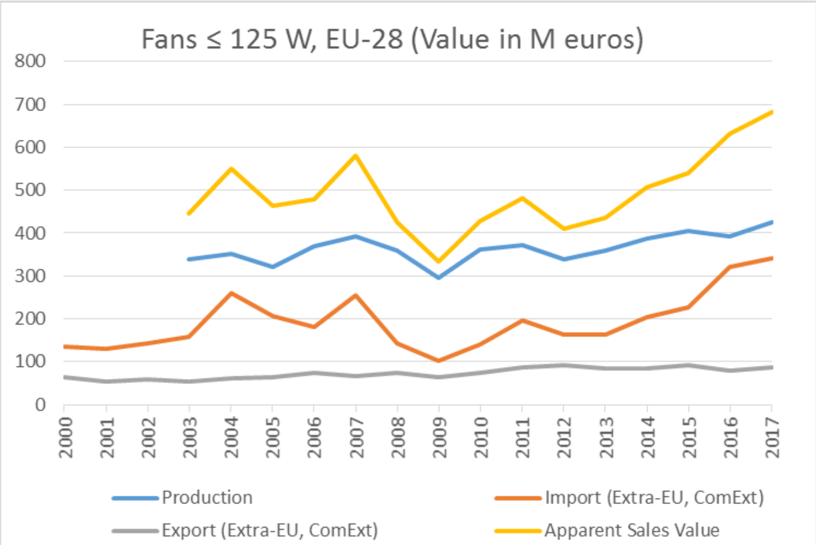


Table 75. EU28 Value summary in M euros for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Fans ≤ 125W. Value of apparent consumption (production + import – export) computed by VHK *(Source: Eurostat 2019, ProdCom code 27511530 and ComExt CN8 codes 84145100 and 84145190).*

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in EU28	358	357	336	340	351	322	369	393	358	296	361	372	338	359	388	404	392	426
Import from Extra-EU28	135	129	143	159	261	206	182	254	143	101	140	196	163	162	204	227	320	341
Export to Extra-EU28	63	55	59	54	61	65	73	67	75	64	73	86	91	85	84	92	80	86
Apparent consumption	**430**	**431**	**420**	**445**	**551**	**463**	**478**	**580**	**426**	**333**	**428**	**482**	**410**	**436**	**508**	**539**	**632**	**681**

Figure 53. EU28 Value summary in M euros for Production, Extra-EU28 Imports, and Extra-EU28 Exports of Fans ≤ 125W. Value of apparent consumption (production + import – export) computed by VHK *(Source: Eurostat 2019, ProdCom code 27511530 and ComExt CN8 codes 84145100 and 84145190).*



Annex II: Reference data for Sales and Stock of VUs

1. Uniclima data for France

Sources:

UNICLIMA comments of July 1990 on EU 1253 and 1254/2014 Review following the 1st stakeholder meeting of 29 May 2019

https://www.uniclima.fr/chiffres-marches.html

In the annual reports on the website, UniClima declares a '*representativité sur le marché*' of 80%. Not clear if this means that total sales in France are around 20% higher than reported. In addition not completely clear if these are the total sales by Uniclima members, or only the part sold in France (could be that a share of the reported VUs is exported?).

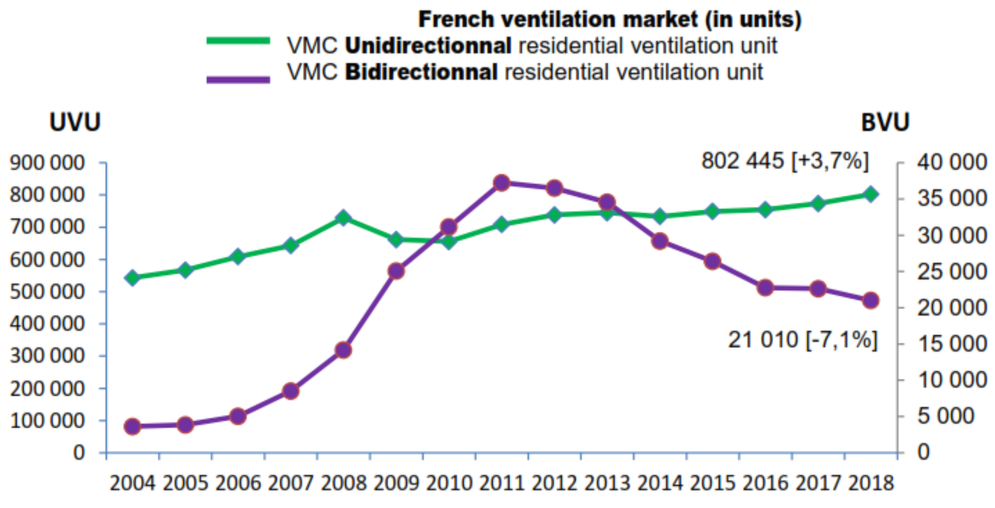
Table 76 Market for Ventilation Units for individual dwellings in France

(source: Uniclima)

- **Individual Dwelling**

Type of ventilation	**Year 2018 (in units)**	**Evolution 2018/2017**
VMC Unidirectionnal exhaust RVU :	**802 445**	**+ 3,7%**
Self regulating		**+ 1,1%**
Humidity controled		**+ 8,9 %**
VMC ***Balanced Ventilation Unit with Heat Recovery***	**21 010**	**- 7,1 %**
Total Unidirectionnal exhaust RVU's and Bidirectionnal RVU's	**823 455**	**+ 1,7%**
Small local fans and decentralized BVU – Flow rate < 400 m3/h*	**439 493**	**+ 2,2%**

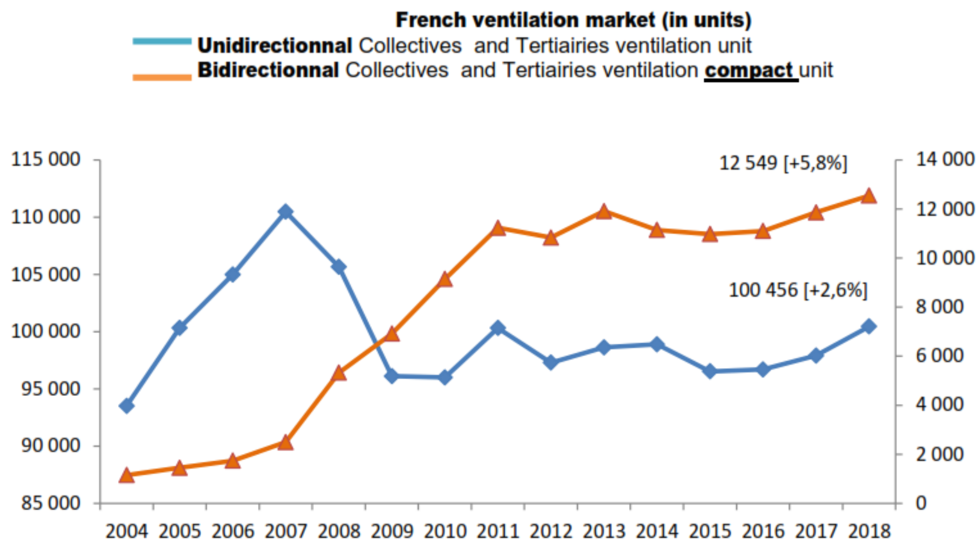
(Source Uniclima)



VMC : Ventilation Mécanique Contrôlée

Table 77 Market for Ventilation Units for collective residential and tertiary sector in France (source: Uniclima)

- **Collective and Tertiary**



(Source Uniclima)

Table 78 Market for tailor-made Air-Handling Units in France (source: PAC&Clim info)

AHU tailor-made	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
< 5000 m3/h with h > 500 mm						892	1,028	1,326	924	756	679
< 5000 m3/h with h < 500 mm						3,034	2,966	3,193	2,792	2,942	2,633
5000 - 15000 m3/h						2,443	2,475	2,554	2,308	2,189	2,065
15000 - 50000 m3/h						957	817	788	708	601	718
> 50000 m3/h						84	125	102	62	101	51
AHU TOTAL	11,487	9,478	8,938	9,564	8,797	7,410	7,411	7,963	6,794	6,589	6,146
o/w with heat recovery									1,846	2,232	2,203

2. FGK-BDH-IKZ data for Germany

Sources:

2019_02_08_OFI_Markt_KWL_vs_Baukonjunktur.pptx, presentation by Oliver Fiedel, Produktmanagement / strategische Projekte Zehnder Group Deutschland GmbH, in cooperation with BDH (Bundesverband der Deutschen Heizungsindustrie) and FGK (Fachverband Gebäude-Klima e.V.)

https://www.ikz.de/nc/detail/news/detail/wohnungslueftung-auf-stand-von-markt-und-normen/, Wohnungslüftung auf Stand von Markt und Normen, Claus Händel, Fachverband Gebäude-Klima e.V., www.fgk.de, IKZ-HAUSTECHNIK 5/2019

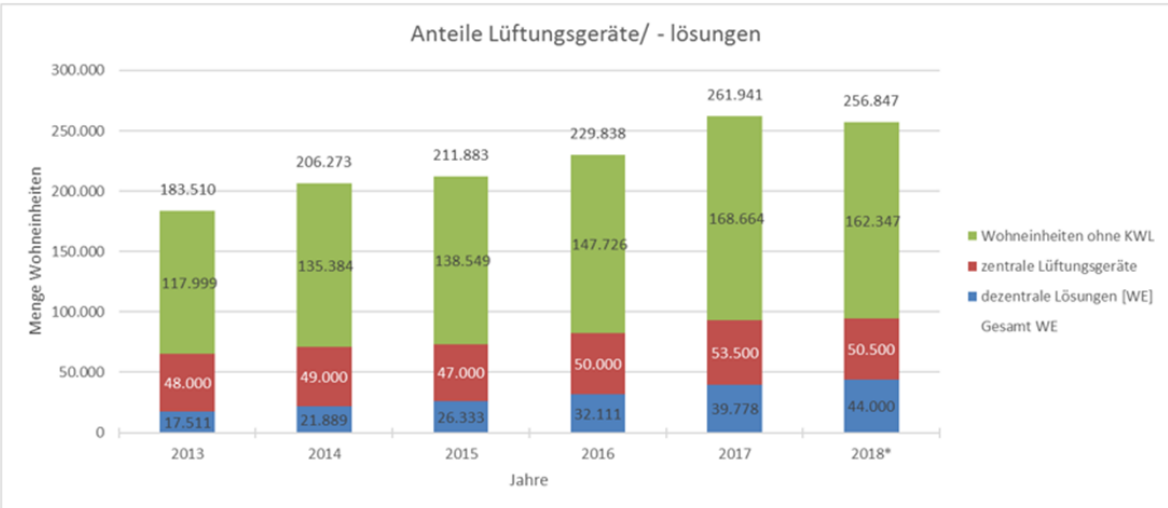
https://www.ikz.de/sanitaertechnik/news/detail/lueftung-nach-neuer-norm/, Autor: Claus Händel, Fachverband Gebäude-Klima e.V. (FGK), Lüftung nach neuer Norm, 27.02.2018

Figure 54, deriving from the first two sources, compares the number of new-built dwellings in Germany in the period 2013-2018 with the number of sold ventilation units with heat recovery, centralized or decentralized. The latter are expressed in number of dwellings using them, counting 4.5 LBVUs per dwelling for the decentralized solution. Comparing with Figure 55 from the third source, the considered VU sales seem to be the total sales, so instead of being implemented in new-built dwellings, a part might be replacement sales (probably small) or sales for renovated dwellings.

The number of 4.5 LBVUs per dwelling on average seems high. It could be that 4.5 supply-only or exhaust-only units are intended, which would then imply 2.25 bidirectional units (pairs) per dwelling. This could not be clarified yet.

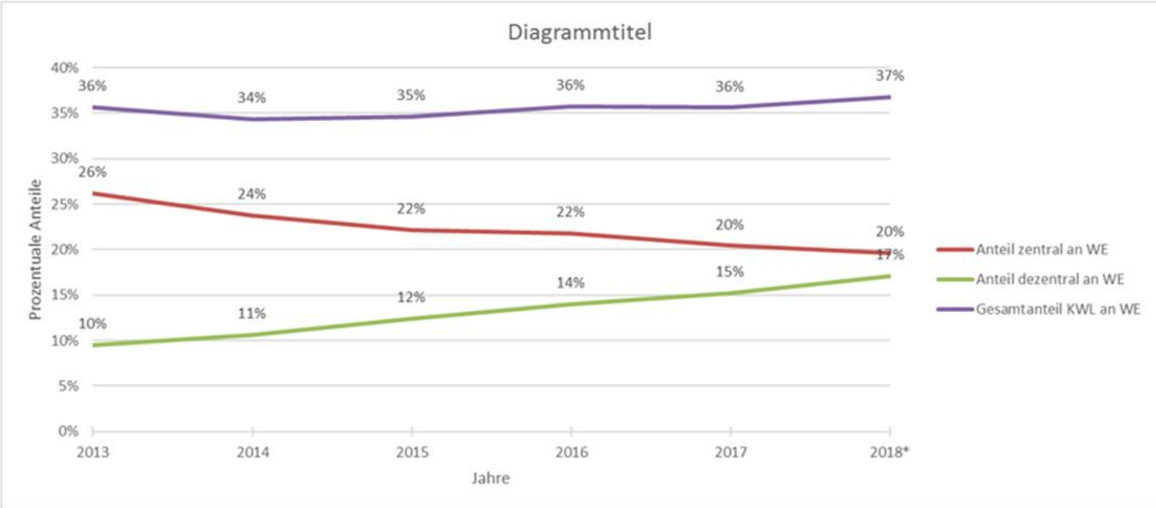
Note that sales data are stated to refer only to Ventilation Units with heat recovery and that these cover 37% oft he new-built dwellings. However, the overall conclusion is that 63% of new-built German dwellings in 2018 does not have a KWL (= Kontrollierten Wohnraumlüftung, i.e. mechanical ventilation). Uncertain how UVUs have been considered in this reasoning.

Figure 54 Market for Balanced Ventilation Units with Heat recovery in Germany compared to number of new-built dwellings (source: IKZ-Haustechnik 5/2019)



- **Die dezentralen Lüftungsgeräte sind mit einem Teiler von 4,5 auf Lösungen pro Wohneinheit umgerechnet.**

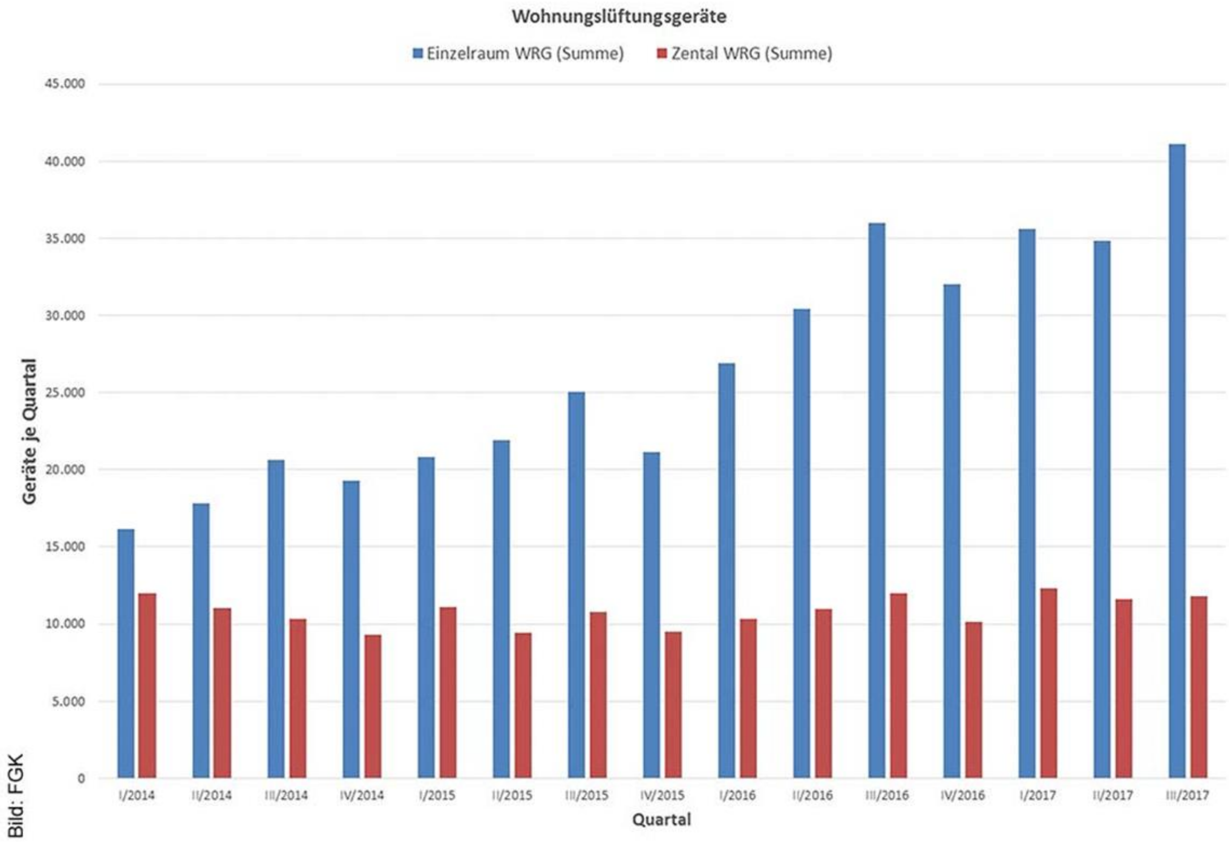
Bild 1: Marktentwicklung für Wohnungen und Wohnungslüftungsgeräte mit Wärmerückgewinnung
(KWL: Kontrollierten Wohnraumlüftung (controlled ventilation of living spaces, i.e. mechanical ventilation))
(WE: Wohneinheiten (dwellings))



- **Nach wie vor werden nur 34 – 37 % aller neugebauten Wohneinheiten mit Lüftung umgesetzt.**
- **Dabei nimmt der Anteil zentralen Lösungen stetig ab und der Anteil dezentraler Lösungen zu.**

Bild 2: Hochrechnung für den Ausstattungsgrad von Neubauten mit Wohnungslüftungsgeräten mit Wärmerückgewinnung

Figure 55 Market for Balanced Ventilation Units with Heat Recovery in Germany, sales per trimester 2014-2017 (Blue: local BVU; red: central BVU; source: FGK-IKZ 2018)



3. Hasselaar for The Netherlands

Source:

Health performance of housing, Indicators and tools, Dissertation by Evert Hasselaar, Delft centre for Sustainable Urban Areas c/o OTB Research Institute for Housing, Urban and Mobility Studies, Delft University of Technology, December 2006

Table 79 Distribution of ventilation systems in the Dutch housing stock per 2006

(Source: Hasselaar)

Dwelling stock NL 2006	6,939,500		
permanently occupied	6,801,000		
	system C	system D	system A
Share of 2006 Stock with system	53%	4%	43%
built before 1945	17%	0%	83%
built 1945-1965	41%	0%	59%
built 1966-1980	55%	1%	44%
built 1981-2006	74%	10%	17%

Of the total building stock of 2006 (around 6.9 million houses) in the Netherlands, 43% has a natural ventilation system, which includes vertical natural exhaust canals to the roof in the kitchen (traditionally separated from the living room), in the bathroom and often also in the toilet, in combination with windows that can be opened.

About 53% is equipped with a **central exhaust fan that extracts air from the kitchen, bathroom and toilet**, in combination with natural inlet through (more modern) grates and windows.

Since 1998, many new houses are equipped with balanced-flow, heat-recovery ventilation systems, and the number amounts to approximately 280,000 houses, which is about 4% of the stock in 2006.

Table 5.1 Distribution of ventilation systems in the Dutch housing stock per 2006 (estimates by author)

Building period	<1945	1945-1965	1966-1980	1981-2006	Total 2006
Social rented sector					
Single family dwellings	A 150,000	A 135,000	A 250,000	A 125,000	
	C 25,000	C 60,000	C 155,000	C 502,000	
			3,000	D 25,000	
Multi family dwellings	A 55,000	A 85,000	A 170,000	A 50,000	
	C 25,000	C 110,000	C 270,000	C 250,000	
			10,000	D 20,000	
Subtotal social rented sector	A 205,000	A 220,000	A 420,000	A 175,000	A 1,020,000
	C 50,000	C 170,000	C 425,000	C 752,000	C 1,397,000
			13,000	D 45,000	D 58,000
Total social rented sector					**2,475,000**
Private rented sector					
Single family dwellings	A 160,000	A 30,000	A 30,000	A 35,000	
	C 35,000	C 18,000	C 40,000	C 130,000	
				D 15,000	
Multi family dwellings	A 100,000	A 25,000	A 20,000	A 25,000	
	C 40,000	C 17,000	C 30,000	C 80,000	
				D 10,000	
Subtotal private rented sector	A 260,000	A 55,000	A 50,000	A 60,000	A 425,000
	C 75,000	C 35,000	C 70,000	C 210,000	C 390,000
				D 25,000	D 25,000
Total private rented sector					**840,000**
Owner-occupied dwelling	A 725,000	A 200,000	A 380,000	A 220,000	A 1,525,000
	C 125,000	C 120,000	C 580,000	C1,050,000	C 1,875,000
			3,000	D 194,000	D 197,000
Total owner occupied					**3,597,000**
Total Dutch housing stock	A1,190,000	A 475,000	A 850,000	A 455,000	A 2,970,000
	C 250,000	C 325,000	C1,075,000	C2,012,000	C 3,662,000
	D 0	D 0	D 16,000	D 264,000	D 280,000
Total number of dwellings					**6,912,200**

type of ventlation system A natural inlet and exhaust
C natural inlet, mechanical exhaust
D balanced flow: mechanical inlet plus exhaust and heat exchange

4. Eurovent data for BVUs with HR and for AHUs

Source: Communication from Eurovent to the study team

Table 80 Sales of Residential Ventilation Units with Heat Recovery in 2017 (Source: Eurovent)

	Market size in units in 2017	Market size in M€ in 2017	Air flow of cubic meters per hour					
			0 - 100 m3/h	101 - 250 m3/h	251 - 500 m3/h	501 - 750 m3/h	751 - 1000 m3/h	TOTAL
EU28	460,859	347,5 M€	33%	29%	34%	3%	1%	100%

Energy classes						
A+	A	B	C	D	E	TOTAL
7%	79%	14%	0.40%	0%	0%	100%

Type of heat recovery					
Crossflow	Counterflow	Rotary	Enthalpy	Ceramic	Total
19%	35%	26%	0.20%	19%	100%

Other details
Units with heat pump / compressor
1%

Table 81 Sales of Air Handling Units in 2017 (Source: Eurovent)

AHU MARKET 2017	Total estimated market 2017 in M€	Total estimated market 2017 in units	Unit market value in € (derived by VHK)
Austria	47.16	5,744	8,209
Belgium	48.65	6,338	7,676
Bulgaria	4.81	497	9,677
Croatia	10.75	759	14,166
Cyprus	2.97	484	6,136
Czech Republic	33.87	6,821	4,966
Denmark	43.49	4,811	9,039
Estonia	10.25	4,225	2,425
Finland	54.18	5,669	9,557
France	149.07	23,556	6,329
Germany	444.50	31,775	13,989
Greece	13.10	1,408	9,306
Hungary	19.67	3,323	5,920
Ireland	31.90	3,405	9,368
Italy	107.63	11,152	9,652
Latvia	8.51	1,207	7,054
Lithuania	18.71	6,353	2,945
Luxembourg	1.45	133	10,896
Malta	1.23	93	13,217
Netherlands	73.86	5,926	12,462
Poland	43.50	9,635	4,515
Portugal	22.09	2,451	9,010
Romania	14.43	1,262	11,440
Slovakia	7.86	1,732	4,537
Slovenia	5.11	726	7,045
Spain	52.58	5,611	9,371
Sweden	168.06	15,596	10,775
United Kingdom	272.65	18,705	14,576
EU28	**1,712.04**	**179,395**	**9,543**
Iceland	3.31	877	
Norway	84.75	8,936	
Switzerland	39.16	5,891	
Turkey	137.50	18,662	
Ukraine	7.30	2,130	

5. Data on Ventilation Units from the Ecodesign Impact Accounting

Source: https://ec.europa.eu/energy/en/studies/ecodesign-impact-accounting-0
For reference and graphs see also par. 2.2.8 of the main text.

Table 82. EU-28 SALES of Ventilation Units from the Ecodesign Impact Accounting (thousands of units)

Thousands	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
NRVU Central Unidir. >125W/fan	169	206	239	263	277	284	291	298	306	313	320	328	335
NRVU Central Balanced >125W/fan	61	106	140	188	257	279	302	328	353	378	404	429	455
Total NRVU	**230**	**312**	**378**	**451**	**534**	**563**	**593**	**626**	**659**	**692**	**724**	**757**	**790**
RVU Central Unidir. ≤125W/fan	1042	1063	2124	2401	2336	2073	1949	2109	2269	2429	2589	2748	2908
RVU Central Balanced ≤125W/fan	37	60	79	148	257	636	816	917	1018	1119	1220	1321	1422
RVU Local Balanced	7	11	21	46	85	186	302	424	546	668	790	912	1035
Total RVU	**1085**	**1133**	**2224**	**2595**	**2677**	**2895**	**3067**	**3450**	**3833**	**4216**	**4599**	**4982**	**5365**
Total VU (res & nonres)	**1315**	**1445**	**2602**	**3047**	**3212**	**3457**	**3660**	**4076**	**4492**	**4908**	**5324**	**5739**	**6155**

Table 83. EU-28 STOCK of Ventilation Units from the Ecodesign Impact Accounting (thousands of units)

Thousands	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
NRVU Central Unidir. >125W/fan	1879	2502	3114	3682	4157	4501	4726	4875	4998	5123	5247	5372	5497
NRVU Central Balanced >125W/fan	233	674	1305	2027	2826	3614	4329	4902	5318	5742	6174	6606	7039
Total NRVU	**2112**	**3176**	**4419**	**5709**	**6983**	**8115**	**9054**	**9777**	**10316**	**10864**	**11421**	**11979**	**12536**
RVU Central Unidir. ≤125W/fan	17148	17501	20975	27298	33878	38186	37438	35790	35435	36991	39653	42373	45093
RVU Central Balanced ≤125W/fan	163	415	767	1279	2140	4245	7492	11019	14191	16265	17999	19716	21433
RVU Local Balanced	33	79	162	325	633	1295	2439	4042	5991	8038	10113	12190	14266
Total RVU	**17344**	**17995**	**21904**	**28902**	**36651**	**43725**	**47368**	**50850**	**55617**	**61294**	**67765**	**74279**	**80792**
Total VU (res & nonres)	**19456**	**21171**	**26323**	**34612**	**43634**	**51841**	**56423**	**60627**	**65933**	**72158**	**79186**	**86257**	**93328**

6. Data on Ventilation Units from Building Heat Demand report

Residential

The 2014 Building Heat Demand report [33] provides data on residential dwellings, their ventilated volume, and the types of ventilation used, for year 2010. See tables below. The number of reported dwellings, 108 mln single family dwellings and 102 mln multi-family dwellings corresponds well with the number of dwellings used in the current study.
Elaborating these data, 69% of the residential dwellings in 2010 used natural ventilation. This percentage is higher in single family dwellings (SFD, 75%) and lower in multi-family dwellings (MFD, 63%). Unidirectional ventilation (exhaust or supply) was used in 29% of the dwellings (23% of SFDs and 35% of MFDs). Only 1.6% of the dwellings used balanced ventilation, of which 75% with heat recovery.

Table 84. EU28-2010 Residential Buildings, numbers and geometry (Source: VHK 2014)

RESIDENTIAL SECTOR, Category	block	dwellings	qv	V	A	S/V	S	A/unit
only primary dwellings taken into account	m units	m units	M m³/h	M m³ @18°C	M m² @18°C		M m² @18°C	m² @18°C
Detached dwellings	34	34	9497	12496	4385	0.85	10622	128

[33] Average EU building heat load for HVAC equipment, Final report, René Kemna, VHK for the European Commission DG ENER C.3, August 2014, https://ec.europa.eu › files › 2014_final_report_eu_building_heat_demand

Semi-detached (2 dwellings/block)	20	39	10181	13395	4700	0.61	8171	128
Terraced houses (block of 15 dwellings)	2.32	35	8282	10898	3824	0.55	5994	128
Single family/duplex dwellings	**56**	**108**	**27960**	**36789**	**12909**	**0.67**	**24787**	
City blocks (130 apartments)	12.8	102	11424	24929	8310	0.28	6980	81
Low-rise detached apartment blocks (25 app.)						0.31		
High-rise apartment blocks (130 apartments)			6419			0.24		
Multi-family dwellings	**12.79**	**102**	**17843**	**24929**	**8310**	**0.28**	**6980**	
TOTAL RESIDENTIAL SECTOR	**68**	**210**	**45803**	**61718**	**21218**	**0.51**	**31767**	**0**

Table 85. EU-28 Total ventilated volume qv in M m3/h for residential dwellings in 2010, per type of ventilation system (Source: VHK 2014)

Description	ventilation qv in M m³/h				
	TOTAL	natural	exhaust or supply	balanced	balanced+ HR
Detached dwellings	9497	7170	2184		142
Semi-detached (2 dwellings/block)	10181	7686	2342		153
Terraced houses (block of 15 dwellings)	8282	6253	1905		124
SINGLE FAMILY/DUPLEX DWELLINGS	**27960**	**21110**	**6431**		**419**
Low-rise multi-family dwellings	11 424	7 400	2 900	100	100
High-rise multi-family dwellings	6 419	2 950	2 850	50	50
MULTIFAMILY DWELLINGS	**16 400**	**10 350**	**5 750**	**150**	**150**
TOTAL RESIDENTIAL	**44360**	**31460**	**12181**	**150**	**569**

Table 86. EU-28 residential dwellings using a certain type of ventilation system in 2010 (Source: VHK elaboration of Table 84 and Table 85)

	Millions of dwellings				
	TOTAL	natural	exhaust or supply	balanced	balanced+ HR
Detached dwellings	34.0	25.7	7.8	0.0	0.5
Semi-detached (2 dwellings/block)	39.0	29.4	9.0	0.0	0.6
Terraced houses (block of 15 dwellings)	35.0	26.4	8.1	0.0	0.5
SINGLE FAMILY/DUPLEX DWELLINGS	**108.0**	**81.5**	**24.8**	**0.0**	**1.6**
Low-rise multi-family dwellings	65.3	46.0	18.0	0.6	0.6
High-rise multi-family dwellings	36.7	18.3	17.7	0.3	0.3
MULTIFAMILY DWELLINGS	**102.0**	**64.4**	**35.8**	**0.9**	**0.9**
TOTAL RESIDENTIAL	**210.0**	**145.9**	**60.6**	**0.9**	**2.6**

Table 87. Share of EU-28 residential dwellings using a certain type of ventilation system in 2010 (Source: VHK elaboration of Table 84 and Table 85)

	Share of dwellings				
	TOTAL	natural	exhaust or supply	balanced	balanced+ HR
Detached dwellings	100%	75%	23%	0%	1.5%
Semi-detached (2 dwellings/block)	100%	75%	23%	0%	1.5%
Terraced houses (block of 15 dwellings)	100%	76%	23%	0%	1.5%
SINGLE FAMILY/DUPLEX DWELLINGS	**100%**	**75%**	**23%**	**0%**	**1.5%**
Low-rise multi-family dwellings	100%	70%	28%	1.0%	1.0%
High-rise multi-family dwellings	100%	50%	48%	0.8%	0.8%
MULTIFAMILY DWELLINGS	**100%**	**63%**	**35%**	**0.9%**	**0.9%**
TOTAL RESIDENTIAL	**100%**	**69%**	**29%**	**0.4%**	**1.2%**

Non-Residential

The 2014 Building Heat Demand report also provides data on ventilation in non-residential buildings (Table 88). The total ventilated volume is close to 54 bn m3/h, of which 54% natural ventilation, 16% unidirectional (exhaust) ventilation, and 32% balanced (22% without heat recovery, 10% with heat recovery).

Table 88. Types of ventilation used in non-residential buildings (source: VHK 2014 Building Heat demand report [33])

Table 23. Ventilation rates EU28 - 2010 (Source: VHK 2014)

NACE 1.1 code	Description	ventilation qv in M m³/h				
		TOTAL	natural	exhaust or supply	balanced	balanced+ HR
A.1	Agriculture (mainly greenhouses)	200	150	33	0	17
D.3	Manufacturing	14400	11 500	2 100	600	200
D.64	Warehouses	4600	3 680	690	161	69
E	Electricity, gas and water supply	288	230	42	12	4
F.45	Construction sector (4 m office, 12.6 m outdoors jobs)	600	240	68	204	87
	TOTAL PRIMARY & SECONDARY SECTOR	**20088**	**15800**	**2934**	**977**	**377**
G.50	Trade and repair motor vehicles	1 267	507	145	431	185
G.51	Wholesale	1 229	492	140	418	179
G.52	Retail	3 517	1 055	468	1 396	599
H.55	Hotels and restaurants	3 354	671	510	1 522	652
I.60-64	Transportation and storage	1015	406	112	345	152
J.65-67	Financial intermediation	947	284	126	374	163
K.70-74	Real estate, renting and business activities	3 562	1 425	406	1 212	519
O.92	Entertainment & news	3053	611	464	1 385	593
O.93.0x	Personal services	700	210	93	278	119
	TOTAL COMMERCIAL BUILDINGS	**18 646**	**5 660**	**2 464**	**7 361**	**3 161**
L.75	Public adminsitration, defence, social security	1656	1 242	79	235	100
N.80	Education	3 960	2 376	2 079	99	198
M.85	Health and social work	5 400	1 620	718	2 143	919
O 90-92	Political, religious, cultural	1547	1 470	78	0	0
O. 92.6/7	Sport	2541	762	338	1 008	432
	TOTAL PUBLIC SECTOR & COMMUNITY BUILDINGS	**15 104**	**7 471**	**3 292**	**3 485**	**1 649**
	TOTAL NON-RESIDENTIAL	**54631**	**28931**	**8689**	**11823**	**5188**
	TOTAL NON-RESIDENTIAL (%)	*100%*	*53%*	*16%*	*22%*	*9%*

7. Lot 6 preparatory study 2012

The 2012 Lot 6 preparatory study [34] in the Task 7 report provides sales and stock for non-residential ventilation units. These data are identical to those in the 2014 Impact Assessment [35] and in the Ecodesign Impact Accounting (par. 2.2.8).

The 2012 study subdivides the Air-handling Units (AHUs) in three maximum flow rate categories:
AHU-L (> 14500 m3/h)
AHU-M (5500-14500 m3/h)
AHU-S (2550-5500 m3/h)

The same study specifies the Central Heat Recovery Ventilation (CHRV) units as having maximum flow rates from 300 to 2250 m3/h.

Table 89. Sales and Stock of Non-Residential Ventilation Units (in millions) from previous studies (source: 2012 preparatory study [34])

Table 7- 6. SALES of Energy-related Product (in mln. units/yr)

Category year-->	1990	1995	2000	2005	2010	2015	2020	2025	2030	2050
CEXH	0.168	0.205	0.237	0.262	0.276	0.282	0.290	0.297	0.304	0.304
CHRV	0.000	0.027	0.043	0.070	0.112	0.124	0.137	0.151	0.166	0.203
AHU-S	0.000	0.009	0.014	0.023	0.038	0.041	0.044	0.047	0.051	0.058
AHU-M	0.029	0.033	0.039	0.045	0.052	0.056	0.060	0.065	0.070	0.081
AHU-L	0.032	0.037	0.043	0.049	0.054	0.057	0.060	0.063	0.066	0.073
TOTAL	**0.229**	**0.311**	**0.376**	**0.449**	**0.532**	**0.560**	**0.590**	**0.623**	**0.658**	**0.646**

Table 7- 7. STOCK of Energy-related Product (in mln. units)

Category year-->	1990	1995	2000	2005	2010	2015	2020	2025	2030	2050
CEXH	2.2	2.4	2.9	3.5	4.3	5.0	5.6	6.1	6.5	7.0
CHRV	0.0	0.2	0.4	0.7	0.9	1.0	1.2	1.3	1.3	1.5
AHU-S	0.0	0.0	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.4
AHU-M	0.3	0.3	0.4	0.5	0.6	0.8	0.9	0.9	1.0	1.1
AHU-L	0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.0	1.1	1.2
TOTAL	**2.8**	**3.3**	**4.4**	**5.5**	**6.7**	**7.9**	**8.8**	**9.6**	**10.2**	**11.0**

In the same 2012 report in Task 2, additional data are presented for the 2008 sales and stock, but these are for the collective residential and non-residential sectors together, and in general the quantities are higher than the final non-residential values presented in Task 7. The Task 2 data (Table 90 below) also include the ventilated volumes and the shares covered by each type of ventilation. In addition a number of LHRV and 'local fans' is reported, that has not been considered in the final Task 7 table, nor in the Impact Assessment or the Ecodesign Impact Accounting.

[34] Sustainable Industrial Policy – Building on the Ecodesign Directive – Energy-Using Product Group Analysis/2 - Lot 6: Air-conditioning and ventilation systems - Final Report Task 7 - Policy- and scenario analysis - Prepared by VHK - 14 June 2012, Main contractor: ARMINES, France, Project leader: Philippe RIVIERE

[35] COMMISSION STAFF WORKING DOCUMENT, IMPACT ASSESSMENT, Accompanying the document 'Commission Regulation implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for ventilation units' and 'Commission Delegated Regulation implementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of ventilation units', {C(2014) 4517 final}, {SWD(2014) 223 final}

Table 90. Sales of Ventilation Units for collective residential and for the tertiary sector in 2008 (source: 2012 preparatory study)

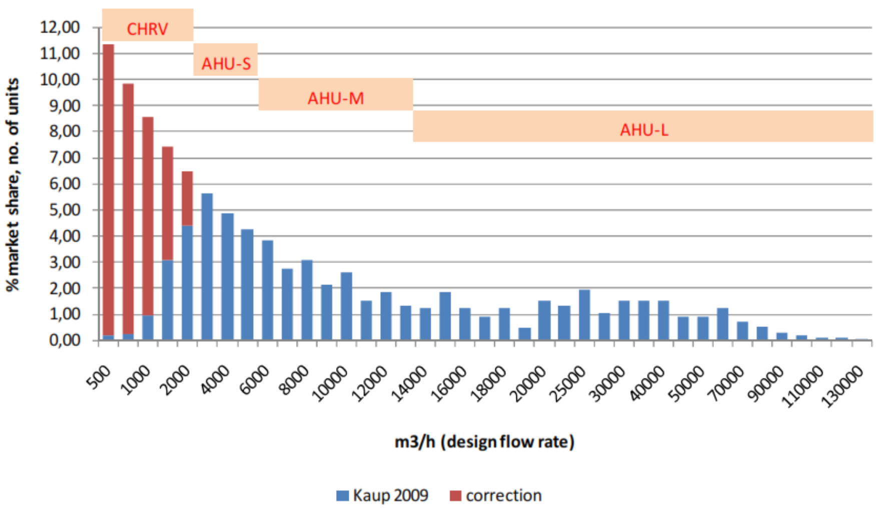
Table 2-11. Ventilation equipment collective residential and non-residential estimated sales and stock 2008 [1] [2]

	SALES 2008										STOCK 2008			2008
	TOTAL SALES				REPLACEMENTS			NEW/1st TIME INST.			TOTAL STOCK			cap.
Ventilation collective residential and non-residential EU-27	units # x 1000	cap 1000 m³/h	total* Mm³/h	%	units # x 1000	total Mm³/h	%	units # x 1000	total Mm³/h	%	units # x1000	total Mm³/h	%	stock m³ %
Mechanical ventilation														
AHU-L(>14500 m³/h)	68	35	2 380	*46%*	34	1 190	*65%*	34	1 190	*35%*	799	27 965	*45%*	*20%*
AHU-M (5500-14500 m³/h)	65	10	650	*13%*	25	250	*14%*	40	400	*12%*	715	7 150	*11%*	*5%*
AHU-S (2550-5500 m³/h)	47	4	188	*4%*	15	60	*3%*	32	128	*4%*	237	948	*2%*	*1%*
CHRV (300-2250 m³/h)	140	2.3	315	*6%*	10	23	*1%*	130	293	*9%*	978	2 201	*4%*	*2%*
Central Exhaust	1 100	1.5	1 650	*32%*	200	300	*16%*	900	1 350	*40%*	16 000	24 000	*39%*	*17%*
LHRV (fans <125W)	30	0.1	3	*0%*	0	0	*0%*	30	3	*0%*	300	30	*0%*	*0%*
local fans (<125 W)	6 000	0.1	600	*12%*	3 000	300	*16%*	3000	300	*9%*	60 000	6 000	*10%*	*n a*
TOTAL MECH. (excl. loc.fans)	*1 450*		**5 186**		*284*	**1 823**		*1 166*	**3 364**		*19 029*	**62 294**		**45%**
Natural ventilation														
						[built 1998]			**[built 2008]**					
Natural (excl local fans)						**2 200**	*55%*		**2 045**			**75 000**		55%
TOTAL ALL						***4.023***			***5.409***			***137.294***		**100%**

[1] VHK on basis of misc. sources (see Annex). Note that the capacity ('cap') refers to the design air flow rate, not to the actual flow rate (see chapter 5 on control factor and misc. factor). For natural ventilation an estimated 'real' air change rate of 1.7 m^3/m^3 was assumed (relating to a ventilated building stock volume of 40 bln. m³). The size distribution for AHUs and CHRV is based partly on Kaup 2009 and partly on a correction that 'mini' and 'compact' units are underrepresented in Kaup's figures (see graph below)

[2] Dedicated buildings are collective residential 16 bln. m³ ventilated volume (37% mechanical ventilation), tertiary sector 29 bln. m³ (60% mech. vent.), industry & agricultural 22 bln. m³ (17% mech. vent); total 67 bln. m³, of which 40% (27 bln. m³) mechanically ventilated and 60% natural or natural with local fans (40 bln.). To this 4.2 mln. establishments with average 500 m³ have to be added (0.645 bln. m³), amongst which high share of bars and restaurants (high hourly air exchange rate of 2.5-4). Small establishments are 3.5 mln. shops/bars/restaurants + 0.8 mln. professional dwellings (doctors, dentists, etc.). Assumed 50% chilled (90% in South, 30% rest EU)

EU-2008 sales size distribution, AHU & CHRV (100%= 320.000 units)



Annex III: Population and Residential Dwellings

1. Population

In 2015 the EU-27 population was 444 million persons. This is projected to increase to 449 mln by 2040. From 2040 onwards, total EU population is projected to slightly decrease.

Table 91. Population (millions of persons)

M persons	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
EU-27	**418**	**424**	**428**	**434**	**441**	**444**	**447**	**448**	**449**	**449**	**449**	**447**	**445**
EU-28 (incl. UK)	**475**	**482**	**487**	**495**	**503**	**509**	**514**	**518**	**521**	**523**	**525**	**524**	**524**
Austria	7.6	7.9	8.0	8.2	8.4	8.6	8.9	9.1	9.4	9.5	9.7	9.8	9.8
Belgium	9.9	10.1	10.2	10.4	10.8	11.2	11.5	11.7	11.9	12.1	12.3	12.4	12.6
Bulgaria	8.8	8.4	8.2	7.7	7.4	7.2	6.9	6.7	6.4	6.2	6.0	5.8	5.6
Croatia	4.8	4.7	4.5	4.3	4.3	4.2	4.1	3.9	3.8	3.7	3.6	3.5	3.4
Cyprus	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.1
Czech Rep.	10.4	10.3	10.3	10.2	10.5	10.5	10.7	10.7	10.7	10.7	10.6	10.6	10.6
Denmark	5.1	5.2	5.3	5.4	5.5	5.7	5.8	6.0	6.2	6.3	6.4	6.4	6.5
Estonia	1.6	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Finland	5.0	5.1	5.2	5.2	5.4	5.5	5.5	5.6	5.6	5.6	5.6	5.5	5.5
France	56.6	57.8	60.5	62.8	64.7	66.5	67.2	68.2	69.1	70.0	70.9	71.3	71.6
Germany	79.1	81.5	82.2	82.5	81.8	81.2	83.2	83.5	83.8	83.7	83.5	83.1	82.7
Greece	10.1	10.5	10.8	11.0	11.1	10.9	10.7	10.5	10.4	10.2	10.0	9.8	9.6
Hungary	10.4	10.3	10.2	10.1	10.0	9.9	9.7	9.6	9.5	9.4	9.3	9.2	9.0
Ireland	3.5	3.6	3.8	4.1	4.5	4.7	4.9	5.1	5.3	5.4	5.6	5.8	5.9
Italy	56.7	56.8	56.9	57.9	59.2	60.8	60.2	59.6	58.9	58.3	57.7	56.8	55.9
Latvia	2.7	2.5	2.4	2.2	2.1	2.0	1.9	1.8	1.7	1.7	1.7	1.6	1.6
Lithuania	3.7	3.6	3.5	3.4	3.1	2.9	2.8	2.6	2.5	2.4	2.3	2.2	2.2
Luxembourg	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9
Malta	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7
Netherlands	14.9	15.4	15.9	16.3	16.6	16.9	17.3	17.6	17.8	17.9	18.0	17.9	17.8
Poland	38.0	38.6	38.3	38.2	38.0	38.0	38.0	37.7	37.4	36.8	36.2	35.5	34.9
Portugal	10.0	10.0	10.2	10.5	10.6	10.4	10.3	10.1	10.0	9.8	9.7	9.4	9.2
Romania	23.2	22.7	22.5	21.4	20.3	19.9	19.3	18.7	18.1	17.7	17.4	17.1	16.7
Slovakia	5.3	5.4	5.4	5.4	5.4	5.4	5.5	5.4	5.4	5.3	5.3	5.2	5.1
Slovenia	2.0	2.0	2.0	2.0	2.0	2.1	2.1	2.1	2.1	2.1	2.1	2.0	2.0
Spain	38.9	39.6	40.5	43.3	46.5	46.4	47.1	47.6	48.1	48.7	49.2	49.6	49.9
Sweden	8.5	8.8	8.9	9.0	9.3	9.7	10.3	10.9	11.5	12.0	12.5	13.0	13.4
United Kingdom	57.2	57.9	58.8	60.2	62.5	64.9	67.1	69.3	71.5	73.4	75.3	76.8	78.3

Notes:

Source up to 2018: Eurostat, Population on 1 January by age and sex [demo_pjan], extracted August 2019
Source after 2018: Eurostat, Population on 1st January by age, sex and type of projection [proj_18np], extracted August 2019
In 1997-1998 data for France switch from 'France (metropolitan)' to 'France' (sudden increase of around 1.5 mln)
Data for Germany include former GDR for all years

2. Household and Household size

In 2015 there were 191 million households in EU-27, on average consisting of 2.33 persons. This is projected to increase to 2013 mln households by 2030 and 202 mln by 2040, with 2.23 persons on average. From 2040 onwards, the number of households is projected to remain stable or decrease.

Table 92. Households (millions)

Millions	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
EU-27	**152**	**159**	**166**	**174**	**182**	**191**	**196**	**200**	**201**	**201**	**202**	**201**	**200**
EU-28 (incl. UK)	**174**	**182**	**190**	**201**	**209**	**219**	**225**	**230**	**233**	**234**	**235**	**235**	**234**
Austria	2.99	3.13	3.28	3.47	3.62	3.82	3.97	4.12	4.23	4.30	4.37	4.41	4.44
Belgium	3.92	4.06	4.20	4.38	4.62	4.70	4.79	4.86	4.94	5.02	5.10	5.15	5.21
Bulgaria	2.75	2.87	2.99	2.87	2.75	2.94	2.89	2.83	2.73	2.64	2.55	2.47	2.39
Croatia	1.41	1.49	1.56	1.57	1.52	1.49	1.46	1.43	1.39	1.36	1.32	1.28	1.24
Cyprus	0.20	0.21	0.22	0.25	0.28	0.30	0.34	0.38	0.40	0.42	0.43	0.44	0.45
Czech Rep.	3.71	3.86	4.03	4.12	4.42	4.64	4.85	4.98	5.03	5.01	4.99	4.98	4.97
Denmark	2.26	2.32	2.39	2.35	2.31	2.37	2.41	2.44	2.49	2.53	2.58	2.60	2.62
Estonia	0.49	0.51	0.54	0.58	0.55	0.57	0.63	0.65	0.66	0.65	0.64	0.64	0.63
Finland	2.00	2.19	2.38	2.40	2.51	2.62	2.71	2.76	2.79	2.78	2.77	2.75	2.72
France	21.77	22.71	23.65	25.86	27.21	28.93	30.26	31.33	31.97	32.39	32.81	32.96	33.12
Germany	34.96	35.96	36.85	38.51	38.61	40.26	41.20	41.76	42.05	41.97	41.90	41.69	41.47
Greece	3.75	3.94	4.12	4.22	4.35	4.38	4.40	4.39	4.34	4.27	4.20	4.12	4.03
Hungary	3.47	3.63	3.79	3.82	4.01	4.15	4.16	4.20	4.18	4.13	4.07	4.02	3.97
Ireland	1.01	1.12	1.24	1.42	1.69	1.73	1.90	1.99	2.06	2.13	2.19	2.25	2.30
Italy	19.72	20.65	21.58	23.17	24.67	25.79	25.99	26.03	25.84	25.57	25.30	24.89	24.49
Latvia	0.78	0.82	0.86	0.81	0.81	0.83	0.87	0.88	0.86	0.83	0.81	0.79	0.78
Lithuania	1.23	1.29	1.35	1.18	1.35	1.33	1.32	1.29	1.22	1.19	1.15	1.12	1.09
Luxembourg	0.14	0.16	0.17	0.18	0.20	0.23	0.26	0.29	0.31	0.34	0.36	0.37	0.39
Malta	0.11	0.12	0.13	0.13	0.14	0.17	0.20	0.24	0.26	0.28	0.29	0.30	0.31
Netherlands	6.09	6.44	6.79	7.07	7.33	7.62	7.95	8.12	8.25	8.29	8.33	8.29	8.25
Poland	11.43	11.96	12.50	12.70	13.28	14.11	14.87	15.26	15.30	15.04	14.79	14.53	14.26
Portugal	3.11	3.30	3.50	3.77	3.94	4.08	4.20	4.27	4.25	4.18	4.11	4.01	3.91
Romania	6.66	6.99	7.30	7.36	7.40	7.47	7.48	7.39	7.19	7.06	6.93	6.80	6.67
Slovakia	1.54	1.62	1.69	1.67	1.75	1.85	1.91	1.95	1.95	1.93	1.90	1.87	1.84
Slovenia	0.65	0.69	0.72	0.75	0.81	0.88	0.91	0.94	0.95	0.94	0.94	0.93	0.92
Spain	11.63	13.03	14.53	15.76	17.65	18.38	18.94	19.53	19.85	20.10	20.34	20.48	20.62
Sweden	3.80	3.93	3.95	4.04	4.46	4.71	5.12	5.53	5.87	6.13	6.39	6.60	6.82
United Kingdom	22.26	23.08	23.90	26.23	27.23	28.27	29.42	30.46	31.45	32.29	33.14	33.79	34.45

Table 93. Number of persons per household

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
EU-27	**2.76**	**2.67**	**2.58**	**2.49**	**2.42**	**2.33**	**2.28**	**2.24**	**2.23**	**2.23**	**2.23**	**2.23**	**2.23**
EU-28 (incl. UK)	**2.73**	**2.65**	**2.56**	**2.47**	**2.40**	**2.30**	**2.28**	**2.25**	**2.24**	**2.24**	**2.24**	**2.24**	**2.23**
Austria	2.56	2.54	2.44	2.36	2.31	2.25	2.24	2.22	2.21	2.21	2.21	2.21	2.21
Belgium	2.54	2.49	2.44	2.38	2.35	2.39	2.40	2.41	2.41	2.41	2.41	2.41	2.41
Bulgaria	3.19	2.94	2.74	2.68	2.70	2.45	2.41	2.36	2.34	2.34	2.34	2.34	2.34
Croatia	3.38	3.13	2.89	2.75	2.83	2.84	2.78	2.76	2.75	2.75	2.75	2.75	2.75
Cyprus	2.87	3.04	3.11	2.93	2.88	2.85	2.59	2.50	2.47	2.47	2.47	2.47	2.47
Czech Rep.	2.79	2.68	2.55	2.47	2.37	2.27	2.20	2.15	2.13	2.13	2.13	2.13	2.13
Denmark	2.27	2.24	2.23	2.30	2.39	2.38	2.43	2.46	2.47	2.47	2.47	2.47	2.47
Estonia	3.22	2.82	2.61	2.36	2.43	2.30	2.11	2.02	1.99	1.99	1.99	1.99	1.99
Finland	2.48	2.33	2.17	2.18	2.13	2.09	2.04	2.01	2.01	2.01	2.01	2.01	2.01
France	2.60	2.54	2.56	2.43	2.38	2.30	2.22	2.18	2.16	2.16	2.16	2.16	2.16
Germany	2.26	2.27	2.23	2.14	2.12	2.02	2.02	2.00	1.99	1.99	1.99	1.99	1.99
Greece	2.70	2.67	2.62	2.60	2.55	2.48	2.43	2.40	2.39	2.39	2.39	2.39	2.39
Hungary	2.99	2.85	2.70	2.65	2.49	2.37	2.34	2.29	2.28	2.28	2.28	2.28	2.28
Ireland	3.47	3.20	3.05	2.90	2.69	2.70	2.60	2.57	2.56	2.56	2.56	2.56	2.56
Italy	2.88	2.75	2.64	2.50	2.40	2.36	2.32	2.29	2.28	2.28	2.28	2.28	2.28
Latvia	3.40	3.04	2.77	2.79	2.62	2.39	2.20	2.08	2.04	2.04	2.04	2.04	2.04
Lithuania	3.00	2.83	2.61	2.84	2.33	2.19	2.09	2.02	2.00	2.00	2.00	2.00	2.00
Luxembourg	2.67	2.60	2.55	2.55	2.45	2.46	2.38	2.37	2.36	2.36	2.36	2.36	2.36
Malta	3.12	3.14	3.10	3.13	3.02	2.55	2.44	2.31	2.27	2.27	2.27	2.27	2.27
Netherlands	2.44	2.40	2.34	2.31	2.26	2.22	2.18	2.16	2.16	2.16	2.16	2.16	2.16
Poland	3.33	3.22	3.06	3.01	2.86	2.69	2.55	2.47	2.45	2.45	2.45	2.45	2.45
Portugal	3.21	3.03	2.93	2.79	2.68	2.54	2.44	2.37	2.35	2.35	2.35	2.35	2.35
Romania	3.48	3.25	3.07	2.91	2.74	2.66	2.58	2.53	2.51	2.51	2.51	2.51	2.51
Slovakia	3.44	3.30	3.19	3.21	3.07	2.94	2.85	2.79	2.77	2.77	2.77	2.77	2.77
Slovenia	3.06	2.90	2.78	2.67	2.54	2.34	2.29	2.21	2.19	2.19	2.19	2.19	2.19
Spain	3.34	3.04	2.78	2.75	2.63	2.53	2.48	2.44	2.42	2.42	2.42	2.42	2.42
Sweden	2.24	2.24	2.24	2.23	2.09	2.07	2.02	1.98	1.96	1.96	1.96	1.96	1.96
United Kingdom	2.57	2.51	2.46	2.29	2.30	2.29	2.28	2.27	2.27	2.27	2.27	2.27	2.27

Notes:

Source for 2005 to 2018: Eurostat, Number of private households by household composition, number of children and age of youngest child (1 000) [lfst_hhnhtych] , extracted August 2019.
Source for 1991 and 2001: Eurostat, Households by size (number of persons) [cens_hndwsize], extracted August 2019.
Some missing data for these years interpolated or extrapolated; some evidently erroneous values corrected
For 1992-2000 and 2002-2004 linear interpolation of number of households.
Presented values for number of persons per household sometimes recomputed by VHK as population / households (Eurostat data not always consistent).
Before 1991 continued trend in number of persons per household and computed households as population / number of persons per household.
For 2019-2030 continued 2009-2018 trend in number of persons per household, but gradually flattened it, and computed households as population divided by number of persons per household.
After 2030 kept number of persons per household constant and computed households as population / number of persons per household.

3. Total Number of Dwellings (Residential)

In 2015 there were 223 mln residential dwellings in EU-27. This is interpreted to include around 15% secondary dwellings (holiday homes). Similar to the population and the number of households, the total number of residential dwellings is projected to almost stabilize by 2030 and decrease from 2040.

Table 94. Number of Dwellings (millions)

Millions	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
EU-27	**174**	**182**	**191**	**203**	**215**	**223**	**229**	**234**	**235**	**235**	**235**	**234**	**233**
EU-28 (incl. UK)	**197**	**207**	**216**	**229**	**242**	**251**	**259**	**264**	**267**	**268**	**269**	**269**	**268**
Austria	3.12	3.26	3.42	3.57	3.87	3.96	4.12	4.27	4.39	4.46	4.53	4.57	4.61
Belgium	4.36	4.51	4.67	4.86	5.09	5.33	5.44	5.51	5.60	5.69	5.78	5.85	5.91
Bulgaria	3.17	3.31	3.46	3.72	3.80	4.77	4.68	4.59	4.43	4.29	4.14	4.01	3.88
Croatia	1.49	1.57	1.64	1.65	1.86	1.92	1.88	1.84	1.79	1.75	1.70	1.65	1.59
Cyprus	0.26	0.28	0.29	0.34	0.42	0.47	0.54	0.59	0.63	0.66	0.68	0.70	0.71
Czech Rep.	4.00	4.15	4.34	4.48	4.70	4.81	5.02	5.16	5.21	5.19	5.17	5.16	5.15
Denmark	2.65	2.72	2.79	2.86	2.94	3.00	3.04	3.08	3.15	3.20	3.26	3.28	3.31
Estonia	0.56	0.59	0.62	0.63	0.65	0.68	0.75	0.78	0.78	0.77	0.76	0.75	0.74
Finland	2.11	2.31	2.51	2.67	2.81	2.95	3.04	3.10	3.13	3.12	3.11	3.09	3.06
France	26.69	27.84	29.00	30.69	32.52	34.04	35.61	36.87	37.62	38.12	38.61	38.79	38.97
Germany	36.42	37.45	38.38	39.55	41.22	41.76	42.74	43.32	43.62	43.54	43.46	43.24	43.02
Greece	5.12	5.39	5.63	6.31	6.72	6.92	6.95	6.94	6.86	6.75	6.64	6.51	6.37
Hungary	3.72	3.89	4.06	4.17	4.33	4.46	4.46	4.51	4.49	4.43	4.37	4.32	4.26
Ireland	1.00	1.11	1.22	1.42	1.61	1.72	1.89	1.98	2.06	2.12	2.18	2.24	2.30
Italy	24.67	25.83	26.99	28.98	30.97	31.99	32.24	32.28	32.05	31.72	31.38	30.88	30.38
Latvia	0.86	0.90	0.94	1.00	1.03	1.05	1.10	1.11	1.08	1.05	1.02	1.00	0.98
Lithuania	1.24	1.30	1.36	1.30	1.27	1.31	1.30	1.27	1.21	1.17	1.13	1.10	1.07
Luxembourg	0.14	0.16	0.17	0.18	0.20	0.23	0.26	0.29	0.31	0.33	0.35	0.37	0.39
Malta	0.14	0.15	0.16	0.16	0.18	0.26	0.31	0.36	0.40	0.42	0.44	0.45	0.46
Netherlands	5.94	6.28	6.62	6.89	7.20	7.45	7.77	7.94	8.07	8.11	8.15	8.11	8.07
Poland	10.83	11.34	11.84	12.78	13.47	14.17	14.93	15.32	15.36	15.10	14.85	14.58	14.31
Portugal	4.45	4.73	5.01	5.67	5.85	5.97	6.13	6.24	6.21	6.11	6.00	5.86	5.71
Romania	7.21	7.57	7.91	8.20	8.43	8.84	8.85	8.75	8.51	8.36	8.21	8.05	7.89
Slovakia	1.65	1.73	1.81	1.91	1.96	2.01	2.08	2.12	2.13	2.10	2.07	2.03	2.00
Slovenia	0.70	0.74	0.77	0.81	0.84	0.88	0.91	0.94	0.95	0.95	0.94	0.93	0.93
Spain	16.30	18.28	20.38	23.13	25.74	26.64	27.45	28.30	28.78	29.13	29.48	29.69	29.89
Sweden	4.75	4.91	4.93	4.97	5.03	5.20	5.65	6.11	6.48	6.76	7.05	7.29	7.53
United Kingdom	23.58	24.45	25.32	26.27	27.45	28.55	29.71	30.77	31.77	32.62	33.47	34.13	34.80

Notes:

Source for 2000 to 2014: EU Buildings Observatory, Copyright European Commission 2016 (https://ec.europa.eu/energy/en/eu-buildings-database), extracted August 2019.
At time of extraction, web-tool for database access was not completely functional (as also stated on website); difficulties encountered during extraction.
Data for Austria were missing in extraction and had to be estimated by VHK.
For 2004-2014: some clearly erroneous data corrected and some missing data interpolated / extrapolated
Before 2004 and after 2014, assumed constant number of dwellings per household and computed number of dwellings as households times number of dwellings per household.
Not always clear if the data include secondary or vacant dwellings. For some countries this seems to be the case, for others not. For EU-28 in 2014, the number of dwellings reported above is approximately 1.15 times the number of households. Per country, this ratio varies from slightly less than 1.0 (Lithuania, Luxemburg, Netherlands) to more than 1.4 (Bulgaria, Cyprus, Greece, Malta, Portugal, Spain).

4. Permanently Occupied Dwellings (All, Single Family, Multi-Family)

The number of permanently occupied residential dwellings in 2015 was 187 mln. This is 85% of all residential dwellings, and in good approximation equal to the number of households (0.98 perm. occupied dwellings per household). Around 46% of the dwellings are single family houses (detached-, semi-detached- or terraced houses) and 54% are apartments in multi-family buildings (city-blocks, low-rise or high-rise apartment buildings). Similar to the population and the number of households, the number of permanently occupied residential dwellings is projected to almost stabilize by 2030 and decrease from 2040.

Table 95. Number of Permanently Occupied Dwellings (millions)

Millions	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
EU-27	**147**	**155**	**162**	**172**	**181**	**187**	**193**	**196**	**198**	**198**	**198**	**197**	**196**
EU-28 (incl. UK)	**170**	**178**	**186**	**197**	**207**	**215**	**222**	**226**	**229**	**230**	**231**	**230**	**230**
Austria	2.87	3.00	3.14	3.28	3.56	3.65	3.80	3.94	4.05	4.11	4.18	4.22	4.25
Belgium	3.94	4.08	4.22	4.41	4.62	4.78	4.88	4.94	5.03	5.11	5.19	5.25	5.30
Bulgaria	2.60	2.71	2.84	2.99	3.07	3.38	3.32	3.25	3.14	3.04	2.93	2.84	2.75
Croatia	1.28	1.36	1.42	1.45	1.49	1.48	1.45	1.42	1.39	1.35	1.31	1.27	1.23
Cyprus	0.20	0.21	0.22	0.25	0.33	0.37	0.42	0.46	0.49	0.51	0.53	0.54	0.56
Czech Rep.	3.49	3.63	3.79	3.89	4.08	4.17	4.35	4.47	4.51	4.50	4.48	4.47	4.46
Denmark	2.31	2.37	2.43	2.49	2.56	2.63	2.66	2.70	2.76	2.80	2.85	2.87	2.90
Estonia	0.54	0.57	0.59	0.60	0.63	0.65	0.71	0.74	0.75	0.74	0.73	0.72	0.71
Finland	1.93	2.11	2.30	2.44	2.54	2.89	2.98	3.04	3.07	3.06	3.05	3.03	3.00
France	22.19	23.15	24.11	25.74	27.11	28.20	29.50	30.54	31.17	31.57	31.98	32.13	32.28
Germany	33.50	34.46	35.31	36.39	37.93	38.53	39.43	39.96	40.24	40.17	40.10	39.89	39.69
Greece	3.48	3.66	3.83	4.29	4.57	4.66	4.68	4.67	4.62	4.54	4.47	4.38	4.29
Hungary	3.41	3.57	3.73	3.94	3.88	3.96	3.97	4.01	3.99	3.94	3.89	3.84	3.79
Ireland	1.00	1.11	1.22	1.42	1.61	1.68	1.84	1.93	2.00	2.06	2.13	2.18	2.24
Italy	19.66	20.59	21.51	22.81	24.06	24.86	25.06	25.09	24.91	24.65	24.39	24.00	23.61
Latvia	0.79	0.83	0.86	0.90	0.81	0.81	0.84	0.85	0.83	0.81	0.79	0.77	0.75
Lithuania	1.24	1.30	1.36	1.30	1.27	1.32	1.31	1.28	1.21	1.18	1.14	1.11	1.08
Luxembourg	0.14	0.16	0.17	0.18	0.20	0.23	0.26	0.29	0.31	0.33	0.35	0.37	0.39
Malta	0.11	0.12	0.12	0.13	0.13	0.18	0.21	0.25	0.27	0.29	0.30	0.31	0.32
Netherlands	5.84	6.17	6.51	6.76	7.04	7.27	7.58	7.75	7.87	7.91	7.95	7.91	7.87
Poland	10.83	11.34	11.85	12.78	13.47	14.31	15.08	15.47	15.51	15.26	15.00	14.73	14.46
Portugal	2.96	3.15	3.33	3.97	3.93	4.09	4.20	4.27	4.25	4.18	4.11	4.01	3.91
Romania	6.50	6.82	7.12	7.25	7.45	7.53	7.54	7.45	7.25	7.12	6.99	6.85	6.72
Slovakia	1.51	1.59	1.66	1.70	1.74	1.78	1.84	1.88	1.88	1.86	1.83	1.80	1.77
Slovenia	0.63	0.66	0.69	0.73	0.77	0.80	0.83	0.86	0.86	0.86	0.85	0.85	0.84
Spain	10.43	11.69	13.04	15.33	17.63	18.38	18.94	19.53	19.86	20.10	20.35	20.49	20.63
Sweden	4.04	4.18	4.20	4.26	4.43	4.51	4.91	5.30	5.62	5.87	6.12	6.33	6.54
United Kingdom	22.70	23.54	24.38	25.40	26.56	27.77	28.90	29.92	30.90	31.72	32.55	33.20	33.85

Table 96. Number of Permanently Occupied Single Family Dwellings (millions)

Millions	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
EU-27	**68**	**72**	**75**	**79**	**83**	**85**	**88**	**90**	**91**	**91**	**91**	**91**	**90**
EU-28 (incl. UK)	**87**	**91**	**95**	**100**	**106**	**108**	**112**	**115**	**116**	**117**	**118**	**118**	**118**
Austria	1.38	1.44	1.51	1.58	1.71	1.75	1.83	1.89	1.94	1.97	2.01	2.02	2.04
Belgium	2.96	3.07	3.17	3.28	3.39	3.49	3.56	3.61	3.67	3.73	3.79	3.83	3.87
Bulgaria	1.43	1.49	1.56	1.64	1.69	1.86	1.82	1.79	1.72	1.67	1.61	1.56	1.51
Croatia	0.85	0.90	0.94	0.92	0.99	0.97	0.96	0.94	0.91	0.89	0.87	0.84	0.81
Cyprus	0.12	0.13	0.14	0.16	0.21	0.23	0.27	0.29	0.31	0.33	0.34	0.35	0.35
Czech Rep.	1.50	1.56	1.63	1.70	1.79	1.82	1.90	1.95	1.97	1.97	1.96	1.95	1.95

Denmark	1.37	1.40	1.44	1.48	1.52	1.55	1.57	1.59	1.62	1.65	1.68	1.69	1.71
Estonia	0.13	0.14	0.15	0.15	0.16	0.16	0.18	0.19	0.19	0.19	0.18	0.18	0.18
Finland	1.04	1.14	1.24	1.32	1.38	1.57	1.62	1.65	1.66	1.66	1.65	1.64	1.63
France	12.47	13.01	13.55	14.50	15.35	16.00	16.73	17.33	17.68	17.91	18.14	18.23	18.31
Germany	15.56	16.00	16.40	17.23	17.74	17.41	17.81	18.05	18.18	18.15	18.11	18.02	17.93
Greece	1.57	1.65	1.73	1.76	1.68	1.67	1.67	1.67	1.65	1.63	1.60	1.57	1.53
Hungary	2.12	2.22	2.31	2.42	2.39	2.44	2.44	2.47	2.45	2.42	2.39	2.36	2.33
Ireland	0.90	1.00	1.11	1.25	1.41	1.46	1.61	1.68	1.75	1.80	1.85	1.90	1.95
Italy	4.49	4.71	4.92	5.56	6.40	6.47	6.52	6.53	6.49	6.42	6.35	6.25	6.15
Latvia	0.36	0.38	0.40	0.42	0.38	0.37	0.39	0.39	0.38	0.37	0.36	0.36	0.35
Lithuania	0.68	0.71	0.74	0.71	0.70	0.72	0.72	0.70	0.67	0.65	0.63	0.61	0.59
Luxembourg	0.08	0.09	0.09	0.10	0.11	0.12	0.14	0.16	0.17	0.18	0.19	0.20	0.21
Malta	0.08	0.08	0.09	0.09	0.10	0.12	0.14	0.16	0.18	0.19	0.20	0.20	0.21
Netherlands	4.16	4.40	4.63	4.82	5.02	5.16	5.39	5.50	5.59	5.62	5.64	5.62	5.59
Poland	3.55	3.72	3.88	4.18	4.45	4.73	4.98	5.11	5.13	5.04	4.96	4.87	4.78
Portugal	1.75	1.86	1.97	2.35	2.30	2.41	2.48	2.52	2.51	2.47	2.43	2.37	2.31
Romania	3.70	3.88	4.05	4.12	4.24	4.28	4.28	4.23	4.12	4.04	3.97	3.89	3.82
Slovakia	0.74	0.78	0.82	0.83	0.86	0.87	0.91	0.92	0.93	0.91	0.90	0.88	0.87
Slovenia	0.39	0.40	0.42	0.44	0.46	0.49	0.50	0.52	0.53	0.52	0.52	0.52	0.51
Spain	3.26	3.66	4.08	4.64	5.15	5.37	5.53	5.71	5.80	5.87	5.94	5.99	6.03
Sweden	1.71	1.77	1.78	1.78	1.93	1.99	2.17	2.34	2.48	2.59	2.70	2.79	2.89
United Kingdom	18.45	19.13	19.81	20.29	22.18	22.87	23.80	24.64	25.44	26.12	26.81	27.34	27.87

Table 97. Number of Permanently Occupied Multi-Family Dwellings (millions)

Millions	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
EU-27	**79**	**83**	**87**	**92**	**97**	**102**	**104**	**106**	**107**	**107**	**107**	**106**	**106**
EU-28 (incl. UK)	**83**	**87**	**91**	**96**	**101**	**106**	**110**	**112**	**113**	**113**	**113**	**112**	**112**
Austria	1.49	1.56	1.63	1.71	1.85	1.90	1.98	2.05	2.11	2.14	2.17	2.19	2.21
Belgium	0.98	1.01	1.05	1.13	1.23	1.29	1.32	1.34	1.36	1.38	1.40	1.42	1.44
Bulgaria	1.17	1.22	1.28	1.35	1.39	1.53	1.50	1.47	1.42	1.37	1.32	1.28	1.24
Croatia	0.44	0.46	0.48	0.53	0.50	0.51	0.50	0.49	0.47	0.46	0.45	0.43	0.42
Cyprus	0.07	0.08	0.08	0.09	0.12	0.13	0.15	0.17	0.18	0.19	0.19	0.20	0.20
Czech Rep.	1.99	2.06	2.16	2.19	2.30	2.34	2.45	2.51	2.54	2.53	2.52	2.51	2.51
Denmark	0.94	0.96	0.99	1.02	1.02	1.06	1.10	1.11	1.13	1.15	1.17	1.18	1.19
Estonia	0.40	0.43	0.45	0.45	0.47	0.48	0.53	0.56	0.56	0.55	0.55	0.54	0.53
Finland	0.89	0.97	0.99	1.06	1.11	1.32	1.37	1.39	1.41	1.40	1.40	1.39	1.38
France	9.72	10.14	10.56	11.24	11.75	12.20	12.76	13.22	13.49	13.66	13.84	13.90	13.97
Germany	17.94	18.45	18.91	19.16	19.35	21.12	21.61	21.91	22.06	22.02	21.98	21.87	21.76
Greece	1.91	2.01	2.14	2.60	2.98	2.99	3.00	3.00	2.97	2.92	2.87	2.81	2.75
Hungary	1.30	1.36	1.50	1.52	1.49	1.53	1.53	1.54	1.54	1.52	1.50	1.48	1.46
Ireland	0.10	0.11	0.10	0.14	0.20	0.21	0.24	0.25	0.26	0.26	0.27	0.28	0.29
Italy	15.16	15.88	16.59	17.25	17.66	18.39	18.53	18.56	18.43	18.24	18.04	17.75	17.46
Latvia	0.42	0.44	0.46	0.49	0.44	0.43	0.45	0.46	0.45	0.44	0.42	0.41	0.41
Lithuania	0.56	0.59	0.61	0.59	0.57	0.60	0.59	0.58	0.55	0.53	0.52	0.50	0.49
Luxembourg	0.06	0.07	0.07	0.08	0.09	0.10	0.12	0.13	0.14	0.15	0.16	0.17	0.18
Malta	0.03	0.04	0.04	0.04	0.03	0.06	0.07	0.08	0.09	0.10	0.10	0.11	0.11
Netherlands	1.68	1.78	1.90	1.96	2.05	2.11	2.20	2.24	2.28	2.29	2.30	2.29	2.28
Poland	7.28	7.62	7.96	8.60	9.02	9.58	10.09	10.36	10.38	10.21	10.04	9.86	9.68
Portugal	1.22	1.29	1.37	1.63	1.60	1.68	1.72	1.75	1.74	1.71	1.69	1.64	1.60
Romania	2.80	2.94	3.07	3.12	3.21	3.25	3.26	3.22	3.13	3.08	3.02	2.96	2.90
Slovakia	0.77	0.81	0.84	0.86	0.89	0.90	0.94	0.95	0.96	0.94	0.93	0.91	0.90
Slovenia	0.25	0.26	0.27	0.28	0.30	0.32	0.33	0.34	0.34	0.34	0.34	0.33	0.33
Spain	7.17	8.03	8.96	10.69	12.48	13.01	13.41	13.83	14.06	14.23	14.40	14.50	14.60
Sweden	2.33	2.41	2.52	2.47	2.47	2.52	2.74	2.96	3.14	3.28	3.42	3.53	3.65

United Kingdom	4.25	4.41	4.46	4.23	4.38	4.90	5.10	5.28	5.45	5.60	5.75	5.86	5.97

Table 98. Share of Single-Family in Permanently Occupied Dwellings

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
EU-27	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%
EU-28 (incl. UK)	51%	51%	51%	51%	51%	50%	51%	51%	51%	51%	51%	51%	51%
Austria	48%	48%	48%	48%	48%	48%	48%	48%	48%	48%	48%	48%	48%
Belgium	75%	75%	75%	74%	73%	73%	73%	73%	73%	73%	73%	73%	73%
Bulgaria	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%
Croatia	66%	66%	66%	63%	66%	66%	66%	66%	66%	66%	66%	66%	66%
Cyprus	64%	64%	64%	64%	64%	64%	64%	64%	64%	64%	64%	64%	64%
Czech Rep.	43%	43%	43%	44%	44%	44%	44%	44%	44%	44%	44%	44%	44%
Denmark	59%	59%	59%	59%	59%	59%	59%	59%	59%	59%	59%	59%	59%
Estonia	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
Finland	54%	54%	54%	54%	54%	54%	54%	54%	54%	54%	54%	54%	54%
France	56%	56%	56%	56%	57%	57%	57%	57%	57%	57%	57%	57%	57%
Germany	46%	46%	46%	47%	47%	45%	45%	45%	45%	45%	45%	45%	45%
Greece	45%	45%	45%	41%	37%	36%	36%	36%	36%	36%	36%	36%	36%
Hungary	62%	62%	62%	61%	62%	62%	62%	62%	62%	62%	62%	62%	62%
Ireland	90%	90%	90%	88%	87%	87%	87%	87%	87%	87%	87%	87%	87%
Italy	23%	23%	23%	24%	27%	26%	26%	26%	26%	26%	26%	26%	26%
Latvia	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%
Lithuania	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%
Luxembourg	56%	56%	56%	56%	56%	55%	55%	55%	55%	55%	55%	55%	55%
Malta	70%	70%	70%	70%	75%	66%	66%	66%	66%	66%	66%	66%	66%
Netherlands	71%	71%	71%	71%	71%	71%	71%	71%	71%	71%	71%	71%	71%
Poland	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%
Portugal	59%	59%	59%	59%	59%	59%	59%	59%	59%	59%	59%	59%	59%
Romania	57%	57%	57%	57%	57%	57%	57%	57%	57%	57%	57%	57%	57%
Slovakia	49%	49%	49%	49%	49%	49%	49%	49%	49%	49%	49%	49%	49%
Slovenia	61%	61%	61%	61%	60%	61%	61%	61%	61%	61%	61%	61%	61%
Spain	31%	31%	31%	30%	29%	29%	29%	29%	29%	29%	29%	29%	29%
Sweden	42%	42%	42%	42%	44%	44%	44%	44%	44%	44%	44%	44%	44%
United Kingdom	81%	81%	81%	80%	84%	82%	82%	82%	82%	82%	82%	82%	82%

Notes:

For 2000-2014 same source and notes as above for Total of Dwellings (Source: EU Buildings Observatory).
For 2000-2014 computed number of permanently occupied dwellings per household (close to 1, varying per country from 0.91 to 1.06). Before 2000 and after 2014 assumed that this number remains constant and computed permanently occupied dwellings as households times number of permanently occupied dwellings per household.
Single Family: includes detached houses, semi-detached houses (2 dwellings per block) and terraced houses (block of on average 15 dwellings).
Multi-Family: includes dwellings in multi-family residential buildings, e.g. city blocks, low-rise detached apartment blocks, high-rise apartment blocks.
Single Family: for 2000-2014 computed share of Single Family in Total Permanently Occupied; assumed that that share remains the same before 2000 and after 2014.
Multi Family: Where complete data are available in source, single family dwellings + multi-family dwellings = total occupied dwellings (more or less). So, where missing, estimated multi-family as all permanently occupied dwellings minus single-family.

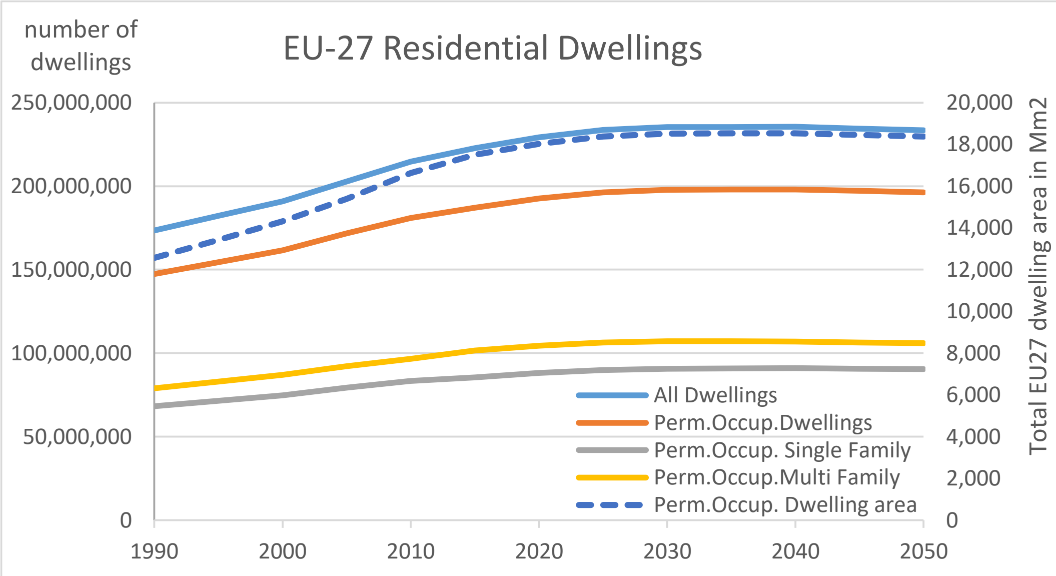


Figure 56. EU-27 Number of residential dwellings: all, permanently occupied, single family and multi-family, and total EU-27 area of permanently occupied dwellings in Mm².

(source: EU Buildings Observatory 2000-2014; VHK elaboration and extrapolation)

5. New-Built Dwellings (All, Single Family, Multi-Family)

Available data from the EU Building Observatory, and their elaboration by VHK, show a strong variation in number of new-built residential dwellings. In the period 1990-2000, annually around 2.0 mln dwellings were built in EU-27, but this gradually increased to a peak of 2.6 mln dwellings in 2006-2007. Due to the economic crisis, starting from 2008, the annual number of new-built dwellings decreased to a minimum of 1.2 mln in 2014, approximately half of the 2006 value.

The number of new-built dwellings is projected to increase again to 1.6 mln by 2020, compensating for the deficit of new-built in earlier years. After 2020 the number is expected to gradually decrease to 0.9 mln in 2050, reflecting the slowdown in growth, and later the decrease, in population and in number of households.

Table 99. Number of New-Built residential dwellings (thousands)

Thousands	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
EU-27	**1963**	**1979**	**2040**	**2594**	**1606**	**1298**	**1601**	**1318**	**1121**	**1010**	**945**	**875**	**872**
EU-28 (incl. UK)	**2153**	**2178**	**2186**	**2749**	**1753**	**1473**	**1853**	**1598**	**1413**	**1279**	**1198**	**1112**	**1111**
Austria	19	34	37	22	15	23	37	37	35	28	25	22	22
Belgium	28	35	43	59	50	49	23	29	36	35	33	31	31
Bulgaria	3	33	9	12	16	12	8	11	13	13	12	12	12
Croatia	28	16	12	23	13	9	3	4	5	5	5	5	5
Cyprus	5	3	5	16	14	4	13	11	9	7	6	5	5
Czech Rep.	38	42	25	33	36	40	55	33	21	16	15	15	15
Denmark	12	17	14	25	10	15	9	17	26	20	18	15	15
Estonia	12	6	1	4	2	4	8	6	2	2	2	2	2
Finland	37	43	32	34	25	27	21	17	13	9	9	9	9
France	275	261	305	470	392	318	327	301	229	213	183	152	153
Germany	372	224	412	242	160	212	273	196	171	131	130	130	129
Greece	37	54	89	195	51	8	21	16	21	20	20	20	19

Hungary	4	39	22	41	21	13	24	15	13	13	13	13	13
Ireland	13	25	50	81	15	13	31	22	20	19	19	18	18
Italy	258	260	245	385	362	148	90	75	96	95	94	93	91
Latvia	14	9	1	4	2	3	10	3	3	3	3	3	3
Lithuania	18	13	4	6	4	7	2	3	4	4	3	3	3
Luxembourg	3	3	2	2	3	5	6	6	6	5	5	5	5
Malta	1	2	2	9	4	5	12	10	8	6	5	4	4
Netherlands	61	75	71	67	56	48	68	49	45	32	28	24	24
Poland	119	113	88	114	136	146	154	86	46	45	45	44	43
Portugal	59	61	73	68	35	18	48	25	19	18	18	18	17
Romania	130	76	26	33	49	37	15	20	26	25	25	24	24
Slovakia	28	17	13	15	17	17	17	10	6	6	6	6	6
Slovenia	7	7	7	8	6	4	8	7	3	3	3	3	3
Spain	338	464	440	604	92	63	214	208	156	158	144	130	131
Sweden	43	45	13	23	20	52	105	100	88	78	74	70	71
United Kingdom	190	199	146	154	146	175	252	280	293	269	253	236	238

Table 100. New-Built residential dwellings as share of total dwelling stock

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
EU-27	**1.13%**	**1.09%**	**1.07%**	**1.28%**	**0.75%**	**0.58%**	**0.70%**	**0.56%**	**0.48%**	**0.43%**	**0.40%**	**0.37%**	**0.37%**
EU-28 (incl. UK)	**1.09%**	**1.05%**	**1.01%**	**1.20%**	**0.72%**	**0.59%**	**0.72%**	**0.60%**	**0.53%**	**0.48%**	**0.45%**	**0.41%**	**0.41%**
Austria	0.61%	1.06%	1.07%	0.61%	0.39%	0.59%	0.91%	0.88%	0.80%	0.62%	0.55%	0.47%	0.47%
Belgium	0.65%	0.79%	0.92%	1.22%	0.98%	0.91%	0.42%	0.52%	0.65%	0.62%	0.57%	0.52%	0.52%
Bulgaria	0.10%	1.00%	0.25%	0.32%	0.41%	0.25%	0.17%	0.23%	0.30%	0.30%	0.30%	0.30%	0.30%
Croatia	1.89%	1.00%	0.74%	1.42%	0.72%	0.46%	0.17%	0.23%	0.30%	0.30%	0.30%	0.30%	0.30%
Cyprus	1.87%	1.00%	1.69%	4.74%	3.40%	0.94%	2.41%	1.87%	1.38%	1.06%	0.90%	0.76%	0.75%
Czech Rep.	0.95%	1.00%	0.58%	0.73%	0.78%	0.82%	1.09%	0.64%	0.39%	0.30%	0.30%	0.30%	0.30%
Denmark	0.45%	0.64%	0.51%	0.87%	0.33%	0.51%	0.28%	0.56%	0.81%	0.63%	0.54%	0.46%	0.46%
Estonia	2.12%	1.00%	0.12%	0.62%	0.35%	0.53%	1.08%	0.80%	0.31%	0.30%	0.30%	0.30%	0.30%
Finland	1.74%	1.88%	1.29%	1.27%	0.89%	0.92%	0.68%	0.55%	0.43%	0.30%	0.30%	0.30%	0.30%
France	1.03%	0.94%	1.05%	1.53%	1.21%	0.94%	0.92%	0.82%	0.61%	0.56%	0.48%	0.39%	0.39%
Germany	1.02%	0.60%	1.07%	0.61%	0.39%	0.51%	0.64%	0.45%	0.39%	0.30%	0.30%	0.30%	0.30%
Greece	0.73%	1.00%	1.59%	3.09%	0.76%	0.11%	0.30%	0.23%	0.30%	0.30%	0.30%	0.30%	0.30%
Hungary	0.10%	1.00%	0.53%	0.98%	0.48%	0.28%	0.54%	0.33%	0.30%	0.30%	0.30%	0.30%	0.30%
Ireland	1.34%	2.23%	4.07%	5.71%	0.91%	0.74%	1.66%	1.10%	0.97%	0.90%	0.85%	0.81%	0.79%
Italy	1.05%	1.01%	0.91%	1.33%	1.17%	0.46%	0.28%	0.23%	0.30%	0.30%	0.30%	0.30%	0.30%
Latvia	1.65%	1.00%	0.10%	0.38%	0.19%	0.29%	0.89%	0.23%	0.30%	0.30%	0.30%	0.30%	0.30%
Lithuania	1.41%	1.00%	0.33%	0.46%	0.29%	0.50%	0.17%	0.23%	0.30%	0.30%	0.30%	0.30%	0.30%
Luxembourg	1.86%	1.94%	0.99%	1.08%	1.39%	1.98%	2.28%	2.06%	1.89%	1.61%	1.40%	1.22%	1.18%
Malta	0.93%	1.00%	1.51%	5.70%	2.53%	1.75%	3.97%	2.92%	2.07%	1.35%	1.06%	0.80%	0.79%
Netherlands	1.02%	1.19%	1.07%	0.97%	0.78%	0.64%	0.88%	0.62%	0.56%	0.40%	0.35%	0.30%	0.30%
Poland	1.09%	1.00%	0.74%	0.89%	1.01%	1.03%	1.03%	0.56%	0.30%	0.30%	0.30%	0.30%	0.30%
Portugal	1.33%	1.30%	1.45%	1.19%	0.61%	0.30%	0.78%	0.40%	0.30%	0.30%	0.30%	0.30%	0.30%
Romania	1.80%	1.00%	0.33%	0.40%	0.58%	0.42%	0.17%	0.23%	0.30%	0.30%	0.30%	0.30%	0.30%
Slovakia	1.73%	1.00%	0.71%	0.78%	0.87%	0.83%	0.84%	0.47%	0.30%	0.30%	0.30%	0.30%	0.30%
Slovenia	1.06%	1.00%	0.88%	0.93%	0.75%	0.42%	0.90%	0.70%	0.33%	0.30%	0.30%	0.30%	0.30%
Spain	2.07%	2.54%	2.16%	2.61%	0.36%	0.24%	0.78%	0.74%	0.54%	0.54%	0.49%	0.44%	0.44%
Sweden	0.91%	0.91%	0.26%	0.46%	0.39%	1.00%	1.86%	1.64%	1.36%	1.15%	1.05%	0.96%	0.94%
United Kingdom	0.81%	0.81%	0.58%	0.59%	0.53%	0.61%	0.85%	0.91%	0.92%	0.82%	0.76%	0.69%	0.68%

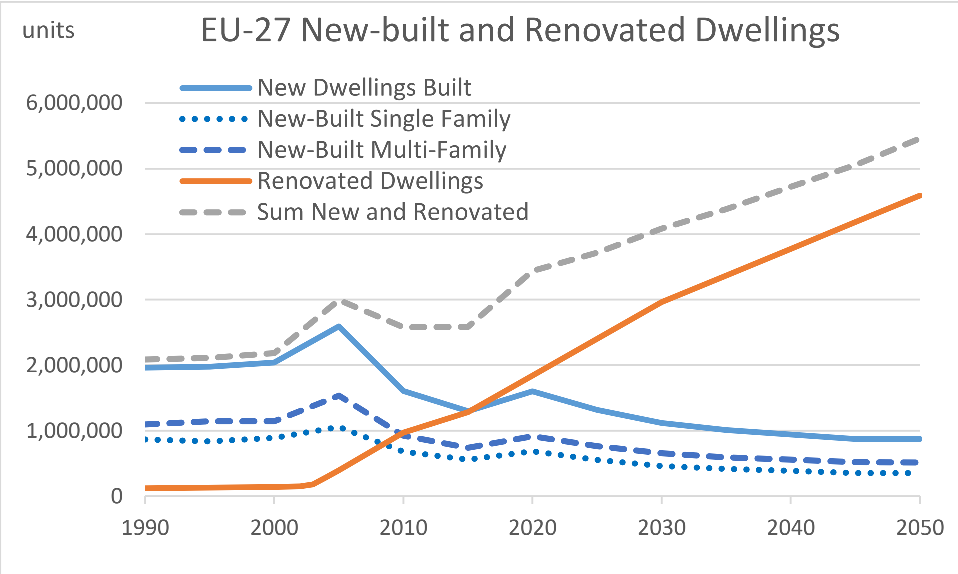
Notes:

For 2000-2014 same notes as above for Residential Dwellings (Source: EU Buildings Observatory).
For 2000-2014 computed share of new dwellings in total dwellings (varying per country in 2014 from 0.07% to 1.90%).

From 2025, imposed that share of new dwellings is identical to the annual increase in total dwelling stock plus an assumed share of dwellings demolished. In absence of data, the latter share is assumed to increase from 0.1% in 2015 to 0.3% in 2030 and later years.
Before 1995, imposed that share of new dwellings is identical to the annual increase in total dwelling stock plus an assumed share of dwellings demolished (0.1%).
Between 2014 and 2025 and between 1995 and 2000, partly extrapolated trends and partly interpolated values.

For 2000-2014, the data in the EU Buildings Observatory database are not always consistent: for some countries/ years, the increase in dwelling stock is higher than the number of new built dwellings in the same year (maybe old buildings recovered that were not counted in stock previously ?)
Single Family: for known data computed share of New Single Family in Total New; assumed that share remains the same before 2000 and after 2014.
Multi Family: Where complete data are available, New single + New multi = total New (more or less). So, where missing, estimate New multi-family as all New dwellings minus New single-family.

Figure 57. EU-27 Number of New-built and Renovated residential dwellings. New-built also subdivided in single family dwellings and multi-family dwellings. Sum of New-Built and Renovated dwellings also shown.



6. Renovated Dwellings (1), data from ZEBRA

(text below taken from ZEBRA website)

In ZEBRA [36], three renovations levels have been defined: "low", "medium" and "deep". However, their definition is different across countries and does not correspond to the same level of energy savings. Therefore, the data are hardly comparable. For that reason, ZEBRA developed an indicator of "**major renovation equivalent**" to ease comparisons.

Major renovations as defined in Article 2 of EPBD recast include renovations where the total cost of the renovation relating to the envelope or its systems is higher than 25% of the value of the building, or more than 25% of the surface of the building envelope undergoes renovation. However, as Article 2 leaves each MSs to interpret and define differently major renovations, countries have chosen different ways to define and monitor them. Because of this lack of official European definition, the **ZEBRA consortium assumes that with major renovations, a building's final energy demand for heating can be reduced by 50 to 80%** (range depending on the country defined by national experts according to the current efficiency of the building stock).

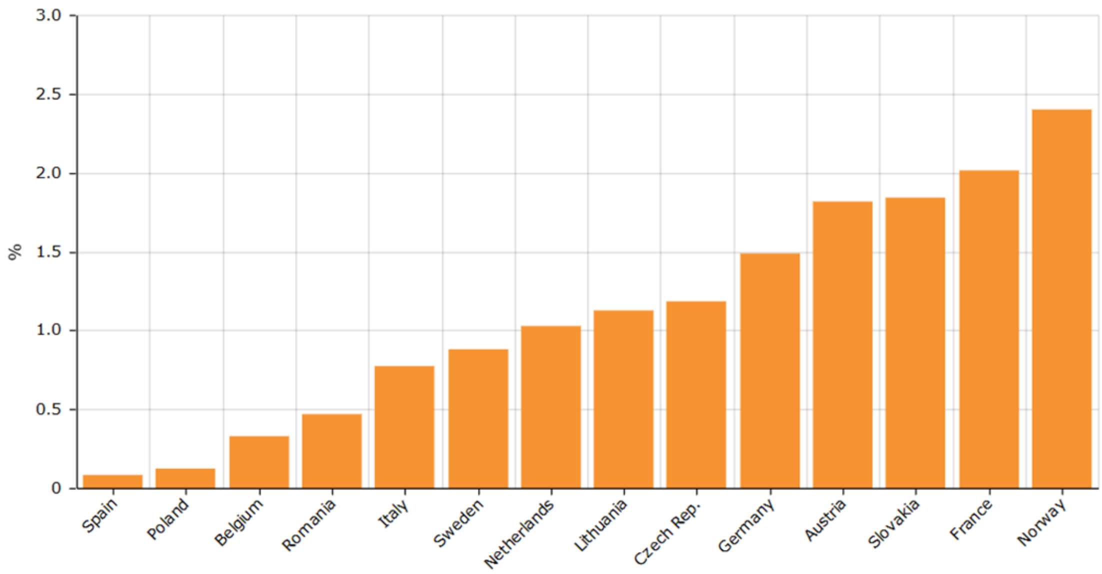
[36] http://www.zebra-monitoring.enerdata.eu/overall-building-activities/average-size-of-new-dwellings.html#equivalent-major-renovation-rate.html

The major renovation equivalent is based on assumptions on the type of measures considered for the different level of renovations. and is determined by country. For example: The Dutch rate for medium level renovations also includes minor (light) measures. For Germany however, figures for minor (light) measures are not gathered and therefore are not considered in the renovation rates. The major equivalent renovation considering all renovation activities should therefore be higher than presented here. For each country, national experts defined the national renovation level and determined to which extent the allocated renovations fulfil / overfulfil the predefined major renovation level (expert guess).

Table 101. Equivalent major renovation rate as reported by ZEBRA [36] for countries where data are available

year	2010	2011	2012	2013	2014
Austria			1.82%		
Belgium					0.33%
Czech Rep.			1.18%		
France	1.78%	1.88%	1.76%	1.75%	2.01%
Germany					1.49%
Italy			0.77%		
Lithuania					1.13%
Netherlands					1.03%
Poland	0.13%	0.13%	0.13%	0.12%	
Romania					0.47%
Slovakia					1.84%
Spain					0.08%
Sweden				0.88%	

Figure 58. Equivalent major renovation rate as reported by ZEBRA [36] for countries where data are available



7. Renovated Dwellings (2), data from IA for EPBD recast

In the Impact Assessment for the 2018 recast of the EPBD [37] an overall EU-28 renovation rate for residential of 0.61% is assumed for 2015, increasing to 1.60% in 2030 (Table 102, options II and III). For non-residential these rates are respectively 0.7% and 1.7%.

According to footnote 79 of the Impact Assessment for the EPBD the above percentages refer to a '**full thermal renovation rate**':

The full thermal renovation rate reflects the amount of buildings that undergo a renovation and upgrade of the total building envelope (roof, external walls, windows and ground floor) developed as an equivalent rate of renovations that include all or only parts of these different components. The full thermal renovation rate is therefore an indicator that describes the number and scope of renovations of the building envelope, while not describing the ambition level (e.g. thickness of insulation) of the single measures. These assumptions are established based on the Invert/EE-Lab (TU Vienna).

Table 102. Average EU-28 renovation rates used in the Impact Assessment for the 2018 recast of the EPBD [37]. (Original: Table 12 Key assumptions of the BEAM modelling and Table 20 Additional assumptions)

	Reference	Option I	Options II/III[78]
Thermal qualities of new buildings	2017-2020: Cost optimal U-values according to MS reports 2021-2025: Introduction of NZEBs (approx. 12.5% improvement) 2026-2030: 7.5% improvement due to new cost optimality values	2017-2020: Cost optimal U-values according to MS reports 2021-2025: Introduction of NZEBs (approx. 12.5% improvement) 2026-2030: 7.5% improvement due to new cost optimality values	2017-2020: Cost optimal U-values according to MS reports 2021-2025: Introduction of NZEBs (approx. 12.5% improvement) 2026-2030: 7.5% improvement due to new cost optimality values
Equivalent full thermal renovation rate[79]	Residential (2015-2030): 0.61 - 0.95% Non-residential (2015-2030): 0.70 - 1.05%	Residential (2015-2030): 0.61 - 1.03% Non-residential (2015-2030): 0.70 – 1.14%	Residential (2015-2030): 0.61 - 1.60% Non-residential (2015-2030): 0.70 – 1.70%
Thermal qualities of renovations	2018-2022: Cost optimal U-values from MS reports 2023-2027: 5% improvement compared to 2018-2022 2028-2030: 5% improvement compared to 2023-2027	2017-2020: Cost optimal U-values from MS reports 2021-2025: 5% improvement compared to 2017-2020 2026-2030: 5% improvement compared to 2021-2025	2017-2020: Cost optimal U-values from MS reports 2021-2025: 5% improvement compared to 2017-2020 2026-2030: 5% improvement compared to 2021-2025
Heating system exchange rates[80]	2015-2030: 3.6 - 4.1%	2015-2030: 3.6 - 4.2%	2015-2030: 3.6 - 4.2%

[37] COMMISSION STAFF WORKING DOCUMENT, IMPACT ASSESSMENT, Accompanying the document Proposal for a Directive of the European Parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings. {COM(2016) 765} {SWD(2016) 415}

	Number of parking space for 100m²	Share of buildings with more than 10 parking space	Average major renovation rate
Single family house	1.25	0%	0.50%
Small multi-appartment (<10 flats)	1.25	0%	0.50%
Large multi-appartment (>10 flats)	1.25	100%	0.75%
Offices	1.00	50%	1.25%
Trade	1.00	50%	1.25%
Education	1.00	75%	1.00%
Touristic	1.00	50%	1.00%
Health	1.00	75%	1.00%
Others	1.00	50%	1.00%

8. Renovated Dwellings (3), study team projection

It is estimated that in 2015 around 1.3 mln dwellings were renovated in EU-27 (where renovation is intended as defined in the previous two sections). This is 0.69% of the 2015 permanently occupied dwelling stock. Stimulated by the EPBD, it is projected that renovations will gradually increase to 3.0 mln in 2030 (1.5% of the stock) and to 4.6 mln in 2050 (2.3% of the stock). Cumulatively this means that 59% of the 2015 dwelling stock will be renovated between 2015 and 2050.

Table 103. Number of Renovated residential dwellings (thousands)

Thousands	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
EU-27	**125**	**134**	**144**	**399**	**972**	**1287**	**1839**	**2401**	**2963**	**3369**	**3775**	**4181**	**4587**
EU-28 (incl. UK)	**130**	**140**	**150**	**413**	**993**	**1314**	**2014**	**2725**	**3435**	**3964**	**4493**	**5023**	**5552**
Austria	1	1	1	11	38	49	51	54	56	55	54	53	52
Belgium	1	1	1	4	8	12	34	57	79	98	116	134	153
Bulgaria	1	1	1	2	2	3	20	38	55	69	83	97	112
Croatia	0	0	0	1	1	1	9	16	24	30	36	42	48
Cyprus	0	0	0	0	0	0	2	3	4	5	6	8	9
Czech Rep.	1	1	1	9	28	37	46	55	64	70	76	82	87
Denmark	0	1	1	1	2	3	17	31	45	57	69	80	92
Estonia	0	0	0	0	0	1	4	8	11	14	17	20	23
Finland	0	0	1	1	2	3	10	27	44	57	70	83	96
France	67	69	72	153	360	422	429	436	443	427	411	395	379
Germany	7	8	9	88	274	426	496	567	637	674	711	748	784
Greece	1	1	1	3	4	5	26	48	69	87	105	123	141
Hungary	1	1	1	2	3	4	24	45	65	82	99	115	132
Ireland	0	0	0	1	1	2	8	15	22	27	33	38	44
Italy	4	5	5	38	110	143	230	318	406	472	539	605	672
Latvia	0	0	0	1	1	1	5	10	14	18	21	25	29
Lithuania	0	0	0	3	7	11	15	19	23	26	29	32	35
Luxembourg	0	0	0	0	0	0	1	2	3	4	5	5	6

Malta	0	0	0	0	0	0	1	2	3	3	4	4	5
Netherlands	35	37	39	43	50	56	73	90	107	118	130	141	153
Poland	2	3	3	8	13	13	84	154	225	283	342	401	460
Portugal	1	1	1	2	3	4	23	42	60	76	91	107	123
Romania	1	2	2	8	18	26	60	95	129	156	184	211	239
Slovakia	0	0	0	5	16	24	26	29	31	31	32	32	32
Slovenia	0	0	0	0	1	1	5	9	13	17	20	24	27
Spain	2	3	3	8	10	10	92	173	255	323	391	459	528
Sweden	1	1	1	7	21	29	45	61	77	89	101	113	125
United Kingdom	5	5	6	15	21	28	176	324	472	595	718	842	965

Table 104. Renovated residential dwellings as share of permanently occupied dwelling stock (for years before 2015 refers to the dwelling stock of that year; for year 2015 and later refers to the 2015 dwelling stock)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
EU-27	**0.09%**	**0.09%**	**0.09%**	**0.23%**	**0.54%**	**0.69%**	**0.95%**	**1.22%**	**1.50%**	**1.70%**	**1.91%**	**2.12%**	**2.34%**
EU-28 (incl. UK)	**0.08%**	**0.08%**	**0.08%**	**0.21%**	**0.48%**	**0.61%**	**0.94%**	**1.27%**	**1.60%**	**1.84%**	**2.09%**	**2.34%**	**2.58%**
Austria	0.02%	0.02%	0.02%	0.34%	1.06%	1.35%	1.41%	1.47%	1.52%	1.5%	1.5%	1.5%	1.4%
Belgium	0.02%	0.02%	0.02%	0.09%	0.18%	0.25%	0.72%	1.19%	1.66%	2.0%	2.4%	2.8%	3.2%
Bulgaria	0.02%	0.02%	0.02%	0.06%	0.08%	0.10%	0.61%	1.11%	1.62%	2.0%	2.5%	2.9%	3.3%
Croatia	0.02%	0.02%	0.02%	0.06%	0.08%	0.10%	0.60%	1.10%	1.59%	2.0%	2.4%	2.8%	3.3%
Cyprus	0.02%	0.02%	0.02%	0.06%	0.08%	0.10%	0.46%	0.81%	1.17%	1.5%	1.8%	2.1%	2.4%
Czech Rep.	0.02%	0.02%	0.02%	0.23%	0.69%	0.88%	1.10%	1.32%	1.54%	1.7%	1.8%	2.0%	2.1%
Denmark	0.02%	0.02%	0.02%	0.06%	0.08%	0.10%	0.64%	1.18%	1.72%	2.2%	2.6%	3.1%	3.5%
Estonia	0.02%	0.02%	0.02%	0.06%	0.08%	0.10%	0.63%	1.17%	1.70%	2.1%	2.6%	3.0%	3.5%
Finland	0.02%	0.02%	0.02%	0.06%	0.08%	0.10%	0.34%	0.93%	1.53%	2.0%	2.4%	2.9%	3.3%
France	0.30%	0.30%	0.30%	0.59%	1.33%	1.50%	1.52%	1.55%	1.57%	1.5%	1.5%	1.4%	1.3%
Germany	0.02%	0.02%	0.02%	0.24%	0.72%	1.11%	1.29%	1.47%	1.65%	1.7%	1.8%	1.9%	2.0%
Greece	0.02%	0.02%	0.02%	0.06%	0.08%	0.10%	0.56%	1.03%	1.49%	1.9%	2.3%	2.6%	3.0%
Hungary	0.02%	0.02%	0.02%	0.06%	0.08%	0.10%	0.61%	1.12%	1.63%	2.1%	2.5%	2.9%	3.3%
Ireland	0.02%	0.02%	0.02%	0.06%	0.08%	0.10%	0.50%	0.90%	1.29%	1.6%	2.0%	2.3%	2.6%
Italy	0.02%	0.02%	0.02%	0.17%	0.46%	0.57%	0.93%	1.28%	1.63%	1.9%	2.2%	2.4%	2.7%
Latvia	0.02%	0.02%	0.02%	0.06%	0.08%	0.10%	0.65%	1.19%	1.74%	2.2%	2.7%	3.1%	3.6%
Lithuania	0.02%	0.02%	0.02%	0.19%	0.55%	0.84%	1.15%	1.46%	1.77%	2.0%	2.2%	2.4%	2.6%
Luxembourg	0.02%	0.02%	0.02%	0.06%	0.08%	0.10%	0.51%	0.93%	1.34%	1.7%	2.0%	2.4%	2.7%
Malta	0.02%	0.02%	0.02%	0.06%	0.08%	0.10%	0.53%	0.97%	1.40%	1.8%	2.1%	2.5%	2.8%
Netherlands	0.60%	0.60%	0.60%	0.63%	0.71%	0.77%	1.00%	1.24%	1.47%	1.6%	1.8%	1.9%	2.1%
Poland	0.02%	0.02%	0.02%	0.06%	0.09%	0.09%	0.58%	1.08%	1.57%	2.0%	2.4%	2.8%	3.2%
Portugal	0.02%	0.02%	0.02%	0.06%	0.08%	0.10%	0.56%	1.02%	1.47%	1.9%	2.2%	2.6%	3.0%
Romania	0.02%	0.02%	0.02%	0.10%	0.24%	0.35%	0.80%	1.26%	1.71%	2.1%	2.4%	2.8%	3.2%
Slovakia	0.02%	0.02%	0.02%	0.29%	0.89%	1.37%	1.49%	1.60%	1.72%	1.7%	1.8%	1.8%	1.8%
Slovenia	0.02%	0.02%	0.02%	0.06%	0.08%	0.10%	0.62%	1.13%	1.65%	2.1%	2.5%	2.9%	3.4%
Spain	0.02%	0.02%	0.02%	0.05%	0.05%	0.06%	0.50%	0.94%	1.39%	1.8%	2.1%	2.5%	2.9%
Sweden	0.02%	0.02%	0.02%	0.17%	0.47%	0.65%	1.01%	1.36%	1.71%	2.0%	2.2%	2.5%	2.8%
United Kingdom	0.02%	0.02%	0.02%	0.06%	0.08%	0.10%	0.63%	1.17%	1.70%	2.1%	2.6%	3.0%	3.5%

Table 105. Cumulative share of the 2015 permanently occupied dwelling stock that is projected to have been renovated in a given year.

Thousands	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
EU-27						**0.7%**	**5.0%**	**11%**	**18%**	**27%**	**36%**	**47%**	**59%**
EU-28 (incl. UK)						**0.6%**	**4.6%**	**10%**	**18%**	**26%**	**36%**	**48%**	**60%**
Austria						1.4%	8.3%	16%	23%	31%	38%	45%	53%
Belgium						0.2%	2.9%	8%	15%	25%	36%	49%	65%

Bulgaria						0.1%	2.1%	7%	14%	23%	35%	48%	64%
Croatia						0.1%	2.1%	7%	14%	23%	34%	47%	63%
Cyprus						0.1%	1.7%	5%	10%	17%	25%	35%	46%
Czech Rep.						0.9%	5.9%	12%	19%	27%	36%	46%	56%
Denmark						0.1%	2.2%	7%	15%	24%	37%	51%	68%
Estonia						0.1%	2.2%	7%	14%	24%	36%	51%	67%
Finland						0.1%	1.0%	4%	11%	20%	31%	45%	60%
France						1.5%	9.0%	17%	25%	32%	40%	47%	54%
Germany						1.1%	7.2%	14%	22%	31%	40%	49%	59%
Greece						0.1%	2.0%	6%	13%	21%	32%	44%	59%
Hungary						0.1%	2.1%	7%	14%	23%	35%	49%	64%
Ireland						0.1%	1.8%	5%	11%	19%	28%	39%	51%
Italy						0.6%	4.5%	10%	18%	27%	37%	49%	62%
Latvia						0.1%	2.2%	7%	15%	25%	37%	52%	69%
Lithuania						0.8%	6.0%	13%	21%	30%	41%	53%	66%
Luxembourg						0.1%	1.8%	6%	12%	19%	29%	40%	53%
Malta						0.1%	1.9%	6%	12%	20%	30%	42%	55%
Netherlands						0.8%	5.3%	11%	18%	26%	34%	44%	54%
Poland						0.1%	2.0%	6%	13%	22%	34%	47%	62%
Portugal						0.1%	2.0%	6%	13%	21%	32%	44%	58%
Romania						0.3%	3.4%	9%	16%	26%	38%	51%	66%
Slovakia						1.4%	8.6%	16%	25%	33%	42%	51%	60%
Slovenia						0.1%	2.2%	7%	14%	24%	35%	49%	65%
Spain						0.1%	1.7%	6%	12%	20%	29%	41%	55%
Sweden						0.7%	5.0%	11%	19%	28%	39%	51%	64%
United Kingdom						0.1%	2.2%	7%	14%	24%	36%	51%	67%

Table 106. Derivation of the renovation target: share of the 2015 dwelling stock to be renovated by 2050

Number of dwellings in thousands	2015 dwelling stock	Share built < 1990	Number built < 1990	Share already renovated by 2015	Share demolished by 2050	Number of < 1990 to be renovated by 2050	Number built 1991-2015	Share to be renovated by 2050	Number of 1991-2015 to be renovated by 2050	Dwellings of 2015 stock to be renovated by 2050	Share of 2015 stock to be renovated by 2050
EU-27	187,090	78%	144,018	20%	9%	97,322	43,072	30%	12,922	110,243	59%
EU-28 (incl. UK)	214,860	78%	167,356	20%	9%	114,605	47,504	30%	14,251	128,856	60%
Austria	3,652	71%	2,580	25%	9%	1,599	1,072	30%	322	1,920	53%
Belgium	4,784	80%	3,803	15%	9%	2,792	981	30%	294	3,087	65%
Bulgaria	3,381	78%	2,641	15%	9%	1,933	741	30%	222	2,156	64%
Croatia	1,480	76%	1,132	15%	9%	826	348	30%	104	931	63%
Cyprus	367	46%	168	15%	9%	109	199	30%	60	169	46%
Czech Rep.	4,166	78%	3,255	25%	9%	2,058	912	30%	273	2,331	56%
Denmark	2,626	85%	2,238	15%	9%	1,661	388	30%	116	1,777	68%
Estonia	648	84%	545	15%	9%	404	103	30%	31	434	67%
Finland	2,891	72%	2,073	15%	9%	1,496	819	30%	246	1,741	60%
France	28,200	73%	20,549	25%	9%	12,818	7,651	30%	2,295	15,113	54%
Germany	38,526	85%	32,836	25%	9%	21,082	5,690	30%	1,707	22,790	59%
Greece	4,656	69%	3,214	15%	9%	2,304	1,442	30%	433	2,736	59%
Hungary	3,963	79%	3,147	15%	9%	2,310	816	30%	245	2,555	64%

Ireland	1,679	55%	920	15%	9%	628		759	30%	228		856	51%
Italy	24,864	81%	20,245	20%	9%	13,908		4,620	30%	1,386		15,294	62%
Latvia	808	87%	704	15%	9%	524		104	30%	31		555	69%
Lithuania	1,320	90%	1,182	20%	9%	824		138	30%	41		865	66%
Luxembourg	228	58%	133	15%	9%	92		95	30%	28		120	53%
Malta	180	63%	113	15%	9%	79		67	30%	20		100	55%
Netherlands	7,270	74%	5,358	25%	9%	3,350		1,912	30%	574		3,923	54%
Poland	14,309	75%	10,706	15%	9%	7,784		3,603	30%	1,081		8,865	62%
Portugal	4,086	68%	2,771	15%	9%	1,979		1,315	30%	394		2,374	58%
Romania	7,530	82%	6,195	15%	9%	4,573		1,334	30%	400		4,974	66%
Slovakia	1,779	88%	1,558	25%	9%	1,005		221	30%	66		1,071	60%
Slovenia	804	81%	648	15%	9%	477		156	30%	47		524	65%
Spain	18,381	62%	11,385	15%	9%	7,986		6,996	30%	2,099		10,085	55%
Sweden	4,512	87%	3,919	20%	9%	2,720		593	30%	178		2,898	64%
United Kingdom	27,771	84%	23,338	15%	9%	17,283		4,432	30%	1,330		18,612	67%

Notes:

For 2010-2015 there are some reference data from ZEBRA. As also stated by ZEBRA, these data are difficult to interpret, because MSs use different definitions for degrees of renovation. Only what ZEBRA calls 'Equivalent major renovation rate' has been taken into account.

The number of renovated dwellings (Table 103) is based on an estimate of the share of the permanently occupied dwelling stock that is renovated annually (Table 104). Before 2015 reference is the permanently occupied dwelling stock of the year; after 2015 reference for all years is the permanently occupied dwelling stock of year 2015.

The annual renovation rates have been determined as follows:

2015:
Where 2010-2015 country data on renovation were available they have been used as rates in 2015, but scaled by a factor 0.75. For countries without data, a low default value has been set for year 2015 (now 0.1%). This leads to an average EU renovation rate in 2015 of 0.61%, which is the same value used in the IA for EPBD for 2015.

Before 2015:
In 2003 the value suggested in the 2010 Supplementary report[38] was used, i.e. 0.05%. Higher values were set for France (0.3%) and The Netherlands (0.6%) to enable matching the available VU sales/stock data for these countries. In 1990 and before set the renovation rate to 0.02% (except FR and NL). For 1990-2003 and 2003-2015 used linear interpolation of the renovation rate.

After 2015:
2050: EPBD target is to have entire stock NZEB by 2050. This seems to imply using BVU with HR in all dwellings, but unlikely that all countries will do this, considering the differences in ventilation habits and needs.

The model sets a target for the part of the 2015 dwelling stock that will have to be renovated by 2050. This part is derived by subdividing the 2015 dwelling stock in dwellings built before 1990 (78%) and dwellings built between 1990 and 2015 (22%). For the latter group it is assumed that 30% will be renovated by 2050 (same % for all countries). For the former group it is assumed that 20% has already been renovated in 2015 and will not be renovated again before 2050 (this % varies per country from 15% to 25%). In addition it is assumed that 9% of the 2015 dwelling stock will have been demolished by 2050, and thus will not be renovated. Overall, this gives a target of 60% of the 2015 dwelling stock to be renovated by 2050. This % varies per country, from 46% to 69%, depending on the average age of the 2015 dwelling stock and on the part of that stock that was already renovated in or before 2015 (see Table 106 above).

Based on the renovation target for 2050, annual renovation rates for the 2015-2050 period have been derived. The 2030 renovation rates have been scaled in such a way that the overall EU rate of 1.6% used in the IA for the EPBD is obtained. Linear interpolation is used between 2015 and 2030 and between 2030 and 2050. It can be verified in Table 105) that the cumulative renovations over the period 2015-2050 lead to the target set for 2050.

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[38] Supplements to Preparatory Study on Residential Ventilation LOT 10 (i.e. mechanical ventilation units with fans < 125 W), Fachinstitut Gebäude-Klima e.V., Contact : Claus Händel, final draft July 2010

9. Dwelling Sizes (area)

When considering dwelling sizes, the area of permanently occupied dwellings is used as a reference in this study. For years 2000-2014 this area has been taken from the EU BSO database, considering the sum of areas for single-family dwellings and multi-family dwellings. In 2014, the total EU-27 area of permanently occupied dwellings was 17 364 Mm^2 with an average dwelling size of 93.6 m^2. This is smaller than the value for all dwellings reported in the EU BSO of 22 599 Mm^2, with an average of 89.9 m^2.

For years before 2000 and after 2014, the study team extrapolated the data. For years after 2014 this was done assuming that the average area per dwelling will remain constant.

Table 107. Total size (area) of all residential dwellings in EU in Mm2
(Source: EU Buildings Observatory)

M m2			2000	2005	2010	2014							
EU-27			16,236	17,506	18,877	22,599							
EU-28 (incl. UK)			18,426	19,832	21,393	22,684							
Austria			317.3	336.2	368.2	394.4							
Belgium			379.3	394.8	413.4	428.8							
Bulgaria			220.8	236.6	243.5	332.1							
Croatia			117.3	127.1	149.6	162.4							
Cyprus			38.6	47.7	60.4	66.6							
Czech Rep.			311.9	339.6	363.9	375.3							
Denmark			311.1	319.1	327.3	355.1							
Estonia			37.3	38.1	40.1	41.4							
Finland			232.8	255.7	274.0	287.9							
France			2,581.7	2,792.3	2,979.9	3,115.3							
Germany			3,247.2	3,393.7	3,574.0	3,785.9							
Greece			478.3	536.2	571.5	583.9							
Hungary			398.0	363.0	398.4	450.5							
Ireland			131.6	160.8	191.8	210.8							
Italy			2,583.4	2,769.2	2,933.2	2,986.7							
Latvia			50.1	57.1	63.2	68.7							
Lithuania			79.5	79.7	83.7	86.9							
Luxembourg			23.1	24.3	26.5	28.8							
Malta			16.7	17.0	18.7	26.7							
Netherlands			703.1	750.2	825.3	886.2							
Poland			790.4	885.1	973.9	1,028.4							
Portugal			433.1	514.4	626.2	661.0							
Romania			271.7	310.5	332.4	358.8							
Slovakia			148.9	162.7	166.7	171.5							
Slovenia			59.1	63.0	68.6	71.3							
Spain			1,814.7	2,083.6	2,340.7	2,433.8							
Sweden			458.8	449.1	462.5	473.0							
United Kingdom			2,190.6	2,325.8	2,515.5	2,726.8							
Avg. m2/dwel.			**85.0**	**86.3**	**87.9**	**89.9**							

Table 108. Total size (area) of permanently occupied residential dwellings in EU in Mm2
(Source for 2000-2014: EU Buildings Observatory, as sum of areas for single-family dwellings and multi-family dwellings; extrapolation to earlier and later years by VHK)

M m2	1990	1995	2000	2005	2010	2014	2020	2025	2030	2035	2040	2045	2050
EU-27	12,562	13,430	14,309	15,385	16,627	17,364	18,027	18,378	18,519	18,525	18,531	18,453	18,375
EU-28 (incl. UK)	14,339	15,350	16,378	17,634	19,061	19,999	20,783	21,232	21,465	21,549	21,632	21,615	21,597
Austria			292.4	309.8	339.3	364.4							
Belgium			345.5	358.3	375.5	386.3							
Bulgaria			181.2	190.3	196.6	233.8							
Croatia			103.8	111.7	119.6	126.1							
Cyprus			29.9	36.3	48.7	54.5							
Czech Rep.			275.2	298.7	320.1	330.8							
Denmark			268.8	275.7	281.5	302.1							
Estonia			34.9	36.1	38.4	39.4							
Finland			213.0	228.0	242.7	254.3							
France			2572.0	2791.3	2974.1	3110.2							
Germany			3202.3	3326.9	3557.9	3645.5							
Greece			329.0	370.3	396.6	409.6							
Hungary			295.0	299.8	353.2	400.0							
Ireland			132.2	157.3	191.0	206.6							
Italy			2058.8	2196.5	2288.0	2322.5							
Latvia			45.9	51.7	49.7	52.7							
Lithuania			79.5	79.7	83.7	86.9							
Luxembourg			22.8	24.0	26.2	28.8							
Malta			13.2	13.6	14.0	18.9							
Netherlands			692.9	741.1	819.5	865.0							
Poland			796.5	885.1	973.9	1028.4							
Portugal			289.6	362.1	421.8	449.6							
Romania			263.7	276.2	295.4	308.0							
Slovakia			134.9	143.1	148.4	150.3							
Slovenia			54.0	57.8	62.2	64.8							
Spain			1174.8	1380.9	1602.9	1707.5							
Sweden			407.0	383.2	406.1	417.4							
United Kingdom			2069.4	2248.9	2434.3	2634.3							
Avg. m2/dwel.	**85.2**	**86.9**	**88.6**	**89.6**	**91.9**	**93.6**	**93.6**	**93.6**	**93.6**	**93.6**	**93.6**	**93.6**	**93.6**

Annex IV: Link between VU sales and Dwellings

1. Methodology

Contents has been moved to paragraph 2.6 of the main text.

2 Shares of Dwellings implementing a certain type of ventilation

Table 109. Share of new-built residential dwellings implementing CBVU

CBVU in New-Built	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2050
EU-27					**1%**	**2%**	**3%**	**5%**	**6%**	**9%**	**9%**	**39%**	**38%**
EU-28 (incl. UK)					**1%**	**3%**	**3%**	**5%**	**6%**	**8%**	**8%**	**39%**	**38%**
Austria	0%	0%	0%	4%	7%	11%	16%	19%	19%	13%	14%	45%	45%
Belgium	0%	0%	0%	1%	2%	3%	4%	5%	5%	3%	3%	45%	45%
Bulgaria	0%	0%	0%	0%	1%	1%	2%	2%	2%	1%	1%	45%	45%
Croatia	0%	0%	0%	0%	1%	1%	2%	2%	2%	1%	1%	20%	20%
Cyprus	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	20%	20%
Czech Rep.	0%	0%	0%	0%	1%	1%	2%	2%	2%	1%	1%	45%	45%
Denmark	0%	0%	0%	5%	10%	17%	24%	28%	28%	20%	20%	70%	70%
Estonia	0%	0%	0%	2%	3%	6%	8%	9%	9%	7%	7%	45%	45%
Finland	0%	0%	0%	6%	13%	16%	22%	100%	100%	100%	100%	100%	100%
France	0%	0%	0%	0%	0%	0%	1%	1%	5%	4%	4%	40%	40%
Germany	0%	0%	0%	0%	1%	2%	4%	7%	11%	11%	12%	35%	35%
Greece	0%	0%	0%	0%	0%	1%	1%	1%	1%	1%	1%	20%	20%
Hungary	0%	0%	0%	0%	1%	1%	2%	2%	2%	1%	1%	45%	45%
Ireland	0%	0%	0%	1%	2%	3%	4%	5%	5%	3%	3%	40%	40%
Italy	0%	0%	0%	0%	1%	1%	2%	2%	2%	1%	1%	20%	20%
Latvia	0%	0%	0%	0%	1%	1%	2%	2%	2%	1%	1%	45%	45%
Lithuania	0%	0%	0%	0%	1%	1%	2%	2%	2%	1%	1%	45%	45%
Luxembourg	0%	0%	0%	0%	1%	1%	2%	2%	2%	1%	1%	40%	40%
Malta	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	20%	20%
Netherlands	0%	0%	0%	3%	8%	14%	20%	24%	25%	41%	50%	55%	55%
Poland	0%	0%	0%	0%	1%	1%	2%	2%	2%	1%	1%	45%	45%
Portugal	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	20%	20%
Romania	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	45%	45%
Slovakia	0%	0%	0%	0%	1%	1%	2%	2%	2%	1%	1%	45%	45%
Slovenia	0%	0%	0%	0%	1%	1%	2%	2%	2%	1%	1%	20%	20%
Spain	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	20%	20%
Sweden	0%	0%	0%	6%	12%	20%	28%	33%	33%	23%	24%	70%	70%
United Kingdom	0%	0%	0%	1%	2%	4%	6%	7%	7%	5%	5%	40%	40%

Table 110. Share of new-built residential dwellings implementing LBVU

LBVU in New-Built	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2050
EU-27					0%	0%	0%	0%	0%	1%	2%	16%	**16%**
EU-28 (incl. UK)					**0%**	**0%**	**0%**	**0%**	**0%**	**1%**	**2%**	**17%**	**17%**
Austria	0%	0%	0%	0%	0.3%	1%	1%	1%	0.2%	0%	0%	25%	25%
Belgium	0%	0%	0%	0%	0.1%	0%	0%	0%	0.1%	0%	0%	10%	10%
Bulgaria	0%	0%	0%	0%	0.0%	0%	0%	0%	0.0%	0%	0%	25%	25%

Croatia	0%	0%	0%	0%	0.0%	0%	0%	0%	0.0%	0%	0%	10%	10%
Cyprus	0%	0%	0%	0%	0.0%	0%	0%	0%	0.0%	0%	0%	10%	10%
Czech Rep.	0%	0%	0%	0%	0.0%	0%	0%	0%	0.0%	0%	0%	25%	25%
Denmark	0%	0%	0%	0%	0.4%	1%	2%	2%	0.3%	0%	0%	20%	20%
Estonia	0%	0%	0%	0%	0.1%	0%	1%	1%	0.1%	0%	0%	30%	30%
Finland	0%	0%	0%	0%	0.4%	0%	0%	0%	0.1%	0%	0%	0%	0%
France	0%	0%	0%	0%	0.0%	0%	0%	0%	0.6%	0%	0%	10%	10%
Germany	0%	0%	0%	0%	0.1%	0%	0%	1%	2.1%	4%	7%	25%	25%
Greece	0%	0%	0%	0%	0.0%	0%	0%	0%	0.0%	0%	0%	10%	10%
Hungary	0%	0%	0%	0%	0.0%	0%	0%	0%	0.0%	0%	0%	25%	25%
Ireland	0%	0%	0%	0%	0.1%	0%	0%	0%	0.1%	0%	0%	20%	20%
Italy	0%	0%	0%	0%	0.0%	0%	0%	0%	0.0%	0%	0%	10%	10%
Latvia	0%	0%	0%	0%	0.0%	0%	0%	0%	0.0%	0%	0%	30%	30%
Lithuania	0%	0%	0%	0%	0.0%	0%	0%	0%	0.0%	0%	0%	30%	30%
Luxembourg	0%	0%	0%	0%	0.0%	0%	0%	0%	0.0%	0%	0%	10%	10%
Malta	0%	0%	0%	0%	0.0%	0%	0%	0%	0.0%	0%	0%	10%	10%
Netherlands	0%	0%	0%	0%	0.4%	1%	1%	1%	1.3%	9%	16%	20%	20%
Poland	0%	0%	0%	0%	0.0%	0%	0%	0%	0.0%	0%	0%	30%	30%
Portugal	0%	0%	0%	0%	0.0%	0%	0%	0%	0.0%	0%	0%	10%	10%
Romania	0%	0%	0%	0%	0.0%	0%	0%	0%	0.0%	0%	0%	25%	25%
Slovakia	0%	0%	0%	0%	0.0%	0%	0%	0%	0.0%	0%	0%	25%	25%
Slovenia	0%	0%	0%	0%	0.0%	0%	0%	0%	0.0%	0%	0%	10%	10%
Spain	0%	0%	0%	0%	0.0%	0%	0%	0%	0.0%	0%	0%	10%	10%
Sweden	0%	0%	0%	0%	0.5%	1%	2%	2%	0.4%	0%	0%	20%	20%
United Kingdom	0%	0%	0%	0%	0.1%	0%	0%	0%	0.1%	0%	0%	20%	20%

Table 111. Share of new-built residential dwellings implementing CUVU

CUVU in New-Built	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2050
EU-27					**20%**	**34%**	**49%**	**61%**	**58%**	**50%**	**38%**	**27%**	**25%**
EU-28 (incl. UK)					**19%**	**33%**	**49%**	**61%**	**57%**	**48%**	**36%**	**26%**	**24%**
Austria	10%	10%	10%	17%	10.0%	25%	41%	47%	40%	23%	14%	10%	10%
Belgium	12%	12%	12%	12%	11.8%	30%	48%	56%	47%	31%	25%	25%	25%
Bulgaria	12%	12%	12%	12%	12.2%	31%	50%	58%	49%	28%	16%	10%	10%
Croatia	12%	12%	12%	12%	12.2%	31%	50%	58%	49%	35%	30%	30%	30%
Cyprus	12%	12%	12%	12%	12.5%	32%	51%	59%	50%	36%	30%	30%	30%
Czech Rep.	12%	12%	12%	12%	12.2%	31%	50%	58%	49%	28%	16%	10%	10%
Denmark	9%	9%	9%	9%	8.7%	22%	35%	41%	35%	20%	12%	10%	10%
Estonia	11%	11%	11%	11%	11.2%	28%	46%	53%	45%	31%	25%	25%	25%
Finland	1%	1%	1%	2%	3.3%	2%	1%	0%	0%	0%	0%	0%	0%
France	45%	45%	45%	45%	45.0%	45%	45%	46%	47%	48%	49%	50%	50%
Germany	18%	18%	18%	18%	18%	34%	50%	56%	47%	27%	16%	10%	10%
Greece	12%	12%	12%	12%	12.3%	31%	50%	58%	49%	36%	30%	30%	30%
Hungary	12%	12%	12%	12%	12.2%	31%	50%	58%	49%	28%	16%	10%	10%
Ireland	12%	12%	12%	12%	11.8%	30%	48%	56%	47%	31%	23%	20%	20%
Italy	12%	12%	12%	12%	12.2%	31%	50%	58%	49%	35%	30%	30%	30%
Latvia	12%	12%	12%	12%	12.2%	31%	50%	58%	49%	32%	25%	25%	25%
Lithuania	12%	12%	12%	12%	12.2%	31%	50%	58%	49%	32%	25%	25%	25%
Luxembourg	12%	12%	12%	12%	12.2%	31%	50%	58%	49%	35%	30%	30%	30%
Malta	12%	12%	12%	12%	12.5%	32%	51%	59%	50%	36%	30%	30%	30%
Netherlands	55%	63%	71%	74%	74.0%	71%	68%	62%	51%	40%	32%	25%	25%
Poland	12%	12%	12%	12%	12.2%	31%	50%	58%	49%	32%	25%	25%	25%

Portugal	12%	12%	12%	12%	12.5%	32%	51%	59%	50%	36%	30%	30%	30%
Romania	12%	12%	12%	12%	12.5%	32%	51%	59%	50%	29%	16%	10%	10%
Slovakia	12%	12%	12%	12%	12.2%	31%	50%	58%	49%	28%	16%	10%	10%
Slovenia	12%	12%	12%	12%	12.2%	31%	50%	58%	49%	35%	30%	30%	30%
Spain	12%	12%	12%	12%	12.5%	32%	51%	59%	50%	36%	30%	30%	30%
Sweden	8%	8%	8%	8%	8.1%	20%	33%	38%	32%	18%	12%	10%	10%
United Kingdom	12%	12%	12%	12%	11.6%	29%	47%	55%	46%	31%	23%	20%	20%

Table 112. Share of new-built residential dwellings implementing LUVUc

LUVUc in New-Built	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2050
EU-27					5%	6%	8%	9%	7%	6%	5%	3%	3%
EU-28 (incl. UK)					**5%**	**6%**	**8%**	**9%**	**7%**	**6%**	**5%**	**2%**	**2%**
Austria	4%	4%	4%	4%	4.0%	5%	7%	7%	6%	5%	3%	0%	0%
Belgium	5%	5%	5%	5%	4.7%	7%	8%	9%	8%	6%	4%	0%	0%
Bulgaria	5%	5%	5%	5%	4.9%	7%	9%	9%	8%	7%	4%	0%	0%
Croatia	5%	5%	5%	5%	4.9%	7%	9%	9%	8%	8%	9%	10%	10%
Cyprus	5%	5%	5%	5%	5.0%	7%	9%	9%	8%	8%	9%	10%	10%
Czech Rep.	5%	5%	5%	5%	4.9%	7%	9%	9%	8%	7%	4%	0%	0%
Denmark	3%	3%	3%	3%	3.5%	5%	6%	7%	6%	5%	3%	0%	0%
Estonia	4%	4%	4%	4%	4.5%	6%	8%	8%	7%	6%	4%	0%	0%
Finland	20%	20%	20%	20%	20%	15%	23%	7%	8%	7%	6%	0%	0%
France	4%	4%	4%	4%	4.1%	6%	8%	9%	8%	8%	5%	0%	0%
Germany	3%	3%	3%	3%	3.0%	4%	6%	7%	7%	4%	2%	0%	0%
Greece	5%	5%	5%	5%	4.9%	7%	9%	9%	8%	8%	9%	10%	10%
Hungary	5%	5%	5%	5%	4.9%	7%	9%	9%	8%	7%	4%	0%	0%
Ireland	5%	5%	5%	5%	4.7%	7%	8%	9%	8%	6%	4%	0%	0%
Italy	5%	5%	5%	5%	4.9%	7%	9%	9%	8%	8%	9%	10%	10%
Latvia	5%	5%	5%	5%	4.9%	7%	9%	9%	8%	7%	4%	0%	0%
Lithuania	5%	5%	5%	5%	4.9%	7%	9%	9%	8%	7%	4%	0%	0%
Luxembourg	5%	5%	5%	5%	4.9%	7%	9%	9%	8%	7%	4%	0%	0%
Malta	5%	5%	5%	5%	5.0%	7%	9%	9%	8%	8%	9%	10%	10%
Netherlands	2%	2%	2%	2%	2.3%	3%	5%	5%	4%	2%	1%	0%	0%
Poland	5%	5%	5%	5%	4.9%	7%	9%	9%	8%	7%	4%	0%	0%
Portugal	5%	5%	5%	5%	5.0%	7%	9%	9%	8%	8%	9%	10%	10%
Romania	5%	5%	5%	5%	5.0%	7%	9%	9%	8%	7%	4%	0%	0%
Slovakia	5%	5%	5%	5%	4.9%	7%	9%	9%	8%	7%	4%	0%	0%
Slovenia	5%	5%	5%	5%	4.9%	7%	9%	9%	8%	8%	9%	10%	10%
Spain	5%	5%	5%	5%	5.0%	7%	9%	9%	8%	8%	9%	10%	10%
Sweden	3%	3%	3%	3%	3.2%	4%	6%	6%	5%	4%	3%	0%	0%
United Kingdom	5%	5%	5%	5%	4.6%	6%	8%	9%	7%	6%	4%	0%	0%

Table 113. Share of renovated residential dwellings implementing CBVU

CBVU in Renovated	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2050
EU-27					1%	2%	3%	5%	5%	5%	6%	27%	27%
EU-28 (incl. UK)					1%	2%	3%	5%	5%	5%	6%	28%	28%
Austria	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	35%	35%
Belgium	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	30%	30%

Bulgaria	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	30%	30%
Croatia	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	15%	15%
Cyprus	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	15%	15%
Czech Rep.	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	30%	30%
Denmark	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	60%	60%
Estonia	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	30%	30%
Finland	0%	0%	0%	2%	4%	7%	10%	126%	67%	67%	67%	67%	67%
France	0%	0%	0%	0%	0%	0%	0%	0%	3.2%	3%	3%	25%	25%
Germany	0%	0%	0%	0%	1%	2%	3%	4%	3.5%	3%	3%	30%	30%
Greece	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	15%	15%
Hungary	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	30%	30%
Ireland	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	30%	30%
Italy	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	15%	15%
Latvia	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	30%	30%
Lithuania	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	30%	30%
Luxembourg	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	30%	30%
Malta	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	15%	15%
Netherlands	0%	0%	0%	1%	3%	5%	6%	9%	12.8%	22%	30%	35%	35%
Poland	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	30%	30%
Portugal	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	15%	15%
Romania	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	30%	30%
Slovakia	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	30%	30%
Slovenia	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	15%	15%
Spain	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	15%	15%
Sweden	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	65%	65%
United Kingdom	0%	0%	0%	1%	3%	5%	6%	8%	7.5%	5%	5%	30%	30%

Table 114. Share of renovated residential dwellings implementing LBVU

LBVU in Renovated	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2050
EU-27					**1%**	**3%**	**6%**	**8%**	**3%**	**3%**	**5%**	**15%**	**14%**
EU-28 (incl. UK)					**1%**	**3%**	**5%**	**7%**	**3%**	**3%**	**5%**	**16%**	**15%**
Austria	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	20%	20%
Belgium	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	10%	10%
Bulgaria	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	25%	25%
Croatia	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	5%	5%
Cyprus	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	5%	5%
Czech Rep.	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	25%	25%
Denmark	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	15%	15%
Estonia	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	15%	15%
Finland	0%	0%	0%	1%	2.4%	5%	7%	8%	7.6%	7%	10%	23%	23%
France	0%	0%	0%	0%	0.1%	0%	0%	0%	1.1%	1%	1%	10%	10%
Germany	0%	0%	0%	1%	2.3%	4%	6%	7%	4.3%	4%	7%	25%	25%
Greece	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	5%	5%
Hungary	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	25%	25%
Ireland	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	20%	20%
Italy	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	5%	5%
Latvia	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	15%	15%
Lithuania	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	15%	15%
Luxembourg	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	10%	10%
Malta	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	5%	5%
Netherlands	0%	0%	0%	1%	2.3%	4%	6%	8%	7.5%	20%	30%	30%	30%
Poland	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	15%	15%

Portugal	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	5%	5%
Romania	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	25%	25%
Slovakia	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	25%	25%
Slovenia	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	5%	5%
Spain	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	5%	5%
Sweden	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	25%	25%
United Kingdom	0%	0%	0%	2%	4.1%	11%	18%	17%	3.4%	2%	3%	10%	10%

Table 115. Share of renovated residential dwellings implementing CUVU

CUVU in Renovated	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2050
EU-27					**37%**	**37%**	**37%**	**33%**	**30%**	**30%**	**24%**	**18%**	**16%**
EU-28 (incl. UK)					**36%**	**36%**	**36%**	**32%**	**30%**	**30%**	**23%**	**20%**	**18%**
Austria	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	13%	14%	15%	15%
Belgium	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	16%	23%	30%	30%
Bulgaria	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	9%	6%	3%	3%
Croatia	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	13%	16%	20%	20%
Cyprus	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	13%	16%	20%	20%
Czech Rep.	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	9%	6%	3%	3%
Denmark	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	13%	14%	15%	15%
Estonia	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	12%	11%	10%	10%
Finland	5%	5%	5%	7%	10.0%	10%	10%	10%	7%	6%	5%	5%	5%
France	30%	30%	30%	30%	30.0%	30%	30%	32%	35%	40%	45%	50%	50%
Germany	5%	5%	5%	5%	4.7%	9%	13%	15%	13%	9%	6%	3%	3%
Greece	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	13%	16%	20%	20%
Hungary	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	9%	6%	3%	3%
Ireland	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	13%	16%	20%	20%
Italy	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	13%	16%	20%	20%
Latvia	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	12%	11%	10%	10%
Lithuania	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	12%	11%	10%	10%
Luxembourg	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	16%	23%	30%	30%
Malta	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	13%	16%	20%	20%
Netherlands	55%	63%	71%	74%	74%	71%	68%	62%	51%	40%	29%	20%	20%
Poland	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	12%	11%	10%	10%
Portugal	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	13%	16%	20%	20%
Romania	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	9%	6%	3%	3%
Slovakia	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	9%	6%	3%	3%
Slovenia	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	13%	16%	20%	20%
Spain	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	13%	16%	20%	20%
Sweden	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	9%	7%	5%	5%
United Kingdom	3%	3%	3%	3%	3.2%	8%	13%	15%	13%	16%	23%	30%	30%

Table 116. Share of renovated residential dwellings implementing LUVUc

LUVUc in Renovated	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2050
EU-27					**20%**	**24%**	**29%**	**31%**	**25%**	**19%**	**15%**	**8%**	**8%**
EU-28 (incl. UK)					**20%**	**25%**	**29%**	**32%**	**26%**	**20%**	**15%**	**8%**	**8%**
Austria	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	18%	5%	5%
Belgium	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	18%	5%	5%

Bulgaria	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	18%	7%	7%
Croatia	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	20%	10%	10%
Cyprus	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	20%	10%	10%
Czech Rep.	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	18%	7%	7%
Denmark	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	18%	5%	5%
Estonia	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	20%	10%	10%
Finland	10%	10%	10%	10%	10.0%	8%	6%	4%	3%	2%	1%	0%	0%
France	21%	21%	21%	21%	21.0%	21%	21%	18%	15%	16%	13%	10%	10%
Germany	17%	17%	17%	17%	16.5%	24%	32%	33%	22%	15%	10%	7%	7%
Greece	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	20%	10%	10%
Hungary	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	18%	7%	7%
Ireland	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	18%	5%	5%
Italy	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	20%	10%	10%
Latvia	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	20%	10%	10%
Lithuania	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	20%	10%	10%
Luxembourg	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	18%	5%	5%
Malta	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	20%	10%	10%
Netherlands	17%	17%	17%	17%	16.5%	24%	32%	32%	18%	15%	12%	10%	10%
Poland	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	20%	10%	10%
Portugal	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	20%	10%	10%
Romania	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	18%	7%	7%
Slovakia	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	18%	7%	7%
Slovenia	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	20%	10%	10%
Spain	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	20%	10%	10%
Sweden	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	16%	0%	0%
United Kingdom	26%	26%	26%	26%	26.3%	36%	46%	50%	42%	30%	18%	5%	5%

3 Sales estimate for non-continuously operating LUVUs

These data are for reference only: LUVUnc have not been used in final scenario analysis.

In Riviere 2009, Lot 10 prep. study on res. ventilation, table 2-17, year 2005 for EU-25, the stock of decentralised VU is 68 mln, of which 63.4 mln intermittent and 4.5 mln continuous. Market of decentralised estimated in 7.3 mln o/w 3.9 hoods and 3.4 fans.

In Haendel 2010, Supplementary study, table 2.2.1-1: in year 2003 for EU27, 29 mln dwellings have been retrofitted with exhaust wall/window fans in e.g. bathroom and kitchen, avg. 1.6 fans / dwelling, for a stock of 46.4 mln fans.
In addition 4.6 mln dwellings with room-based extract fans, avg. 2.6 fans / dwelling, for a stock of 11.9 mln fans.
So total stock of LUVU around 58.3 mln fans in 33.6 mln dwellings.
Corresponding annual LUVU sales in 2003 (tables 2.2.2-1 and -2): 4.1 mln o/w 3.6 mln like-for-like replacement, 0.4 mln for new-built and 0.1 for renovation (at 0.05% renovation rate).

In Riviere 2012, Task 2 of Lot 6 prep. study, table 2-11, sales of 6 mln local fans < 125W are mentioned in year 2008 for EU-27. Although this is for collective residential and non-residential together, these sales would lead to a stock of 102 mln LUVUs (life 17 years), which would correspond to roughly 51 mln dwellings (if 2 LUVU/dwelling).

The data from Haendel have been used for year 2003:
Total LUVU sales in 2003: 4.1 mln
of which LUVUc: 0.245 mln (6%, following Riviere 2009)
of which LUVUnc: 3.855 mln (94%)
These sales are assumed to exclude range hoods.

Haendel reports 3.6 mln replacement sales in 2003, so applying a lifetime of 17 years, in good approximation, these 3.6 mln were the total sales in 1986. These are expected to be almost all LUVUnc.

Linear interpolation applied between 1986 and 2003. Before 1986 extrapolated trend.

Between 2003 and 2020 the sales for LUVUnc have been assumed to remain constant.

For 2050, a target of 15% has been set for the share of dwellings using one or more LUVUnc. This corresponds to having 4.15 mln sales in 2050, applying linear interpolation between 2003 and 2050.

Annex V: Non-residential Buildings

1. Non-Residential Building Stock in EU BSO database

According to the EU Building Stock Observatory (BSO) database, in the period 2010-2013 there were around 15.7-16.0 mln non-residential buildings in EU-28. These covered a floor area of 6.7-6.9 million m2, for an average area per building of 424-429 m2. The breakdown suggests that this includes offices, wholesale and retail, hotels and restaurants, health care and educational buildings. Data for 'other' buildings are present for only 9 of the 28 Member States. Consequently this does not seem to cover all non-residential buildings, e.g. a large part of industrial buildings seems to be missing.

The average annual variation of the stock in the EU BSO database over the period 2010-2013 is around 0.5% (positive for some countries; negative for others). This would suggest a new-construction rate of 0.6-0.8% (adding a reasonable demolition rate).

Table 117. Number and Area of Non-Residential Buildings, per Member State and EU totals (Source: EU Building Stock Observatory database)

	Number of Buildings (thousands)					Total Area of Buildings (M m2)					Average Area per Building (m2)			
	2010	**2011**	**2012**	**2013**		**2010**	**2011**	**2012**	**2013**		**2010**	**2011**	**2012**	**2013**
EU-27	14,209	14,271	14,398	14,476		5,869	5,917	5,993	6,048		413	415	416	418
EU-28 (incl. UK)	15,742	15,795	15,926	15,982		6,667	6,717	6,806	6,856		424	425	427	429
Austria	194	195	197	198		116	117	119	118		599	600	604	596
Belgium	786	785	782	782		180	184	187	185		229	235	239	237
Bulgaria	65	64	64	64		91	91	90	89		1,398	1,414	1,406	1,394
Croatia	119	118	117	118		35	35	35	36		296	298	302	302
Cyprus	41	41	42	42		8	8	8	8		187	190	193	196
Czech Rep.	137	138	141	140		176	175	175	175		1,282	1,271	1,246	1,249
Denmark	147	147	148	148		111	113	114	115		759	766	774	780
Estonia	19	19	19	20		13	12	12	13		650	635	641	632
Finland	219	222	225	227		114	117	120	122		520	525	532	536
France	1,417	1,430	1,439	1,457		922	931	938	948		651	651	652	651
Germany	2,901	2,944	2,986	3,029		1,608	1,635	1,671	1,671		554	555	559	552
Greece	531	499	468	451		84	80	77	74		159	160	164	163
Hungary	112	115	120	121		139	142	145	146		1,243	1,232	1,212	1,208
Ireland	67	66	67	68		84	81	82	82		1,254	1,224	1,211	1,207
Italy	2,178	2,204	2,285	2,252		288	289	287	285		132	131	126	126
Latvia	28	29	28	29		23	24	24	24		813	822	826	827
Lithuania	85	85	86	89		50	49	51	52		586	582	590	582
Luxembourg	11	12	12	13		13	13	14	14		1,153	1,145	1,130	1,127
Malta	15	14	15	15		3	3	3	3		203	207	211	211
Netherlands	927	935	932	923		534	539	544	549		576	576	583	595
Poland	850	851	854	881		472	472	484	499		555	554	566	566
Portugal	664	643	618	610		107	107	104	104		162	166	168	171
Romania	357	357	371	378		62	62	62	63		175	173	168	165
Slovakia	15	15	15	15		102	100	98	102		6,697	6,674	6,657	6,650
Slovenia	74	73	76	77		14	14	14	14		185	186	186	187
Spain	1,935	1,949	1,962	1,967		343	346	348	349		178	178	178	178
Sweden	316	320	326	362		177	179	187	208		560	560	574	576
United Kingdom	1,533	1,524	1,529	1,506		797	800	813	808		520	525	532	536

Table 118. Number and Area of Non-Residential Buildings, EU-28 total per type of Building (Source: EU Building Stock Observatory database)

EU-28	Number of Buildings (thousands)					Total Area of Buildings (M m2)					Average Area per Building (m2)			
	2010	**2011**	**2012**	**2013**		**2010**	**2011**	**2012**	**2013**		**2010**	**2011**	**2012**	**2013**
Total	15,742	15,795	15,926	15,982		6,667	6,717	6,806	6,856		424	425	427	429
Offices (Private and Public)	3,101	3,161	3,236	3,277		1,711	1,777	1,852	1,873		552	562	572	572
Wholesale & Retail	6,035	5,985	5,979	5,970		1,841	1,814	1,794	1,811		305	303	300	303
Hotels and Restaurants	1,142	1,153	1,175	1,167		955	951	953	944		836	824	811	808
Health care	580	587	598	606		442	449	457	465		762	764	765	767
Educational	824	826	836	838		1,105	1,129	1,150	1,161		1,341	1,367	1,375	1,384
Not specified	4,059	4,082	4,102	4,124		614	597	600	604		151	146	146	146

Notes:

Source for 2000 to 2015: EU Buildings Observatory, Copyright European Commission 2016 (https://ec.europa.eu/energy/en/eu-buildings-database), extracted August 2019.
At time of extraction, web-tool for database access was not completely functional (as also stated on website); difficulties encountered during extraction.
Data for Austria were missing in extraction and had to be estimated by VHK.
Number of buildings for Czech Republic, Hungary, Latvia and Slovenia computed as sum of data reported for subcategories of buildings.

For a limited number of countries additional data for other years are available (in number of buildings and/or in building floor area), within the 2000-2015 period. These are not reported here.

The number of reported buildings for the subtypes (offices, wholesale and retail, hotels and restaurants, health care, educational) does not seem to cover all types of non-residential buildings, e.g. industrial buildings, but also other types, seem to be missing. Yet, only 9 of the 28 countries present data for 'other' buildings.

Examining the available data in detail raises doubts on their accuracy. As an example, the average area of a health care building is 400-500 m2 for 17 countries but 1300-1700 m2 for the other 11 countries. A similar situation is encountered for hotels and restaurants that are e.g. average 250 m2 in Italy but 2172 m2 in Germany. And the average wholesale and retail building is average e.g. 61 m2 in Spain, but 1800 m2 in The Netherlands.

Work on the EU BSO (Building Stock Observatory) is ongoing. For the progress of the project see e.g. https://aldren.eu › uploads › 2019/02 › EU-BSO-Workshop_2_-2019

2. Non-Residential Building Stock in Ecofys 2011 report

An Ecofys study of 2011 [39] reports data on the EU-27 stock of non-residential buildings, probably for year 2009. This stock was derived by extrapolating the data for five reference countries (Sweden, Germany, Spain, Hungary, Poland) to EU level.

In 2009, the study reports 12.5-14 mln [40] non-residential buildings with a total floor area of 12.4-13.3 bn m2 (Table 119, Table 120). This includes industrial buildings and 'other' buildings. Note that the number of buildings is smaller than in the EU BSO database (previous point; 15.7-16 mln) although not all industrial and 'other' buildings seemed to be included there. Instead, the Ecofys value for floor area is much larger than the one from the EU BSO (6.7-6.9 bn m2), almost double.

[39] Panorama of the European non-residential construction sector, Final report, Ecofys 2011

[40] In different tables of the same report, different total values appear.

Ecofys also reports the age-structure of the non-residential buildings: 70% of the buildings in the 2009 stock was built before 1990.

An average new construction rate of 2.1% is reported (Table 121), but this is mainly based on the years before the economic crisis. This could explain why the value is much higher than the average annual variation of the stock in the EU BSO database over the period 2010-2013, which is around 0.5%. Even when adding a reasonable demolition rate (Ecofys reports 0.2% in 2009), this would imply a new construction rate below 1%.

Ecofys reports an average energy-related renovation rate of 2.1%. However, considering the Ecofys definitions for 'complete', 'partial' and 'particular' renovations, only 'complete' renovations involve installing or upgrading the HVAC system, and in that case the renovation rate relevant for this study would be closer to 0.4-0.5%.

Table 119. EU-27 Non-Residential Building Stock in 2009 according to Ecofys, number of buildings and floor area (source: [39])

Table 14. Extrapolated EU27 building stock including "Other buildings"

	Non-government owned offices	Trade facilities	Gastronomic facilities	Health facilities	Educational facilities	Industrial buildings	Public buildings	Other buildings	**Total**
Northern Europe EU27									
Buildings	27,134	16,679	6,597	20,288	59,247	194,613	27,134	26,885	**356,547**
Floor area [Mio m²]	47.7	29.3	11.6	35.6	104.1	194.6	9.0	47.2	**479.1**
Western Europe EU27									
Buildings	1,200,354	1,192,100	1,465,150	121,663	144,214	1,180,094	871,799	642,660	**6,818,034**
Floor area [Mio m²]	917.4	1,490.1	596.0	781.1	905.4	1,180.1	871.8	642.7	**7.384.6**
North Eastern Europe EU27									
Buildings	39,860	333,388	85,764	19,043	37,356	275,103	168,553	1,124,362	**2,083,428**
Floor area [Mio m²]	53.1	213.8	35.0	15.5	99.3	349.3	135.0	360.3	**1,261.2**
South Eastern Europe EU27									
Buildings	4,627	734,185	232,186	19,887	56,246	204,413	159,798	103,114	**1,514,456**
Floor area [Mio m²]	36.1	131.7	124.7	46.3	63.7	316.4	92.3	141.2	**952.5**
Southern Europe EU27									
Buildings	86,395	312,650	118,469	52,653	158,694	522,299	25,090	396,655	**1,672,906**
Floor area [Mio m²]	117.7	426.0	161.4	71.7	216.2	711.6	34.2	540.4	**2,279.2**
Total EU27									
Buildings EU27	1,358,370	2,589,001	1,908,167	233,535	455,757	2,376,522	1,230,343	2,293,676	**12,455,371**
Floor area EU27	1,171.9	2,291.0	928.7	950.2	1,388.7	2,752.0	1,142.3	1,731.8	**12,356.6**

Table 120. Age structure of EU-27 Non-Residential Building Stock in 2009 according to Ecofys, for number of buildings and for floor area (source: [39])

Table 15. Number of non-residential buildings in the EU27 [1,000 units]

Age structure	Private offices	Trade facilities	Gastro-nomic facilities	Health facilities	Educa-tional facilities	Industrial buildings	Public buildings	Other buildings	Total
Until 1980	594.2	1,566.7	1,291.4	143.9	333.7	1,636.2	687.4	1.841.1	**8.102.7**
1980 -1989	223.1	329.7	373.5	29.9	71.7	329.3	173.5	183.6	**1701.8**
1990 -1999	373.3	459.1	207.2	38.4	56.1	237.1	318.1	505.7	**2,190.9**
2000-2009	197.3	481.3	99.7	35.3	22.2	377.6	177.0	601.0	**1,999.5**
Total	**1,387.8**	**2,836.8**	**1,971.8**	**247.6**	**483.1**	**2,580.2**	**1,356.0**	**3,131.4**	**13,994.8**

Table 16. Floor area of the non-residential building stock in the EU27 [Mio m²]

Age structure	Private offices	Trade facilities	Gastro-nomic facilities	Health facilities	Educa-tional facilities	Industrial buildings	Public buildings	Other buildings	Total
Until 1980	507.6	1,247.5	609.2	611.8	1,124.5	1,867.0	619.3	1,190.3	**7,783.1**
1980 -1989	185.8	272.1	176.0	121.7	152.4	362.5	169.0	205.6	**1,642.2**
1990 -1999	307.4	409.4	97.4	123.1	124.6	219.4	279.0	202.9	**1,757.1**
2000-2009	210.3	520.2	71.7	104.9	60.6	561.5	175.7	400.1	**2,108.2**
Total	**1,211.2**	**2,449.2**	**954.3**	**961.5**	**1.462.1**	**3,010.4**	**1,242.9**	**1,999.0**	**13,290.6**

Table 121. New construction rates, Demolition rates and Renovation rates for EU-27 Non-Residential Buildings according to Ecofys (source: [39])

Table 55. Summary of metabolism rates in representative countries and EU27

	Germany	Hungary	Poland	Spain	Sweden	EU27 (weighted)
New construction rate						
Private offices	0.7 %	4.0%	5.3 %	4.7 %	1.2 %	**2.6 %**
Trade facilities	2.4 %	1.9 %	4.4 %	1.5 %	3.5 %	**2.4 %**
Gastronomic facilities	0.1 %	0.9 %	2.6 %	1.4 %	1.8 %	**0.9 %**
Health facilities	1.4 %	0.8 %	3.1 %	3.1%	0.5 %	**2.0 %**
Educational facilities	1.4 %	0.8 %	1.0 %	0.5%	0.4 %	**1.0 %**
Industrial buildings	3.5 %	1.7 %	1.9 %	3.5 %	1.3 %	**3.1 %**
Public buildings	0.9 %	0.7 %	5.3 %	4.0 %	n.a. %	**2.2 %**
Other buildings	1.0 %	2.7 %	1.6 %	8.4 %	2.5 %	**3.2 %**
Total (weighted)	**1.0 %**	**1.7 %**	**2.3 %**	**4.2 %**	**1.3 %**	**2.1 %**
Demolition rate						
Non-residential sector	0.29 %	n.a.	n.a.	0.1 %	0.6 %*	**0.2 %**
Renovation rate						
Overall renovation rate	**11.0 %**	**6.2 %**	**5.6 %**	**20.1 %**	**14.3 %**	**12.4 %**
Energy related renovation rate	2.3 %	1.7 %	1.2 %	4.1 %	2.8 %	**2.6 %**
Not energy related renovation rate	8.7 %	4.5 %	4.4 %	16.0 %	11.4 %	**9.8 %**

Table 53. Calculated renovation rates in the selected countries, divided by energy related and not energy related renovations

Country	Total renovation rate (modernisation, maintenance and energy related refurbishments)	Thereof energy related renovation rate	Thereof not energy related renovation rate
Germany	11.0%	2.3%	8.7%
Sweden	14.3%	2.8%	11.4%
Hungary	6.2%	1.7%	4.5%
Poland	5.6%	1.2%	4.4%
Spain	20.1%	4.1%	16.0%

Table 54. Renovation rates in the selected countries, divided by renovation type and energy and not energy related renovations

Country	Energy related renovations			Not energy related renovations		
	complete renovation	partial renovation	particular renovation	complete renovation	partial renovation	particular renovation
Germany	0.5%	1.5%	0.3%	0.1%	3.4%	5.2%
Sweden	0.4%	2.1%	0.4%	0.1%	5.0%	6.4%
Hungary	0.2%	1.5%	0.0%	0.0%	3.6%	0.9%
Poland	0.2%	0.9%	0.1%	0.0%	2.2%	2.2%
Spain	0.7%	2.7%	0.6%	0.1%	5.9%	10.0%

Note: new construction rates based on 2005-2009 for Germany, 2001-2008 for Sweden, 2000-2010 for Hungary, 2005-2009 for Poland, 2005-2009 for Spain.
Note: Demolition rates for 2009.
Note: According to the Ecofys definitions of 'complete', 'partial' and 'particular' renovations, only 'complete' renovations involve installing or upgrading the HVAC system.

3. Area of Non-Residential Buildings from Building Heat demand report

The 2014 EU Building Heat demand report [33] provides data on the total EU-28 floor area of non-residential buildings, with a detailed breakdown per type of building / sector. These data have been further elaborated in the context of the ecodesign preparatory study on Lighting Systems [41], adding a breakdown per type of space inside the buildings.

A total floor area of 11.8 bn m2 for non-residential buildings in 2014 is estimated. This is slightly below the Ecofys estimates (12.4 – 13.3 bn m2), but much higher than the number from the EU BSO (6.7-6.9 bn m2).

[41] Preparatory study on lighting systems , 'Lot 37', VITO / VHK / Kreios / P.Waide for the European Commission DG ENER C3, December 2016

Table 122. Total EU-28 Area of Non-Residential Buildings in 2014, based on data in EU Buildings Heat demand report, overview, types of space per sector, and total areas per type of space (source: [33] and [41])

Overview

sector	EU-28 area M m2	Share % of total
Industry	2461	21%
Retail (&Wholesale)	2382	20%
Offices	2115	18%
Education	1302	11%
Hospitals (& HealthCare)	907	8%
Hotels & Restaurants	754	6%
Sports	544	5%
Other	1308	11%
Total Non-Residential	**11773**	100%
Residential	*21218*	

Types of spaces per sector

	EU-28 area M m2	% of area
Total Manufacturing / Industry	**2461**	**100.0%**
Production Area	1476	60%
Reception / Circulation Areas	246	10%
Toilets, showers, wardrobes	246	10%
Offices	246	10%
Technical Service Rooms	246	10%
Total Retail /Wholesale/Trade	**2382**	**100.0%**
Shops < 30 m2	643	27%
Shops > 30 m2	402	17%
Reception / Circulation Areas	450	19%
Common toilets and wardrobes	113	5%
Storeroom / Warehouse	774	32%
Total Hotel & Restaurant	**754**	**100.0%**
Rooms (excl. toilet/shower)	138	18%
Toilet/Shower in rooms	34	4%
Common toilets/wardrobes	27	4%
Reception/ Circulation areas	49	7%
Breakfast / Eating areas	285	38%
Coffee-shops, Bars, Discos	78	10%
Offices	11	2%
Meeting Rooms	33	4%
Kitchen	60	8%
Technical areas	40	5%
Total Education	**1302**	**100.0%**
Creche, play area	24	2%
(Pre-)Primary resting area	63	5%
Class Rooms	440	34%
Meeting Rooms	160	12%
Library	45	3%
Teacher's Room	25	2%

	EU-28 area M m2	% of area
Computer education area	45	3%
Reception/ Circulation Area	225	17%
Common toilets / wardrobes	69	5%
Standard Offices	134	10%
Technical Service Rooms	71	5%
Total Hospitals/Healthcare	**907**	**100.0%**
Wards / Bedrooms	191	21%
Dayroom / Eating Room	67	7%
Examination/Treatment Rooms	180	20%
Waiting Area	111	12%
Reception / Circulation Areas	129	14%
Toilets, wardrobes, showers	80	9%
Standard offices	49	5%
Laboratories	66	7%
Technical / Production Areas	34	4%
Total Offices	**2115**	**100.0%**
Cellular office	660	31%
Open Plan / Landscape Offices	609	29%
Reception/ Circulation Area	423	20%
Toilets / wardrobes / showers	148	7%
Meeting Rooms	169	8%
Copying, Server, Archive, Tech.	106	5%
Total Sports	**544**	**100.0%**
Sports Hall	242	44%
Toilets / wardrobes / showers	102	19%
Reception/ Circulation Area	66	12%
Mensa, Restaurant, Bar, Resting area	66	12%
Offices	68	12%
Parking in structures	**290**	**100%**

	EU-28 area M m2	% of area
public access	262	90%
private access (offices)	28	10%
Total Stations, Airports, similar	**107**	**100%**
passenger/client (waiting) area	42.8	40%
reception and circulation areas	32.1	30%
customs and security	5.35	5%
common toilets, wardrobes, etc	10.7	10%
offices	16.05	15%
Total Entertainment and news	**617**	
Video and Movie production and Cinemas	152	

	EU-28 area M m2	% of area
Radio and TV	107	
Theatre, Dancing, Amusement	358	
Total Miscellaneous	**294**	
Prisons	34	
Fire service activities	4	
Waste disposal / sewage	37	
Political, religious & churches	152	
Libraries, museums, zoo	67	
Total Agriculture	**35**	
Greenhouses (heated area)	20	
Live stock breed (heated area)	15	

Areas per types of space

type of space	EU-28 area M m2	Share % of total
circulation areas	1620	13.8%
manufacturing area	1476	12.5%
toilets, showers, wardrobes	829	7.0%
Storeroom / Warehouse	774	6.6%
offices (cellular)	660	5.6%
Shops < 30 m2	643	5.5%
offices (open space)	609	5.2%
Class rooms and similar	573	4.9%
offices (general, small)	525	4.5%
technical / service areas	502	4.3%
eating / drinking areas	496	4.2%
Shops > 30 m2	402	3.4%
meeting rooms	362	3.1%
Theatre, Dancing, Amusement park	358	3.0%
Parking in structures	290	2.5%
Sports Hall	242	2.1%
Hospital wards/bedrooms	191	1.6%
Examination / Treatment Rooms	180	1.5%
waiting areas	179	1.5%
Political and religious (incl. churches)	152	1.3%
Video & Movie production & Cinemas	152	1.3%
Hotel rooms (excl. toilet/shower)	138	1.2%
Libraries, museums, zoo	112	1.0%
Radio and TV	107	0.9%
Laboratories	66	0.6%
Kitchens	60	0.5%
Waste disposal / sewage	37	0.3%
Greenhouses & Livestock breeding	35	0.3%
Prisons	34	0.3%
Fire service activities	4	0.0%

4. New-built non-residential buildings

The information in the EU BSO on the annual number of new-built non-residential buildings is not complete: for many countries no data are available (Table 123, Table 124). For the countries where data are available over the 2010-2013 period, the amount of new-built is around 1% of the building stock.

Additional data for new-built non-residential buildings are available from the ZEBRA project, but in terms of floor area (Table 125). These data are also not complete, but cover different countries. Dividing these new-built floor areas by the total non-residential floor areas reported in the EU BSO, the amount of new-built seems to be around 2% of the building stock. However, as seen above, the total floor area in the EU BSO seems to be underestimated by a factor 2, so the real new-construction rate is probably closer to 1% also for the area data.

Table 123. Number of New-Built Non-Residential Buildings, for Member States and years where data are available (Source: EU Building Stock Observatory Database, download 20190911 https://ec.europa.eu/energy/en/eu-buildings-database)

units	**2000**		**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Sum								39,790	45,700	54,400	41,610	36,335	
Austria													
Belgium	6,400		4,220	4,510	4,520	4,780	4,430	4,750	4,590	4,540	4,460	4,490	
Bulgaria			6,110	7,040	7,050	6,090	4,870	4,580	5,550	5,110	4,830	4,510	
Croatia								1,380	1,310	1,100	1,170	1,130	
Cyprus													
Czech Rep.													
Denmark								1,600	1,550	1,340	1,440	1,520	
Estonia												785	
Finland													
France													
Germany													
Greece													
Hungary									5,240	6,140	5,330	5,030	3,330
Ireland													
Italy										10,730			
Latvia			2,070	2,510	2,210	2,090	1,530	1,150	1,480	1,540	1,490	1,610	
Lithuania												1,070	
Luxembourg	290		240	290	290	280	280	280	340	290	370	290	
Malta			330	270	260	190	200	460	410	420	410	510	
Netherlands													
Poland													
Portugal	11,430		10,800	11,200	10,880	10,540	9,330	8,340	8,440	8,180	7,230		
Romania			10,480	11,390	11,230	9,430	8,600	7,580	8,010	7,090	7,090	7,800	
Slovakia													
Slovenia													
Spain	15,970		19,160	21,410	20,830	13,930	12,180	9,670	8,780	7,920	7,790	7,590	
Sweden													
United Kingdom													

Note: annual totals cover different numbers of countries and are therefore not directly comparable.

Table 124. Share of New-Built Non-Residential Buildings in Building Stock, for Member States and years where data are available (Source: derived by VHK from EU BSO Database)

units	2000		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Sum								0.96%	1.08%	0.83%	0.98%		
Austria													
Belgium			0.53%	0.57%	0.57%	0.61%	0.56%	0.60%	0.59%	0.58%	0.57%	0.57%	0.53%
Bulgaria								7.03%	8.66%	8.01%	7.59%		
Croatia								1.16%	1.11%	0.94%	0.99%		
Cyprus													
Czech Rep.													
Denmark								1.09%	1.05%	0.91%	0.97%	1.02%	
Estonia													
Finland													
France													
Germany													
Greece													
Hungary									4.55%	5.13%	4.42%		
Ireland													
Italy										0.47%			
Latvia								4.04%	5.16%	5.41%	5.19%		
Lithuania													
Luxembourg								2.53%	2.91%	2.33%	2.92%		
Malta								3.17%	2.86%	2.86%	2.76%		
Netherlands													
Poland													
Portugal								1.26%	1.31%	1.32%	1.19%		
Romania								2.12%	2.24%	1.91%	1.87%		
Slovakia													
Slovenia													
Spain								0.50%	0.45%	0.40%	0.40%		
Sweden													
United Kingdom													

Table 125. Area of New-Built Non-Residential Buildings in M m2, and share in total non-residential building area, for Member States and years where data are available
(Source for new-built areas: http://www.zebra-monitoring.enerdata.eu/overall-building-activities/share-of-new-dwellings-in-residential-stock.html#share-of-new-construction-in-total-non-residential-floor-area.html, download: 20190828)
(Source for shares: VHK computation, dividing the ZEBRA new-built areas by the total NRES building stock areas from EU BSO, where data were available in both sources)

	New-built floor area (M m2)							Share of BSO total floor area					
	2010	2011	2012	2013	2014	2015		2010	2011	2012	2013	2014	2015
Sum	106	102	94	91	83			2.3%	2.2%	2.2%	2.1%		
Austria	3.33	2.64	2.77	2.35	2.41			2.1%	1.6%	1.7%	1.5%		
Belgium	6.10	6.38	6.52	6.16	6.23	5.76		3.4%	3.5%	3.5%	3.3%		
Bulgaria													
Croatia													
Cyprus													
Czech Rep.	1.06	0.98	1.18	1.08	1.24			1.0%	1.0%	1.0%	1.0%	0.9%	
Denmark	2.99	2.26	2.47	1.98				2.4%	1.9%	2.0%	1.6%		

Estonia													
Finland										0.25%			
France	21.88	24.26	23.32	27.27	24.99	22.89		2.4%	2.6%	2.5%	2.9%		
Germany	25.48	26.00	26.62	27.23	26.31			1.6%	1.6%	1.6%	1.6%		
Greece													
Hungary													
Ireland													
Italy	16.40	14.14	11.17	7.98	7.09	3.81		4.0%	3.4%	2.6%	1.9%		
Latvia													
Lithuania	0.21	0.24	0.15	0.27				0.4%	0.5%	0.3%	0.5%		
Luxembourg	0.21	0.12	0.22	0.22				1.6%	0.9%	1.5%			
Malta													
Netherlands	3.50	3.20						1.4%	1.2%				
Poland													
Portugal	11.15	9.00	9.36	7.48	4.82								
Romania	3.43	4.26	3.39	3.17	3.83	2.66		1.5%	1.9%	1.4%	1.3%		
Slovakia													
Slovenia													
Spain	8.12	5.75	3.95	3.38	3.05			2.4%	1.7%	1.1%	1.0%		
Sweden	2.40	3.02	2.42	2.38	2.55			1.1%	1.4%	1.0%	0.9%		
United Kingdom													

Note: annual totals cover different numbers of countries and are therefore not directly comparable.

5. Renovated non-residential buildings

Some data on the renovation of non-residential buildings are available from the ZEBRA-project (http://www.zebra-monitoring.enerdata.eu/overall-building-activities). They are limited to the period 2010-2016, but only available for Belgium, Czech Republic, Italy, The Netherlands, Poland and Spain (and not always for all years). The reported renovation rates (any level of depth) are 3.0-3.5% for Belgium, 0.5-0.9% for Italy, 0.6-0.7% for Poland and 0.3-0.5% for Spain. The data for The Netherlands are anomalous: 17% in 2011, 71% in 2012 and 93% in 2013.

In the Impact Assessment for the EPBD recast, a renovation rate of 0.7% has been assumed for 2015, and 1.70% for 2030 (see Annex III.7).

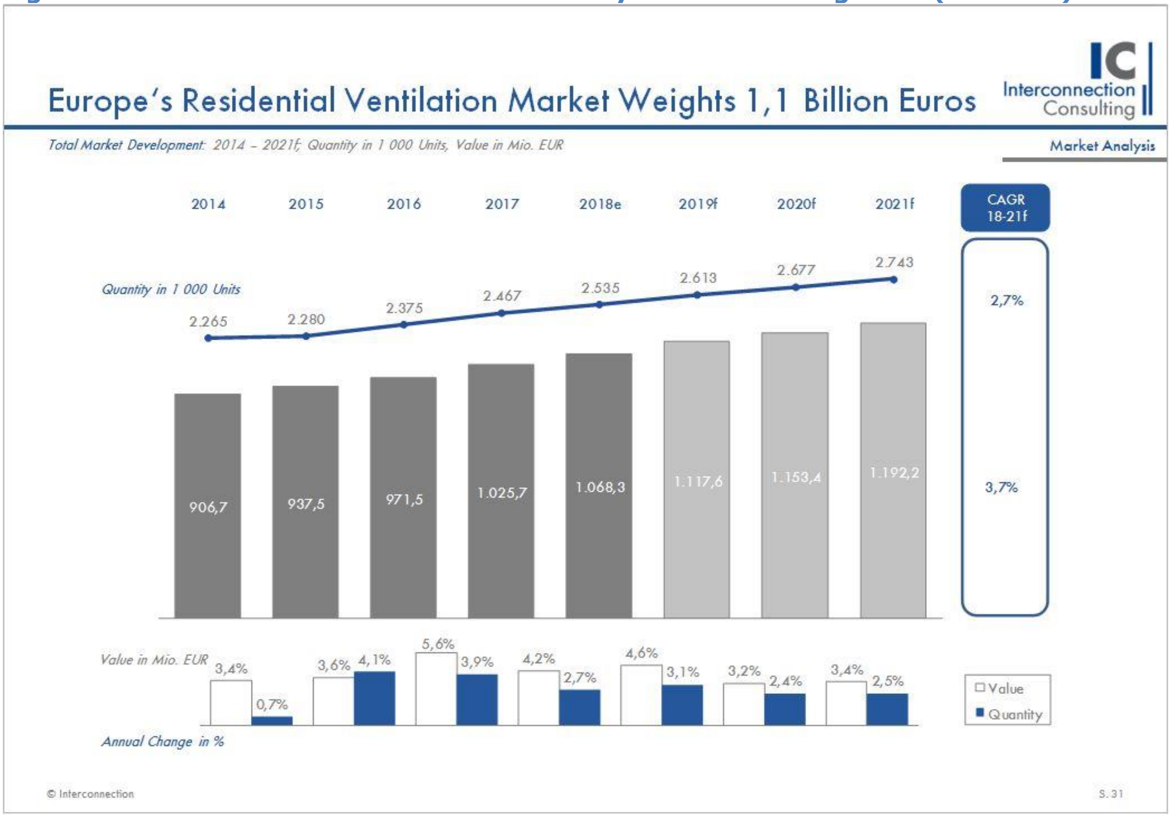
Ecofys (Annex V.2) reports an average energy-related renovation rate of 2.1%. However, considering the Ecofys definitions for ‘complete’, ‘partial’ and ‘particular’ renovations, only ‘complete’ renovations involve installing or upgrading the HVAC system, and in that case the renovation rate relevant for this study would be closer to 0.4-0.5%.

Annex VI: Prices and VU market

1. Data from Interconnection Consulting

In their press release [42], Interconnection Consulting (IC) published aggregated data on the development of Europe's residential ventilation market. According to IC, indicators suggest that the market for residential ventilation systems in the markets analysed (Germany, Austria, Switzerland, France, the UK, Italy, Poland, and the Benelux countries) will increase at an annual rate of 2.7% to 2021. France is the largest market, with a share of 32.3% of the countries analysed, followed by Germany (22.9%) and the Benelux region (21.6%).
These data probably refer to all residential ventilation units, both extract UVUs and BVUs with heat recovery, both centralised and decentralised (the manually operated and temporarily functioning bathroom and toilet fans are not in these figures).

Figure 59. Market for residential ventilation systems according to IC (09-2018) [42]



Other data from a 2015 IC research (limited to the same countries) have been discussed by MarktMeinungMensch [43]:

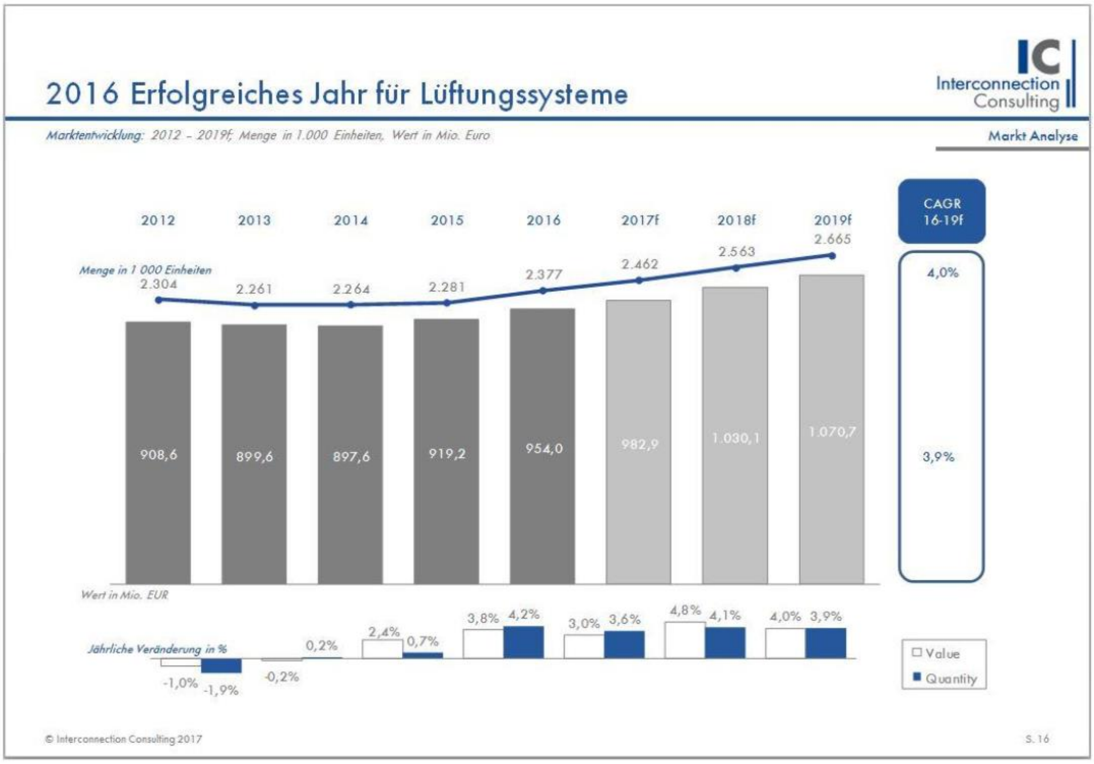
- In 2015 around 210 thousand central BVUs with Heat Recovery were sold.
- In 2015, sales of local BVUs with HR increased by 10.6% compared to 2014.
- In 2015, almost 2 mln UVUs without heat recovery were sold, for a value of M€ 508.7, representing 60% of the market. Market share of UVUs was 65.5% in 2011 and is expected to decrease to 55.8% in 2018.
- Largest increase in market share of central BVU with HR is found in the Benelux and the United Kingdom. Largest increase in market share of local BVU with HR is found in Germany, Austria and Italy.

[42] https://www.interconnectionconsulting.com/news/kwl-2/

[43] http://www.marktmeinungmensch.de/news/kontrollierte-wohnraumlueftungen-in-europa-2016/

- 87% of Central BVU with HR are used in new-built because they need extensive duct works.
- 60% of the UVUs are used in renovation.

Figure 60. Market for residential ventilation systems according to IC (2016) [43]



Elaborating the most recent set of data (Figure 59), the average market value of a residential ventilation unit varies from 400 euros in 2014 to 435 euros in 2021. The increase could be due to an increase in the share of more expensive BVUs, and a decrease in share of cheaper UVUs. It is not known if the presented data have been inflation corrected.

Using the indication from [43] that in 2015 nearly 2 million UVUs were sold with a market value of 508.7 M€, an **average market value of € 254 for UVUs and € 1530 for BVUs** can be derived.

Table 126. Estimate of average market value per Residential Ventilation Unit
(Source: VHK elaboration of public data from Interconnection Consulting)

	2014	2015	2016	2017	2018	2019	2020	2021
Units (thousands)	2265	2280	2375	2467	2535	2613	2677	2743
Market value (M€)	906.7	937.5	971.5	1025.7	1068.3	1117.6	1153.4	1192.2
RVU Unit value (€)	400	411	409	416	421	428	431	435
variation		2.7%	-0.5%	1.6%	1.4%	1.5%	0.7%	0.9%
UVU units (thousands)		2000						
UVU value (M€)		508.7						
UVU Unit value (€)		**254**						
BVU units (thousands)		280						
BVU value (M€)		428.8						
BVU Unit value (€)		**1531**						

5 Eurovent data

Eurovent's EMI provides a dataset containing the EU-28 total sales figures for residential BVU (with heat recovery) and non-residential AHUs for year 2017 (see par.2.2.5 and Annex II.4).

The document mentions a total of 460,859 residential **BVUs with heat recovery** sold in 2017, with a total market value of 347.5 million euro, leading to an **average ex-works price of € 754,-**. This includes LBVU and CBVU of all sizes up to 1000 m3/h. 79% has energy class A. Note that this average market value is less than half of the value derived from IC data for year 2015 at the previous point (€ 1531).

As regards non-residential **AHUs**, total sales in 2017 were 179,395 units with a market value of 1712 million euros and an **average ex-works price of around € 9.500,-**. The average price per Member State varies from below € 3000 in Estonia and Lithuania to between € 13,000 and 15,000 in Croatia, Germany, Malta and United Kingdom.

6 BVU market data published by Daikin based on BRG source

Source: Ventilation and climate control - Market and product development trends - Henk Kranenberg, Daikin Europe NV, 13/11/2018 (par. 2.2.7 of main text).

Table 127. BVU market data published by Daikin based on BRG source

TECHNOLOGY	MARKET VALUE (M€)		GROWTH RATE 2017 - 2020
	2017	2020	
AHU	1 971 €	2 207 €	12%
Centr. HRV (Comm.)	375 €	413 €	10%
Centr. HRV (Resid.)	471 €	570 €	21%
Local HRV	93 €	127 €	36%
TOTAL	*2 910 €*	*3 317 €*	*14%*

Source: BRG study "The European Ventilation Product Markets", November 2015

MARKET	MARKET VALUE (M€)		GROWTH RATE 2017 - 2020
	2017	2020	
Austria	155 €	179 €	15%
Belgium	97 €	111 €	15%
Czech Republic	47 €	56 €	19%
Denmark	143 €	162 €	13%
Finland	177 €	186 €	5%
France	126 €	147 €	17%
Germany	735 €	887 €	21%
Italy	123 €	147 €	19%
Netherlands	113 €	147 €	30%
Norway	122 €	129 €	6%
Poland	59 €	66 €	11%
Russia	273 €	219 €	-20%
Spain	67 €	81 €	21%
Sweden	271 €	325 €	20%
Switzerland	201 €	232 €	15%
United Kingdom	200 €	242 €	21%
TOTAL	*2 910 €*	*3 317 €*	*14%*

Source: BRG study "The European Ventilation Product Markets", November 2015

The data from Kranenberg / Daikin have been elaborated by VHK to remove the contributions of Norway, Russia and Switzerland. In addition, to have an idea of the implied average market value per unit, the reported total market values have been divided by the sales estimated in this study for the same countries (Table 128).

This (rough) estimate leads to an **average market value of € 8600-9500 for AHUs**. This is close to the estimate derived from Eurovent data at the previous point.

The estimate for residential BVUs is **€ 1190 – 1380 for CBVU and € 375 for LBVU**, with a weighted average of € 875-930. This is somewhat higher than the € 754 derived from Eurovent data, but much lower than the € 1531 derived from IC data.

For **non-residential CHRV, an average market value of € 2050-2090** is estimated. This is much higher than the € 1190 – 1380 for residential CBVU, but average size (max flow rate) will also be higher.

Table 128. Elaboration of Residential BVU market data published by Daikin

	2017	2020
Of the total, Norway, Russia and Switzerland cover	29%	17%
Assume same % apply per VU type:		
remain for AHU	1396	1821
remain for CHRV non-residential	266	341
remain for CHRV residential, M€	334	470
remain for Local HRV, M€	66	105
estimated sales AHU, 90% of EU-28 (000 units)	161	192
estimated sales CHRV nres., 90% of EU-28 (000 units)	127	166
estimated sales CBVU in countries covered (000 units)	281	340
estimated sales LBVU in countries covered (000 units)	175	279
estimate unit market value AHU	**8649**	**9503**
estimate unit market value CHRV non-residential	**2089**	**2048**
estimate unit market value CBVU residential	**1186**	**1384**
estimate unit market value LBVU residential	**376**	**375**
sales weighted average all residential BVU+HR	875	929

7 Price data from 2014 Impact Assessment

The 2014 Impact Assessment (IA) [44] in Annex C reports the price breakdown for Ventilation Units. In addition to the street price for the VU itself, the additional costs for installation materials (ducts, orifices, grids, air inlet provisions, overflow provisions, etc.), and labour costs for installation (for new-built or for renovation). The information is based on the underlying preparatory studies for Lot 10 and Lot 6.

For **residential VUs**, the data in the IA are the same as those used in the 2010 Supplementary study (par. 2.2.10). There, the **2003 data** are valid for a CUVU or CBVU with a maximum flow rate of 250 m3/h, for a LUVU of 80 m3/h and an LBVU of 115 m3/h. Table 129 reports the original data from the IA (interpreted to be in 2003 euros) and the conversion to 2015 euros made by the study team [45]. Below, reference is made to the 2015 euros.

For **LUVUs** the street price was € 109 in 2003, with no additional cost for installation materials and € 69 (new-built and renovation) for labour costs (all incl. VAT, in 2015 euros). A manufacturer selling price (msp) of € 63 was estimated for year 2003.

For **CUVUs** the street price was € 356 in 2003, with additional € 755 for installation materials and € 425 (new-built) or € 1038 (renovation) for labour costs (all incl. VAT, in 2015 euros).

[44] COMMISSION STAFF WORKING DOCUMENT, IMPACT ASSESSMENT, Accompanying the document 'Commission Regulation implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for ventilation units' and 'Commission Delegated Regulation implementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of ventilation units', SWD(2014) 222 final, European Commission 2014

[45] Eurostat's Harmonized Index of Consumer prices (HICP) is 100 in 2015 and 79.5 in 2003, so the applied conversion factor from 2003 to 2015 euros is 100/79.5=1.26

A manufacturer selling price (msp) of € 208 was estimated for year 2003. This is lower than the € 254 derived from IC data for year 2015.

For **CBVUs** the street price was € 2735 in 2003, with additional € 944 for installation materials and € 1661 (new-built) or € 2768 (renovation) for labour costs (all incl. VAT, in 2015 euros). A manufacturer selling price (msp) of € 1596 was estimated for year 2003. This is close to the € 1531 derived from IC data for year 2015 (but LBVUs were also included therein), and considerably higher than the € 1190 derived from Daikin data for year 2017.

For **LBVUs** the street price was € 1312 in 2003, with additional € 126 for installation materials and € 138 (new-built or renovation) for labour costs (all incl. VAT, in 2015 euros). A manufacturer selling price (msp) of € 766 was estimated for year 2003. This is more than double the € 375 derived from Daikin data for year 2017.

For **non-residential VUs**, most price/cost data in the IA are the same as those used in the 2012 Lot 6 preparatory study [46] (par. 2.2.11). However, there are some deviations as regards the costs of replacement sales [47]. As the IA is more recent than the Lot 6 study, the values of the IA have been preferred. The data in the IA are valid for year 2010, for CEXH with maximum flow rate of 1500 m3/h, CHRV with 2250 m3/h, and AHUs with respectively maximum flow rates of 4000 m3/h (size S), 10000 m3/h (size M) and 35000 m3/h (size L). (other key figures of the base cases in Table 130).

Table 131 reports the original data from the IA (in 2010 euros) and the conversion to 2015 euros made by the study team [48]. Below, reference is made to the 2015 euros.

For **CEXHs** (CUVUs) the street price (builder price) was € 685 in 2010, with additional € 2122 for installation materials (not applicable to replacements) and € 2928 (new-built) or € 4095 (renovation) or € 263 for installation labour costs (all excl. VAT, in 2015 euros).
A manufacturer selling price (msp) of € 324 was estimated for year 2010 for non-residential CUVUs with 1500 m3/h. This is higher than for the residential CUVUs with 250 m3/h (€ 208 in 2003 from IA data; € 254 in 2015 from IC data).

For **CHRVs** (CBVUs) the street price (builder price) was € 5703 in 2010, with additional € 7700 for installation materials (not applicable to replacements) and € 11200 (new-built) or € 13500 (renovation) or € 2200 for installation labour costs (all excl. VAT, in 2015 euros).
A manufacturer selling price (msp) of € 2700 was estimated for year 2010 for non-residential CBVUs with 2250 m3/h. This is higher than the € 2089 derived from Daikin data for 2017.

For **AHU-S** of 4000 m3/h the street price (builder price) was € 8086 in 2010, with additional € 37200 for installation materials (not applicable to replacements) and € 55800 (new-built) or € 67000 (renovation) or € 3100 for installation labour costs (all excl. VAT, in 2015 euros).
A manufacturer selling price (msp) of € 4320 was estimated for year 2010 for non-residential AHUs with 4000 m3/h.

[46] Sustainable Industrial Policy – Building on the Ecodesign Directive – Energy-Using Product Group Analysis/2 - Lot 6: Air-conditioning and ventilation systems - Final Report Task 7 - Policy- and scenario analysis - Prepared by VHK - 14 June 2012, Main contractor: ARMINES, France, Project leader: Philippe RIVIERE

[47] In the Task 2 report of the Lot 6 preparatory study, the installation labour costs for replacement sales are relatively low, while, erroneously, the costs of installation materials for new-built and renovation are also counted in the case of replacement. In the Task 6 report of the same study, the installation labour costs for replacements have been increased, while the costs of installation materials are no longer being considered for replacements.

The Impact Assessment uses the lower installation labour costs for replacement sales of Lot 6 Task 2 (and not the later, higher ones from task 6), does not consider costs for installation materials, but also uses a reduced basic price for the VU itself, excluding the builder mark-up (i.e. for replacements, the product's installer price is used, while for new-built and renovation the product's builder price is applied).

[48] Eurostat's Harmonized Index of Consumer prices (HICP) is 100 in 2015 and 92.6 in 2010, so the applied conversion factor from 2010 to 2015 euros is 100/92.6=1.08

For **AHU-M** of 10000 m3/h the street price (builder price) was € 13590 in 2010, with additional € 106000 for installation materials (not applicable to replacements) and € 159000 (new-built) or € 190800 (renovation) or € 5230 for installation labour costs (all excl. VAT, in 2015 euros).
A manufacturer selling price (msp) of € 8639 was estimated for year 2010 for non-residential AHUs with 10000 m3/h.

For **AHU-L** of 35000 m3/h the street price (builder price) was € 31840 in 2010, with additional € 414000 for installation materials (not applicable to replacements) and € 620900 (new-built) or € 745100 (renovation) or € 12250 for installation labour costs (all excl. VAT, in 2015 euros).
A manufacturer selling price (msp) of € 21600 was estimated for year 2010 for non-residential AHUs with 35000 m3/h.

In the current model in 2010, the sales estimates for AHUs are 38% size L, 36% size M and 26% size S, which would lead to a weighted average msp for AHUs of € 12440. This is higher than derived from the Daikin data for 2017 (€ 8650) or from the Eurovent data for 2017 (€ 9500).

Table 129. Price breakdown for Residential Ventilation Units in year 2003, as reported in the 2014 Impact Assessment (top), and study team conversion to 2015 euros (bottom).

Table C-1 . Acquisition costs for domestic ventilation units (2003)

	local exhaust	central exhaust	central HR	local HR
Product price				
Manufacturing selling Price, VAT excl.	€ 50	€ 165	€ 1 269	€ 609
Ex. Wholesale price, VAT excl. (msp + 20%)	€ 60	€ 198	€ 1 522	€ 731
Ex. Installer, VAT excl. (wholesaleprice + 20%)	€ 73	€ 237	€ 1 827	€ 877
Consumer street price, VAT included	**€ 87**	**€ 283**	**€ 2 174**	**€ 1 043**
Installation materials				
Installation Kit, VAT included	-	€ 300	€ 600	€ 100
Supply / overflow provisions, VAT included	-	€ 300	€ 150	-
Total	**€ 87**	**€ 883**	**€ 2 924**	**€ 1 143**
Installation costs per unit				
Installation costs New built, VAT included	€ 55	€ 330	€ 1 320	€ 110
Installation costs Renovation, VAT included	€ 55	€ 825	€ 2 200	€ 110
Average installation costs	€ 55	€ 577	€ 1 760	€ 110
Total costs per unit for New Built	€ 142	€ 1 213	€ 4 244	€ 1 253
Total costs per unit for Renovation	€ 142	€ 1 708	€ 5 124	€ 1 253
Total average costs per unit	**€ 142**	**€ 1 708**	**€ 5 124**	**€ 1 253**

Converted to 2015 euros	local exhaust	central exhaust	central HR	local HR
Product price				
Manufacturing selling price, VAT excl. (msp)	63	208	1596	766
Wholesale price, VAT excl. (msp+20%)	75	249	1915	920
Installer price, VAT excl. (wholesale+20%)	92	298	2298	1103
Consumer street price, VAT included	**109**	**356**	**2735**	**1312**
Installation kit, VAT included	0	377	755	126
Supply/overflow provisions, VAT included	0	377	189	0
Total installation materials	**0**	**755**	**944**	**126**
Product + Installation materials	**109**	**1111**	**3678**	**1438**
installation costs new-built, VAT included)	69	415	1661	138
installation costs renovation, VAT included)	69	1038	2768	138
Average installation costs per unit	**69**	**726**	**2214**	**138**
total costs new-built, VAT included)	179	1526	5339	1576
total costs renovation, VAT included)	179	2149	6446	1576
Average total costs per unit	**179**	**1837**	**5893**	**1576**

Table 130. Key figures of non-residential VU base cases (Source: Lot6 preparatory study [46]).

Table 6-1. Key figures CEXH Base Case (Sold 2010)

Parameters	**CEXH**
performance data	
design/ effective/ average flow rate [000m³/h]	1.5/ 1.13/ 0.96
pressure drop external/internal/total [Pa]	154/ 37/ 191
specific fan power [kW/(m³/s)]	1.08
individual rated fan power [kW]	0.345
fans system efficiency [-]	23%
heat recovery thermal efficiency [-]	0%
misc factor	1.33
control factor on-off/variable/total	0.8/ 0.8/ 0.64
consumption data	
electricity consumption AHU [MWh/a]	1.33
electricity rate EUR/kWh	0.18
electricity costs AHU [000 EUR /a]	0.2
ventilation heat loss Avg/Warm/Cold climate**[MWh/a]	22/ 10/ 45
fossil fuel (ca. gas) rate[EUR/kWh]	0.052
space heating cost Avg/Warm/Cold climate [000 EUR/a]	1.1/ 0.5/ 2.3
ventilation cooling loss Avg/Warm/Cold climate [MWh/a]	1.9/ 8.7
space cooling extra costs [000 EUR/a]	0.2/ 1.0
total extra energy cost Avg/Warm/Cold [000 EUR/a]	1.6/ 1.7/ 2.6

Table 6-2. Key figures CHRV Base Case (Sold 2010)

Parameters	**CHRV**
performance data	
design/ effective/ average flow rate [000m³/h]	2.25/ 2.0/ 1.1
pressure drop external/internal/total [Pa]	160/ 140/ 300
specific fan power [kW/(m³/s)]	1.72
individual rated fan power [kW]	0.536
fans system efficiency [-]	35%
heat recovery thermal efficiency [-]	80%
misc factor	1.10
control factor on-off/variable/total	0.6/ 0.8/ 0.48
consumption data	
electricity consumption AHU [MWh/a]	3.21
electricity rate EUR/kWh	0.18
electricity costs AHU [000 EUR /a]	0.6
ventilation heat loss Avg/Warm/Cold climate**[MWh/a]	5/ 2/ 13
fossil fuel (ca. gas) rate[EUR/kWh]	0.042
space heating cost Avg/Warm/Cold climate [000 EUR/a]	0.3/ 0.1/ 0.7
ventilation cooling loss Avg/Warm/Cold climate [MWh/a]	0.4/ 2.0
space cooling extra costs [000 EUR/a]	0.0/ 0.2
total extra energy cost Avg/Warm/Cold [000 EUR/a]	0.9/ 0.9/ 1.2

Table 6-3. Key figures AHU Base Cases (Sold 2010)

Parameters	AHU-S	AHU-M	AHU-L
performance data			
design/ effective/ average flow rate [000m³/h]	4.0/ 3.64/ 1.92	10.0/ 8.7/ 4.8	35.0/ 29.7/ 16.8
pressure drop external/internal/total [Pa]	244/ 292/ 536	450/ 334/ 784	575/ 391/ 966
specific fan power [kW/(m³/s)]	1.98	2.7	3.42
individual rated fan power [kW]	1.1	3.75	15.75
fans system efficiency [-]	54%	58%	61%
heat recovery thermal efficiency [-]	44%	44%	44%
misc factor	1.10	1.15	1.18
control factor on-off/variable/total	0.6/ 0.8/ 0.48	0.6/ 0.8/ 0.48	0.6/ 0.8/ 0.48
*consumption data**			
electricity consumption AHU [MWh/a]	6.59	22.46	94.33
electricity rate EUR/kWh	0.18	0.14	0.10
electricity costs AHU [000 EUR /a]	1.2	3.1	9.4
ventilation heat loss Avg/Warm/Cold climate**[MWh/a]	24/ 11/ 53	61/ 27/ 132	213/ 95/ 462
fossil fuel (ca. gas) rate[EUR/kWh]	0.052	0.042	0.032
space heat extra cost Avg/Warm/Cold climate* [000 EUR/a]	1.3/ 0.6/ 2.7	2.6/ 1.1/ 5.5	6.8/ 3.0/ 14.8
ventilation cooling loss Avg/Warm/Cold climate [MWh/a]	2.1/ 9.8	5.3/ 24.4	18.6/ 85.4
space cooling extra costs [000 EUR/a]	0.2/ 1.1	0.5/ 2.1	1.2/ 5.3
total extra energy cost Avg/Warm/Cold * [000 EUR/a]	2.7/ 2.8/ 3.9	6.2/ 6.4/ 8.7	17.4/ 17.8/ 24.2

Table 131. Price breakdown for Non-Residential Ventilation Units in year 2010, as reported in the 2014 Impact Assessment (top), and study team conversion to 2015 euros (bottom).

Table C-2. Prices base-case non-residential ventilation units (Sales 2010)

Product -->	CEXH	CHRV	AHU-S	AHU-M	AHU-L
Features					
flow rate (m^3/h) [5]	**1.500**	**2.250**	**4.000**	**10.000**	**35.000**
Ext. ΔP (in Pa) [6]	154	181	244	460	670
HRS market share[7]	0%	100%	70%	70%	70%
HRS thermal efficiency [8]	0%	80%	62%	62%	62%

PRICES in Euro 2010

	CEXH	CHRV	AHU-S	AHU-M	AHU-L
labour	45	500	680	1 200	2 000
materials	150	1 000	1 520	2 800	6 000
overhead	105	1 000	1 800	4 000	12 000
msp	***300***	**2 500**	***4 000***	**8 000**	**20 000**
wholesale price	390	3 250	4 800	8 800	21 000
installer price [1]	488	4 063	5 760	9 680	22 680
builder price [2]	634	5 281	7 488	12 584	29 484
ducts, grills, ctrls [3]	1 965	7 130	34 445	98 155	383 292
inst. labour avg. [4]	2 172	8 072	37 692	106 229	412 175

[1]= end-customer unit price replacement (excl. VAT)

[2]= end-customer unit price new built/retrofit (excl. VAT)

[3]= not for replacements

[4]= "avg."= For CHRV the split up is 45/45/10 between new built/retrofit/replacement(in 2010); for CEXH and AHU the split up is 35/30/35 between new built/retrofit/replacement(in 2010).

END PRICES

Inst. labour new built	*2 711*	*10 338*	*51 667*	*147 233*	*574 938*
Inst. labour retrofit	*3 792*	*12 477*	*62 001*	*176 679*	*689 926*
inst. replacement(50% on ex installer price)	*244*	*2 031*	*2 880*	*4 840*	*11 340*

[5] Design flow rate F (in m³/h) assumed at around 65-70% of flow rate at 0 Pa [EN 13799 and other source mentioned in Task 1]

*[6]Design external pressure drop h (in Pa), according to EN 13799 is measured at 65% of maximum (flow rate=0). Practical values above are estimated as follows: if design flow rate F<10 000 m³/h then href= 0.036*F+100 ; if 10 000≤ F <25 000 m³/h then href=0.0146*F+304; if F≥25 000 m³/h then href=75*ln(F)-190.5 (equation Kaup, supply side, but subtract 100 for heat/cool coil)*

[7] HRS=Heat Recovery System. First estimates

Converted to 2015 euros	CEXH	CHRV	AHU-S	AHU-M	AHU-L
design flow rate (m3/h)	1500	2250	4000	10000	35000
manufacturer labour	49	540	734	1296	2160
manufacturer materials	162	1080	1641	3024	6479
manufacturer overhead	113	1080	1944	4320	12959
manufacturer selling price (msp)	**324**	**2700**	**4320**	**8639**	**21598**
wholesale price	421	3510	5184	9503	22678
installer price [1]	527	4388	6220	10454	24492
builder price [2]	**685**	**5703**	**8086**	**13590**	**31840**
materials for installation [3]	**2122**	**7700**	**37198**	**105999**	**413922**
installation labour, new-built	2928	11164	55796	158999	620883
installation labour, renovation	4095	13474	66956	190798	745060
installation labour, replacement	263	2193	3110	5227	12246
installation labour, average [4]	**2346**	**11307**	**40704**	**114718**	**445113**
total cost, new-built	5734	24567	101080	278587	1066646
total cost, renovation	6902	26877	112240	310387	1190823
total cost, replacement	790	6581	9330	15680	36739
total cost, average [4]	**4354**	**23808**	**72316**	**196110**	**743431**

Same notes [1], [2], [3], [4] as above.
The averages are valid for the 2010 sales distribution of the IA; not necessarily for the 2010 sales distribution in the current study.
For CHRV, average for installation labour was corrected (IA average did not use the announced 45/45/10 split for new-built/renovation/replacement).
Total costs added by the study team.

8. Price data from Ecodesign Impact Accounting

In the Ecodesign Impact Accounting (EIA, see also par. 2.2.8), prices of ventilation units are defined by means of three price-efficiency pairs (Table 132, Table 134), respectively for a base case (BC), for an average improvement option (MID, typically corresponding to LLCC) and for the best-available technology option (BAT).

In the case of VUs, the efficiency parameter considered is the kWh primary energy consumed (kWhprim), which is the sum of the electricity consumption (multiplied by 2.5 to convert to primary energy) and the space heating primary energy losses (at 75% average efficiency) due to the ventilation heat losses associated with the VU [49].

Depending on the scenario, the electric efficiency and thermal efficiency of the VUs increase with the years, leading to a decrease of the kWh primary energy consumed. The price of the VU in a given year is determined in EIA using the kWhprim of that year, interpolating between the three price-efficiency pairs. This price is then decreased (for ECO-scenarios after 2010) by 'PriceDec' % per year (Table 132, Table 134), to account for the decrease of the price over time due to the learning effect and due to the increase in sales quantities.

The EIA price includes the acquisition costs for the VU itself (unit), costs for installation materials (kit) and installation labour costs (install). The price breakdown over unit, kit and install is defined in EIA as shown in Table 132 and Table 134. The unit-price is further split in shares for industry, wholesale, retail and VAT, and used in EIA to compute the revenues

[49] The heat losses considered are versus a theoretical 0% heat loss, i.e. they are not the decrease in losses versus natural ventilation. The primary energy of space heating appliances corresponding to these losses is calculated for 75% efficiency. Average climate, 5000 h/a heating season, 8.8° temperature difference, thermal capacity of air 0.000344 kWh/m³.K, 100 m2 reference dwelling. Natural ventilation 2.2 m3/h/m2, 220 m3/h/unit. See EIA LoadNotes for further details.

per sector. For the residential VUs, the EIA price includes 20% VAT. For non-residential VUs, the EIA price is without VAT.

In addition, EIA specifies the maintenance and repair costs, in euros per year.

In general, EIA data are based on data from the 2014 Impact Assessment and on preparatory studies underlying that IA.

For **residential VUs** (< 125W per fan), basic EIA price data are provided in Table 132, while the top part of Table 133 shows the derived annual prices depending on the VU-efficiency of the year. The bottom part of the same table provides the breakdown of the primary energy consumption (kWhprim) of the VU, for the BAU-scenario in 2010 and for the ECO-scenario in 2015. The difference in prices between 2010 and 2015 derives from efficiency improvements due to the Ecodesign and Energy Labelling regulations for VUs.

For **residential CUVUs for the 2010 base case (BAU-scenario)** the unit price was € 349, with additional € 614 for installation materials and € 598 installation labour costs (all incl. VAT, in 2015 euros). These figures are comparable to those derived from the 2014 IA for year 2003: unit price € 356, additional € 755 for installation materials and € 425 (new-built) or € 1038 (renovation) for installation labour costs.
For **residential CUVUs for the 2015 VU with improved efficiency (ECO-scenario)** the unit price is € 589, with additional € 1036 for installation materials and € 1009 installation labour costs (all incl. VAT, in 2015 euros). The overall, temporary, price increase is 69%, but the improved VU leads to 45% lower primary energy consumption.

For **residential CBVUs for the 2010 base case (BAU-scenario)** the unit price was € 2389, with additional € 682 for installation materials and € 1626 installation labour costs (all incl. VAT, in 2015 euros). These figures are comparable to those derived from the 2014 IA for year 2003: unit price € 2735, additional € 944 for installation materials and € 1661 (new-built) or € 2768 (renovation) for installation labour costs.
For **residential CBVUs for the 2015 VU with improved efficiency (ECO-scenario)** the unit price is € 2899, with additional € 827 for installation materials and € 1973 installation labour costs (all incl. VAT, in 2015 euros). The overall, temporary, price increase is 21%, but the improved VU leads to 54% lower primary energy consumption.

For **residential LBVUs for the 2010 base case (BAU-scenario)** the unit price was € 1305, with additional € 103 for installation materials and € 115 installation labour costs (all incl. VAT, in 2015 euros). These figures are comparable to those derived from the 2014 IA for year 2003: unit price € 1312, additional € 126 for installation materials and € 138 (new-built or renovation) for installation labour costs.
For **residential LBVUs for the 2015 VU with improved efficiency (ECO-scenario)** the unit price is € 1336, with additional € 105 for installation materials and € 118 installation labour costs (all incl. VAT, in 2015 euros). The overall, temporary, price increase is 2.4%, but the improved VU leads to 58% lower primary energy consumption.

Local UVUs are not considered in EIA (assumed to be below 30 W and thus out-of-scope of the regulations).

Table 132. Price data for residential ventilation units from the 2018 Ecodesign Impact Accounting, price-efficiency data pairs and price breakdown

Residential	BC	BC	mid	mid	BAT	BAT	PriceDec		Maint
	price €	kWh prim	price €	kWh prim	price €	kWh prim	%		(€/a)
CUVU	1365	4980	1831	4139	2,298	3299	0.6%		10
CBVU	4617	1897	5186	1422	5,756	947	0.7%		52
LBVU	1315	2209	1440	1515	1,565	820	0.9%		22

	Overall price breakdown			Unit price breakdown			
	unit	kit	install	VAT	retail	whole	industry
CUVU	0.22	0.39	0.38	0.17	0.17	0.16	0.50
CBVU	0.51	0.15	0.35	0.17	0.17	0.16	0.50
LBVU	0.86	0.07	0.08	0.17	0.17	0.16	0.50

Table 133. Price data for residential ventilation units from the 2018 Ecodesign Impact Accounting, prices in €/unit (acquisition + installation + VAT), per year, in function of Ecodesign scenarios

	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU									
CUVU	1561	1514	1468	1424	1381	1365	1365	1365	1365
CBVU	4697	4617	4617	4617	4617	4617	4617	4617	4617
LBVU	1523	1454	1389	1326	1315	1315	1315	1315	1315
ECO									
CUVU	1561	2634	2554	2476	2401	2329	2258	2190	2123
CBVU	4697	5699	5517	5340	5169	5003	4842	4687	4617
LBVU	1523	1559	1489	1422	1358	1315	1315	1315	1315

	Year 2010 and before (BAU)						Year 2015 (ECO)				
	Unit €	Kit €	Install €	Total €	kWh prim		Unit €	Kit €	Install €	Total €	kWh prim
CUVU	349	614	598	1561	4625		589	1036	1009	2634	2545
CBVU	2389	682	1626	4697	1830		2899	827	1973	5699	837
LBVU	1305	103	115	1523	1057		1336	105	118	1559	446
	kWhelec	kWhheat	kWhheat	kWhheat	kWhprim		kWhelec	kWhheat	kWhheat	kWhheat	kWhprim
		saved vs.	natural	loss vs. 0%				saved vs.	natural	loss vs. 0%	
		natural						natural			
CUVU	454	951	4440	3489	4625		244	2505	4440	1935	2545
CBVU	501	3863	4440	577	1830		246	4218	4440	222	837
LBVU	217	1706	2220	514	1057		134	2109	2220	111	446

For **non-residential VUs** (> 125W per fan), EIA provides only sales weighted average price and efficiency data for all NRVUs together. Data per base case (CEXH, CHRV, AHUs) have been reconstructed for years 2010 and 2015, using data from the EIA LoadNotes and from files underlying the EIA analyses.
Basic EIA price data are provided in Table 134, while the top part of Table 135 shows the derived annual prices depending on the VU-efficiency of the year (available only for the NRVU weighted average). The bottom part of the same table provides the breakdown of the primary energy consumption (kWhprim) of the VU, for the BAU-scenario in 2010 and for the ECO-

scenario in 2015. The difference in prices between 2010 and 2015 derives from efficiency improvements due to the Ecodesign and Energy Labelling regulations for VUs.

For **non-residential CEXHs (CUVUs) for the 2010 base case (BAU-scenario)** the unit price was € 685, with additional € 2160 for installation materials and € 3240 installation labour costs (all incl. VAT, in 2015 euros). These figures are comparable to those derived from the 2014 IA for year 2010: unit price € 685, additional € 2122 for installation materials and € 2928 (new-built) or € 4095 (renovation) or € 263 (replacement) for installation labour costs.
For **non-residential CEXHs (CUVUs) for the 2015 VU with improved efficiency (ECO-scenario)** the unit price is € 689, with additional € 2172 for installation materials and € 3258 installation labour costs (all incl. VAT, in 2015 euros). The overall, temporary, price increase is 0.6%, but the improved VU leads to 9% lower primary energy consumption.

For **non-residential CHRVs (CBVUs) for the 2010 base case (BAU-scenario)** the unit price was € 5988, with additional € 8051 for installation materials and € 12473 installation labour costs (all incl. VAT, in 2015 euros). These figures are comparable to those derived from the 2014 IA for year 2010: unit price € 5703, additional € 7700 for installation materials and € 11200 (new-built) or € 13500 (renovation) or € 2200 (replacement) for installation labour costs.
For **non-residential CHRVs (CBVUs) for the 2015 VU with improved efficiency (ECO-scenario)** the unit price is € 6005, with additional € 8073 for installation materials and € 12507 installation labour costs (all incl. VAT, in 2015 euros). The overall, temporary, price increase is 0.3%, but the improved VU leads to 47% lower primary energy consumption.

For **non-residential AHU-S for the 2010 base case (BAU-scenario)** the unit price was € 8418, with additional € 38600 for installation materials and € 58400 installation labour costs (all incl. VAT, in 2015 euros). These figures are comparable to those derived from the 2014 IA for year 2010: unit price € 8086, additional € 37200 for installation materials and € 55800 (new-built) or € 67000 (renovation) or € 3100 for installation labour costs.
For **non-residential AHU-S for the 2015 VU with improved efficiency (ECO-scenario)** the unit price is € 8549, with additional € 39200 for installation materials and € 59300 installation labour costs (all incl. VAT, in 2015 euros). The overall, temporary, price increase is 1.6%, but the improved VU leads to 51% lower primary energy consumption.

For **non-residential AHU-M for the 2010 base case (BAU-scenario)** the unit price was € 13990, with additional € 109000 for installation materials and € 163200 installation labour costs (all incl. VAT, in 2015 euros). These figures are comparable to those derived from the 2014 IA for year 2010: unit price € 13590, additional € 106000 for installation materials and € 159000 (new-built) or € 190800 (renovation) or € 5230 (replacement) for installation labour costs.
For **non-residential AHU-M for the 2015 VU with improved efficiency (ECO-scenario)** the unit price is € 14000, with additional € 109100 for installation materials and € 163400 installation labour costs (all incl. VAT, in 2015 euros). The overall, temporary, price increase is 0.1%, but the improved VU leads to 49% lower primary energy consumption.

For **non-residential AHU-L for the 2010 base case (BAU-scenario)** the unit price was € 32500, with additional € 310800 for installation materials and € 630800 installation labour costs (all incl. VAT, in 2015 euros). These figures are comparable to those derived from the 2014 IA for year 2010: unit price € 31840, additional € 414000 for installation materials and € 620900 (new-built) or € 745100 (renovation) or € 12250 (replacement) for installation labour costs.
For **non-residential AHU-L for the 2015 VU with improved efficiency (ECO-scenario)** the unit price is € 32300, with additional € 308700 for installation materials and € 626600 installation labour costs (all incl. VAT, in 2015 euros). The overall, temporary, price increase is -0.7%, but the improved VU leads to 47% lower primary energy consumption.

Table 134. Price data for non-residential ventilation units based on the 2018 Ecodesign Impact Accounting (elaboration by the study team)

Non-Residential	BC	BC	mid	mid	BAT	BAT	PriceDec		Maint
	price €	kWh prim	price €	kWh prim	price €	kWh prim	%		(€/a)
CEXH	6084	24659	6580	17342	18719	1072	0.4%		72
CHRV	25249	13087	26886	6590	30665	3734	0.4%		135
AHU-S	101404	40874	107478	22732	107478	22732	0.4%		191
AHU-M	278402	117120	288743	69167	288743	69167	0.4%		652
AHU-L	955508	443682	979719	262607	979719	262607	0.4%		2739
Avg. BVU	284202	129172	293027	75701	294680	74451	0.4%		798
Avg. NRVU	139915	74951	144419	45424	151513	36382	0.4%		421

	Overall price breakdown			Unit price breakdown			
	unit	kit	install	VAT	retail	whole	industry
CEXH	0.11	0.35	0.53	0.00	0.10	0.10	0.80
CHRV	0.23	0.30	0.47	0.00	0.10	0.10	0.80
AHU-S	0.08	0.37	0.55	0.00	0.10	0.10	0.80
AHU-M	0.05	0.38	0.57	0.00	0.10	0.10	0.80
AHU-L	0.03	0.32	0.65	0.00	0.10	0.10	0.80
Avg. BVU	0.05	0.33	0.62	0.00	0.10	0.10	0.80
Avg. NRVU	0.08	0.34	0.57	0.00	0.10	0.10	0.80

Table 135. Price data for non-residential ventilation units from the 2018 Ecodesign Impact Accounting, prices in €/unit (acquisition + installation), per year in function of Ecodesign scenarios

	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU									
Avg. NRVU	140881	139915	139915	139915	139915	139915	139915	139915	139915
ECO									
Avg. NRVU	140881	140420	139915	139915	139915	139915	139915	139915	139915

	Year 2010 and before (BAU)						Year 2015 (ECO)				
	Unit €	Kit €	Install €	Total €	kWh prim		Unit €	Kit €	Install €	Total €	kWh prim
CEXH	685	2160	3240	6084	24659		689	2172	3258	6119	22207
CHRV	5988	8051	12473	26512	8072		6005	8073	12507	26585	5519
AHU-S	8418	38611	58365	105394	28958		8549	39212	59274	107034	17203
AHU-M	13988	109019	163196	286203	80945		14004	109146	163385	286535	50915
AHU-L	32476	310776	630798	974050	305010		32261	308722	626630	967613	197967
Avg. NRVU	11369	48534	80978	140881	68618		11332	48375	80713	140420	51900
	kWhelec	kWhheat	kWhheat	kWhheat	kWhprim		kWhelec	kWhheat	kWhheat	kWhheat	kWhprim
		saved vs.	natural	loss vs. 0%				saved vs.	natural	loss vs. 0%	
		natural						natural			
CEXH	1331	13537	34868	21331	24659		1124	15471	34868	19398	22207
CHRV	1604	48241	52302	4061	8072		1355	50170	52302	2132	5519
AHU-S	3497	72767	92982	20215	28958		2953	83161	92982	9822	17203
AHU-M	11244	179620	232455	52836	80945		9494	205276	232455	27179	50915
AHU-L	46104	623845	813594	189749	305010		38931	712953	813594	100641	197967
Avg. NRVU	8400	94169	141787	47618	68618		7093	107620	141787	34167	51900

9. List Price data from a manufacturer

List price data (2019) from a manufacturer were found on internet [50] and are shown in Table 136. Actual street prices (excl. VAT) are assumed to be around 30% lower [51].

For **CBVU with heat recovery** and maximum flow rate below 250 m3/h, an average street price excl. VAT around **€ 1750** can be estimated. For models of 300-400 m3/h this increases to **€ 2000 – 2600**, where models with higher thermal efficiency cost around 7% more than comparable models with lower efficiency. A model with enthalpy heat exchanger costs 70% more than the same model with standard heat exchanger.

For **LBVU with heat recovery** and maximum flow rate 70 m3/h, a street price excl. VAT of **€ 917** can be estimated.

For **CUVU roof-top extract units**, estimated street prices excl. VAT vary from around € 1500 at 2000 m3/h to around € 3700 at 13000 m3/h, with an **average around € 2100**.

Table 136. List Price data (2019) from a manufacturer of Ventilation Units

		voltage	max elec.	max flow	price € (excl. VAT)		max eff.	label
VU model	VU type	V	power W	m3/h	list	-30% €	thermal %	class
CWL-F-Excellent-150	CBVU+HR		72	150	2470	1729	94%	A
CWL-F-Excellent-150+preheater	CBVU+HR		72	150	2580	1806		A
CWL-180 Excellent	CBVU+HR		132	180	2480	1736	92%	B
CWL-T-Excellent	CBVU+HR		164	300	2885	2020	93%	A
CWL-F-Excellent-300	CBVU+HR		163	300	2885	2020	92%	A
CWL-300	CBVU+HR		138	300	2950	2065	89%	A
CWL-2-325	CBVU+HR		145	325	3170	2219	98%	A
CWL-2-325-enthalpy	CBVU+HR		145	325	5400	3780		A
CWL-400	CBVU+HR		172	400	3570	2499	93%	A
CWL-2-400	CBVU+HR		178	400	3770	2639	99%	A
CWL-D-70	LBVU+HR			70	1310	917	87%	A
Roof Extract Fan DV-2-225	CUVU	230	179	2000	2110	1477		
Roof Extract Fan DV-2-225	CUVU	400	194	2000	2370	1659		
Roof Extract Fan DV-2-250	CUVU	230	375	3300	2350	1645		
Roof Extract Fan DV-2-250	CUVU	400	381	3300	2565	1796		
Roof Extract Fan DV-2-315	CUVU	230	520	4500	2480	1736		
Roof Extract Fan DV-2-315	CUVU	400	662	5000	2690	1883		
Roof Extract Fan DV-2-400	CUVU	400	533	5200	3165	2216		
Roof Extract Fan DV-2-450	CUVU	400	912	7000	3470	2429		
Roof Extract Fan DV-2-500	CUVU	400	3280	13000	5305	3714		

[50] WOLF VENTILATION SYSTEMS PRICE LIST JANUARY 2019. https://a2t.dk › PL_Lueftungssysteme_Januar-2019__4800719__Buch

[51] Some internet sales' sites for Ventilation Units show both an original price and a discounted price, and it is not uncommon for the latter to be around 30% lower than the former. Differences between 15 and 30% are also mentioned in earlier ecodesign studies on ventilation units.

10. Price data collection from internet sales' sites

Price data for on-line sales of Ventilation Units have been collected from the following sites:

- https://www.amazon.de
- https://www.acsalesdirect.co.uk
- https://sks24.at
- https://www.gamma.nl
- https://www.ventilatieland.nl
- https://www.idealo.it/

The collection is certainly not exhaustive (there are too many sites and too many VU-models on the market to make a full survey), but it is believed to give a good idea of the 2019 street prices for several types of VUs, and of the product features that this price depends on.

Prices presented below exclude VAT [52] and are intended to include delivery costs [53]. Where different prices for the same VU-model were available on different sites, the lowest offered price has been considered [54].

Prices are presented below per type of VU (with or without heat recovery, central or local), in function of the declared maximum flow rate, but the flow rate is not the only parameter influencing the price, and, especially for the smaller VUs, not even the main parameter. Parameters that influence the price are e.g.:

- The type of VU, i.e. with or without heat recovery, central or local
- Maximum flow rate
- Electric efficiency
- EC-motor or AC-motor
- 1-phase 230 V or 3-phase 400 V supply
- Thermal efficiency (for models with heat recovery)
- Type of heat exchanger (for models with heat recovery)
- Noise level
- Number of inlets (mainly for CUVUs)
- Presence of filters and type of filter (mainly for BVUs)
- Suitability of the model to optionally add certain types of control
- Number of control speed settings (1,2,3,5,7,..) or continuous control or fully automatic
- Accessibility of fans / filters for maintenance and cleaning
- Presence or not of a timer (with or without delay function)
- Presence or not of sensors (humidity, CO2, presence/movement, odour, light)
- User control interface (on/off switch, pull-cord, multiple-button control panel, touch-screen control display, dedicated remote control unit, app-control from mobile phone, tablet or computer (WiFi, blue tooth)
- Presence of closure grills, guards, automatic no-return valves, power supply cable with plug, type of plug, other installation-related components,
- Suitability for high air temperatures; including grease collection (for kitchen exhaust)
- Aesthetics / design, e.g. material (plastic, glass, metal), colour and shape of the room-inlet valve, display of e.g. humidity and temperature, presence of LED-lights on or around the inlet valve.

[52] Website prices including VAT have been divided by 1.2 (20% VAT considered)

[53] On many sites and for many models, delivery is free. For the cheaper VU-models, there may be shipping costs if the total order does not exceed a certain threshold. Delivery costs may depend on the country where the VU is to be delivered.

[54] It is not uncommon for prices to differ by 50-100% depending on the website, see e.g. idealo.it (a price comparison site), but it is not always straightforward to establish if it is really the same product being offered.

LUVUnc

For a sample of 121 non-continuously operating local unidirectional exhaust fans (LUVUnc), used mainly in bathrooms and toilets, an average price of € 57 (excl. VAT) and an average maximum flow rate of 130 m3/h are derived from on-line sales data.
For 59 models with a maximum flow rate **below 100 m3/h**, the average declared flow rate is 92 m3/h with a price of **€ 51** (excl. VAT).
For 53 models with a maximum flow rate **between 100 and 250 m3/h**, the average declared flow rate is 147 m3/h with a price of **€ 65** (excl. VAT).
For 9 models with a maximum flow rate **above 250 m3/h**, the average declared flow rate is 285 m3/h with a price of **€ 52** (excl. VAT).

Remarks:

- As shown in Figure 61, there is a large spread in prices for any given flow rate. The LUVUnc price depends more on the presence of sensors, control options and aesthetics' features than on the maximum flow rate.

- The cheapest LUVUnc models have a price excl. VAT between € 10 and € 15, but a more common price for a basic model (without timer, sensors, or special aesthetic features) is € 25 to € 30.

- The most expensive LUVUnc model of € 208 (excl. VAT) has a declared maximum flow rate of 140 m3/h, a maximum electric power of only 5 W, and a noise level as low as 19 dB(A) at maximum flow. It has a timer with delay function, humidity sensor, odour sensor, light sensor, bluetooth wireless control from app, and automatic 1 h ventilation after 26 h of non-activity.

- Table 138 shows the influence of various product features on the LUVUnc price. The survey is based on data from the same internet site and for VU-models from a single manufacturer, so data should be comparable.

  For a 100 m3/h VU, prices range from € 24 to € 103 (excl. VAT) depending on the features.

  The advanced series has significantly lower electrical power and noise level, but also 50-90% higher prices than the basic series.

  Adding a timer costs € 7 to € 27 extra (30-70% of basic price).
  Adding a timer and a humidity sensor costs € 26 to € 60 extra (50-200% of basic price).

- With 2 exceptions, all models of the sample declare a power below 30 W and would thus be exempted from the current regulations. Note that there are also 7 models with maximum flow rate > 250 m3/h that declare a power less than 30 W [55].

- In the section on sales and stock, LUVUs were generally assumed to be less than 100 m3/h, but more than half of the LUVUnc models offered on the market is above 100 m3/h, and some are even above 250 m3/h. This should be taken into account when formulating the base cases in Task 5.

[55] The power declaration on the internet sales sites does not always seem to be the maximum power.

Figure 61. Collection of on-line (Internet) price data, for non-continuously operating LUVUnc (bathroom / toilet exhaust fans), in function of maximum flow rate. In 2019 euros, incl. delivery costs, excl. VAT. (source: VHK 2019)

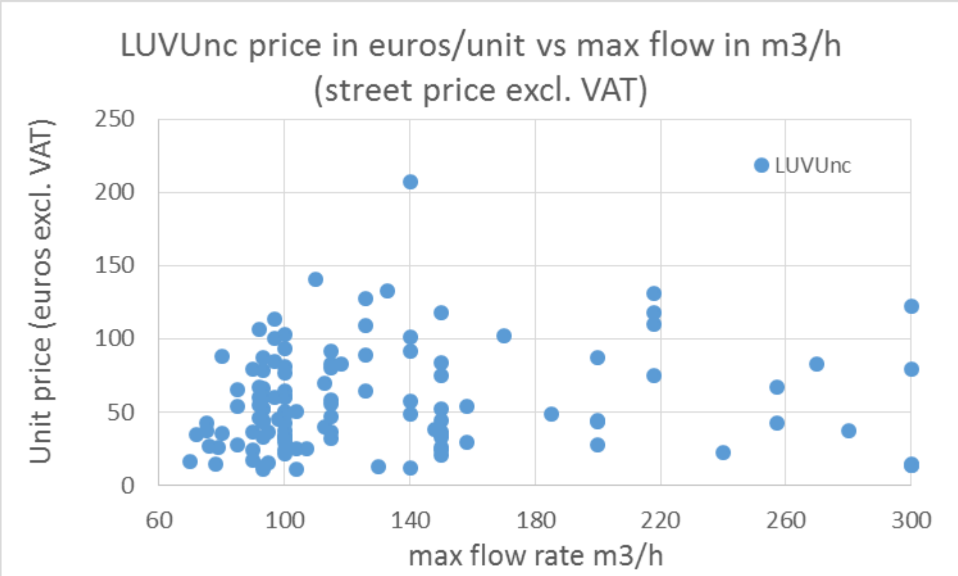


Table 137. Average on-line (Internet) price data, for non-continuously operating LUVUnc (bathroom / toilet exhaust fans), per maximum flow rate category. In 2019 euros, incl. delivery costs, excl. VAT. (source: VHK 2019)

	Number	Average flow m3/h	Average price €
Entire sample	121	130	57
of which ≤ 100 m3/h	59	92	51
of which 100-250 m3/h	53	147	65
of which > 250 m3/h	9	285	52

Table 138. Influence of product features on LUVUnc price (excl. VAT). (source: VHK 2019 [56])

	flow	power	noise	Product features						price
series	m3/h	W	dB	switch	timer	RH[1]	Cord[2]	Valve[3]	Aesthetics[4]	€
basic	**100**	15	32	x						24
				x	x					32
				x			x			32
					x	x				50
de Luxe	100	19	39	x						33
				x	x					47
					x	x				61
				x				x		60
					x	x		x		103
design	100	19	39	x					white	37
				x					gold/silver	42
				x					st. steel	50
				x	x				white	64
				x	x				st. steel	76
					x	x			white	81
					x	x			st. steel	93
advanced	93	8	26	x					plastic	44
				x					glass	52
				x	x				plastic	61
				x			x		plastic	52
				x	x (+d)[5]				plastic	66
					x	x			plastic	79
					x	x			glass	87
basic	**150**	16	36	x						26
				x	x					33
				x			x			35
					x	x				52
de Luxe	150	20	42	x						36
					x	x		x		118
design	150	24	42	x					white	45
					x	x			white	83
advanced	140	10	34	x					plastic	48
				x					glass	57
					x	x			plastic	92
					x	x			glass	101
basic	**200**	20	40	x						28
				x	x					44
				x			x			45
					x	x				87
design	300	24	49	x					white	79
					x	x			white	122

1: Humidity sensor; 2: with pull-cord to operate the on/off switch and power supply cable with plug; 3: automatic closure (no-return) valve; 4: white, gold/silver, stainless steel refers to the colour, not the material; 4: plastic, glass refer to the material (both opaque white); 5: with delay function

[56] Based on information from https://www.ventilatieland.nl for VU-models from Europlast

LUVUc

For a sample of 10 local unidirectional ventilation units suitable for continuous operation (LUVUc), an average price of € 161 (excl. VAT) and an average maximum flow rate of 146 m3/h are derived from on-line sales data.

Remarks:

- As shown in Figure 62, prices depend on the flow rate, approximately varying as € 67 + 0.65 x flow rate in m3/h.

Figure 62. Collection of on-line (Internet) price data, for continuously operating LUVUc, in function of maximum flow rate. In 2019 euros, incl. delivery costs, excl. VAT. (source: VHK 2019)

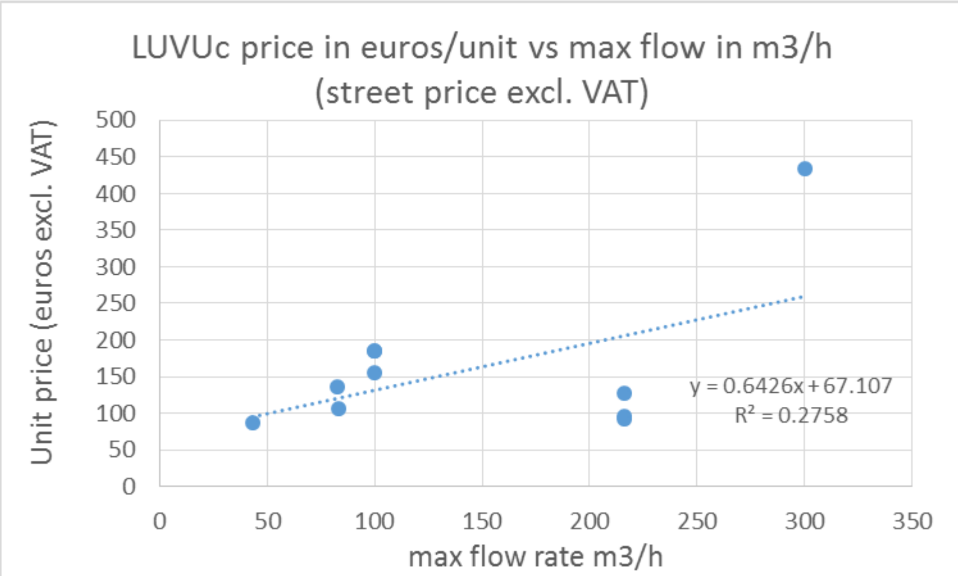


Table 139. Average on-line (Internet) price data, for continuously operating LUVUc. In 2019 euros, incl. delivery costs, excl. VAT. (source: VHK 2019)

	Number	Average flow m3/h	Average price €
Entire sample	10	146	161

CUVU

For a sample of 166 continuously operating central unidirectional exhaust fans (CUVU), an average price of € 891 (excl. VAT) and an average maximum flow rate of 3255 m3/h are derived from on-line sales data. This includes 67 models suitable for kitchen exhausts, with allowable air temperature above 100°C and grease collection, which would be out-of-scope for the current regulations.
For 41 models with a maximum flow rate **between 250 and 1000 m3/h**, the average declared maximum flow rate is 551 m3/h with a price of **€ 248** (excl. VAT).
For 125 models with a maximum flow rate **above 1000 m3/h**, the average declared flow rate is 4142 m3/h with a price of **€ 1102** (excl. VAT). Excluding the 67 models suitable for kitchen exhaust, the average declared flow rate is 3903 m3/h with a price of **€ 994** (excl. VAT).

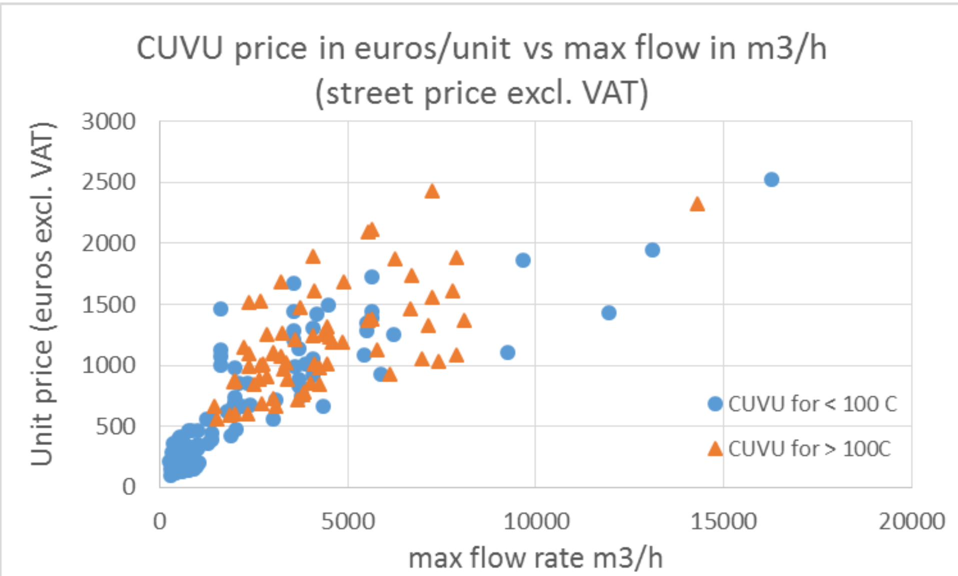
Remarks:

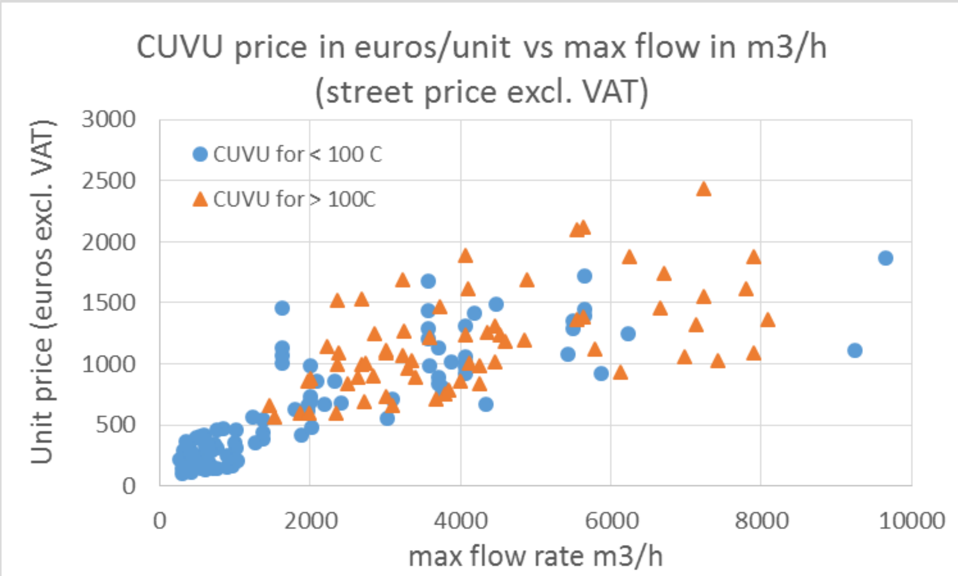
- As shown in Figure 63, there is a spread in prices for a given flow rate, but in general prices depend on the flow rate, approximately varying from € 200 at 300 m3/h to € 500 at 2000 m3/h and € 1500 at 6000 m3/h.

- In the section on sales and stock, a CUVU category between 100 and 250 m3/h was distinguished, but during the on-line survey of prices, not even one CUVU was found in this category. This should be taken into account when formulating the base cases in Task 5.

- In addition to the maximum flow rate, product features influencing the price are the number of inlets, the presence of sensors, control options (0-10 V, remote, Wifi, continuous or in discrete steps, number of steps, continuous pressure control), use of EC or AC motor, power supply 230V or 3-phase 400V, metal or plastic housing, suitability for kitchen exhaust).

Figure 63. Collection of on-line (Internet) price data, for continuously operating CUVU, in function of maximum flow rate. Same data presented with 3 different scales. In 2019 euros, incl. delivery costs, excl. VAT. Models suitable for kitchen exhaust (air temperature above 100°C; grease collection) separately indicated. (source: VHK 2019)





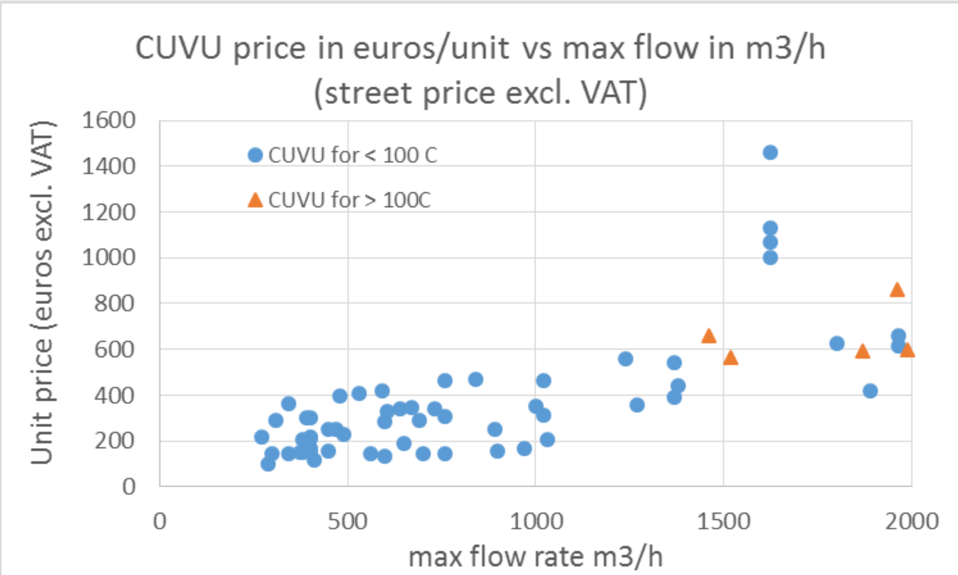


Table 140. Average on-line (Internet) price data, for continuously operating CUVU, per maximum flow rate category. In 2019 euros, incl. delivery costs, excl. VAT. (source: VHK 2019)

	Number	Average flow m3/h	Average price €
Entire sample	166	3255	891
of which ≤ 250 m3/h	0		
of which 250-1000 m3/h	41	551	248
of which > 1000 m3/h	125	4142	1102
of which for T < 100 C	58	3903	994

CBVU

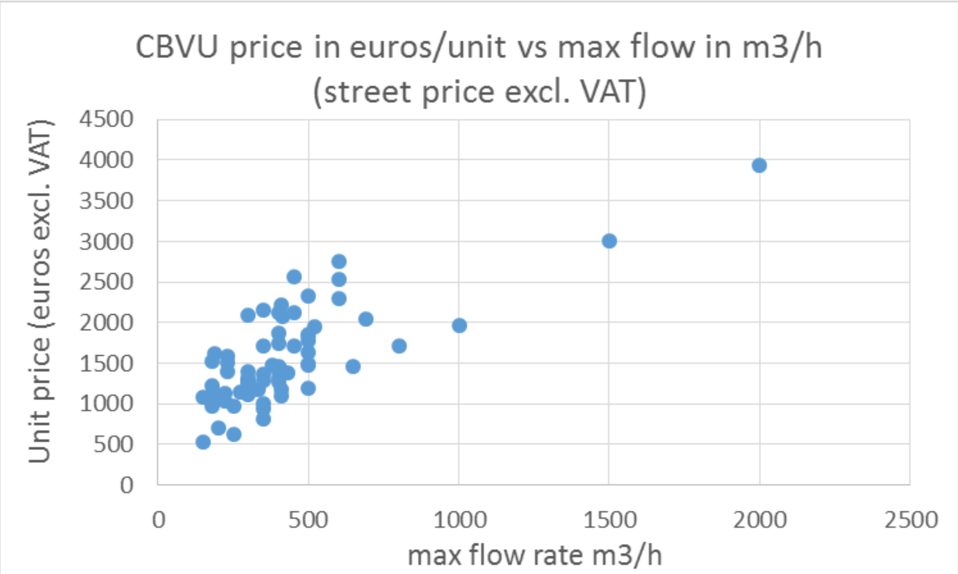
For a sample of 68 central bidirectional ventilation units (CBVU), an average price of € 1562 (excl. VAT) and an average maximum flow rate of 421 m3/h are derived from on-line sales data.
For 14 models with a maximum flow rate **below 250 m3/h**, the average declared maximum flow rate is 202 m3/h with a price of **€ 1134** (excl. VAT).
For 50 models with a maximum flow rate **between 250 and 1000 m3/h**, the average declared maximum flow rate is 439 m3/h with a price of **€ 1625** (excl. VAT).
For 2 models with a maximum flow rate **above 1000 m3/h**, the average declared flow rate is 1750 m3/h with a price of **€ 3471** (excl. VAT).

Remarks:

- As shown in Figure 64, there is a spread in prices for a given flow rate, but in general prices depend on the flow rate, approximately varying as € 723 + 2 x flow rate in m3/h.

- The most expensive models (350 m3/h – € 2162; 450 m3/h – € 2570; 600 m3/h – € 2762) have an enthalpy heat exchanger (additional cost € 450 for such an exchanger).

Figure 64. Collection of on-line (Internet) price data, for central bidirectional ventilation units (CBVUs), in function of maximum flow rate. Same data presented with 2 different scales. In 2019 euros, incl. delivery costs, excl. VAT. (source: VHK 2019)



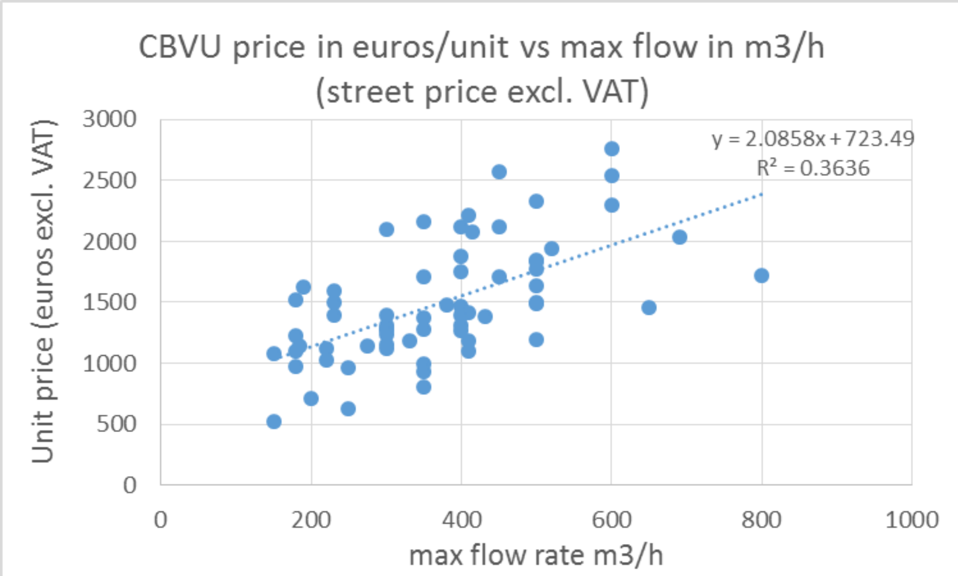


Table 141. Average on-line (Internet) price data, for CBVU, per maximum flow rate category. In 2019 euros, incl. delivery costs, excl. VAT. (source: VHK 2019)

	Number	Average flow m3/h	Average price €
Entire sample	68	421	1562
of which ≤ 250 m3/h	14	202	1134
of which 250-1000 m3/h	50	439	1625
of which > 1000 m3/h	2	1750	3471

LBVU

For a sample of 45 local bidirectional ventilation units (LBVU), an average price of € 565 (excl. VAT) and an average maximum flow rate of 82 m3/h are derived from on-line sales data.
For 37 models with a maximum flow rate **below 100 m3/h**, the average declared maximum flow rate is 50 m3/h with a price of **€ 403** (excl. VAT).
For 5 models with a maximum flow rate **between 100 and 250 m3/h**, the average declared maximum flow rate is 140 m3/h with a price of **€ 1013** (excl. VAT).
For 3 models with a maximum flow rate **above 250 m3/h**, the average declared flow rate is 383 m3/h with a price of **€ 2122** (excl. VAT).

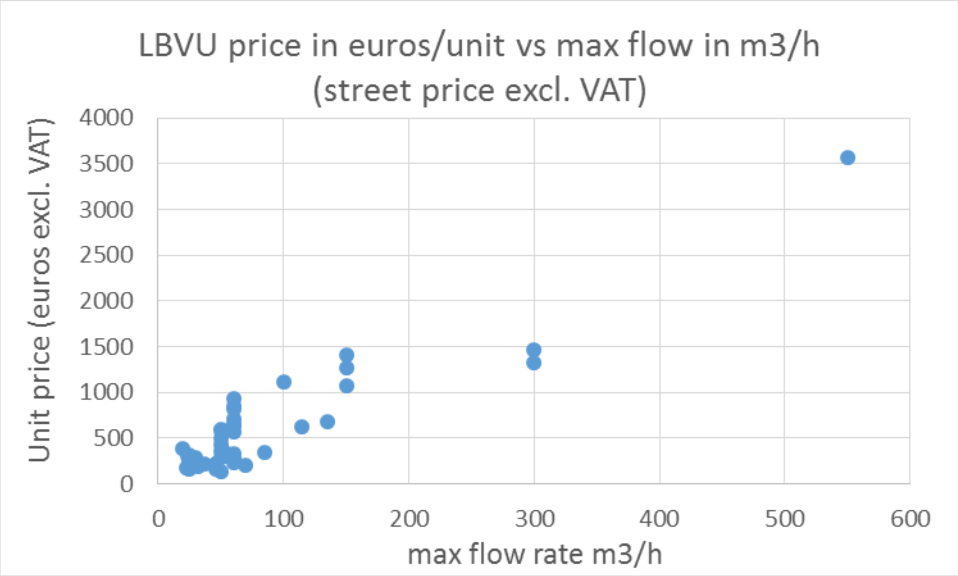
Remarks:

- As shown in Figure 65, there is a spread in prices for a given flow rate, but in general prices depend on the flow rate, approximately varying as € 36 + 7 x flow rate in m3/h.

- There tends to be some confusion in the documentation as regards maximum flow rate and power: not always clear if it refers to the single airstream or to the sum of inlet and exhaust. Some suppliers do not even report flow rate and/or power.

- There are several different systems, all presented as LBVU: single alternating fan, two alternating fans, 2 non-alternating fans. There are also modular systems with multiple alternating fans. Note that to create an adequate ventilation, two LBVUs per room would be required, at some distance the one from the other.

Figure 65. Collection of on-line (Internet) price data, for local bidirectional ventilation units (LBVUs), in function of maximum flow rate. Same data presented with 2 different scales. In 2019 euros, incl. delivery costs, excl. VAT. (source: VHK 2019)



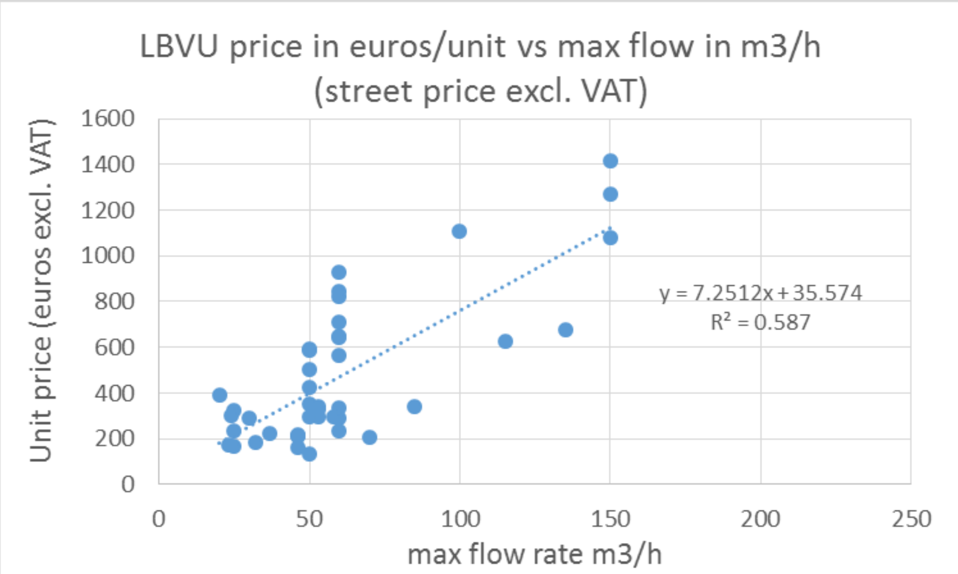


Table 142. Average on-line (Internet) price data, for LBVU, per maximum flow rate category. In 2019 euros, incl. delivery costs, excl. VAT. (source: VHK 2019)

	Number	Average flow m3/h	Average price €
Entire sample	45	82	565
of which > 250 m3/h	3	383	2122
of which 100-250 m3/h	5	140	1013
of which ≤ 100 m3/h	37	50	403

AHU-S

For a sample of 16 air-handling units with maximum flow rate below 5500 m3/h (AHU-S), an average price of € 7674 (excl. VAT) and an average maximum flow rate of 2024 m3/h are derived from on-line sales data.

Remarks:

- As shown in Figure 66, prices depend on the flow rate, approximately varying as € 3668 + 2 x flow rate in m3/h.

- Price data all from the same internet site, for models of the same manufacturer. All models have an EC motor, 0-10V control, and a heating element for the supplied air, either a coil for warm water, or an electric heating element.

Figure 66. Collection of on-line (Internet) price data, for Air-Handling Units ≤ 5500 m3/h (AHU-S), in function of maximum flow rate. In 2019 euros, incl. delivery costs, excl. VAT. (source: VHK 2019)

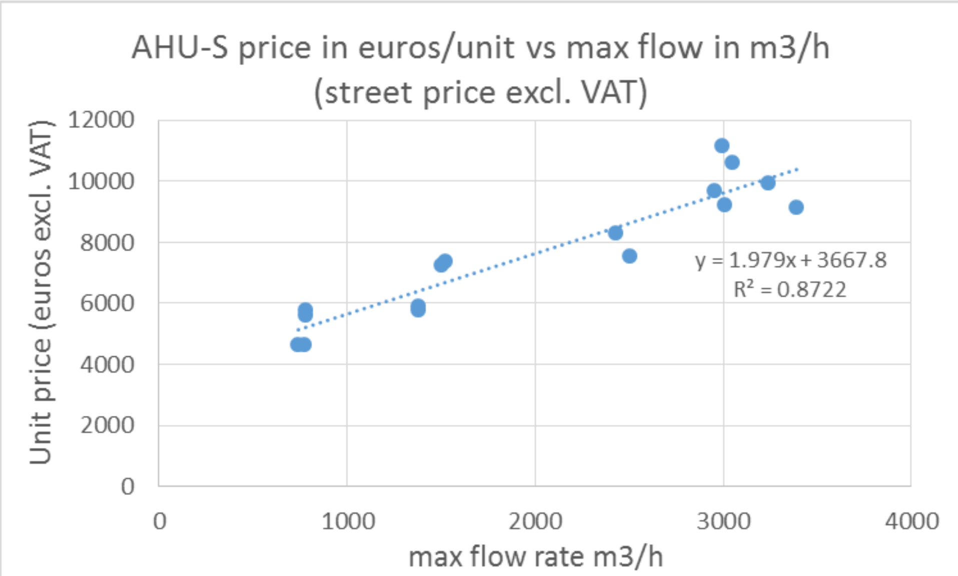


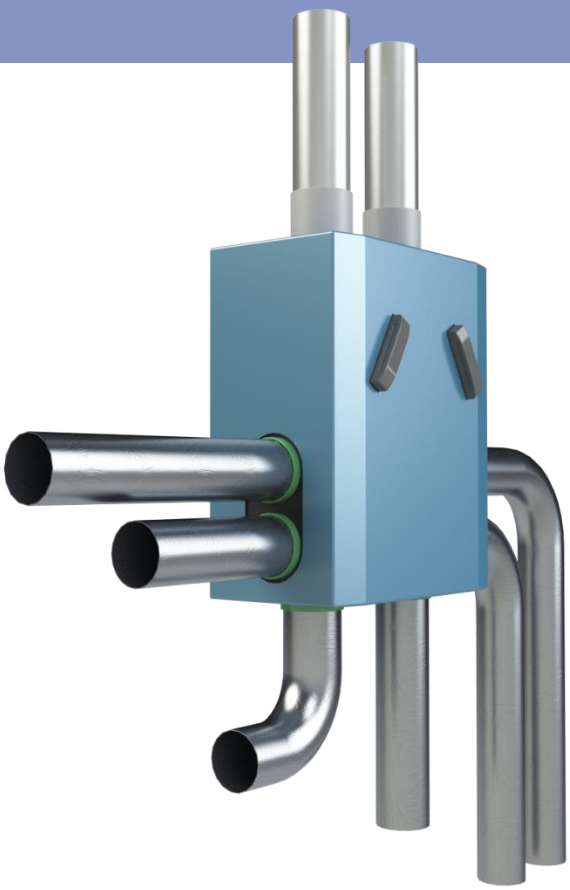
Table 143. Average on-line (Internet) price data, for AHU-S ≤ 5500 m3/h. In 2019 euros, incl. delivery costs, excl. VAT. (source: VHK 2019)

	Number	Average flow m3/h	Average price €
Entire sample	16	2024	7674

European Commission

Ventilation Units

Ecodesign and Energy Labelling



Preparatory Review Study
Phase 1.1 and phase 1.2

Final Report

TASK 3. Use-phase Impacts

Review study on Regulations EU 1253/2014 (Ecodesign requirements for ventilation units) and EU 1254/2014 (energy labelling of residential ventilation units)

Prepared by
VHK, Delft (NL), for the
European Commission, DG GROW

March 2020

Grow

Prepared by

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Contract manager: VITO

Project website: www.ecoventilation-review.eu

Specific contract: No 681/PP/GRO/IMA/18/1131/10204-SI2.798223
Contract starting date: February 5th 2019

Consortium:

Cover: Ventilation unit [picture VHK 2019].

This study was ordered and paid for by the European Commission, Directorate-General Grow.

Executive summary Use-phase Impacts

Introduction
In the EU28, poor indoor air quality plays a crucial role in the annual 500.000 premature deaths and more than 2 million disability adjusted lifeyears (DALYs) attributed to air pollution. Poor indoor air quality also negatively affects cognitive functions and productivity of office workers. These 'use-phase impacts' of poor ventilation on health and productivity come with huge economic costs. Proper ventilation provisions are key in improving indoor air quality (IAQ) and reducing human exposure to pollutant concentrations that typically occur in indoor air.

This Task 3 report of the preparatory review study on Ecodesign and energy labelling of ventilation units analyses the use-phase impacts, end-of-life phase and local infrastructure. Especially as regards the performance in the use-phase, which is the core of this product, the Task 3 report already makes preliminary proposals on modification of the existing regulations to improve both the ventilation- and energy performance, also based on the feedback from stakeholders in the first stakeholder meeting 29 May 2019 (see also project website www.ecoventilation-review.eu). In the future Tasks 4 to 7 various aspects of these, and possible more preliminary proposals will be investigated further. Stakeholder input in that continuing process is very welcome.

Building codes
As mentioned in Task 1, the current nation building codes in most Member States play an important part in the building ventilation. They prescribe the type of air exchange provisions for the various room types and their ventilation capacity. As it is - and despite accepted EU standards on ventilation - there are large differences between Member States in both the minimum required ventilation rates and physical air exchange provisions. However, what all building codes have in common is the fact that they do not refer to the actual ventilation performance in practice. It is generally assumed that when ventilation systems are designed and installed according to building codes (applying the correct installed ventilation capacities per m^2 and/or per person), these ventilation rates are actually achieved when needed. This is not the case.

Various monitoring studies in the residential sector demonstrate that, although total air exchanges over the dwelling could in theory be enough to achieve acceptable IAQ-levels, the air exchange rate in the occupied spaces is often too low. Higher pollutant concentrations cannot always be detected and people adapt to gradually changing IAQ-levels. Unless in extreme cases, the occupant's sensory system is not a reliable control mechanism for operating the ventilation provisions. As a result, the occupants are often exposed to higher pollutant concentrations than can be considered healthy by any standard.

Ventilation Performance
The solution is to bring about ventilation systems that are capable of inducing the right air exchange rates in the right place at the right time, preferably without the need for human intervention. When people are present in a room or other confined space the air exchange should meet at least the minimum design rates. This should determine the ventilation performance and is thus also the yardstick for energy efficiency, i.e. the energy consumption per ventilation performance unit.

<u>*Proposed revisions for assessing the Energy Performance VUs*</u>

Based on the analysis of the *Use-phase Impacts* as described in this Task 3, the modifications to the existing regulations that are proposed for further improvement of both the ventilation- and energy performance are summarised below, including a reference to the sections that give further explanation. As mentioned in the introduction, these proposals will be the basis for further discussions with stakeholders.

WITH REGARDS TO RVUs

1.

New parameter: Ventilation Performance Indicator: VPI (section 1.2 and 1.5)

It is proposed to assess and communicate the Ventilation Performance of the VU-package that is offered on the market, based on its technical features (room-based air exchange provisions associated with the VU and co-supplied controls). The VU-package may consist of only the ventilation unit (in which case default controls etc. will be assumed), but the VU-package may also include specific controls and even (if applicable) specific ventilation supply grids, in which case the additional supplied components are used to determine the ventilation performance. Depending on the type of VU and supplied controls (and possibly any other components) the Ventilation Performance Indicator is determined. The Ventilation Performance Indicator is to be displayed on the Energy Label.

It is proposed to develop and use a predefined VPI-table containing the ventilation performance indicators for the various ventilation package types that are offered on the market, and to include this table as an annex to the RVU-regulations.

Furthermore it is proposed to use the ventilation performance assessment method that is developed together with EVIA, UGent and VHK for residential ventilation systems to determine the values for the VPI-table.

2.

New list of CTRL-factors (section 1.3 and 1.5)

It is proposed to replace the four *CTRL*-factors (1.0, 0.95, 0.85 and 0.65) of the current regulation by a new and larger table for which the *CTRL*-factor of a VU-package (used in the SEC-formula of the RVU-regulations) will be determined based on a fixed reference ventilation performance. Only then, the energy performance indicators can be compared to each other (see section 1.5.1) .

It is proposed to develop and use a predefined *CTRL*-table containing the control factor for the various ventilation package types that are offered on the market, and to include this table as an annex to the RVU-regulations.

Furthermore it is proposed to use the ventilation performance assessment method that is developed together with EVIA, UGent and VHK for residential ventilation systems to determine the values for the *CTRL*-table.

3.

Modifications regarding energy recovery (section 1.7)

3.a.

It is proposed to include latent heat & humidity recovery feature into the revised Regulations, using the formula: $\eta_e = \eta_t + 0.08 * \eta_{x\_c}$ where

η_e = efficiency of the total recovered energy (thermal + humidity)

η_t = efficiency of the thermal heat recovery (sensible and latent)

η_{x_c} = efficiency of the humidity recovery (to be tested acc. to FprEN 13141-7 or FprEN 13141-8)

0.08 = conversion or bonus factor that converts humidity efficiency figure to a thermal efficiency figure.

3.b.

It is proposed to find a way to display the differences in specific energy consumption (SEC) for the various climate zones on the Energy Label (label lay-out comparable to the Energy Label for room air conditioners).

3.c.

It is proposed to use temperature efficiency values in the SEC-formula that are corrected for internal and external leakages, for indoor and outdoor mixing and for airflow sensitivity, following the FprEN13142. Or in other words: $\eta_t = \eta_5$ instead of η_0

4.

Modifications regarding filters (section 1.9)

4.a.

It is proposed to include reference filters in the VUs that accommodate filters and to increase the initial pressure drop of the reference filters by a factor 1.5, when the effective power input and the specific power input (SPI) and the reference flowrate are determined,

Reference filter classes are set at:

- ISO ePM1 = 50% for the supply
- ISO course = 60% for the exhaust

4.b.

It is proposed to set limit values for filter velocity for ducted RVUs (not for non-ducted RVUs), and to use the following values:

- 0.2 m/s for ISO ePM1 / ISO ePM2.5 / ISO ePM10 filters
- 0.5 m/s for ISO course filters

4.c.

It is proposed to include the following information regarding filters in the *information requirements* for RVUs:

- Filter classes used for supply and exhaust
- Filter-velocity
- Clean pressure drop
- Final pressure drop (and related expected filter change intervals)
- Power consumption of used/full filters in case they are not exchanged (possibly as alternative, the energy performance of the filter?)
- Filter by-pass leakage indication

5.

Modifications regarding reference external pressure difference (section 1.10)

5.a

Instead of a fixed reference external pressure of 50 Pa at which the reference flowrate is to be determined, it is proposed to use a mathematical function that relates the applicable reference external pressure to the maximum declared flowrate and the dimensions of the ducts (where the cross section of the junction or spigots of the RVU serves as a reference for the air ducts that are used).

For RVUs having spigots with cross-sections comparable to Ø d=125 mm spigots:

$$\Delta P_{s,ext.} = 0.0025 * q_{max}^{\ 2}$$

For RVUs having spigots with cross-sections comparable to Ø d=160 mm spigots:

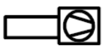
$$\Delta P_{s,ext.} = 0.0007 * q_{max}^{\ 2}$$

5.b
Regarding reference pressure parameters:

It is proposed to use the following pressure parameters in the EU regulation for ventilation units for determining the reference point for the energy efficiency assessment:

- p_{us} : Unit static pressure as difference between static pressure at unit outlet and total pressure at unit inlet
- p_u : Unit pressure as difference between total pressure at unit outlet and total pressure at unit inlet

These pressure parameters lead to a single and unambiguous reference point. The pressure parameters are in full analogy to the pressure parameters p_f and p_{fs} for fans according to ISO 5801 and shall be linked to the intended installation category of the ventilation according to the following table:

Installation category			Example (ventilation unit)	Pressure parameter RVU, NRVU	Pressure parameter Fans *)
A	free inlet / free outlet		**wall fan with casing**	p_{us}	p_{fs}
B	free inlet / ducted outlet		**„toilet fan“ (box fan)**	p_u	p_f
C	ducted inlet / free outlet		**roof fan**	p_{us}	p_{fs}
D	ducted inlet / ducted outlet		**duct fan, air handling unit**	p_u	p_f

6.
Modifications regarding limit values for BVU-leakages (section 2.1)

It is proposed to introduce the following limit values for Internal and External BVU-leakages:

For ducted BVUs, following FprEN 13141-7

- Class A2 (<7%) when pressurization test is used
- Class C3 (<4%) when in-duct tracer gas test is used

For non-ducted BVUs, following FprEN 13141-8 is als

- Class U2 (<7%)

It is also proposed to correct the declared outdoor supply and indoor exhaust mass-flows for these leakages.

7.
Modifications regarding indoor/outdoor airtightness & airflow sensitivity (Section 2.2)
It is proposed to correct the *CTRL*-factor for airflow-sensitivity 'v', using the following multiplier $F_{CTRL,v}$

$$F_{CTRL,v} = \frac{1}{(1-v)}$$

It is also proposed to correct for the indoor/outdoor airtightness 'q_{vio}' , using the following multiplier $F_{CTRL,qvio}$

$$F_{CTRL,qvio} = \frac{q_{vio@5Pa} + q_{v,ref}}{q_{v,ref}}$$

Where $q_{vio@5Pa}$ is the q_{vio} value, recalculated from 20 to 5 Pa pressure difference

8.
Modificatinos regarding energy consumption for defrosting (section 2.4)
Because numerous defrosting strategies are applied in the market, all with different impacts on related energy consumptions, FprEN 13142:2019 proposes an alternative approach for calculating the energy consumption for defrosting.
In view of its complexity and given its impact on the total energy consumption for ventilation, it is proposed to ask stakeholder to suggest a more simplified approach for this.

WITH REGARDS TO NRVUs

9.
Modifications regarding Energy Recovery and life-cycle costs (section 1.6.4 and 1.7.3)

9.a.
It is proposed to include latent heat & humidity recovery feature into the revised Regulations, using the following formula: $\eta_e = \eta_t + 0.08 * \eta_{x\_c}$, where

η_e = efficiency of the total recovered energy (thermal + humidity)
η_t = efficiency of the thermal heat recovery (sensible and latent)
η_{x_c} = efficiency of the humidity recovery for cooling conditions (defined as per prEN308, exhaust air 25°C DB (18°C WB), outdoor air 35°C DB (25°C WB)
0.08 = conversion or bonus factor that converts humidity efficiency figure to a thermal efficiency figure.

9.b.
Proposal to increase limit values for minimum thermal efficiency to 77% (value resulting in maximised economic savings in cold climates when lower energy-prices are assumed)

9.c.
Proposal to increase limit values for minimum energy recovery efficiency for HR-systems that enable humidity recovery to 80%.

9.d.
Proposal to allow a reduction on limit values for η_t or $SFP_{int\text{-}limit}$ for non-residential BVUs that have smart controls (≥ IDA-C5, following table 12 of EN 16798-3)

Since smart controls can significantly reduce the amount of energy needed for ventilation, the actual need for high efficiency HR-systems is diminished. The same goes for the $SFP_{int,limit}$ –values. A bonus on the η_e of the HR-system or the $SFP_{int,limit}$ is an elegant way to compensate for that. This approach offers an alternative for situations where the default HR-limit values would result in uneconomic application of the HR-system. Bonus scheme to be determined with stakeholders.

9.e.

Set a specific bonus E on the $SFP_{int-limit}$ for HR-systems that enable humidity transfer of: $E = (\eta_{e\_nrvu} - 0.73) * 3000$

10.
Modifications regarding Filters (section 1.8.1 and 1.9)

10.a.

It is proposed to separate the $SFP_{int-limit}$ in two values, one for the NRVUs without filters and a separate one for the various filter classes. Depending on the filter efficiency class a dedicated SFP filter correction factors F is determined. More filter efficiency classes can be added to the list with F factors in the Regulation, having a clear reference the new ISO 16890 standard and related definitions. This approach differentiates more clearly the power consumption related to the initial pressure difference of the filter section. It also allows to set separate limit values for filters en encourages the development of more energy efficient filters.
The table below presents the extended list of filters that is proposed (yellow cells correspond with existing Regulation; new filters and F-values (grey cells) are based on recommendations from EVIA & Eurovent). The second table presents the proposed revisions in the SPF_{int_limit} formulas.

Proposed default filters and F values (based on 2018 requirements)

	Filter class acc. to EN ISO 16890 and proposed F -values							
Filter class EN 779	ISO ePM1		ISO ePM2,5		ISO ePM10		ISO Coarse	
		F SFP		***F*** SFP		***F*** SFP		***F*** SFP
G4							≥ 60%	**90**
M5					≥ 50%	**150**		
M6			≥ 50%	**170**				
F7	≥ 50%	**190**						
F8	≥ 70%	**230**						
F9	≥ 80%	**260**						

Proposed revisions in formulas for $SFP_{int-limit}$ values

For Run around coil HRS:

$SFP_{int-limit} = 1260 + E - 300*qnom/2 + F_{sup} + F_{exh}$ *if* $qnom<2\ m^3/s$ *and*

$SFP_{int-limit} = 960 + E + F_{sup} + F_{exh}$ *if* $qnom\geq 2\ m^3/s$

All others HRS

$SFP_{int-limit} = 760 + E - 300*qnom2 + F_{sup} + F_{exh}$ *if* $qnom<2\ m^3/s$ *and*

$SFP_{int-limit} = 460 + E + F_{sup} + F_{exh}$ *if* $qnom\geq 2\ m^3/s$

UVU intended to be used with filters

$SFP_{int-limit} = F_{sup}$ or F_{exh}

F_{sup} and F_{exh} values are taken from table above

For a future Tier, the following F-values are proposed.

Proposed default filters and F values for a future Tier

	Filter class acc. to EN ISO 16890 and proposed F -values							
Filter class EN 779	ISO ePM1		ISO ePM2,5		ISO ePM10		ISO Coarse	
		F SFP		***F*** SFP		***F*** SFP		***F*** SFP
G4							≥ 60%	**70**
M5					≥ 50%	**120**		
M6			≥ 50%	**135**				
F7	≥ 50%	**150**						
F8	≥ 70%	**185**						
F9	≥ 80%	**210**						

10.b

It is proposed to introduce the parameter *filter-velocity*, and set the limit value for *filter-velocity* to 0.2 m/s

10.c

It is proposed to set limit values for the maximum allowable final pressure drop of filter and adjust the (visual or auditory) filter signalling system accordingly. The following limit-values are proposed:

Proposed limit values for final pressure drop filters

Filter class	**Final pressure difference**
ISO coarse	The smaller value of either adding 50 Pa to the clean filter pressure difference or three times the pressure difference of clean filters
ISO ePM1 ISO ePM2.5 ISO ePM10	The smaller value of either adding 100 Pa to the clean filter pressure difference or three times the pressure difference of clean filters

10.d

It is proposed to include the following information regarding filters in the information requirements:

- Filter classes used for supply and exhaust
- Filter-velocity
- Clean pressure drop
- Final pressure drop (and related expected filter change intervals)
- Power consumption of used/full filters in case they are not exchanged (possibly as alternative, the energy performance of the filter?)

11.

Modifications in NRVU-declaration when working point is unknown (section 1.10)

11.a.

For NRVUs for which the actual working point is not known at the time the unit is placed on the market (as is the case for mass-produced NRVUs), the manufacturers can declare an area (in a Q/ΔP-graph), defined by multiple Q/ΔP-values for which the SFP_{int}-values meet the requirements or the regulations (see also Guidelines accompanying the EU1253 and 1254 regulations, oct.2016).

11.b.

Regarding reference pressure parameters (see item 5b):

12.
Modifications concerning leakages (section 2.1.3)

12.a.
It is proposed to introduce two parameters for internal leakage *OACF* and *EATR* (following EN16798-3), where EATR= exhaust air transfer ratio, and OACF= outdoor air correction factor.

12.b
It is proposed to set minimum leakage requirements:

EATR (applicable to all Heat Recovery sections except RACs)

- Maximum allowable EATR at design conditions: ≤5%
- For EATR < 1% no additional compensation action required
- For EATR between 1 and 5%, the nominal supply flowrate shall be increased with the EATR-percentage to compensate for the exhaust air leakage at design conditions and to ensure that the required supply flowrate is delivered.

For NRVUs including a RAC (wit common wall between supply and extract air)

- EATR < 0,1%

OACF

- At design conditions OACF must be within the range 0.90 tot 1.10

External leakages (applicable to all NRVU)

- For negative pressure (to be tested at -400Pa) : 1,32 $l/s/m^2$
- For positive pressure (to be tested at +700Pa) : 1,90 $l/s/m^2$

m^2 relates to the outer surface of the NRVU

12.c
It is proposed to correct mass flows etc. due to internal leakages

Regarding SFP_{int}

SFP_{int} shall include all impacts of internal (OACF and EATR) and external leakages at nominal conditions to ensure that the required outdoor air supply flowrate and extract flowrate will be delivered. These impacts include increased airflow pressure losses.

Regarding supply flowrate

Actual supply flowrate must be increased to ensure it contains the correct outdoor flow. As a result, the power consumption of the supply fan will increase, the related pressure drop will increase and the heat recovery temperature ratio may decrease.

Regarding extract flowrate

- When EATR ≤ 1%, no action is required
- When EATR > 1%, adjust the extracted airflow rate $q_{extr} = q_{req} * (1+ EATR)$

Regarding OACF

Correction of the supply air inlet mass flow from the required supply air outlet mass flow and OACF (regardless the quality of the supply air) can be calculated as follows: $Q_{m,21} = OACF * q_{m,22}$

13. Modifications concerning defrosting (section 2.4)

For non-residential BVUs stakeholders propose to determine the required defrosting-/frost prevention energy per climate zone (cold, average, warm) and include the results in the *information requirements* of the regulation. The determination of the required defrosting-/frost prevention energy is preferably based on a simplified calculation method, using common reference conditions like climate zone, operating time, temperature and moisture content of the extract air. The calculation method should also take into account the control logic that is used for the defrosting function.

So far, no concrete proposal for such a simplified calculation method has yet been made by the stakeholders.

Introduction

This final Task 3 report covers the current status of the work that has been done for Phase 1.1 and phase 1.2 of the Review Study, comprising the Technical Analysis and the update of the Preparatory studies. According to the Terms of Reference (T.o.R.) Phase 1.1 shall assess the items listed in Article 8 of Regulation 1253/2014 (Ecodesign of Ventilation Units) and Article 7 of Regulation 1254/2014 (Energy Labelling of Residential Ventilation Units), being:

a) the need to set requirements on air leakage rates in the light of technological progress
b) the possible extension of the scope of Regulation 1253/2014 to cover unidirectional units with an electric power input of less than 30 W, and bidirectional units, with a total electric power input for the fans of less than 30 W per air stream
c) the verification tolerances set out in Annex VI to Regulation 1253/2014
d) the appropriateness of taking into account the effects of low-energy consuming filters on the energy efficiency
e) the need to set a further tier with tightened Ecodesign requirements
f) the possible inclusion of other ventilation units, notably of non-residential units and of units with a total electric power input smaller than 30 W under Regulation 1254/2014,
g) the specific energy consumption calculation and classes for demand controlled unidirectional and bidirectional ventilation unit (in this respect, it would be very relevant to provide, if possible, an estimate of the efficiency and energy labelling levels of the installed base of residential and non-residential ventilation units in the European Union (EU).

According to the Terms of Reference the following additional items need to be analysed:
h) the influence of the ambient conditions and the climatic zones in the EU on the quantitative requirements for heat recovery
i) the need of specific provisions (and related formulation) on historic or listed buildings where the lack of space available can make it challenging to fit in ventilation units compliant with the two Regulations.
j) the need for (further) clarification on the nature of 'box fans' and 'roof fans', in particular concerning their compliance with the two Regulations, and the fans Ecodesign regulation 327/2011.
k) the need/feasibility to impose quantitative requirements on the maximum internal leakage for bidirectional ventilation units, as well as the need/feasibility of correction factors for the declared thermal efficiency of a residential ventilation units, based on the internal leakage rate
l) Introduction, in the text of the two Regulations (e.g. in the definitions of unidirectional and bidirectional ventilation units), of the clarifications contained in the 'Question on a combination of a supply UVU and an exhaust UVU being considered as a BVU (11-2016)2'
m) Improvement/increased description of the definition of 'nominal flow rate' of non-residential ventilation units
n) Improvements/changes in the definition of 'ventilation unit', with particular regard of the inclusion/exclusion of ventilation units for industrial applications (on the basis of FAQ 10 of the 'Guidelines accompanying Regulation (EU) No 1254/2014

with regard to the energy labelling of residential ventilation units and Regulation (EU) No 1253/2014 with regard to Ecodesign requirements for ventilation units'.

o) The application and potential improvement of the requirement on the provision of instructions for the effective material recycling of the ventilation units (as in Annex IV - point 3 - of the Regulation 1253/2014).
p) Other clarification requests from stakeholder in the context of the stakeholder consultation process.

And finally, if needed, the existing 'Guidelines accompanying Regulation (EU) No 1254/2014 with regard to the energy labelling of residential ventilation units and Regulation (EU) No 1253/2014 with regard to Ecodesign requirements for ventilation units' will be updated .

In the subsequent phase 1.2 the Preparatory Studies are updated, where according to the T.o.R. at least the following additional items need to be addressed:

1) the identification of potential new functional parameters at product level, in particular concerning the indoor air quality when relevant and feasible
2) resource efficiency aspects3 - most likely disassembly, recyclability, reparability, durability and content of Critical Raw Materials (CRM), following the adoption of the Circular Economy Package in December 2015 and the new Ecodesign Working Plan 2016-2019. This includes the analysis of requirement already set (on the instruction for material recycling), their effectiveness in promoting the resource efficiency of ventilation unit, and the identification of additional and/or more ambitious requirements, when relevant (e.g. on the content of CRM in magnets).
3) the potential inclusion in the analysis of smart controls and demand control options (such as, but not limited to, solutions for building/home energy management system based on the European standards SAREF/SAREF4ENER).

The study is performed as a supplement to already existing preparatory studies for Lot 6 and Lot 10, indicating that topics that have already been addresses will not be addressed again, unless there are new elements to be reported.

This sub-report on Task 3, specifically deals with updates on topics regarding Use Phase Energy Impacts, End of Life Behaviour and Local Infra Structure.

Acronyms and units

Acronyms

AC/DC	Alternating/Direct Current
ADCO	Administrative Co-operation
AHRI	American Air Conditioning, Heating and Refrigeration Institute
AMCA	Air Movement and Control Association
ATEX	ATmosphères EXplosibles
BC	Backward Curved
BVU	Bidirectional Ventilation Unit
CECED	European Committee of Domestic Equipment Manufacturers
CEN	European Committee for Standardization
CFD	Computer Fluid Dynamics
CIRCA	Communication and Information Resource Centre
CLP	Classification, Labelling and Packaging (Regulation)
DigitalEurope	Association representing the digital technology industry in Europe
DoC	Document of Conformity
DoE	US Department of Energt
EC	Electronically Commutating
EN	European Norm
EPEE	European Partnership for Energy and the Environment
Eurovent	Association of European refrigeration, air conditioning, air handling, heating and ventilation industry
EVIA	European Ventilation Industry Association
FC	Forward Curved
GWh	Giga Watt hour 109 Wh
HNL	Howden Netherlands
HRS	Heat Recovery System
ICSMS	Information and Communication System on Market Surveillance
ISO	International Standardisation Organisation
JBCE	Japan Business Council in Europe
JRAIA	Japan Refrigeration and Air Conditioning Industry Association
N	Efficiency grade
NRVU	Non-Residential Ventilation Unit
RAC	Run Around Coil
RAPEX	EU Rapid Alert System
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (Regulation)
RoHS	Restriction of Hazardous Substances (directive)
RVU	Residential Ventilation Unit
rpm	rounds per minute (unit for fan rotation speed)
TC	Technical Committee (in ISO, CEN, etc.)
TWh	Tera Watt hour 1012 Wh
UVU	Unidirectional Ventilation Unit
VU	Ventilation Unit
WEEE	Waste of electrical and electronic equipment (directive)
WG	Working Group (of a TC)
yr	year

Parameters

A	floor surface area building [m²]
cair	specific heat air [Wh/ m³.K]
Q	heat/energy [kWh]
q	hourly air exchange [$m^3.h^{-1}/ m^3$]
rec	ventilation recovery rate [-]
S	shell surface area building [m²]
SV	shell surface/volume ratio building
t	heating season hours [h]
T_{in}	Indoor temperature [°C]
T_{out}	outdoor temperature [°C]
U	insulation value in [W/K. m²]
V	heated building volume [m³]
ΔT	Indoor-outdoor temperature difference [°C]
η	efficiency [-]

Units

€	Euro
°C	degree Celsius
a	annum (year)
bn	billion (1000 million)
CO_2	carbon-dioxide (equivalent)
h	hours
K	degree Kelvin
kWh	kilo Watt hour
m	metre or million
m^2	square metre
m^3	cubic metre
Pa	Pascal
W	Watt

Table of Contents

1. Use phase – Direct Energy Impacts

1.1. Introduction

As a reminder: Ventilation is the air exchange in buildings between indoors and outdoors in order to serve the human metabolism, control indoor humidity, dilute or remove background pollutants from buildings materials, furniture and cleaning agents, dilute or remove specific pollutants from point-sources (odours and humidity from cooking, bathing, smoking; carbon-monoxide and other toxins from open or half-open appliances) and provisions of oxygen to open or half-open combustions appliances.
Depending on the location of the buildings, additional functions may be added like filtering the outdoor air (remove outdoor pollutants like PM, NOx, pollen) and sound attenuation (e.g. traffic noise).

The direct energy impacts of ventilation is determined by:

a) The amount of air that is exchanged and the difference in energy content between the supply and exhaust airstreams. Determining factors here are:

a.1)
The national buildings codes, prescribing the ventilation capacity that needs to be installed and the type of air-exchange provisions that are allowed in the various rooms
a.2)
The technical infrastructure of the ventilation systems, determining its technical ability to vary the air exchanges per individual room or building section
a.3)
The number of people and occupancy patterns in the building concerned
a.4)
The type of controls and operating devices that are used
a.5)
The IAQ-levels that are pursued
a.6)
The difference in energy content of the exchanged air depends on climate zone and the fact whether or not heat exchangers are applied

a) The energy that is needed to transport the supply and exhaust airflow, which is determined by:

b.1)
Type of fans that are used
b.2)
Pressure drop/resistance in the whole system (casing, filters, ductwork, supply and exhaust air terminal devices)
b.3)
Ductwork leakages

With the revised EPBD (2018) the attention for ventilation is growing. Where ventilation used to be the balancing item in the realisation of a building, the pursuit for near zero emission buildings and related high insulation and airtightness values has clearly re-positioned *ventilation* as a crucial function in achieving a healthy and comfortable living- and working environment.

Topics that are being addressed with renewed focus and can be considered crucial for the direct energy impacts during use-phase are:

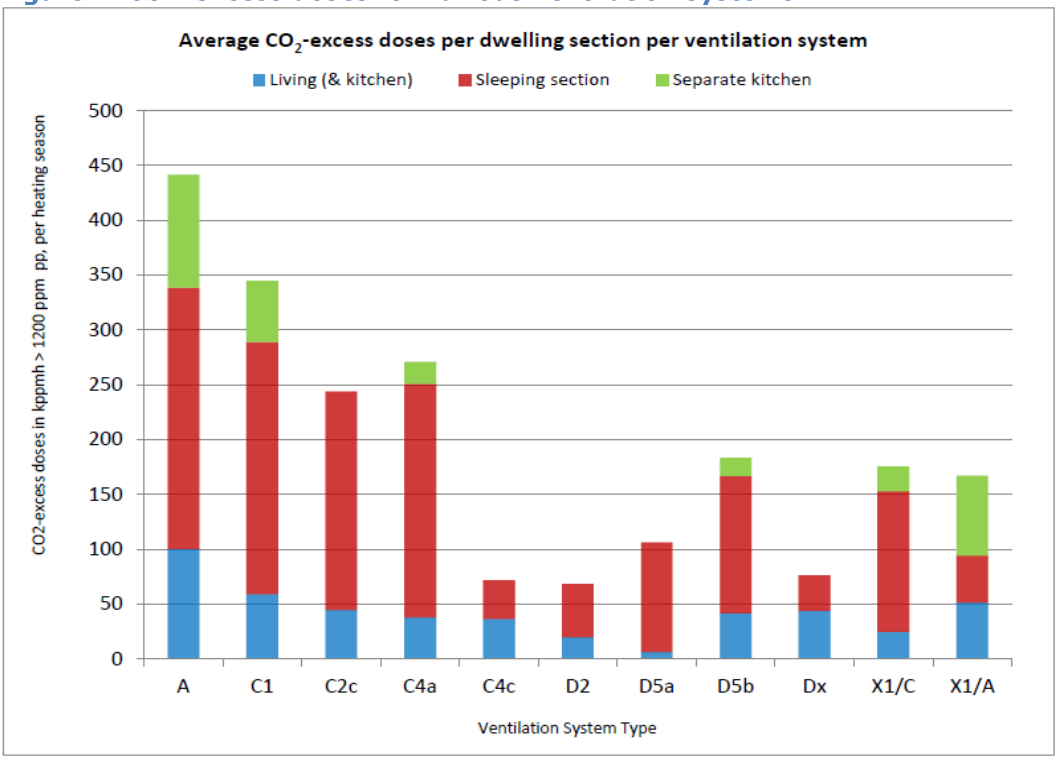
- Ventilation Performance
- DCV
- IAQ-category
- Heat recovery
- Power consumption VU

Experiences with the current regulations and important new insights related to these five topics will be discussed in this chapter.

1.2. Ventilation Performance

Clearly, ventilation is not solely about exchanging air in the most efficient manner. The air exchanges serve a specific purpose, and one needs to assess to what extend this purpose is served. In that sense, assessing the energy consumption of a ventilation system on the basis the number of air changes per hour over the building or dwelling (ach) is not a very sophisticated method. Field research on real-life performance indicates that not all air exchanges can be considered useful. Air exchanges (above minimal or basic ventilation rates) that are induced during periods when occupants are not present, are in most cases useless.
Figure 1 illustrates the results of a full year monitoring study concerning the ventilation performance in the various rooms of a dwelling, comparing 11 different building code compliant ventilation systems in the Netherlands. Before the start of the monitoring project all ventilation systems were checked and adjusted in order to comply with latest building code requirements.

Figure 1. CO2-excess doses for various ventilation systems[1]

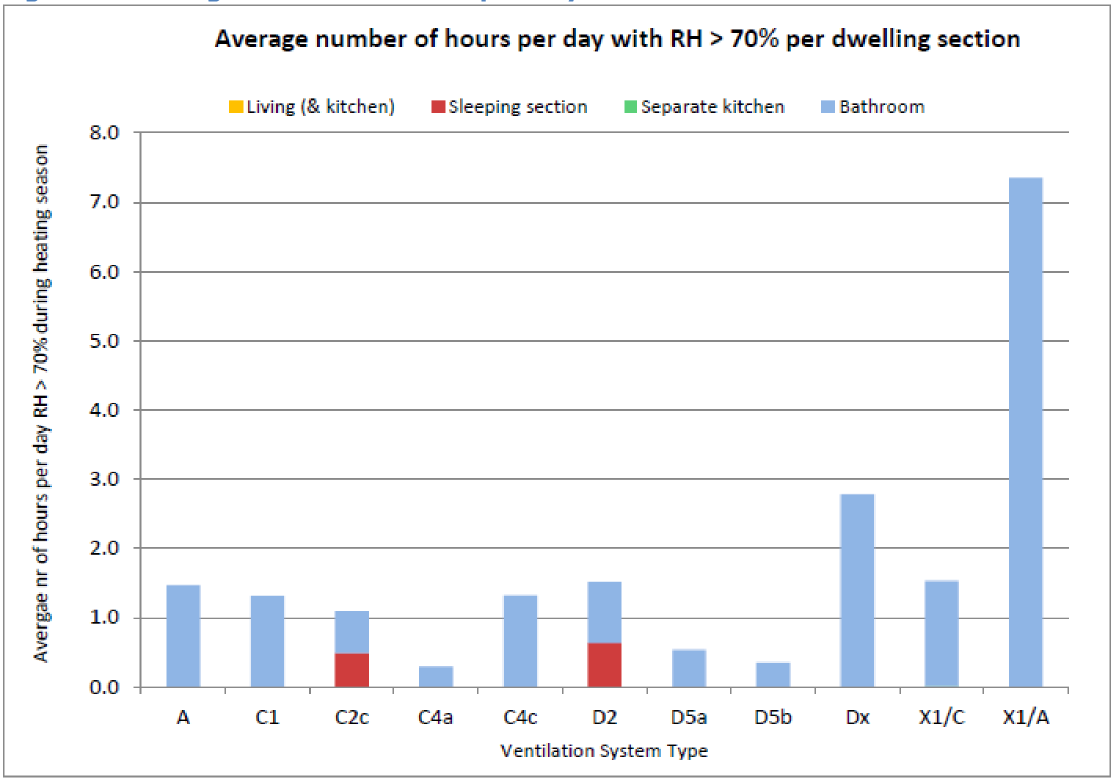


[1] Consortium MONICAIR, Final Report WP1a, Results of a monitoring study into the Indoor Air Quality and energy efficiency of residential ventilation systems, December 2014.

The various ventilation systems differ in type of air exchange provisions applied in the various rooms (natural or mechanical driving forces) and in type of controls for the various rooms. The CO_2-excess doses are an indication for the amount of time and the extent to which the limit concentration of 1200 ppm CO^2 is exceeded[2], or in other words, an indication of the air exchange rates in the various rooms during presence.

Apart from CO_2 concentrations the monitoring study also looked at the humidity levels in the various rooms, and determined the average number of hours per day that humidity levels were above 70% RH. The results show that only during approximately 1 hours per day the RH-levels in (mainly the bathroom) rise above 70%. A group of dwellings with only natural exhaust provisions (system X1/A) had a serious problem with RH-levels above 70% during more the 7 hours a day (see figure 2).

Figure 2. Average number of hours per day with RH>70%



These results indicate that there are huge differences in ventilation performance between building code compliant ventilation systems, especially where the average ventilation rate per occupant is concerned (figure 3). The CO_2 excess doses in kppmh (above 1200 ppm) for building-code-compliant systems may vary from 50 kppmh per person to around 350 kppmh per person during heating season. This figure of 350 kppmh implies that, with an average excess dose of e.g. 400 ppm above 1200, during heating season each occupant will be confronted for 875 hours with CO_2-levels of on average 1600 ppm. If this occupant is on average 12 hours per day at home, this means that around 35% of this time the ventilation is inadequate according to Dutch building codes where CO_2 excess dose values of around 35 – 50 kppmh are pursued.

Main conclusion of these long-term monitoring studies is that the performance of newly installed ventilation systems that comply with the latest building codes, may vary by a factor of 1 to 7 and is generally not in line with the desired objective. This is in contradiction

[2] Reference value that is used in the Dutch building code.

with the general assumption that ventilation systems that comply with buildings codes will achieve an acceptable performance.
In the last couple of years various field trial and monitoring studies have been performed in various countries, all indicating that there are significant differences in the performance of the various ventilation systems.[3 4 5]

The existing building codes and national ventilation standards apparently are not enough to achieve well-performing ventilation systems. Closer examinations shows that most buildings codes and national ventilation standards are of prescriptive nature. Generally speaking building codes only require that air exchange provisions are installed in the various rooms of a building with a certain minimum ventilation capacity. The nature of these air exchange provision (driven forces) are generally not prescribed, nor are the type of controls. Also the requested real-life performances of these air exchange provisions – other than having a certain minimum and a certain maximum capacity – are not specified.
The general assumption is that the ventilation systems themselves are technically able to vary air exchanges rates per individual rooms and that occupants are able to operate the ventilation provisions in such a way that the correct air exchanges are achieved in each room. Field research and monitoring studies however show that this is not the case. Occupants will react upon clearly detectable pollutants such as very high humidity levels and unpleasant odours, but they do not respond to (for humans) undetectable indoor pollutants, which are many. Furthermore occupants will adapt to building-up pollutant concentrations and slowly deteriorating indoor air qualities which negatively effects their ability to take appropriate action.

1.2.1. Ventilation Performance Assessment Method (VPA-Method)

To meet the needs for better performing ventilation systems, a special group within EVIA (Taskforce IAQ) together with the University of Gent and VHK, have been working for two years on a methodology that employs an extended product approach and with which the performance of residential ventilation systems can be assessed.

The method discriminates two technical system properties that determine to what extend the ventilation system is capable of inducing the *right air exchange rates* in the *right place* at the *right time*:

1. The technical ability of the system to *vary* the air exchange rates per individual room (opposite to central ach)
2. The ability to *correctly control* the air exchange rates per individual room

Ad 1. Ability to *vary* air exchange rates per individual room

Depending on the ventilation system type that is applied, the technical ability of the system to vary the air exchange rates per room will be different. For some ventilation system types for instance, the air exchange over the whole dwelling needs to be increased to achieve a certain air exchange rate in the occupied room. Unfortunately such systems also increase the air exchange rates in the other (unoccupied) rooms of the building to levels above basic ventilation rates, leading to unnecessary use of energy.

[3] Tappler, P., Hutter, H.P., Hengsberger, H., Ringer, W. (2014), Lüftung 3.0 – Bewohnergesundheit und Raumluftqualtität in neu errichteten energieefficienten Wohnhäusern, Österreichisches Institut für Baubiologie und Bauökologie (IBO), Wien, Austria

[4] McGill, G.M., Oyedele, L.O., Keeffe, G.K., McAllister, K.M., Sharpe, T. (2015), Bedroom Environmental Conditions in Airtight Mechanically Ventilated Dwellings, Conference Proceedings Healthy Buildings Europe May 2015, The Netherlands, Paper ID548.

[5] Sharpe, T., McGill, G., Gupta,R., Gregg, M., Mawditt, I., (2016), Characteristics and Performance of MVHR Systems, A meta study of MVHR systems used in the Innovative UK Building Performance Evaluation Programme, Report published by Fourwalls Consultants, MEARU and Oxford Brookes University.

Especially in residential buildings ventilation systems are applied that have a limited ability to vary the air exchange rates per individual room. The most commonly applied system in the residential sector for instance, is system C (or VST3 in table 3 below) that uses a central fan (UVU) connected to a duct system that extract air from all the wet rooms (kitchen, bathroom toilet), combined with manually controlled and naturally driven air exchange provisions in the habitable rooms (natural supply grids in the façade and overflow components in internal doors). By operating the central exhaust fan, the total air exchange over the building is increased. Depending on the position of the natural supply grids in the various rooms (open, closed or in between), the position of the various internal doors, the airtightness of the buildings, the location of the leakages and the wind pressure over the building, the supply air enters the building at certain points, which may not always be located in the rooms that need the air exchange. This means that although the ventilation system operates as intended and replaces indoor air with outdoor air, the occupants do not benefit from these air exchanges nor does the building itself. This implies that the energy consumption related to these air exchanges serves no purpose and was in fact in vain.

In order to be able to assess the differences in systems ability to vary the flow rates per individual room or section of a building, the VPA-Method discriminates the systems commonly available on the market, on the basis of the air exchange provisions in the various rooms (habitable space: e.g. living room, bedroom, study, etc.; exhaust spaces: toilet, bathroom, kitchen, utility, etc.) (see table 26)

Table 3. Ventilation System Types (VST) according to the VPA-Method

VST	roomtype	air exchange provision		Indication
1	habitable spaces	supply	natural direct supply	NDS
		extract	natural indirect extract	NIE
	exhaust spaces	supply	natural indirect supply	NIS
		exhaust	natural direct exhaust	NDE
2	habitable spaces	supply	mechanical indirect supply	MIS
		exhaust	natural direct exhaust	NDE
	exhaust spaces	supply	mechanical indirect suply	MIS
		exhaust	natural direct exhaust	NDE
3	habitable spaces	supply	natural direct supply	NDS
		extract	mechanical indirect extract	MIE
	exhaust spaces	supply	mechanical indirect supply	MIS
		exhaust	mechanical direct exhaust	MDE
4	habitable spaces	supply	natural direct supply	NDS
		exhaust	mechanical direct exhaust	MDE
	exhaust spaces	supply	mechanical indirect supply	MIS
		exhaust	mechanical exhaust	MDE
5	habitable spaces	supply	mechanical direct supply	MDS
		extract	mechanical indirect extract	MIE
	exhaust spaces	supply	mechanical indirect supply	MIS
		exhaust	mechanical direct exhaust	MDE
6	habitable spaces	supply	mechanical indirect supply	MIS
		exhaust	mechanical direct exhaust	MDE
	exhaust spaces	supply	mechanical indirect supply	MIS
		exhaust	mechanical direct exhaust	MDE
7	habitable spaces	supply	mechanical direct supply	MDS
		exhaust	mechanical direct exhaust	MDE
	exhaust spaces	supply	mechanical indirect supply	MIS
		exhaust	mechanical direct exhaust	MDE

Legend: N= Natural, M=Mechanical, D= Direct, I= Indirect, S= Supply, E= Exhaust

Ad 2. Ability to *correctly control* the air exchanges per individual room

Next to the technical ability to vary the air exchanges rates per individual room, the capability of the system to *adequately control* the air exchange rates per individual room plays an important role. This ability fully depends on the type of controls (DCV) that are used.

1.3. Demand Controlled Ventilation (DCV)

Ventilation control (DCV) is the key element in achieving high ventilation performance levels and often also in accomplishing an overall low energy consumption during use-phase. Problem however is that the sector uses the term DCV for a variety of features that one way or another are intended to adjust the supply- and/or exhaust airflow rate of ventilation provisions based on whatever parameter.

To give some examples:
- wind-pressure controlled supply grids
- self-regulating exhaust fans
- humidity controlled supply grids
- manual local ventilation control (vs pre-set central control)
- time or clock controlled ventilation provisions
- presence sensor controlled ventilation provisions
- humidity controlled ventilation provisions
- CO_2 controlled ventilation provisions
- VOC controlled ventilation provisions

For a proper application in a ventilation performance assessment method, the term DCV needs to be further specified. In addition, the assessment of the effects such controls have on the overall ventilation performance tends to be poor if one does not include the technical ability of the applied air exchange provisions. To give an example: the use of a CO_2-sensor in the living room controlling the central exhaust fan of a system C or VST3 was initially valued in an earlier version of Dutch EPBD as a feature with which the ventilation performance could be increased while simultaneously the overall air exchanges over the dwelling could be reduced. Monitoring study showed that the opposite was the case: during the evening when the living room was occupied the air exchange rates were increased to maximum values, but because the increased extract rates occur in the separate wet rooms and also the increased supply rates occur in other rooms than the living room, the CO_2-concentration in the living room kept increasing. During the night when only the bedrooms where occupied, CO_2-levels in the living room decreased and as a result central extract fan was turned down.
But with this, the air exchanges in the bedrooms were also decreased, leading to high CO_2-concentrations during sleep as well.

In summary, ventilation control is not only about placing sensors or operating elements in various places of a building, it is also about the technical ability of the ventilation system to control air exchange rates in individual rooms. In order to properly value the effect of sensors or operating elements (DCV), this technical ability needs to be evaluated in parallel.
This also means that, for assessing the real effects of demand controlled ventilation (DCV) the approach that currently is applied in national and EU-regulations, can be further improved. Current Regulations EU 1253/2014 and 1254/2014 use the following definitions:

> *(19)'demand control' means a device or set of devices, integrated or as a separate delivery, that measures a control parameter and uses the result to regulate automatically the flow rate of the unit and/or the flow rates of the ducts;*
>
> *(21) 'demand controlled ventilation (DCV)' means a ventilation unit that uses demand*

control;

(24) 'central demand control' means a demand control of a ducted ventilation unit that continuously regulates the fan speed(s) and flow rate based on one sensor for the whole ventilated building or part of the building at central level;
(25) 'local demand control' means a demand control for a ventilation unit that continuously regulates the fan speed(s) and flow rates based on more than one sensor for a ducted ventilation unit or one sensor for a non-ducted unit;

Ventilation controls are valued with the following CTRL-factor:

- *Manual control (no DCV) : 1*
- *Clock control (no DCV) : 0,95*
- *Central demand control : 0,85*
- *Local demand control : 0,65*

As can be concluded from these definitions and control factor values, the level of discrimination between systems is limited. Applying two sensors (of any kind) in for instance a central ducted exhaust system that is not capable of controlling the ventilation rates per room, is (energy-wise) valued the same as a system that uses local non ducted ventilation units with a local sensor (of any kind). This approach also ignores the fact that the ventilation performance between the two systems is different.
For a proper assessment of the impact controls can have on the ventilation performance and related IAQ-levels, the various options for controls and operating elements need to be valued as well.

The VPA-Method that is being developed with EVIA values the various control and operating elements based on the probability that they achieve the air exchange rates that are requested according the EPBD standard FprEN16798-1 for the individual rooms, both during occupation and absence. This means that the ability of the applied controls to detect presence and absence plays a crucial role. But also the ability of the controls to detect pollutants that are typical for the rooms concerned (habitable spaces, wet or exhaust spaces).
In short, the VPA-Method determines the ability of a ventilation system to induce the *right air exchange rates* in the *right place* at the *right time*, using the FprEN16798-1 as a reference for the air exchanges rates and related IAQ-categories.

1.4. IAQ-category

Purpose of a ventilation system is to create an acceptable indoor air quality in buildings by exchanging indoor air with outdoor air. The first and principal strategy for achieving acceptable IAQ-levels obviously is to reduce source emissions by selecting the right buildings materials and interior products. But after having done that, the second important strategy is ventilation: exchanging indoor air with outdoor air. In most locations the outdoor air is cleaner than the indoor air, but in case the outdoor air would have pollutant concentrations, it needs to be filtered before being supplied to the various rooms in a building.

The ventilation system can be designed in such a way that higher or lower IAQ-categories can be achieved. In a building with a certain load of indoor source emissions and a given outdoor air quality, higher ventilation rates during presence and absence will lead to higher IAQ-levels. As a consequence, higher IAQ-levels will lead to increased energy use. In other words, the energy consumption of a ventilation system will also depend on the IAQ-categories that are pursued and the indoor pollutant loads at hand.

Based on air exchange rates

The EPBD standard FprEN16798-1 offers the first proposal for discriminating IAQ-categories on a EU-level, based on actually achieved air exchange rates during occupancy (not just on the installed capacity of the ventilation provisions). As can be concluded from table B.7 from this standard (see also Task 1), the ventilation rates needed per square meter to sufficiently dilute building emissions of very low polluting buildings are a factor 0.25 smaller that the ventilation rates for non-low polluting buildings (see table below). By increasing the ventilation rates, higher IAQ-categories can be achieved.

Table 1. Building ventilation rates for various IAQ-cat. acc. to FprEN16798-1 table B.7

Category	Very low polluting building, LPB-1 $l/(s\ m^2)$	Low polluting building, LPB-2 $l/(s\ m^2)$	Non low-polluting building, LPB-3 $l/(s\ m^2)$
I	0,5	1,0	2,0
II	0,35	0,7	1,4
III	**0,2**	**0,4**	**0,8**
IV	0,15	0,3	0,6

Table B.6 of this standards lists the ventilation rates that are requested for sedentary non-adapted adults for diluting emissions (bio-effluents) from people. Again, higher ventilation rates per person will result in higher IAQ-categories.

Table 2. Ventilation rates per person for various IAQ-cat. acc to FprEN16798-1 table B.6

Category	Expected Percentage Dissatisfied	Airflow per non-adapted person l/(s per person)
I	15	10
II	20	7
III	30	4
IV	40	2,5

When the buildings are not occupied, other (lower) ventilation rates can be used. Annex B of the FprEN16798-1 also give values for minimum ventilation rates during unoccupied periods.
This IAQ approach that is based on pre-defined air exchange rates, implies that the IAQ-category for which the ventilation system is designed will have a significant effect on the energy consumption during use-phase.

Alternative approaches

Discussions in the academic world on alternative approaches, using pollutant concentrations instead of pre-defined ventilation rates for determining IAQ-categories, are ongoing. The difficulty with this approach is the fact that there are thousands of possible emissions and pollutants, many of which are probably not harmful for people. Research questions that need to be addressed here are:

- which pollutants are harmful, at what concentrations and during what exposure time?
- can we measure all these pollutants with sufficient accuracy?

- where to measure the various pollutants
- how to discriminate between pollutants originating from indoor or outdoor sources

The prospect of installing dozens of sensors in the various rooms of a building is not a very realistic one. Whatever the outcome of this research will be, the strategy to remove and dilute the various pollutant concentrations will remain the same: exchanging the *right amount of indoor air with (if needed pre-filtered) outdoor air* in the *right place* at the *right time*. This means that detection of occupancy will still be needed to determine the *right place and time* and to apply the *correct ventilation r*ates. It is therefore more probable that this type of research will lead to a more substantiated decision on the actual ventilation rates that are needed for the various rooms in a building during presence and absence.

A second alternative approach that is currently being explored concerns methods for cleaning and recirculation indoor air.

Current practice

Current practice in the residential sector (and probably in a part of the non-residential sector as well) is that IAQ-category is generally not a topic that is actively being addressed. Moreover, a larger part of the ventilation systems (especially in the residential sector) is not even able to control the air exchange rates in the various rooms, let alone achieve better IAQ-categories.
Although some member states do apply (either implicitly or explicitly) different design CO_2-concentrations for prescribing the minimum ventilation capacity that needs to be installed, this difference in minimum ventilation capacity to be installed does not stem from any intended discrimination in IAQ-levels, but from the reining culture and attitude in the various countries towards ventilation. France accepts relatively high CO_2- concentration levels (up to 2000 ppm), while some Scandinavian countries prefer levels of around 800 ppm CO_2. Netherlands and Belgium with 1200 ppm CO_2 are somewhere in between. The minimum ventilation capacities to be installed will therefore be higher in Scandinavia than in the Netherlands and Belgium and the lowest in France.

Assuming that these installed capacities can actually be achieved in the various rooms during presence, and assuming that emissions from buildings in the different member states are comparable, these differences in installed capacities would imply that member states pursue different IAQ-levels, which is odd to say the least. But as indicated in section 2.3 on market trends, building codes are lagging behind in this respect[6].

The revised EPBD directive (EU) 2018/844 with its increased focus on healthy indoor environment, inspection of stand-alone ventilation systems and smart-readiness –indicator, may help putting this important subject on the agenda.
In the future, ventilation systems might even be designed to supply different IAQ-levels for different target groups or market segments (e.g. vulnerable groups such as young and elderly people, people suffering from respiratory and cardiovascular diseases etc.)
Whatever the case, in the end the advantages of an improved IAQ (increased wellbeing, health and productivity) need to be measured against the additional energy cost.

Missing link

What is missing is an assessment method indicating what the ability of a ventilation system is to achieve the *right air exchange rates* in the *right place* at the *right time*. So before the

[6] The Netherlands may be mentioned as an exception; the Dutch standardisation body NEN is working on a new ventilation standard and tries to include a method for assessing the differences in ventilation performance of the various systems (2019).

energy performance can be assessed, it must be determined what overall airflows the ventilation system at hand would need to induce (given the nature of its air exchange provisions and controls) to achieve these IAQ-related reference ventilation rates during presence and absence in habitable and wet rooms. The overall airflow and related energy that is needed to achieve these reference air exchange rates during presence and absence in habitable and wet rooms, can then be used as indicator for the energy performance. The more control a ventilation system has over the air exchange rates in the various individual rooms of a dwelling (flow control and targeted IAQ-detection per room), the lower its energy use for a reference ventilation performance.

This energy use associated with this *reference ventilation performance*, is the key parameter to be used for comparing the energy performance between ventilation systems and related ventilation units.
The *expected ventilation performance* (given the nature of the ventilation unit, related air exchange provisions and controls) is the key parameter that determines the expected real-life energy use of the mechanical ventilation unit at hand. As evidenced by various field trials and monitoring studies, these ventilation performance levels are in many cases below the reference ventilation rates belonging to IAQ-category II.

Since it can be assumed that the ventilation rates that are needed during presence and absence in habitable and wet rooms to achieve certain IAQ-categories are the same for all the member states, the ventilation rate values described in Informative Annex B of FprEN16798-1 can be used as the reference situation.

1.5. Proposed revisions addressing Ventilation Performance and DCV

1.5.1. RVUs

Since especially for residential ventilation systems the technical ability to control the air exchanges rates in the various rooms of a dwelling could be problematic because of the ventilation system types that are typically used here, it is proposed to address and integrate the key parameters mentioned in the previous section (Ventilation Performance, IAQ and DCV) in the revised SEC calculations.

In more concrete terms, it is proposed to use the Ventilation Performance Assessment Method (VPA-Method) that has been developed for EVIA (together with UGent and VHK) and use the related calculation tools to:

1.
Calculate the *CTRL*-factor that would theoretically apply for achieving the reference Ventilation Performance (to be defined), in order to determine the Energy Performance of the unit at hand using the SEC-formula.

2.
Determine the *expected* the Ventilation Performance of the RVU at hand

Ad 1). CTRL-factor for SEC-calculaltion
The following procedure is proposed to calculate the CTRL-factor that is to be used for the SEC-calculation:

Step 1.
Determine the ventilation requirement per m^2 heated floor area that is needed to achieve a *reference* IAQ-category for the *reference* Ventilation Unit Package

Step 2.
Determine the ventilation requirement per m^2 heated floor area that is needed to achieve the *reference* IAQ-category for a specific Ventilation Unit Package (consisting of the Ventilation Unit, controls, any other ventilation components that might be needed for the system). If only the Ventilation Unit is offered, default components will be used to determine the ventilation requirement.

Step 3.
Calculate the *CTRL*-factor by dividing the outcome of 2) by the outcome of 1)

Using this approach, an (expandable) list of *CTRL*-factors can be composed for all Ventilation Unit Packages that are offered on the market. Such a list may constitute an integral part of the Regulation text and can be updated on a regular basis. By adjusting the SEC-calculation in this manner, the following improvements are implemented:

- The energy performance is assessed at a reference IAQ-category instead of an assessment without any reference to IAQ
- The ventilation controls are valued in a more realistic manner that improves the comparison between systems

Preliminary calculations using the above described approach indicate that CTRL-factors can become as low as 0.5.

Ad 2). Ventilation Performance Indicator
It is proposed – as requested by various stakeholders - to also use the Ventilation Performance Assessment Method (VPA-Method) to determine the expected Ventilation Performance of the system concerned (Ventilation Performance Indicator), and display this feature on the energy label (in a manner to be determined).

The Ventilation Unit Package may consist of a Ventilation Unit and possibly controls and any other ventilation components that might be needed for the system; if only the Ventilation Unit is offered, default components will be used. The VPA-Method uses the technical specifications of Ventilation Unit Package, to determine (calculate) the Ventilation Performance Indicator, based on a reference average EU-dwelling and on reference installed ventilation capacities that comply with IAQ-category II, of the FprEN 16798-1.

1.5.2. NRVUs

For non-residential ventilation systems, the technical ability to control the air exchanges per room/section of a building is less of a problem since most of the rooms or sections of the building are equipped with mechanical air exchange provisions (either supply, exhaust of both are mechanically driven).
A proper valuation of the controls that are applied however still remains very important and is currently not addressed in the Regulation EU 1253 for the non-residential ventilation units. It determines to what extent the air exchanges are targeted to the actual ventilation needs and because of that the related saving can be huge. Especially in the warm climate zones related savings may exceed the savings achievable with heat recovery.
To minimise energy losses and optimise the ventilation performance for NRVUs, stakeholders ask for additional measures in the revised regulation.

Some stakeholders opt for minimum requirements regarding ventilation controls, amongst which:

- The ability to communicate with a Building Management System
- Steering the fresh air supply rate through demand controls (Tier 1: by clock programs and/or presence detection, Tier 2: automatic controls linked to air quality measurements)
- Etc.

Other stakeholders emphasize that – because of the wide range of non-residential applications – a simplified approach for valuing the controls similar to the residential sector, is not possible or feasible for the following reasons:

- The application of the NRVU is not known to the manufacturer, implying that the proper controls cannot be selected
- The key elements with which demand control ventilations can be achieved (i.e. VAV controller, dampers, diffusors etc.) are not part of the AHU delivery
- A large share of AHUs are not equipped with any control system because this is part of the installers work or of the team that is responsible for the overall building automation control system, in which case the manufacturer has no influence on the decisions concerning controls.

Another proposal therefore is to apply a simple bonus system on the minimum requirement regarding the SFP_{int} for NRVUs with e.g. 20%, when the unit is equipped with certain control systems.

Considering the arguments, it is true that NRVU manufacturers are not always consulted when the overall system design, system performance and necessary controls are discussed. Introducing minimum requirements for controls would imply that NRVUs can only be offered and sold with the controls to acquire the mandatory CE-mark.

A possible solution to address the topic of smart controls in the revised Regulation for NRVUs and at the same time offer a solution for the fact that heat recovery is not always desired, especially in warmer climates, could lie in a trade-off between sophisticated automatic controls (based on air quality or presence detection) and the minimal requested thermal efficiency of the heat recovery system (HRS).

This proposal will be further discussed with stakeholder.

1.6. Heat recovery

After having optimised the efficacy of the air exchanges for ventilation purposes (implying that the *right air exchange rates* are induced in the *right place* at the *right time* by selecting the proper ventilation provision and controls), the next important product feature that determines the energy consumption during use-phase is the fact whether or not heat recovery systems are applied. With heat recovery systems, large parts of the thermal energy content of the extract air can be regained. This can be either heat or cooling energy, depending on the season and the climate zone.

1.6.1. Heat recovery system types

Depending on the type of the ventilation unit, several types of heat recovery systems are possible. For Bidirectional Ventilation Units (BVUs) the following HR-system types are covered by the Regulation EU 1253 and 1254, while noting that currently the Regulations only look at sensible heat recovery and do not value the latent heat and humidity recovery that can be achieved with enthalpy heat recovery systems.

Table 3. Heat recovery system types covered by EU 1253/1254 (moisture recovery excl.)

Type Ventilation Unit	**Type of heat recovery system** Recovered (heating or cooling energy) is supplied to the ventilation supply air
BVU	Air to air recuperative heat exchanger
	Air to air recuperative enthalpy heat exchanger
	Air to air regenerative heat exchanger
	Air to air regenerative enthalpy heat exchanger
	Air to air Run Around Coil (RAC)
	Air to air heat pump
	Combination of air to air heat pump and air to air heat exchanger

Next to these ventilation exhaust air to ventilation supply air heat recovery systems, other heat recovery systems are possible that do not feed the recovered energy directly into the ventilation supply air. The recovered energy can for instance be used for domestic hot water (DHW) and/or for hydronic heating or cooling or for air heating or cooling. In case of multifunctional ventilation units, additional components can be added to fulfil these functions, like air source heat pumps (ASHP) that use additional outdoor air and/or sections for recirculation of air in case of air heating/cooling systems.

See table 5 below, in which also the multi-functional BVUs that are described in the FprEN 16573:2015 (no. 4 to 18) are included.

Table 4. HR system types in multifunctional BVUs not covered by EU 1253/1254

Type Ventilation Unit	**No**	**Type of heat recovery system**	**Regulation**
UVU extract	-	Air to water heat pump for DHW	EU 813/814
Multi-functional BVU	4	Air to water heat pump for DHW	*Not covered*
	5	Air to water heat pump for hydronic heating/cooling	*Not covered*
	6	Air to water heat pump for DHW *or* hydronic heating/ cooling	*Not covered*
	7	Air to water heat pump for DHW *and* hydronic heating/ cooling	*Not covered*
	8	Air to air HE & ASHP for air heating/cooling using recirculation	*Not covered*
Multi-functional BVU	9	Air to air HE + air to water HP for DHW	*Not covered*
	10	Air to air HE + air to water HP for hydronic heating/ cooling	*Not covered*
	11	Air to air HE + air to water HP for DHW *or* hydr.heating/cooling	*Not covered*
	12	Air to air HE + air to water HP for DHW *and* hydr.heating/cooling	*Not covered*
	13	Air to air HE & ASHP for supply air heating/cooling and DHW *or* hydronic heating/cooling	*Not covered*
	14	Air to air HE & ASHP for supply air heating/cooling and DHW	*Not covered*
	15	Air to air HE & ASHP for supply air heating/cooling and DHW *and* hydronic heating	*Not covered*
	16	Air to air HE & ASHP for supply air heating/cooling with recirculation air and DHW	*Not covered*
	17	Air to air HE & ASHP for supply air heating/cooling with recirculation air and DHW *or* hydronic heating/cooling	*Not covered*
	18	Air to air HE & ASHP for supply air heating/cooling with recirculation air *and/or* DHW	*Not covered*

1.6.2. Heat recovery in multifunctional BVUs

Multifunctional BVUs (MF-BVUs) are not covered in any Regulation yet. The proposal to include these units in the revised EU 206/2012 Regulation is not supported by stakeholders (EHI, EHPA, EPEE, EUROVENT, EVIA). Instead industry associations request these multifunctional units to be covered within the revised EU 1253/1254 Regulations, and suggest that FprEN16573 may serve as a framework for assessing the energy performance of these multifunctional BVUs

The tests that are described in the FprEN 16573:2017 for multifunctional BVUs include the regular tests for ventilation units according to FprEN1314-7, and also the tests for determining the energy contribution to or energy performance of the other functions DHW, air heating/cooling or hydronic heating/cooling and combinations thereof.

An important thing to note here is the fact that the contribution of the energy recovery due to the ventilation function is determined at reference flowrate (= 70% of the maximum installed capacity). Clearly the higher the test ventilation flowrates are, the better the energy performance or contribution to the other functions (DHW, hydronic heating/cooling, air heating/cooling) will be.

The following explanation gives an idea of how this reference flowrate (= 70% of the maximum installed capacity) relates to real-life situations in residential dwellings.

> *Provided the VU is correctly dimensioned for the residential dwelling concerned, and the installed ventilation capacity in the wet rooms corresponds to at least the design airflow rates belonging to IAQ category II (see table B.13 of Informative Annex B of FprEN16798-1), the total installed extract capacity for an average dwelling with a 100 m2 heated surface with a separate kitchen, bathroom, toilet and three habitable rooms, will be around 195 m3/h, corresponding to 1.95 $m^3/h/m^2$ per square meter of heated surface. 70% of this capacity corresponds to a ventilation rate of around 1.3 $m^3/h/m^2$ per square meter of heated surface, which perfectly matches the net reference ventilation requirement q_{ref} of 1.3 $m^3/h/m^2$ that is used in the SEC-formula for RVUs.*
> *However, most of the member-states have buildings-codes in place that request lower ventilation capacities to be installed, typically 40% to 75% of the design airflow rates for exhaust rooms mentioned in the FprEN16798-1.*
> *In addition, the implicit assumption that a ventilation rate of 70% of the installed maximum capacity, is on average continuously achieved, does not correspond with real life situations in residential dwellings. At best, such ventilation rates are obtained during presence, while during absence basic ventilation rates are achieved, which already reduces the average ventilation rate to values lower than 70% of max capacity. In real life, the total on average achieved ventilation rate of the RVU depends and the RVU-type and on the operating elements and controls (sensors) that are used, resulting in even lower values.*
> *Long-term monitoring studies in the Netherlands (with buildings codes prescribing roughly 75% of the FprEN16798-1 extract design airflow rates) indicate, that depending on type of VU and type of operating elements and controls, the average ventilation rates for correctly tuned (i.e. building code compliant) systems are between 0.41 and 1.3 $m^3/h/m^2$ per square meter of heated surface, with an overall average of around 1.0 $m^3/h/m^2$. For countries with building-codes prescribing lower extract rates (amongst others UK, France, Poland, Germany, Greece), the real-life average mechanical ventilation rates will be even lower.*

This explanation illustrates, that in case a multifunctional ventilation unit is driven by its operating elements & controls linked to the ventilation function only, the resulting ventilation airflows will be low; most probably too low for a meaningful economic application of the ventilation air as heating source for the heat pumps in the multifunctional unit.

It also means that manufacturers will opt for higher ventilation airflow rates than on average achieved with ventilation units only.

Because stakeholders (EHI, EHPA, EPEE, EUROVENT, EVIA) want these multifunctional ventilation units to reside under the VU-Regulations EU 1253/1254, the first assessment should relate to the ventilation functions and in second instance to the other heating functions.

Finding the optimum

The basic principle that is proposed here, is one whereby the manufacturer declares at what specific average ventilation airflow rates $q_{v,MF,ref}$ (in m^3/h/m^2) the multifunctional unit should operate to achieve its optimum *overall* energy performance at the declared heat/cool capacity and dhw-pattern.

There is an optimum to be found when maximising the energy performance of the combined functions of the multifunctional bidirectional ventilation unit (MF-BVU) compared to single product energy performances, and this optimum can be determined by selecting the preferred specific average ventilation airflow rates[7], or in other words the preferred dwelling size (heated surface area). Without this relation, the energy performance of the additional heating functions of the MF-BVU can be maximised: they will always have their best energy performance at maximum ventilation airflow rates. But increasing ventilation airflow rates will lower the energy performance of the ventilation function and must be taken into account in the overall energy performance assessment.

The manufacturer of the MF-BVU can best specify this specific average ventilation airflow rates $q_{v,MF,ref}$ themselves. A check will be necessary, to confirm that the supplied operating-elements & controls for ventilation, indeed facilitate the specified $q_{v,MF,ref}$ value.

$$q_{v,MF,ref} = \text{specific average ventilation airflow rate for MF-BVU in } \mathrm{m^3/h/m^2}$$

Since this $q_{v,MF,ref}$ represents an average flowrate (time weighted average between maximum and minimum installed capacity), this $q_{v,MF,ref}$ value can never be the same as the maximum ventilation capacity of the MF-BVU. Therefore the reference flowrate (= 70% of the maximum installed capacity) can - for the time being - remain the key assumption for determining the energy performance of the additional heating functions of the MF-BVU.

By providing this $q_{v,MF,ref}$ figure, the manufacturer indicates for what dwelling-size (heat-load) this MF-BVU is best suited (70% * $q_{v,MF,\ max}$) / $q_{v,MF,ref}$ = preferred dwelling size).

MF-BVUs for which the ventilation operating range (maximum en minimum airflow rates) can be adjusted to the size of the dwelling (simultaneously changing its heating/cooling capacity and possibly dhw-pattern), multiple dwelling sizes will be possible, while the specific average ventilation airflow rates in m^3/h/m^2 can remain the same. So in a way, this $q_{v,MF,ref}$ figure also provides guidelines for the installer on how and where to use this product.

Energy performance ventilation function of a MF-BVU

With the SEC-formula in the EU 1253/2014 regulation, the energy performance of the ventilation function of the MF-BVU can be determined.

When the specific average ventilation airflow rates $q_{v,MF,ref}$ in m^3/h/m^2 of a MF-BVU is known, this figure can be used to determine the CTRL-factor that is to be used in the SEC-formula

$$CTRL = q_{v,MF,ref} \,/\, q_{ref}$$

in which

$q_{v,MF,ref}$ specific average ventilation airflow rate for MF-BVUs in m^3/h/m^2

[7] MF-BVUs are primarily used in NZE-Buildings for which transmission losses are minimised and building heat loads are primarily determined by the ventilation losses.

q_{ref} is the net reference ventilation requirement (set at 1.3 m³/h/m²) and

Proposal therefore is that, if and when multifunctional BVUs are to be added to the scope of Regulations EU1253/1254, the contribution of the energy recovery from ventilation to the other heating functions (DHW, hydronic/heating, air heating/cooling) is determined at 70% of its maximum ventilation capacity. The energy performance of its ventilation function is determined with the SEC-formula from the EU 1253/2014 regulation, using for the CTRL-factor the value that is ascertained with the formula: $CTRL = q_{v,MF,ref} / q_{ref}$, where the $q_{v,MF,ref}$ -value is specified by the manufacturer of the MF-BVU.

1.6.3. Humidity recovery

Latent heat recovery and humidity recovery are not included in the energy performance assessment method of existing regulations EU 1253/1254. The heat recovery test mentioned in the Regulation prescribes a test where the temperature ratio of the heat exchanger is determined under dry conditions of the HRS and standard air conditions at balanced mass flow, reference flowrate and temperature difference between indoor and outdoor air of 13 K.

Test standard FprEN13141-7 allows standard tests to be performed for the following temperature pairs $\vartheta_{11}/\vartheta_{21}$:

1. 20°C DB/7°C mandatory for all HE types
2. 20°C DB/2°C optional for recuperative, mandatory for enthalpy HE
3. 20°C DB/-7°C optional

And for units that are designed to operate at outdoor temperatures below -15°C, the cold climate test shall be performed:

4. 20 DB/-15°C optional

Measuring of latent heat recovery should not be a problem. Procedures for testing and determining the humidity recovery efficiency of enthalpy exchangers are also already included in the various test standards.

Recovery of latent heat and humidity can be advantages. Especially in warm climate zones recovery of latent heat and humidity is an asset since it can significantly reduce the energy needed for cooling, when compared to sensible heat recovery only.
In average and colder climates recovery of humidity will lower the risk of frozen heat exchangers and will help increasing the humidity levels of the indoor air during winter periods.

For the reasons mentioned above, industry associations are in favour of including this latent heat & humidity recovery feature into the revised Regulations. Their proposal is to use an energy efficiency parameter 'η_e' instead of the temperature efficiency 'η_t', and to apply the limit values for energy recovery to η_e instead of η_t, with

$$\eta_e = \eta_t + c * \eta_{x\_c}$$

where

η_e = efficiency of the total recovered energy (thermal + humidity)

η_t = efficiency of the thermal heat recovery (sensible and latent)

η_{x_c} = efficiency of the humidity recovery for cooling conditions (defined as per prEN308, exhaust air 25°C DB (18°C WB), outdoor air 35°C DB (25°C WB) c = conversion or bonus factor that converts humidity efficiency figure to a thermal efficiency figure. EVIA proposes a factor of 8%. Using this factor the formula becomes:

$$\eta_e = \eta_t + 0.08 * \eta_{x\_c}$$

Including humidity recovery into the revised regulations represents an important step. Not because it makes the application of heat/energy-recovery in warmer climates more viable (which indeed is the case), but because is also introduces a new topic into the discussion, namely a potential carry-over of contaminants and micro biological contamination in enthalpy exchangers for both regenerative and recuperative type of exchangers.
This topic further has to be discussed with stakeholders to determine whether it is necessary to set minimum limit values on the contaminant carry-over for the various exchanger materials.

1.6.4. Heat recovery and life cycle cost

Several stakeholders mention the fact that the mandatory application of heat recovery in ventilation systems (which is the case for non-residential ventilation units, NRVUs) does not always result in energy savings. In trade fair buildings and shopping malls for instance, heat recovery is often not desired and the by-pass facility is used during most of its operating time. As a consequence life cycle costs for such applications are unnecessarily increased since energy recovery is not desired and the power consumption of the fans is increased due to additional pressure drops in heat exchanger and by-pass circuit.

In general it can be stated that life cycle cost of heat recovery ventilation systems is influenced by the following three parameters that determine the operating time of the heat recovery function:

- Internal thermal loads
- Occupation times
- Climate zone

Internal loads
High internal thermal loads (as is the case in the above mentioned fair trade- and shopping mall buildings) reduce the need for heat recovery. Internal temperatures are already high and the removal of heat could be more desired than its recovery.

Occupation
In buildings that are less frequently occupied, the operating time of the heat recovery unit can also be reduced. Buildings with strong varying occupancy, the ventilation rates may vary as well, leading to partial ventilation rates and to reduced heat recovery in absolute terms.

Climate zone
Depending on the outdoor weather conditions, the need to recover heat may be further reduced. In warm climate zones, the difference between indoor and outdoor temperatures is reduced leading to earlier switch over points to the by-pass facility. Also the amount of heat that is recovered will be reduced due to smaller temperature differences.

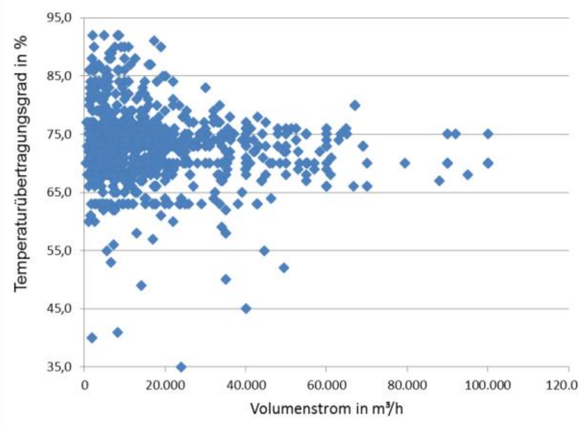
These three parameters, together with the controls that are actually implemented in the heat recovery ventilation system, determine to what extent energy is indeed recovered and to what extent acceptable life cycle costs are achieved. Clearly, the application of smart or

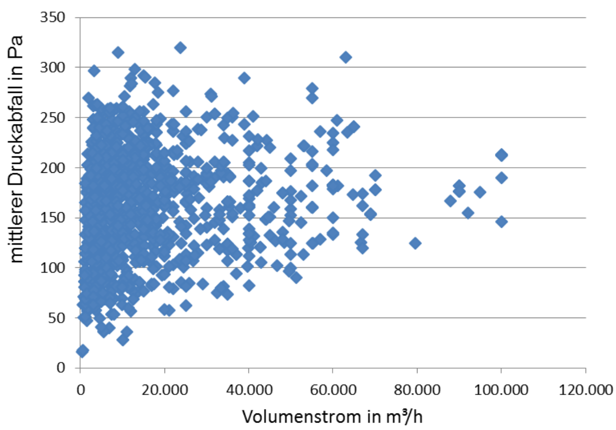
dumb controls will influence the amount of air that will be exchanged, which in its turn effects the amount of energy recovered and its life cycle costs. In other words, there is a trade-off between smart controls on one hand and energy recovery and life cycle costs on the other.
The paper 'European Study on Heat recovery in non-residential buildings' [8] addresses this topic from various angles. The paper not only looks at the overall energy recovery, including the trade-off between increased temperature efficiency and higher power consumption due to increased pressure drops, but also at the life cycle cost in relation to operating time and climate zones. Short summary of this paper that evaluated around 5000 non-residential BVUs over a period of 4 years (2014 to 2017) is presented below:

The temperature ratio of non-residential HR-systems has increased over the years from on average 60% in 2006 to around 73% in 2017. This upward trend was not continuous and had a dip in 2013. The EU 1253/2014 Regulation however restored the upward trend and had a significant contribution in the overall improvement for HR-systems, because not only did it help further improving the temperature ratios, it also contributed to the reduction of the fan power consumption that normally show increases with rising HR-efficiencies. By reducing the flow velocities in the HR-section (bigger HR-units), the pressure drop increase over the HR could be restricted. The effective air velocity relative to the clear cross section in the HR was 2.32 m/s in 2013 and in 2017 the value was on average 2.15 m/s. The mean differential pressure over the HR was around 181 Pa in 2014 versus around 167 Pa in 2017.

The scatterplots in figure 3 indicate that the temperature ratio varies between 63 and 90% and that the pressure drop over the HR ranges from around 50 to 300 Pascal, depending on the type of HR-system that is applied. In other words the spreads around the average values are considerable.

Figure 3. Scatterplots of temperature ratio (left) and HR pressure loss (right) in 2016 [6].





The paper states that the Ecodesign 1253/2014 regulation clearly had its positive effect on the development of heat recovery efficiency and HR-pressure drops. But it also questions whether the HR-limit values should be increased much further. Annex VII of the Regulations mentions heat recovery benchmark figures of 85%. Imposing such figures would indeed increase the amount of energy that will be recovered by around 10 – 15%, but it is also expected that it would increase the equipment cost by a factor 2.
To assess the interrelation between temperature ratio and economic viability, the paper described the results of a sensitivity analysis that was performed using data of 3300 air handling unit (AHU) designs from 2015 up to 2018.

The following parameter values were used in the sensitivity analysis:

[8] Prof. Dr. C. Kaup, Prof. J. Knissel, European Study on Heat recovery in non-residential buildings, 13th REHVA HVAC World Congress CLIMA 2019, Bucharest

- Cost for heating : 0.043 €/kWh
- Cost for cooling : 0.041 €/kWh
- Cost for electricity : 0.091 €/kWh
- Interest rate : 2.4%
- Price increase : 1.7% per annum
- Lifetime HR : 15 years
- Investment cost HR : €21,350,-
- Running times : 8760, 5000 and 2350 hours
- Climate zones : Helsinki, Mannheim, Lisbon
- Air volume flows : 100% of the target air volume during daytime, 50% during night time

In the table 6 below the results are presented for five different situations:

- Existing situation 2016
- 1D optimised system
- Efficiency limit values of around 85% (Bench mark 2020)
- 3D optimised system
- Efficiency limit values of around 85% and optimal flow velocity of about 1.1 m/s

Table 5. Differential costs for various heat recovery systems (source [8])

Differential costs (HR energy savings - *minus* – energy_maintenance_investment costs for HR)						
	run time	actual	1 D Opt.	Benchmark 2020	3D Opt.	Benchmark 2020 (@ 1,1 m/s)
	h/a	€/a	€/a	€/a	€/a	€/a
Helsinki	2.350	1.558	2.138	-169	2.251	225
	5.000	5.458	5.705	3.936	6.155	4.668
	8.760	10.802	10.989	9.804	11.882	10.980
Mannheim	2.350	251	1.123	-1.674	1.204	-1.524
	5.000	2.923	3.394	1.007	3.741	1.673
	8.760	6.717	6.925	5.114	7.641	6.260
Lisbon	2.350	-1.048	139	-3.045	172	-2.722
	5.000	-715	587	-3.149	742	-2.513
	8.760	568	1.564	-1.942	1.920	-1.000

The results indicate that although it might lead to a reduction of the overall energy consumption and related emissions, a further increase of the efficiency limit values will not always result in acceptable payback periods, using energy costs as mentioned on the previous page. On the contrary, in some cases the average annual differential costs are negative, suggesting that the investments cannot be recovered. Increasing the limit values to benchmark values of around 85% would lead to negative differential costs in the warm climate zones, even if the flow velocity in the HR-section is reduced to 1.1 m/s (yellow column). An overall optimisation (red column) of the HR-system (optimising efficiency and pressure drop levels per climate zone / operating time combination could lead to positive differential costs over the whole range.

The reference data were also used to calculate the efficiencies that could lead to optimised differential cost for the three climate zones and running times. The air velocity in the HR devices was set to an average of w = 1.1 m/s (lower speeds are hardly possible since the system should also be able to operate in part load).

The two tables 7 and 8 below indicate what the efficiency figures preferably should be to maximise differential costs for two different energy price levels.

Table 6. 3D optimised efficiencies at 0.043/0.041/0.091 €/kWh for heating/cooling/electricity respectively (source [8])

		3D-Optimum	∅ Diff.-costs	ΔP	w
2.350 h/a		%	€/a	Pa	m/s
north	Helsinki	**61**	2.251	**58**	**1,22**
middle	Mannheim	**53**	1.204	**42**	**1,22**
south	Lisbon	**31**	172	**15**	**1,18**
5.000 h/a					
north	Helsinki	**71**	6.155	**72**	**1,09**
middle	Mannheim	**66**	3.741	**56**	**1,09**
south	Lissabon	**47**	742	**25**	**1,08**
8.760 h/a					
north	Helsinki	**77**	11.882	**87**	**1,03**
middle	Mannheim	**73**	7.641	**70**	**1,03**
south	Lissabon	**58**	1.920	**35**	**1,02**

Table 7. 3D optimised efficiencies at 0.08/0.08/0.15 €/kWh for heating/cooling/electricity respectively (source [8])

		3D-Optimum	∅ Diff.-costs	ΔP	w
2.350 h/a		%	€/a	Pa	m/s
north	Helsinki	**71**	6.944	**61**	**1,01**
middle	Mannheim	**65**	4.097	**47**	**1,01**
south	Lisbon	**45**	773	**21**	**1,03**
5.000 h/a					
north	Helsinki	**79**	16.945	**91**	**1,00**
middle	Mannheim	**75**	10.762	**71**	**0,99**
south	Lissabon	**60**	2.725	**35**	**0,99**
8.760 h/a					
north	Helsinki	**83**	30.774	**119**	**1,01**
middle	Mannheim	**80**	20.616	**96**	**0,99**
south	Lissabon	**68**	6.005	**51**	**0,98**

Main conclusion of this European study is that - although the overall energy consumption and related emissions in most cases are reduced - it will not always be economically feasible to increase the limit values for HR efficiencies. Short operating times and warmer climate zones both lower the optimal heat recovery efficiency value when economic feasibility is pursued. In such cases the actual energy rates determine the allowable limit values for HR-efficiency.
With current energy prices the optimised efficiencies would be around 77% for a continuously running HR-system in cold climates, to around 31% for a running time of 2350 hours per annum in warm climate zones (using relative low energy prices of 0.043/ 0.041/ 0.091 €/kWh for heating/ cooling/ electricity respectively).

1.7 Proposed revisions addressing heat recovery

1.7.1. RVUs

Include latent heat & humidity recovery feature into the revised Regulations, using the following formula

$$\eta_e = \eta_t + 0.08 * \eta_{x\_c}$$

where

η_e	=	efficiency of the total recovered energy (thermal + humidity)
η_t	=	efficiency of the thermal heat recovery (sensible and latent)
η_{x_c}	=	efficiency of the humidity recovery (to be tested according to FprEN 13141-7 or FprEN 13141-8))
0.08	=	conversion or bonus factor that converts humidity efficiency figure to a thermal efficiency figure. EVIA proposes a factor of 8%.

Including humidity recovery into the revised regulations represents an important step. Not because it makes the application of heat/energy-recovery in warmer climates more viable (which indeed is the case), but because is also introduces a new topic into the discussion, namely a potential carry-over of contaminants and micro biological contamination in enthalpy exchangers for both regenerative and recuperative type of exchangers.

For that reason it has to be discussed with stakeholders what minimum limit values can be set related to the contaminant carry-over for the various exchanger materials (could be a requirement directed to the heat exchanger manufacturers).

It is also proposed to find a way to display the differences in specific energy consumption (SEC) for the various climate zones on the Energy Label (label lay-out comparable to the Energy Label for room air conditioners).

1.7.2 Multifunctional residential BVUs

If and when multifunctional residential BVUs are to be added to the scope of Regulations EU1253/1254, the following approach is recommended:

1.
Only multifunctional residential BVU-packages (MF-BVUs) that fulfil these multiple functions completely (as in 'no other products are needed to meet the declared capacity of the functions that are offered by the MF-BVU, (heat-load / cool-load / dhw-tapping pattern, and the ventilation needs)) can reside under the regulations.

2.
The contribution of the energy recovery from ventilation to the other heating functions (DHW, hydronic/heating, air heating/cooling) are determined at the reference ventilation rate of the MF-BVU, which corresponds to 70% of its maximum ventilation capacity.

3.
The manufacturer specifies at what specific average ventilation airflow rates $q_{v,MF,ref}$ (in $m^3/h/m^2$) the multifunctional unit should operate to achieve its optimum overall energy performance and its declared heat/cool-load and/or dhw-pattern.

4.
Test institute tests and confirms that the supplied ventilation controls and related options for control-settings are in line with and facilitate the specified specific average ventilation airflow rates $q_{v,MF,ref}$ (in $m^3/h/m^2$).

5.
The energy performance of the ventilation functions of the MF-BVU is determined with the SEC-formula from the EU 1253/2014 regulation, using for the CTRL-factor the value that is ascertained with the formula: $CTRL = q_{v,MF,ref} / q_{ref}$.

1.7.3 NRVUs

a) Regarding humidity recovery

Include latent heat & humidity recovery feature into the revised Regulations, using the following formula

$$\eta_e = \eta_t + 0.08 * \eta_{x\_c}$$

where

η_e	=	efficiency of the total recovered energy (thermal + humidity)
η_t	=	efficiency of the thermal heat recovery (sensible and latent)
η_{x_c}	=	efficiency of the humidity recovery for cooling conditions (defined as per prEN308, exhaust air 25°C DB (18°C WB), outdoor air 35°C DB (25°C WB)
0.08	=	conversion or bonus factor that converts humidity efficiency figure to a thermal efficiency figure. EVIA proposes a factor of 8%.

b) Regarding limit values and life-cycle-cost

b.1)
Proposal to increase limit values for minimum thermal efficiency η_t to 77% (this limit value resulting in maximised economic savings in cold climates when relative low energy prices of 0.043/ 0.041/ 0.091 €/kWh for heating/ cooling/ electricity respectively are used).

b.2)
Proposal to increase limit values for minimum energy recovery efficiency η_e for HR-systems that enable humidity recovery to 80% (value depends on energy prices that are considered representative)

b.3)
Proposal to allow a reduction on limit values for η_t or $SFP_{int\text{-}limit}$ for non-residential BVUs that have smart controls (≥ IDA-C5, following table 12 of EN 16798-3)

Since smart controls can significantly reduce the amount of energy needed for ventilation, the actual need for high efficiency HR-systems is diminished. The same goes for the $SFP_{int,limit}$ –values. A bonus on the η_e of the HR-system or the $SFP_{int,limit}$ is an elegant way to compensate for that. Bonus scheme to be determined with stakeholders.

b.4)
Set a specific bonus E on the $SFP_{int\text{-}limit}$ for HR-systems that enable humidity transfer of:

$$E = (\eta_{e\_nrvu} - 0.73) * 3000$$

1.8 Determining SPI and SFP of VUs

1.8.1 Effect of filters

Currently the energy impact of *clean* filters is included in the Regulations for RVUs and NRVUs. When the maximum flowrate is determined, the VU must be completely installed (e.g. including clean filters); see also EU 1353/2014, Article 2, definition (4).

If filters are not present in NRVUs, the Regulation prescribes a fixed default correction value for the pressure drop to be used for the filter classes medium and/or fine filters.
For RVUs no correction factor is prescribed in case filters are not present. This probably means that a lot of bidirectional RVUs are tested without filters, leading to somewhat higher declared flowrates and somewhat lower SPI-values.

In real-life, filters can have a significant higher impact on the SPI / SFP –values (and declared flowrates) than currently included in the Regulation. Depending on filter class, filter size (= air velocity over the filter media) and the filter resistance characteristic at growing dust loads, the pressure drop over a filter can easily increase by a factor 7, from for instance 30 Pa for the clean filter to above 200 Pa when filters are not replaced regularly.
And although filters are also an important parameter in the overall IAQ-performance of the ventilation unit, applied filter classes etc. are no subject in the current Ecodesign information requirements. Here, filter by-pass leakages can play an important role (especially in RVUs) since it influences the fraction of supply air that passes the filter; but also on this topic there are no information requirements.

It is the study team's opinion that the real-life effect of filters should be more prominently addressed in the energy assessments of ventilation units.

Filter class
In the current regulation EU/1253 three filter classes are distinguished for NRVUs for the cases filters are not provided for the test. The regulation prescribes the following SFP filter correction factors F (as from January 1st 2018) when calculating the maximum $SFP_{int-limit}$:

- Fine filter : F = 190
- Medium filter : F = 150
- Both medium& fine : F = 340

This implies that the $SFP_{int-limit}$ is determined for the NRVU including filters. But what to do when other filter efficiency classes than *Fine* and *Medium*, or other combinations than the one mentioned here, are to be used?

Proposal regarding filter classes therefore is to separate the $SFP_{int-limit}$ in two values, one for the NRVUs without filters and a separate one for the various filter classes. Depending on the filter efficiency class a dedicated SFP filter correction factors F is determined. More filter efficiency classes can be added to the list having a clear reference the new ISO 16890 standard and related definitions.

This approach differentiates more clearly the power consumption related to the filter section. It also allows to set separate limit values for filters en encourage the development of more energy efficient filters.

For RVUs, filters are probably not at all taken into account when the SPI value is determined. Filters will always be applied, not only for filtering the supply air but also to protect the heat exchanger from fouling. Proposal here is to define reference filter classes for the exhaust and supply side and include them when the SPI of the unit is tested. This could be a simple way for RVUs to always include the power consumption of filters (also when they are not present) and also encourage the use of more energy efficient filters.

An additional proposal is to include information regarding the filter classes in the information requirements for both RVUs and NRVUs.

Filter size

The size of the filter determines the air velocity over the filter media and the air velocity determines the pressure drop over the filter section. So velocity over the filter media (filter-velocity) is the key factor that determines the power consumption due to filters. The size of the filter also influences the speed with which the pressure drop over the filter increases due to dust loading. With a smaller filter this gradient can be higher than with larger filters.
Some stakeholders are in favour of setting limit values for filter-velocity, while others are of the opinion that this would impede the further development of filters.
Their argument is that, setting limit values on filter-velocity would mean that the filter dimensions are fixed, and that smaller filters having the same filtration classes at higher filter-velocities, are not valued. Especially in (local) RVUs, reduction of filter dimensions can be an important topic. For NRVUs, this topic is less important.

Regarding filter size, it is therefore proposed to introduce the parameter *filter-velocity* and to set limit values for the filter-velocity for NRVUs and central RVUs, but not for local RVUs.

Filter clogging

During use, the pressure difference over the filter due to clogging will increase from its initial value (Δp_i = initial or clean pressure drop) to a final value (Δp_e =end-of-life value) which ideally coincides with the filter exchange interval. This final pressure drop value is determined by the manufacturer and defines the expected filter lifetime. Assuming a linear relation between lifetime and pressure drop, the average pressure drop (related real life power consumption due to the filters) can be determined at $(\Delta p_i + \Delta p_e)/2$ (the pressure difference at half of the filters lifetime). When long filter exchange intervals are employed, the power consumption related to the use of filters will increase and vice versa.

Question is whether this energy use of filters related to filter clogging is to be included in the revised VU-Regulations and if yes, how to do this?

For NRVUs it is proposed to set limit values for the final pressure drop of filters (see section 1.9 for further details).

For RVUs it is proposed the use the 'filter clogging compensation factor' FC as explained in Annex D of the FprEN 13142:2019 (see also section 1.9 for further details).

Another necessary step would be to include information on these filter characteristics into the information requirements for RVUs and NRVUs, amongst which:

- Filter classes used for supply and exhaust
- Filter-velocity
- Clean pressure drop
- Final pressure drop (and related expected filter change intervals)

For RVUs the filter by-pass leakage can be included, since this is an issue in some of the RVUs, especially the local RVUs.
Relevant information in this context relates to the fact that Eurovent has been working on an update of its filter classification program.

EUROVENT Filter Classification
Eurovent has been working on a new energy efficiency classification for air filters for NRVUs, based on the new EN ISO 16890:2016 standard. This new classification will cover all air filter products in the scope of the Eurovent Certified Performance programme as from January 1st 2019. For each filter class according to EN ISO 16890:2016, energy efficiency class limits are determined, measured at 0.944 m3/s. The classification is based on the ISO efficiency rating and the related Annual Energy Consumption in kWh/year. See table below.

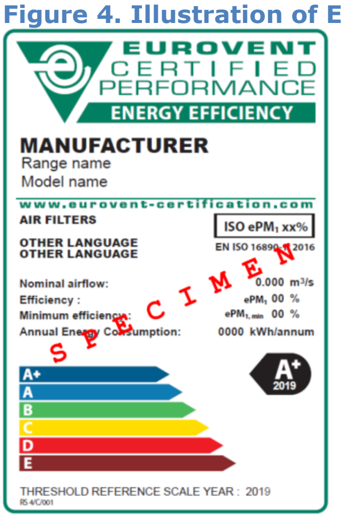
Table 8. Energy efficiency class limits for filter classes according to EN ISO 16890

M_X = 200 g (AC Fine)	AEC in kWh/y FOR ePM_1					
	ePM_1 and $ePM_{1,min}$ ≥ 50%					
	A+	A	B	C	D	E
50&55%	800	900	1050	1400	2000	>2000
60&65%	850	950	1100	1450	2050	>2050
70&75%	950	1100	1250	1550	2150	>2150
80&85%	1050	1250	1450	1800	2400	>2400
>90%	1200	1400	1550	1900	2500	>2500

M_X = 250 g (AC Fine)	AEC in kWh/y FOR $ePM_{2.5}$					
	$ePM_{2.5}$ and $ePM_{2.5,min}$ ≥ 50%					
	A+	A	B	C	D	E
50&55%	700	800	950	1300	1900	>1900
60&65%	750	850	1000	1350	1950	>1950
70&75%	800	900	1050	1400	2000	>2000
80&85%	900	1000	1200	1500	2100	>2100
>90%	1000	1100	1300	1600	2200	>2200

M_X = 400 g (AC Fine)	AEC in kWh/y FOR ePM_{10}					
	ePM_{10} ≥ 50%					
	A+	A	B	C	D	E
50&55%	450	550	650	750	1100	>1100
60&65%	500	600	700	850	1200	>1200
70&75%	600	700	800	900	1300	>1300
80&85%	700	800	900	1000	1400	>1400
>90%	800	900	1050	1400	1500	>1500

Figure 4. Illustration of EUROVENTS air filter energy efficiency label



1.8.2 Actual working point RVUs /NRVUs

RVUs

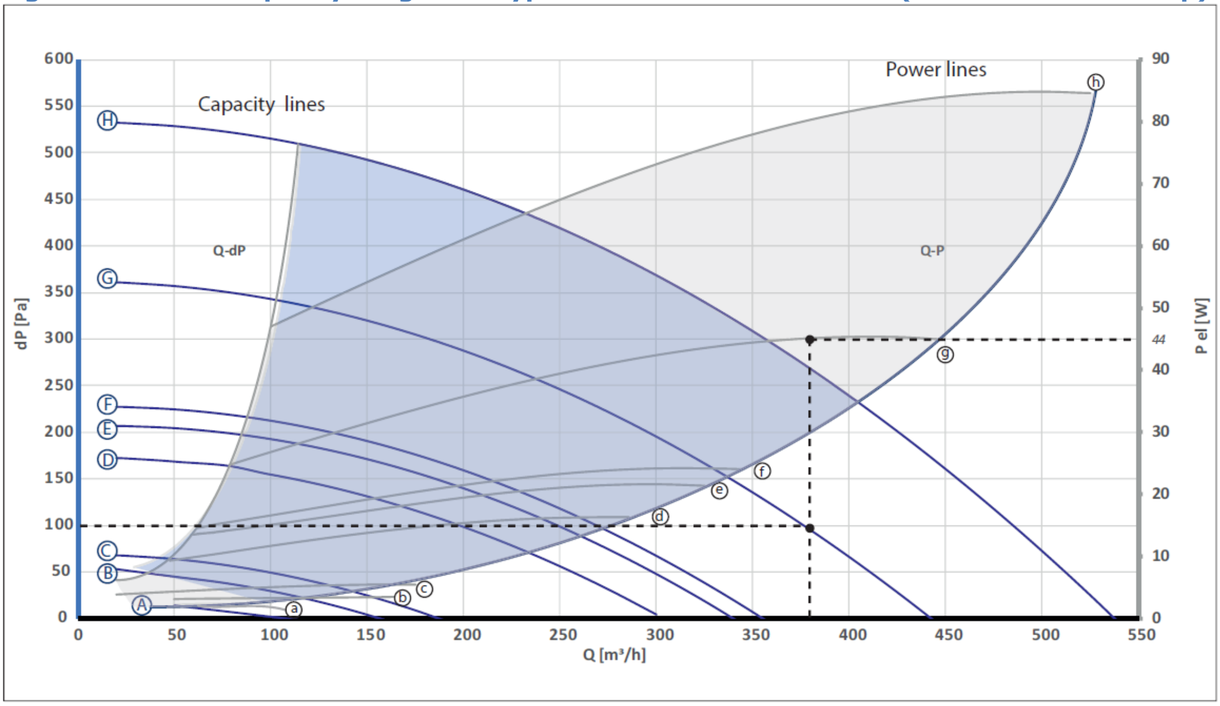
For RVUs the SEC-value is calculated based on the Specific Power Input (SPI) measured at the reference airflow rate. For ducted RVUs, this reference airflow rate corresponds to at least 70% of the maximum airflow rate measured at 50 pascal external pressure difference. Based on this value the energy class of the RVU is determined (G to A+).
Purpose of the Energy Labelling scheme is to allure end-users and system-designers to buy RVUs with better energy labels.

Practice over the last couples of years is, that selecting a RVU on the basis of the energy label not always results in a real-life energy consumption that is coherent to the labelling scheme. RVUs rated in class A may effectively operate in class B or vice versa.
This is due to the fact that the external pressure difference in the field differs from the reference that is set at 50 Pa.

Depending on the total length and the diameter of the duct system, the number of bends and connection pieces and the actual flow rates, the external pressure differences may be higher or lower than the reference value. Especially for RVUs with maximum flowrates above 250 m3/h (250 – 1000), corresponding external pressure differences tend to considerably higher than 50 or 100 Pa.

The primary technical parameter on the basis of which an RVU is selected for a specific dwelling is the maximum airflow rate of the unit; the maximum airflow rate must be high enough for the dwelling concerned. An additional problem here is the fact that RVUs (especially UVUs) are designed to be able to serve a large range of dwellings, from small to large. The maximum flowrates of a typical UVU can be adjusted using dipswitches or installer software, from for instance 125 m3/h to over 500 m3/h. This "one size fits all"-philosophy makes it more difficult to select a representative external pressure difference to determine maximum airflow of the unit.

Figure 5. Airflow capacity range of a typical residential extract VU (source ithodaalderop)



Combining the reference external pressure difference of 50 pascal to determine the maximum flowrate of this typical extract UVU gives very high values. As a result the SPI measurements will yield low values, which are not representative for most of the real-life situations.

A more differentiated approach to set reference values for the external pressure difference, could be to define a relation between the maximum declared airflow rate of the RVU and the reference external pressure difference. The cross section of the junctions of spigots of the RVU may serve as a reference for the air ducts and related flow resistances.

Table 9. Example of relation Qmax to ref. ext. ΔP for RVUs with spigot d=125mm

Max declared flowrate	Reference ext. ΔP
100	25
150	56
200	100
250	156
300	225

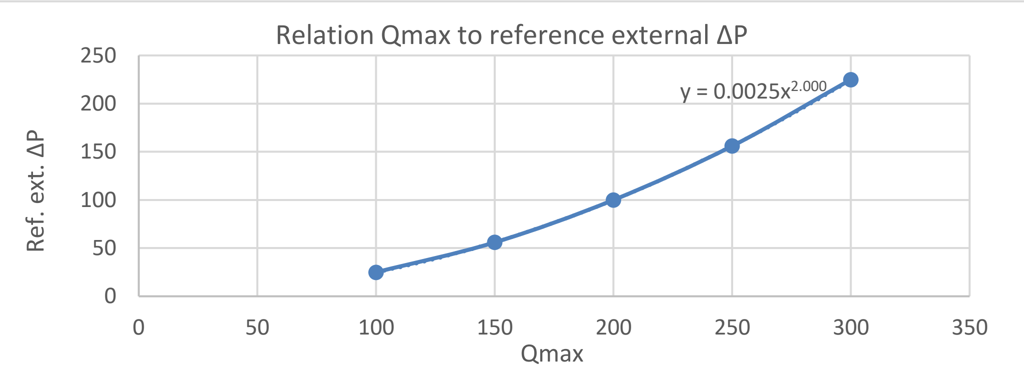
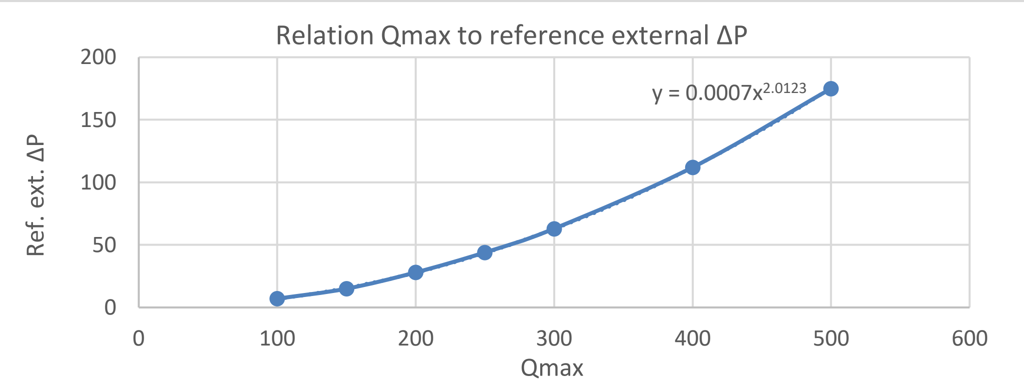


Table 10. Example of relation Qmax to ref. ext. ΔP for RVUs with spigot d=160mm

Max declared flowrate	Reference ext. ΔP
100	7
150	15
200	28
250	44
300	63
400	112
500	175



In this approach, the maximum declared flowrate of the RVU should be indicative for the reference external pressure difference of the RVU. The reference airflow rate' (expressed in m3/s) is the abscissa value to a point on a curve in the flow rate/pressure diagram which is on or closest to a reference point at 70 % at least of the maximum flow rate determined at the thus established external pressure difference for ducted units and at a minimum pressure for non-ducted units. For bidirectional ventilation units, the reference air volume flow rate applies to the air supply outlet.

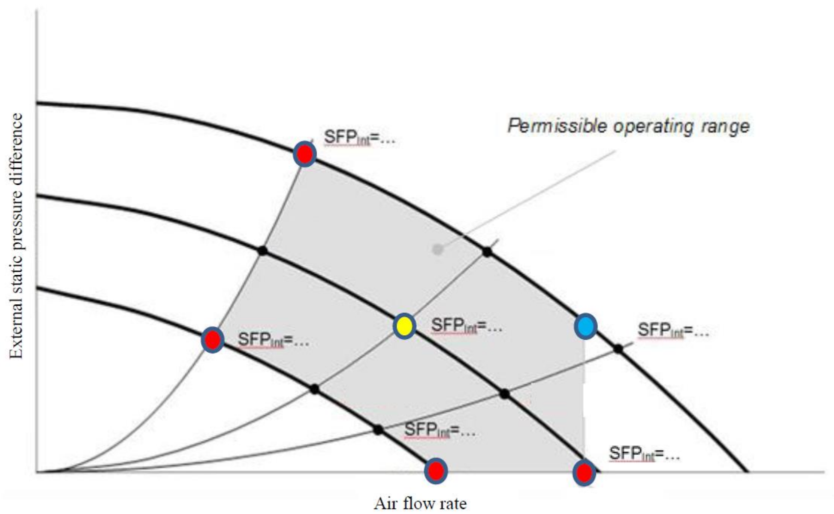
With this approach, selecting a RVU on the basis of the energy label will results in a real-life energy consumption that is coherent to the labelling scheme. Additional advantage of this approach is that it may encourage the use RVUs that have air ducts with bigger cross sections which reduces both power consumption and air noise levels.

NRVUs

Also for NRVUs the situation may occur that the actual working point is not known at the time the unit is placed on the market (as is the case for mass-produced NRVUs), indicating that the nominal airflow, at which compliance to the EN1253 regulation needs to be established, is not known.

As already indicated in the Guidelines accompanying the EU1253 and 1254 regulations, the manufacturers can declare an area (in a Q/ΔP-graph), defined by multiple Q/ΔP-values for which the SFP_{int}-values meet the requirements or the regulations.

Figure 6. Example of declaration of a mass-produced NRVU



In such a case, the declaration is as follows:

1.

All values in Annex V in the Regulation (information requirements) for one nominal point within the grey area, with the largest flow and corresponding static pressure (indicated by the blue dot in Figure above)

2.

A graphical representation as above, containing at least five points where the outer limit is described in all cross sections (indicated by red dots in Figure 12) and an additional point yellow dot in the middle of the grey area, where the following values are indicated for each point:

a) Internal specific fan power of ventilation components (SFP_{int}) and/or fan efficiency (ηvu) regarding type of unit
b) Thermal efficiency of a non-residential HRS (η_{t_nrvu}) (for BVUs only)
c) Sound power level (LWA)

d) Nominal flowrate (q_{nom})
e) Nominal external pressure ($\Delta p_{s,ext}$)

The customer can use the NRVU if their operation point(s) (design working point(s) is within the declared area (grey area where the NRVUs comply with the minimum requirements). The declaration as a mass produced product is optional, but all values with in the grey area must meet the requirements of the Regulation.

1.8.3 Reference pressure parameters VUs

Current regulations use the parameter 'external static pressure difference' $\Delta P_{s,ext}$ in the energy efficiency assessment of RVUs and NRVUs. This parameter however does not consider the dynamic pressure at inlet and/or outlet of the ventilation unit as component in the energy transformation from electric energy (input) to flow energy (output). This can lead to an incorrect assessment of the energy efficiency of ventilation units.

A document provided by a stakeholder contains some clear examples of the mistakes that can be make when this parameter $\Delta P_{s,ext}$ is used.[9]

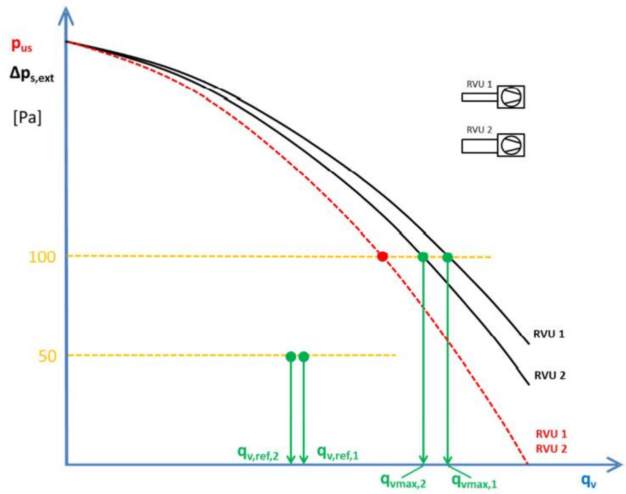
<u>Example RVU: roof fan with ducted inlet</u>

Given:
Two RVUs with identical energy and flow performance but featuring different inlet cross section areas

$A_{inlet,1} < A_{inlet,2}$
(A_{inlet} = duct cross-section area at inlet)

$p_{us,1}(q_v) = p_{us,2}(q_v)$
(p_{us} = difference between the static pressure at unit outlet and total pressure at unit inlet and q_v = air volume flow)

$P_{el,1}(qv) = P_{el,2}(qv)$
(P_{el} electrical power input)



The external static pressure difference $\Delta p_{s,ext}$ depends on the inlet dimension. The two RVUs with different cross-section areas at inlet have to be assessed at different flow rates qv,ref , because the reference point according to EU 1253/2014 is set at a fixed pressure level ($\Delta p_{s,ext}$ = 50 Pa). Depending on the efficiency characteristic of the integrated fan the electrical power input of both RVUs will differ, e.g. with the result: SPI,1 < SPI,2 . The specific power input SPI, used to calculate the SEC value which is the eco-design requirement for RVUs and also relevant for their energy labelling, is different for both units and might lead to different SEC classes, although the flow and energy efficiency performance of both units are the same.

The described situation is in principle valid for ducted units in general.

[9] Dipl. Ing. H. Keller, New pressure reference parameter for a correct energy efficiency assessment of ventilation units, March 2019

<u>Example NRVU: box fan with ducted outlet</u>

According to regulation EU 1253/2014 the energy efficiency requirement for NRVU-UVUs is η_{vu}. As corresponding actual unit parameter the Commission Communication specifies the fan efficiency η_{fan} which in case of UVUs without filter shall be understood as external static efficiency and determined in line with ISO 5801.

$$\eta_{fan} = \frac{qv * \Delta Ps,ext}{Pel}$$

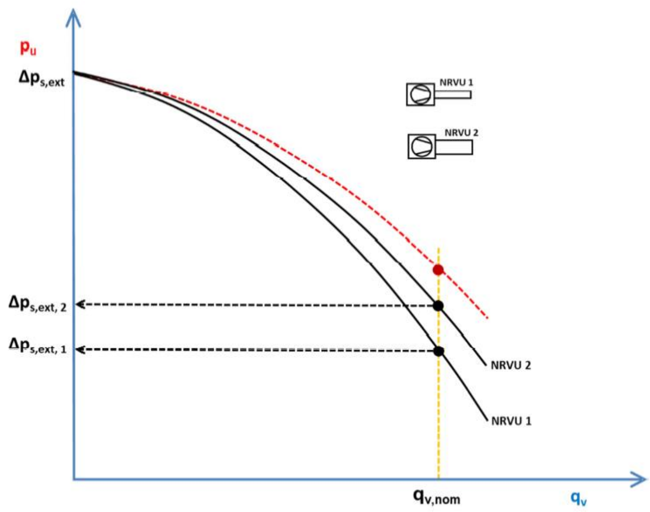
Although the energy efficiency requirement of NRVUs is linked to an air flow rate (not to a fixed pressure value like for RVUs) using the external static pressure difference $\Delta ps,ext$ for calculating the external fan efficiency η_{fan} can create a similar distortion as described in the previous example

Given:
Two NRVUs with identical energy and flow performance but featuring different outlet cross section areas

$A_{outlet,1} < A_{outlet,2}$
(A_{outlet} = duct cross-section area at outlet)

$p_{u,1}(q_{v,nom}) = p_{u,2}(q_{v,nom})$
(p_u = difference between total pressure at unit outlet and total pressure at unit inlet and $q_{v,nom}$ = nominal air volume flow)

$P_{el,1}(q_{v,nom}) = P_{el,2}(q_{v,nom})$
(P_{el} electrical power input)



The two NRVUs with different cross-section areas at outlet can be assessed at the same nominal flow rate $q_{v,nom}$. The corresponding external static pressure difference $\Delta p_{s,ext}$ however is different, because it depends on the outlet dimension, i.e. on the dynamic pressure at outlet.
As result of the different external static pressure curves and identical electric power input at the same nominal air volume flow the external static fan efficiency η_{fan} is different for both units, although their flow performance and energy efficiency are the same.

The described situation is in principle valid for ducted units in general.

With regard to SFP_{int}, which is another energy efficiency requirement to be applied for UVUs with filter and BVUs, the explained problem does not occur, because SFP_{int} at a certain duty point is not dependent on the type of pressure parameter used to specify the duty point.

<u>Proposed solution</u>
Both examples described above prove that the external static pressure difference $\Delta p_{s,ext}$ is not in all cases a suitable reference parameter to evaluate the energy efficiency of ventilation units. Furthermore it becomes obvious that the dynamic pressure in all existing duct connections has to be considered when a correct energy efficiency rating shall be made.

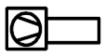
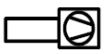
As a conclusion it is proposed to use the following pressure parameters in the EU regulation for ventilation units for determining the reference point for the energy efficiency assessment:

p_{us} : Unit static pressure as difference between static pressure at unit outlet and total pressure at unit inlet

p_u : Unit pressure as difference between total pressure at unit outlet and total pressure at unit inlet

These pressure parameters lead to a single and unambiguous reference point (see red dot in the diagrams above). The pressure parameters are in full analogy to the pressure parameters p_f and p_{fs} for fans according to ISO 5801 and shall be linked to the intended installation category of the ventilation according to the following table:

Table 11. Pressure parameters to be used for different VUs

Installation category			Example (ventilation unit)	Pressure parameter RVU, NRVU	Pressure parameter Fans *)
A	free inlet / free outlet		**wall fan with casing**	**p_{us}**	p_{fs}
B	free inlet / ducted outlet		**„toilet fan“ (box fan)**	**p_u**	p_f
C	ducted inlet / free outlet		**roof fan**	**p_{us}**	p_{fs}
D	ducted inlet / ducted outlet		**duct fan, air handling unit**	**p_u**	p_f

*) acc. to EU 327/2011, resp. ISO 5801

It is also possible to calculate the design duty point based on the static pressure drop of the duct system. In this case the external static pressure difference $\Delta_{ps,ext}$ is the relevant pressure parameter of the unit. But for the purpose of energy efficiency assessment only the pressure parameters p_u und p_{us} are generally correct. The draft standards FprEN 13141-4, -7, -8, EN 13053 and prEN 17291 describe how the new pressure parameters and the external static pressure difference $\Delta_{ps,ext}$ of a unit are related.

The use of the new reference pressure parameters will not affect the ErP data of ventilation units which are ducted on both sides (cat D) and featuring the same areas at inlet and outlet. Also the ErP data for non-ducted units (cat A) will remain the same. Thus a large majority of ventilation units on the market doesn’t have to be re-assessed in terms of eco-design, when the proposed pressure parameters are implemented in the revised regulation EU 1253/2014.

Possible consequences:

The introduction of the proposed pressure parameters may require different efficiency limits (η_{vu}) for the installation categories A/C and B/D (analogue to fans).

Currently A, B and C units are often discriminated compared to Cat D units because the casing of A, B, C units often incorporates e.g. a non-removable protection grid which is part of the duct system in case of D units and not considered there.
EU1253/2014 is a product regulation for ventilation units and unit integrated parts of the duct system should not affect the unit's energy efficiency assessment in a negative way. Therefore those functional components which are part of the duct system in category D units should not be considered for the energy efficiency assessment of all VU-types.

1.9 Proposed revisions regarding Filters

RVUs

For RVUs, the initial pressure difference of filters is not taken into account when the SPI value is determined. Nevertheless, filters will always be applied in case of BVUs, not only for filtering the supply air but also to protect the heat exchanger from fouling. Proposal therefor is to define reference filter classes for the exhaust and supply side and include them when the SPI of the unit is tested. This is a simple way for RVUs to include initial pressure difference of filters.
Proposal for reference filter classes for residential BVUs:
- Supply : ISO *e*PM1 = 50%
- Exhaust : ISO course = 60%

Regarding filter size, it is proposed to introduce the parameter *filter-velocity* and to set limit values for the filter-velocity for central RVUs, but not for local RVUs.
The following values are proposed by stakeholder:
- 0.2 m/s for ISO ePM1 / eMP2.2 / ePM10 filters
- 0.5 m/s for ISO coarse filters

Regarding the effect of filter clogging, it is proposed to use the 'filter clogging compensation factor' *FC*, described in informative Annex D of the FprEN 13142.
The filter compensation factor (*FC*) is determined by adding an additional pressure drop during the test of the unit. This additional pressure is set to 1,5 times the initial pressure drop of the clean filter and is deemed to be representative of the additional filter pressure drop caused by dust collection during half of its life. The *FC* factor is calculated according to the following formula

$$FC = \frac{(q_{\mathrm{vref}} - q_{\mathrm{vfc}})}{q_{\mathrm{vref}}}$$

where

q_{vref} is the reference air flow according to EN 13141-series using clean filters;

q_{vfc} is the air flow with an additional pressure drop of 1,5 times the initial pressure drop

For bidirectional ventilation units, FC shall be determined on both supply and exhaust sides.

In line with this Annex D approach it is proposed to include the following adjustment in the revised regulations related to filter clogging:

- Determine the SPI of the BVU by measuring at 1.5 * initial filter pressure drop, to obtain the representative SPI figure of the BVU with filters

- Correct the declared flowrate q_{vref} by multiplying it with *FC* : $q_{vref,corr} = FC * q_{vref}$

In addition, it is proposed is to include information regarding the filters in the information requirements for RVUs:

- Filter classes used for supply and exhaust
- Filter-velocity
- Clean pressure drop
- Final pressure drop (and related expected filter change intervals)
- Power consumption of used/full filters in case they are not exchanged (or alternatively the energy performance of the filter)
- Filter by-pass leakage (is an issue in some of the RVUs, especially the local RVUs).

<u>NRVUs</u>

For NVRUs the proposal regarding filter classes is to separate the $SFP_{int\text{-}limit}$ in two values, one for the NRVUs without filters and a separate one for the various filter classes. Depending on the filter efficiency class a dedicated SFP filter correction factors F is determined. More filter efficiency classes can be added to the list with F factors in the Regulation, having a clear reference the new ISO 16890 standard and related definitions. This approach differentiates more clearly the power consumption related to the initial pressure difference of the filter section. It also allows to set separate limit values for filters en encourage the development of more energy efficient filters. The 2018 requirements of the existing Ecodesign Regulation for NRVUs are summarized in the table below.

Table 12. 2018 requirements for SFP acc. to EU 1253

For Run around coil HRS:	
$SPF_{int\text{-}limit} = 1600 + E - 300 * qnom/2 - F$	$if\ qnom < 2\ m^3/s\ and$
$SPF_{int\text{-}limit} = 1300 + E - F$	$if\ qnom \geq 2\ m^3/s$
All others HRS	
$SPF_{int\text{-}limit} = 1100 + E - 300 * qnom2 - F$	$if\ qnom < 2\ m^3/s\ and$
$SPF_{int\text{-}limit} = 800 + E - F$	$if\ qnom \geq 2\ m^3/s$
UVU intended to be used with filters	
$SPF_{int\text{-}limit} = 230$	
F = 150 if medium filter is missing	
F = 190 if fine filter is missing	
F = 340 if both the medium and the fine filters are missing	

Table 14 presents the extended list of filters that is proposed (yellow cells correspond with existing Regulation; new filters and F-values (grey cells) are based on recommendations from EVIA & Eurovent). Table 15 presents the proposed revisions in the SPF_{int_limit} formulas.

Table 13. Proposed default filters and F values (based on 2018 requirements)

	Filter class acc. to EN ISO 16890 and proposed F -values							
Filter class EN 779	ISO ePM1		ISO ePM2,5		ISO ePM10		ISO Coarse	
		F SFP		***F*** SFP		***F*** SFP		***F*** SFP
G4							≥ 60%	**90**
M5					≥ 50%	**150**		
M6			≥ 50%	**170**				
F7	≥ 50%	**190**						
F8	≥ 70%	**230**						
F9	≥ 80%	**260**						

Table 14. Proposed revisions in formulas for $SPF_{int\text{-}limit}$ values

For Run around coil HRS:

$SPF_{int\text{-}limit} = 1260 + E - 300*qnom/2 + F_{sup} + F_{exh}$ *if $qnom<2\ m^3/s$ and*

$SPF_{int\text{-}limit} = 960 + E + F_{sup} + F_{exh}$ *if $qnom\geq 2\ m^3/s$*

All others HRS

$SPF_{int\text{-}limit} = 760 + E - 300*qnom2 + F_{sup} + F_{exh}$ *if $qnom<2\ m^3/s$ and*

$SPF_{int\text{-}limit} = 460 + E + F_{sup} + F_{exh}$ *if $qnom\geq 2\ m^3/s$*

UVU intended to be used with filters

$SPF_{int\text{-}limit} = F_{sup}$ or F_{exh}

F_{sup} and F_{exh} values are taken from table 14

Stakeholders also propose new F-values for a future Tier in the revised Regulation (see Table 16.)

Table 15. Proposed default filters and F values for a future Tier

	Filter class acc. to EN ISO 16890 and proposed F -values							
Filter class EN 779	ISO ePM1		ISO ePM2,5		ISO ePM10		ISO Coarse	
		F SFP		***F*** SFP		***F*** SFP		***F*** SFP
G4							≥ 60%	**70**
M5					≥ 50%	**120**		
M6			≥ 50%	**135**				
F7	≥ 50%	**150**						
F8	≥ 70%	**185**						
F9	≥ 80%	**210**						

Regarding filter size, it is proposed to introduce the parameter *filter-velocity* and to set limit values for all filters in NRVUs. Stakeholder propose a *filter-velocity* limit value of 0.2 m/s

Regarding the energy use of filters due to dust loading it is proposed to set limit values to the maximum allowable final pressure difference for filters. Stake holders propose the following values:

Table 16. Proposed limit values final pressure drop of filters

Filter class	Final pressure difference
ISO coarse	The smaller value of either adding 50 Pa to the clean filter pressure difference or three times the pressure difference of clean filters
ISO ePM1 ISO ePM2.5 ISO ePM10	The smaller value of either adding 100 Pa to the clean filter pressure difference or three times the pressure difference of clean filters

Introducing these limit values implies that the visual or auditory signalling system - indicating that the filter needs to be replaced - actually use these limit values.

In addition, it is proposed is to include information regarding the filters in the information requirements for NRVUs:

- Filter classes used for supply and exhaust
- Filter-velocity
- Clean pressure drop
- Final pressure drop (and related expected filter change intervals)
- Power consumption of used/full filters in case they are not exchanged (or alternatively the energy performance of the filter)

1.10 Proposed revision regarding actual working point/reference pressure

RVUs

Practice over the last couples of years is, that selecting a RVU on the basis of the energy label not always results in a real-life energy consumption that is coherent to the labelling scheme. RVUs rated in class A may effectively operate in class B or vice versa.
This is due to the fact that the external pressure difference in the field differs from the reference that is set at a fixed value.

For that reason a more differentiated approach for setting reference values for the external pressure difference is proposed: an exponential function indicating the relation between q_{max} and the reference external pressure difference $\Delta P_{s,ext}$.

Proposed exponential functions (to be discussed with stakeholders):

For RVUs having spigots with cross-sections comparable to Ø d=125 mm spigots:

$$\Delta P_{s,ext.} = 0.0025 * q_{max}{}^2$$

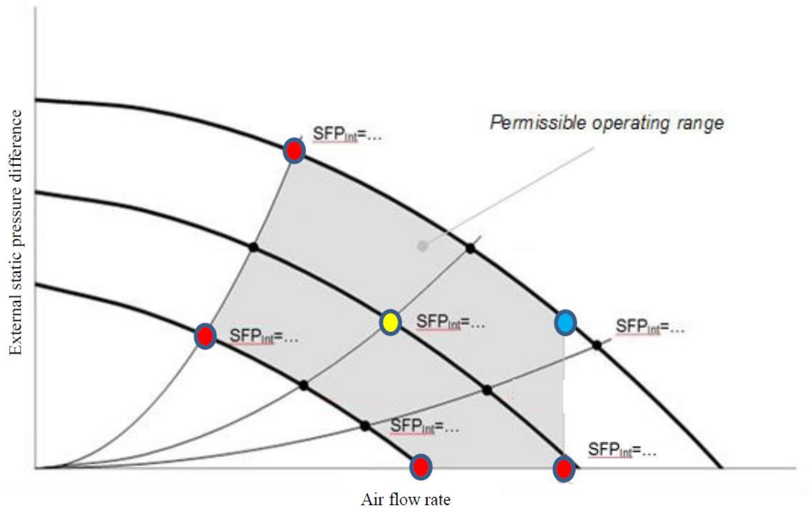
For RVUs having spigots with cross-sections comparable to Ø d=160 mm spigots:

$$\Delta P_{s,ext.} = 0.0007 * q_{max}{}^2$$

NRVUs

For NRVUs for which the actual working point is not known at the time the unit is placed on the market (as is the case for mass-produced NRVUs), the manufacturers can declare an area (in a Q/ΔP-graph), defined by multiple Q/ΔP-values for which the SFP_{int}-values meet the requirements or the regulations (see also Guidelines accompanying the EU1253 and 1254 regulations, oct.2016).

Figure 7. Example of declaration of a mass-produced NRVU



In such a case, the declaration is as follows:

1.

All values in Annex V in the Regulation (information requirements) for one nominal point within the grey area, with the largest flow and corresponding static pressure (indicated by the blue dot in Figure above)

2.

A graphical representation as above, containing at least five points where the outer limit is described in all cross sections (indicated by red dots in Figure 12) and an additional point yellow dot in the middle of the grey area, where the following values are indicated for each point:

f) Internal specific fan power of ventilation components (SFP_{int}) and/or fan efficiency (ηvu) regarding type of unit
g) Thermal efficiency of a non-residential HRS (η_{t_nrvu}) (for BVUs only)
h) Sound power level (LWA)
i) Nominal flowrate (q_{nom})
j) Nominal external pressure ($\Delta p_{s,ext}$)

The customer can use the NRVU if their operation point(s) (design working point(s) is within the declared area (grey area where the NRVUs comply with the minimum requirements). The declaration as a mass produced product is optional, but all values with in the grey area must meet the requirements of the Regulation.

Regarding reference pressure parameters

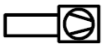
It is proposed to use the following pressure parameters in the EU regulation for ventilation units for determining the reference point for the energy efficiency assessment:

p_{us} : Unit static pressure as difference between static pressure at unit outlet and total pressure at unit inlet

p_u : Unit pressure as difference between total pressure at unit outlet and total pressure at unit inlet

These pressure parameters lead to a single and unambiguous reference point. The pressure parameters are in full analogy to the pressure parameters p_f and p_{fs} for fans according to ISO 5801 and shall be linked to the intended installation category of the ventilation according to the following table:

Table 17. Pressure parameters to be used for different VUs

Installation category			**Example (ventilation unit)**	**Pressure parameter RVU, NRVU**	**Pressure parameter Fans *)**
A	free inlet / free outlet		**wall fan with casing**	p_{us}	p_{fs}
B	free inlet / ducted outlet		**„toilet fan“ (box fan)**	p_u	p_f
C	ducted inlet / free outlet		**roof fan**	p_{us}	p_{fs}
D	ducted inlet / ducted outlet		**duct fan, air handling unit**	p_u	p_f

*) acc. to EU 327/2011, resp. ISO 5801

It remains possible to calculate the design duty point based on the static pressure drop $\Delta_{ps,ext}$ of the duct system. The draft standards FprEN 13141-4, -7, -8, EN 13053 and prEN 17291 describe how the new pressure parameters and the external static pressure difference $\Delta_{ps,ext}$ of a unit are related.

The use of the new reference pressure parameters will not affect the ErP data of ventilation units which are ducted on both sides (cat D) and featuring the same areas at inlet and outlet. Also the ErP data for non-ducted units (cat A) will remain the same. Thus a large majority of ventilation units on the market doesn’t have to be re-assessed in terms of eco-design, when the proposed pressure parameters are implemented in the revised regulation EU 1253/2014.

2. Use phase – Indirect Energy Impacts

Indirect energy use for ventilation purposes can be caused by:

- leakages and mixing
- indoor/outdoor airtightness and airflow sensitivity
- dimensions, shape and leakages of the duct work
- defrosting strategies
- ventilation effectiveness
- energy use of auxiliary devices
- impact ventilation on heat loads dwelling (influences temperature regimes heating systems)
- influence ventilation on IAQ and human well-being and performance levels

2.1 Leakages and mixing

Leakages inside a bidirectional ventilation unit (BVU) will compromise the ventilation capacity of the unit because outdoor supply flowrates and/or exhaust air flowrates are not in conformity with the specifications of the product. Leakages will also influences the heat recovery performance.
Mixing of the supply and exhaust airflows inside or outside the building (a risk associated with room-based non-ducted VUs) will have a similar effects.
Anecdotal reports on leakage rates for non-ducted local BVUs mention leakages of up to 40%, indicating that these unintended airflows can have a significant impact on the key performances of such ventilation units.
Apart from a mandatory notification in the Information Requirements, the current Regulations EU 1253/2014 and 1254/2014 do not consider leakages or mixing when determining the heat recovery performance, the SPI and SFP, and the outdoor supply air flowrate of RVUs and NRVUs. The regulation does state that in any case, the measurement of the temperature ratio is to be done with a balanced mass flow, but whether this balanced mass flow is achieved with leakages and/or mixing is no topic.

Article 8 of the EU 1253 Regulation specifically asks for an assessment of the need to include this topic in a future revised regulation.

The terminologies, definitions and test methods that are used to assess the various types of leakages and leakage rates are not very consistent. The various standards do not use the same terms and definitions and also the Regulations works with different terminology and descriptions. In addition, the proposals for how to compensate for these various leakage types is not very consistent.

This section tries to explain and unify the various terms used for leakages and airflow mixing and to propose a unified method regarding compensating measures for these unintended airflows.

2.1.1. Leakages according to EN Standards

Non-Residential BVUs

The standard for rating and performance testing of AHUs and its components, EN **13503:2018**, states that the leakages between airflows shall be taken into account when testing the heat recovery section. In section 6.4.3 Construction, it is stated that in order to avoid significant bypass leakage, each heat exchanger shall be sealed within the casing of the air handling unit by means of sealing strips. Furthermore, the tests for thermal performances shall not be made when internal leakages of the HRS section, rated according to EN 308 are too high.

Test standard **EN 308** (Heat exchangers — Test procedures for establishing performance of air to air and flue gases heat recovery devices) specifies in section 5.5 on temperature and humidity ratios, that these ratios can be influenced by external and internal leakage. Thus the test shall not be carried out if the maximum of the external and internal leakage rates, as described in the 5.2 and 5.3, exceed **3 %** of the nominal air flow rate q_{mn}.
The following heat exchanger types are distinguished in the EN 308:

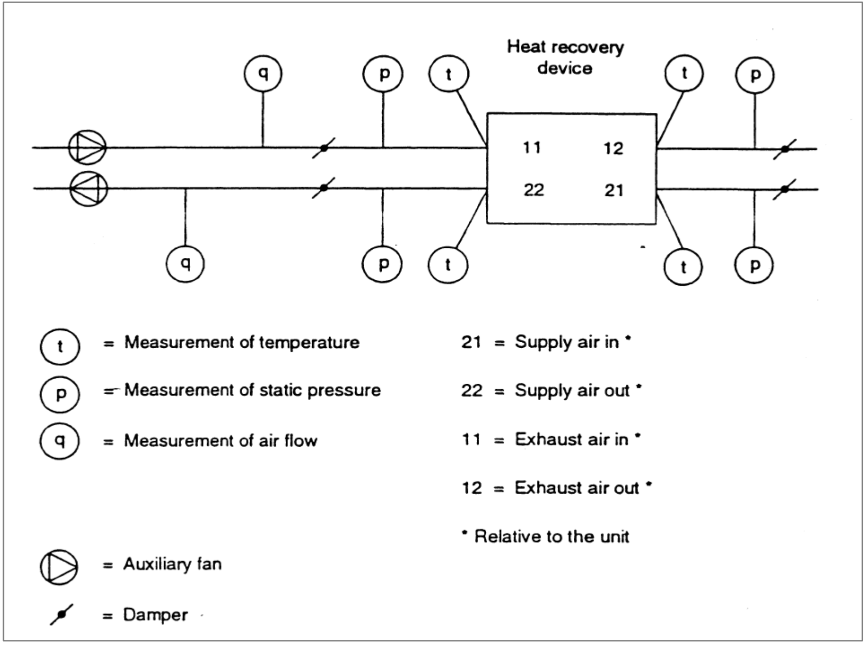
Category I	Recuperative heat exchangers
Category II	With intermediary heat transfer medium
	Category IIa - without phase-change
	Category IIb - with phase-change (heat pipe,..)
Category III	Regenerators (containing accumulating mass)
	Category IIIa - non hygroscopic
	Category IIIb - hygroscopic

The following terms and definitions for leakages are used in EN 308:

4.4
External leakage: the air leakage to or from air flowing through the heat recovery device to or from the environment.
4.5
Internal leakage: the air leakage between the primary and secondary air flows in a heat recovery device.
4.6
Internal exhaust air leakage: the internal air leakage from the exhaust-air side to the supply-air side of a recovery device
4.7
Carry-over air flow: the transfer of exhaust air into the supply air side in a heat recovery device of category III at over pressure on the supply air side.

The external leakage fraction and internal exhaust air leakage fraction are tested by applying an pressure difference over the partition walls between related compartments.
The carry-over mass flowrate of exhaust air into the supply air side for recovery devices belonging to category III, shall be determined at a static pressure difference $\Delta p_{22.11}$ of 0 Pa to 20 Pa and shall be performed using an inert tracer gas that is injected into the exhaust inlet section. Air samples are taken at sections 11 (exhaust air inlet opening) to 22 (supply air outlet opening) to determine the carry-over and from section 21 (supply air inlet opening) to confirm the purity of supply inlet air (see also figure 22).

Figure 8. Testing arrangement for ratio tests and pressure drop test acc. EN 308



Residential BVUs

For residential BVUs the standards FprEN 13141-7 and FprEN13141-8 contain sections describing the various leakages and their test methods. The following terms and symbols are used:

Table 18. Terms and symbols used for leakages in the EN13141-series

FprEN 13141-7	Test method	
	Recuperative HE	**Regenerative HE**
q_{ve} : external leakage	Pressure method	Press. or tracer gas method
q_{vi} : internal leakage	Pressure method	tracer gas method
R_s : transfer ratio R_s	n.a.	tracer gas method
FprEN13141-8		
q_{ve} : external leakage	Pressure method	Pressure method
q_{vi} : internal leakage	Pressure method	n.a.
R_s : exhaust air transfer ratio R_s	n.a.	tracer gas method (rotary he) calculation (alternating he)
R_{me} :outdoor mixing	tracer gas method	tracer gas method
R_{mi} : indoor mixing	tracer gas method	tracer gas method

Definitions used in FprEN13141-7

3.1 external leakage q_{ve}
leakage to or from the air flowing inside the casing of the unit to or from the surrounding air

3.2 internal leakage q_{vi}
leakage inside the unit between the exhaust and the supply air flows

3.3 transfer ratio *R_s*
mass transfer of the discharged air to a zone (in Figure 8: from extract (11) to supply (22)) that is actually recirculated air from the same zone, due to internal leakage and external casing leakage

Note: If the transfer ratio is determined with the induct method then it is called $R_{s,int}$ and if it is determined with the chamber method then it is called $R_{s,tot}$.

Definitions used in FprEN13141-8

Definitions used for external and internal leakage and for transfer ratio Rs are the same as in FprEN13141-7. The following terms for mixing are added:

3.6 outdoor mixing *R_{me}*
mixing of the two air flows external to the equipment under test between discharge and intake ports at outdoor terminal points caused by short circuiting

3.7 indoor mixing *R_{mi}*
mixing of the two air flows external to the equipment under test between discharge and intake ports at indoor terminal points caused by short circuiting

All leakages shall be determined before the temperature ratio test is performed. When the temperature ratios of the residential BVUs are determined according to FprEN 13141-7 and FprEN13141-8 (referred to as η_0), no corrections are made to compensate for the leakages. For balanced units the mass flows shall be balanced within max. 3%. If the mass flow differences are > 3%, the unit is declared unbalanced and the imbalance shall be reported.

The FprEN 13142 'Required and optional performance characteristics of residential ventilation products' requests a correction on this η_0 value. This correction is to be based on the following leakage parameters:
- w : internal leakage as % of reference airflow
- o : outdoor mixing as % of reference airflow
- y : indoor mixing as % of reference airflow
- z : external leakage as % of reference airflow
- v : airflow sensitivity as % of reference airflow

Table 19. Temperature ratio correction at reference airflow (Table 2 in the FprEN13142)

Measure	**Result**	**Unit**	**Temp. ratio correction**	
			Non-ducted units	**Ducted units**
Temperature ratio on supply air side	η_0	—	—	—
Internal leakage	w	—	$\eta_1 = \eta_0 \times (1- 0{,}7 \times (w -0{,}02))$	$\eta_1 = \eta_0 \times (1- 0{,}7 \times (w - 0{,}02))$
Outdoor mixing	o	—	$\eta_2 = \eta_1 \times (1 - (o -0{,}02))$	$\eta_2 = \eta_1$ [a]
Indoor mixing	y	—	$\eta_3 = \eta_2 \times (1 - (y -0{,}02))$	$\eta_3 = \eta_2$ [a]
External leakage	z	—	$\eta_4 = \eta_3$ [b]	$\eta_4 = \eta_3$ [b]
Air flow sensitivity	v	—	$\eta_5 = \eta_4 \times (1 - (v -0{,}02))^{0{,}4}$	$\eta_5 = \eta_4 \times (1 - (v -0{,}02))^{0{,}4}$

[a] The outdoor mixing depends on the duct system and not on the unit. There is no mixing in typical installations.
[b] The impact of external leakage depends on the design of the unit. No further correction shall be done.

NOTE.
To take into account the uncertainty of measurement, the corrections given in Table 2 are applied for each individual value in percentage only if the deviation for each criterion given in Table 2 is bigger than 2 %, and the correction is reduced from this percentage.

Following this standard, it is the η_5 value that is to be used for indicating the actual temperature ratio of a residential BVU

2.1.2. Leakages according to EU 1253 Regulation

The Regulations uses the following terms and definitions for leakages:

(7) 'internal leakage rate' means the fraction of extract air present in the supply air of ventilation units with HRS as a result of leakage between extract and supply airflows inside the casing when the unit is operated at reference air volume flow, measured at the ducts; the test shall be performed for RVUs at 100 Pa, and for NRVUs at 250 Pa;

(8) 'carry over' means the percentage of the exhaust air which is returned to the supply air for a *regenerative* heat exchanger according to the reference flow;

(9) 'external leakage rate' means the leakage fraction of the reference air volume flow to or from the inside of the casing of a unit to or from the surrounding air when it is subjected to a pressure test; the test shall be performed at 250 Pa for RVUs and at 400 Pa for NRVUs, for both under and over pressure;

(10) 'mixing' means the immediate recirculation or short-circuiting of airflows between discharge and intake ports at both the indoor and outdoor terminals so that they do not contribute to the effective ventilation of a building space, when the unit is operated at reference air volume rate;

(11) 'mixing rate' means the fraction of extract airflow, as part of the total reference air volume, that recirculates between discharge and intake ports at both the indoor and outdoor terminals and thus does not contribute to the effective ventilation of a building space, when the unit is operated at reference air volume (measured at 1 m distance from the indoor supply duct), less the internal leakage rate;

For recuperative heat exchangers the Regulation only addresses internal leakages from exhaust-air-in to the supply-air-out (7), from (11) to (22).
Leakages on the other side of the heat-exchanger, occurring from supply-air-in to exhaust-air-out, from (21) to (12), are not considered in Regulation. Such leakages however, can seriously compromise the outdoor supply air capacity of the unit and should also be taken into account.

2.1.3 Comments Stakeholders on terms &definitions for leakages

Comments Regarding NRVUs

Stakeholders make several proposals for improvement. Regarding type, terminology en definitions of leakages stakeholders propose the following.

Internal leakage can go both ways, from exhaust to supply and from supply to exhaust. Both leakages must be assessed and currently only the leakage from exhaust to supply side is addressed in the Regulation.
For *regenerative heat exchangers* the air leakage from the exhaust to the supply side has been given a different name: ‘carry-over’. The term however relates to the same air leakage type, but has been given a different name because its transmission mechanism is different.

It is therefore proposed to change the current definition used in the Regulation:

(7) ‘internal leakage rate’ means the fraction of extract air present in the supply air of ventilation units with HRS as a result of leakage between extract and supply airflows inside the casing when the unit is operated at reference air volume flow, measured at the ducts; the test shall be performed for RVUs at 100 Pa, and for NRVUs at 250 Pa;

Into

(7^{I})‘Internal leakage rate’ is the air leakage inside the casing between supply and exhaust airflows when the unit is operated at nominal flow rate and designed pressure relations;

To quantify both types of the internal leakage, two parameters are proposed (following EN 16798-3):

1.
Leakage rate from supply to exhaust side

OACF: Outdoor Air Correction Factor, defined as the ratio of *outdoor airflow measured in the outdoor duct* to *the supply airflow measured in the indoor duct*; in formula: OACF = $q_{m,21}$ / $q_{m,22}$. The internal leakage rate is then defined as OACF-1

If this OACF factor is > 1, more air is transferred from the supply to the exhaust air side. With OACF < 1 more air is transferred from exhaust to the supply air side (recirculation of exhaust air)

2.
Leakage rate from exhaust to supply side (for regenerative and recuperative HEs)

EATR: Exhaust Air Transfer Ratio, defined as the percentage of the exhaust air which is returned to the supply air for a heat exchanger, measured at the supply air duct when the unit is operated at nominal flowrate. In formula: EATR = 1 - $q_{m,2,net}$ / $q_{m,22}$

Where $q_{m,2,net}$ is the fraction of the supply air outlet mass flow that originated as supply air inlet. The net supply air outlet mass flow is determined by subtracting air transferred from the exhaust side of the exchanger from the gross airflow measured at the supply air outlet side of the exchanger (according to AHRI Standard 1060).

EATR is still to be measured using an inert gas that is injected into the exhaust inlet section. Air samples are taken at sections 11 (exhaust air inlet opening) to 22 (supply air outlet opening) to determine the carry-over and from section 21 (supply air inlet opening) to confirm the purity of supply inlet air.

With these two parameters OACF and EATR the internal leakages in a non-residential BVU-unit are considered completely defined.

Corrections for leakages NRVUs

Because the purpose of the BVU (and the ventilation section in an AHU) primarily is to exchange indoor air with outdoor air and not to recirculate air, stakeholders propose redefine the original definition for '*nominal flowrate'* and add a new definition for *'required supply flowrate'.*

Current definition nominal flowrate

> *(6) 'nominal flow rate (q_{nom})' (expressed in m^3/s) means the declared design flow rate of an NRVU at standard air conditions 20 °C and 101 325 Pa, whereby the unit is installed complete (for example, including filters) and according to the manufacturer instructions;*

Proposed adjusted definition nominal flowrate:

> *(6^I) 'Nominal flow rate (q_{nom}, expressed in m^3/s)' is the declared design flow rate of an NRVU distributed to and/or extracted from the building, including any leakages or any pressure balancing flow, at standard air conditions (20°C and 101.325 Pa), whereby the unit is installed complete (e.g. including filters) and according to the manufacturer instructions.*

New definition:

> *Required supply flow rate (q_{req}, expressed in m^3/s) is the required design outdoor flow rate of an non-residential BVU, at standard air conditions (20°C and 101.325 Pa), whereby the unit is installed complete (e.g. including filters) and according to the manufacturer instructions.*

This adjustment in definitions allows for a differentiation between the airflow that is supplied by the BVU (which depending on leakages may not all be outdoor air) and the actual required outdoor air. High figures for OACF and EATR surely will affect the indoor air quality and the energy efficiency of the unit. It will also have an improper effect on the perceived economic effectiveness of BVUs if these leakages are not properly communicated and corrected for.

To limit the effects internal and external leakages might have on ventilation performance, the following additional requirements are proposed by stakeholders:

a)

Set Minimum Leakage Requirements for NRVUs:

a.1) External leakages (applicable to all NRVU)

- For negative pressure (to be tested at -400Pa) : 1,32 $l/s/m^2$
- For positive pressure (to be tested at +700Pa) : 1,90 $l/s/m^2$

m^2 relates to the outer surface of the NRVU

a.2) EATR (applicable to all Heat Recovery sections except RACs)

- Maximum allowable EATR at design conditions: ≤5%
- For EATR < 1% no additional compensation action required
- For EATR between 1 and 5%, the nominal supply flowrate shall be increased with the EATR-percentage to compensate for the exhaust air leakage at design conditions and to ensure that the required supply flowrate is delivered.

a.3) For NRVUs including a RAC (wit common wall between supply and extract air)

- EATR < 0,1%

a.4) OACF

- At design conditions OACF must be within the range 0.90 tot 1.10

b)

Correct mass flows and related measurements due to internal leakages

b.1) regarding SFP_{int}

SFP_{int} shall include all impacts of internal (OACF and EATR) and external leakages at nominal conditions to ensure that the required outdoor air supply flowrate and extract flowrate will be delivered. These impacts include increased airflow pressure losses.

b.2) regarding EATR and supply flowrate

Actual supply flowrate must be increased to ensure it contains the correct outdoor flow. As a result, the power consumption of the supply fan will increase, the related pressure drop will increase and the heat recovery temperature ratio may decrease.

b.3) regarding EATR and extract flowrate

- When EATR ≤ 1%, no action is required
- When EATR > 1%, adjust the extracted airflow rate $q_{extr} = q_{req} * (1 + EATR)$

These adjustments are needed to maintain airflow balance in the building.

b.4) regarding OACF

Correction of the supply air inlet mass flow from the required supply air outlet mass flow and OACF (regardless the quality of the supply air) can be calculated as follows:

$$Q_{m,21} = OACF * q_{m,22}$$

Comments Regarding Residential BVUs

As for non-residential BVUs, stakeholders also propose to introduce limit values for the maximum allowable internal leakage rates in residential BVUs. The upcoming harmonised standards Fpr EN13141-7 and FprEN 13141-8 contain leakage classification tables that can be used to set limit classes.

For recuperative heat exchangers, the internal leakage is measured using the pressure method. The standards FprEN 13141-7 /-8 do not discriminate between internal leakages from the extract-side to the supply-side, and leakages from outdoor air supply to the exhaust side (corresponding to EATR and OACF respectively).
The test set-up described in annex B.2 also indicates that only the internal leakages from the extract-side to the supply-side is measured.

This would mean that for recuperative heat exchangers both standards FprEN 13141-7 /-8 do not assess the leakages from the outdoor-air-supply directly to the exhaust-air-side.

It has to be discussed with stakeholders whether this conclusion is legitimate and whether these leakages should be included in the overall assessment of residential BVUs.

Looking at the leakage classification tables of both standards, the following leakage classes are used:

In FprEN 13141-7: ducted BVUs
Stakeholders propose to use class A2 (see table below) as limit value for internal and external leakages for recuperative heat exchangers.

Table 20. Leakage classification - pressure method (table 4 in FprEN 13141-7)

Class	Pressurization test		
	Internal leakage (at 100 Pa)		**External leakage** (at 250 Pa)
A1	≤ 3 %	and	≤ 3 %
A2	≤ 7 %	and	≤ 7 %
A3	≤ 14 %	and	≤ 14 %
not classified	> 14 %	or	> 14 %

For BVUs with regenerative heat exchangers class C3 is proposed (see table below)

Table 21. Leakage classification – in-duct traces gas method (table 7 in FprEN 13141-7)

Class	Tracer gas test		Pressurisation test
	Transfer ratio from extract to supply air $R_{s,int}$		**External leakage** (at 250 Pa)
C1	≤ 0,5 %	and	≤ 3 %
C2	≤ 2 %	and	≤ 3 %
C3	≤ 4 %	and	≤ 3 %
not classified	> 4 %	or	> 3 %

In FprEN 13141-8: unducted BVUs
For non-ducted residential BVUs the class U2 (see table below) can be used as limit value for internal and external leakages, for any type of heat exchanger (recuperative regenerative, alternating regenerative)

Class	**Internal leakage**				**Outdoor mixing**		**Indoor mixing**		**External leakage**	
	at 20 Pa	at 100 Pa	R_s						at 50 Pa	at 250 Pa
	%	%	%		%		%		%	
U1	≤ 3	≤ 8,5	≤ 2 %	and	≤ 2	and	≤ 2	and	≤ 3	≤ 8,5
U2	≤ 7	≤ 21,5	≤ 5 %	and	≤ 5	and	≤ 5	and	≤ 7	≤ 21,5
U3	≤ 14	≤ 43	≤ 10 %	and	≤ 10	and	≤ 10	and	≤ 14	≤ 43
Not classified	> 14	> 43	> 10 %	or	> 10	or	> 10	or	> 14	> 43

Eurovent points out that the internal leakage measurement methods (pressure for recuperative and tracer gas for regenerative HRS) differ considerable and that their results are not comparable at all.
It is recommended to define a consistent measurement method for both type of HRS, preferably based on the pressure method, considering the pressure difference (inside-outside) at reference air flowrates.

It is to be discussed with stakeholder and test institutes to determine whether this is feasible.

Apart from setting limit values to the internal and external leakages (for all residential BVUs) and to the indoor- and outdoor mixing rates (for non-ducted residential BVUs), it is proposed to adjust declared outdoor supply air mass-flows and temperature ratios accordingly.

Proposals for correcting the temperature ratios from η_0 to η_5 are already included in the FprEN13142 (see table 20).
Proposals on how to correct the declared outdoor supply air mass-flows and indoor air exhaust mass flows need to be discussed amongst stakeholder.

2.2 Indoor/outdoor airtightness and airflow sensitivity

2.2.1 Explaining the parameters

Indoor/outdoor airtightness and airflow sensitivity are two typical parameters that can be associated with non-ducted ventilation units.

The FprEN 13141-8 uses the following definitions:

Indoor/outdoor airtightness : q_{vio}
Maximum air volume flow at static pressure difference of -20 Pa and +20 Pa corresponding to the setting when the fans are "OFF" and all additional shutters are closed.

Airflow sensitivity : v
Maximum relative deviation of the maximum airflow q_{vmax} due to static pressure differences of -20 Pa and +20 Pa.

Explanation

Local non-ducted ventilation units require openings in the building shell through which the ventilation air (supply and/or exhaust) can be transported. Such openings in the building shell may also lower the airtightness values of the building. Due to pressure differences over the building shell the local VU may induce unintended infiltration airflows when the *indoor/outdoor airtightness* of the local VU does not suffice.
In buildings that are equipped with local non-ducted RVUs that have a low *indoor/outdoor airtightness*, the building's airtightness will be reduced, resulting in a higher n50 value and higher infiltration rates. Higher infiltration flowrates will negatively affect the energy consumption the dwelling needs for space heating; it may also negatively affect the effectiveness of the ventilation.

Local non-ducted RVUs do not need fans that can overcome higher pressure differences associated with ductwork. As a result, low-pressure (axial) fans are often used because they are cheaper. But unfortunately these low-pressure fans are also more receptive to pressure differences over the façade. This means, that the actual flowrates achieved by the local non-ducted RVU can be dependent on the pressure difference over the building shell. To assess this *airflow sensitivity* to pressure differences, the deviations in air volume flow are measured at different pressure differences.
When local non-ducted RVUs are applied that are highly sensitive to pressure differences over the building shell, there will be considerable differences between the requested airflow and the actual airflow. This means that airflows are either too high or too low. In other words, either energy is wasted or the IAQ is compromised. In addition, if a heat recovery system is used in these non-ducted RVUs, its efficiency or temperature ratio will also be compromised, because the airflows will be far from balanced.

2.2.2 How to correct for these parameters?

The current version of the FprEN 13142 contains a proposal for correcting the measured temperature ratio due to high airflow sensitivity values (see table 20, last row).

Apart from that, no other correction are proposed by stakeholders so far.
Proposal of the study team is to at least discuss the following additional corrections:

1.
Adjustment of the *CTRL*-factor for non-ducted VUs, based on the airflow sensitivity factor v, representing the maximum deviation of q_{vmax} at +/– 20 Pa, expressed as a percentage of q_{vmax}.

The airflow sensitivity factor v, is a parameter indicating the ventilation unit's ability to exchange the air inside a building against pressure variations between indoor and outdoor. High values for this factor v, indicate that the VU is not always able to deliver the requested air exchanges during presence (higher flowrates) and absence (lower flowrates).
In other words, this factor v influences the units ability to accurately control the flowrates.

It is therefore proposed to adjust the *CTRL* factor that is used in the SEC-calculation with a correction factor that is related to the airflow sensitivity factor v

CTRL-correction factor due to airflow sensitivity factor v:

$$F_{CTRL,v} = \frac{1}{(1-v)}$$

2.
Adjustment of the *CTRL*-factor for non-ducted VUs, based on the indoor/outdoor airtightness (q_{vio}) of the VU, representing the infiltration airflows at +/– 20 Pa over switched-off local non-ducted ventilation unit.

The indoor/outdoor airtightness (q_{vio}) is an indication for the additional leak in the building shell, caused by the application of the local non-ducted VUs. Because this additional leak is induced by the ventilation unit, the corrections to be made should also relate to the ventilation unit and not to any EPBD-parameter like overall building-airtightness.

It is assumed that these additional leaks will increase the unintended airflows and therefore also increase the energy consumption for ventilation. It is therefore proposed to adjust the *CTRL* factor that is used in the SEC-calculation with a correction factor that is related to the indoor/outdoor airtightness (q_{vio}). For this, the airflow measured at +/- 20 Pa is to be recalculated to a reference ΔP (10 or 5 Pa, to be determined).

CTRL-correction factor due to indoor/outdoor airtightness (q_{vio}):

$$F_{CTRL,qvio} = \frac{q_{vio@5Pa} + q_{v,ref}}{q_{v,ref}}$$

2.3 Ductwork

In the context of the extended product approach, the ductwork and related components are addressed because they can have a significant effect on the performance of a VU. When centralised VUs are selected, ductwork is an essential necessary component of the system and its effects need to be included in the assessment when an extended product approach is applied.
Not only the ducts need to be considered in this context, but also its related components, such as fittings, tees, bends, reducers, in- and outlets, valves, grills, silencers etc.

The two key parameters '*ductwork pressure-drop*' and '*ductwork leakage*' are the ones, that to a large extent can influence both the energy- and ventilation performances of the ventilation unit concerned.

The technical report of the ASIEPI project[10] on building and ductwork airtightness estimated the heating energy impact of duct leakage in a ventilation system on the order of 0-5 kWh per m2 of floor area per year plus additional fan energy use for a moderately cold European region (2500 degree-days). The energy efficiency of systems is even more affected when the system includes air heating or cooling.

2.3.1 Ductwork pressure-drop

To overcome the pressure-drop (or flow-resistance) that is created in the ductwork system, the fan will have to work harder to provide the requested airflows. The higher the total pressure-drop over the ductwork, the more power the fan consumes.
Pressure losses are caused by flow friction and local flow disturbances in components. Both result in local velocity changes causing flow-resistance. To minimise flow resistance, the flows shall be as smooth and even as possible within the entire ductwork system.

Pressure losses in a duct can be calculated with the following formula:

$$\Delta p = \lambda_f * \frac{L}{D} * \frac{\rho * v^2}{2}$$

Where

λ_f	: friction factor
L	: length of the duct [m]
D	: diameter of the duct [m]
ρ	: specific mass
v	: is the mean velocity, defined the ratio of the flowrate (in m^3/s) and the cross-section of the duct (A in m^2)

For a circular duct the following relation applies:

$$v = \frac{4 * q_v}{\pi * D^2}$$

For a given (fixed) duct system, changes in the air flowrate will influence:
- The air velocity v (linear relation with q_v)
- The pressure loss over the duct system (typically increases with factor v^2)
- The power consumption of the fan (typically increases with factor v^3)

[10] G. Guyot, F. R. Carrié and P. Schild, "Project ASIEPI – Stimulation of good building and ductwork airtightness through EPBD," 2010

Example: if the flowrate in this fixed duct system is increased with a 100%, the air velocity increases with a factor 2, the pressure drop with a factor 4 and the fans power consumption with a factor 6.

The formulas also indicate that the selection of the duct's cross-section is the first and far most important decision with regards to minimising the flow-resistance in the ductwork and minimising the power consumption of the fan.

2.3.2 Ductwork leakage

Ductwork leakages are harmful for the energy performance and the ventilation performance of the VU-system. When ventilation airflows are corrected for leakages, power consumption can increase considerably. In case no corrections are made, the required airflows will not be achieved in the various rooms of a building, leading to suboptimal IAQ-levels.
Minimum limit values for ductwork airtightness should therefore be required to minimise these harmful effects.

Leakage values have been reported, varying from 0.5 to 7% (field studies from Scandinavian countries)[11] to over 20% (field studies from France and Belgium[12] and USA[13]) of the on average generated ventilation airflow rates. If leakages of e.g. 20% are to be compensated for by increasing the flowrate, the power consumption of the fan would increase with around 70%! Related noise levels will also considerably increase.

Test standards airtightness ductwork

In Europe, ductwork airtightness classes A to D are defined in European Standard EN 12237 for metallic circular ducts and EN 1507 for rectangular ducts. Class A is the leakiest class, Class D most airtight. The classification is based on maximum values of the leakage coefficient per m2 of duct surface area (in $m^3/(s\ m^2\ Pa^{0.65})$).

Table 22. Airtightness classification according to EN 12237:2003

Duct tightness class	Static pressure boundary values (P_s) Pa		Leak index boundary value (f_{max}) $m^3s^{-1}m^{-2}$
	Overpressure	Negative pressure	
A	500	500	$0,027 \cdot p_t^{0,65}\ 10^{-3}$
B	1000	750	$0,009 \cdot p_t^{0,65}\ 10^{-3}$
C	2000	750	$0,003 \cdot p_t^{0,65}\ 10^{-3}$
D	2000	750	$0,001 \cdot p_t^{0,65}\ 10^{-3}$

The true leakage flowrate is very difficult to measure, but with the relations given in the last column of table 23 they can be approximated. So if the leakage class or the ductwork and the operating pressure is known, the expected leakages can be calculated. Example: tightness class A, duct surface = 15 m2 and operating pressure = 100 Pa.

$$Q_{vl} = K * A * \Delta P_{op}^{0.65} = 0.027 * 15 * 100^{0.65} = 8.1\ {}^{l}/_{s} = 29.2\ {}^{m^3}/_{h}$$

[11] Rehn. C. Ventøk 5.1 and 5.8, *Kanaler – et effektivt distribusjonssystem for luft*. 2001

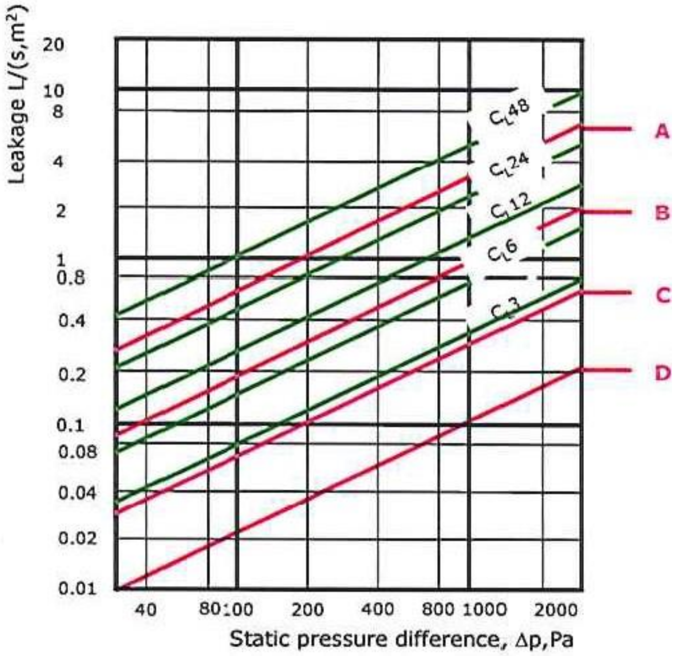
[12] Carrié, F.R.; Bossaer, A.; Andersson, J.V.; Wouters, P. Liddament, M.W. 'Duct Leakage in European Buildings: status and perspectives'. Energy and Buildings, No.32 (2000). pp.235–243

[13] Wray, C.P.; Diamond, R.C. and Sherman, M., Rationale for measuring duct leakage flows in large commercial buildings. LBNL 58252. Lawrence Berkeley National Laboratory, 2004

Table 23. Leakage classes and leakages per m² duct surface at various operating pressures

Leakage class	Leakage coefficient K	Leakage at 100 Pa	Leakage at 400 Pa
	$l/(s\ m^2\ Pa^{0.65})$	l/s per m²	l/s per m²
Class A	$K < K_A = 0.027$	0.54	1.33
Class B	$K < K_A = 0.009$	0.18	0.44
Class C	$K < K_A = 0.003$	0.06	0.15
Class D	$K < K_A = 0.001$	0.02	0.05

Figure 9. Graphic representation relation leakage class/operating pressure/leakage



The airtightness classes of the ductwork components is rarely achieved in a real-life installed ductwork system. To measure the on-site ductwork airtightness the EN 12599 'Test procedures and measurement methods to hand over air conditioning and ventilation systems' has been set up. This standards is currently being revised. Its main purpose is to verify whether the on-site ductwork and ventilation system is fit for purpose; the airtightness of the overall ductwork system is the main subject to be worked on in this revision[14]. The Airtightness classes for the overall system are defined in EN 16798-3 (see table below).

Table 24. Classificiation of system air tightness class according to EN 16798-3

Air tightness class		Air leakage limit (f_{max})
Old	New	$m^3/s/m^2$
	ATC 7	Not classified
	ATC 6	$0.067 * P_t^{0.65} * 10^{-3}$
A	ATC 5	$0.027 * P_t^{0.65} * 10^{-3}$
B	ATC 4	$0.009 * P_t^{0.65} * 10^{-3}$
C	ATC 3	$0.003 * P_t^{0.65} * 10^{-3}$
D	ATC 2	$0.001 * P_t^{0.65} * 10^{-3}$
	ATC 1	$0.00033 * P_t^{0.65} * 10^{-3}$

[14] Dr. Ing. F. Bitter, On site ductwork airtightness measurements in standardization (Revision of EN 12599), TightVent Europe Webinar, April 2019.

In a recent study[15], the impact of ductwork-leakages on fan power consumption and noise production in single family dwellings was investigated.
The table below indicates the differences in fan power consumption for four different dwellings and different leakage classes at continuous maximum design flowrates.

Table 25. Annual electricity use of both fans in kWh, assuming an efficiency of 0.27

Annual energy use of both fans (kWh)				
	House 1	House 2	House 3	House 4 (specific to the French market)
3*class A	888	703	2359	315
1.5*class A	641	565	1488	211
Class A	571	523	1255	183
Class B	485	471	984	150
Class C	459	454	904	140
Class D	450	449	878	137
No leakage	446	446	865	135

The impact of leakages on sound power initiated by the fan, is illustrated in the table below. The figures relate to the sound power to the dwelling (through the supply ducts), measured according to ISO 5135 for the Brink VU-unit 'Excellent 400. The figures indicate that depending on ductwork leakage, noise levels in the rooms can be more than doubled.

Table 26. Sound power in the ductwork for three different houses, comparing leaky and airtight ductwork.

	HOUSE 1		HOUSE 2		HOUSE 3	
	3*Class A	Class D	3*Class A	Class D	3*Class A	Class D
Required flowrate (m^3/h)	286	226	264	225	424	302
Required pressure (Pa)	172	111	148	110	309	162
Sound power to dwelling (dB)	78.7	73.1	75.5	73.1	80.4	78.7
Sound power to dwelling with A correction and silencer dB(A)	43.9	38.5	41	38.5	46.8	43.9
Sound power to each room (- 6dB)	37.9	32.5	35	32.5	40.8	37.9

15 Leprince, V., Lightfoot, M., De Jong, J., Impact of ductwork leakages on the fan energy use and sound production of central mechanical ventilatioon units in houses, 40th AIVC Conference, Gent, 2019.

2.4 Defrosting strategies

Currently, the Regulation does not discriminate between types of defrosting strategies that are applied in residential or non-residential BVUs. Depending on the type of heat exchanger and climate zone, heat recovery systems can be more or less sensitive to freezing, indicating that additional energy for defrosting is needed to keep the BVU in continuous operation in colder periods and colder climates. For non-residential BVUs this defrosting energy is not taken into account at all. For residential BVUs only a default calculation for Q_{defr} is used for recuperative heat exchangers (for regenerative heat exchangers Q_{defr} =0).

$$Q_{defr} = t_{defr} * \Delta T_{defr} * c_{air} * q_{net} * pef$$

Where

t_{defr} is the duration of defrosting period (i.e. when outdoor temperature is below –4°C in hours per year

ΔT_{defr} is the average difference in K between the outdoor temperature and -4°C during the defrosting period

Stakeholders put forward the following proposals:

2.4.1 Non-residential BVUs and defrosting

For non-residential BVUs the following additional measures are proposed:

Determine the required defrosting-/frost prevention energy per climate zone (cold, average, warm) and include the results in the *information requirements* of the regulation.

The determination of the required defrosting-/frost prevention energy is preferably based on a simplified calculation method, using common reference conditions like climate zone, operating time, temperature and moisture content of the extract air. The calculation method should also take into account the control logic that is used for the defrosting function.

No concrete proposal for such a simplified calculation method has yet been made by the stakeholders.

2.4.2 Residential BVUs and defrosting

For residential BVUs the following additional measures are proposed:

Because in practice there are numerous defrosting strategies available on the market, which all of them can be controlled in either a simplified or more advanced manner, the differences in energy consumption for frost-prevention can be considerable.

It is therefore proposed to include the description of the defrosting strategy in the *information requirements.*

Furthermore stakeholders propose to modify the SEC-calculation, and consider more detailed aspects when determining the Q_{defr}. It is recommended to use the Informative Annex E of the FprEN 13142 (and more in particular paragraph E.2.5 of this Annex) to develop a more targeted approach for determining the annual energy consumption for frost-prevention/defrosting purposes.

Annex E, paragraph E.2.5 of FprEN 13142:2019

E.2.5.1 Annual Electricity consumption for defrosting

Annual *electricity consumption* for defrosting is calculated using the formula:

$$E_{defr} = E_{\Delta P,ext.defr} + E_{\Delta P,int.defr} + E_{preh} + E_{pump.defr}$$

where

E_{defr} : is the annual electricity consumption per m2 heated floor area for defrosting, in kWh/m^2·a;

$E_{\Delta p,ext,defr}$: is the annual electricity consumption use due to external pressure losses of external defrosting devices per m^2 heated floor area in kWh/m^2·a;

$E_{\Delta p,int,defr}$: is the annual electricity consumption due to internal pressure loss during frost growing per m^2 heated floor area in kWh/m^2·a;

E_{preh} : is the annual electricity consumption for an electric preheater per m^2 heated floor area in kWh/m^2·a;

$E_{pump,defr}$: is the annual electricity consumption use for defroster pump per m^2 heated Floor area in kWh/m^2·a.

See Annex E of the prEN13142, sections E.2.5.2 to E.2.5.5 for further explanation on how to calculate these four different parts of this formula (which all have their own formulas).

E.2.5.6 Annual heating energy consumption for defrosting

The annual *heating energy consumption* for defrosting per m2 heated floor is calculated as:

$$\Delta E_{AH,defr} = \Delta E_{h,preh} + \Delta E_{by} + \Delta E_{su} + \Delta E_{ex} - \Delta E_{vent} - \Delta E_{el,preh} - \Delta E_{earth}$$

where

$\Delta E_{AH,defr}$: is the annual heating energy consumption for defrosting per m2 heated floor area in kWh/m2·a;

$\Delta E_{h,preh}$: is the annual heating energy consumption for preheating (by space heating generation) per m2 heated floor area in kWh/m2·a;

ΔE_{by} : is the annual heating energy consumption for bypassing the heat recovery per m2 heated floor area in kWh/m2·a;

ΔE_{su} : is the annual heating energy consumption for lowering of the supply air flow rate per m2 heated floor area in kWh/m2·a;

ΔE_{ex} : is the annual heating energy consumption for increasing of the exhaust air flowrate per m2 heated floor area in kWh/m2·a;

ΔE_{vent} : is the annual heating energy reduction by ventilator heat per m2 heated floor area in kWh/m2·a;

$\Delta E_{el,preh}$: is the annual heating energy reduction by an electric preheater per m2 heated floor area, in kWh/m2·a;

ΔE_{earth} : is the annual heating energy reduction by an earth to air heat exchanger per m2 heated floor area in kWh/m2·a.

See Annex E of the prEN13142:2019 sections E.2.5.7 to E.2.5.12 for further explanation on how to calculate these seven different parts of this formula (each having their own second-line formulas).

For the parameters that are used in these - in total eleven - second line formulas, default values are generated for the climate zones 'average' and 'cold' (see tables E.9 and E.10 in Annex E of the FprEN13142:2019).

Considering the details of this proposal, it seems a quite complex and extensive approach in the light of its relative impact.
It is proposed to discuss with stakeholder whether a more simplified approach can be developed from the work that has been so far in Annex E.

2.5 Ventilation effectiveness

The ventilation effectiveness describes the relation between the pollution concentrations in the supply air, the extract air and the indoor air in the breathing zone (within the occupied zone). It is defined as

$$\varepsilon_v = \frac{C_{ETA} - C_{SUP}}{C_{IDA} - C_{SUP}}$$

where

ε_V : is the ventilation effectiveness

C_{ETA} : is the pollution concentration in the extract air

C_{IDA} : is the pollution concentration in the indoor air (breathing zone within in the occupied zone)

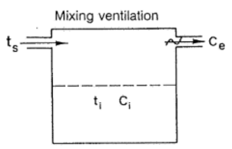
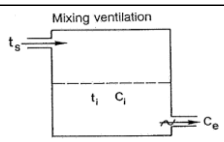
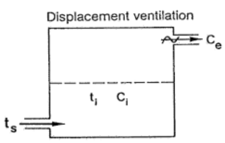
C_{SUP} : is the pollution concentration in the supply air

The ventilation effectiveness depends on the air distribution and the kind and location of the air pollution sources in the space. It is furthermore a function of temperature and flow rate of the supply air. Depending on these variables, it may have different values for different pollutants. If there is complete mixing of air and pollutants, the ventilation effectiveness is 1.

NOTE Another term frequently used for the same concept is "contaminant removal effectiveness".

If the air quality in the breathing zone is better than in the exhaust, the ventilation effectiveness is higher than one, and the desired air quality in the breathing zone can be achieved with a lower ventilation rate. If the air quality in the breathing zone is poorer than in the exhaust air, the ventilation effectiveness is lower than one and more ventilation is required.
The ventilation effectiveness may be calculated by numerical simulation or measured experimentally. When such data are not available, the typical values given in Table 26 for different ventilation principles may be used. The values in Table 26 consider the impact of air distribution but not of the location of the pollution sources in the space. The pollution sources are assumed to be evenly distributed throughout the ventilated space.

Table 27. Typical values for ε_V for different ventilation configurations[16]

Ventilation principle	Temperature difference between supply air and air in breathing zone (t_S-t_i in °C)	Ventilation effectiveness ε_V
	< 0	0.9 – 1.0
	0 – 2	0.9
	2 - 5	0.8
	> 5	0.4 – 0.7
	< -5	0.9
	-5 – 0	0.9 – 1.0
	> 0	1.0
	> 2	0.2 – 0.7
	0 – 2	0.7 – 0.9
	< 0	1.2 – 1.4

[16] CEN - CR 1752, Ventilation for buildings - Design criteria for the indoor environment, 1999

2.5.1 Ventilation effectiveness in residential buildings

As can be concluded from the previous section, the considerations regarding the ventilation effectiveness are mainly room based and where it is assumed that (during presence) ventilation rates are induced according to design values.

As indicated in section 1.2 Ventilation Performance, residential ventilation systems do not always meet these basic conditions. Targeted air exchanges (in the right room at the right time) are rather the exception than the rule, illustrating that there is an important step in-between the residential ventilation system and the ventilation effectiveness in a room.
For residential systems, the far and foremost important aspect to look at therefore is the ventilation performance (are the air exchanges induced in the right room at the right time), and only subsequently to the ventilation effectiveness in the room.

Experimental studies show that, depending on location of the exhaust and supply openings and depending on the difference between supply air temperature and room temperature, a ventilation effectiveness of around 1 can be achieved for ventilation systems applying the air mixing principle.

Only for ventilation units/systems having their supply and exhaust openings very close to each other, short circuiting can occur. This will negatively influence the ventilation effectiveness. In those cases the amount of *'indoor mixing'* must be measured. For local BVUs this effect is covered in the test standard FprEN 13141-8.

Main conclusion of the above two sections:
For residential systems the ventilation effectiveness can be set to an average value of 1. For ventilation units suffering from short circuiting or indoor mixing, it is proposed to correct the declared ventilation flowrates for this mixing or short circuiting, following the test results from FprEN 13141-8. By doing this, its influence on the ventilation effectiveness is accounted for and needs no further corrections.

2.5.2 Comments stakeholder on ventilation effectiveness

The SEC-formula currently holds a parameter MISC, which is an aggregated general typology factor for ventilation effectiveness, duct leakage and extra infiltration. The following values are used for this MISC-factor:

	MISC
Ducted ventilation units	1.1
Non-ducted ventilation units	1.21

Stakeholders propose the following adjustments:

a) <u>Regarding infiltration</u>

Stakeholders believe that the current values for MISC do not sufficiently address the topic infiltration. They feel that the impact of the over or under pressure in the building (induced by UVU-systems) on the in-/exfiltration rates is not adequately accounted for in comparison to BVUs that result in a neutral pressure in the building.

Stakeholder therefore propose to include a new parameter '*INF*' into the SEC-formula. This *INF*-factor is used to adjust the q_{ref} (reference natural ventilation rate per m2 heated floor area (in m³/h/m²)) having a default value of 2.2 m³/h/m², according to the following table 27. See also informative Annex F of the FprEN 13142:2019

Table 28. Infiltration INF parameter (Table F1 in EN13142:2018)

Climate	t_h	Δt_h	*INF*	
			Exhaust Supply	Balanced
Cold	6 552	14,5	0,10	0
Average	5 112	9,5	0,18	0
Warm	4 392	5	0,36	0

This proposal implies that the reference - being a naturally ventilated dwelling with an average ventilation rate of 2.2 m³/h/m²- that currently serves as benchmark for all VUs, would need to change only for the UVU-systems. Only for UVU systems, this reference ventilation rate of 2.2 is increased with values varying from 0.10 to 0.36 m³/h/m², leading to a considerable increase of the ventilation performance for UVUs compared to the current SEC-formula and compared to the BVUs.

The following comments can be made in relation to this proposal:

- the reference must remain the same for all VUs and cannot be changed for only a few VUs
- increased infiltration rates reduce the authority of the ventilation system, or in other words its ventilation performance is impaired
- more infiltration leads to an increase of untargeted air exchanges, leading to more energy consumption for heating

So, instead of an increase of the ventilation performance of UVUs, the over or under pressure caused by UVU-systems lead to a reduced ventilation performance and an increase of the energy-consumption.

Recommendation therefore is not to accept this proposal.
Instead it is proposed to use the Ventilation Performance Assessment Tool (VPA-Tool) as described in section 1.2.1 to determine the impact of airtightness, leakages and infiltration on the ventilation- and the energy performance of the VU, since all these aspects are integrated in the VPA-Method.

b) <u>Regarding cascading in dwelling</u>

Stakeholders claim that the current values for the MISC do not reflect the real aspects of cascading VUs in dwellings. The term 'cascading' is not further explained in this context but is it assumed that the term is used for indicating the difference between a central RVU and several decentralised RVUs and its effect on the overall airflow in a dwelling.
To reflect the real effect of cascading, stakeholders propose the following adjusted values for the MISC factor (see table 28). See also table F2 in informative Annex F of the FprEN 13142:2019.

Table 29. Modified MISC parameter (Table F2 in EN13142:2018)

Unit	Overflow MISC
Exhaust ventilation unit	1
Supply ventilation unit	1
Balanced ventilation unit (single dwelling)	1
Balanced ventilation unit (single room)	1,5 to 2,0

As can be deducted from the table 28 and the use of the term 'Overflow MISC', stakeholders and the working group members of this standard probably refer here to the 'overflow' of air from the supply-spaces to the exhaust spaces, which does not occur when only local non-ducted BVUs are used. This overflow transports the (used) air coming from the supply spaces, via the connecting spaces to the exhaust spaces, where the air is expelled. This overflow helps exchanging the airflow in the connecting spaces. Other than this, this overflow is not considered to have a further impact on the effectiveness of the ventilation in the supply and exhaust spaces (see also section 2.5.1).

The proposed change in the MISC factor for non-ducted BVUs (from 1.21 to a value between 1.5 – 2.0) would imply that the energy performance of these units is substantially reduced. Or in other words, the nominal energy consumption of residential BVUs would increase by a factor of around 1.2 to 1.6 compared to the previous regulation, while in reality only the ventilation performance in the connecting spaces is affected.
As a matter of fact, when these non-ducted BVUs are installed in habitable spaces combined with ducted or non-ducted UVUs in wet spaces, this envisaged problem would not even occur. In these cases, air will still be transported through the connecting spaces to the exhaust spaces.

It is therefore recommended not to include this proposal in the revision of the VU-Regulations. As an alternative, the minimisation of air exchanges occurring in connecting spaces due to the use of exclusively non-ducted BVUs in all spaces (affecting the ventilation performance in connecting spaces), could be valued in the VPA-method that employs an extended product approach (see also section 1.2.1).

2.6 Energy use supply-air-heater

Residential ventilation units are offered on the market with the option to include an (electric) heater for pre-heating of the supply air for comfort reasons. This auxiliary device may or may not also be used for defrosting or frost-prevention purposes. This section however only relates to its use for additional comfort reasons (i.e. energy-use for defrosting is not the subject of this paragraph).

RVUs that are placed on the market having such (possibly electric) heaters that enables the pre-heating of supply air for comfort reasons, partially fulfil a space-heating function as well. Currently this feature is not included in the assessment of the energy performance of RVUs according to the Regulations EU 1253/1254.

Question that was posed is whether or not to include this feature in the proposals for a revised VU-regulation.

Looking at it from the demand side (the market), there is – especially in NZE-Building – a growing need for ventilation systems that fulfil additional heating/cooling functions. Because heating (and cooling) demands in NZE-Buildings are considerably reduced, the remaining heating and cooling demands are small and in an increasing number of cases the ventilation air can be used to supply these reduced amount of heating and/or cooling.

When such a ventilation unit can fulfil all of the ventilation/heating and/or cooling demands it can be defined as a multifunctional BVU, and should be covered accordingly.

If however, the RVU with supply-air heater only covers a part of the heating demand (e.g. heating of rooms that have a low heat demand like bedrooms in NZE-Buildings), this additional heating function should be addressed when the energy performance of such ventilation units are assessed.

Question remains whether the impacts of adding a supply-air heater is to be covered by the Ecodesign regulation for VUs. For various reasons this does not seem a sensible approach:

- First of all, the supply-air-preheater is (in most cases) a separate unit than can be added to the ventilation system afterwards, i.e. it is not an integrated part of the ventilation unit.
- Secondly, its function is heating and not ventilation (adding an electric preheater does not affect the ventilation function).
- Since it provides a partial heating function, and operates next to another heat system, its effect on energy consumption for space heating should be assessed in the EPBD.
- Thirdly, air heaters are already regulated under EU 2016/2281 ("Lot 21")

Proposal therefore is, not to include the impact of supply-air-preheaters in the revised regulation for VUs

2.7 Impact ventilation on heat load dwelling

The heating energy that is used for ventilation represents a significant part of the total heating energy consumption of buildings. In the final report on average EU building heat load for HVAC equipment[17] it is concluded that the average air exchanges of the average residential EU dwelling due to ventilation and infiltration is around 0.72 $m^3/h/m^3$. Per square meter of heated space this corresponds to around 2.05 m^3/h, of which around 0.7 m^3/h relates to infiltration and around 1.35 $m^3/h/m^2$ to ventilation.

The report[16] further concludes that the average EU residential dwelling size in 2010 is 90 m2 (heated space), its average total transmission losses 7100 kWh/year (79 $kWh/m^2/year$) and average total ventilation- and infiltration losses (share of heat recovery excluded) of around 4900 kWh/year (54 $kWh/m^2/year$). With total internal and solar gains or around 3800 kWh/year (42 $kWh/m^2/year$), this results in an average heat load for primary dwellings in 2010 of 8200 kWh/year (91 $kWh/m^2/year$).

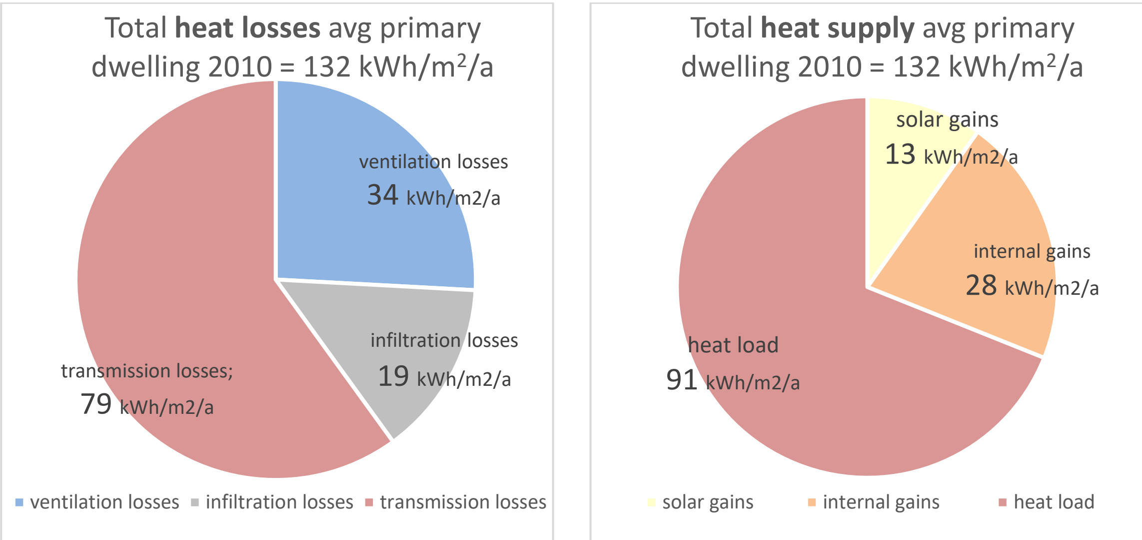


Figure 10. Heat losses and heat supply of the average EU2010 residential dwelling

Ventilation- and infiltration losses account for **40%** of the average heat losses in the average 2010 residential dwelling. The other 60% relates to transmission losses (including cold-bridges). The resulting average heat-load of 91 $kWh/m^2/a$ will require more heat input, since heating system efficiency will never be 100%. In the EIA study, the average heating system efficiency that was calculated, is around 52%, indicating that this heat load of 91 kWh/m2/a will result in a heating energy consumption of 175 kWh/m2/a.

In the new-to-built dwellings and the dwellings that will be deep-renovated, these figures will drastically change, due to the high insulation values and increased airtightness of the buildings. Depending on the final heating energy consumption per m2 of heated space, various label categories for dwellings are applicable.

[17] Average EU building heat load for HVAC equipment. Specific contract No. ENER/C3/412-2010/15/FV2014-558/SI2.680138 with reference to Framework Contract ENER/C3/412-2010, August 2014

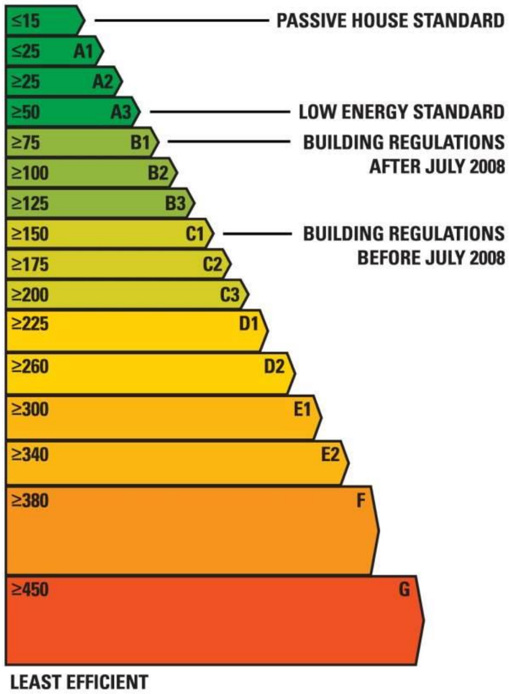


Figure 11. Energy consumption in kWh/m^2/a and Energy Class (A to G) according to the BER-Certificate[18]

Passive House requirements are the highest. For a building to be considered a Passive House, it must meet the following criteria[19]:

1. The Space Heating Energy Demand is not to exceed 15 kWh per square meter of net living space (treated floor area) per year or 10 W per square meter peak demand.
In climates where active cooling is needed, the Space Cooling Energy Demand requirement roughly matches the heat demand requirements above, with an additional allowance for dehumidification.

2. The Renewable Primary Energy Demand (PER, according to PHI method), the total energy to be used for all domestic applications (heating, hot water and domestic electricity) must not exceed 60 kWh per square meter of treated floor area per year for Passive House Classic. .

3. In terms of Airtightness, a maximum of 0.6 air changes per hour at 50 Pascals pressure (ACH50), as verified with an onsite pressure test (in both pressurized and depressurized states).

4. Thermal comfort must be met for all living areas during winter as well as in summer, with not more than 10 % of the hours in a given year over 25 °C. For a complete overview of general quality requirements (soft criteria) see Passipedia.

All of the above criteria are achieved through intelligent design and implementation of the 5 Passive House principles: thermal bridge free design, superior windows, ventilation with heat recovery, quality insulation and airtight construction.

[18] Hunter, G., Hoyne, S., Noonan, L., Creation of an improved residential space heating calculation model fort he Irish energy performance assessment tool, ECEEE 2015 Proceedings.

[19] https://passiv.de/en/02_informations/02_passive-house-requirements/02_passive-house-requirements.htm

The average EU2010 residential dwelling (see figure 10) consumes 175 kWh/m²/a of heating energy and falls under energy class C1(see figure 11). If this dwelling is to be renovated according to the passive house principles using condensing boilers as heat generator, transmission losses should be reduced to around 30 – 35 kWh/m²/a, and infiltration losses to around 2 kWh/m2/a.

Using a ventilation system that has identical ventilation airflows as the EU2010 dwelling, with ventilation heat losses of 34 kWh/m2/a, the total heat losses are reduced with 42%, from 132 to 69 kWh/m2/a. The heat load that remains is then 28 kWh/m2/a; with the same heating system efficiency of 52% the heating energy consumption becomes almost 54 kWh/m2/a (Class A3 in figure 11) .

When a ventilation system is applied that uses sophisticated ventilation controls that can automatically adjust the ventilation rates per individual room, based on IAQ (with a CRTL-factor of 0.5), the ventilation heat losses can be further reduced to 17 kWh/m2/a, leading to an overall heat loss of 52 kWh/m2/a and a remaining heat load of 11 kWh/m2/a (see figure 12). The heating energy consumption becomes 21 kWh/m2/a, which equals Class A1 (see figure 11).

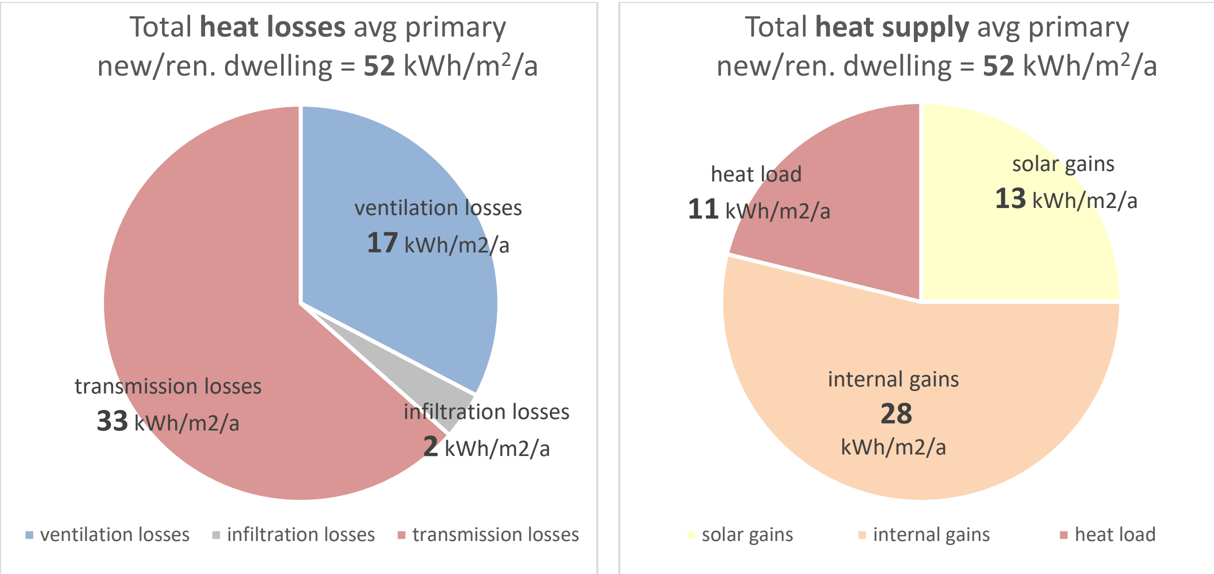


Figure 12. Heat losses and heat supply of a new average 90 m2 residential dwelling, with high (passive house standard) insulation- and airtightness levels and smart ventilation controls.

With ventilation systems that apply heat recovery, the energy consumption for space heating can be further decreased to values below 15 kWh/m2/a, which means that the passive house standard is achieved.

For the Kranichstein Passive House project[20], the energy calculations were done according to the European EN 832 standard (see figure 13). The calculated value for heating is 10.5 kWh/(m²yr).

[20] https://passipedia.org/planning/thermal_protection/thermal_protection_works/insulation_works_-_evidence_no.2_heating_energy_use_in_a_well_insulated_new_building

The actual energy use recorded between 1991 and 2006 was 9.2 kWh/(m²yr) i.e. slightly lower. (This variation remains within the accuracy limits typical for such measurements and calculations.)

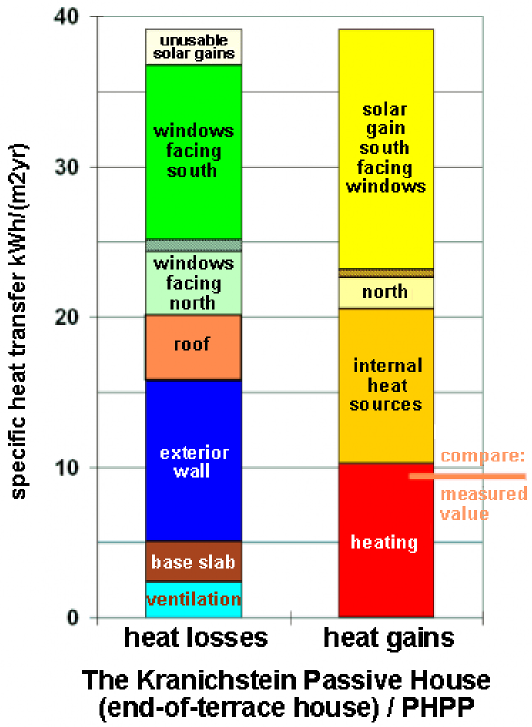


Figure 13. Energy balance according to EN832 for the Kranichstein Passive House (end-of-terrace house.

Conclusions

The calculations and considerations in this section illustrate that optimising ventilation systems while minimising infiltration losses can reduce the heat load of the average 2010 dwelling with around 35% when smart controlled ventilation systems without HRS are applied, and up to around 50% when smart controlled ventilation systems with HRS are applied. If also the transmission losses are reduced to passive house standards, the heat load can be further reduced with in total 90%!

These significant reductions of the heat load does not only mean the energy consumption for space heating is reduced with the same percentages. It also implies that the heat emitter capacity relative to the heat load of the average 2010 dwelling increases with the same percentages. This means that the supply- and return temperatures of the heating systems can be reduced and the heat generator efficiency is increased. Especially for systems heating systems using heat pumps this can have a huge impact on the seasonal space heating performance.

2.8 Pollutants, IAQ and its impact on well-being and performance

2.8.1 Introduction

People spend most of their time indoors. On average 60 – 90% of the time people work, sleep or relax within the walls of any kind of building. Inhalation of clean indoor air therefore is extremely important for the health of the population as a whole, and particularly for vulnerable groups like babies, children, elderly and people already suffering from for instance respiratory or allergic diseases.

The IAQ-levels that are achieved in buildings depend on the pollutant emissions from applied materials and human activities inside the buildings, on the ventilation rates that are applied and on pollutants concentrations in the outdoor air. During presence in the building, people are exposed to these IAQ-levels which can affect their well-being and performance levels.
This section attempts to summarize the knowledge that has been accumulated over the years on indoor and outdoor air quality and its impact on well-being and performance levels of the inhabitants.

2.8.2 Indoor Air Pollutants

A large number of indoor air pollutants have been associated with health responses.
Indoor pollution sources that release gases or particles into the air are the primary cause of indoor air quality problems in homes. Inadequate ventilation can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the home. High temperature and humidity levels can also increase concentrations of some pollutants.

Table 30. Common Indoor Air Pollutants

Indoor Air Pollutant	Source
Carbon dioxide (CO_2)	– Human breathing – Tobacco smoking – Combustion sources
Carbon monoxide (CO)	– Combustion sources like cooking stove – Vehicle/engine exhaust – Tobacco smoking
Respirable suspended particulates (RSP or PM_{10})	– Combustion sources like cooking stove, – Equipment like photocopiers and printers – Tobacco smoking, – From outdoors
Nitrogen dioxide (NO_2)	– Combustion sources like cooking stove – Vehicle/engine exhaust – Smoking – From outdoors
Ozone (O_3)	– Equipment (photocopiers, printers and fax machines) – Air purifiers with high voltage discharge components
Formaldehyde (HCHO)	– Pressed-wood furniture and products – Adhesives – Paints – Urea-formaldehyde foam insulation (UFFI) – Tobacco smoke – Incense burning

Total volatile organic compounds (TVOC)	– New furniture and furnishings. – Renovation materials like paints and solvents, – Consumer and aerosol products like cleaning agents, disinfectants, pesticides, cosmetics & fragrance products – Dry-cleaned clothes – Smoking
Radon (Rn)	Concrete building materials containing granite
Biological contaminants (bacteria. fungi/mould, viruses, dust mites)	– Dirty air conditioner/ventilation system filter and ducting; – Growth accelerated by inadequate ventilation, and damp and dusty environment
Mould	Grows rapidly on organic matter under wet and warm condition
Environmental tobacco smoke	Smoking

The relative importance of any single source depends on how much of a given pollutant it emits and how hazardous those emissions are. In some cases, factors such as how old the source is and whether it is properly maintained are significant. For example, an improperly adjusted gas stove can emit significantly more carbon monoxide than one that is properly adjusted.

Some sources, such as building materials, furnishings, and household products like air fresheners, release pollutants more or less continuously. Other sources, related to activities carried out in the home, release pollutants intermittently. These include smoking, the use of unvented or malfunctioning stoves, furnaces, or space heaters, the use of solvents in cleaning and hobby activities, the use of paint strippers in redecorating activities, and the use of cleaning products and pesticides in housekeeping.
High pollutant concentrations can remain in the air for long periods after some of these activities.

health and comfort problems. Unless they are built with special mechanical means of ventilation, homes that are designed and constructed to minimize the amount of outdoor air that can "leak" into and out of the home may have higher indoor pollutant levels than other homes. However, because some weather conditions can drastically reduce the amount of outdoor air that enters a home, pollutants can build up even in homes that are normally considered "leaky".

Typical Indoor Pollutant Concentrations

In the official report of IAIAQ-project[21] both the typical and high-end concentration levels of some indoor air pollutants for European conditions are summarised, including an indication of the contribution of the indoor sources to these concentration levels.

Table 31. Typical and high-end concentration levels of indoor pollutants

Pollutant	Typical levels [µg/m³]	Contribution indoor source [%]	High-end levels [µg/m³]	Contribution indoor source [%]
PM 2.5	10 - 40	*30%*	100 – 300	*> 90%*
CO	1 – 4	*0%*	100 – 200	*> 99%*
NO2	10 – 50	*20%*	100 – 200	*> 75%*
Formaldehyde	20 – 80	*> 90%*	200 – 800	*> 99%*
Benzene	2 – 15	*40%*	50	*> 75%*
Naphthalene	1 – 3	*30%*	1.000	*> 99.9%*
Radon [Bq/m³]	20 - 100	*> 90%*	100.000	*> 99.9%*

[21] Jantunen M., Oliveira Fernandes E., Carre P., Kephalopoulos S., Promoting actions for healthy indoor air (IAIAQ). European Commission Directorate General for Health and Consumers, Luxembourg, 2011.

The sources of exposure which are taken into consideration here (and are assumed to be manageable by buildings and IAQ related policies) are:

- ambient outdoor air quality
- building materials
- fixed heating and combustion equipment/appliances
- water systems, leaks and condensation
- furnishings, decoration materials and electric appliances
- cleaning agents and other household products
- underlying soil (incl. the building characteristics which influence the radon entry from the soil).

2.8.3 Outdoor Air Pollutants

Outdoor air pollutants can be categorised as primary or secondary. Primary pollutants are directly emitted to the atmosphere, whereas secondary pollutants are formed in the atmosphere from precursor pollutants through chemical reactions and microphysical processes. Air pollutants may have a natural, anthropogenic or mixed origin, depending on their sources or the sources of their precursors.

Key primary air pollutants include:

- particulate matter (PM)
- black carbon (BC),
- sulphur oxides (SOX),
- nitrogen oxides (NOX) (which includes both nitrogen monoxide, NO, and nitrogen dioxide, NO2),
- ammonia (NH3),
- carbon monoxide (CO),
- methane(CH4),
- non-methane volatile organic compounds (NMVOCs), including benzene (C6H6)
- certain metals
- polycyclic aromatic hydrocarbons (PAHs) including benzo[a]pyrene (BaP).

Key secondary air pollutants are:

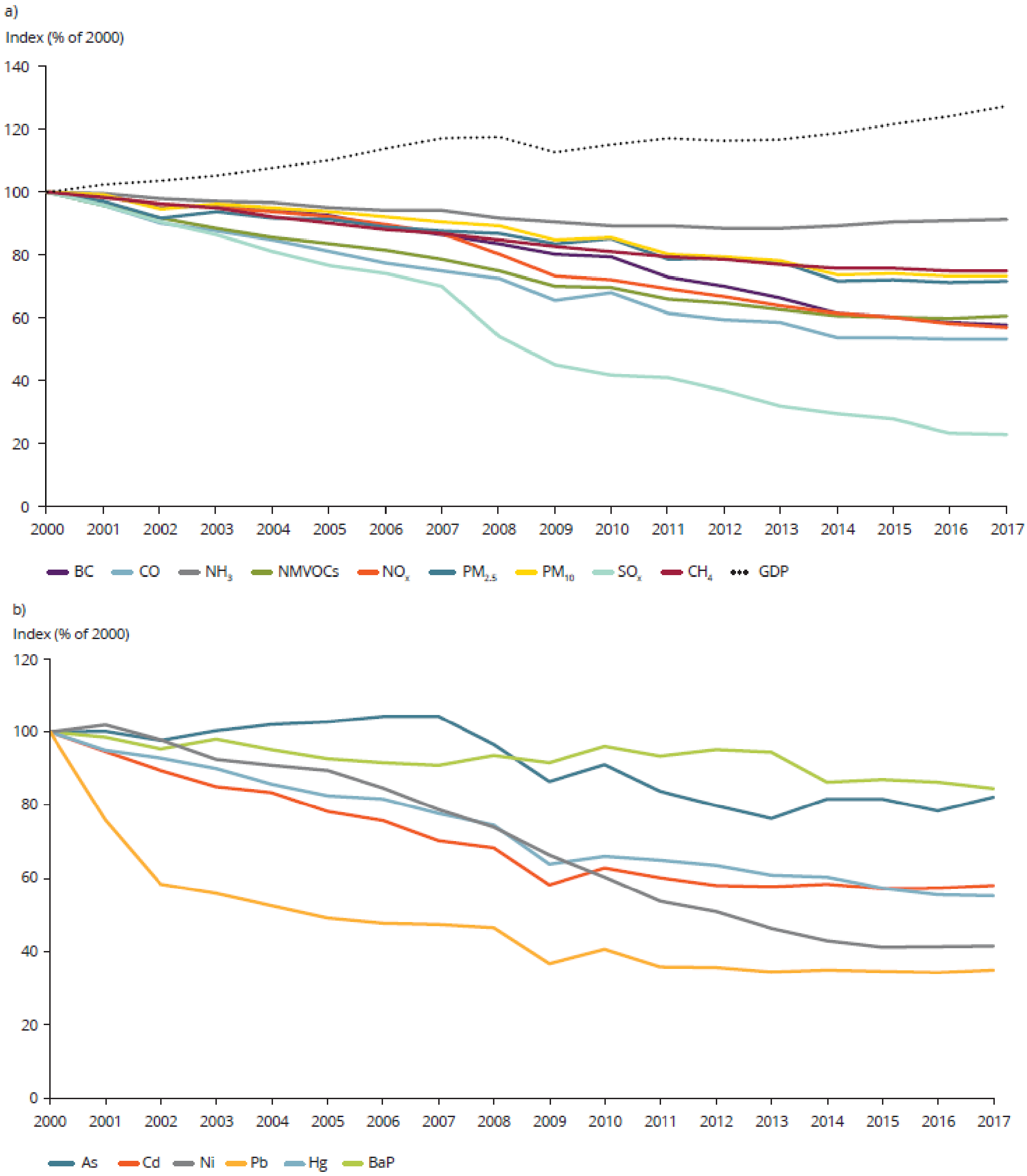
- PM (formed in the atmosphere),
- ozone (O3),
- NO2
- several oxidised volatile organic compounds (VOCs).

Key precursor gases for secondary PM are sulphur dioxide (SO_2), NO_X, NH_3, and VOCs. Gases SO_2, NO_X and NH_3 react in the atmosphere to form particulate sulphate (SO_4^{2-}), nitrate (NO_3^-) and ammonium (NH_4^+) compounds. These compounds form new particles in the air or condense onto pre-existing ones to form secondary inorganic PM.
Certain NMVOCs are oxidised to form less volatile compounds, which form secondary organic aerosols. Ground-level (tropospheric) O_3 is not directly emitted into the atmosphere. Instead, it is formed from chemical reactions in the presence of sunlight, following emissions of precursor gases, mainly NO_X, NMVOCs, CO and CH_4. These precursors can be of both natural (biogenic) and anthropogenic origin. NO_X in high-emission areas also depletes tropospheric O_3 as a result of the titration reaction with the emitted NO to form NO_2 and oxygen.

Trends in EU-28 pollutant emissions

In their recent report on (outdoor) air quality in Europe[22], the European Environmental Agency states that the total emissions of air pollutants in the EU28 is declining since the reference year 2000.

Figure 14. Trends in EU-28 emissions, 2000-2017 (% of 2000 levels): (a) SOX, NOX, NH3, PM10, PM2.5, NMVOCs, CO, CH4 and BC. Also shown for comparison is EU-28 gross domestic product (GDP, expressed in chain-linked volumes (2010), % of 2000 level); (b) As, Cd, Ni, Pb, Hg and BaP



Note: CH4 emissions are total emissions (integrated pollution prevention and control sectors 1-7) excluding sector 5: land use, land use change and forestry. The present emission inventories include only anthropogenic VOC emissions.

[22] EEA Report No 10/2019, Air quality in Europe – 2019 report, European Environment Agency, Copenhagen, Denmark, October 16, 2019

Figure 14 shows that for all primary and precursor pollutants contributing to ambient air concentrations of PM, O3 and NO2, as well as arsenic (As), cadmium (Cd), nickel (Ni), lead (Pb), mercury (Hg) and BaP (8), decreased between 2000 and 2017 in the EU-28.
SOX emissions show the largest reductions (77 % in the EU-28) and NH3 emissions the smallest (9 % in the EU-28). However, NH3 emissions have been increasing since 2013, mainly driven by the agriculture sector.

During the period 2000-2017, emissions showed a significant absolute decoupling (10) from economic activity, which is desirable for both environmental and productivity gains. This is indicated by the contrast between a reduction in EU-28 air pollutant emissions and an increase in EU-28 gross domestic product (GDP), which effectively means that there are now fewer emissions for each unit of GDP produced per year.
The greatest decoupling has been for SOX, CO, NOX, BC and certain metals (Ni, Pb, Cd, Hg) and organic species (BaP), for which emissions per unit of GDP were reduced by over 40 % between the years 2000 and 2017. A decoupling of emissions from economic activity may be due to a combination of factors, such as increased regulation and policy implementation, fuel switching, technological improvements and improvements in energy or process efficiencies, and the increase in the consumption of goods produced in industries outside the EU.

Main sources of pollutants

The main sectors contributing to emissions of air pollutants in Europe are:

1. Transport, split into road and non-road (which includes, for example, air, rail, sea and inland water transport)
2. commercial, institutional and households
3. energy production and distribution
4. industry, split into energy use in industry, and industrial processes and product use
5. agriculture
6. waste, which includes landfill, waste incineration with heat recovery and open burning of waste

In general, most sectors show significant reductions in emissions.

For both road and non-road transport sectors, emissions of key pollutants (e.g. NOX) have decreased significantly, although transported passenger and freight volumes have been gradually increasing. Policy actions at EU level have been taken to address transport-related air pollution while allowing sectoral growth. Regulating emissions by setting emission standards (e.g. Euro 1-6) or by establishing requirements for fuel quality are good examples of such actions at EU level. Emissions from aviation and international shipping activities (for which aviation cruise and international maritime navigation activities are not considered in the total emissions because of the reporting regulation are still an important issue in Europe.

The commercial, institutional and households show small reductions in absolute terms, but are in fact still considerable when compared to the energy consumption increase due to growing number of buildings. Since 2014 however, some of the pollutant emissions have shown a small increase.

Emissions of pollutants from industry (the industrial processes and product use sector and the energy use in industry sector), and energy production and distribution have significantly decreased since 2000, with the largest decoupling between emissions and key indicators seen for the energy production and distribution sector and the industrial processes and product use sector. Energy use in industry is the only sector in which the indicator for the sector activity — electricity consumption — has almost flattened since 2008, but the decoupling is still very prominent. The decrease in emissions reflects the EU legislation targeting stationary emission sources in the industry and energy sectors (EEA, 2017a, 2018b), setting emission limits for medium-sized combustion plants (EU, 2015) and adopting sectoral implementing decisions on the best available techniques (under Directive 2010/75/EU on industrial emissions (EU, 2010)).

Agriculture and waste are the other sectors in which the reduction in emissions has been the lowest since 2000 — less than 10 % — showing a limited decoupling with the key indicators. However, there are exceptions, and some pollutant emissions have decreased, such as those of BaP in agriculture, and those of CH4 and Hg in waste.

Figure 15. Contribution to EU-28 emissions from the main source sectors in 2017 of SOX, NOX, primary PM10, primary PM2.5, NH3, NMVOCs, CO, BC and CH4 (source: footnote 21)

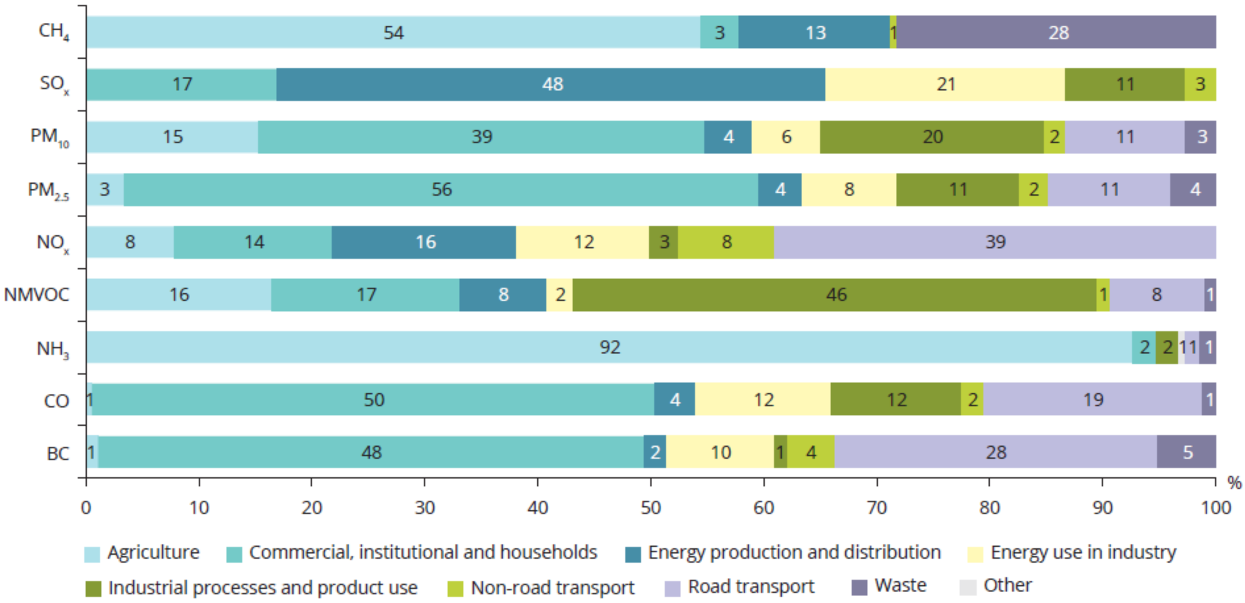
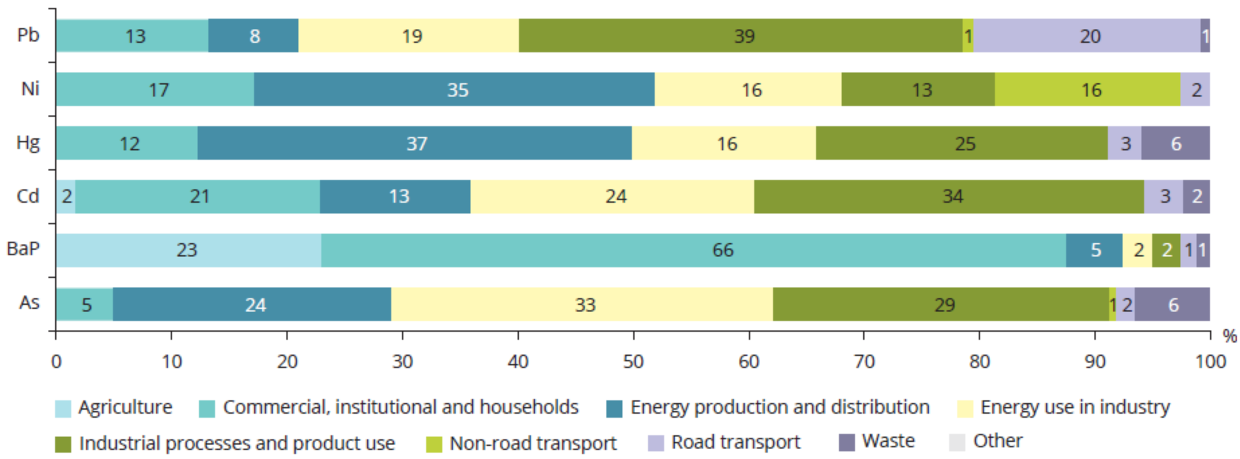


Figure 16. Contribution to EU-28 emissions from the main source sectors in 2017 of As, Cd, Ni, Pb, Hg and BaP (source: footnote 21)



Notes:
The emissions reported from Portugal (2000-2017) and from Bulgaria (2000-2006) for the activity 'asphalt blowing in refineries' (under the industrial processes and product use sector) were not taken into account to ensure consistency between the nationally reported data (they were not reported by any other country).

Only sectors contributing more than 0.5 % of the total emissions of each pollutant were considered.

When the sum of all contributions is either 99 or 101, it is due to rounding of the numbers.

The road transport sector was the most significant contributor to total NOX emissions and the second largest contributor to BC, CO, primary PM2.5 and Pb emissions. The energy production and distribution sector was the largest contributor to SOX, Hg, and Ni, as well as a significant contributor to NOX, As, and CH4 emissions. The industrial processes and product use sector (13) contributed the majority of NMVOC, Cd, and Pb emissions, and the second largest emissions of primary PM, As, and Hg. The energy use in industry sector contributed the majority of As emissions, the second largest amount of SOX and Cd, and significant amounts of Pb, Hg, Ni, CO and BC emissions.
The commercial, institutional and households sector was the largest contributor to BaP, primary PM, CO and BC, and it also contributed to NMVOC, Cd, SOX, Ni, and NOX emissions. The agriculture sector contributed the majority of NH3 and CH4 emissions, as well as a significant amount of BaP, NMVOC and primary PM10 emissions. The waste sector is the second largest contributor to CH4 emissions.

Outdoor pollutant concentrations

Particulate matter

Concentrations of particulate matter (PM) continued to exceed the EU limit values and the WHO Air Quality Guidelines (AQGs) in large parts of Europe in 2017. For PM10, concentrations above the EU daily limit value were registered at 22 % of the reporting stations (646 out of 2 886) in 17 of the 28 EU Member States (EU-28). For PM2.5, concentrations above the annual limit value were registered at 7 % of the reporting stations (98 out of 1 396) in seven Member States and three other reporting countries.
The long-term WHO AQG for PM10 was exceeded at 51 % of the stations (1 497 out of 2 927) and in all of the reporting countries, except Estonia, Finland and Ireland. The long-term WHO AQG for PM2.5 was exceeded at 69 % of the stations (958) located in all of the reporting countries, except Estonia, Finland and Norway.
A total of 17 % of the EU-28 urban population was exposed to PM10 levels above the daily limit value and 44 % was exposed to concentrations exceeding the stricter WHO AQG value for PM10 in 2017.
Regarding PM2.5, about 8 % of the urban population in the EU-28 was exposed to levels above the EU annual limit value, and approximately 77 % was exposed to concentrations exceeding the WHO AQG value for PM2.5 in 2017.
In spite of the decreasing values in exposure to PM2.5 observed since 2006, four Member States have yet to meet the exposure concentration obligation, set under the Ambient Air Quality Directive and due to be attained in 2015.

Ozone

In 2017, 20 % of stations (378 out of 1 903) registered concentrations above the EU ozone (O3) target value for the protection of human health. These stations were located in 17 of the EU-28 and six other European reporting countries. The long-term objective was met in only 18 % of the stations (337) in 2017.
The WHO AQG value for O3 was exceeded in 95 % of all the reporting stations (1 806). About 14 % of the EU-28 urban population was exposed to O3 concentrations above the EU target value threshold. The percentage of the EU-28 urban population exposed to O3 levels exceeding the WHO AQG value was 96 % in 2017, scarcely showing any fluctuation since 2000.

Nitrogen dioxide

Concentrations above the annual limit value for nitrogen dioxide (NO2) are still widely

registered across Europe, even if concentrations and exposures continue to decrease. In 2017, around 10 % of all the reporting stations (329 out of 3 260) recorded concentrations above this standard, which is the same as the WHO AQG.
These stations were located in 16 of the EU-28 and four other reporting countries. In total, 86 % of concentrations above this limit value were observed at traffic stations. Around 7 % of the EU-28 urban population was exposed to concentrations above the annual EU limit value (which is equal to the WHO AQG) for NO2 in 2017; this represents the lowest value since 2000.

Benzo[a]pyrene, an indicator for polycyclic aromatic hydrocarbons

Thirty-one per cent of the reported benzo[a]pyrene (BaP) measurement stations (218 out of 712) registered concentrations above 1.0 ng/m3 in 2017. They belonged to 13 Member States (out of 24 EU-28 and two other countries reporting data) and were located mostly in urban areas. Seventeen per cent of the EU-28 urban population was exposed to BaP annual mean concentrations above the EU target value in 2017, which is — together with the figure recorded in 2009 — the lowest value since 2008. Overall, 83 % were exposed to concentrations above the estimated reference level.

Other pollutants: sulphur dioxide, carbon monoxide, benzene

Only 21 stations (representing less than 2 % of a total of more than 1 400 stations) in two of the EU-28 and four other reporting countries reported values for sulphur dioxide (SO2) above the EU daily limit value in 2017. However, 43 % of all SO2 stations, located in 28 reporting countries, measured SO2 concentrations above the WHO AQG, which is more stringent than the EU daily limit value. This signified that 31 % of the EU-28 urban population in 2017 was exposed to SO2 levels exceeding the WHO AQG.
Exposure of the European population to carbon monoxide concentrations above the EU limit value and WHO AQG was very localised and infrequent. Only four stations (of which three were outside the EU-28) registered concentrations above the EU limit value in 2017. Likewise, concentrations above the limit value for benzene were observed at only three European stations (all of them located in the EU-28) in 2017.

Toxic metals

European emissions of arsenic, cadmium, nickel, lead and mercury have been declining since 2000. This has led, on average, to a decrease in air concentrations and deposition, especially in industrial sites, as energy production and industrial activities were the main anthropogenic sources of these metals during the period 2008-2017. Despite the considerable decrease in emissions of toxic metals into the air during the period 2000-2017, long-term risks to human health and ecosystems still remain, as a result of the accumulation of metal in soils, sediments and organisms from past anthropogenic emissions. It is therefore necessary to continue efforts to reduce air emissions of toxic metals, focusing on implementing the best available techniques and reducing the use of toxic metals in products.

2.8.4 Air Quality Standards

Guidelines for indoor pollutant concentrations

Table 33 gives the air quality guideline (AQG) values for indoor pollutant concentrations as formulated by the World Health Organisation (WHO). For some pollutants no indoor air requirements have been defined yet by WHO. For those values WHO outdoor requirements are used.

Table 32. WHO guideline values for indoor pollutant concentrations (2010)

<table>
<tr><th>Pollutant</th><th>Averaging period</th><th>Air Quality Guideline</th><th>Critical outcome</th></tr>
<tr><td>Benzene</td><td colspan="2">No safe level can be determined</td><td>Acute myeloid leukaemia, genotoxicity</td></tr>
<tr><td rowspan="4">Carbon monoxide</td><td>15 min. mean</td><td>100 mg/m³</td><td rowspan="4">Acute exposure-related reduction of exercise tolerance and increase in symptoms of ischaemic heart disease</td></tr>
<tr><td>1 hour mean</td><td>35 mg/m³</td></tr>
<tr><td>8 hour mean</td><td>10 mg/m³</td></tr>
<tr><td>24 hour mean</td><td>7 mg/m³</td></tr>
<tr><td>Formaldehyde</td><td>30 min. mean</td><td>100 µg/m³</td><td>Sensory irritation</td></tr>
<tr><td>Naphthalene</td><td>annual mean</td><td>10 µg/m³</td><td>Respiratory tract lesions leading to inflammation and malignancy</td></tr>
<tr><td rowspan="2">Nitrogen dioxide</td><td>1 hour mean</td><td>200 µg/m³</td><td rowspan="2">Respiratory symptoms, bronchoconstriction, increased bronchial reactivity, airway inflammation and decreases in immune defence</td></tr>
<tr><td>annual mean</td><td>20 µg/m³</td></tr>
<tr><td>PAHs</td><td colspan="2">No safe level can be determined</td><td>Lung cancer</td></tr>
<tr><td>Radon</td><td>(Country specific)</td><td>100 Bq/m³</td><td>Lung cancer; Suggestive evidence of an association with other cancers, in particular leukaemia and cancers of the extra thoracic airways</td></tr>
<tr><td>Trichloroethylene</td><td colspan="2">No safe level can be determined</td><td>Carcinogenicity (liver, kidney, bile duct and non-Hodgkin's lymphoma)</td></tr>
<tr><td>Tetrachloroethylene</td><td>annual mean</td><td>250 µg/m³</td><td>Effects in the kidney indicative of early renal disease</td></tr>
<tr><td rowspan="2">Sulphur dioxide</td><td>10 min. mean</td><td>500 µg/m³</td><td rowspan="2">Respiratory diseases</td></tr>
<tr><td>24 hour mean</td><td>20 µg/m³</td></tr>
<tr><td>Ozone</td><td>8 hour mean</td><td>100 µg/m³</td><td>Physiological and inflammatory lung effects</td></tr>
<tr><td rowspan="2">PM 2.5</td><td>24 hour mean</td><td>25 µg/m³</td><td rowspan="4">Cardiopulmonary diseases and long cancer</td></tr>
<tr><td>annual mean</td><td>10 µg/m³</td></tr>
<tr><td rowspan="2">PM 10</td><td>24 hour mean</td><td>50 µg/m³</td></tr>
<tr><td>annual mean</td><td>20 µg/m³</td></tr>
</table>

<u>Guidelines for outdoor pollutant concentrations</u>

Table 34 summarizes the air quality guidelines (AQGs) as defined by the World Health Organisation (WHO) for ambient air.

Table 33. WHO Air Quality Guidelines for ambient air

Pollutant	Averaging period	Air Quality Guideline	Critical outcome
Sulphur dioxide	10 min. mean	500 µg/m^3	Respiratory diseases
	24 hour mean	20 µg/m^3	
Ozone	8 hour mean	100 µg/m^3	Physiological and inflammatory lung effects
PM 2.5	24 hour mean	25 µg/m^3	Cardiopulmonary diseases and long cancer
	annual mean	10 µg/m^3	
PM 10	24 hour mean	50 µg/m^3	
	annual mean	20 µg/m^3	
NO_2	1 hour mean	200 µg/m^3	Respiratory symptoms, bronchoconstriction, increased bronchial reactivity, airway inflammation and decreases in immune defence
	annual mean	40 µg/m^3	
BaP	annual mean	*0.12 ng/m^3 **	
CO	1 hour mean	30 mg/m^3	Acute exposure-related reduction of exercise tolerance and increase in symptoms of ischaemic heart disease
	8 hour mean	10 mg/m^3	
Benzene C_6H_6	annual mean	*1.7 µg/m^3 **	Acute myeloid leukaemia, genotoxicity
Pb	annual mean	*0.5* µg/m^3	Exposure to toxic metals affects several human organs and systems and impairs their function (brain, nervous system, kidneys, respiratory system, skeletal system, etc.)
As	annual mean	*6.6 ng/m^3 **	
Cd	annual mean	5 ng/m^3	
Ni	annual mean	*25 ng/m^3 **	

* As WHO has not set an AQG for BaP, C6H6, As and Ni, the RL was estimated assuming an acceptable risk of additional lifetime cancer risk of approximately 1 in 100 000 (following the EEA Report No 10/2019, Air quality in Europe – 2019 report, European Environment Agency, Copenhagen, Denmark, October 16, 2019).

Table 35 summarizes the air quality standards that were set in the two Ambient Air Quality Directives presently in force (EU 2004 and 2008)

Table 34. Air Quality Guidelines according to EU Ambient Air Quality Directives

Pollutant	Averaging period	Air Quality Guideline	Comments
PM10	24 hours	Limit value: 50 µg/m^3	*Not to be exceeded on more than 35 days per year*
	calendar year	Limit value: 40 µg/m^3	
PM2.5	calendar year	Limit value: 20 µg/m^3	
		Exposure concentration obligation : 20 µg/m^3	*Average exposure indicator (AEI) (a) in 2015 (2013-2015 average)*
		Nat. exposure reduction target: 0-20 % reduction in exposure	*AEI (a) in 2020, the percentage reduction depends on the initial AEI*

O_3 Ozone	8 hour	Target value: 120 µg/m^3	*Not to be exceeded on more than 25 days/year, averaged over 3 years (b)*
		Long-term objective: 120 µg/m3	
	1 hour	*Information threshold: 180µg/m^3*	
		Alert threshold: 240 µg/m_3	
NO_2	1 hour mean	Limit value: 200 µg/m^3	*Not to be exceeded on more than 18 hours per year*
		Alert threshold: 400 µg/m_3	*To be measured over 3 consecutive hours over 100 km2 or an entire zone*
	calendar year	Limit value: 40 µg/m^3	
BaP	calendar year	Target value: 1 ng/m^3	*Measured as content in PM10*
SO_2	1 hour	Limit value: 350 µg/m^3	*Not to be exceeded on more than 24 hours per year*
		Alert threshold: 500 µg/m_3	*To be measured over 3 consecutive hours over 100 km2 or an entire zone*
	1 day	Limit value: 125 µg/m^3	*Not to be exceeded on more than 3 days per year*
CO	8 hour	Limit value: 10 mg/m^3	
Benzene C_6H_6	calendar year	Limit value: 5 µg/m^3	
Pb	calendar year	Limit value: 0.5 µg/m^3	*Measured as content in PM10*
As	calendar year	Target value: 6 ng/m^3	*Measured as content in PM10*
Cd	calendar year	Target value: 5 ng/m^3	*Measured as content in PM10*
Ni	calendar year	Target value: 20 ng/m^3	*Measured as content in PM10*

Notes:
(a) AEI: based upon measurements in urban background locations established for this purpose by the Member States, assessed as a 3-year running annual mean.
(b) In the context of this report, only the maximum daily 8-hour means in 2017 are considered, so no average over the period 2015-2017 is presented.

2.8.5 Impact IAQ on well-being and performance

As indicated in previous sections, the IAQ is the result of pollutant emissions from applied materials and human activities inside the buildings, on the ventilation rates that are applied and on pollutants concentrations in the outdoor air. During presence in the building, people are exposed to these IAQ-levels which can affect their well-being and performance levels.

Impact on Health

The EEA Report No 10/2019 summarises the health effects of air pollution as follows:
Air pollution (be it indoor or outdoor) is a major cause of premature death and disease and is the single largest environmental health risk in Europe (WHO), causing around 500 000 premature deaths[23] in 2016 attributable to PM2.5, NO2 and O3 in the EU28. This is around 10% of number of total annual deaths in EU28 and 1‰ of the total EU28 population.

[23] Premature deaths are deaths that occur before a person reaches an expected age. This expected age is typically the life expectancy for a country stratified by sex. Premature deaths are considered preventable if their causes can be eliminated.

When expressed in Year of Life Lost (YLL)[24], these figure add up to around 4.6 million years in 2016, indicating that on average these 500.000 people that died premature lost 9 years of their life.
Heart disease and stroke are the most common reasons for premature death attributable to air pollution, followed by lung diseases and lung cancer (WHO). The International Agency for Research on Cancer has classified air pollution in general, as well as PM as a separate component of air pollution mixtures, as carcinogenic. In 2018, household (indoor) and ambient air pollution were recognised as one of the risk factors for non-communicable diseases, together with unhealthy diets, tobacco smoking, harmful use of alcohol and physical inactivity (UN 2018).

Both short- and long-term exposure of children and adults to air pollution can lead to reduced lung function, respiratory infections and aggravated asthma. Maternal exposure to ambient air pollution is associated with adverse impacts on fertility, pregnancy, new-borns and children (WHO). There is also emerging evidence that exposure to air pollution is associated with new-onset type 2 diabetes in adults, and it may be linked to obesity, systemic inflammation, ageing, Alzheimer's disease and dementia).
The effects of air pollution on health depend not only on exposure, but also on the vulnerability of people. Vulnerability to the impacts of air pollution can increase as a result of age, pre-existing health conditions or particular behaviours. A large body of evidence suggests that people of lower socio-economic status tend to live in environments with worse air quality (EEA).

<u>DALYs and IAQ- related diseases</u>

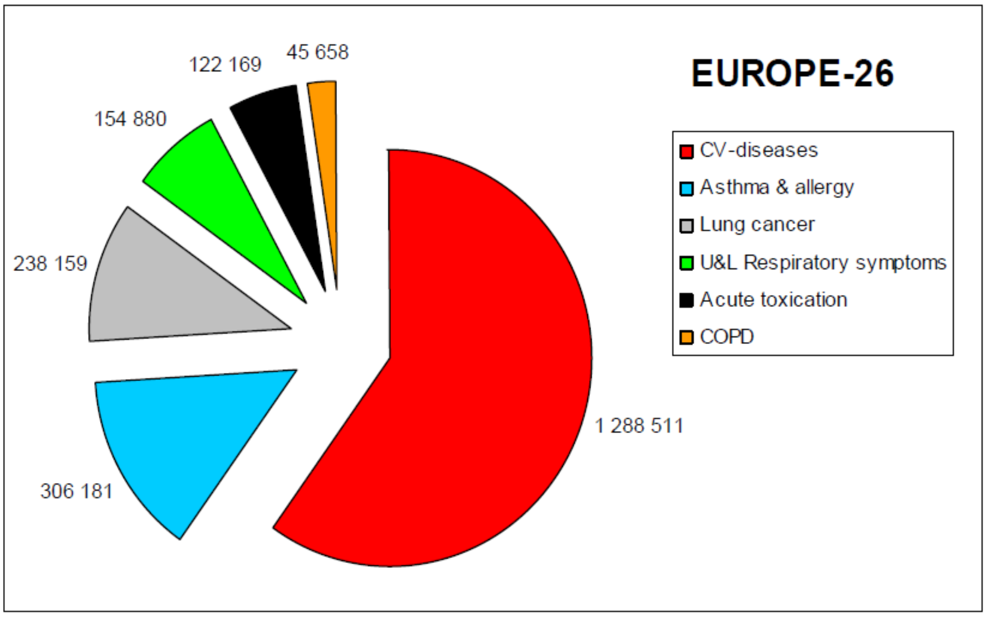
The common unit to express the total burden of all diseases related to air pollution is the DALY: Disability Adjusted Lifeyears). The unit is developed and supported by the WHO and is used for the quantification and comparison of a wide variety of health effects.

The IAIAQ-study[25] calculated in 2011 that in the burden of diseases (BoD) attributable to IAQ (indoor air only) in EU-26 is ca. 2 million DALYs per year, in other words, two million years of healthy life is lost annually (see also figure 17). This equals about 3% of the total BoD due to all diseases from all causes in Europe. Not all of this loss is preventable, even in principle, partly because all exposures cannot be reduced to zero (e.g. radon, fine PM or bio-aerosols from outdoor air), and partly because the dose/ response and attributable risk coefficients are derived from epidemiological data around the current exposure levels and may not be valid at lower exposure levels. Note the dominating 60 % proportion of CV-diseases, followed by the 35 % proportion of the respiratory diseases, asthma, lung cancer, upper and lower respiratory infections and COPD. For comparison, the contributions of these two categories to the total BoD in DALY/year in EU-27 are 19 % for CV-diseases and 9 % for the respiratory diseases.

[24] Years of life lost (YLL) is defined as the years of potential life lost due to premature death. It is an estimate of the average number of years that a person would have lived if he or she had not died prematurely. YLL takes into account the age at which deaths occur and is greater for deaths at a younger age and lower for deaths at an older age. It gives, therefore, more nuanced information than the number of premature deaths alone.

[25] Jantunen M., Oliveira Fernandes E., Carre P., Kephalopoulos S., Promoting actions for healthy indoor air (IAIAQ). European Commission Directorate General for Health and Consumers, Luxembourg, 2011.

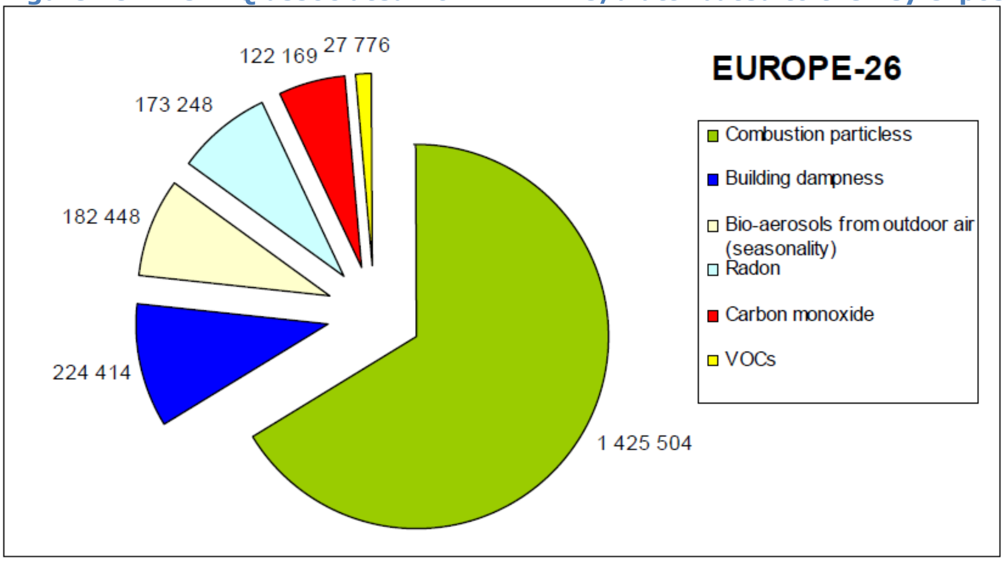
Figure 17. The IAQ associated BoD in DALYs/a attributed to the key health outcomes. The total BoD for the EU-26 is 2 MDALY/a.



DALYs and IAQ- related pollutants

A whole 2/3 of the IAQ associated BoD is caused by exposure to fine PM (best represented by PM2.5). Indoor air exposure to fine PM originates mostly from outdoor air and indoor combustion of solid fuels for cooking and heating, if present. Also the outdoor air fine PM originates mostly from combustion sources, local and distant, in particular where the levels exceed rural background. Fine PM exposure is mostly responsible for the CV-diseases but also for COPD and lung cancer.

Figure 18. The IAQ associated BoD in DALYs/a attributed to the key exposure agents



The other significant exposures are building dampness (11 %) and bio-aerosols from outdoor air (8 %). The impacts of both are assessed by their association to both induction and aggravation of asthma and dampness also by its association with respiratory diseases and symptoms. 9 % of all lung cancer cases in Europe are attributable to Radon (8 % of IAQ DALYs). Indoor exposure to carbon monoxide from indoor combustion sources (6 % or more) ranks among the highest causes of acute lethal toxication around Europe. In spite of the fact that in the case of CO poisoning the cause of death or non-lethal toxication is rather easy to diagnose, CO-toxication statistics are largely missing (18/26), highly diverse (8/26) and poorly comparable across Europe. The given estimate represents only lethal toxications and is certainly an underestimate of the total CO associated DALYs in EU-26.

The relatively small estimated role of the VOCs is further explained in the report of the IAIAQ-project [22]:

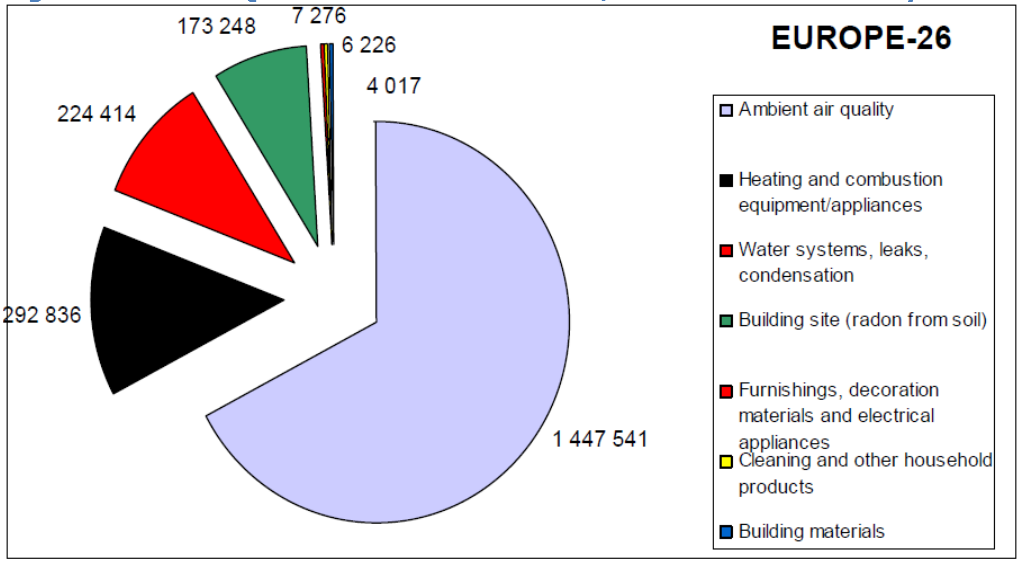
- Firstly, there is only epidemiological data about specific disease dose/response which can be credibly extrapolated to indoor air levels for only very few VOCs, benzene, naphthalene and formaldehyde (Kotzias et al. 2006, INDEX report). For the other VOCs there is experimental toxicological data on animals and volunteering humans mostly at very much higher than common indoor air levels. Some VOC mixtures have in some laboratory experiments been shown to be much more potent than the sum of individual VOCs. High indoor air TVOC levels have also been associated with sick building syndrome and reduced learning in schools or productivity at workplaces, and, furthermore, interventions to reduce such levels by increased fresh air exchange, case by case, have been shown to reduce the symptoms and improve performance. Such interventions, however, are not specific for the VOCs, but dilute the levels of all contaminants generated indoors. No theory for causality or D/R model exists to link the common indoor air levels of dozens of VOCs to population level burden of disease.
- Secondly, population representative indoor air VOC exposure data exist only for two countries, Germany and France, and a number of cities studied in the EXPOLIS, MACBETH, AIRMEX and PEOPLE projects.
- Thirdly, the health problems of VOCs appear mostly in new, newly renovated of refurbished buildings, which – at any time – represent only a few percent of the total building stock occupied by the population. Therefore, even if significant health impacts were found in such buildings, the impact on the national BoD remains relatively small in comparison to e.g. indoor exposure to fine PM of outdoor origin which affects most of the urban populations, or to ETS which still affect majority of the population in many European countries.

Consequently, the public health role of the VOCs is certainly underestimated and should not be ignored. Besides, this role is highly relevant for the quality, safety and liability of European building products and materials and daily household products.

DALYs and IAQ-related pollutant sources

Ambient outdoor air is the source of the indoor air contaminants (mostly fine PM and bio-aerosols, but also some VOCs), which are responsible some 2/3 of the total BoD from indoor air exposures. Heating and combustion equipment, most importantly cooking and heating with solid fuels (14 %), water systems, water leaks and condensation (11 %), and underlying soil (as source of radon, 8 %), are the other important sources for the IAQ associated BoD.
In comparison the roles of furnishings, decoration materials, household products and building materials appear small, but the points in the discussion about the VOCs in the section above should be taken into consideration here, too.

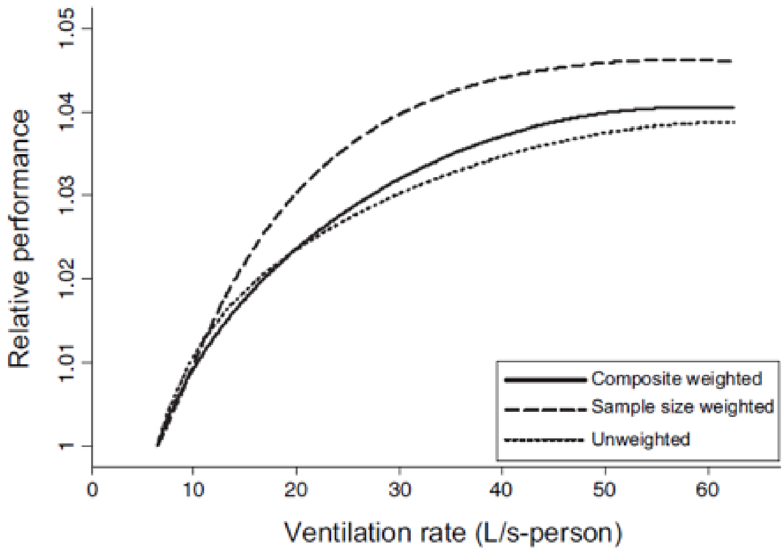
Figure 19. The IAQ associated BoD in DALYs/a attributed to the key sources of exposure.



Impact on Performance

Several studies investigated the effect of Indoor Air Quality (IAQ) on performance and productivity. In the paper 'Ventilation and Work Performance[26]' the link between ventilation rates and performance is investigated by analysing existing studies on this topic. The studies that were included in the review, assessed the performance of various tasks in laboratory experiments and measured performance at work in real buildings. Almost all studies found increases in performance with higher ventilation rates.

Figure 20. Relative performance in relation to performance at ventilation rate of 6.5 l/s per person.

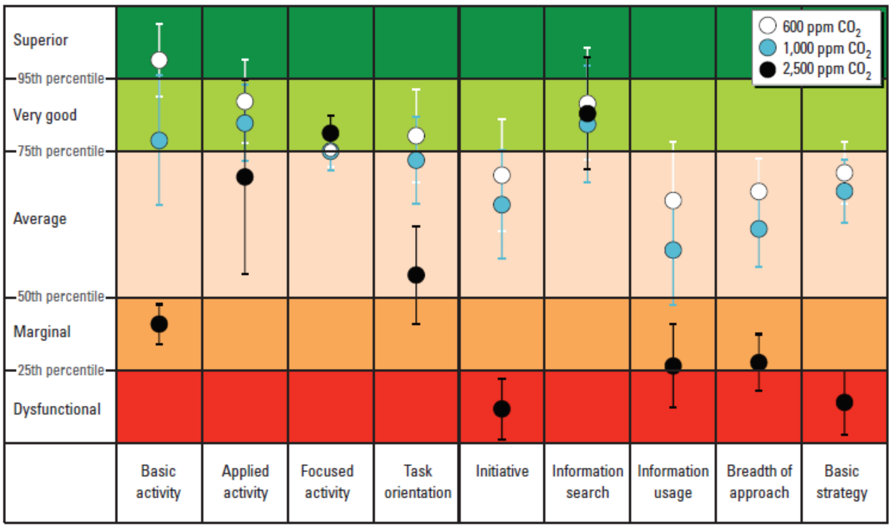


[26] Seppänen O., Fisk W.J., Lei G.H., Heinonen J., Ventilation and Work Performance, Indoor Air, Volume 16, p28-36, February 2006

One of the most widely used metrics for measuring ventilation is CO_2 concentration in the habitable space. Scientists have used CO_2 as a representative gas (indicator), and correlate that level to higher levels of VOCs, microbial contaminants, and allergens. However, some research questions whether CO_2 itself may also leading to occupant performance reduction.

In 2012 the Department of Psychiatry and Behavioural Science, Upstate Medical University, in New York and the Indoor Environment Department, Lawrence Berkeley National Laboratory performed a study in in which participants were subjected to different levels of CO_2 for 2.5 hour intervals in an attempt to see how the different concentrations affected decision making skills. 22 participants were exposed to CO_2 at 600, 1000, and 2500 ppm, and at the end of each period took a test measuring decision making performance, health symptoms, and perceived air quality. This study found that relative to the 600 ppm level, performance on 6 of 9 scales was reduced moderately at 1000 ppm, and performance on 7 of 9 scales was greatly reduced at 2500 ppm (see also figure 21).

Figure 21. Impact of CO2 on human decision-making performance. Error bars indicate 1 SD.



In 2015 a study was performed that looked into associations between cognitive function scores with CO2-levels, ventilation rates and VOC exposures in office workers[27].

The objective of the study was to simulate indoor environmental quality (IEQ) conditions in "Green" and "Conventional" buildings to evaluate the impacts on an objective measure of human performance: higher-order cognitive function. The following method was applied: Twenty-four participants spent 6 full work days (0900–1700 hours) in an environmentally controlled office space, blinded to test conditions. On different days, they were exposed to IEQ conditions representative of Conventional [high concentrations of volatile organic compounds (VOCs)] and Green (low concentrations of VOCs) office buildings in the United States (see table 36). Additional conditions simulated a Green building with a high outdoor air ventilation rate (labelled Green+) and artificially elevated carbon dioxide (CO2) levels independent of ventilation.

The main results were that on average, cognitive scores were 61% higher on the Green building day and 101% higher on the two Green+ building days than on the Conventional

[27] Allen J.G., MacNaughton P., Satish U., Santaman S.,Vallarino J., Spengler J.D., Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments, Environmental Health Perspectives, Volume 124, No. 6, June 2016.

building day ($p < 0.0001$). VOCs and CO2 were independently associated with cognitive scores (see table 37).

Conclusions: Cognitive function scores were significantly better under Green+ building conditions than in the Conventional building conditions for all nine functional domains. These findings have wide-ranging implications because this study was designed to reflect conditions that are commonly encountered every day in many indoor environments.

Table 35. Average indoor environmental conditions simulated in each room of the TIEQ lab.

Variable	Day 1 Green+		Day 2 Moderate CO_2		Day 3 High CO_2		Day 4 Green		Day 5 Conventional		Day 6 Green+	
Date	4 November		5 November		6 November		11 November		12 November		13 November	
Day of the week	Tuesday		Wednesday		Thursday		Tuesday		Wednesday		Thursday	
Room	502	503	502	503	502	503	502	503	502	503	502	503
Experimental parameters												
CO_2 (ppm)	563	609	906	962	1,400	1,420	761[b]	726[b]	969	921	486	488
Outdoor air ventilation (cfm/person)[a]	40	40	40	40	40	40	20	20	20	20	40	40
TVOCs (μg/m^3)	43.4	38.5	38.2	28.6	32.2	29.8	48.5	43.5	506	666	55.8	14.9
Other environmental parameters												
Temperature (°C)	23.9	24.5	22.4	23.9	21.3	22.0	22.9	23.7	21.8	22.5	20.7	21.3
Relative humidity (%)	31.0	30.4	34.2	31.6	38.7	38.3	34.3	33.3	39.6	38.3	27.8	26.8
NO_2 (μg/m^3)	57.9	58.9	53.2	54.1	60.8	58.4	51.3	45.6	54.6	50.8	56.5	55.5
O_3 (μg/m^3)	3.42	21.2	14.4	13.0	1.37	0.00	6.85	238	1.83	1.71	1.37	4.11	6.85
$PM_{2.5}$ (μg/m^3)	2.38	3.49	3.35	2.58	2.97	2.42	1.26	1.83	1.68	1.34	1.26	1.38
Noise (dB)	51.3	49.9	49.7	48.8	52.5	48.8	49.6	48.7	51.1	48.8	50.5	49.2
Illuminance (mV)	2.95	2.70	2.89	2.83	2.31	2.04	3.11	2.93	2.74	2.51	2.39	2.28
Irradiance (mV)	9.07	8.76	9.45	9.37	6.00	6.05	9.90	9.60	8.30	8.14	6.70	6.82

Abbreviations: TIEQ, Total Indoor Environmental Quality; TVOCs, total volatile organic compounds.

[a] A constant air flow rate of 40 cfm/person was maintained on all study days, with 100% outdoor air used on days 1, 2, 3, and 6 and 50% outdoor air and 50% recirculated air used to achieve an outdoor air ventilation rate of 20 cfm/person on days 4 and 5.

[b] Average concentration from 1400 to 1700 hours was 926 ppm, but lower CO2 concentrations in the morning hours during the approach to steady state led to a lower average CO2 concentration.

Table 36. Generalized additive mixed effect models testing the effect of IEQ condition and on cognitive scores, normalized to the "Conventional" condition, treating participant as a random intercept.

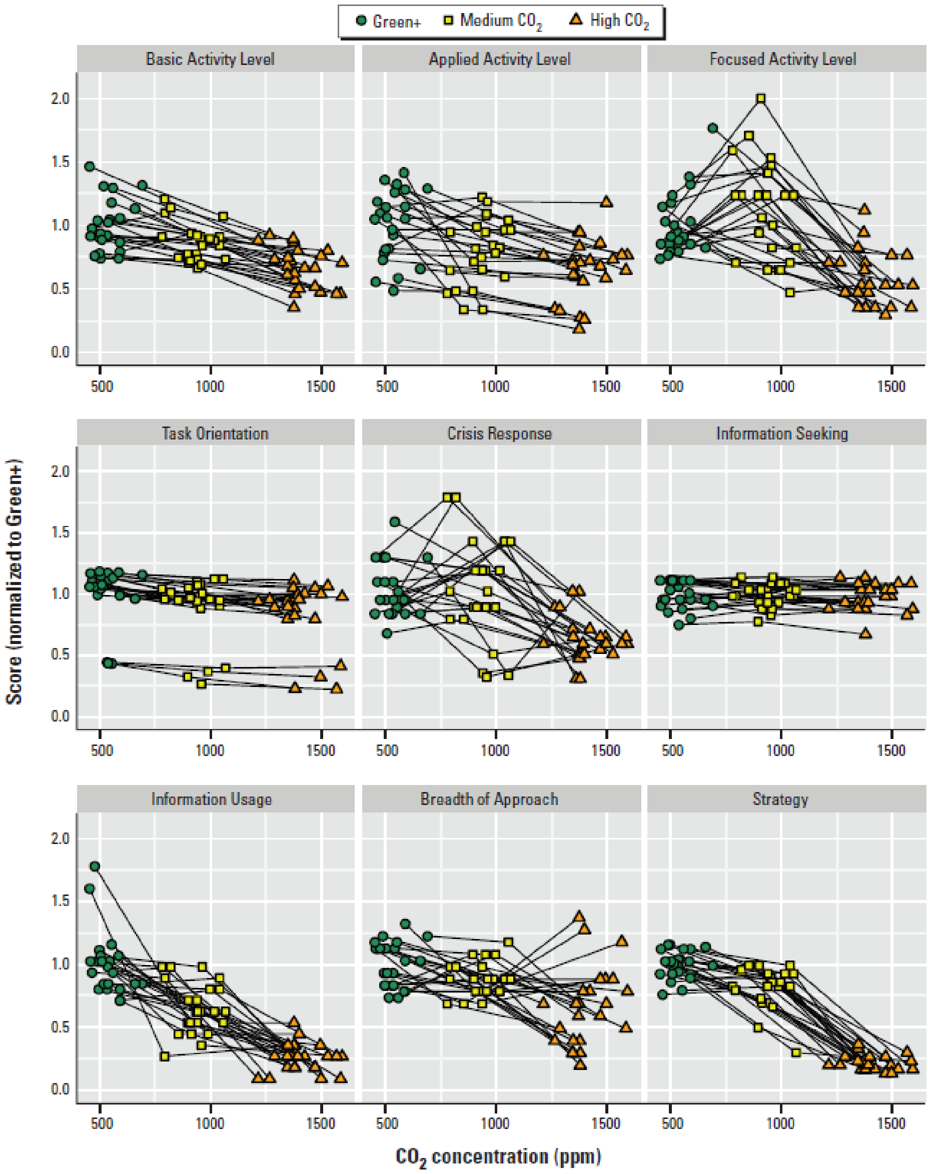
Condition	Cognitive domain: estimate, [95% confidence interval], (*p*-value) Basic Activity Level	Applied Activity Level	Focused Activity Level	Task Orientation	Crisis Response	Information Seeking	Information Usage	Breadth of Approach	Strategy	Average
Day 1 Green+	1.35 [1.28, 1.43] (< 0.0001)	1.39 [1.26, 1.52] (< 0.0001)	1.44 [1.27, 1.62] (< 0.0001)	1.14 [1.11, 1.17] (< 0.0001)	2.35 [1.91, 2.78] (< 0.0001)	1.10 [1.07, 1.14] (< 0.0001)	3.94 [3.47, 4.41] (< 0.0001)	1.43 [1.25, 1.60] (< 0.0001)	3.77 [3.40, 4.14] (< 0.0001)	1.99 [1.89, 2.09] (< 0.0001)
Day 2 Moderate CO_2	1.20 [1.13, 1.27] (< 0.0001)	1.08 [0.95, 1.21] (0.23)	1.68 [1.51, 1.85] (< 0.0001)	1.05 [1.02, 1.08] (0.0009)	2.05 [1.63, 2.48] (< 0.0001)	1.11 [1.08, 1.15] (< 0.0001)	2.61 [2.15, 3.07] (< 0.0001)	1.29 [1.12, 1.46] (0.0013)	3.17 [2.81, 3.53] (< 0.0001)	1.69 [1.59, 1.79] (< 0.0001)
Day 3 High CO_2	0.91 [0.84, 0.98] (0.015)	0.88 [0.75, 1.01] (0.081)	0.85 [0.68, 1.02] (0.087)	1.00 [0.97, 1.03] (0.76)	1.33 [0.90, 1.75] (0.14)	1.08 [1.05, 1.12] (< 0.0001)	1.01 [0.55, 1.48] (0.95)	0.98 [0.81, 1.15] (0.78)	0.83 [0.47, 1.19] (0.36)	0.99 [0.89, 1.09] (0.78)
Day 4 Green	1.14 [1.06, 1.21] (0.0003)	1.04 [0.91, 1.18] (0.51)	1.51 [1.34, 1.68] (< 0.0001)	1.03 [1.00, 1.06] (0.065)	1.97 [1.54, 2.40] (< 0.0001)	1.09 [1.05, 1.12] (< 0.0001)	2.72 [2.26, 3.19] (< 0.0001)	1.21 [1.04, 1.38] (0.018)	2.83 [2.46, 3.19] (< 0.0001)	1.61 [1.51, 1.71] (< 0.0001)
Day 5 Conventional (Reference)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Day 6 Green+	1.37 [1.30, 1.44] (< 0.0001)	1.33 [1.20, 1.46] (< 0.0001)	1.52 [1.35, 1.69] (< 0.0001)	1.15 [1.12, 1.19] (< 0.0001)	2.27 [1.85, 2.69] (< 0.0001)	1.11 [1.08, 1.15] (< 0.0001)	4.04 [3.58, 4.51] (< 0.0001)	1.50 [1.33, 1.67] (< 0.0001)	3.98 [3.62, 4.34] (< 0.0001)	2.03 [1.93, 2.13] (< 0.0001)
R^2	0.34	0.17	0.33	0.03	0.28	0.06	0.69	0.27	0.79	0.81

The effects of CO_2 on cognitive function scores while all other parameters were held constant are depicted in Figure 22. Because the air in each room was not completely mixed, there was some variability in CO_2 levels between cubicles. Each line represents the change in an individual's CO_2 exposure and cognitive scores from one condition to the next, normalized to the average CO_2 exposure across all participants during the Green+ conditions.

For seven of the nine cognitive function domains, average cognitive scores decreased at each higher level of CO_2 (Table 37). Cognitive function scores were 15% lower for the moderate CO_2 day (~ 945 ppm) and 50% lower on the day with CO_2 concentrations of ~1,400 ppm than on the two Green+ days (Table 37, dividing the average Green+ estimate by the moderate CO_2 and high CO_2 estimates, respectively). The exposure–response curve between CO_2 and cognitive function is approximately linear across the CO_2 concentrations used in this study; however, whether the largest difference in scores is between the Green+ conditions and the moderate CO_2 condition or the moderate CO_2 condition and the high CO_2 condition depends on the domain (Figure 22).

Ventilation rate, CO_2, and TVOCs were modelled separately from study day to capture the independent effects of each factor on cognitive function scores, averaged across all domains. A statistically significant increase in scores was associated with ventilation rate, CO_2, and TVOCs ($p < 0.0001$ for all three parameters). On average, a 400-ppm increase in CO_2 was associated with a 21% decrease in a typical participant's cognitive scores across all domains after adjusting for participant, a 9.4 l/s increase in outdoor air per person was associated with an 18% increase in these scores, and a 500-µg/m3 increase in TVOCs was associated with a 13% decrease in these scores.

Figure 22. Cognitive function scores by domain and participant and the corresponding carbon dioxide concentration in their cubicles. Each line represents the change in an individual's CO_2 exposure and cognitive scores from one condition to the next, normalized to the average CO_2 exposure across all participants during the Green+ conditions [26].



Economic Implications

Several studies also looked into the economic impacts of improved ventilation in buildings. Current building ventilation standards are based on acceptable minimums. Research performed over the last decades, demonstrates the human health benefits of increased ventilation above such minimums. In addition, improvements on human decision-making performance in office workers have been demonstrated, which can directly be translated into increased productivity. However, adoption of enhanced ventilation strategies is lagging.

In their research study 'Economic, Environmental and Health Implications of Enhanced Ventilation in Office Buildings[28]' the researchers tried to evaluate two of the perceived potential barriers to more widespread adoption: economic and environmental costs.

Methods that were used, included an estimation of the energy consumption associated per building occupant costs for office buildings in seven U.S. cities, representing different climate zones for three ventilation scenarios (standard practice (9.4 l/s), 30% enhanced ventilation, and 18.8 l/s/person) and four different heating, ventilation and air conditioning (HVAC) system strategies (Variable Air Volume (VAV) with reheat and a Fan Coil Unit (FCU), both with and without an energy recovery ventilator). In addition, results from our previous research on cognitive function and ventilation were paired with labour statistics to estimate the economic benefit of increased productivity associated with increasing ventilation rates.

It was found that doubling the ventilation rate from the minimum, cost less than $40 per person per year in all climate zones investigated. When energy recovery ventilation systems are used, energy costs are significantly reduced, and in some scenarios led to a net savings. At the highest ventilation rate, adding an HR essentially neutralized the environmental impact of enhanced ventilation. The same change in ventilation improved the performance of workers by 8%, equivalent to a $6500 increase in employee productivity each year. Reduced absenteeism and improved health are also seen with enhanced ventilation.

Main conclusion of this study is that the economic implications of health benefits and performance increase of an office-worker associated with enhanced ventilation rates by far exceed the increased energy costs per office-worker.

2.8.6 Proposed revisions addressing IAQ-implications

The impacts of suboptimal IAQ-levels on people's health and performance are significant. Bad indoor air quality is associated with a considerable number of premature deaths (up to 500.000 per year in EU28) and a significant total burden of diseases (> 2 million DALYs per year). Bad indoor air quality also compromises cognitive performance levels and reduces the productivity of office workers. These IAQ-impacts also result in substantial economic losses.

From the previous sections it can be concluded that the IAQ is primarily determined by

1) indoor pollutant emitting sources,
2) outdoor air pollutant concentrations, and
3) the applied ventilation rates during occupancy (occupancy = exposure).

To limit the negative implications of suboptimal IAQ-levels on the number of premature deaths, total burden of diseases, productivity and related economic losses, the primary strategies are therefore:

Ad 1)
As stated earlier, primary strategy obviously must be to reduce the indoor sources that emit pollutants to the air. This can be achieved by selecting proper building materials and interior and home decorating products and furniture. Development of such strategies is up to the member states and falls outside the scope of this revision study.

[28] MacNaughton P., Peques J., Satish U., Santanam S., Spengler J., Allen J., Economic, Environmental and Health Implications of Enhanced Ventilation in Office Buildings, International Journal of Environmental Research and Public Health, 2015, 12.

Ad 2)
Since the indoor air quality (IAQ) is not only determined by its indoor pollutant emissions but - through infiltration and ventilation – also by the outdoor pollutants, it is important verify what the average outdoor pollutant concentrations are, before building permits are granted and ventilation systems are designed.
Pollutant emissions to the outdoor air are declining since 2000 and with it the resulting pollutant concentrations in the ambient air. This implies that in most locations and situations the outdoor air quality will be good enough to efficiently dilute the indoor air pollutant concentrations without inserting additional outdoor pollutant. No additional measures are needed.
But in some cases (especially certain traffic intense urban areas or areas near polluting industrial activities) the outdoor air may have increased pollutant concentration levels, making it recommendable to use air supply filters and thus reduce the PM10- and PM2.5 concentrations, before the outdoor air is used to dilute indoor pollutant concentrations. In incidental cases and extreme circumstances it might also be recommendable to use active carbon filters as well for the mitigation of the health effects of higher NO_2 and ozone concentrations. Of course it is better to prevent having habitable buildings in such locations, but in some occasions a combination of unavoidable circumstances may have led to such undesirable conditions.

In summary, once the need for filtration is demonstrated, the filters that are to be applied, including all its relevant specifications, must be clearly communicated. In that sense, the EU 1253/2014 should be updated with information requirements regarding the filters:

- Filter classes used for supply and exhaust
- Filter-velocity
- Clean pressure drop
- Final pressure drop (and related expected filter change intervals)
- Power consumption of used/full filters in case they are not exchanged
- Filter by-pass leakage (is an issue in some of the RVUs, especially the local RVUs).

(See also section 1.9).

In their Position Paper PP-2019-07-25, EUROVENT proposes to go a step further and introduce minimum requirements on the fine dust particle concentration in the supply air of ventilation systems in the future review of the EPBD. The following considerations are formulated in this context:

- The provision of quality air is crucial in spaces designed for human occupancy, and in many industrial applications with hygienic demands as well.
- The supply air classes in standard EN 16798-3, which are based on WHO air quality guidelines, can serve as a basis for enforceable requirements.
- In the first instance, Eurovent proposes to require that the supply air of ventilation systems be at least SUP2.
- Requirements on particle concentration should be placed in regulations that apply to complete systems or buildings.

In a second step, Eurovent also requests the European Commission to monitor, report, and set EU-wide recommended limits on the particle concentration in indoor air itself.

Table 37. Supply air categories according to EN 16798-3

SUP1	refers to supply air with concentrations of PM which fulfilled the WHO (2005) guidelines limit values multiplied by a factor x0,25 (annual mean for PM2.5 ≤ 2.5 µg/m³ and PM10 ≤ 5 µg/m³).
SUP2	refers to supply air with concentrations of PM which fulfilled the WHO (2005) guidelines limit values multiplied by a factor x0,5 (annual mean for PM2.5 ≤ 5 µg/m³ and PM10 ≤ 10 µg/m³).
SUP3	refers to supply air with concentrations of PM which fulfilled the WHO (2005) guidelines limit values multiplied by a factor x0,75 (annual mean for PM2.5 ≤ 7.5 µg/m³ and PM15 ≤ 15 µg/m³).
SUP4	refers to supply air with concentrations of PM which fulfilled the WHO (2005) guidelines limit values (annual mean for PM2.5 ≤ 10 µg/m³ and PM10 ≤ 20 µg/m³).
SUP5	refers to supply air with concentrations of PM which fulfilled the WHO (2005) guidelines limit values multiplied by a factor x1,5 (annual mean for PM2.5 ≤ 15 µg/m³ and PM10 ≤ 30 µg/m³).

These requirements would apply to ventilation systems that at least consist of one ventilation unit (as defined in Commission Regulation (EU) No 1253/2014) intended to replace utilised air by outdoor air in a building or a part of a building.

Ad 3)
As indicated in this section, ventilation rates have a significant effect on IAQ-levels. Higher ventilation rates per person will improve the indoor air quality en reduce the negative implications with regard to productivity and health.
National building codes prescribe what minimum required ventilation capacity must be installed in the various rooms or spaces of a building. Higher ventilation capacities are allowed, but in practice they are not installed.
The ventilation rates that are actually achieved in real-life – during presence and absence – is no parameter in the building codes. Real-life ventilation rates do however, to a large extent, determine the occurring IAQ-levels. Unfortunately, the reality in many residential buildings is that the intended ventilation rates are not achieved (see section 1.2), and IAQ-levels are compromised.

For this reason it is proposed to assess the ventilation performance of residential ventilation units using the VPA-Method that was developed together with EVIA and adjust the EU 1254/2014 Regulation accordingly (see also section 1.5.1).

It is expected that with the addition and promotion of the Ventilation Performance Indicator, the uptake of Ventilation Systems that actually improve the IAQ in residential buildings and help abating the negative implications with regard to productivity and health, will be stimulated.

3. End Of Life behaviour

3.1 Introduction

This sub-task on End-of-Life behaviour requires Identification of actual user requirements (avg. EU) regarding end-of-life aspects.

In December 2015 the Commission issued a standardisation request to the European Standardization organisations regarding Ecodesign requirements on material aspects for energy-related products. The standardisation work is performed in CEN-CLC/J WG 10 under M/543[29].

The Technical Boards of CEN and CENELEC established a joint technical body to prepare standards that cover both electro technical and non-electro technical matters.

CEN- CENELEC Technical Committee 10, known as 'Energy-related products – Material Efficiency Aspects for Ecodesign', has created 6 Working Groups that are responsible for the development of the standardisation deliverables:

- WG 1 'Terminology'
- WG 2 'Durability'
- WG 3 'Ability to repair, reuse and upgrade energy-related products'
- WG 4 'Ability to remanufacture and method for determining the proportion of reused components in products'
- WG 5 'Ability to recycle and recover energy-related products, recycled material content of energy-related products'
- WG 6 'Documentation and/or marking regarding information relating to material efficiency of the product'

Publication of the Standards is expected in the course of 2020.

<u>EoL according to MEEUrP</u>

Although the present Ecodesign Directive of 2009 does not mention the concept of circular economy, it is abundantly clear that life-cycle thinking forms the absolute core of the Directive and the regulations that stem from it. For that purpose the Directive even contains definitions for 'life-cycle', 'reuse', 'recycling', 'recovery' and 'waste', which form the basis for circular economy thinking (or resource efficiency). This idea is visible in Article 4(a) of 2009/125/EC which requires that measures are preceded by an analysis that considers the whole life cycle of the product, and that the measures relate to relevant environmental parameters of products such as 'energy consumption', but also 'use of materials from recycling activities', 'ease for reuse and recycling', 'incorporation of used components', 'avoidance of technical solutions detrimental to reuse and recycling', and 'extension of lifetime' (see 2009/125/EC, Annex I, item 1.3).

The effects of (possible) measures on these parameters can already be assessed using the present MEErP Ecoreport tool for environmental analysis.

There are already several examples of measures that have addressed these parameters, such as the limitation of mercury in lighting products, the minimum lifetime of vacuum cleaner motor and suction hose, and, more recently, the availability of spare parts, repair

[29] https://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=564

and maintenance information and requirements for dismantling for material recovery and recycling in regulations for washing machines and dishwashers.

The above requirements can, in the near future, become even more specific now that multiple (horizontal) standards covering circular economy aspects (developed under Mandate 543) have been finalised or are nearing finalisation. Based on these standards other product- or product group specific standards can be developed by product technical committees, that would allow more specific requirements.

Case Study CE and Ecodesign

In the period 2015-2018 a case study was performed by DG JRC and DG Grow[30], applying a more general concept of Circular Economy (CE) aspects into a real-world Ecodesign implementation policy process: the development of Ecodesign Requirements for enterprise-servers. Challenges encountered during the various policy steps were analysed, solutions adopted and methods implemented. Based on these experiences, recommendations were formulated for a more dedicated application of CE-principles into the Ecodesign product policy. The following recommendations are made:

- ensure early (preferably during the preparatory study) interaction between policy makers, material efficiency experts and other relevant stakeholders
- have all the relevant material efficiency data inputs and indicators available during the process
- maintain a continuous and iterative interaction during multiple stakeholder consultations
- involve material efficiency experts (including recyclers, re-use operators, etc.) during the whole process
- develop material efficiency requirements, based on available standardised methods

As a result of this approach, the draft regulation for enterprise-servers contains the following requirements regarding material efficiency:

- Requirements regarding design for disassembly
- Requirements regarding the content of Critical Raw Materials (CRM)
- Requirements regarding the latest available firmware
- Requirements regarding the availability of secure data deletion

3.2 Results previous Preparatory Studies

The Lot 6 preparatory studies from June 2012 focussed on determining the material fractions to recycling, re-use and disposal and the fraction of second hand use and refurbishment.

Starting point of the analysis is the identification of the total Bill-of-Materials in the product and subsequently the End-of-Life flows. At the time, authors have tried to retrieve this data through desk-research and a questionnaire amongst stakeholders, from which it could be concluded with absolute certainty that for the products in the scope, no information on the materials composition or End-of-Life flows was available in the public domain, nor from any manufacturer. Hence, for the purpose of the environmental analysis of Base Cases VHK has

[30] Peiro, L.T., Polverini, D., Ardente, F., Mathieus, F., Advances towards circular economy policies in the EU: The new Ecodesign regulation of enterprise servers, Resources, Conservation & Recycling, July 2019.

made an estimate based on their own engineering knowledge. These BoMs and EoL flows were first presented in the second stakeholder meeting of the project, including industry and environmental NGOs, and till the present day no protests or alternative proposals came forward. From this it was concluded that this information is acceptable.

3.2.1 Bill-of-Materials

In summary, for AHUs the information shows a 96-97% mass fraction for metals (80% steel), of which 95% will be recycled. The electronics (ca. 1-2 kg Printed Circuit Boards) are easy to disassembly and will go a special shredder route for recovery of special and precious metals. The remainder consists of plastics and rubbers, of which a small part (10%) will be recycled and the rest will be used for heat recovery. Eventually, 6.5% of the product mass will end up as waste (5% landfill, 1.5% incineration).

For CHRV and CEXH the fraction of plastics in the product, especially the casing, is on average higher than for AHUs, i.e. 50% plastics in CEXH and 20% plastics in CHRV at the expense of the metals fraction. Metals will still be 95% recycled, whereby galvanised ('zinc-coated') steel does not pose any particular problems[31]. For plastics –after 20 years exposure to contamination—it is expected that on average most will end up in waste incineration with heat recovery. The Printed circuit boards are in general easy to dismantle also for CEXH and CHRV; here a special shredder route for recovery of special and precious metals will be followed.

The graph below gives an overview of the material split (in mass) for the 5 Base Cases.

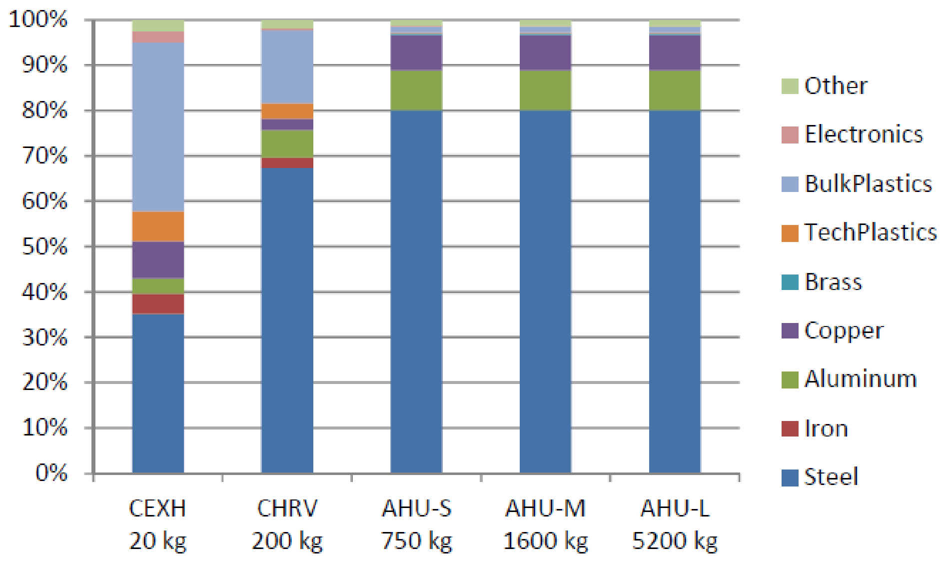


Figure 23. Materials composition of Base Cases

3.2.2 End-of-Life fractions to recycling, re-use and disposal

From the declarations of the stakeholders we learn that up until today practically all products end up in general disposal circuits.

[31] See http://www.zinc.org/basics/zinc_recycling

3.2.3 Second-hand use

Ventilation units are part of the building installation and change owner when the building changes owner. There is no second-hand market for ventilation units from demolished buildings or for ventilation units that have reached their end-of-life.

3.3 Identification of new Circular Economy requirements

Inventory to be made together with stakeholders.

Following the feedback from stakeholder, Task 6 will contain a more elaborated section regarding circular economy aspects (spare parts, repairability, firmware updates, etc.).

4. Local Infrastructure

4.1 Introduction

Apart from the typical local infrastructural elements in dwellings that are needed to build ventilation systems (which were already discussed in the previous preparatory study on Ventilation (Lot 6; Air-conditioning and ventilation systems, Contract No. ENTR/2009/035 /LOT6 /S12.549494), there are some new subjects related to local infrastructure that need further consideration, amongst which:

- Historic and listed buildings and their infra-structural limitations
- Shared ventilation systems
- Installer know-how and practice
- Telecom and remoter control

4.2 Historic and listed buildings

In some specific cases of refurbishment, especially for historically listed buildings, the Ecodesign requirements for new ventilation units are in various cases not applicable because of the actual building architecture. Often, the new ventilation units replacing the old/existing ventilation units, cannot be installed due to limited space in the installation rooms. The existing installation rooms in historical buildings are in most cases too small for ventilation units that have the same operation point and fulfil all Ecodesign regulation.

In general, historical buildings and listed buildings may have special laws and exemptions in national or local building codes. Stakeholders suggest that on the basis of these national codes, and an investigation of the feasibility of the refurbishment by local authorities, ventilation units can be excluded from meeting minimum requirements if needed, given the architecture of the building, while still respecting the higher standard of energy efficiency.

The European Commission Regulation (EU) No 548/2014 of 21 May 2014 for power transformers already allows exemptions for such cases. Therefore Stakeholders propose to adapt the Regulation 1253 along the following lines (text based on wording included in the Transformers regulation No 548/2014). Stakeholders propose the following text,

This Regulation shall not apply to:

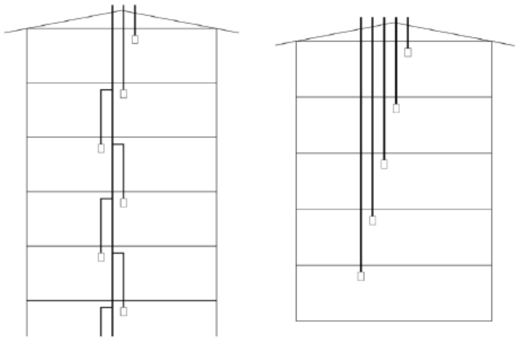
1. ventilation units for historic and listed buildings where the installation cannot be achieved in the available space, without changing the historic character of the building and entailing disproportionate costs associated to their transportation and/or installation,

except as regards the product information requirements and technical documentation set out in Annex V."

4.3 Collective ventilation systems

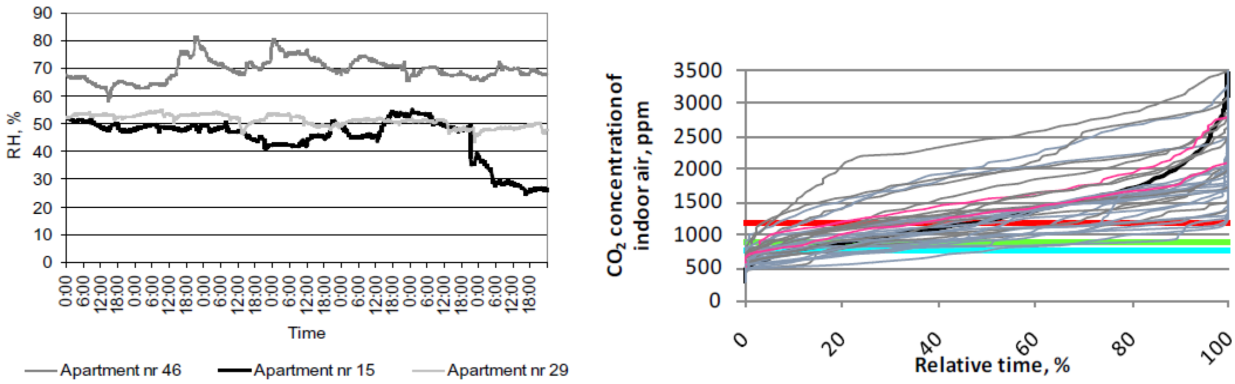
Multi-family apartment buildings represent around half of the total number of permanently occupied residential dwellings in the EU28 (see Task 2, section 2.4). Historically, such buildings have natural ventilation provisions, comparable to old single family dwellings, using central passive stack ventilation (PSV) ducts or chimneys per apartment, all of them reaching to the roof of the building.

Figure 24. Natural ventilation (PSV-ducts) for typical old apartment buildings



In the study 'Ventilation Solutions in Renovated Apartment Buildings in Cold Climates[32] ', it was found that partial renovation of these buildings (e.g. insulating the building shell and windows, without renovating the ventilation system), will lead to serious IAQ-problems (see figure 25). Both humidity and CO2- concentration levels may exceed limit values for longer periods.

Figure 25. RH (left) and CO_2-concentrations (right) in bedrooms of partly renovated apartment building in wintertime.



Renovation projects needs to include the ventilation systems as well in order to secure the indoor air quality. Different ventilation system types may be applied in renovated (and new built) multi-family apartment buildings, all with different impacts on the ductwork and infrastructure of the building. The study[32] mentioned above, analysed some basic ventilation options for low-rise apartment buildings and summarizes the main pros and cons, amongst which:

1. Collective mechanical exhaust
2. Collective mechanical exhaust with heat pump
3. Collective central balanced ventilation with HRS

[32] Koiv T.A., Mikola A., Simson R., Ventilation Solutions in Renovated Apartment Buildings in Cold Climate Conditions, Engineering 2015, 7, 129-139, March 2015.

4. Central BVU with HRS
5. Non-ducted room BVU with HRS combined with local extract UVUs in wet rooms
6. Non-ducted alternating BVU (in pairs) combined with PSV in wet rooms

The findings of the study are summarised in the table below:

Table 38. Pros and Cons of different ventilation systems in apartment buildings

Ventilation system	Pros	Cons
1. Collective mech. exhaust	+ Limited construction work + Compared with natural ventilation, relative stable air exchanges over the dwelling	– High energy consumption – Possible cold draughts – External noise and pollutants are transferred indoors
2. Collective mech. exhaust with HP	+ Limited construction work + Compared with natural ventilation, relative stable air exchanges over the dwelling + 47% of the heat consump. was provided by the HP	– Requires very good design – Requires higher vent.rates – Possible cold draughts – External noise and pollutants are transferred indoors – Additional costs for filters
3. Collective central BVU with HRS	+ Ensures good IAQ	– Ventilation ducts in building and individual apartments – AHU in the staircase – Requires very good design and installation – Expensive – Additional costs for filters – Risk of noise
4. Central BVU per apartment with HRS	+ Ensures good IAQ	– Ventilation ducts in dwelling – Rel. expensive for small apartments – Additional costs for filters – Risk of noise
5. Non-ducted room BVUs with HRS & local extract UVUs in wet rooms	+ Limited construction work + Ensures good IAQ + Demand controlled ventilation further reduces energy consumption	– Frost protection switches of BVU below -18°C – Risk of noise
6. Non-ducted alternating BVU & PSV in wet rooms	+ Limited construction work	– High risk of noise – External noise and pollutants are transferred indoor – Sensitive to ΔP over façade, thus reduced heat recovery and variable airflows – Possible cold draughts

In apartment buildings that already use collective central extract ventilation, the combination with a central heat pump that recovers the energy from the extract air for DHW- or and/or space heating purposed, could be an economic solution because it requires limited modifications to the infrastructure.
Individual apartments can best be renovated using a BVU per apartment or using non-ducted room based BVUs that can overcome higher pressure difference over the façade; this will become more important in apartments at higher floors.
The best solution for renovation should always be based on an assessment of the combined technologies used for DHW, space heating and ventilation. If for instance electric DHW is used, the mechanical extract ventilation of an individual apartment can perfectly be combined with a heat pump storage water heater (HPWH).

4.4 Installer know-how and practice

Inspection and maintenance of ventilation systems is extremely important to secure the ventilation performance and quality of the supply air.

In the residential sector and with regards to stand-alone ventilation systems (single family dwellings), limited to no attention is given to inspection and maintenance of ventilations systems. In many cases, even the necessary checks and adjustments of the ventilation flowrates, are not performed before the system is handed over.

Article 19a of the EPBD Directive 2018/844, includes the requirement for the Commission to perform, before 2020, a feasibility study assess the relevance and feasibility to introduce EU provisions for the inspection of stand-alone ventilation systems in buildings, e.g., the development or improvement of technical standards, guidelines and practices, or the possible extension of the mandatory regular inspection requirements to stand-alone ventilation systems.

The objectives are to deliver:
1) An analysis of the stock of ventilation systems in EU buildings, including their technical characteristics, the distribution systems and foreseen evolution of the stock;
2) A review of existing regulations, schemes, guidelines and standards on the inspection of ventilation systems, and other relevant initiatives and projects, in the EU, and, where relevant, in other regions;
3) An investigation of the relevance and feasibility of further promotion of inspections of building stand-alone ventilation systems at the EU level and an exploration of the possible approaches to this end, including non-legislative and legislative measures, and including in relation to Articles 14-15 EPBD.

The study is ongoing and is being carried out by INIVE and BPIE. In the report covering objective 2) it was found that most of the identified national and European guidelines and standards do not only cover inspection. They often cover all ventilation related subjects, including installation, commissioning or maintenance guidelines or requirements, including an inspection part, covering different levels of inspection, from checklists based on visual checks to measurement protocols.
Measurements, if any, are mainly focused on airflow rates, but also to a less extent on measurements of fan electrical consumption and ductwork airtightness. Measuring indoor air quality parameters and noise is rare.
The report also identifies interesting results from European, international and national projects that help to identify what could be the contents of an inspection scheme. Other initiatives than inspection, aiming at improving the quality of the stand-alone ventilation systems and thus reducing the needs for inspection, have been identified. They include:
- performance product certification with database,
- clear design, installation and commissioning procedures,
- training/qualification/certification of the competence of professionals,
- increase of occupants awareness
- use of smart ventilation systems.

In the non-residential sector and collective air conditioning systems (including ventilation) more attention it given to service, maintenance and inspection, mainly because it is more common to have service contracts for these kind of installations and because it is mandatory according to the EPBD-regulation.

In the light of the findings regarding ventilation performance in residential dwellings (see section 1.2 and 1.5) it is recommended to include the inspection and possible upgrade of ventilation controls in any checklist for (mandatory) inspection.

4.5 Telecom, remote control and Internet of Things (IoT)

A fast growing technology with a huge potential for monitoring and improving ventilation performance, relates to application of electronic controls and sensors that communicate with the internet and stores relevant data on servers, that – with user group specific data analyses – can be used to improve ventilation- and energy performance, inspection and maintenance. Building automation and electronic monitoring of technical building systems already have proven to be an effective replacement for inspections, and hold great potential to provide cost-effective and significant energy savings for both consumers and businesses. Compared to other measures, the installation of such equipment can be considered to be cost-effective.

Obstacles to overcome might be the fact that the (small) installer of stand-alone-ventilation systems might be reluctant to adopt these new technologies and its associated '*empowered consumers*' that claim immediate attention from the installer.
Installers that are working in the non-residential and commercial sector may have less problems with this IoT-approach and may even already be active in this field.

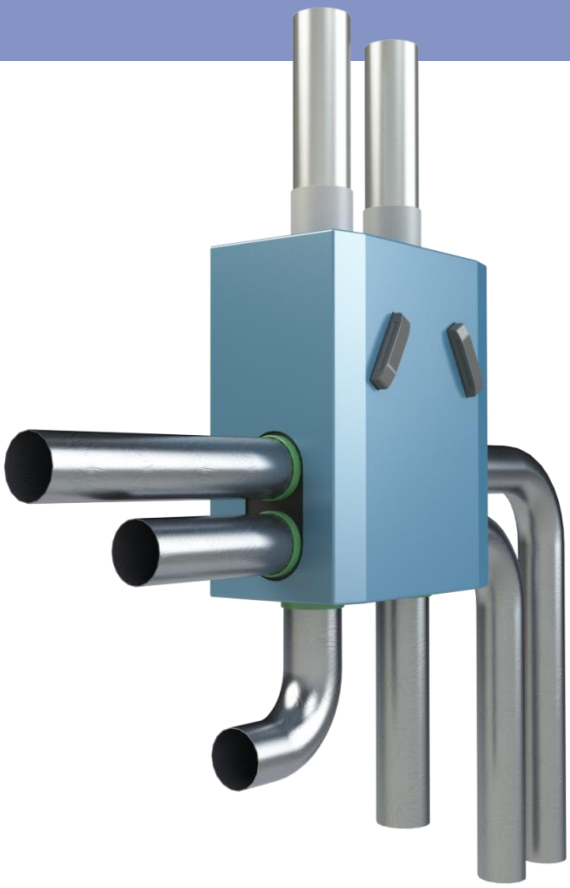
For consumers it is a very good way to get acquainted with the actual ventilation performance and IAQ-levels in his dwelling and take appropriate action.

ANNEX I : STAKEHOLDER COMMENTS TO EXISTING REGULATION

(See Interim Report Phase 1.1 Technical Analysis, May 2019)

Ventilation Units

Ecodesign and Energy Labelling



Preparatory Review Study

Phase 1.1 and phase 1.2

Final Report

TASK 4. Technologies

Review study on Regulations EU 1253/2014 (Ecodesign requirements for ventilation units) and EU 1254/2014 (energy labelling of residential ventilation units)

Prepared by
VHK, Delft (NL), for the
European Commission, DG GROW

March 2020

Grow

Prepared by

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Contract manager: VITO

Project website: www.ecoventilation-review.eu

Specific contract: No 681/PP/GRO/IMA/18/1131/10204-SI2.798223
Contract starting date: February 5th 2019

Cover: Ventilation unit [picture VHK 2019].

This study was ordered and paid for by the European Commission, Directorate-General Grow.

Executive summary Technologies

This is the final Task 4 report of the preparatory review study on the Ecodesign Commission Regulation (EU) No. 1253/2014 and Energy Label Commission Delegated Regulation (EU) No. 1254/2014 for Ventilation Units.

This Task 4 report deals with the new technological developments that are considered relevant for the review of the current Ventilation Unit Regulations.
Technologies that were already discussed in the previous LOT 10 (2009) and LOT6 (2012) studies (i.e. fan types, fan efficiency, motor controls (VSD) and motor types) are not repeated here.

Since smart ventilation control is considered one of the key technologies with which the energy consumption for ventilation can be further reduced, while simultaneously improving the ventilation performance, Chapter 1 covers the Best Available Technology (BAT) for occupancy- and IAQ-sensors and for monitoring devices. Not all sensors are equally suited for all room types however, which requires that their suitability for the different room types is further discussed.
Local demand-controlled ventilation cannot be achieved by only using the right sensors in the right locations. It also requires the technical ability of the ventilation system to vary the airflow rates per individual room. Chapter 2 therefore highlights the technical developments for ducted systems in this area and describes the best available technology regarding flowrate control per individual room. In view of a possible inclusion of ventilation units with an electric power consumption below 30 watts and their intrinsic characteristic of enabling local flowrate control, non-ducted local UVUs and BVUs with power consumption below 30 watts per airstream and their best available technologies are discussed in the last paragraph of this chapter 2.
Chapter 3 covers the non-ducted alternating BVUs, which is a relatively new product group in the ventilation sector gaining increased attention from several member states. Several scientific studies have recently been performed which facilitates a proper evaluating of this product. The chapter describes the best available technology and discusses the research that has been done.
Because it is proposed to include humidity recovery (through enthalpy heat exchangers) in the revised Regulations (see also Task 3 report section 1.7), the product types and their humidity recovery technologies are further discussed in Chapter 4. Apart from rotary wheels, enthalpy plate heat exchangers and regenerative heat exchangers with alternating airflows are further discussed. The fact that some of the materials used for regenerative heat exchangers are also used in the field of air cleaning (abatement of gaseous pollutants) raises the question regarding the risk of a possible transfer of gaseous pollutants.
In Chapter 5 the topics on filter technology are further addressed. Depending on the required indoor air quality and the available outdoor air quality, filtration may be needed. The additional pressure drop and related energy consumption can be further reduced by developments in filter technology. The chapter also addresses the topic of indoor air cleaning and recirculation, which can potentially reduce the amount of air that needs to be replaced by outdoor air, thus reducing the heating/cooling energy that is lost due to this air exchange.

Introduction

This draft Task 4 report covers the current status of the work that has been done for Phase 1.1 and phase 1.2 of the Review Study, comprising the Technical Analysis and the update of the Preparatory studies. According to the Terms of Reference (T.o.R.) Phase 1.1 shall assess the items listed in Article 8 of Regulation 1253/2014 (Ecodesign of Ventilation Units) and Article 7 of Regulation 1254/2014 (Energy Labelling of Residential Ventilation Units), being:

a) the need to set requirements on air leakage rates in the light of technological progress
b) the possible extension of the scope of Regulation 1253/2014 to cover unidirectional units with an electric power input of less than 30 W, and bidirectional units, with a total electric power input for the fans of less than 30 W per air stream
c) the verification tolerances set out in Annex VI to Regulation 1253/2014
d) the appropriateness of taking into account the effects of low-energy consuming filters on the energy efficiency
e) the need to set a further tier with tightened Ecodesign requirements
f) the possible inclusion of other ventilation units, notably of non-residential units and of units with a total electric power input smaller than 30 W under Regulation 1254/2014,
g) the specific energy consumption calculation and classes for demand controlled unidirectional and bidirectional ventilation unit (in this respect, it would be very relevant to provide, if possible, an estimate of the efficiency and energy labelling levels of the installed base of residential and non-residential ventilation units in the European Union (EU).

According to the Terms of Reference the following additional items need to be analysed:
h) the influence of the ambient conditions and the climatic zones in the EU on the quantitative requirements for heat recovery;
i) the need of specific provisions (and related formulation) on historic or listed buildings where the lack of space available can make it challenging to fit in ventilation units compliant with the two Regulations;
j) the need for (further) clarification on the nature of 'box fans' and 'roof fans', in particular concerning their compliance with the two Regulations, and the fans Ecodesign regulation 327/2011;
k) the need/feasibility to impose quantitative requirements on the maximum internal leakage for bidirectional ventilation units, as well as the need/feasibility of correction factors for the declared thermal efficiency of a residential ventilation units, based on the internal leakage rate;
l) Introduction, in the text of the two Regulations (e.g. in the definitions of unidirectional and bidirectional ventilation units), of the clarifications contained in the 'Question on a combination of a supply UVU and an exhaust UVU being considered as a BVU (11-2016)2';
m) improvement/increased description of the definition of 'nominal flow rate' of non-residential ventilation units;
n) improvements/changes in the definition of 'ventilation unit', with particular regard of the inclusion/exclusion of ventilation units for industrial applications (on the basis of FAQ 10 of the 'Guidelines accompanying Regulation (EU) No 1254/2014

with regard to the energy labelling of residential ventilation units and Regulation (EU) No 1253/2014 with regard to Ecodesign requirements for ventilation units'.

o) the application and potential improvement of the requirement on the provision of instructions for the effective material recycling of the ventilation units (as in Annex IV - point 3 - of the Regulation 1253/2014);
p) other clarification requests from stakeholder in the context of the stakeholder consultation process.

And finally, if needed, the existing 'Guidelines accompanying Regulation (EU) No. 1254/2014 with regard to the energy labelling of residential ventilation units and Regulation (EU) No 1253/2014 with regard to Ecodesign requirements for ventilation units' will be updated.

In the subsequent phase 1.2 the Preparatory Studies are updated, where according to the T.o.R. at least the following additional items need to be addressed:

1) the identification of potential new functional parameters at product level, in particular concerning the indoor air quality when relevant and feasible;
2) resource efficiency aspects3 - most likely disassembly, recyclability, reparability, durability and content of Critical Raw Materials (CRM), following the adoption of the Circular Economy Package in December 2015 and the new Ecodesign Working Plan 2016-2019. This includes the analysis of requirement already set (on the instruction for material recycling), their effectiveness in promoting the resource efficiency of ventilation unit, and the identification of additional and/or more ambitious requirements, when relevant (e.g. on the content of CRM in magnets);
3) the potential inclusion in the analysis of smart controls and demand control options (such as, but not limited to, solutions for building/home energy management system based on the European standards SAREF/SAREF4ENER).

The study is performed as a supplement to already existing preparatory studies for Lot 6 and Lot 10, indicating that topics that have already been addresses will not be addressed again, unless there are new elements to be reported.

This sub-report on Task 4, specifically deals with updates on topics regarding Technologies.

Acronyms and units

Acronyms

AC/DC	Alternating/Direct Current
ADCO	Administrative Co-operation
AHRI	American Air Conditioning, Heating and Refrigeration Institute
AMCA	Air Movement and Control Association
ATEX	ATmosphères EXplosibles
BC	Backward Curved
BVU	Bidirectional Ventilation Unit
CECED	European Committee of Domestic Equipment Manufacturers
CEN	European Committee for Standardization
CFD	Computer Fluid Dynamics
CIRCA	Communication and Information Resource Centre
CLP	Classification, Labelling and Packaging (Regulation)
DigitalEurope	Association representing the digital technology industry in Europe
DoC	Document of Conformity
DoE	US Department of Energy
EC	Electronically Commutating
EN	European Norm
EPEE	European Partnership for Energy and the Environment
Eurovent	Association of European refrigeration, air conditioning, air handling, heating and ventilation industry
EVIA	European Ventilation Industry Association
FC	Forward Curved
GWh	Giga Watt hour 109 Wh
HNL	Howden Netherlands
HRS	Heat Recovery System
ICSMS	Information and Communication System on Market Surveillance
ISO	International Standardisation Organisation
JBCE	Japan Business Council in Europe
JRAIA	Japan Refrigeration and Air Conditioning Industry Association
N	Efficiency grade
NRVU	Non-Residential Ventilation Unit
RAC	Run Around Coil
RAPEX	EU Rapid Alert System
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (Regulation)
RoHS	Restriction of Hazardous Substances (directive)
RVU	Residential Ventilation Unit
rpm	rounds per minute (unit for fan rotation speed)
TC	Technical Committee (in ISO, CEN, etc.)
TWh	Tera Watt hour 1012 Wh
UVU	Unidirectional Ventilation Unit
VU	Ventilation Unit
WEEE	Waste of electrical and electronic equipment (directive)
WG	Working Group (of a TC)
yr	year

Parameters

A	floor surface area building [m^2]
cair	specific heat air [Wh/ m^3.K]
Q	heat/energy [kWh]
q	hourly air exchange [$m^3.h^{-1}$/ m^3]
rec	ventilation recovery rate [-]
S	shell surface area building [m^2]
SV	shell surface/volume ratio building
t	heating season hours [h]
T_{in}	Indoor temperature [°C]
T_{out}	outdoor temperature [°C]
U	insulation value in [W/K. m^2]
V	heated building volume [m^3]
ΔT	Indoor-outdoor temperature difference [°C]
η	efficiency [-]

Units

€	Euro
°C	degree Celsius
a	annum (year)
bn	billion (1000 million)
CO_2	carbon-dioxide (equivalent)
h	hours
K	degree Kelvin
kWh	kilo Watt hour
m	metre or million
m^2	square metre
m^3	cubic metre
Pa	Pascal
W	Watt

Table of Contents

1. Monitoring and Local Detection Ventilation Demand

1.1. Introduction

Local *sensors* and *monitoring* systems are making a cautious start with filling the void in the human sensory system to assess the ventilation performance. Where the occupants do not have the ability to correctly assess the ventilation performance and related IAQ-levels, local sensors and monitoring systems can. *Local ventilation control* refers to the ability of ventilation systems to adjust the ventilation rates in each individual room or space separately (opposite to central ventilation rate control).
This combined approach of local sensors, local ventilation control and monitoring, can ultimately have a huge impact on both the energy- and ventilation performance and as such may elegantly solve the conflicting requirements concerning energy consumption (aiming at lowering the ventilation rates) and indoor air quality (preferring higher ventilation rates). Local sensors that detect presence and number of people in a confined space, as well as local sensors that detect actual pollutants concentrations can be used to determine the required ventilation rates in order to minimise exposure. During absence and low pollutant concentration levels, the minimum required ventilations rates can be applied in order to minimise energy consumption for ventilation.

This chapter 1 will further discuss the technical developments as regards to the sensors for detected local ventilation demand and the monitoring systems. The following three chapters (chapter 2, 3 and 4) address the technical options that have been developed over the last decade for controlling the airflow rates per individual room or space with ducted- and non-ducted ventilation units.

To further indicate the type of controls that are meant in this context, the table below summarises the control types and their classification according to the EN 16798-3. IDA-C5 and IDA-C6 are the control classes that are referred to in this context of local demand control.

Table 1. Possible types of control of the airflow rate (Table 12 in EN 16798-3)

Category	Description
IDA – C 1	The system runs constantly.
IDA – C 2	Manual control The system runs according to a manually controlled switch.
IDA – C 3	Time control The system runs staged according to a given time schedule.
IDA – C4	Presence control The system runs dependent on the presence (light switch, infrared sensors etc.)
IDA – C5	Demand control (based on the number of occupants) The system runs staged dependent on the number of people in the space.
IDA – C 6	Demand control (based on air quality indicator) The system is controlled by sensors measuring indoor air parameters or adapted criteria, which shall be specified (e.g. CO_2, mixed gas, humidity or VOC sensors). The used parameters shall be adapted to the kind of activity in the space.

Complementary to the descriptions presented in table 1 for IDA-C5 and IDA-C6, a more detailed assessment is needed to determine when what type of IAQ /Demand Control –

sensors are preferred for what situations. Surely, not all sensors are equally suitable for all room types. Without such an assessment, the efficacy of the various sensor types cannot be determined. Typical room types that can be discriminated with regards to ventilation systems intended to"
'replace air that is utilised/polluted due to presence of human beings and their use of the building including emissions from building materials, decorative and interior product equipment' are the following:

1.
<u>Habitable and otherwise occupied spaces</u>
Spaces that are typically occupied for longer periods and need ventilation (air exchanges) '*due to presence of human beings and their use of the building including emissions from building materials, decorative and interior product equipment'.* They typically produce category ETA1 (ETA2) extract air (see also EN 16798-3 and -4).
Examples (for residential and non-residential sector):

- Bedrooms
- Living rooms
- Living kitchens (opposite to separate kitchen)
- Study rooms
- Recreation rooms
- Dining rooms
- Offices
- Meeting rooms
- Classrooms
- Other workspaces used for activities not producing other emissions than the ones stated in the definition above.

Pollutant load for these spaces are strongly related to the number of occupants; in case there are no occupants, the required basic ventilation levels are applicable in order to dilute the emissions coming from building materials, decorative and interior product equipment.

2.
<u>Exhaust spaces</u>
Spaces that are occupied for short periods and in which emissions (humidity, odours, cooking fumes, etc.) are actively produced, and therefore preferably apply the air exchanges by means of direct exhaust of the polluted air. They typically produce category EHA3 (EHA4) exhaust air (see also EN 16798-3 and -4).
Examples (for residential and non-residential sector):

- Bathrooms
- Kitchens
- Toilets and washrooms
- Laundry rooms
- Utilities
- Other

Pollutant loads for these exhaust spaces are not only related to people entering the room (and causing the emissions), but mainly to the amount of the pollutants that are produced. Related pollutant concentrations can remain too high for a certain period of time, even after the occupant has left the specific room or space.
In case of no occupants, the required basic ventilation levels are applicable in order to dilute the emissions coming from building materials, decorative and interior product equipment.

1.2. Occupancy sensors

Occupancy sensors are defined here as sensing devices that are capable of counting the number of occupants in a room. In that sense, they are different from *presence sensors*, which are only capable of determining whether or not the room is occupied, regardless the number of occupants.
The combined use of occupancy sensors and local ventilation controls will lead to more accurately measured ventilation rates. This optimises both the IAQ- and the energy performance of the ventilation system.

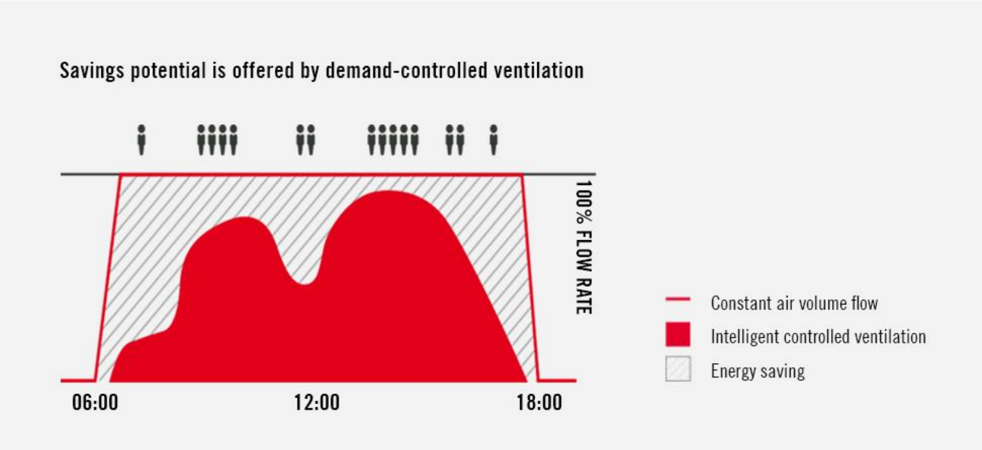


Figure 1. Saving potential occupancy-controlled ventilation

Various technologies can be used to determine the number of people in a room.

1.2.2. Infrared counters

Density (https://www.density.io/)

Density is an IR Depth Sensor, that counts people as they walk beneath the unit, in and out of a space. The Density DPU and Bracket need to be centred and installed directly above the entryway to ensure people are detected.

Figure 2. Density IR Depth Sensor

In the first mass market sensor, they have combined a powerful people counter, a modern Application Programming Interface, a dedication to privacy, and a sensor-as-a-service business model. The hardware is free. Users pay a monthly fee for access to the data. Prices start at USD 45 / sensor / month.

Density uses depth technology, computer vision, and an on-board quad-core processor to anonymously measure and manage entrances and exits through a door. The sensor attaches above a doorway, and tracks movement frame-by-frame with two infrared beams that bounce off from the floor. Algorithms filter out signal noise — boxes, strollers, pushcarts, plates, and other items being carried or pushed — to measure the direction, collision, and speed of people walking into and out of view. The data is funnelled via Wi-Fi to Density's cloud-hosted backend, where it is processed and analysed. A basic web dashboard provides insights like the real-time capacity of a room and historical crowd sizes, and an API allows third-party apps, services, and websites to make use of the data in novel ways.

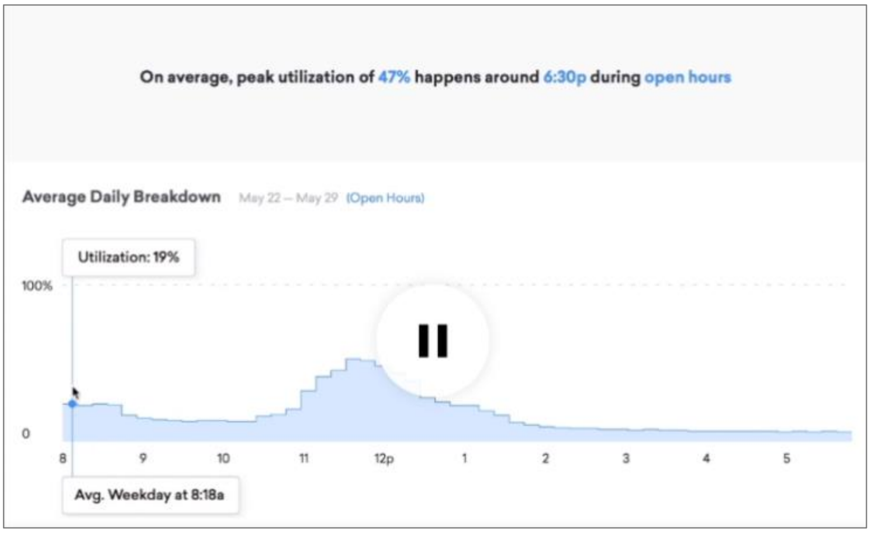


Figure 3. Example of Density dashboard

IEE People Counter

IEE has developed a 3D sensor that uses MLI (Modulated Light Intensity) technology. This technology is based on the optical time of flight (TOF) principle, where an active, non-scanning light source emits modulated near-infrared light. The phase shift between the light emitted by the source and the light reflected by the people and objects in the field of view is measured to create a real-time topographic image of the monitored area. The overhead-located 3D MLI Sensor™ processes 3D data in order to detect and count the number of people in a specific area and track the direction of their movements.

Figure 4. IEE People Counter

Device Properties	PC96M4.0	PC64M4.0
Mounting height	2.5 to 3 m	3.0 to 5.0 m
Detection area	1.5 m x 0.9 m to 2.5 m x 1.5 m	1.5 m x 0.8 m to 3.2 m x 1.6 m
Field of view/illumination	90° x 60°	60° x 40°
Type of illumination	Modulated near infrared light (NIR)	
Weight	0.8 kg (Core Housing) + 0.16 kg (Design Housing)	
Dimensions of the Core Housing	Ø 138 mm x H 60 mm	
Dimensions of the Design Housing	Ø 147 mm (integration cutout diameter), Ø 181 mm (outside rim diameter), 70 mm (height)	
Operational temperature range	–20°C to +50°C	
Core housing ingress protection	IP 30	
Supply voltage	24 V DC ± 15%	
Power consumption	max. 1.0 A at 24 V DC	
Housing material	Polymer	
Technology	3D MLI Sensor™	

Figure 5. Technical properties IEE PC

Test scenarios have demonstrated that IEE's People Counter's sophisticated algorithms ensure reliable segmentation, tracking and counting of people. With high accuracy levels around 99%, IEE's People Counter provides reliable data for demand-controlled ventilation.

Bi-directional IR people counter

Bi-directional wireless infrared-based people counters are so called 'break-beam sensors, having both an emitter and a receiver. The sensors are typically placed on one or two sides of a doorway, depending on the type used. The more intelligent versions can detect bidirectional movement. The data can be transmitted wirelessly to a bridge device.

Figure 6. Examples of break-beam IR sensors

These sensors may be adequate to determine the total number of people that visited a particular room over a certain period (visitors per day), but they have limitations as regards to their ability to determine the instantaneous number of occupants in the room, due to:

- Blindness: Break beam sensors are inaccurate. The sensor becomes blind when two people enter at the same time (side-by-side) or enter and exit at the same time.
- Human movement is complex: Break beam sensors rely on signal processing to sort out when a person has entered. The signal is hard to make sense of when lines form or people bring boxes and bags with them.

PIR: Passive Infra-Red sensor

Passive infrared sensors have widespread use in many applications, including motion detectors for alarms, lighting systems and hand dryers. Combinations of multiple PIR sensors have also been used to count the number of humans passing through doorways.
In a practical research[1] it was demonstrated that a single PIR sensor can be used as a tool for occupancy estimation inside of a monitored environment. Using flexible nonparametric machine learning algorithms useful information about the occupancy could be extracted from a single PIR sensor. This approach makes use of the motion patterns generated by people within the monitored environment. The proposed counting system uses information about those patterns to provide an accurate estimate of room occupancy which can be updated every 30 seconds. The system was successfully tested on data from more than 50 real office meetings consisting of at most 14 room occupants.

While the accuracy of the proposed system does not yet reach the current state of the art obtainable with stereo cameras and computationally demanding image processing algorithms (or multi-sensor devices), the research project shows the ability to count the number of room occupants to within ±1 individual while substantially reducing the hardware costs, computational power and the need for specialist installation. Applications where accuracy is not critical, for instance, optimizing energy usage in buildings, can benefit from this cost-effective and easy to deploy approach.

1.2.3. Cameras / Optical Sensors

Modern video-based people counting uses IP cameras with embedded video analytics for maximum accuracy and reliability. The cameras are typically placed above the area where you want to count the people that enter. Authorized users can then view real-time and historical statistics from any device and location. The system is easy to add to your existing network as it is based on IP cameras.

Example: AXIS People Counter (https://www.axis.com/products/axis-people-counter)

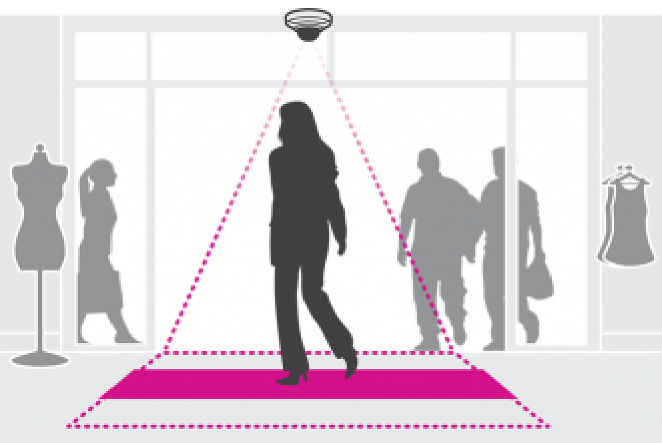


Figure 7. Illustration from AXIS

The AXIS People Counter automatically counts in real time the number of people passing under a camera and in which direction. AXIS People Counter is an automated system that enables simultaneous two-way counting of people moving in and out of a passageway. It disregards baby carriages and shopping carts. The software is built on advanced and proven

[1] Raykov, Y.P, Ozer, E., Dasika, G., Boukouvales, A., Little, M.A., Predicting room occupancy with a single beam passive infrared (PIR) sensor through behaviour extraction, UBICOMP '16, September 12-16, Heidelberg, Germany.

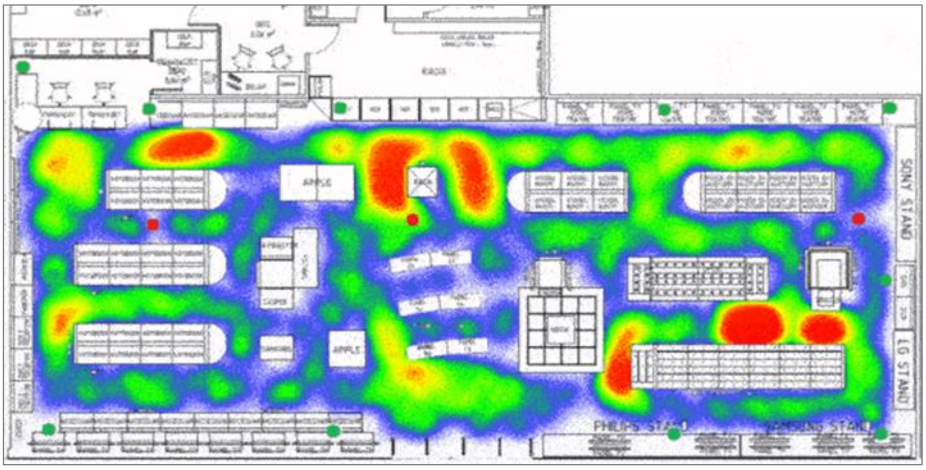
algorithms from Cognimatics, whose programs have led in retail analytics for more than a decade. Offering high-speed execution and low memory requirements, the software has been installed in thousands of cameras worldwide.

Camera-based occupancy detection unfortunately has various limitations, of which privacy is is the most important. Security and privacy of innocent people are seriously compromised during camera-based occupancy. Unauthorized persons or intruders can access people flow information. In order to secure occupancy information from attackers, image data should be in an encrypted format.

1.2.4. WLAN/Wi-Fi and Bluetooth tracking

WLAN/Wi-Fi tracking works as follows:

- Mobile phones are always looking for known Wi-Fi networks. It does this out of convenience so you can automatically connect to a known network without manually selecting it.
- The way your phone finds a Wi-Fi network is by sending out what is called a "probe request" (Bluetooth does similar).
- All Wi-Fi routers can track your phone. All you need is to have your Wi-Fi turned on.
- Multiple routers are listening and triangulating. They compare the relative strength of that signal to one another and can approximate where you are in the building.
- The routers roll up this data and send it to an analytics platform that may looks like the picture below:



Average costs for such a system varies widely by platform. Depending on the analytics, it can vary from ten 10 euros a month to thousands of euros per month. Existing enterprise Wi-Fi system need to be upgraded and extended with additional software.
Depending on the environment the technology is deployed, this can be considered an invasive technology. It is not "opt-in" meaning, the users the system tracks haven't given their permission. Main drawback of Wi-Fi tracking, though, is inaccuracy. The system usually isn't granular enough to determine the use of a specific room. So you end up with heat maps and approximation like graphic above.

1.3. IAQ-sensors

IAQ sensors are defined here as sensing devices that can measure certain pollutant concentrations in the air. Four types of IAQ-sensors are predominantly used in the ventilation sector:

1. CO2 sensors
2. RH-sensors
3. TVOC sensors
4. PM-sensors

1.3.1. CO_2 sensors

Carbon dioxide (CO_2) is not only a by-product of combustion, it is also a result of the metabolic process in living organisms. Because carbon dioxide is a result of human metabolism, concentrations within a building often are used to indicate whether adequate fresh air is being supplied to the space. Moderate to high levels of carbon dioxide can cause headaches and fatigue, and very high concentrations can produce nausea, dizziness, and vomiting. Loss of consciousness can occur at extremely high concentrations. To prevent or reduce high concentrations of carbon dioxide in a building or room, fresh air should be supplied to the area. CO_2 cannot be detected with your senses alone. Carbon dioxide does not have a colour or smell. The only way you can know the level of carbon dioxide in your home for sure is through a carbon dioxide monitor.

Carbon dioxide levels and potential health problems are indicated below:

- 250-350 ppm: background (normal) outdoor air level
- 350-1000 ppm: typical level found in occupied spaces with good air exchange
- 1000-2000 ppm: level associated with complaints of drowsiness and poor air
- 2000-5000 ppm: level associated with headaches, sleepiness, and stagnant, stale, stuffy air; poor concentration, loss of attention, increased heart rate and slight nausea may also be present.
- > 5,000 ppm: This indicates unusual air conditions where high levels of other gases also could be present. Toxicity or oxygen deprivation could occur. This is the permissible exposure limit for daily workplace exposures.

The main types of CO_2 sensors on the market fall into three categories:

I) Non-dispersive infrared sensors
II) Electrochemical sensors
III) Metal oxide semiconductor sensors

<u>Non-Dispersive Infrared (NDIR) CO_2 Sensors</u>

A NDIR CO_2 sensor works as follows: Air will enter the sensor; the sensor then activates a light set at one of the specific wavelengths for CO_2, usually around four microns, at one end of the sensor. The other side will hold a receptacle that will measure how much light makes it to the other side. Once the light is activated, any CO_2 in the air sample will absorb some of the beams. In doing so, the amount of light that makes it to the other side of the sensor decreases. The amount of light that gets absorbed depends on how much carbon dioxide is present. The more CO_2 is present, the more light will be absorbed.
Main advantages of this sensor type are 1) they are very long-lasting (> 10 years), 2) other substances will not interfere with readings, and 3) they work well at common CO_2 ranges (around 1000ppm). Main drawback is the fact that they can be affected by humidity and temperature.

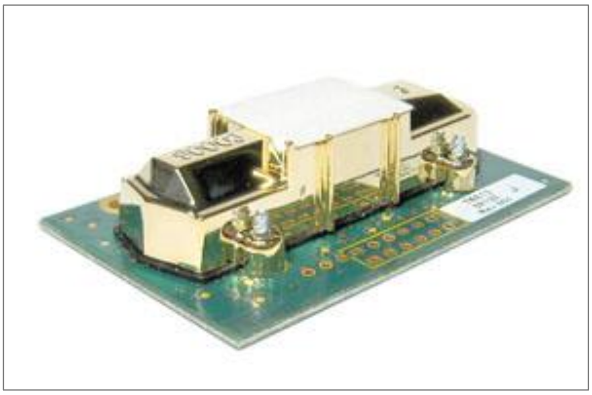



Figure 8. NDIR CO2 sensors from2 different manufacturers

OEM prices are estimated at between 10 – 70 euro, depending on batch size. For this study, an OEM-price (VAT excluded) of 20 euro will be used for lifecycle cost calculations.

Technical Specifications Telaire T6713 EP

Method	: Non-Dispersive Infrared (NDIR), gold plated optics, diffusion sampling (with Telaire's Patented ABC Logic Self Calibrated Algorithm)
Meas. Range	: Output bounded 400 to 5000 ppm
Dimensions	: 1.18 in X 0.787 in X 0.34 in (30 mm X 15.6 mm X 8.6 mm)
Accuracy	: Accuracy @ 25°C: ±6% of the reading Accuracy @ -10°C to +40°C: ±10% of the reading
Start Up Accur.	: +/- 150ppm - ABC logic first corrects after 24 hrs
Temp. Dep.	: 5 ppm per °C or 0.5% of the reading per °C, whichever is greater
Stability	: < 2% of FS over life of sensor (15 years typical)
Press. Dep.	: 0.13% of reading per mm Hg
Calibr. Interval	: Not required
Response Time	: < 3 minutes for 90% step change typical
Signal Update	: Every 5 seconds
Warm Up Time	: < 2 minutes (operational), 10 minutes (maximum accuracy)
Operat. Cond.	: -10°C to +40°C (14°F to 104°F), 0 to 95% RH, non-condensing
Storage Cond.	: -30°C to 70°C (-22°F to 158°F)

Operating Temperature Range -10°C – 40°C (14°F to 104°F)

<u>Electrochemical CO_2 sensor</u>

Electrochemical carbon dioxide sensors measure electrical current or conductivity to determine how much CO_2 is present in the air.
When CO_2 enters the sensor, it chemically reacts within the sensor. As this reaction occurs, the sensor experiences an electrical change. Depending on the specific type of sensor, the reaction can make the sensor pick up an electrical current, change an existing current, or change how well the sensor would carry a current. The sensor will then use the type and amount of electrical change to determine how much CO_2 is present.
The chemical material itself has the highest sensitivity of CO_2, but the chemical material is also sensitive to other gas like CO, Alcohol and other gas. To get the real level of CO_2 in the air, it needs to work with other gas sensors to calibrate the data. Another disadvantage relates to the fact that the sensor material is consumable. It means that the accuracy of the sensor will go down as time goes on.

In summary: Advantage of this sensor type is the fact that it is less susceptible to humidity and temperature changes than NDIR or MOS sensors. Disadvantages relate to the fact that other substances can throw off readings, that the sensor does not last as long as NDIR sensors and that the sensor can "drift," and lose accuracy.

OEM prices are estimated around 5 - 50 euro, depending on type and batch size. For this study, an OEM-price (VAT excl.) of 15 euro will be used for lifecycle cost calculations.

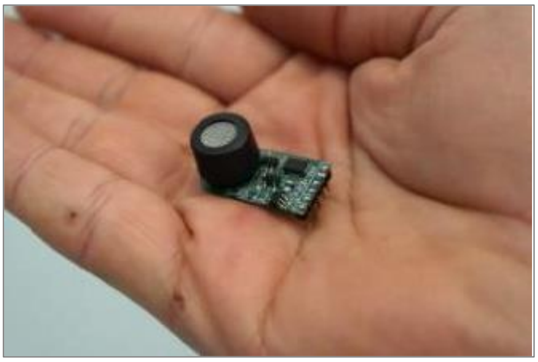


Figure 9. AR-5000 CO2 sensor from PSS Korea

AR-5000 CO_2 sensor module is a compact electrochemical type gas sensor using solid electrolytes where the EMFs are measured proportional to the logarithm of the CO_2 concentration in the ambient (Nernst equation). The circuit measures the EMF of the sensor and automatically converts it into CO_2 concentration. It provides I2C output (slave up to 50 kHz) for digital interface. Since the sensing element is made of dense ceramics, it is quite durable and is generally resistant to hostile environments

Table 2. AR-5000 CO_2 sensor characteristics

Item		Contents			
		Min.	Typ.	Max.	Units
Detection Range		0		5000	ppm
Operating Temperature		0		60	°C
Operating Humidity		5		90	%RH
Storage Temperature		-10		70	°C
Life Expectation			5		year
Response Time			3	10(diffusion)	seconds
Size		13x25x11			mm
Weight		2			g
Temperature Coefficient		5 ppm/°C (or <0.5%/°C)			
Accuracy		±5% (or ±50 ppm)			
Packaging Type		Glass Polyvinyle Plastic Custom			

<u>Metal Oxide Semiconductor CO_2 sensors</u>

MOS carbon dioxide sensors use the resistivity of metal compounds to test the amounts of gas in the air. Resistivity is how easily electricity flows through something. So, something like copper, which is used a lot in wiring, would be less resistant than rubber, which is used to stop electric currents.
A MOS sensor has a metal strip or film that is exposed to the air you want to test. This strip has a constant electric current running through it. As the target gas comes into contact with the piece, it will interact with the metal and change the chemical composition either through a reduction or oxidation reaction. When this happens, the resistivity, or conductivity, or the metal will be altered. The kind of resistance change, whether increasing or decreasing, and the magnitude of this change determines the concentration of the target gas. Based on what kind of metal it is, different gases will react to the strip.

Advantages: their very simple design makes them easy to use. Disadvantages: Readings can be affected by temperature and humidity; More suited for higher, less common CO_2 concentrations (>2000 ppm); Other substances in the air can throw off readings.

OEM prices are estimated around 5 - 50 euro, depending on type and batch size.
For this study, an OEM-price (VAT excl.) of 15 euro will be used for lifecycle cost calculations.

1.3.2. Humidity sensors

Humidity sensors are used to detect when moisture is produced in e.g. bathroom, kitchens and laundry room, etc. and subsequently increase ventilations rates in order to directly remove this surplus of moisture production.
Humidity sensors are sometimes also used to detect occupancy and adjust ventilation rates accordingly. A person could perspire and exhale 40 g of water vapour per hour when sleeping, 70 g/h when seated and 90 g/h when standing or doing housework. This person related humidity production changes the RH-values in a room. Detection of such changes may be used to control the ventilation rates. Unfortunately, there are more parameters that influence the real-time humidity values which makes it difficult to accurately relate humidity changes to occupancy. Temperature, outdoor humidity levels, indoor activities and ventilation rate itself all influence the actual occurring RH-levels. RH-sensors are therefore less accurate in occupancy detection than e.g. CO_2 sensors.

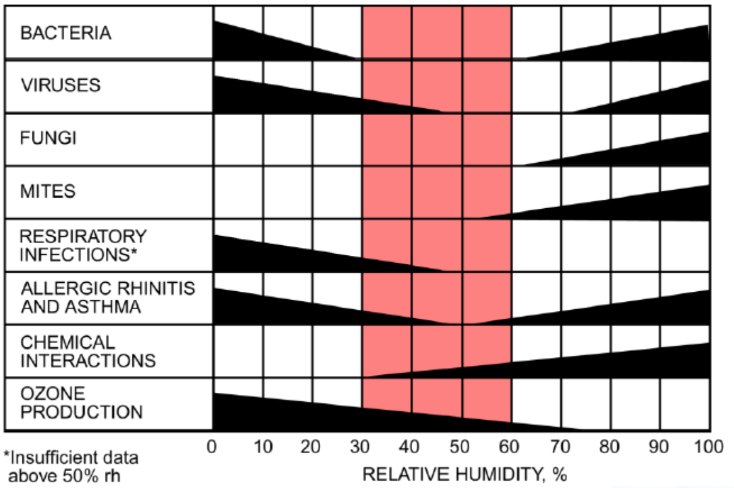


Figure 10. Optimal relative humidity ranges for health[2]

RH-values that are generally considered optimal for human occupancy are the values in the mid-range, between 30-60% relative humidity.

There are various types of humidity sensors; they come in different sizes, operate in different temperatures, and they detect different levels of accuracy. There are three main types of humidity sensors:

<u>Capacitive</u>

These sensors measure moisture levels using a humidity-dependent condenser; they are suitable for wide RH ranges and condensation tolerance. These sensors are commonly used in industrial and commercial environments.

<u>Resistive</u>

These sensors can measure the electrical change in devices such as conductive polymers and treated substrates. They are suitable for use in residential and commercial environments.

[2] E.M. Sterling, A. Arundel, and T.D. Sterling, Criteria for Human Exposure to Humidity in Occupied Buildings (ASHRAE Transactions, 1985), Vol. 91, Part 1

Thermal Conductivity

These sensors are suitable for use in environments that have high temperatures. They measure humidity by calibrating the difference between the thermal conductivity of dry air and that of moist air.

Depending on sensor accuracy, type and batch size, OEM prices may vary between 1-30 euro. For this study, an OEM-price (VAT excl.) of 5 euro will be used for lifecycle cost calculations.

1.3.3. TVOC sensors

TVOC sensors are sensing devices that are capable of measuring VOC and/or TVOC concentrations in the air.

Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids. VOCs are numerous, varied, and ubiquitous. They include both human-made and naturally occurring chemical compounds. Most scents or odours are of VOCs. Long-term exposure to VOCs in the indoor environment can contribute to sick building syndrome. In offices, VOC results from new furnishings, wall coverings, and office equipment such as photocopy machines, which can off-gas VOCs into the air. Organic chemicals are widely used as ingredients in household products. Paints, varnishes and wax all contain organic solvents, as do many cleaning, disinfecting, cosmetic, degreasing and hobby products. Fuels are made up of organic chemicals. All these products can release organic compounds while you are using them, and, to some degree, when they are stored. During certain activities indoor levels of VOCs may reach 1,000 times that of the outside air. Studies have shown that individual VOC emissions by themselves are not that high in an indoor environment, but the indoor total VOC (TVOC) concentrations can be up to five times higher than the VOC outdoor levels. New buildings especially, contribute to the highest level of VOC off-gassing in an indoor environment because of the abundant new materials generating VOC particles at the same time in such a short time period. In addition to new buildings, many consumer products emit VOCs, therefore the total concentration of VOC levels is much greater within the indoor environment.
VOC concentration in an indoor environment during winter is three to four times higher than the VOC concentrations during the summer. High indoor VOC levels are attributed to the low rates of air exchange between the indoor and outdoor environment as a result of tight-shut windows. Good ventilation and air-conditioning systems are helpful at reducing VOCs in the indoor environment.

Health effects due to exposure to higher VOC-concentrations may include: Eye, nose and throat irritation, headaches, loss of coordination and nausea, damage to liver, kidney and central nervous system. Some organics can cause cancer in animals, some are suspected or known to cause cancer in humans. Key signs or symptoms associated with exposure to VOCs include: conjunctival irritation, nose and throat discomfort, headache, allergic skin reaction, dyspnoea, declines in serum cholinesterase levels, nausea, emesis, epistaxis, fatigue and dizziness.

Key strategy for reducing indoor VOC-concentrations is avoiding or limiting the use of products that emit VOCs, i.e. by selecting the right building materials, decorative- and interior products, and choosing the right home and personal care products (cleaners, disinfectants, air fresheners, cosmetics, etc.). As a second stage strategy, increased ventilation rates are used to reduce TVOC concentrations.

Types of VOC-sensors

Nearly all small commercial VOC sensors are based on one of the six principles of operations summarized below:

- Photo-ionization detectors (PID), both portable handheld instrument and Original Equipment Manufacturers (OEMs)
- OEM electrochemical sensors either of amperemetric or potentiometric type,
- OEM metal oxide sensors (MOx) with change of conductivity instead of chemical reaction,
- Optical sensors including UV portable spectrometers,
- Portable or micro-gas chromatograph (µGC) that combines micro column with MOx or PID OEM as detectors.
- Electronic noses and sensor-arrays.

Main question related to (T)VOC sensors regards its suitability as main indicator for ventilation control for human occupancy. As already indicated, there are thousands of VOCs and their concentrations may incidentally change due to certain activities that may occur both indoors and outdoors. Basing ventilation rates on incidentally occurring (T)VOC emission may be difficult.
Several case studies were done to assess the suitability of TVOS-sensor for ventilation control for human occupied buildings.
1.
DTI[3] tested six different TVOC sensors and found that they were good at detecting changes in the IAQ. Other conclusions were that there are differences between sensor models as regards to their sensitivity, differences in types of VOCs that are measured, differences in response to changes in RH and temperature. Furthermore, there were variations between sensors of the same model, and last but not least there are differences in de way ventilation rates are controlled. Overall conclusion is that, although they are not plug and play yet, it considered possible to make them suitable for ventilation control.
2.
Together with the Aarhus University and the Danish Technological Institute, the Technical University of Denmark[4] also performed laboratory measurements on MOS VOC sensors.
MOS VOCD sensors are advertised as smaller, cheaper and less energy consuming sensors, that do not only indicate CO2-concentrations but also measure various VOCs (odours), making them suitable for usage in all rooms of a building and for IoT (Internet of Things) applications.
Issues that were found relate to:

- Information is missing regarding the sensor properties
- Different response for multiple samples of same sensor type and same manufacture
- Auto-calibration function (to background pollutant levels) can have adverse effect
- Definition of set-point value is problematic due to the broad range of sensitivities and the relative nature of the response
- It is not known, which pollutant is driving the response

It is concluded that additional future work is necessary with regards to accuracy, pollutants driving the response and the auto-calibrating functions, before they can be used for DCV-control.
3.
University of Gent[5] did a monitoring study, comparing values coming from dedicated NDIR CO_2 sensors with emulated CO_2 concentration values coming from MOS TVOC-sensors.
The hypothesis that both CO_2 and VOC can be used as indicator for changing IAQ caused by occupancy and activities of people was further investigated in this study.
As can be seen from Figure 11, the moments that VOC-signals increase and decline run synchronously to the CO_2 signals. As regards to the dynamics and unpredictability, there are huge differences between the two signals.

[3] Lyng, N.L., Can TVOC-sensors be used for ventilation control?, Danish Technological Institute. AIVC Webinar 'Using MOS sensors to measure VOC for ventilation controls, September 2018.

[4] Kolarik, J., MOS VOC sensors' properties and suitability for DCV-control, Technical University of Denmark, AIVC Webinar, September 2018.

[5] De Sutter, R., Laverge, J., Janssens, A., Performance of demand controlled ventilation systems controlled by VOC- and CO2- sensors, juni 2016, University of Gent.

Figure 12 shows the general average correlation between the VOC and the CO_2 concentrations. They not only show strong variations between dwellings, but also between user profiles. It was also identified, that when ventilation systems is controlled by the CO2 signal, these correlations were much higher compared to a situation where ventilation is controlled by the VOC signal.

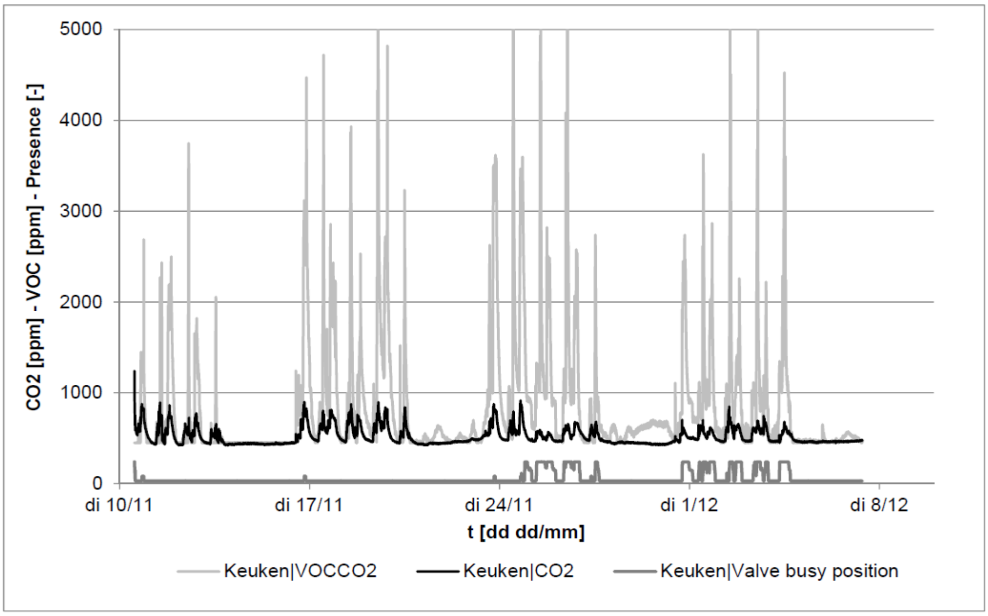


Figure 11. Comparison measured values for CO2- and VOC concentrations

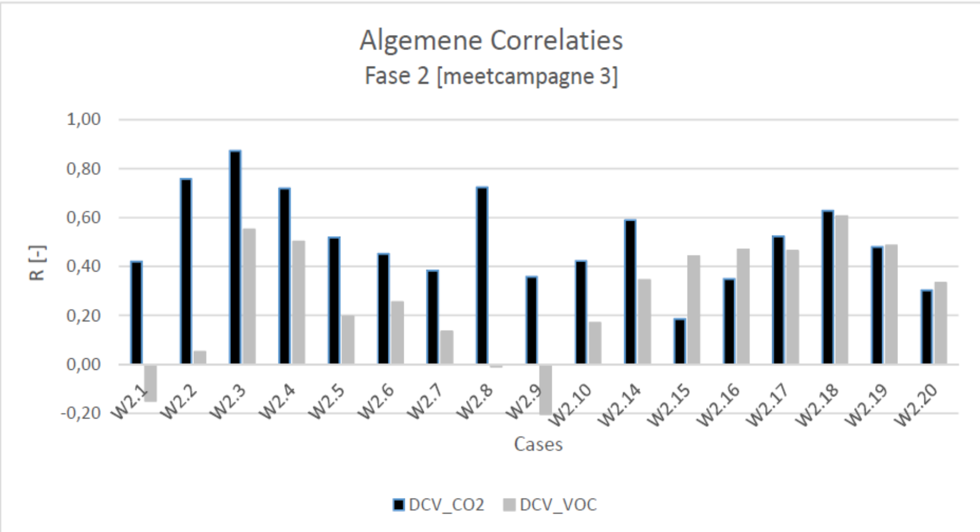


Figure 12. Correlation between NDIR CO2 and MOS TVOC values

Main conclusions of the study are that raw TVOC-signals may be used for event detection (and occupancy), but that the equivalent TVOC-concentration in general is more than 50% higher than the CO2-conentration. TVOC-controls increased the total ventilation rates significantly (with around +70% in bedrooms and +175% in kitchens). TVOC-concentrations peaks much more with occupant behaviour, so transforming TVOC-signals to a usable input for ventilation control still requires some work.

OEM prices for TVOC sensors are comparable to the electrochemical CO_2-sensors and are estimated around 5 to 50 euro, depending on type and batch size. For this study, an OEM-price (VAT excl.) of 10 euro will be used for lifecycle cost calculations.

1.3.4. PM-sensors

Particulate Matter (PM) is a mixture of airborne solid particles and liquid droplets that - when inhaled - and may cause serious health problems. PM includes particles with different characteristics – i.e. shape, optical properties, size and composition – but it is most commonly divided into sub-categories based on the particle size information.
Different PM categories are usually reported under the common nomenclature of PMx, where 'x' defines the maximum particle diameter in the airborne particle mixture or 'aerosol'. For example, PM2.5 defines inhalable particles with a diameter of generally 2.5 micrometres and smaller, PM10 particles with a diameter of 10 micrometres and smaller, and so forth.

The PM10 and PM2.5 categories have been historically identified by national governments as important monitoring levels to assess the quality of the air we breathe, because PM10 particles irritate exposed mucous such as the eyes and throat and PM2.5 particles travel all the way through the lungs into the alveoli. New categories like PM1.0 and PM4.0 are also finding their way into air quality monitoring devices as these new outputs provide additional information to the traditional PM10 and PM2.5 levels, enabling a better particle pollution analysis and the development of new device-specific actions based on the detected aerosol type (e.g. house dust vs. smoke).

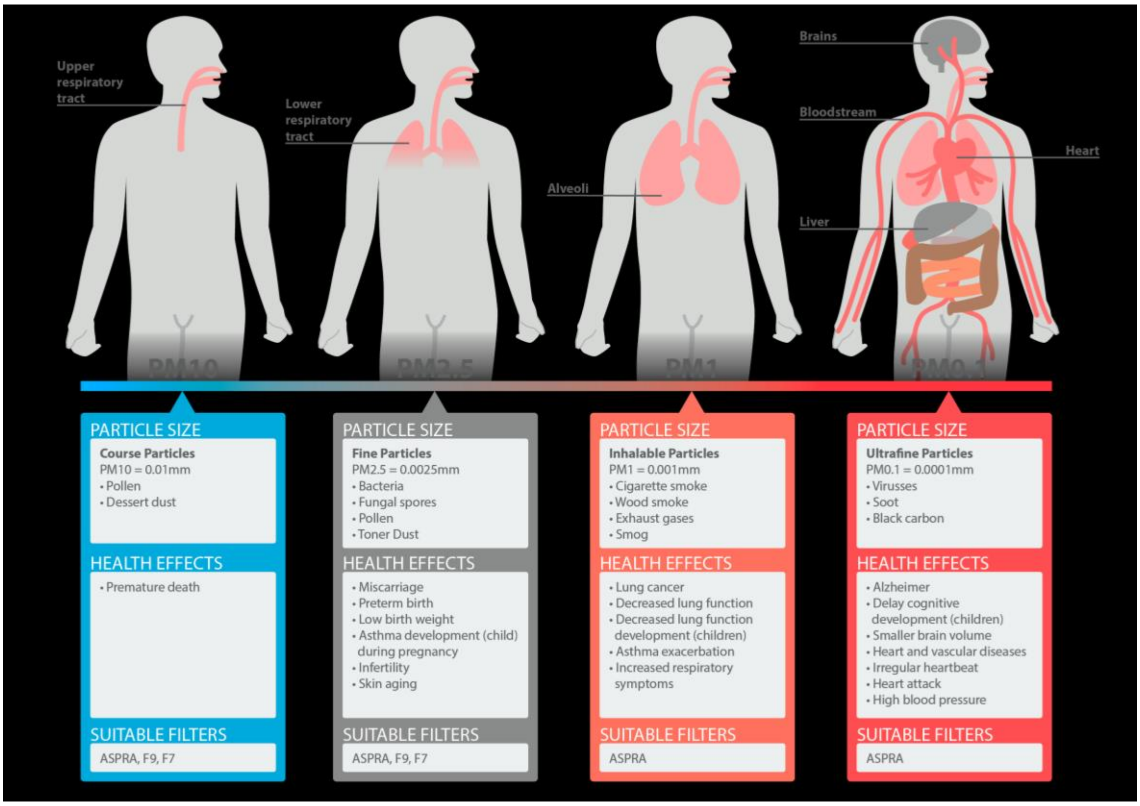


Figure 13. PM and their effect in the body (source: VFA-Solutions)

Indoor PM can be generated through cooking, combustion activities (including burning of candles, use of fireplaces, use of unvented space heaters or kerosene heaters, cigarette smoking) and some hobbies. Indoor PM can also be of biological origin.
Indoor PM levels are also dependent on several other factors including outdoor PM levels, infiltration, types of ventilation and filtration systems used. In homes without smoking or other strong particle sources, indoor PM would be expected to be the same as, or lower than, outdoor levels.

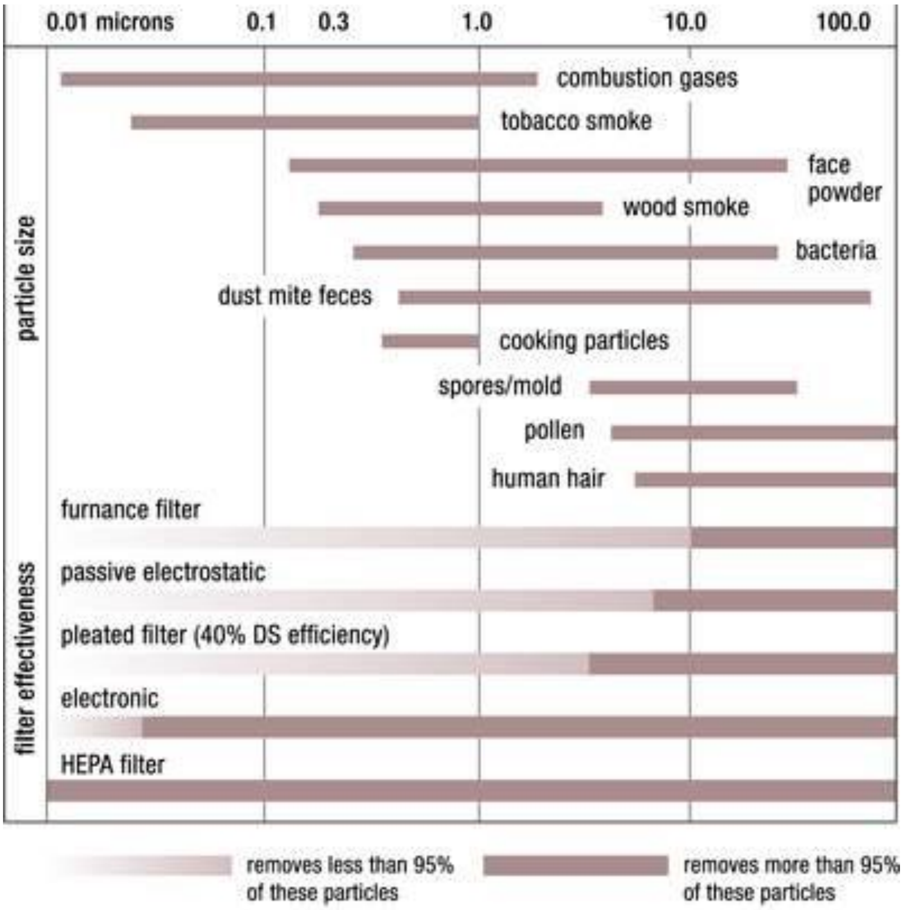


Figure 14. Size range of common pollutant sources
(source: John Wiley & Sons, Best practices guide residential construction 2006)

Cooking without proper extraction of the cooking fumes, can be an important source for high indoor PM-concentrations. In a field study performed by TNO[6] in the Netherlands, it was found that PM-peaks due to cooking can be very high (up to 1900 µg/m^3). The table below provides information on type of dwellings, kitchen hoods, ventilation types and family composition of the location where the field trials were performed.

Table 3. Dwelling and kitchen characteristics of the field study locations

Measurement	Cooker	Hood type	Capacity [m³/hour]	Vent. system	Ventilation [m³/hour]	Volume living room/kitchen [m³]	# persons	Dwelling type
Ettenleur	Gas	motorised	700[1]	C	700 + 75[1]	240	4	detached
Delft 2	Gas	motorised	166/212/238	C	166 + 13	120	2	row
Leiden	Induction	recirculation	500[1]	D	> 100	350	4	row
Amsterdam 2	Induction	recirculation	400[1]	D	60	110	2	apartment
Bilthoven	Gas	motorless	155	D	155 + 21	85	2	apartment
Delft 1	gas	motorless	123	D	123	128	4	row
Voorschoten	gas	motorless	35[1]	C	35 +15[1]	125	4	row
Den Haag	induction	motorless	38	C	69	120	4	semidetached
Amsterdam 1	gas	no hood-	-	A	40[1]	15	2	apartment
Ettenleur	gas	motorised[2]	-	C	75	240	4	detached

[1]Estimated from supplier information. [2]During half the week the motorised hood was intentionally not used.

[6] Jacobs, P., Borsboom, W., Kemp, R., PM2.5 in Dutch Dwellings due to cooking, TNO The Netherlands, September 2016, 37th AIVC Conference Alexandria.

Main results of the field trials are presented in Table 4. The last column in this table gives the averaged PM-increase over the period 18.00 – 23.00 hours due to cooking. Peaks that were not related to cooking in this period are not included in these averages. These averages can be considered indicative for the additional exposure to PM2.5 caused by cooking. From the table it may be concluded that the kitchen hood, its ventilation capacity and its efficacy play an important role in this PM-increase and related exposure. Another influencing factor on the PM-exposure related to cooking that is identified is the kitchen hood airflow rate in relation to the volume and ventilation of the kitchen itself.

Table 4. Results of the field measurements

Measurement	Cooker	Hood type	Capacity [m^3/hour]	Air exchange rate[1] [ACH]	Max. PM due to cooking [ug/m^3]	PM increase 18.00 – 23.00 hour [ug/m^3]
Ettenleur	gas	motorised	700[4]	3.2	16 - 25[2]	0
Delft 2	gas	motorised	166/212/238	1.5	10 - 25[2]	0.5
Leiden	induction	recirculation	500[4]	0.3	70 - 110[2]	8
Amsterdam 2	induction	recirculation	400[4]	0.5	57	0 - 8
Bilthoven	gas	motorless	155	2.1	174	3
Delft 1	gas	motorless	123	1.0	40 - 94[2]	10
Voorschoten	gas	motorless	35[4]	0.4	242 - 1919[2]	16
Den Haag	induction	motorless	38	0.3	20	-[3]
Amsterdam 1	gas	no hood	-	2.7	651	5
Ettenleur	gas	no hood[1]	-	0.3	121 - 350[2]	44

[1]Air exchange rate with hood in operation. [2]Pancakes with bacon. [3]Ambient too high. [4]Supplier information.

Type of PM-sensors

The real-time optical particle counters (OPCs) have progressively found their way into the air quality monitoring market. These instruments are based on different optical principles, typically scattering or absorption, with light scattering being the most commonly used. In these OPCs, the particle passes through the light source (usually a laser beam) and causes scattering (or absorption) of the incoming light, which is then detected by a photodiode and converted into real-time particle count and mass concentration values.
Currently, optical detection is the most widespread technique due to its ease of use and unbeatable cost-performance ratio. In recent years, OPCs have become small enough to be integrated into air conditioners, air quality monitors and air purifiers, and are used to regulate and control air quality in households, cars and outdoor environments.

Prices for low cost PM sensors may vary between €5 and around €60, depending on accuracy and batch size.

Not all OPCs perform in the same way and the quality of their measurement depends greatly on the design and engineering of the device. The optical principle works very well in terms of particle counting, but as these devices are used mainly for the estimation of the PM mass concentration, they will be susceptible to estimation errors due to the different optical properties of the particles (e.g. shape and colour) and different mass densities. The quality of the mass estimation will thus vary highly depending on the manufacturer algorithm used to convert the measured optical signal into PM mass concentration. But also, the internal airflow engineering has a high impact on the accuracy and drift of these sensors as particles can accumulate easily on their optical elements (laser, photodiode, beam-dump) and degrade their output over time if they are not properly engineered.

Example Sensirion SPS30[7]

The working principle of the Sensirion SPS30 is based on laser scattering. A controlled airflow is created inside the sensor by means of a fan. As shown in Figure 15, an internal feedback

[7] Lattanzio, L., Particulate Matter Sensing for Air Quality Measurements, Sensor Insights, December 2018.

loop between the microprocessor and fan stabilizes the fan speed and therefore the airflow through the sensor.

Environmental PM travels inside the sensor from inlet to outlet, carried by the airflow. In correspondence with the photodiode, particles in the airstream pass through a focused laser beam, causing light scattering. The scattered light is then detected by the photodiode and converted to a mass/number concentration output through Sensirion's proprietary algorithms, which run on the SPS30 internal microcontroller.

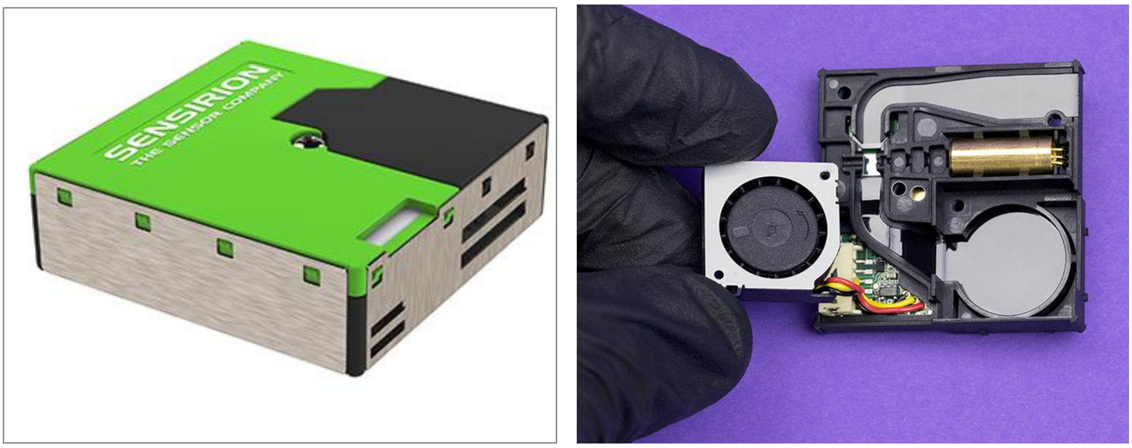


Figure 15. Sensirion SPS30 (source https://www.sensirion.com/en)

1.4. Occupancy measurement via sensors fusion

Relying on single sensor data may cause significant errors. Due to different applications and targeting higher accuracy, a fusion of multiple sensors is more and more being used in occupancy detection and estimation. In a recent study[8] a literature review was done on this topic, looking at the integration of multiple sensors such as light, acoustic, temperature, motion, CO_2, humidity and PIR sensors for accurate occupancy detection.

A short summary of the findings of this literature review (see study paper, page 4 to 6):

- A new method introduced as SUN (sensor-utility-network) utilises a number of sensor measured data which reduced error from 70 to 11% as compared to such method which uses solely one sensor output. The occupancy was measured via distributed sensor measures such as CO_2, PIR, video, sound and badge counters.
- Ebaddat et al., used three different sensors data i.e., CO_2, ventilation actuation signals and temperature to build a dynamic model for occupancy. However, it has been pointed out in a research that temperature parameter contains less information gain for occupancy modelling.
- Zhang et al. concluded in their research that the correlation between the number of occupants and each individual environmental variable temperature, relative humidity, CO_2 and acoustic ranks approximately 11.98%, 32.49%, 35.70% and 48.05%, respectively.
- For the demand-driven application such as HVAC, Yang et al. presented a multi-sensor-based occupancy estimation model, which can estimate the number of people using the combination of indoor temperature, humidity, CO_2 concentration, light, sound and motion.

[8] Ahmad, J., Larijani, H., Emmanuel, R., Mannion, M., Javed, A., Occupancy detection in non-residential buildings – A survey and novel privacy preserved occupancy monitoring solution, Applied Computing and Informatics, December 2018, https://doi.org/10.1016/j.aci.2018.12.001

- Another implicit method for occupancy was proposed via the data obtained from (1) physical sensors: temperature sensor, relative humidity sensor, light levels sensor; and (2) software sensors: computer power consumption.
- In experiments with a Random Neural Network (RNN), occupancy was estimated from four sensors: (1) environmental CO_2 sensor (2) Air inlet CO_2 sensor (3) room temperature sensor and (4) Air inlet temperature. The occupancy information is further utilized in the HVAC system and the accuracy of the smart controller was 94.87%, 98.39%, and 99.27% for heating, cooling, and ventilation, respectively. Occupancy estimation time in was slower due to CO_2 sensor which is improved via a Hybrid RNN based occupancy estimation and PIR and magnetic reed switches.
- With data obtained from room temperature, inlet air temperature, inlet CO_2 concentration, indoor CO_2 levels, detection of a single occupant was tested. The accuracy of the estimation proposed in was around 92%.
- Another multiple sensor-based technique for correct occupancy estimation was proposed, based on sensors motion detection, power consumption, CO_2 concentration sensors, microphone and door/window positions. This research used feature selection via information gain strategy and concluded that indoor environment temperature has a very low role in occupancy detection. Acoustic sensors were the main feature in the proposed occupancy detection algorithm.
- Candanedo et al. proposed a model for occupancy detection via light, humidity, CO_2, and temperature measurements using Classification and Regression Trees (CART), Random Forest (RF) and Linear Discriminant Analysis (LDA). However, this work is limited to occupancy detection only and cannot estimate the number of occupants. The reported accuracy of Candanedo et al. model was surprisingly 95 to 99%. Using only the temperature data, the accuracy was 83 to 85%.
- Instead of utilizing multiple wireless sensors, Jiang et al. measured carbon dioxide concentration via CO_2 sensor for real-time indoor occupancy. The authors utilized Feature Scaled Extreme Learning Machine (FS-ELM) algorithm, which is a variation of the standard Extreme Learning Machine (ELM). The performance of FS-ELM is better than ELM in occupancy estimation problem. The measured CO_2 concentration had some serious spikes which was resolved with pre-smoothing filtering. Authors found out that pre-smoothing the CO_2 data can greatly improve the estimation accuracy up to 94%.

1.5. Suitability sensors for different room types

Depending on the type of rooms and the activities that are performed in the rooms, the sensors discussed in the previous sections can be more suitable or less suitable for DCV in specific room types. The table below attempts to make an initial evaluation/classification of the suitability of sensors for various room types in buildings primarily intended for human occupancy. Proposed classification is partly based on the definition with regards to the purpose of the ventilation that is meant in this context.
Text used in VU Regulation to describe the ventilation function: *'replacement of the air that is utilised/polluted due to the presence of human beings and their use of the building, including emissions from building materials, decorative and interior product and equipment'*

Table 5. Initial assessment suitability sensor types for DCV in various room types

Room types	**Habitable spaces**	**Exhaust spaces**			**Storage spaces**	**Connecting spaces**
Description	Rooms occupied by people for non- or low emitting activities such as: – Leisure – Sleeping – Eating – Hobbies – Waiting – Studying – Working	Rooms where people's activities produce pollutants that are preferably directly expelled, amongst which: 1) Odours 2) Moisture 3) Cooking fumes 4) High VOCs emissions			Rooms where items are kept or stored that have no to limited pollutant emissions	Rooms/spaces that need to be crossed before reaching a specific room
Examples	Living room Bedroom Diner Study Waiting room Office	Toilet	Bathroom Utility room	Kitchen Printer room	Pantry Storage room	Corridor Hall Stairway
Typical occupation	Long periods of occupation (> 1 hour)	Short visits (5 min.)	Visits of up to 0.5 hour	Visits of up to 1 hour	Short visits (< 5 min.)	Short visits (< 5 min.)
Preferred ventilation strategy	*During presence:* Predefined vent. rates per person to dilute bio-effluents and building/room emissions *During absence:* Basic vent. rates per m^2 to dilute building & room emissions	*Presence:* Predefined high extract rates + after run time *Absence:* Predefined basic extract rates	*Presence:* Predefined high extract rates + after run time *Absence:* Predefined basic extract rates	*Presence:* Predefined high extract rates+ after run time *Absence:* Predefined basic extract rates	*Continuous*: basic ventilation rates to dilute/ extract building, room- & storage emissions	*Continuous*: basic ventilation rates to dilute/ extract building & room emissions

People counters (all types)	+	+	+	+	No DCV needed therefore no sensors needed	
Bi-directional IR-laser	+/–	+/–	+/–	+/–		
PIR presence detection	–	+	+/–	+/–		
NDIR CO_2	+	+/–	+/–	+/–		
Electrochem. CO_2	+/–	?	–	–		
MOS CO_2	+/–	?	–	–		
TVOC	+/–	+	+/–	+		
Humidity sensors	+/–	–	+	+		
PM sensors1)	–	–	+/–	+		

1) PM is primarily generated in the kitchen; PM sensors are mainly used to assess the outdoor air quality and the need for filtration.

Because occupancy- and related exposure time are the longest in habitable spaces, these rooms are the most important where human exposure to pollutants concentrations is concerned. The exhaust spaces are important because – depending on ventilation strategy – the pollutants produced may spread to the rest of the building when not adequately removed; in case of excess moisture is not sufficiently removed, this may also bring damage to the building.

This initial evaluation of the applicability of sensors can be used for assessing the controls factor in residential ventilation systems (see Task 3 report, section 1.2 Ventilation Performance).

1.6. Monitoring and feedback systems

1.6.1 Introduction

Monitoring is the regular observation and recording of IAQ-levels in the various rooms of a dwelling. It is the process of routinely gathering information and making this information real-time available to the inhabitants. Purpose of the feedback can be twofold:

1) To influence the behaviour of the inhabitants where the operation of the ventilation provisions is concerned
2) To check or monitor the performance of demand-controlled ventilation (DCV) systems

As regards the first objective, there are many handheld sensor devices than can assist inhabitant to check IAQ-levels and operate ventilation provisions accordingly. Although this approach can be very helpful in creating awareness regarding worsening IAQ levels and indeed may improve the way ventilation provisions are operated, they do not - according to the study team - represent the ultimate solutions for achieving continuously good IAQ-levels with low energy use. Since the human sensory system is not reliable for sensing IAQ-levels, this approach requires continuous vigilant control of the handheld IAQ-devices as well as continuous adjustments to the ventilation provisions. This is not considered a viable long-term solution for the IAQ-problem.

The second objective of the monitoring and feedback systems (see under 2 above) is therefore considered a more feasible solution for improving IAQ-levels while minimising energy consumption. Using real-time data regarding IAQ-levels as direct input data for the demand-controlled ventilation systems is regarded as the future way to go for buildings with varying human occupancy rates.

1.6.2. Example of cloud connected smart DCV systems

A first large scale study into the effects of sensor-controlled cloud connected residential DCV-systems is described in the paper 'Large-scale performance analysis of a smart residential MEV system based on cloud data' presented at the 40th AIVC Conference in Ghent, October 2019[9].

Since IoT (Internet of Things) devices also become available in the residential ventilation industry, investigation of the real performance of these ventilation units during their lifetime becomes possible. The paper represents the first study into the real-life performance of a demand controlled central mechanical extract ventilation (DC-MEV) unit. The study compares the performance of units without air extraction in the bedrooms (no-smartzone) with units

[9] De Maré, B., Germonpré, S., Laverge, J., Losfeld, F., Pollet, I., Vandekerckhove, S., Large-scale performance analysis of a smart residential MEV system based on cloud data, 40th AIVC Conference, Ghent, Belgium.

that do apply direct extraction in the bedrooms (smartzone). About 350 units were analysed over a period of 4 months from December 2018 up to March 2019, corresponding with the main winter period in Belgium. Half of the units were installed as a smartzone system which means there is mechanical extraction from habitable rooms (bedrooms) as well. The air extraction was controlled on different parameters (humidity, CO_2 and VOC) depending on the room type. Indoor climate and IAQ were analysed with respect to design criteria set out in standards as well as fan characteristics and energy consumptions.

DC-MEV-System

Passive vents (ventilation grids), placed on top of the windows, supply the outdoor air in the habitable rooms. These passive vents are pressure controlled and can gradually be adjusted by the inhabitants between fully open and closed. By means of valves directly attached to the central unit at the end of the extract duct, the air extraction was locally controlled on different parameters depending on the room type: in bathroom and utility room on absolute and relative humidity (AH and RH); in kitchen and bedroom (if extraction available) on CO2 and in toilets on volatile organic compounds (VOC). Sensors were located at the valves and not within the rooms, which means that sensor values could - to a certain extent - deviate somewhat from the room conditions.
The following standard control algorithms were implemented in the system to regulate the extract airflow rate between a minimum and the required airflow capacity of the room according to the Belgian regulations. The nominal flow rates are for open kitchen: 75 m^3/h; bathroom, closed kitchen and laundry: 50 m^3/h; toilet: 25 m^3/h; bedroom: 30m^3/h).

- CO2: proportional between 800 – 950 ppm CO_2
- Humidity: step function as a function of a gradient $\Delta AH/\Delta t$ and a RH threshold
- VOC: step function as a function of a gradient $\Delta VOC/\Delta t$

Main results

Since the ventilation systems are also controlled on humidity, periods of RH levels >80% were limited. The typical RH ranges (between 30 and 70% or 25 and 60%) set out in standards for habitable spaces were fulfilled during at least 80% of the time, without causing complaints from the users.

As regards the CO_2 concentration in bedrooms, overall average values were below 950 ppm during at least 90% of the night-time. When considering only active ventilation (i.e. during occupancy) this percentage varied between 70 and 80%, with a dominant group in category 800-950 ppm and only about 20% in the category < 800 ppm. During 95% of the occupied time the values remain below 1200 ppm (see also Figure 16). The average daily exposure over the dwellings was 245 ppmh/day which is only 33% of the 773 ppmh/day by van Holsteijn and Li (2014). This big difference can be explained by the lower control setpoint of 950 ppm instead of 1200 ppm.

These CO_2 concentrations during occupancy in the habitable spaces (bedrooms) are the ones that really matter because they are directly related to human exposure. These measured CO2-concentrations related to smartzone VUs can most probably be further improved (reduced) when the control algorithms for habitable spaces are adjusted, allowing a higher maximal airflow rate (higher than the value prescribed by the Belgian building codes (30 m^3/h)) for the parent bedrooms.

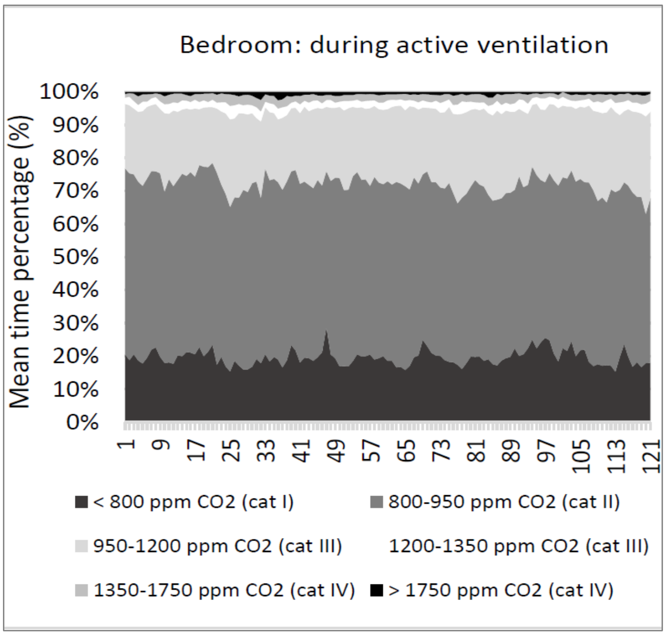


Figure 16. Average CO_2 concentrations in bedrooms for smartzone DC-MEV-units, during active ventilation

The dwellings without smartzone VU (i.e. no mechanical extraction from habitable rooms) were monitored separately. It was found that in such cases many elements have an impact on the IAQ in the bedrooms, such as size of the supply opening, position of the door, occupancy level and wind direction. As a consequence, CO_2 levels may vary between very good (< 1000 ppm) and very bad (> 2000 ppm). In general, omitting direct extraction from the bedroom gave rise to CO2 concentration levels to above 1350 ppm (category IV and V) in the parent bedroom.

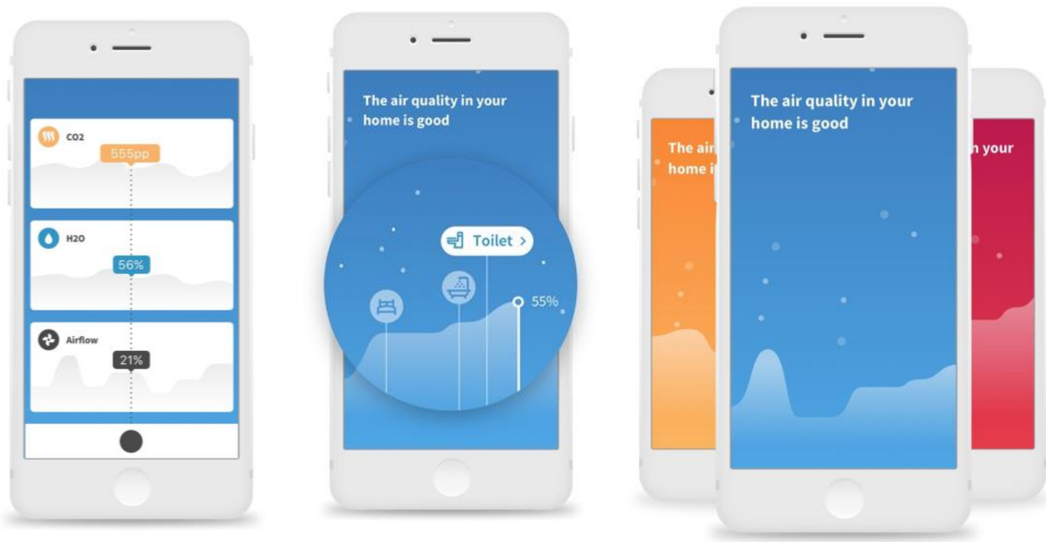


Figure 17. Screenshots of the app that can be used by the inhabitants when cloud connected components are used

This study clearly demonstrates that whether or not having a mechanical ventilation component in the habitable spaces, strongly influences the IAQ-levels in these rooms. The study also reflects the fact that, using cloud connected devices in combination with the proper sensors and control algorithms, the ventilation performance can be made visible to the user and – more importantly- largely be improved.

2. Flowrate control per room

2.1 Introduction

Local demand-controlled ventilation cannot be achieved solely by placing the correct sensors in the right locations (see previous chapter). Local DCV also requires the technical ability of the system to vary the ventilation flowrate in each and every room individually.
Where flowrate control per individual room is already common practice in the large majority of the ventilation systems for non-residential buildings, the residential sector is only recently moving away from systems where exclusively one central fan (or two in case of HR) is being controlled. Main reason for this transition, is the fact that monitoring studies indicate that flowrate control per individual room can improve both the ventilation performance and the energy performance of the overall system. Different technical principles can be used to achieve better flowrate control per individual room. The principles that are discussed in this chapter, refer to solutions that imply actual changes in the infrastructure (i.e. ductwork).

2.2 Ducted mechanical extraction with valves in all rooms for MEV

In the traditional MEV-systems, natural supply provisions in habitable spaces are combined with ducted mechanical exhaust in wet spaces, using one central extract fan. These systems have limited control over the ventilation airflows per individual room.
Several manufacturers have solved this, by extending the ducted mechanical extraction to all the rooms in a dwelling, including the habitable spaces, and by adding a controllable valve in all the individual extract ducts. This enables the variation of the extract flow rates for each room individually. With the correct sensors for the various rooms and proper control software for both fan and valves, the right air exchange rates can be achieved in each and every room independently of each other. This system is referred to as ‘VST4’ (see table 3 Task3 report).

The Demand-Flow system from Itho Daalderop achieves this by applying an additional manifold or plenum box, containing enough spigots for all the rooms in a dwelling. All spigot are equipped with control valves. The control valves related to the wet rooms are controlled by a humidity sensor, and the control valves for the habitable rooms by a CO_2-sensor. The plenum box is connected to a basic unidirectional VU. A separate control unit (type DF2-R) controls all the valves and the central extract fan.


Figure 18. Itho Daalderop DemandFlow system

Source: https://test.ithodaalderop.nl/producten/ventilatie-hele-huis/vraaggestuurde-ventilatie/demandflow

Another, similar solution is offered by Renson. Main difference is that all the spigots and control valves that are needed are directly connected to the unidirectional extract VU. Each spigot may contain one or more sensors, depending on the room type that is connected.

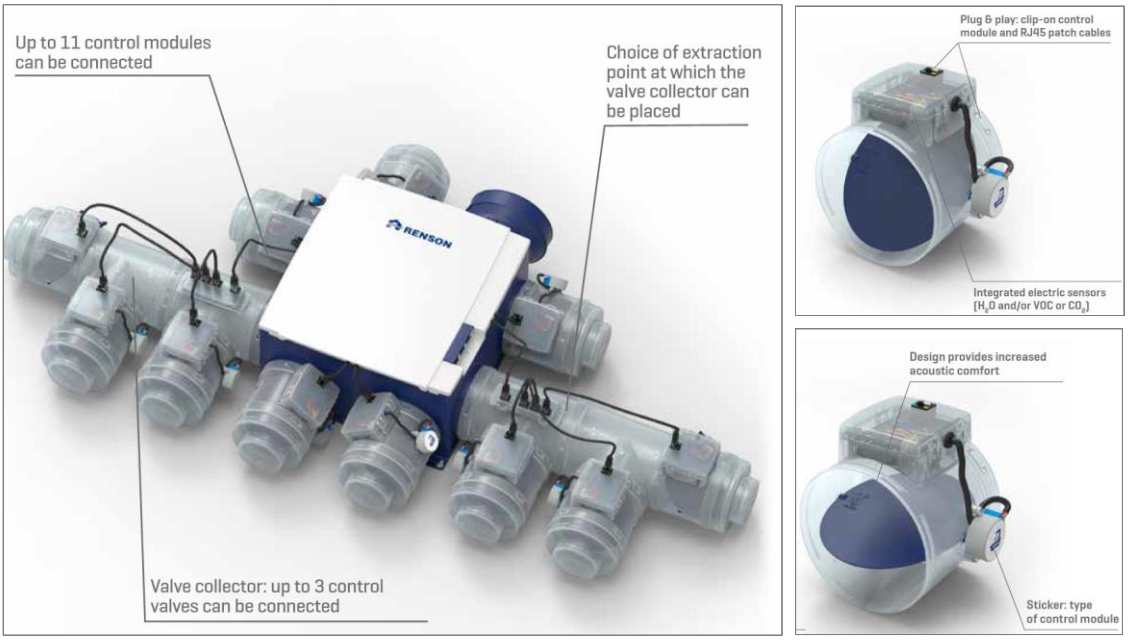


Figure 19. Renson Healthbox 3.0

Source: https://www.renson.eu/en-gb/producten-zoeken/ventilatie/mechanische-ventilatie/units/healthbox-3-0

The unit can be used in combination with a Wi-Fi connected installer app, that allows for testing and calibrating the airflows (flow resistance may be different for each room and each dwelling) and commissioning of the ventilation system. Maximum flowrates may be different per room type, depending on the country of installation and its specific buildings codes. If desired, the maximum airflow rates can be adjusted. Renson also provides a web portal with which installers can manage and monitor their installations.

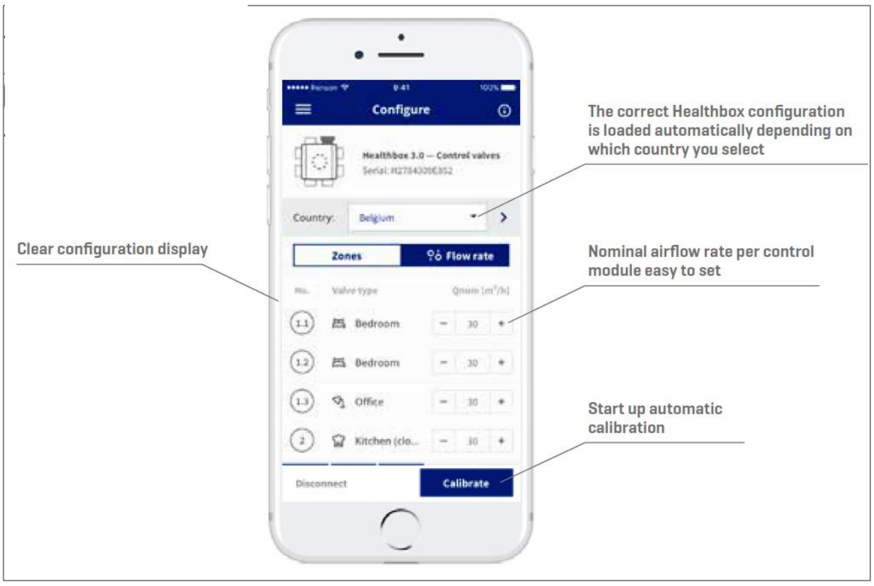


Figure 20. Renson installation app

Source: https://www.renson.eu/en-gb/producten-zoeken/ventilatie/mechanische-ventilatie/units/healthbox-3-0

2.3 Ducted mechanical extraction with valves in all rooms for MVHR

The same approach as described in paragraph 2.2 can be used for a central mechanical ventilation system with heat recovery (MVHR). The only difference is that now, the ducted mechanical extraction with controllable valves in all rooms are combined with a mechanical central supply provision in the connecting spaces (corridor, hallway, staircase) which replaces the natural supply provisions in the habitable spaces. The fresh and preheated outdoor air is now provided by a BVU and indirectly supplied to all the wet and habitable rooms. The total mechanical extract airflow is balanced with the total mechanical supply airflow and energy is recovered using a heat exchanger. This system is referred to as 'VST6' (see table 3 Task3 report).

The same components are used as illustrated in Figure 18, only the extract unidirectional VU is replaced by a bidirectional ventilation unit with heat recovery. Also, the appropriate software and control algorithms for steering the two fans and (if necessary) any additional valves, are installed.

2.4 Ducted mechanical supply/exhaust in HS/ES with valves (MVHR)

The standard ducted BVU-system in the residential sector (referred to as VST5 in table 3 of the Task 3 report) is a system were only the two central fans are controlled. The system consists of supply ducts with fixed valves to all habitable spaces, and exhaust ducts with fixed supply valves to all wet spaces. Varying the flowrate of both fans is done simultaneously, keeping both airflows in balance. This ducted BVU system with fixed valves only allows for changes in the overall airflow over the dwelling. If the airflow in one room is increased, it also increases in all the other rooms.

The principle that some manufacturers currently apply for the exhaust ducts only (see paragraph 2.2 and 2.3), can obviously also be applied for both the supply ducts and the exhaust ducts. By doing so, the standard ducted BVU system can be transformed into a system that allows flowrate control for all rooms individually. This can further improve the ventilation performance and energy efficiency of the standard BVU.

As far as the study team was able to determine, no BVU type VST5 systems could be found on the market that apply controllable valves in all wet spaces and in all habitable spaces with related actuators and control algorithms. In this respect it appears that there is room for further improvement of this standard ducted BVU-type.

2.5 Non-ducted local VUs and/or BVUs in ES/HS

Another way to achieve flowrate control in each room individually, is to apply non-ducted mechanical local ventilation units instead of central ducted mechanical VU having only one central fan, in which case the individual fans in each room can be controlled separately. Various products are placed on the market for this purpose:

a) Non-ducted local exhaust VUs

b) Non-ducted local supply VUs

c) Non-ducted local BVUs with recuperative heat exchanger

d) Non ducted local alternating BVU with regenerative heat exchanger

Advantage of this non-ducted local approach is the fact that the ductwork needed for centralized fans no longer is required. For retrofit, this is a big advantage and saves drilling and channelling activities. A second advantage relates to the fact that the airflow resistance due to the ductwork no longer applies, indicating that the power consumption needed for achieving similar airflows can be reduced.

2.5.1 Non-ducted local exhaust VUs

The ventilation units that are referred to here, are the non-ducted local extract fans that continuously extract air in baseload airflow rates (e.g. according EN 16798-1) and are in addition capable of achieving the flowrates following the minimum to-be-installed capacity according to applicable building codes or EN 16798-1 guidelines.

In that sense, bathroom- and kitchen extractor fans that can only manually be switched between on and off, do not qualify as a non-ducted local exhaust ventilation unit. There must be a continuous base load extract airflow than cannot be switched off. And the unit must be capable of achieving the minimum requested extract rates according to building codes and/or European guidelines. The units can be switched from basic continuous to higher extract flowrates by practically any type of control. Manufacturers often have the complete range of control options available: manual, timer, humidity, presence, VOC, CO_2 etc. See pictures below for some examples of these fans.

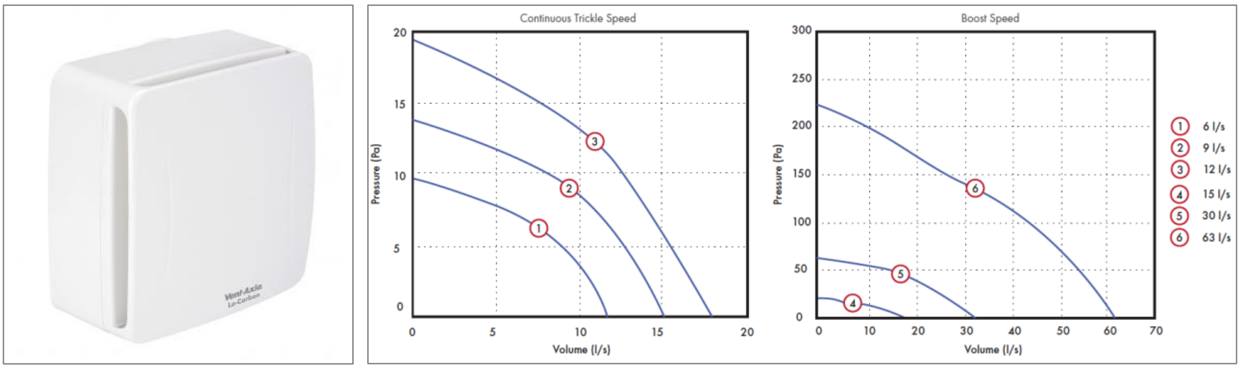


Figure 21. VentAxia Low-Carbon Quadra

Source: https://www.vent-axia.com/range/lo-carbon-quadraselv

The VentAxia Low-Carbon Quadra is a rectangular extract unit (230x260 mm) with a centrifugal fan and continuous basic flowrates varying from 6 to 12 l/s and high flowrates varying from 15 to 63 l/s. List price excl. VAT around 250 euro.

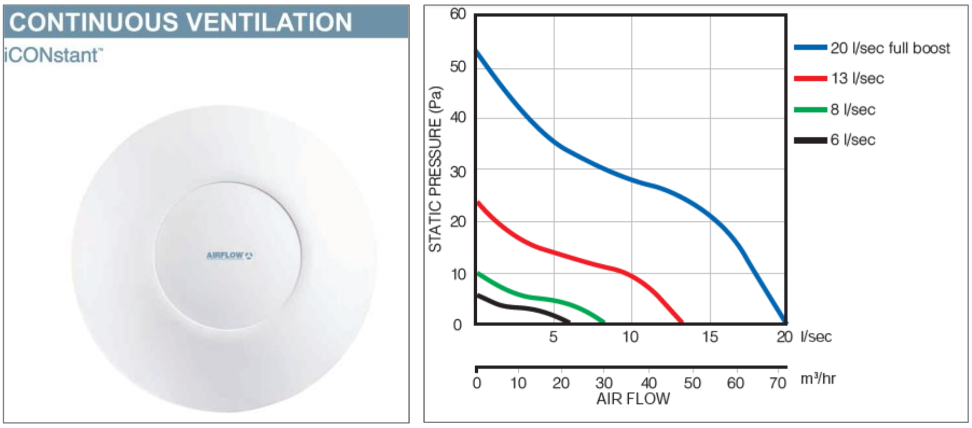


Figure 22. iCONstant by Airflow

Source: https://www.airflow.com/products/pg_iCONstant1/iCONstant-Fan-Range

The iCONstant from Airflow is a round (d= 197 mm) extract unit with an axial fan and continuous basic flowrates varying from 6 to 12 l/s and high flowrates varying from 22 to 72 l/s. List price excl. VAT around 170 euro.

Important to note here is the difference in the QH-curves of these two example fans. The axial fan is much more pressure sensitive than the centrifugal fan. With higher counteracting elevated pressure differences over the façade, the axial fan may achieve no basic extract rates at all. In case of negative pressure differences, the basic extract rates may be doubled. These differences in sensitivity will have an effect on the ventilation performance and thus also on the IAQ-levels.

2.5.2 Non-ducted local supply VUs

In principle, a similar description/explanation as for local exhaust UVUs could be given for local supply UVUs. The fact is, however, that only a very limited number of local non-ducted supply fans are offered on the market. The dominant supply provisions in the market are in fact passive natural supply grids, a.k.a. trickle vents or air inlets. These passive supply provisions are cheap and do not use electrical energy. The downside however is that they also suffer from pressure sensitivity, indicating that depending on the wind pressure and wind direction, the air supply may not always correspond to the actually needed supply rates in the various rooms. Furthermore, natural passive supply grids are generally manually operated of not operated at all, implying that correct control is more the exception than the rule. These two downsides will influence the ventilation performance, the energy performance and related IAQ-levels. With supply fans, these two drawbacks can be avoided.

Figure 23. S-fan, example of local supply fan
(source: https://www.climarad.nl/producten/actueel/climarad-s-fan/)

<u>Technical specs S-fan:</u>

Fan type	: 1x centrifugal
Nominal airflow	: 50 m^3/h
Maximum airflow	: 300 m^3/h
Controls	: CO_2, RH, T_{inside} $T_{outside}$
Communication	: RF
Specific Power Input SPI	: 0.07 $W/m^3/h$
Standby consumption	: < 1 Watt
Filtration	: G4 / F7 optional
List price (VAT excl.)	: around 600 euro

2.5.3 Non-ducted local BVUs with recuperative heat exchanger

Non-ducted local BVUs with recuperative heat exchanger have been on the market since end of the previous century (around 1990-2000). They consist of a recuperative heat exchanger, two fans, controls, one or two wall ducts and an outlet- and inlet opening on both the indoor- and outdoor side of the unit. Many manufactures nowadays have such units in their product portfolio.

Their benefits include the ease-of installation (no ductwork through the building is needed) and with it their total acquisition costs and the fact that – with the right sensors - flowrates can be controlled per individual room.

The issues of this type of solution mainly relate to noise production at elevated flowrates, its susceptibility to recirculation of air (in- and outlet are very close to each other) and, not least, the compromises that are needed in terms of product specs to keep the units small and less

obtrusive. Heat exchangers, fans, filters, supply and exhaust surfaces are mostly smaller than preferred.
Finally, depending on the type of fan and overall technical design of the product, their flowrates may be susceptible to pressure differences / wind load over the façade, which can seriously affect the overall heat recovery efficiency and ventilation performance. For that reason, the *indoor/outdoor airtightness* and *airflow sensitivity* are important parameters and their values need to be determined according to the related standard (FprEN13141-8). With these values, corrections are to be made on the overall average temperature efficiency of the unit and on its ventilation performance.

Some examples of non-ducted local BVUs with recuperative HEs:

Figure 24. Example local BVU: Lunos Nexxt

Source: https://www.lunos.de/en/product/nexxt-en/

Fan type	: 2x centrifugal
Wall ducts	: 1x D=160 mm
Max flowrate	: 110 [m^3/h]
SPI	: 0.29 [$W/m^3/h$]
Heat exchanger type	: recuperative enthalpy (i.e. moisture is transferred)
Temperature efficiency	: counterflow :73% and crossflow 62% @75 [m^3/h]
Size	: w x h x d = 480 x 480 x 170 mm
Sound power level	: 49 dB(A) @ reference flowrate of 75 [m^3/h]
Internal & external leakage	: 2%
Mixing rate	: 2%
Airflow sensitivity	: 0%
Indoor/outdoor airtightness	: 1 m3/h
Filters	: M5, F7 or F9
List price excl. VAT	: around 1000 euro

Measurements according EU 1254/2014

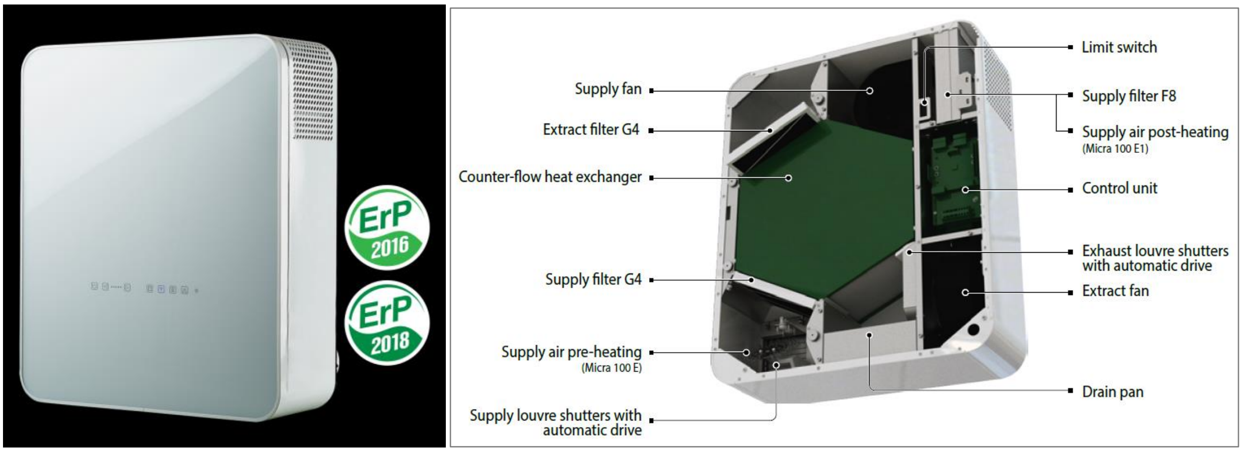


Figure 25. Example local BVU: VENTS Micra 1000

Source: https://ventilation-system.com/de/series/micra-100

Fan type : 2x centrifugal
Motor type : EC (electronically commutated)
Wall ducts : 2x D=100 mm
Max flowrate : 100 [m^3/h]
SPI : 0.483 [$W/m^3/h$]
Heat exchanger type : recuperative, optional enthalpy
Temperature efficiency : counterflow recuperative :92% @ …[m^3/h]?
Dimensions : w x h x d = 550 x 650 x 200 mm :
Sound power level : 47 dB(A) @ reference flowrate
Internal & external leakage : 1%
Mixing rate : 20%
Airflow sensitivity : 7%
Indoor/outdoor airtightness : 7 m3/h
Filters : G4 or F8
List price excl. VAT : around 1000 euro? (no internet supplier found)

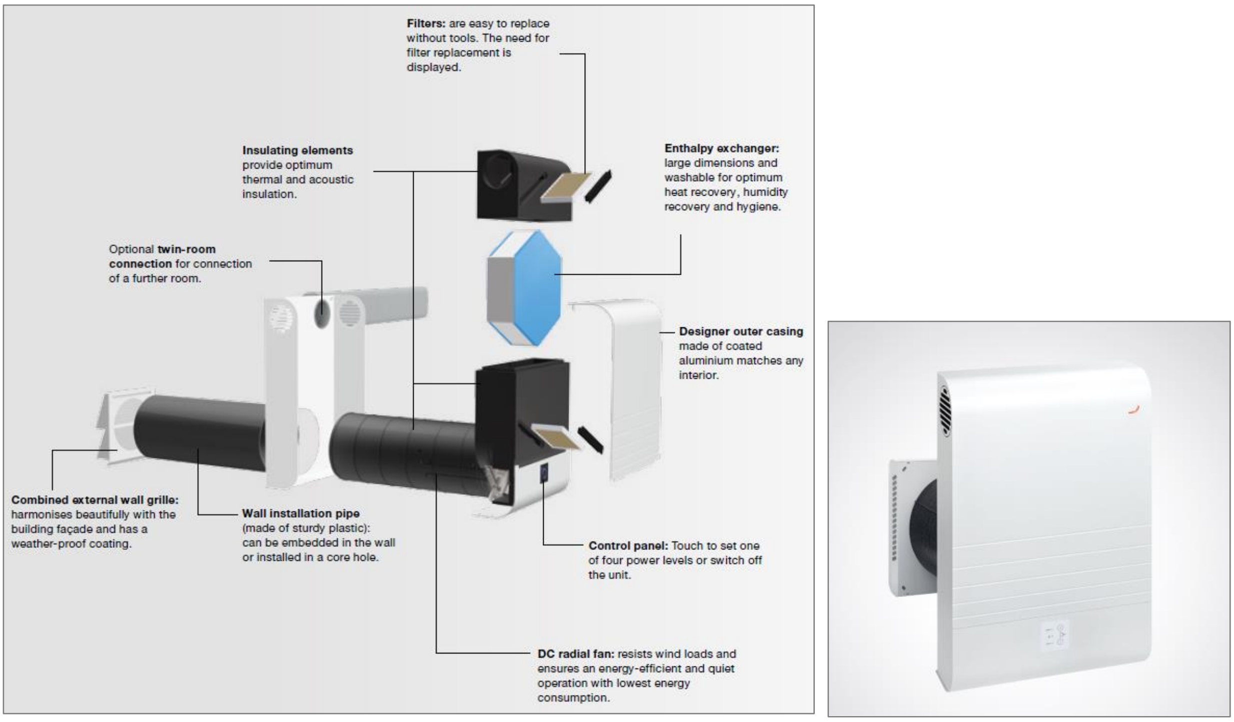


Figure 26. Example local BVU: Zehnder ComfoAir 70

Source: https://www.international.zehnder-systems.com/products-and-systems/comfosystems/zehnder-comfoair-70

Fan type	: 2x radial
Motor type	: EC
Wall ducts	: 1x D=250 mm
Max flowrate	: 60 [m^3/h]
SPI	: 0.21 [W/m^3/h]
Heat exchanger type	: enthalpy
Temperature efficiency	: counterflow recuperative :76% @ 42[m^3/h]?
Dimensions	: w x h x d = 660 x 440 x 141 mm :
Sound power level	: 47 dB(A) @ reference flowrate
Internal & external leakage	: 1%
Mixing rate	: Class U1
Airflow sensitivity	: <10%
Indoor/outdoor airtightness	: 5 and 7 m3/h
Filters	: G4 or F7
List price excl. VAT	: around 1200 euro

2.5.4 Non-ducted local BVUs with regenerative heat exchanger

The non-ducted local BVU with a regenerative heat exchanger is a relatively new type of product. Because of that and because this product is becoming quite popular in certain countries, a separate chapter (Chapter 3) is dedicated to this this product type.

3. Non-ducted alternating local BVUs

Another version of the non-ducted local BVU concerns the alternating BVU using a single fan and a regenerative heat exchanger. These products are on the market since the beginning of this century, and - when looking at their sales development in certain countries – are becoming quite favourable.
As indicated, they consist of a regenerative heat exchanger, one fans, controls, one wall ducts and an opening on both the indoor- and outdoor side, which is alternately used as air inlet or outlet. Several manufactures nowadays have such units in their product portfolio.

Alternating local BVUs are used to provide ventilation for living rooms and bedrooms. An integrated thermal accumulator in combination with and reversible fan are used for heat recovery purposes. The integrated thermal accumulator charges itself with heat energy from the room's air as it flows to the exterior (extract air). After 70 seconds, the fan changes direction and the stored heat energy is transferred to the incoming outside air (supply air). For this principle to work correctly and to ensure the room's pressure stability the incoming air and extract air volumes must match, indicating that two units are required operating in sync: one ventilation unit works in supply air mode while the other works in extract air mode at the same time. These decentralized ventilation systems are based on the free movement of air between individual pairs of ventilation units. Therefore, internal doors must not have air-tight seals. Adequate air transfer measures are required (an air gap of about 10 mm below the door, a ventilation grille or similar, etc.)

The benefits of these units mainly include the ease-of installation (no ductwork through the building is needed) and - compared to the recuperative BVUs - even lower total acquisition costs due to the fact that the product is even smaller and uses less components (one fan, one flow path). Also, for this product type there is the benefit that – with the right sensors - flowrates can be controlled per individual room.
These products also have some noteworthy disadvantages, however. These issues again, mainly relate to noise production at elevated flowrates and the compromises that are needed in terms of product specs to keep the units small and less obtrusive. Heat exchangers, fan, filters and airflow openings are mostly smaller than preferred.
Another issue relates to the possible recirculation of air, not only between the two units of a pair of alternating BVUs, but also in a single unit: i.e. a part of the used air that is exhausted could be pulled in again, and alternatively a part of the fresh supplied air can be pulled out again. This recirculation affects the ventilation effectiveness.
Finally, because many of these products use small axial fans, their flowrates are susceptible to pressure differences / wind load over the façade, which can seriously affect the overall heat recovery efficiency and ventilation performance. For these reasons, the *indoor/outdoor airtightness*, the *airflow sensitivity* and the *exhaust- and supply air transfer ratios* are important parameters and their values need to be determined according to the related standard (FprEN13141-8). With these values, corrections are to be made on the overall average temperature efficiency of the unit and on its ventilation performance.

The followings section gives some examples of these alternating BVUs together with their technical specifications. The subsequent paragraph discusses some of the tests and monitoring studies that were performed on these units. For many of these products test data regarding *indoor/outdoor airtightness*, *airflow sensitivity* and the *exhaust- and supply air transfer ratios* are not available. Main reason for this probably is that the related standard FprEN13141-8 is not approved and applicable yet.

3.1 Examples of alternating non-ducted BVUs

Some examples of non-ducted local alternating BVUs with regenerative heat exchangers and their technical specifications are presented in this section.

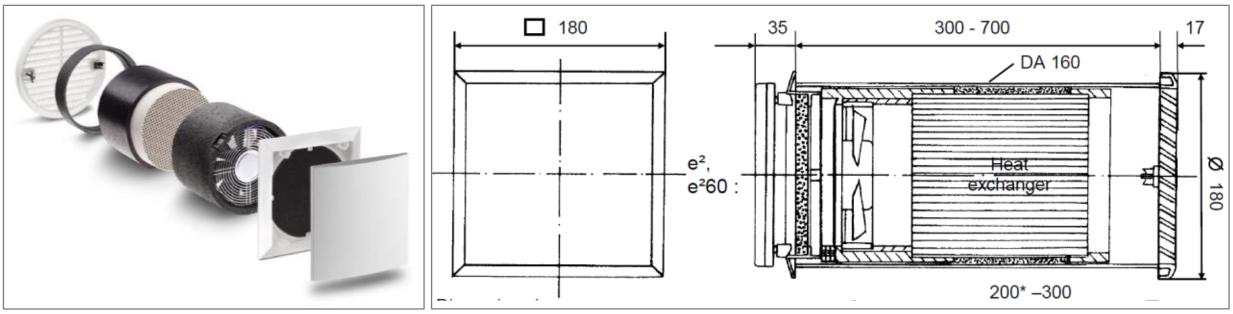


Figure 27. Example local alternating BVU: Lunos e^2

Source: https://www.lunos.de/en/product/

Decentralised ventilation devices with heat recovery of the type e² only function in pairs. One device operates 70 s (50s for e² short) in supply air operation, the other 70 s (50 s for e²short) in exhaust air operation at the corresponding airflow level as set. Then the air direction is changed. It is thus ensured that the total of the airflow volume supplied is equal to the total exhaust airflow volume. If a device pair operating in alternating (or push-pull) mode is installed and operated in two different rooms of an apartment, a sufficiently dimensioned interconnection between the air movement must be provided by excess flow air vent. If a pair of devices is installed in one room, the minimum distances as indicated below are recommended.

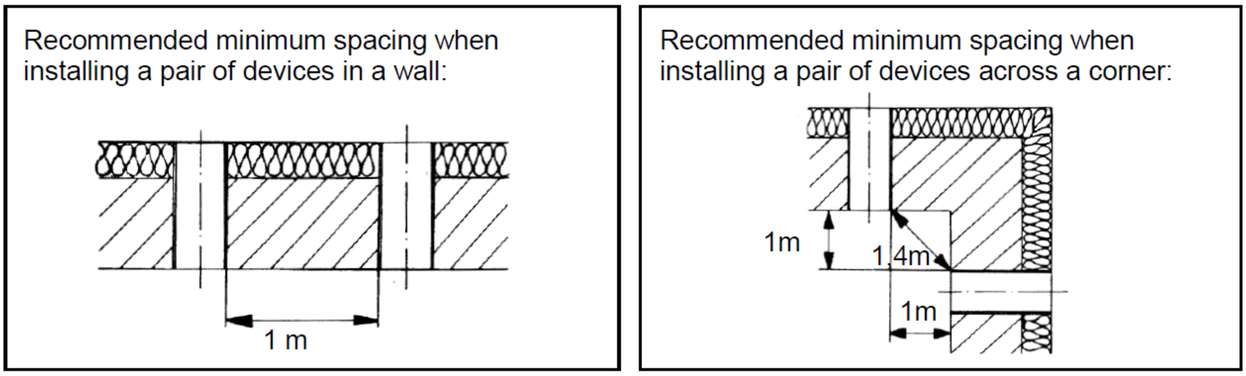


Figure 28. Recommended spacing between a pair of Lunos e^2 units

<u>Produktdatenblatt Lunos e^2 (gem.VO 1254/2014 vom 11 juli 2014, ref. E222 12.19)</u>

Fan type	: 1x axial (ebm-papst)
Motor type	: 12 V DC
Wall ducts	: 1x D=160 mm
Max flowrate	: 38 [m^3/h] (figure relates to a pair of devices)
SPI	: 0.21 [W/m^3/h]
Heat exchanger type	: regenerative with humidity recovery
Temperature efficiency	: 85% @ 26.6 [m^3/h]
Dimensions	: inner cover w x h x d = 180 x 180 x 35 mm
Sound power level	: 40 dB(A) @ reference flowrate (@26.6 [m^3/h])
Internal & external leakage	: 0%
Mixing rate	: 0%
Airflow sensitivity	: 53%
Indoor/outdoor airtightness	: 3.9 m3/h

Filters	: G3
List price per pair	: around 1000 euro (excl. VAT and excl. installation cost)

Figure 29. Example local alternating BVU: Korasmart Tube 2400

Source: https://www.korado.com/products/local-ventilation-units/korasmart-tube-2400-and-2400e.html

Fan type	: 1x axial
Motor type	: ?
Wall ducts	: 1x D= 160 mm
Max flowrate	: 45 [m^3/h] (figure relates to a pair of devices)
SPI	: 0.18 [W/m^3/h]
Heat exchanger type	: regenerative
Temperature efficiency	: 81% @ 32[m^3/h]
Dimensions	: inner cover w x h x d = 279 x 279 x 63 mm
Sound power level	: 46 dB(A) @ reference flowrate (@32 [m^3/h])
Internal & external leakage	: -
Mixing rate	: -
Airflow sensitivity	: +32% / -42%
Indoor/outdoor airtightness	: +2.7 / -1.2 m3/h
Filters	: G3
List price per pair	: around 900 euro (excl. VAT and excl. installation cost)

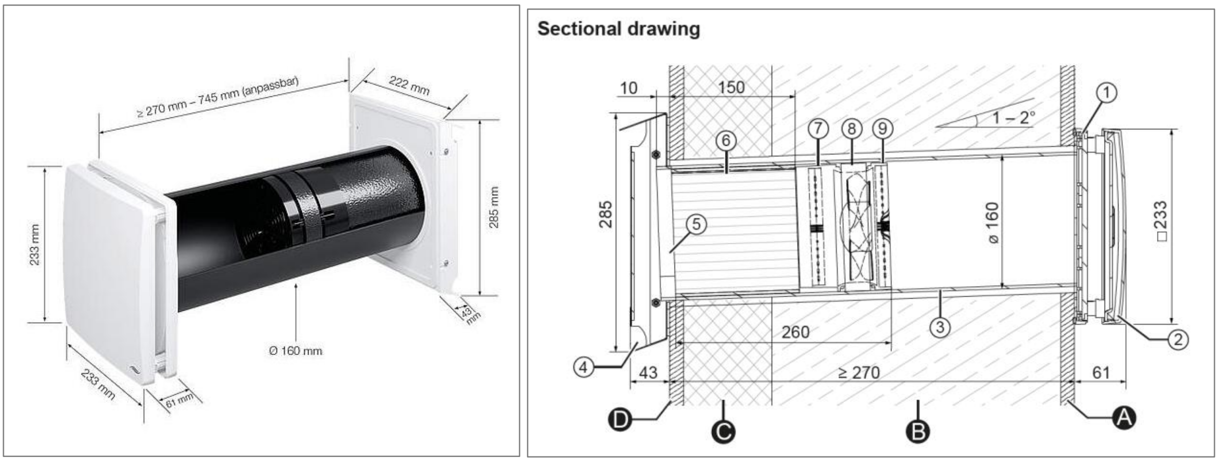


Figure 30. Example local alternating BVU: inVENTer iV-Smart+

Source: https://www.inventer.eu/products/ventilation-units/inventer-iv-smart/

Fan type	: 1x axial
Motor type	: 24V DC
Wall ducts	: 1x D= 160 mm
Max flowrate	: 58 [m^3/h] (figure relates to a pair of devices)

SPI	: 0.15 [W/m^3/h]
Heat exchanger type	: regenerative
Temperature efficiency	: 87% @ 42[m^3/h]
Dimensions	: inner cover w x h x d = 233 x 215 x 61 mm
Sound power level	: 46 dB(A) @ reference flowrate (@32 [m^3/h])
Internal & external leakage	: -
Mixing rate	: -
Airflow sensitivity	: 29.4%
Indoor/outdoor airtightness	: 6.3 m3/h
Filters	: G3
List price per pair	: around 1000 euro (excl. VAT and excl. installation cost)

3.2 Monitoring & simulation studies alternating BVU

Various studies have been carried in the last couple of year to gain more knowledge and information regarding the actual performance of these alternating BVUs. The important studies are summarized below.

3.2.1 Impact of pressure conditions on performance alternating BVU

A recent paper in *Energies* (https://www.mdpi.com/1996-1073/12/13/2633/htm), describes the result of a study into 'The impact of air pressure conditions on the performance of single room ventilation units in multi-story buildings'[10] .

In Estonia, multi-story apartment buildings constitute about 60% of the whole dwelling stock, and the majority (75%) of the buildings were built primarily in 1961–1990. Part of the building stock built before the 1990s has already been renovated but for many apartment buildings this process is yet to start.
Typical multi-story apartment buildings have been built with natural ventilation, where fresh outdoor air enters through leaks or openings of the windows and doors, mixes with the warm room air, and leaves the building through shafts in the bathroom and kitchen. With retrofitting the building envelope, in order to achieve necessary thermal insulation for reducing the energy consumption for space heating, the air tightness of the building increases and the air flow through cracks and leaks is reduced. As a result, the air changes through natural ventilation decrease and the required air ventilation rates are no longer achieved. Several analyses on the performance of ventilation in old Estonian dwellings show that the average indoor air CO_2-concentrations in occupied periods is above 1200 ppm which means the air change rate is too low to ensure good indoor air quality. With the renovation of old apartment buildings, the improvement of ventilation is therefore unavoidable in order to provide healthy indoor environment for the occupants.

Single room ventilation units with heat recovery is one of the ventilation solutions that have been used in renovated residential buildings in Estonia. In multi-story buildings, especially in a cold climate, the performance of units is affected by the stack effect and wind-induced pressure differences between the indoor and the outdoor air. Renovation of the building envelope improves air tightness and the impact of the pressure conditions is amplified. The aim of this study was to predict the air pressure conditions in typical renovated multi-story apartment buildings and to analyse the performance of room-based ventilation units. The field measurements of air pressure differences in a renovated 5-story apartment building during the winter season were conducted and the results were used to simulate whole-year pressure conditions with IDA-ICE software. Performance of two types of single room ventilation units

[10] Mikola, A., Simson, R., Kurnitski, J., The impact of air pressure conditions on the performance of single room ventilation units in multi-story buildings, Energies 2019, 12, 2633, July 2019.

were measured in the laboratory and their suitability as ventilation renovation solutions was assessed with simulations.

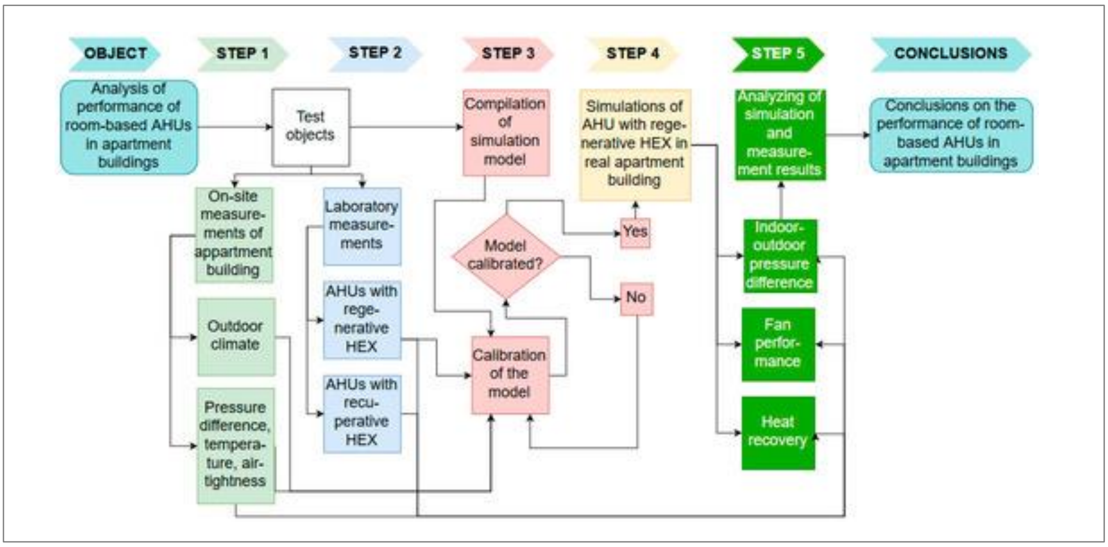


Figure 31. Flow chart of the studies that were performed

Source: Mikola, A., Simson, R., Kurnitski, J. (see footnote)

<u>Results field measurements</u>

The results of field measurements showed that the pressure difference across the building envelope was negative during the entire measurement period in the first-floor apartment and mostly negative in the fifth-floor apartment (see Figure 33 left).

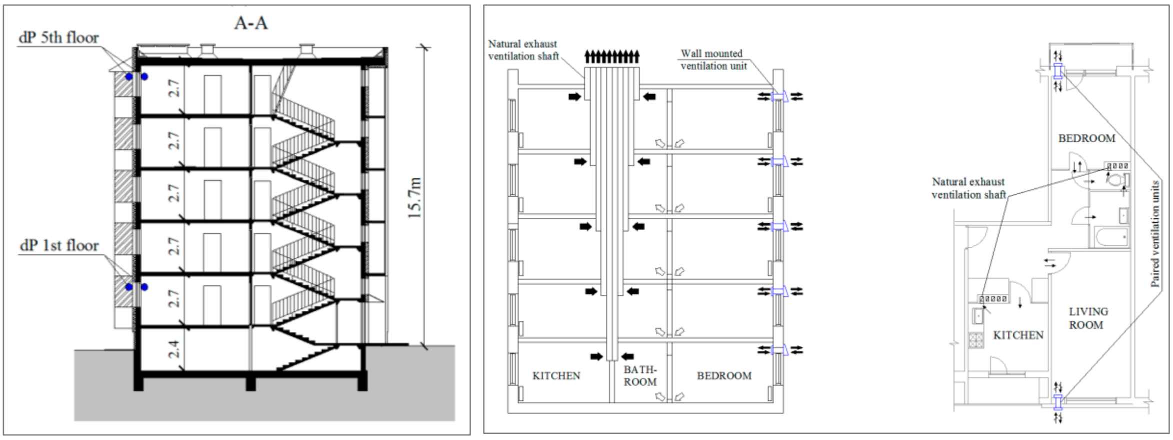


Figure 32. Cross section & measurement points (left); principle of ventilation system (right)

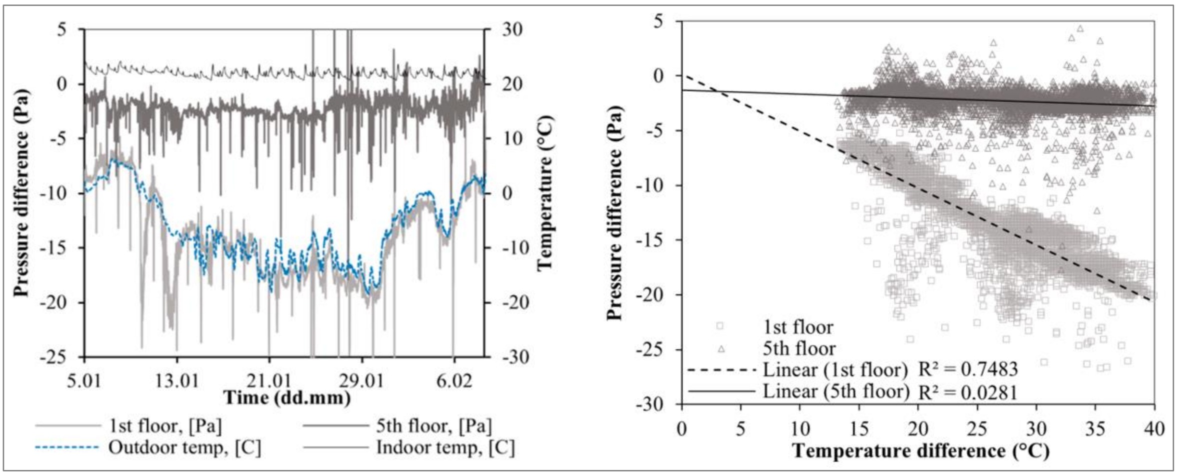


Figure 33. Left: measured indoor & outdoor pressure differences and indoor/outdoor temperature. Right: Relation pressure conditions and indoor/outdoor Temp-difference.
Source: Mikola, A., Simson, R., Kurnitski, J. (see footnote)

Occasional peaks toward zero-pressure difference are most likely caused by using the cooker hood, opening the windows or external doors to the balcony or staircase, the peaks and periods toward greater difference indicate the wind-induced effect. Pressure difference caused by wind can be dominant also for longer periods. The results indicate that the pressure difference is mostly caused by the stack effect being strongly dependent on the outdoor temperature in the bottom floor apartment, whereas on the top floor the dependence is weak due to the reduced height of the shaft (see Figure 32 right). The measured indoor temperature during the measurement period in both apartments was roughly between 20 and 22 °C. The dependence between the indoor and outdoor pressure and temperature is shown in Figure 33 on the right.

Results Laboratory Measurements
Based on the results of laboratory measurements the fan performance and HEX temperature efficiency of the alternating BVUs were studied. The measurement results of the performance of the unit are shown in Figure 34. In the beginning of the tests the value of under pressure in the room was −2 Pa which means that supply and extract airflows were more or less equal. After the pressure difference increased the extract air flow decreased and supply airflow increased at the same time. As results indicate, the supply and extract airflows are equal only at very low pressure differences. The greater the difference, the more the air flows differ. It can be seen that in case of 75% fan power, with differential pressure over −20 Pa the extract airflow is close to zero and the supply airflow around 60 m3/h (Figure 34 left). The supply–exhaust cycles, which are presented in Figure 34 on the right, show a quick drop of the supply air temperature after the cycle change. During the tests, the outdoor air temperature was close to −5 °C. If the supply and extract airflows are equal, the supply air temperature was about 7 °C but if the pressure difference was increased from 0 Pa–20 Pa in test room, the supply air temperature at the end of the supply working cycle was about −2 °C.

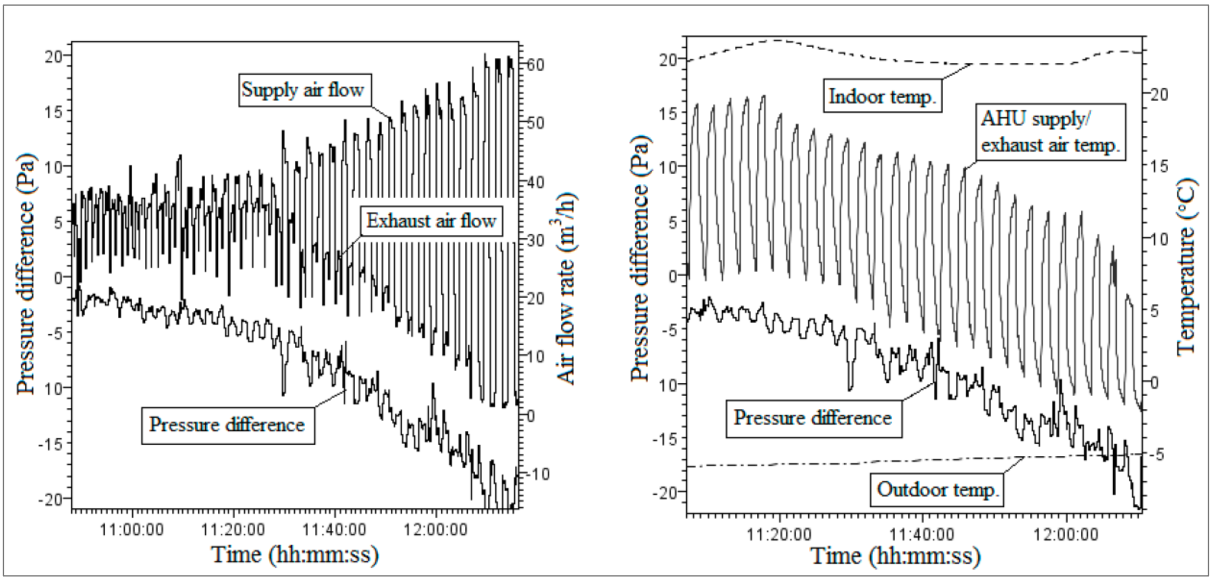


Figure 34. Measured airflows and temperatures of alternating BVU

Source: Mikola, A., Simson, R., Kurnitski, J. (see footnote)

The fan performance curves were constructed for the fan speed levels of 25%, 50%, 75%, and 100% (see Figure 35 left). The fan performance curves show how the supply and extract airflows of the ventilation units are related to the in-and outdoor pressure difference. It is also possible to present how the pressure difference is related to the temperature efficiency of studied ventilation units (see Figure 35 right). The results indicate that if the pressure difference rises, the temperature efficiency decreases. The same trend appears for all tested fan speeds. For example, in case the 50% speed level, the temperature efficiency is over 0.5 if the pressure difference is smaller than 4 Pa.

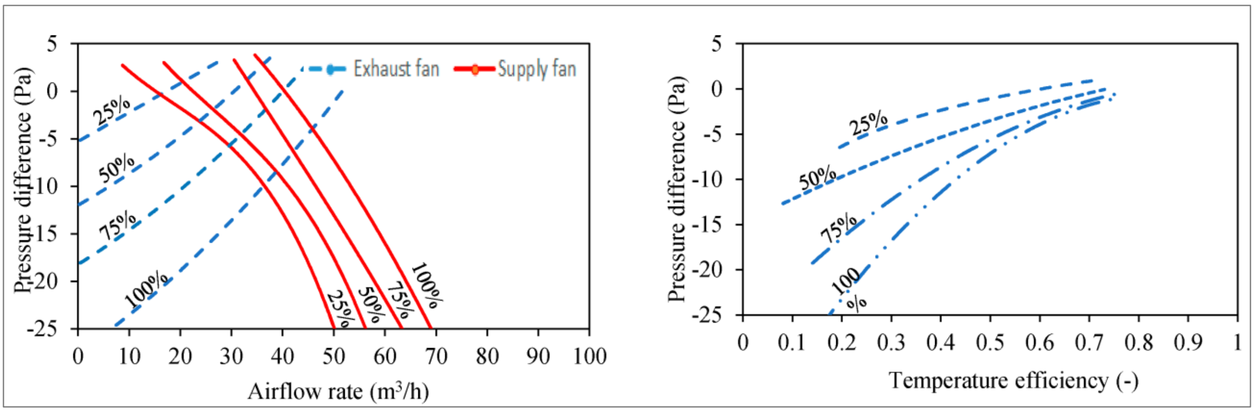


Figure 35. measured performance curves and temperature efficiencies of alternating BVU with axial fan and regenerative heat exchanger

Source: Mikola, A., Simson, R., Kurnitski, J. (see footnote)

To compare these results with the other type local BVUs (the ones with two centrifugal fans and a recuperative HEX), fan performance curves and temperature efficiency graphs were also constructed for this type of unit.
Again, the fan performance curves were established for the fan speed levels 25%, 50%, 75%, and 100%. Compared to the ventilation units with regenerative HEX, the units with recuperative heat exchanger perform adequately in case of higher pressure differences between indoor and outdoor air. However, if the pressure difference is −20 Pa at fan speed level 50%, the airflow balance is also compromised (supply airflow is about 15% higher than exhaust airflow). The temperature efficiency of ventilation units with recuperative HEX is

presented in Figure 36 on the right-hand side. Compared to units with regenerative HEX, the temperature efficiency of studied ventilation units is significantly better at higher pressure difference conditions. The pressure difference influences the temperature efficiency the most in lower fan speed levels.

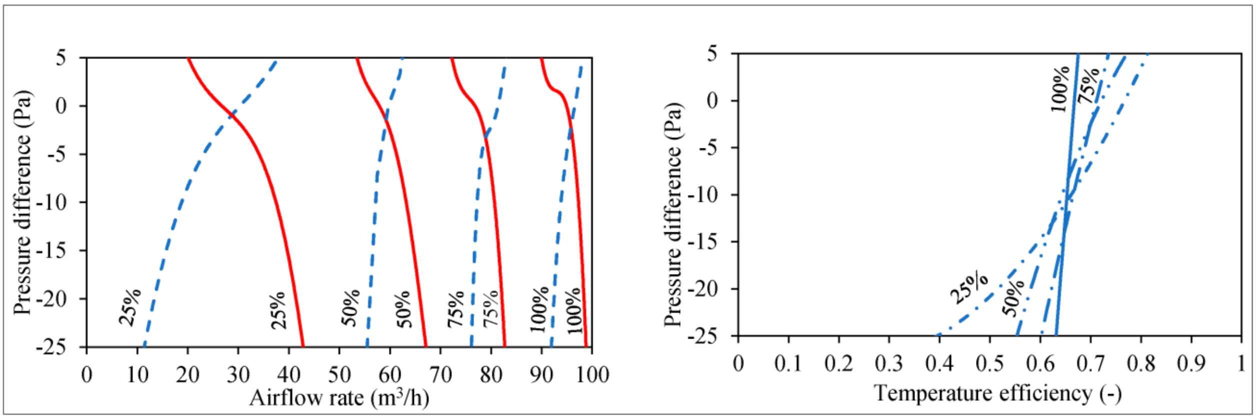


Figure 36. measured performance curves and temperature efficiencies of BVU with two centrifugal fans and recuperative heat exchanger

Source: Mikola, A., Simson, R., Kurnitski, J. (see footnote)

The performance curves of both BVU-types illustrate that – even at 0 pascal pressure difference - the airflow balance differs for each fan speed. With higher delta P, the airflow balance progressively deteriorates particularly for the alternating units, leading to considerable reductions of the heat recovery efficiency and thermal comfort.

The paper finally concludes that test results show, that in cold periods, apartments in the first floor can be under negative pressure as high as −20 Pa for longer periods of time. In ventilation system planning, values of −10 Pa in fifth floor, −15 Pa in third floor and −20 Pa in first floor apartments can be recommended to be used as design values for ventilation units. The simulation results of single room units with regenerative HEX show that during heating season, supply air temperature was close to the outdoor temperature and that supply airflow rate was much higher than exhaust airflow rate, showing that the unit operated as air intake. Due to the differences in supply and exhaust airflows, there is a risk for freezing the heat exchanger, which excludes using studied ventilation units in rooms with high humidity. The laboratory measurement results confirmed, that the axial fan used in the ventilation unit was not capable to work in typical pressure conditions occurring in multi-story building in cold periods, in order to achieve sufficient air change rate, heat recovery and supply air temperature, with noise levels under acceptable limits. In the case of the unit with recuperative HEX and centrifugal fans, under the same circumstances, the temperature efficiency of the unit remained higher than 0.5 even under negative pressure as high as−25 Pa, making it possible to use the device in first floor apartments.

3.2.2 Project EwWalt

In the project 'EwWalt'[11] (Energetische Bewertung dezentraler Einrichtungen für die kontrollierte Wohnraumlüftung mit alternierender Betriebsweise), some of the gaps in knowledge concerning the performance of these alternating units are further addressed.

[11] Mathis, P., Röder, T., Klein, B., Hartmann, T., Knaus, C., EwWalt - Energetische Bewertung dezentraler Einrichtungen für die kontrollierte Wohnraumlüftung mit alternierender Betriebsweise, TGA-Report Nr. 6, Veröffentlicht: 03/2019, Bestell-Nr.: 335

Topics like system design, sensitivity to pressure differences, characteristic heat recovery performance, ventilation effectiveness and appropriate test standards, are further investigated in this study that is performed under the supervision of RWTH Aachen, with contributions from HLK Stuttgart and ITG Dresden.

System designs

Various system designs were simulated using CFD-calculations. For both apartment buildings and single-family dwellings, different system designs were evaluated, all within the preconditions stipulated in the DIN 1946-6:2009.

Building:

- New built (insulation values according to DIN 1946)
- Airtightness: n50 = 1
- Wind conditions: weak winds
- Wind shielding correction factor: ε_A = 1.00
- Correction factor for height: ε_H = 1.00

Ventilation units

- Basis is 'Nennlüftung'
- Max. airflow for a pair of alternating BVUs is 45 m3/h
- Alternating BVUs may only be applied in pairs (electronically connected)
- In kitchens and bathrooms on external facade, twin-units are applied (= a pair of alternating BVUs)
- In internal bathrooms, extraction UVUs are applied with max. airflow of 60 m3/h
- Overflow components in internal doors to allow airflow between rooms
- Alternating BVUs are placed at the height of the window lintel, 30 cm distance from a window, opposite of the internal door

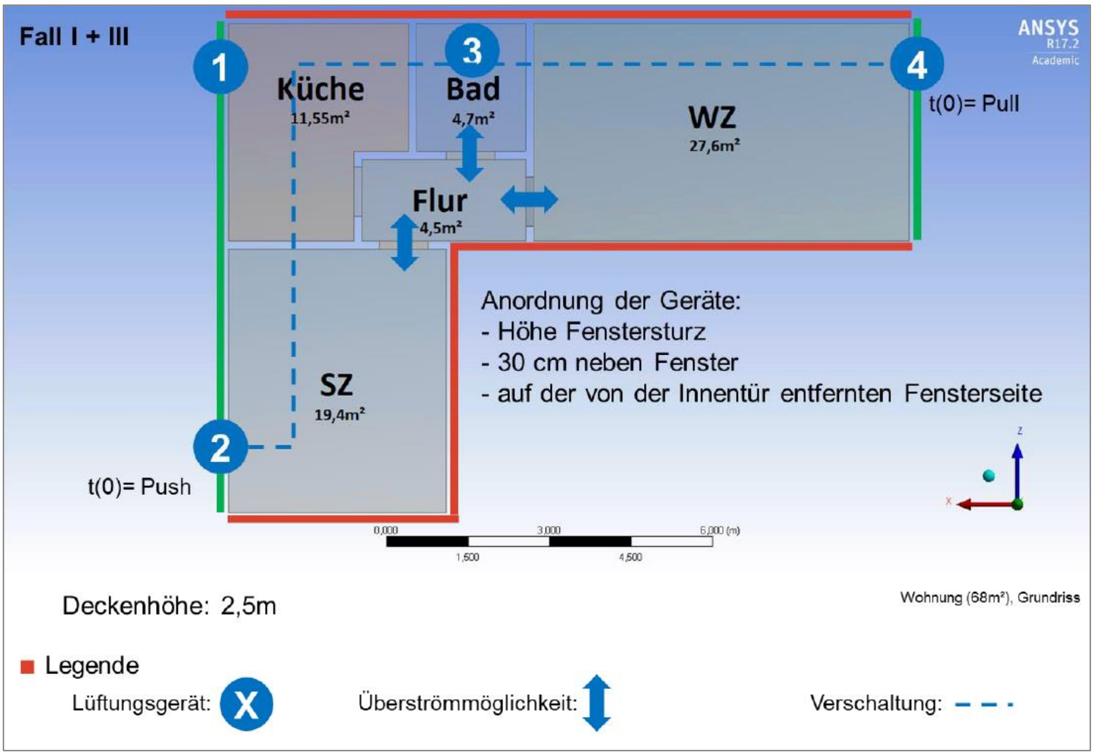


Figure 37. System design Case I and III for an apartment: Alternating BVU No. 2 and 4 are connected (a pair) and require an overflow between SZ (bedroom) and WZ (living room), No. 1 is a twin-unit and No.3 is an extract UVU which also requires an overflow.

Source: Mathis, P., Röder, T., Klein, B., Hartmann, T., Knaus, C.: EwWalt Study

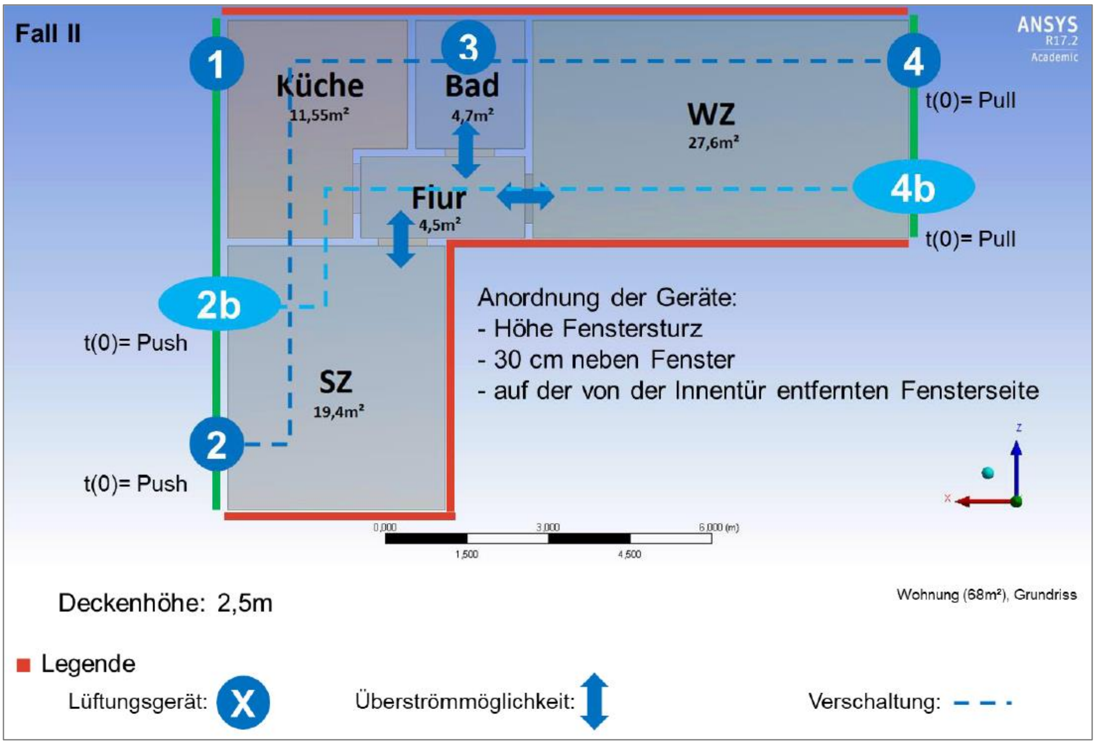


Figure 38. System design Case II for an apartment: Alternating BVUs No. 2 & 2b and 4 and 4b are connected (a pair in both habitable spaces), No. 1 is a twin-unit and No.3 is an extract UVU which requires an overflow.

Source: Mathis, P., Röder, T., Klein, B., Hartmann, T., Knaus, C.: EwWalt Study

Ventilation effectiveness

Comprehensive CFD-calculations were performed for the various system designs under various conditions (varying indoor/outdoor temperatures, wind pressures, bathroom extraction flowrates, and cycle-times) to simulate the airflows and related *air exchange effectiveness* in the various rooms.

This air exchange effectiveness (ε^a) represents the ratio between shortest possible time needed for replacing the air in the room (τ_n) and the average time actually needed for the air in the room to be exchanged (τ_{exe}):

The average time for air exchange can be calculated as $\tau_{exe} = 2 \cdot \langle\tau\rangle$, where $\langle\tau\rangle$ represents the average of local values of age of air. The shortest possible time needed for replacing the air in the room (τ_n) is a reciprocal value of the number of air changes in the room (τ_n = $1/n_{AC}$). Table 6 presents the air exchange efficiency values for characteristic flow types.

Table 6. Air Exchange Effectiveness for characteristic room ventilation flow types

Flow pattern	Air exchange efficiency	Comparison with the average time of exchange
Unidirectional flow	0.5 - 1.0	$\tau_n < \tau_{exc} < 2\tau_n$
Perfect mixing	0.5	$\tau_{exc} = 2\tau_n$
Short Circuiting	0 - 0.5	$\tau_{exc} > 2\tau_n$

The CFD-calculations indicate that, irrespective of the various conditions, the air exchange effectiveness of the various system designs with alternating BVUs is on average predominantly around 0.5. Due to the an-isothermal airflow coming from the alternating BVUs, the mixing of the supply airflow is enhanced (similar to recuperative BVUs). The spread around this mean is somewhat bigger though for alternating units.

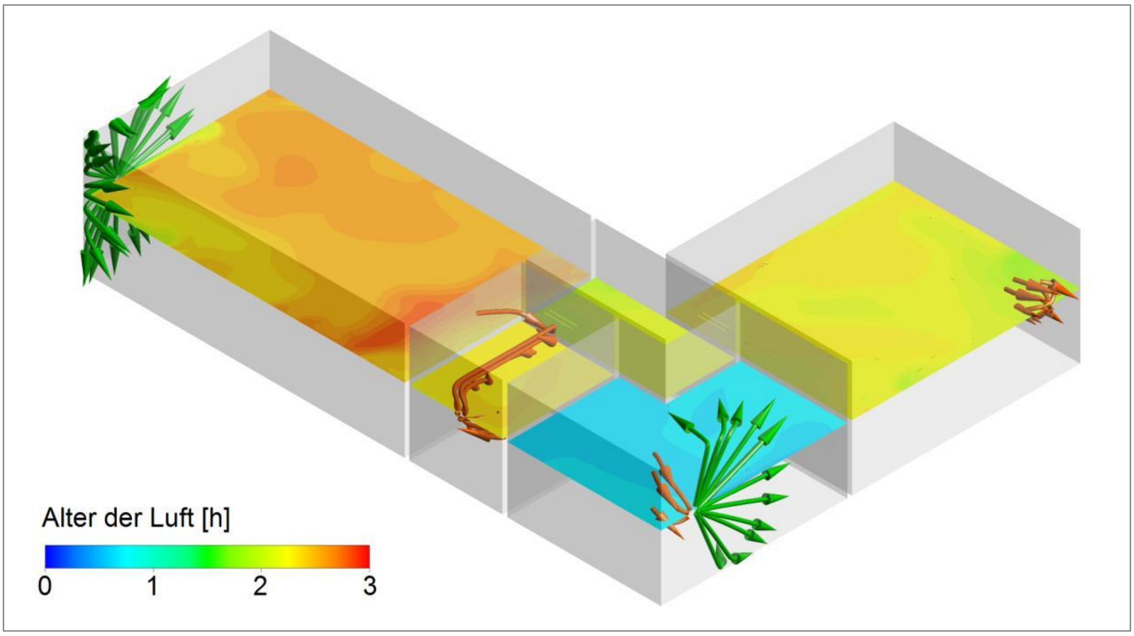


Figure 39. Example plot of a simulation of the age of the air in the various rooms with active extract ventilation according 'Nennlüftung'

Source: Mathis, P., Röder, T., Klein, B., Hartmann, T., Knaus, C.: EwWalt Study

Conditions that have the strongest influence on the magnitude of these variations are wind pressure and airtightness of the dwelling.

Sensitivity to pressure differences

In the EwWalt project the airflow characteristics of three different alternating BVUs (appliance A, B and C) were measured according FprEN 13141-8. The maximum flowrates measured were 28 m3/h for appliance A, 23 m3/h for B and 30 m3/h for appliance C. Their respective airflow sensitivity (to pressure differences) are given in the graphs below.

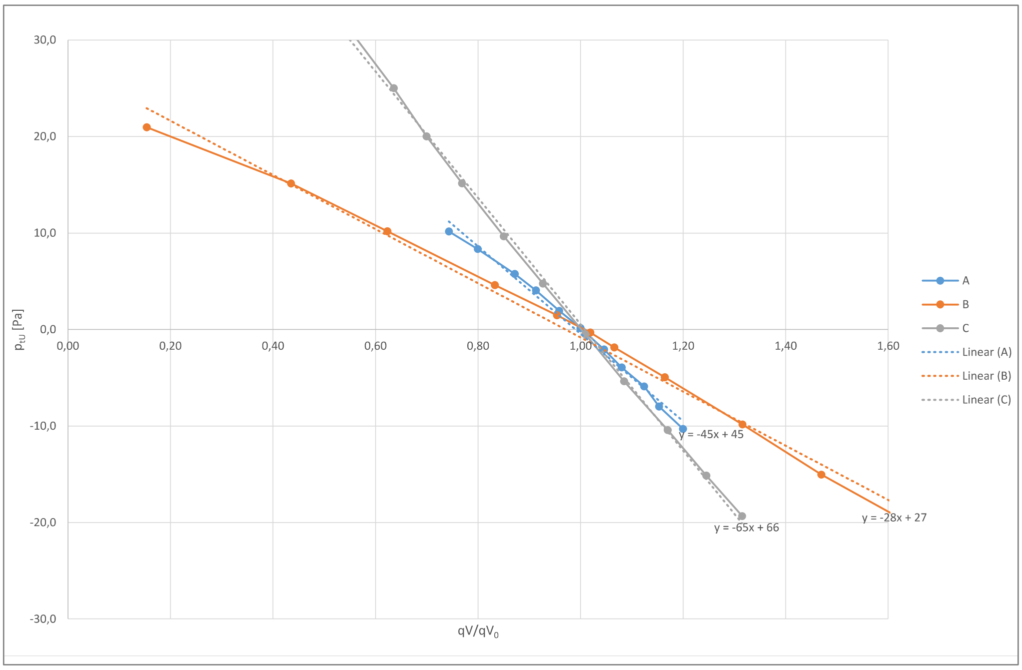


Figure 40. Maximum airflow characteristics (qv,max) of alternating BVUs A, B and C

Source: Mathis, P., Röder, T., Klein, B., Hartmann, T., Knaus, C.: EwWalt Study

Appliance B (red line) is the most sensitive to pressure differences. At 10 Pa the maximum airflow against the pressure is reduced with 38% and with pressure increased with around 32%. Appliance C is the less pressure sensitive: at +10 Pa the maximum airflow against the pressure is reduced with 15% and with the pressure, increased Pa with around 17%.

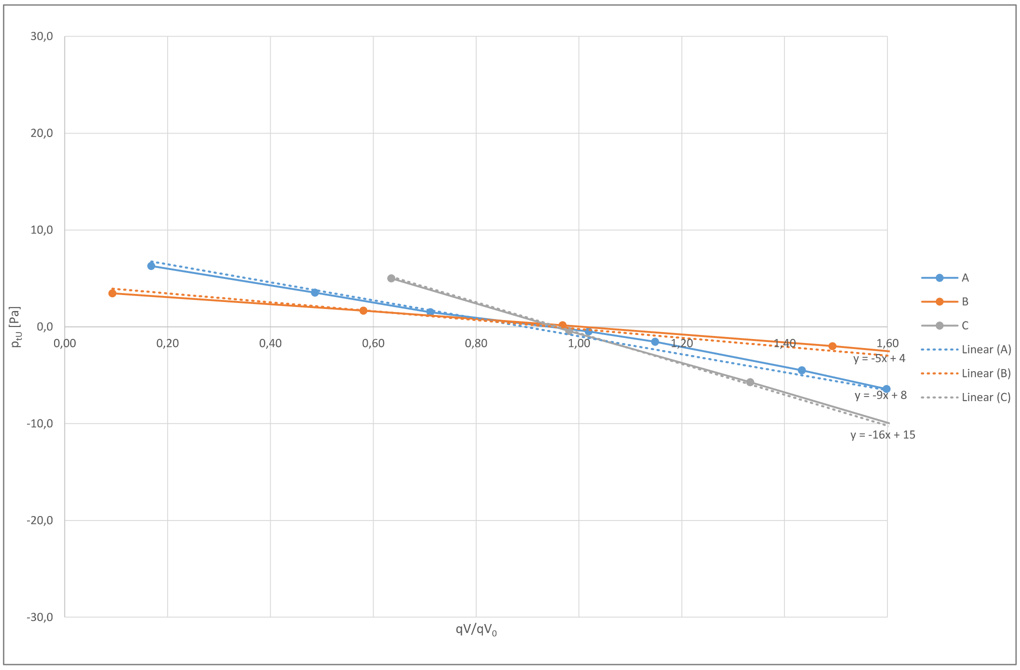


Figure 41. Minimum airflow characteristics (qv,min) of alternating BVUs A, B and C

Source: Mathis, P., Röder, T., Klein, B., Hartmann, T., Knaus, C.: EwWalt Study

Also, at minimum airflow appliance B (red line) is the most sensitive to pressure differences. At +5 Pa the minimum airflow is reduced with 90% and at -5 Pa with around 80%. Appliance

C is the less pressure sensitive: at +5 Pa the minimum airflow is reduced with 35% and at -5 Pa with around 30%.

This means that the sensitivity to pressure differences is high, especially at lower flowrates, indicating that the heat recovery function is severely compromised. For dwellings with alternating BVUs on opposite sides of the dwelling, a high airflow sensitivity will have only limited effects on the total air exchange airflows, due to cross ventilation. But for dwellings with alternating BVUs on only one pressure side of the dwelling, the consequences will be considerably bigger because cross ventilation is not applicable.

Heat recovery & test standards

In the EwWalt project, heat recovery measurements according to the direct method (following an older version of the EN 13141-8) were compared to HR measurements according to the indirect (or purge-air) method (following the DIBt). There are also differences in the applicability of both methods (see table below).

Table 7. Applicability of test methods

	Direct method (EN13141-8:2018)	Indirect method (DIBt)
Independent of appliance properties	-	+
Exhaust air temperature efficiency	+	+
Temperature efficiency humid air	+	+
Humidity transfer efficiency	-	+
Applicable to recuperative BVUs	O	+

The comparative measurement results show that that the temperature efficiency figures are higher (too high?) and less accurate (due to inhomogeneous supply airflow) when the direct method is used. The differences between the two methods are around 6% for the supply air temperature ratio and around 10% for the exhaust air temperature ratio.
In the new prEN 13141-8 adjustments will be made regarding the testing of heat recovery for alternating units and the purge air method (indirect method) will be used.

3.2.3 Overall valuation alternating BVUs

As regards the air exchange effectiveness, alternating BVUs can successfully deployed, as long as they are installed in pairs and - in case buildings suffer from prevailing increased pressure differences over the building -, the units can be installed on both pressure sides of the building.
In case only one pressure side of a building can be used for installing alternating BVUs, an increased pressure difference over this facade will influence the air exchange effectiveness, especially in cases where the supply airflow is compromised (i.e. ε^a will become lower than 0.5). In addition, requested ventilation rates may not always be achieved.

In a way, alternating BVUs can be considered a hybrid solution, combining properties of passive pressure-controlled ventilation grids with characteristics of fans driven recuperative BVUs. When there is no or minimal pressure difference over the façade holding the alternating BVUs, they will function as intended both in terms of air exchange effectiveness and heat recovery.
When the pressure difference over the façade increases, the units on one pressure side of the building will have higher supply airflow and lower exhaust airflows, while the units on the other pressure side of the building have the opposite. Due to cross ventilation the air exchange

effectiveness remains, but the heat recovery function is compromised. Under such conditions, alternating BVUs show similarities with passive pressure-controlled ventilation grids that also rely on cross ventilation when pressure differences over the facades of the building increases.

As regards basic ventilation (Feuchteschutzlüftung) and Nennlüfting (when considered over the whole building and when related to airtight buildings), the use of sensor controlled alternating BVUs represent a considerable improvement compared to window ventilation (Fensterlüftung), mainly because manual operation (of windows) is no longer requested and comfort issues are reduced. And in addition, some heat is also recovered.

But when targeted room-based ventilation airflow rates are pursued, following EN16798-1 and related airflow rates belonging to IAQ-category I or II during *presence* and basic ventilation rates during *absence*, alternating BVUs will find difficulties meeting these requirements for the following reasons:

- Pressure differences can strongly influence the supply airflow rate. Many factors can disturb the preferred zero pressure difference between inside and outside and with it, the requested supply airflow, amongst which: wind load building/facade, temperature gradient of the air, temperature difference (between inside and outside), use of a chimney (open fire, passive stack), etc.
- In the case alternating BVUs are installed on both pressure sides of the building, the supply air in a room may result from cross ventilation, in which case the position of the internal doors, the airtightness of the building, and the operating modes of the other BVUs will have an influence.
- In the case alternating units are only installed on one pressure side, supply airflows will either be too big or too small.
- To achieve IAQ class I or II airflow rates during presence, a pair of BVUs needs to be installed in each and every habitable room. Following EN16798-1, a parent bedroom for instance requires 70 to 50 m3/h of airflow respectively during presence (to keep CO_2-levels below limit values), implying that the bedroom requires a pair of alternating BVUs operating at maximum airflow rates, producing around 46 dB(A) of noise. Provided that pressure differences are limited and the supply airflow rates are actually achieved, noise production could become an obstacle for achieving class I or II airflow rates.
- The airflow sensitivity of the alternating BVU is an even greater problem for achieving basic ventilation rates during absence. Because its sensitivity increases at lower flowrates, it will be even harder to achieve these low flowrates during absence, in which case cross ventilation is practically indispensable to achieve requested basic ventilation rates. Dwellings that do not have two opposite facades will have difficulties achieving basic ventilation rates in all rooms using alternating BVUs.

An additional topic that needs further investigation and clarifications concerns the products hygiene. Do the humidity recovery function combined with alternating airflows pose any risk in the hygiene and health area? It is unknown whether sufficient research has already been done here.

Summary

Sensor controlled alternating BVUs represent a considerable improvement compared to window ventilation commonly applied in Germany and some other member states. Compared to this convectional way of window ventilating, alternating BVUs improve both the air exchange (ventilation) performance and the energy performance.

When judged against to the objective of achieving optimal ventilation performance (*'targeted ventilation during presence with category I or II IAQ-related airflow rates and maximized heat recovery and basic ventilation during absence'*) alternating BVUs will have difficulties meeting these performance goals, mainly due to their airflow sensitivity, related reduced heat recovery and noise production. Due to this, the occurring airflow rates coming from alternating BVUs cannot be tailored to the actual airflow needs in the various individual rooms. This reduces both the ventilation performance and energy performance of alternating BVUs. Values resulting from the airflow sensitivity tests (FprEN 13141-8) will need to be used to correct the temperature and humidity efficiency figures and to correct the ventilation performance figure. As proposed in the Task 3 report, the temperature efficiency figure is to be corrected according to Table 2 of the FprEN 13142: instead of η_0 the corrected η_5 will be used, with holds (amongst others) a correction for the airflow sensitivity. In addition, it is proposed in Task 3 to apply a correction factor when determining CTRL-factor, based on the airflow sensitivity figure (*v*) and the indoor/outdoor airtightness q_{vio} of the unit.

4. Enthalpy heat exchangers

Enthalpy heat exchangers are air to air exchangers that are also capable of transferring the humidity content from one airflow to the other airflow. For the indoor relative humidity during winter times this is generally an advantage because it helps maintaining indoor RH-values within the comfort zones (see Figure 42). Without humidity transfer the indoor air can become very dry (< 30% RH).
In summertime, humidity transfer is convenient in the warmer climates, because the it reduces the thermal capacity of the humid supply air, which reduces the energy consumption for cooling.

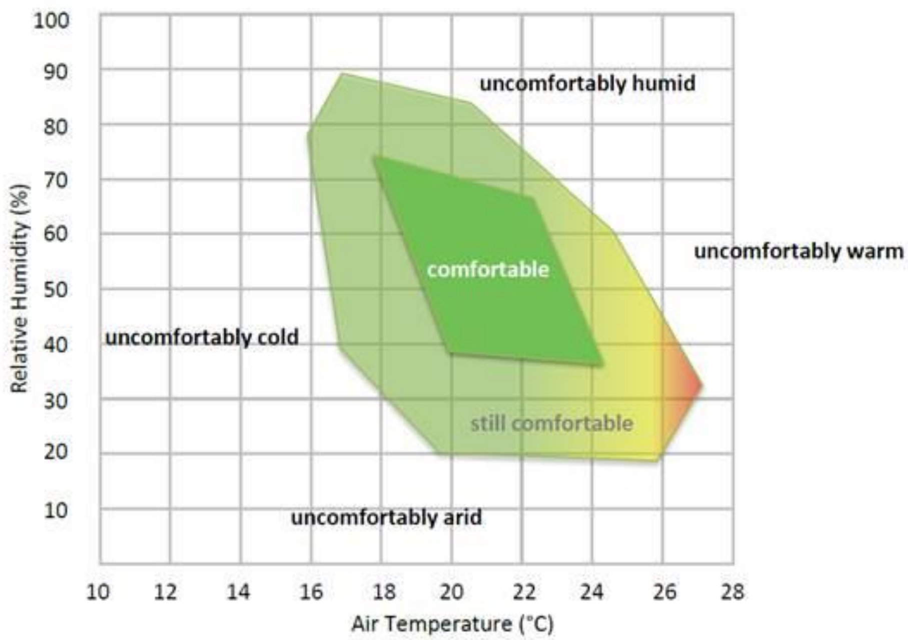


Figure 42. Indoor climate comfort zones

In other words, humidity transfer additional to the transfer or sensible heat clearly represents an added value which is currently not valued in the Ecodesign and Energy labelling Regulations for VUs.

Three different technical principles for enthalpy heat exchangers are offered on the market:

1) Rotary heat exchangers or rotary wheels

2) Enthalpy plate heat exchangers, using a water vapour permeable sheet or membrane

3) Regenerative alternating air flow heat exchangers

4.1 Rotary wheels

At the moment, these types or enthalpy heat exchangers are probably most popular in the non-residential sector. The concept of a rotary wheel is simple. At the point in a building's ventilation system where fresh air and exhaust air run counter currently, but adjacent to each other, a rotary wheel can be placed in the ventilation system such that half of the wheel will be exposed to fresh, incurrent air, and the other half to contaminated, excurrent air. This allows the rotary wheel to absorb the desired temperature and humidity properties of the excurrent air (which has been conditioned to be suitable for within the building) and transfer them to the incurrent air. In this way, the incurrent air is preconditioned to be close to a desired temperature and humidity. This process is passive and can significantly reduce the energetic and monetary cost of using new energy and moisture to treat incurrent air. Depending on the conditions, energy recovery wheels can reduce the energetic demand of conditioning incurrent air by up to 90%.

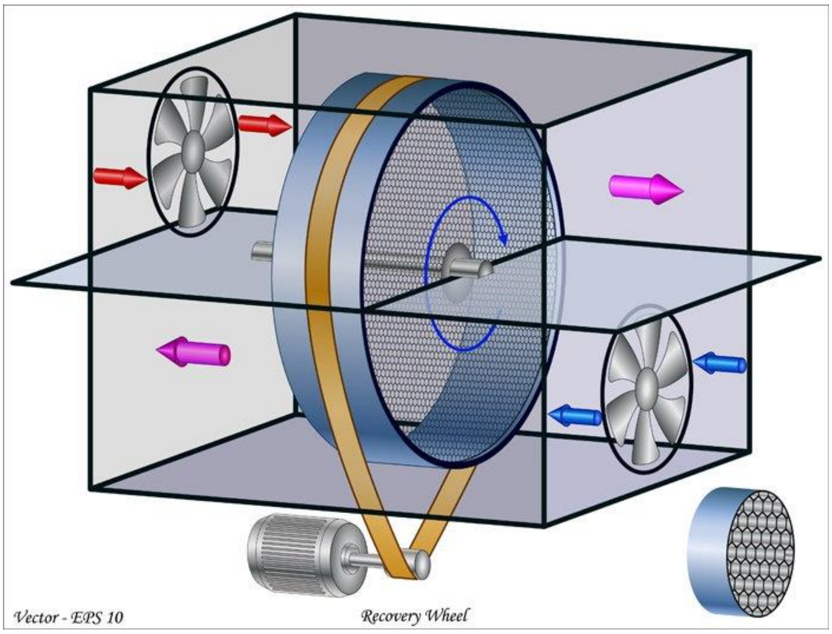


Figure 43. Principle of the energy recovery wheel (ERW)

Source: https://web.uponor.hk/radiant-cooling-blog/understanding-energy-recovery-wheels/

The energy recovery wheel (ERW) is made of a complex lattice of sensible energy absorbing metal alloy, which is usually coated with a moisture absorbing substance such as silica gel or a molecular sieve. The honeycomb matrix of metal and moisture absorbing material maximizes the surface area the air passes over, to optimize the area for energy transfer. As the excurrent air passes through the ERW, the half of the wheel exposed will absorb sensible and latent energy from the air, and then carry that energy as it slowly rotates, to be exposed and transferred to the incurrent air to be released. The physical properties of the ERW allow it to be adjusted to either warm up or cool down, to humidify or desiccate, incurrent air into a building. This adjustment capability is critical for the functionality of the ERW in different seasons. In a hot, humid summer the ERW can be used to passively cool down and desiccate the incurrent air into a building, and in winter then ERW can be used to warm up and humidify the incurrent air into the building. In both cases, the ERW recycles the desirable properties of the air already inside the building, transferring that energy, rather than forcing the use of new energy.

<u>Cross contamination</u>

It is not very well known that there can be issues regarding the materials used for humidity transfer in regenerative heat exchangers like rotary wheels.
There are several materials that can be used for coating the aluminium or fibre matrix of the energy recovery component. Commonly used sorption materials are *silica gel*, *molecular sieves*, *ion exchangers*, *zeolites* etc. Possible transfer of other gases besides water vapor is very probable with some of these materials. It is claimed that up to 20-40% of exhaust air VOC gases can be carried over in the matrix material (MBCO= matrix borne carry over) to supply air, if wrong type of sorption material is used. When limit values are of 5% on EATR

are used for obvious reasons, it is also justifiable to discuss and consider this matrix borne carry over (MBCO).

Silica gel and zeolite e.g. are also used in some applications for removing organic solvents and other VOC types, i.e. proving the obvious risk of VOC carry over in the matrix (MBCO).

Together with the suppliers of these materials, one has to discuss how the VOC gas transfer can be minimized e.g. by using the correct materials and how find other ways to limit the possible VOC carry over to values of maximal 5-10% (to be discussed).

Some examples of Rotary wheels

Figure 44. Non-residential BVU/NRVU: CASA R15 Smart

Source: https://www.swegon.com/globalassets/_product-documents/home-ventilation/air-handling-units/swegon-casa-r-series/_en/r15_smart_en_p.pdf

Manufacturer	: Swegon
Drive type	: Variable speed drive
HR-system	: Regenerative / rotary
Temperature eff.	: Up to 86% (EN308), compliant with Ecodesign limit value
Casing sound power	: 50 dB(A)
Flowrate	: 360 - 1710 m3/h
Controls	: Demand-controlled humidity function (standard)
	: Automatic summer function and passive cooling
Anti-frost protection	: yes
SFP	: ?
External leakage	: ?
EATR	: ?
AOCF	: ?
Energy Label	: n.a.
Dimensions	: WxHxD = 1080 x 788 x 1100 mm

Figure 45. BVU: Domekt-R-300-V-R1-M5

Source: https://www.komfovent.com/en/product/domekt-r-300-v-2/

Manufacturer	: Komfovent
Drive type	: Variable speed drive
HR-system	: Regenerative
Thermal efficiency	: 85%
Casing sound power	: 40 dB(A)
Reference flowrate	: 220 m3/h
Reference ΔP	: 50 Pa
SPI	: 0.28 W/m^3/h]
CTRL factor	: 0.65
External leakage	: < 1%
Carry over	: <0.5%
Energy Label	: A+
Dimensions	: WxHxD = 502x610x598

4.2 Enthalpy plate heat exchangers

Recently, enthalpy plate heat exchangers are gaining momentum, especially in the residential sector. They save heating- and cooling energy and control the humidity of the air supplied. They humidify the air in wintertime and dry the air in the summertime. Another important advantage relates to the fact that enthalpy plate heat exchangers are not easily covered by ice during low outdoor temperatures (unlike the conventional counter- or cross flow plate heat exchangers).
Enthalpy plate heat exchangers are made from a special membrane that allows the return of moisture back onto the premises (which cannot be done with conventional plate heat exchangers).

Polymer membrane enthalpy he

Amongst others, the company dPoint Technologies produces a polymer membrane that is frequently used in enthalpy plate heat exchangers. This membrane consists of a dense continuous selective film layer (<5 microns) on a porous substrate, having the following properties:

– High transport of water vapour
– High selectivity
– Excellent dimensional stability, durability
– Wash-able, freeze tolerant
– Antimicrobial resistance

The membrane is tested on VOC and contaminant cross over. Furthermore, fungal tests according to ISO 846A and AATCC 30 are performed on the material, as are bacterial tests according to ISO 846C and AATCC 147.
The hygiene is ensured at any time due to the anti-microbial properties of the membrane using Microban®. Only heat and water vapour are transferred.

In a study[12], performed by the Department of Building Service Engineering, Faculty of Mechanical Engineering of the Budapest University of Technology, the performance of two counterflow heat exchangers were tested and compared: a sensible heat exchanger using polystyrene as he-material, and an enthalpy plate heat exchanger using polymer membrane and he-material. The energy exchange performance were experimentally tested under different operating conditions by selecting three European cities with three different climate zones (cold climate Reykjavik, average climate Budapest and warm climate Rome). The results show that the energy recovery from ventilation air using the polymer membrane (indication PEE) counterflow heat exchanger performs better that polystyrene based (indication PHE) counterflow heat recovery unit.

Figure 46 and Figure 47 give the calculated energy savings for the two heat exchanger types during the winter period and summer period. The additional savings related to the humidity transfer of the enthalpy heat exchanger are significant and may be sufficient to account for the additional investment cost related to this type of heat exchanger.

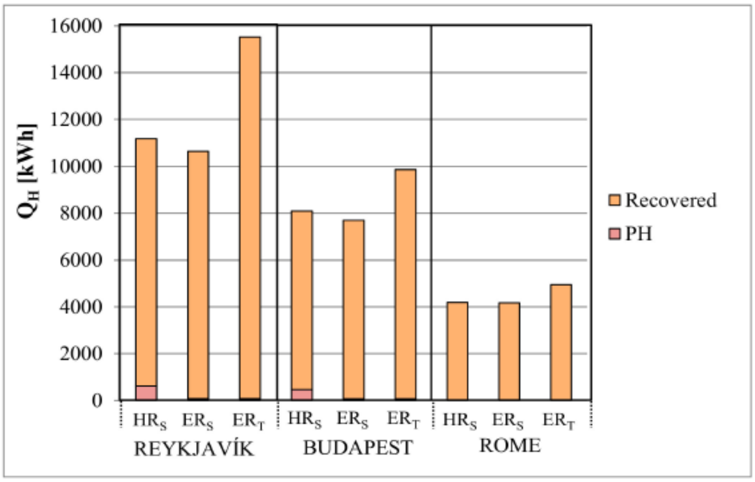


Figure 46. Energy recovered during heating period (HR_S = recovered sensible heat in PHE; ER_T = total recovered energy in PEE)

Source: Kassai, M., Al-Hyari, L. (see footnote)

[12] Kassai, M., Al-Hyari, L., Investigation of Ventilation Energy Recovery with Polymer Membrane Material-Based Counterflow Energy Exchanger for Nearly Zero Energy Buildings, Energies 2019, 12, 1727; doi:10.3390/en12091727.

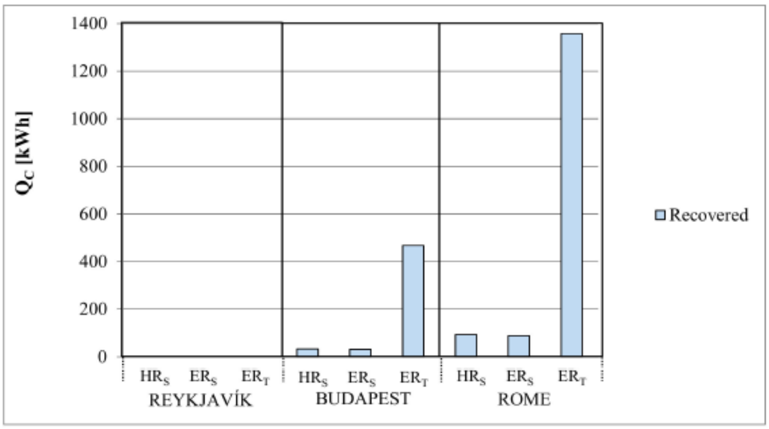


Figure 47. Energy recovered during cooling period (HR_S = recovered sensible heat in PHE; ER_T = total recovered energy in PEE)

Source: Kassai, M., Al-Hyari, L. (see footnote)

Example of polymer membrane Enthalpy plate heat exchangers

Figure 48. residential BVU: Zehnder ComfoAir Q350 ERV

Source: https://www.international.zehnder-systems.com/products-and-systems/comfosystems/

Manufacturer	: Zehnder
Drive type	: Variable speed drive
HR-system	: Recuperative/enthalpy
Thermal efficiency	: 85%
Casing sound power	: 40 dB(A)
Maximum flowrate	: 350 m^3/h
Reference flowrate	: 245 m3/h
Reference ΔP	: 40 Pa
SPI	: 0.15 $W/m^3/h$]
CTRL factor	: 0.65 (2 sensors)
External leakage	: < 1,2 %
Internal leakage	: < 1.8 %
Energy Label	: A+
Dimensions	: WxHxD = 725x850x570

Paper enthalpy he

Another material that is used to create enthalpy plate heat exchangers is treated paper. The Lossnay core is an example of such a product.
The Lossnay core is a crossflow energy recovery unit constructed from specially treated paper with a corrugated structure. The fresh air and exhaust air passages are totally separated allowing the fresh air to be introduced without mixing with the exhaust air. The Lossnay Core uses the heat transfer properties and moisture permeability of the treated paper. Total heat (sensible heat plus latent heat) is transferred from the stale exhaust air to the ventilation air being introduced into the system when they pass through the Lossnay.

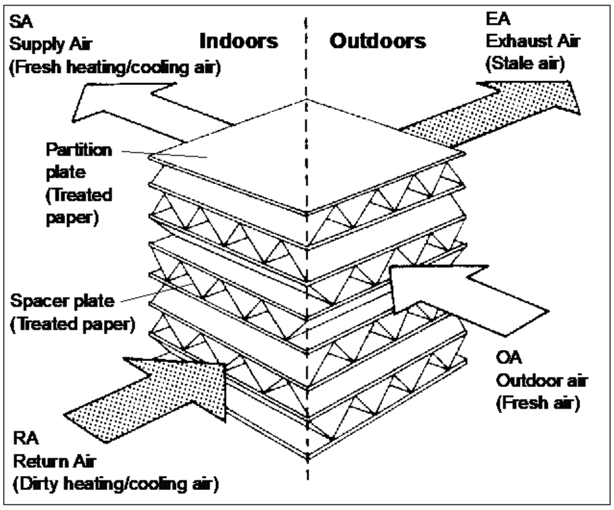


Figure 49. Lossnay core construction

Source: http://www.mitsubishielectric.com.au

The paper partition plates are treated with special chemicals so that the Lossnay Core becomes an appropriate energy recovery unit for ventilation purposes. The he-membrane itself has the appropriate qualities, amongst which:

- Incombustible and strong.
- Selective hygroscopicity and moisture permeability that permits the passage of only water vapor (including some water-soluble gases).
- Gas barrier properties that do not permit gases such as CO_2 from entering the conditioned space.

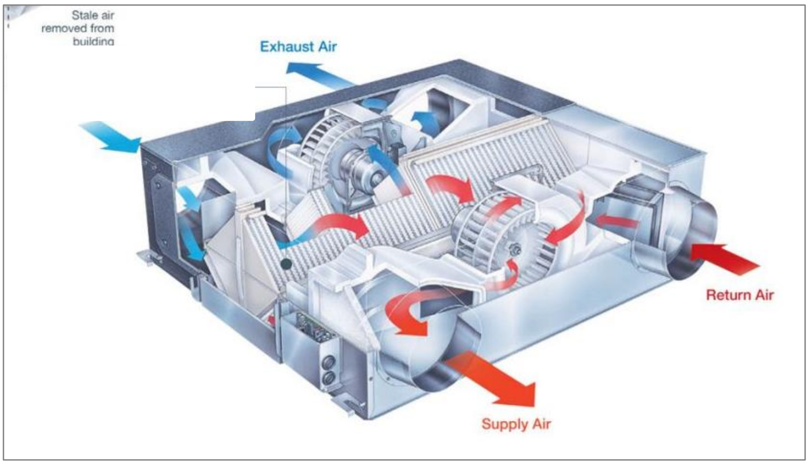


Figure 50. Losnay residential BVU

Source: http://www.mitsubishielectric.com.au/2096.htm

4.3 Regenerative heat exchangers with alternating airflows

This type of enthalpy heat exchanger also uses the regenerative heat exchanger type like in rotary wheels, but now the airflow is redirected, instead of moving (rotating) the heat exchanger itself.

The heat recovery ventilation system consists of two static accumulation masses that alternately are heated by the exhausted warm air. The damper system serves to direct the flow of air in and out in the relevant areas of accumulation. The sector loaded with warm exhaust air is used in the next cycle for the incoming air. This is heated almost to the temperature of the indoor environment and is introduced into the building through the air entrance. At the same time after that the sector with the air inlet has been discharged, it is automatically converted on the flow of exhausted air, in this way the sector is again heated in the next cycle.

Adjustments to the energy-recovery performance can be made through the variation on the time interval of the frequency deviation of the dampers, which can be adjusted from 100% to 0%. With 0% value, the dampers are no longer changed and it enables a free cooling of the building through the air entrance. The gradual adjustment of the system can be regulated with any desired control algorithms.

Like with rotary systems, the alternation of exhaust and supply airflows in the heat exchanger sections, ensure that the heat recovery system is frost resistant. Therefore, it does not need expensive bypass systems or preheating.

The paragraph on cross contamination in section 4.1 is also applicable for the types of enthalpy exchangers.

<u>Some examples</u>

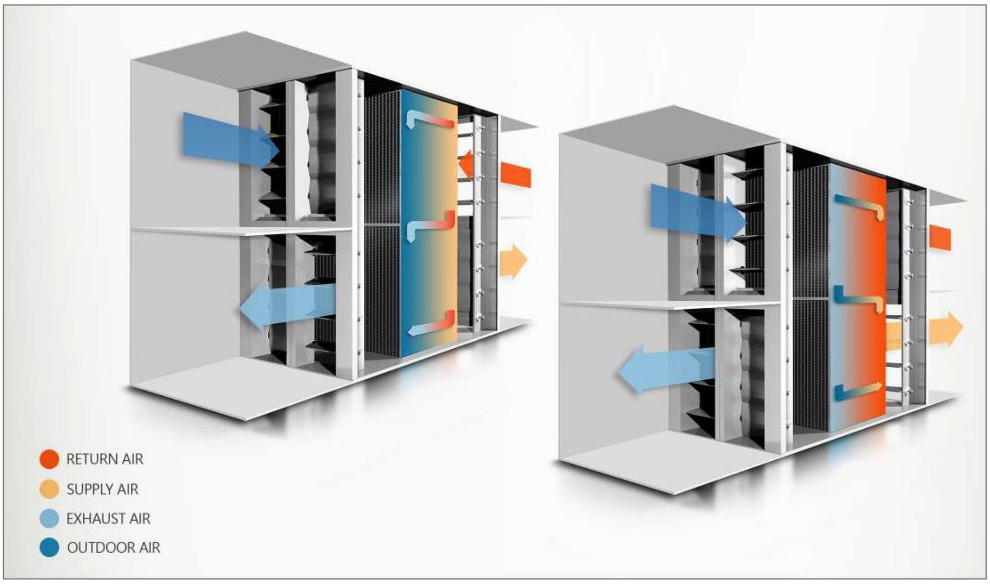


Figure 51. Enthalpy exchanger in non-residential BVU/NRVU: Accuair Enthalpy System

Source: https://ericorporation.com/products/enthalpy-exchanger-accuair/

Manufacturer	: ERI Corporation
Maximum airflow	: various sizes means various q_{max} values
Temp. efficiency	: up to 90%
Hum. Recovery	: up to 70%
Dimensions	: depends on selected size; from H*W*L = 1135*600*1510 mm to 2505*2400*1819 mm

A BVU-unit similar to the one described in Figure 51 was tested at the Galway-Mayo Institute of Technology in Galway Ireland. A paper[13] that was presented during the CLIMA 2019 on this topic describes the main results:

The aim of the study was to investigate the thermal performance characteristics of a reverse-flow energy recovery ventilator (RF-ERV) designed for domestic indoor climate control applications. The principle of operation of the RF-ERV in cold climates is described. A total of eight steady state tests were conducted in a controlled test environment under various operating conditions. Ventilation rates ranged from 144.2 to 330.8 m^3/h, the enthalpy ratio ranged from 72.8% to 88.6%, temperature ratio ranged from 86.0% to 92.9% and humidity ratio ranged from 9.8% to 77.1%, respectively. Maximum recovered energy of 2218.7 W, 1794.5 W and 424.2 W for total, sensible and latent heat was calculated under Test 8 conditions, respectively, corresponding with a total electrical power input of 111.1 W. During the sub-zero Celsius ODA Tests 7 and 8, the RF-EVR flap switching interval of 300 seconds was sufficient to avoid ice formation and therefore negates the need for frost protection unit. Subsequently, the highest recovery efficiency ratio (RER = total recovered thermal energy – total electrical power input) of 19.97 was recorded under these conditions.

The regenerative heat exchangers that are used in non-ducted alternating BVUs (see section 3.1) are also capable of transferring the humidity from one airflow to the other airflow. These regenerative he-cores generally have a honeycomb-like shape. The biggest hole number is around 40 per square centimeter and its density around 4~6 grams per cubic centimeter. The water absorption rate is above 20%.
Materials used here are e.g. Cordierite, Corundum Mullite, Mullite or Silicon Oxide.

Figure 52. Enthalpy regenerative exchanger in residential non-ducted alternating BVU

Source: https://www.ventilation-alnor.co.uk/index/products-en/heat-recovery-%E2%80%93-air-handling-units/heat-recovery-units-hru-wall/

These materials however are also used in abatement of Volatile organic compounds (VOC) , hazardous air pollutants (HAP), carbon monoxide (CO), nitrogen oxides (NOx), organic particulate matter (OPM), HC nytron, SO_2, odours, and other air toxics in oil and chemical industry through a regenerative thermal oxidizer (RTO) device.

[13] Hunt, D., Mac Suibhne, N., Dimanche, L., McHugh, D., Lohan, J., Thermal performance characterization of a reverse-flow energy recovery ventilator for residential building application, CLIMA 2019, http://doi.org/10.1051/e3sconf/201911101010

Possible transfer of other gases besides water vapor is therefore very probable with some of these materials. Together with the suppliers of these materials, limit values for the matrix borne carry over to the supply air (MBCO) need to be discussed to minimize this risk.

5. Filter technology

5.1 Introduction

Although ventilation plays a crucial role in maintaining a clean indoor environment, in some cases ventilation systems can also be a source for airborne pollutants as a result of polluted outdoor air, inadequate system design, internal leakage and cross-contamination, etc. Thus, air filtration technology plays a key role in protecting human health by removing indoor and outdoor air pollutions.

Mechanical ventilation (exchanging indoor air with outdoor air using one or more fans), consumes both heating energy and electricity. The use of filters will increase the electricity consumption for ventilation because filters increase the resistance in the flow path of the supply and exhaust air. It is therefore important to try to reduce the additional pressure induced by filters. To give a rough indication: an increase of 50 pascal for filter purposes in the ventilation supply airstream of on average 110 m^3/h in all EU28 dwellings would results in an additional total annual power consumption of around 6.5 TWh[14] (26 kWh/an/hh).

And if parts of the indoor air can also be cleaned by filtration and recirculation (i.e. without exchanging indoor air with outdoor air) this could also contribute to further energy savings without compromising on IAQ, because heating energy is no longer necessary to reheat the fresh outdoor air.

Technical developments related to these two topics will be further discussed here.

5.2 Filtration and pressure drop

Filters may be used for the filtering of both particulate matter (PM) and gas-phase pollutants (VOCs, odours, etc.) that are present in the outdoor- or indoor air. This section 'on filters and pressure drop' only refers to filters that are used for removing PM, because there are no test standards (yet) for gas-phase pollutants and their application for indoor air in buildings still is limited (see further explanation under section 5.3.2).

With around 80%, energy consumption represents the largest share in the total lifecycle cost for filters. Remaining 20% relates to initial investments and disposal (source : https://filterservices.com/pressure-drop-considerations-in-air-filtration/). The pressure drop of the filter is the precursor for the energy consumption.

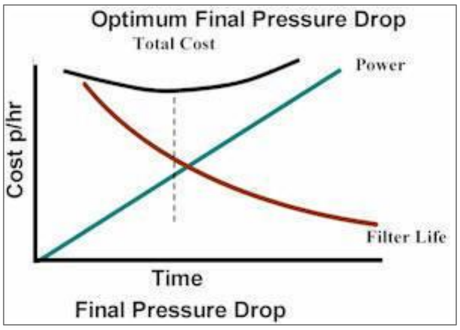


Figure 53. Optimum filter costs

[14] TWh_{deltaP} = (qv*deltaP*hours*No EU28 dwellings)/(eta_{fan}*1000) = 0,03*50*8760*250*10^6/(0.5*1000)=6.57 TWh

Source: R.H. Avery, Optimum Final Pressure Drop, *NAFA Guide to Air Filtration* 3rd Edition, Chapter 13

Figure 53 illustrates the optimal change-out point of an air filter – that point where the pressure drop increases electrical consumption and overtakes the initial cost of the filter.

Obviously, filter pressure drop is not the same for all the existing filter types and filter brands. The same goes for filter pressure drop at end of life. To manifest the differences between filters, Eurovent further developed their Guideline 4/21-2019 regarding the Energy Efficiency Evaluation of Air Filters for General Ventilation Purposes (see also Task 3 report section 1.8.1).

5.2.1 EUROVENT Guideline on Energy Efficiency of Filters

This Eurovent Guideline that was updated in November 2019:

- Implements the EN ISO 16890 classification and testing methods
- Defines energy efficiency evaluation methods
- Defines the energy efficiency of air filters for general ventilation purposes

The aim of this guideline is to assess the yearly energy consumption based on a laboratory test procedure which can be the basis for an energy efficiency classification, to give the user of air filters guidance for the filter selection.

Two important notes to this:

- In order to actually reduce the energy consumption by using more energy efficient filters, it is also required that the speed of the fan can be adjusted accordingly to supply the requested air (if the fan is operated at a fixed speed, lowering the (average) pressure drop of the air filters will result in an increased air volume flow rate; in the worst case scenario, this may even result in a situation where the fan is operated in a region with lower efficiency resulting in an increased overall)
- The method provided in this document is based on laboratory test data with standardized test conditions, which may differ significantly from the individual application in a building ventilation unit. Hence, the yearly energy consumption calculated following this guideline, can only be used as an indicator for the classification system and relates only to the contribution of the air filters involved. The yearly energy consumption in an individual, actual application may differ from this significantly.

The calculation principle used is as follows:

The energy consumption of a fan in an air handling unit can be evaluated as a function of the volume flow rate supplied by the fan, the fan efficiency, the operation time, and the difference of the total pressure (static plus dynamic pressure) after the fan and the static pressure of the ambient air (assuming that the fan sucks in air from a static reservoir). Typically, the volume flow rate supplied by the fan and the pressure difference the fan has to overcome are related to each other by the characteristic fan curve. The efficiency of the fan is a function of the fan speed. The actual fan efficiency also strongly depends on the design and the layout of the fan and can be in the best case as high as 0.80 or even higher, and in the worst case as low as 0.25 or even lower.

The portion of the total yearly energy consumption which is related to the filters' pressure drop can be calculated using the following equation:

$$W = \frac{q_V \cdot \overline{\Delta p} \cdot t}{\eta \cdot 1000}$$

Where we define: q_V = 0.944 m³/s, t = 6000 h/a and η = 0.5

For a detailed description of the test- and rating method, see the latest version of the Eurovent Guideline 4/21-2019 regarding the Energy Efficiency Evaluation of Air Filters for General Ventilation Purposes.

The certification program applies to air filter elements rated as ISO PM1, PM2.5 and PM10 (according to EN ISO 16890) referring to a front size of 592 x 592 mm and nominal airflow rates between 0.24 and 1.5 m³/s. The filters shall be declared according to one of the following filter groups (see following tables).

Table 8. Energy classes Eurovent Filter Groups (with Mx = max. dust load, AEC = ann. electricity consumption)

M_X = 200 g (AC Fine)	AEC in kWh/y FOR ePM1					
	ePM_1 and $ePM_{1,\,min} \geq 50\%$					
	A+	A	B	C	D	E
50% & 55%	800	900	1050	1400	2000	>2000
60% & 65%	850	950	1100	1450	2050	>2050
70% & 75%	950	1100	1250	1550	2150	>2150
80% & 85%	1050	1250	1450	1800	2400	>2400
> 90%	1200	1400	1550	1900	2500	>2500

M_X = 250 g (AC Fine)	AEC in kWh/y FOR ePM2.5					
	$ePM_{2.5}$ and $ePM_{2.5,\,min} \geq 50\%$					
	A+	A	B	C	D	E
50% & 55%	700	800	950	1300	1900	>1900
60% & 65%	750	850	1000	1350	1950	>1950
70% & 75%	800	900	1050	1400	2000	>2000
80% & 85%	900	1000	1200	1500	2100	>2100
> 90%	1000	1100	1300	1600	2200	>2200

M_X = 400 g (AC Fine)	AEC in kWh/y FOR ePM10					
	$ePM_{10} \geq 50\%$					
	A+	A	B	C	D	E
50% & 55%	450	550	650	750	1100	>1100
60% & 65%	500	600	700	850	1200	>1200
70% & 75%	600	700	800	900	1300	>1300
80% & 85%	700	800	900	1000	1400	>1400
> 90%	800	900	1050	1400	1500	>1500

Compared to the previous edition, the November 2019-version now includes an Annex 1 in which a method is given for recalculation of energy consumption at air flow rate different that the nominal one (tested). This simple formula was developed based on several tests performed be various manufactures. The formula works well within the Eurovent classification range. The lower deviation of the actual air flow rate from the nominal one, the higher its accuracy.

In their study[15] 'Status on Air Filter Characteristics and Energy Efficiency', the authors analysed a sample of 1800 certified filter test results. The results (see figure below) prove that only a minor portion of certified air filters have proper energy performance and the rest are certified as Classes C, D and E. The authors conclude that the topic filters need more efforts and attention from manufactures to further improve on their filter products.

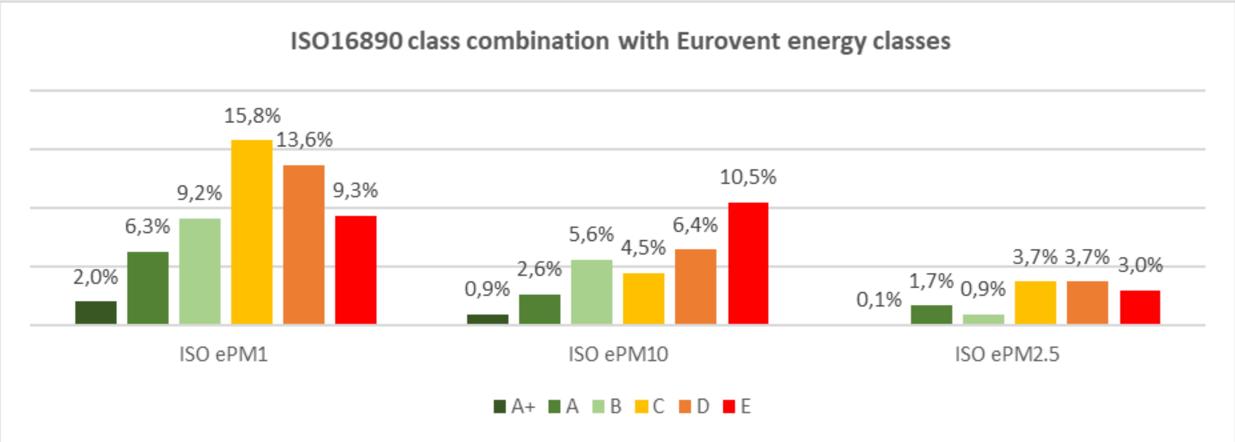


Figure 54. ISO Class rating (ISO 16890) and Eurovent Energy Efficiency Class percentages Source: Vadoudi, K., Kelijian, G., Marinhas, S. (see footnote)

5.2.2 Developments PM-filters and pressure drop

As can be deducted from the previous section, there is still a lot to be gained where the energy performance of filters is concerned. A labelling scheme as developed by Eurovent and its members, can become an important instrument in the pursuit for reduced pressure drops in filter technology.

A technology that is worth mentioning in this context, is the use of electrostatic filters. The EN ISO 16890 allows for the test and assessment of electrostatic filters. The advantage of electrostatic filters over traditional fibre-based filters can be that:

- Due to the working principle the pressure drop can in principle be low (lower) compared to fibre-based filters.
- Pressure drop remains constant or only increases only a little bit with increased dust loading, implying that flow control for the purpose of compensating increased pressure drops are not necessary.
- As a result, the energy consumption due to the filter is constant and does not increase during use.

[15] Vadoudi, K., Kelijian, G., Marinhas, S., Status on Air Filter Characteristics and Energy Efficiency, 40th AIVC Conference, October 2019, Ghent, Belgium.

Figure 55. Example active electronic filter

Source: Expansion Electric

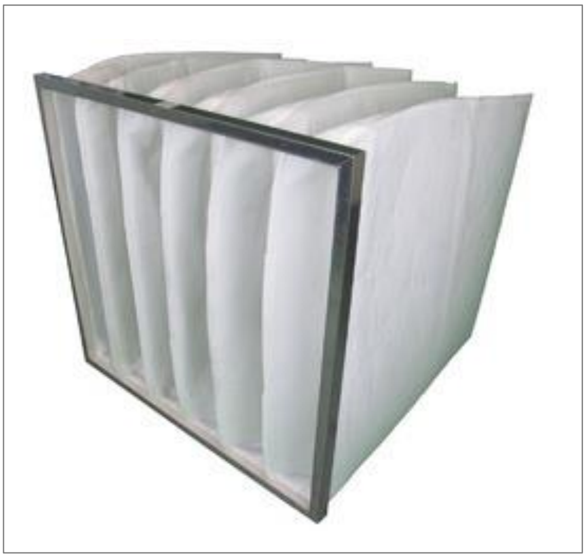


Figure 56. Example pocket filter

Random picture of pocket filter

For comparison, a calculation is made of the annual electricity consumption for an ePM1:70% electrostatic filter with an averaged ΔP of 62 Pa and an ePM1:70% pocket filter with an averaged ΔP of 215 Pa.

Electrostatic filter FE600 ePM1:70%

E = 0.944*62*6000 / (0.5*1000) = 351168/500 = 702 kWh/year

Average Pocket filter ePM1:70%

E = 0.944*215*6000 / (0.5*1000) = 1217760/500 = 2435 kWh/year

Types of electrostatic filters

Two types of electrostatic filters can be distinguished: passive and active electrostatic filters.

The general principle in in the electrostatic filtering systems technology relates to the electrostatic effect that occurs when a polluting particle (dust, smoke, fibres, etc ...) has, on its surface an electric charges (positive and/or negative) that makes it adhere to another surface (filter fibres, walls, curtains, TV and laptop screens, etc..) with equal but opposite charge. If the particle mass is sufficiently small, the electric charge presents on its surface makes it adhere to another opposite electric charge, present on the surface of the mattress filter. By applying this electrostatic effect, high filter efficiencies can be achieved, also for smaller particle sizes.

Passive electrostatic filters

When this phenomenon is enhanced artificially, by electrostatically charging the fibres of a filter, a so-called "passive electrostatic filter" is obtained, which in order to work well must be made with very high electrical resistivity fibres, as for example the rectangular plastic fibres. Its negative aspect is that just the deposit of polluting particles on the filter fibres makes it immediately decrease the ability of pollution's abatement.

Moreover, if the environment is particularly damp, the water contained in the air condenses on the surface of the fibres and eliminates in a very short time each electric charge, transforming the product into a simple mechanical sieve filter. To overcome this problem the so-called 'buffer' filtering systems were created, in which the filtering means are submerged in an electric field which maintains the attraction power and the pollutants retention. The negative side is in the operation, starting from the fact that it depends on a filter mattress (the so-called buffer) that, even if electrostatically charged, presents the same disadvantages of the mechanical filters.

<u>Active electrostatic filters</u>

Filtration with an active electrostatic system consists of a two-phase system thanks to which it is possible to obtain the precipitation of solid or liquid particles contained in the air flow through the action of an electric field.

The company 'Expansion Electronic' uses the following illustration and accompanying text for explaining the principle of active electrostatic filters:

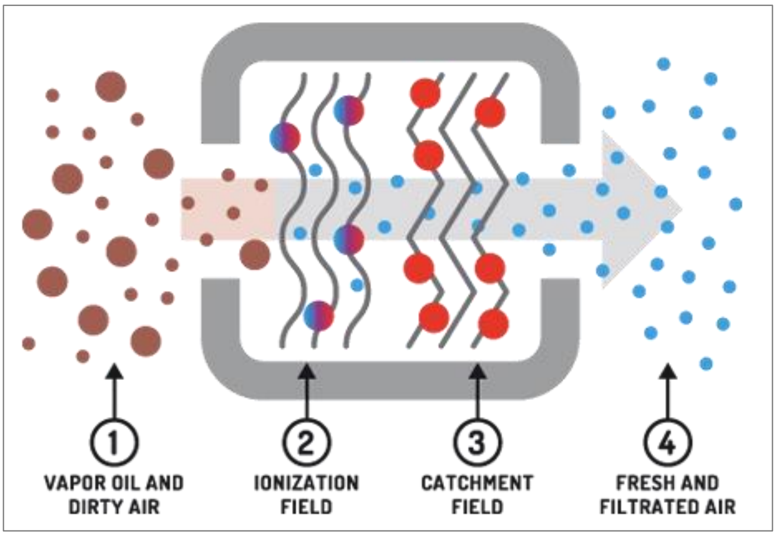


Figure 57. Principle of active electrostatic filter

Source: https://www.expansion-electronic.eu/index.php/en/what-we-do/operating-principle

In a first phase, the air that passes through the FE System electrostatic filter is subjected to the action of an electric field with positive ionization, generated by a powered wire with high electrical voltage placed between two plates connected to ground: that field causes the liberation of positive ions, generating a phenomenon known as "crown discharge". The electrical charges that migrate between the electrode and the grounded surfaces collide with the air particles present in the air flow, giving to them part of their positive electric charge.

In the second phase, the previously loaded gaseous flow crosses the electric field of catchment: this is constituted by positively charged plates and by plates connected to ground, alternately arranged.

Thanks to that shape of the FE System electrostatic filter and to the participation of the electrostatic force, the solid particles contained in the air are attracted to the positively charged catchment plates, since they are negatively charged.

Periodically, depending on the concentration of the pollutants, it is necessary to wash the filter with a particular detergent, in order to guarantee a better performance and a longer life cycle of the product.

In that sense the application of active electrostatic filters, can also help reducing the waste flows of traditional fibre-based filters which need to be replaces regularly and cannot always be cleaned.

5.3 Cleaning and recirculation of indoor air

The requirements for ventilation in most standards and guidelines are based on the assumption that the quality of (clean) outdoor air is acceptable. In various location around the world however, outdoor air quality can be very poor. In such cases, an alternative strategy may be to substitute ventilation-with-outdoor -air, at least in part, with air-cleaning and recirculation. By doing this the energy for heating or cooling the ventilation air and for transporting the air (fan energy) may be saved. For locations where the outdoor air is sufficiently clean, this air-cleaning strategy may also be an alternative additional strategy, provided it can increase the IAQ-performance without impairing the energy performance.

5.3.1 Cleaning indoor air from particulate matter

Indoor PM levels are dependent on several factors amongst which:

- outdoor PM levels,
- infiltration,
- types of ventilation and filtration systems used,
- indoor sources,
- personal activities of occupants.

Main indoor sources of PM are cooking, combustion activities (including burning of candles, use of fireplaces, use of unvented space heaters or kerosene heaters), cigarette smoking and some hobbies.

In homes without smoking or other strong particle sources, indoor PM would be expected to be the same as, or lower than, outdoor levels (source: https://www.epa.gov/indoor-air-quality-iaq/indoor-particulate-matter).

Primary and preferential strategy for reducing indoor generated PM obviously is source control: use efficient cooking hoods, avoid unvented fireplaces or heaters, prohibit smoking indoors.

This strategy always prevails any use of air circulation combined with PM-filters.

5.3.2 Cleaning indoor air from gaseous pollutants

The previous section basically indicates that recirculating and cleaning of indoor air is more about removing or reducing gaseous pollutants (coming from building materials, furniture and decorative products, office equipment, combustion equipment, occupants and their activities) than reducing PM-concentrations.

Opposite to the filtration of particulate matter (PM) however, (for which standards and test methods are already available), the technology of gas-phase air-cleaning is not supported by any standards on how to evaluate its efficiency and effectiveness in removing gaseous pollutants.

To fill this gap in knowledge, the Energy in Buildings and Communities Programme (EBC) of the IEA started a new EBC Annex 78, titled 'Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications'. The duration of this research-project is from 2018 – 2020, and the operating agents are Prof. Bjarne Olesen and Dr. Pawel Wargocki, both from the Technical University of Denmark. Participating countries are Canada, Czech Republic, P.R. China, Denmark, Finland, Italy, Japan, Singapore, USA.

Main objectives of this project are:

- quantify the energy performance of using air cleaning as part of the ventilation requirements,
- analyse how air cleaning can partially substitute for ventilation,
- advance standard testing procedures for air cleaners,
- carry out field studies of the energy performance and indoor air quality in buildings using gas phase air cleaning

(See also https://iea-ebc.org/projects/project?AnnexID=78)

Technical principles for removal of gaseous pollutants

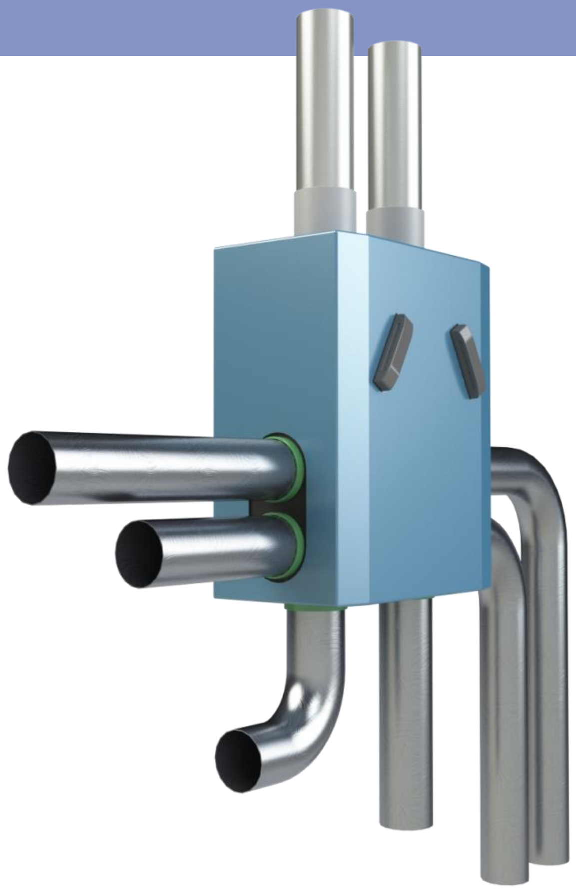
Technology	Mechanism	Advantages	Disadvantages
Ionization	A discharge wire charges incoming particles and VOCs, that collect on oppositely charged plates	– Quiet – Low maintenance – Low pressure drop	– Generates ozone
Adsorption	The gases physically adsorb onto high-surface area medio (activated carbon)	– Potential for high removal efficiency for many gaseous pollutants – No by product formation	– Regular replacement needed – Effectiveness unknown – High pressure drop – Different removal efficiency for different gasses – Test methods limited or lacking
Chemisorption	Gases chemically adsorb onto media coated or impregnated with reactive compounds	– Potential for high removal efficiency for many gaseous pollutants – Chemisorption is an irreversible process (pollutants are permanently captured)	– Regular replacement needed – Effectiveness unknown – High pressure drop – Different removal efficiency for different gasses – Test methods limited or lacking
Catalytic oxidation	(Photo)catalytic oxidation (PCO) in which a high-surface-area medium is coated with titanium dioxide as a catalyst; gases adsorb onto the media and UV lamps activate the titanium oxide which reacts with the adsorbed gases and transforms them	– Can degrade a wide array of gaseous pollutants (e.g. aldehydes, aromatics, alkanes, olefins, halogenated hydrocarbons) – Can be combined with adsorbent media to improve effectiveness	– Can generate harmful by-product (formaldehyde, acetaldehyde, ozone) – No test methods – Relatively low removal efficiency – Lack of studies to validate performance – Catalyst has finite lifespan

Plasma	Electric current is applied to create an electric arc; incoming gases are ionized and bonds are broken to chemically transform the gaseous pollutants	– Can have high removal efficiency – Can be combined with other air cleaning technologies to improve performance	– Wide variety of plasma generation types yields confusion on how a product actually works – By-products are formed (included particles and gaseous pollutants)
Ozone	Intentional generation of ozone using corona discharge, UV or other method to oxidize odorous compounds and other gases	– Reacts with many indoor gases – Can be combined with adsorbent media to improve effectiveness	– High ozone generation rates – High amounts of by-product formation – Can cause degradation to indoor materials
Ultraviolet	UV-light kills or inactivates airborne microbes	– Can be effective at high intensity and sufficient contact time – Can be used to inactivate microbes on cooling coils and other surfaces	– Can generate ozone – May cause eye injury – High electrical power draw requirements – Inactivates but does not remove microbes

Source: www.epa.gov/iaq

Ventilation Units

Ecodesign and Energy Labelling



Preparatory Review Study

Phase 1.1 and phase 1.2

Final Report

TASK 5. Base Cases

Review study on Regulations EU 1253/2014 (Ecodesign requirements for ventilation units) and EU 1254/2014 (energy labelling of residential ventilation units)

Prepared by
VHK, Delft (NL), for the
European Commission, DG GROW

August 2020

GROW

[empty on purpose]

Prepared by

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Contract manager: VITO

Project website: www.ecoventilation-review.eu

Specific contract: No 681/PP/GRO/IMA/18/1131/10204-SI2.798223

Contract starting date: February 5th 2019

Cover: Ventilation unit [picture VHK 2019].

This study was ordered and paid for by the European Commission, Directorate-General Grow.

Executive summary

This Task 5 report of the review study of Commission Regulation (EU) No. 1253/2014 (ecodesign ventilation units) and Commission Delegated Regulation (EU) No. 1254/2014 (energy labelling of ventilation units) combines the information of the preceding Task 1 to 4 reports in order to provide a picture of the environmental and economic significance of ventilation products in the European Union and the contribution of individual base cases therein. In order to correctly define the base cases, the calculation method for the regulations was revisited and the role of infiltration in ventilation of buildings was made clear.

Chapter 1 gives a general introduction to Task 5 and the main findings in Tasks 1 to 4. It announces the innovative method for rating Ventilation Performance and in that context refers to the discussion of natural ventilation and infiltration rates in the Annex.

Chapter 2 describes the general approach to determine the ventilation performance for naturally and mechanically ventilated spaces. The ventilation performance is a measure of the ability of the ventilation system to induce the right air exchange rates in the right place at the right time. The method first defines the reference flows to be achieved (the optimal situation) and assesses the probable air exchange rates induced by ventilation systems in dependence of their technical characteristics (controls amongst others).

Chapter 3 applies the above method to 5 base cases of residential ventilation units and 5 non-residential ventilation units and describes the basis for the environmental and economic assessment of typical ventilation units such as the air exchange rates established in Chapter 3. The basic performance data of ventilation units is supplemented with data regarding power consumption (Specific Power Input SPI, Specific Fan Power SFP) to allow calculating the overall annual electricity consumption and indirect energy consumption by heating systems.

Chapter 4 combines the above data and data covering other life cycle phases from the extraction of raw materials to production, to distribution, to use and to end-of-life to allow an calculation of life cycle impacts. The MEErP Ecoreport calculation of resource consumption and environmental impacts shows that the use-phase dominates the major impact categories such as gross energy requirement and greenhouse gas emissions. Material consumption typically represents a very small share in overall impacts, becoming visible only in the most material intensive Air Handling Units (AHUs).

Chapter 5 presents the life cycle costs, combining information from Task 2 regarding purchase, installation and maintenance costs, with energy costs (for electricity and heating) and end-of-life costs (which includes scrap value) calculated in this report. The calculation shows that energy costs dominate for Unidirectional Ventilation Units UVUs (between 73-92% of life cycle costs) whereas for smaller Bidirectional Ventilation Units BVUs the purchase costs become as important as energy costs. For larger BVUs and AHUs purchase can be between 10% to 35%. For smaller BVUs the costs for maintenance (filter costs) are also significant.

Chapter 6 combines the data from Chapter 4 and 5 to provide an overview of impacts and costs of VUs at EU level. It shows that the combined stock of ventilation units is responsible for almost 1.2% of overall EU electricity consumption, and 1.3% of EU greenhouse gas emissions. It also shows that although the three AHU types represent 8% of EU stock of VUs (units), they are responsible for 68% of annual electricity costs for VUs and 48% of EU annual life cycle costs of the combined EU ventilation units .

Acronyms and units

Acronyms

AC/DC	Alternating/Direct Current
ADCO	Administrative Co-operation
AHRI	American Air Conditioning, Heating and Refrigeration Institute
AMCA	Air Movement and Control Association
ATEX	ATmosphères EXplosibles
BC	Backward Curved
BVU	Bidirectional Ventilation Unit
CECED	European Committee of Domestic Equipment Manufacturers
CEN	European Committee for Standardization
CFD	Computer Fluid Dynamics
CIRCA	Communication and Information Resource Centre
CLP	Classification, Labelling and Packaging (Regulation)
DigitalEurope	Association representing the digital technology industry in Europe
DoC	Document of Conformity
DoE	US Department of Energy
EC	Electronically Commutating
EN	European Norm
EPEE	European Partnership for Energy and the Environment
Eurovent	Association of European refrigeration, air conditioning, air handling, heating and ventilation industry
EVIA	European Ventilation Industry Association
FC	Forward Curved
GWh	Giga Watt hour 10^9 Wh
HNL	Howden Netherlands
HRS	Heat Recovery System
ICSMS	Information and Communication System on Market Surveillance
ISO	International Standardisation Organisation
JBCE	Japan Business Council in Europe
JRAIA	Japan Refrigeration and Air Conditioning Industry Association
N	Efficiency grade
NRVU	Non-Residential Ventilation Unit
RAC	Run Around Coil
RAPEX	EU Rapid Alert System
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (Regulation)
RoHS	Restriction of Hazardous Substances (directive)
RVU	Residential Ventilation Unit
rpm	rounds per minute (unit for fan rotation speed)
TC	Technical Committee (in ISO, CEN, etc.)
TWh	Tera Watt hour 1012 Wh
UVU	Unidirectional Ventilation Unit
VU	Ventilation Unit
WEEE	Waste of electrical and electronic equipment (directive)
WG	Working Group (of a TC)
yr	year

Parameters

A	floor surface area building [m²]
c_{air}	specific heat air [Wh/ m³.K]
Q	heat/energy [kWh]
q	hourly air exchange [$m^3.h^{-1}$/ m³]
rec	ventilation recovery rate [-]
S	shell surface area building [m²]
SV	shell surface/volume ratio building
t	heating season hours [h]
T_{in}	Indoor temperature [°C]
T_{out}	outdoor temperature [°C]
U	insulation value in [W/K. m²]
V	heated building volume [m³]
ΔT	Indoor-outdoor temperature difference [°C]
η	efficiency [-]

Units

€	Euro
°C	degree Celsius
a	annum (year)
bn	billion (1000 million)
CO_2	carbon-dioxide (equivalent)
h	hours
K	degree Kelvin
kWh	kilo Watt hour
m	metre or million
m^2	square metre
m^3	cubic metre
Pa	Pascal
W	Watt

Table of Contents

1 Introduction

1.1 Task 5 scope

Task 5 provides a picture of the environmental and economic significance of ventilation products in the European Union and the contribution of individual base cases therein. It uses as inputs the findings from the previous Tasks 1 to 4 and forms the basis for the subsequent Tasks 6 (Improvement options) and 7 (Scenarios).

The MEErP methodology prescribes that the environmental and economic assessment is performed for average product(s), i.e. "Base cases" or representative for the whole of the EU-27 market.

Hereafter a summary is given of the main findings of Tasks 1 to 4 that will feed into the analysis of the base cases. Note that the latest Task 1 to 4 reports take into account the stakeholder comments from the first stakeholder meeting of 29 May 2019. The findings of the 2nd stakeholder (web-)meeting of 7 May 2020 are taken into account here and especially in the Task 6 report.

1.2 Summary of Task 1: Scope & Legal aspects

The preliminary assessment in Task 1 showed that the options and related impacts of extending the scope to VU-units < 30 watts are interesting and needed to be further investigated in the subsequent Tasks.

As regards multifunctional residential BVUs, the EU-saving potential in the short term might not be enough to justify extension of the scope per 2020/2021 (date of possible revision), but that it certainly is recommended to anticipate future extensions by providing a proposal for a method to rate these multifunctional BVUs under revised VU-Regulations EU 1253/2014 and EU 1254/2014.

Stakeholders proposed to use a more precise definition for VUs, explaining the primary purpose for the intended replacement of air.

Various detailed proposals were made by stakeholders regarding adjustments and further explanation of the current text in the Regulations.

1.3 Summary of Task 2: Markets

Accuracy of Prodcom data for this product group is very limited, partly due to ambiguous definitions. Complete time-histories and projections on sales and stock of ventilation units are available from older (2012) Ecodesign studies. For recent years there are only fragmented data (one country, one year, etc.) and no projections for e.g. the impact of the strong decrease in new buildings following the 2008 financial crisis, the provisions of the 2018 recast of the Energy Performance of Buildings Directive (EPBD), i.e. all new-built to be NZEB (Nearly-Zero Energy Building) by 2020, and the entire EU-28 stock of buildings to be NZEB by 2050.

Therefore, in particular for the future projection of sales and stock of ventilation units (Task 7), the study team developed a Buildings-Ventilation Model (BVM), linking the sales of VUs to the number of new-built and renovated residential dwellings and non-residential buildings. The sales and stock numbers are also used in the EU figures in Chapter 7.

1.4 Summary of Task 3: Usage

In Task 3 the following items were proposed

WITH REGARDS TO RVUs[1]:

1. Introduce a new Ventilation Performance Indicator VPI.
2. Introduce a new list of CTRL-factors in the SEC formula.
3. Modifications regarding energy recovery.
    a. Include a latent heat & humidity recovery feature in the revised Regulations;
    b. display the differences in specific energy consumption (SEC) for the various climate zones on the Energy Label (label lay-out comparable to room air conditioners);
    c. correct for internal and external leakages, for indoor and outdoor mixing and for airflow sensitivity, following the FprEN13142, temperature efficiency values in the SEC-formula.
4. Introduce modifications for filters[2] including new information requirements for RVU-filters.
5. Introduce modifications of reference external pressure difference[3], specifically to add new reference pressure parameters (pus and pu[4]), unambiguously determining the reference point for the energy efficiency assessment.
6. Modify limit values for BVU-leakages following FprEN 13141-7 (ducted BVUs) and FprEN 13141-8 (non-ducted BVUs) and declare supply and exhaust mass flows corrected accordingly.
7. For non-ducted (local) RVUs, correct the CTRL-factor for airflow-sensitivity ‘v’ and indoor/outdoor airtightness 'qvio'.
8. Modify the energy consumption for defrosting according to a simplified version of FprEN 13142:2019.

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[1] RVU: Residential Ventilation Unit - see glossary

[2] The Task 3 proposals for reference filters (4a) and to limit values for filter velocity (4b) were rejected following stakeholder consultation.

[3] The Task 3 proposal (5a) to relate the applicable reference external pressure to the maximum declared flowrate and the dimensions of the ducts was rejected following stakeholder consultation.

[4] pus : Unit static pressure as difference between static pressure at unit outlet and total pressure at unit inlet. pu : Unit pressure as difference between total pressure at unit outlet and total pressure at unit inlet. These pressure parameters are in full analogy to the pressure parameters pf and pfs for fans according to ISO 5801

WITH REGARDS TO NRVUs[5]:

9. Modifications regarding Energy Recovery and life-cycle costs (section 1.6.4 and 1.7.3).
    a. it is proposed to include latent heat & humidity recovery features;
    b. proposal to increase limit values for minimum thermal efficiency to 77% (value resulting in maximised economic savings in cold climates when lower energy-prices are assumed);
    c. proposal to increase limit values for minimum energy recovery efficiency for HR-systems that enable humidity recovery to 80%;
    d. proposal to allow a reduction on limit values for ηt or SFPint-limit for non-residential BVUs that have smart controls;
    e. set a specific bonus E on the SFPint-limit for HR-systems that enable humidity transfer.
10. Modifications regarding Filters[6]
    a. determine the SFPint-limit on the bases of pre-defined SFPint values (F) for the various filter classes. Depending on the filter efficiency class a dedicated SFP filter correction factors F is determined. More filter efficiency classes can be added to the list with F factors in the Regulation, having a clear reference to the new ISO 16890 standard and related definitions;
    b. to include new information requirements regarding filters.
11. Modifications in the NRVU-declaration when working point is unknown
    a. the manufacturers can declare an area (in a Q/ΔP-graph), defined by multiple Q/ΔP-values for which the SFPint-values meet the requirements or the regulations (see also Guidelines accompanying the EU1253 and 1254 regulations, oct. 2016);
    b. new reference pressure parameters (see item 5b).
12. Modifications concerning leakages
    a. to introduce two parameters for internal leakage OACF (outdoor air correction factor) and EATR (exhaust air transfer ratio);
    b. to set minimum leakage requirements (EATR and OACF limit values);
    c. to correct mass flows, SFPint, etc. due to internal leakages.
13. Concerning defrosting for non-residential BVUs, stakeholders propose to determine the required defrosting-/frost prevention energy per climate zone (cold, average, warm) and include the results in the information requirements of the regulation. So far, no concrete proposals for such a simplified calculation method has yet been made by the stakeholders.

Regarding the first point on Ventilation Performance: this is a key element in quantifying the functioning of ventilation units and thus Chapter 2 of this report gives an explanation. Other

[5] NRVU: Non-Residential Ventilation Unit - see glossary

[6] Proposals 10 b. and 10c from Task 3 are replaced by minimum requirements for the annual energy consumption (AEC) for NRVU-filters

items on the list above are discussed in the Task 6 report, and are not further addressed here.

Chapter 3 applies the method for assessment of ventilation performance of various types of ventilation units (in typical ventilation systems). The results are included in the descriptions of the various base cases.

The Task 3 report gives information on

- Ventilation effectiveness (removal of pollutants);
- Indoor and outdoor air pollutants;
- End-of-Life Behaviour (material composition, fractions to recycling, re-use and waste disposal.

This information is fed into the definition of the base cases in Chapter 3 which subsequently provides the structure for the environmental assessment of the base cases in Chapters 4 and an economic analysis of the base cases in Chapter 5.

Chapter 6 gives the aggregated EU numbers of environmental impacts and Life Cycle Costs (sales and stock).

1.5 Summary of Task 4: Technologies

Task 4 does not repeat the discussion of technologies already discussed in the previous preparatory study. The following new subjects are discussed:

- best Available Technology (BAT) for occupancy, IAQ-sensors and for monitoring devices. Not all sensors are equally suited for all room types however which requires that their suitability for different room types is taken into account;
- local demand-controlled ventilation requires using the right sensors in the right locations and the technical ability of the ventilation system to vary the airflow rates per individual room. Technical developments for ducted systems in this area and the BAT regarding flowrate control per individual room;
- in view of a possible inclusion, non-ducted local UVUs and BVUs with power consumption below 30 watts per airstream and their best available technologies are discussed;
- non-ducted alternating BVUs are a relatively new product group in the ventilation sector and are gaining increased attention from several member states. Several scientific studies have recently been performed which facilitates a proper evaluating of this product;
- because it is proposed to include humidity recovery (through enthalpy heat exchangers) in the revised Regulations (see Task 3), the product types and their humidity recovery technologies are further discussed, e.g. rotary wheels, enthalpy plate heat exchangers and regenerative heat exchangers with alternating airflows. The fact that some of the materials used for regenerative heat exchangers are also used in the field of air cleaning (abatement of gaseous pollutants) raises the question regarding the risk of a possible transfer of gaseous pollutants;

- filter technology depends on the required indoor air quality and the available outdoor air quality. The pressure drop and related energy consumption can be further reduced by developments in filter technology;
- the topic of indoor air cleaning and recirculation is addressed, which can potentially reduce the amount of air that needs to be replaced by outdoor air, thus reducing the heating/cooling energy that is lost due to this air exchange.
-

The information on technical design options is relevant for Task 5 as the base cases represent the present market average, but is in particular relevant in tasks 6 and, in aggregated form, Task 7.

2 Method for determining Ventilation Performance

2.1 Introduction

The energy rating of an RVU in both ecodesign and energy label regulations is based on Specific Energy Consumption SEC for ventilation, expressed in net kWh primary energy consumed per m² heated floor area of a dwelling or building, i.e. in kWh/(m².a). The formula for SEC, given below, consists of three parts (symbols as defined in regulation No. 1253/2014):

I. the energy consumption of the mechanical ventilation unit (+)
II. the space heating energy saved by the mechanical versus natural ventilation (-) and
III. the energy consumed for defrosting, as appropriate (depends also on climate).

$$SEC = \overbrace{t_a \cdot pef \cdot q_{net} \cdot MISC \cdot CTRL^x \cdot SPI}^{\text{I.}} - \overbrace{t_h \cdot \Delta T_h \cdot \eta_h^{-1} \cdot c_{air} \cdot (\underbrace{q_{ref} - q_{net} \cdot CTRL} \cdot MISC \cdot \underbrace{(1-\eta_t)})}^{\text{II.}} + \overbrace{Q_{defr}}^{\text{III.}}$$

The energy saving in the second part is, apart from a number of constants, due to two possible variables:

1. the (lower) average flow rate needed with mechanical ventilation $q_{net}*CTRL$ versus the natural ventilation flow rate q_{ref} and;
2. the possible thermal heat recovery efficiency η_t.

Only the first bullet point is of interest for ventilation performance. The flow rates q_{net} and q_{ref} are default values (1.3 m³/h.m² for q_{net} and 2.2 m³/h.m² for q_{ref}). The $CTRL$ factor has four possible values (1/0.95/0.85 or 0.65 for manual/clock/central or local ventilation demand).

It is important to realise that these values are empirical values for average mechanical and natural ventilation units installed, based on the best available knowledge at the time of the 2012-2013 ecodesign preparatory studies. They are not necessarily based on a comparison between mechanical and natural ventilation systems with the same ventilation performance, i.e. the appropriate air exchange rate at the right time and place in a dwelling according to certain minimum benchmarks. The reason is, that in 2012-2013 there was no consensual ventilation performance rating; the most common residential ventilation requirement in the EU building codes was, and to a large extent still is, a minimum air exchange rate per hour (ACH) for the whole dwelling and minimum extraction rates for wet spaces.

Especially with increased air tightness of the building shell and the increased awareness of the importance of indoor air quality for health and wellbeing, it is proposed --in extensive consultation with the stakeholders-- to make a step-change and **take the most recent findings and standards in the field of residential ventilation performance on board**.

2.2 IAQ benchmark

The basis for all ventilation performance based ratings is the **indoor air quality (IAQ) benchmark**. It is proposed to use the EN16798-1:2019 [7], the most recent EPB (Energy Performance of Buildings) standard, prescribing minimum air exchange rates for exhaust ('wet') spaces like kitchen, bathroom, toilet on the one hand and the 'habitable' spaces (living room, bedrooms, etc.) on the other.

The standard lists the design airflow rates for extraction of spaces and habitable spaces for performance categories IV (low) to I (high). For the IAQ-benchmark, category II is selected, corresponding to a design allowing for CO_2-concentrations of 1200 ppm (800 ppm above outdoor CO2 concentration). For this category II, the standard prescribes for a total **<u>occupied</u>** space with surface A_{total}:

- Per m² A_{total} : AER (air exchange rate): 0.42 l/s/m² A_{total} (= 1.51 m³/h/m²)
- For indiv. wet spaces : extract rates: kitchen=20 l/s, bathroom=10 l/s, toilet=10 l/s
-

This 0.42 l/s AER per m² A_{total} preferably is converted to a related AER per m² of habitable surface A_{hab}, because the air exchanges are primarily needed in the spaces that are occupied for longer periods, i.e. the habitable spaces. With a ratio of on average 1.5 (A_{total}/A_{hab}), the reference AER for habitable spaces becomes 0.63 l/s/m² (= 2.27 m³/s/m²)

The same Annex B of EN16798-1 states a minimal air exchange rate for **<u>non-occupied</u>** areas of 0.10 - 0.15 l/s/m² of heated space. Converted to habitable space, the reference air exchange rate during absence values becomes 0.15 – 0.20 l/s/m² of habitable spaces. For benchmarking the lower value (0.15 l/s/m²) will be used. Such airflow rates are needed to dilute pollutant concentrations coming from building materials and interior products.

For wet spaces the reference air extract rate during absence is set at 20% of the values during presence: kitchen=4 l/s, bathroom=2 l/s and toilet=2 l/s. These extract airflows are a.o. needed to remove excess moisture and humidity from plaster and other hygroscopic materials.

Table 1. Benchmark (Category II) flowrate parameters for HS and ES (Habitable (HS) and Exhaust (ES) Spaces

	HS presence	HS absence	ES presence	ES absence
q_{bench}	2.27 m³/h/m² (m² relates to HS)	0.54 m³/h/m² (m² relates to HS)	Kitchen :72m³/h Bathroom:36m³/h Toilet :36m³/h	Kitchen :14.4m³/h Bathroom:7.2m³/h Toilet :7.2m³/h

The IAQ-benchmark applies equally to **<u>all</u>** of the following average flow rate parameters (all in m³/h per m² heated floor surface):

– the <u>optimal</u> flow rate of a mechanical ventilation system q_{opt};

[7] EN 16798-1:2019 'Energy performance of buildings - Ventilation for buildings - Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics - Module M1-6'.

- the natural ventilation flow rate q_{ref};
- the flow rate of a mechanical ventilation system using the average technology q_{net};
- the declared ventilation flow rate of the ventilation unit at hand q_{sys}.

This will be discussed in the following sections.

2.3 Ventilation flow rates

2.3.1 Basics

To translate the IAQ-benchmark flowrates into flowrates of a (residential) ventilation system they are applied to the **average EU-dwelling** with a total heated floor area of 93 m² (Eurostat 2012[8]), an average room height of 2.6 m and an inner volume of 240 m³. The lay-out of the dwelling and surface areas were agreed upon with stakeholders and are expected to represent the main influence factors as regards ventilation airflows. Room sizes and lay-out for this average dwelling are given in the figure below. There are 3 Exhaust Spaces ES (bathroom, toilet and kitchen (which is an open kitchen adjoining the dining room)) and three Habitable Spaces HS (living/dining room and two bedrooms). The assumed airtightness n50 of the dwelling with mechanical ventilation units are related to the year and to the type of installation (new built, renovation or replacement). For installations related to new built and renovation after 2020, the airtightness is assumed to be n50=2.[9]

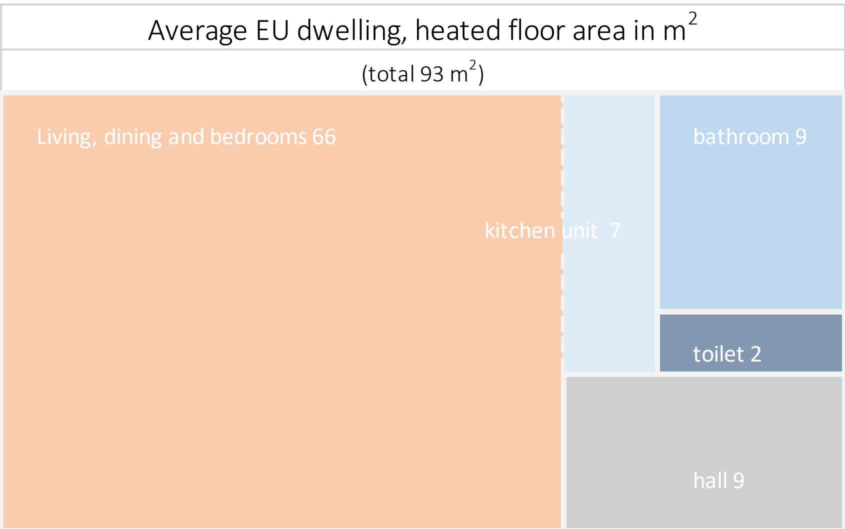


Figure 1. Average EU dwelling heated surface area in m²

The **occupancy schedule**, i.e. time spent in the various spaces by a household of 2.4 inhabitants (average EU value for 2012[10]), was developed in the context of the recent

[8] Eurostat, Average size of dwelling by household type and degree of urbanisation[ilc_hcmh02], extract 2020 for reference year 2012.

[9] Leading to an average infiltration of 0.12 l/s or 0.44 m³/h per m² heated floor area with mechanical systems

[10] Eurostat, Average household size - EU-SILC survey[ilc_lvph01], extract 2020 for reference year 2012.

Netherlands standard on ventilation performance NEN 1087[11] and is based on the results of extensive consumer surveys over the last decade. The occupancy level is given in Table 1. Note that the 'habitable spaces' in this context is intended to indicate all heated spaces in the dwelling except the 'exhaust spaces' (a.k.a. 'wet spaces').

2.3.2 Optimal flow rate q_{opt}

The optimal flow rate of a mechanical ventilation system q_{opt} is the minimum flow rate at IAQ-benchmark conditions matching exactly the heated surface and occupation level of the individual spaces at any given time. The calculation is given in Table 2. Note that the calculation for the two types of spaces is different and made transparent in this table.

Table 2. Assessment of the optimal specific flow rate per m² heated dwelling area

Dwelling	Surface	Time	Occupied			Non-occupied			Total
	m²	*%/day*	*h/d*	*m³/h.m²*	*m³/d*	*h/d*	*m³/h.m²*	*m³/d*	*m³/d*
Non-exhaust spaces									
dwelling not occupied(100%m²)	66	*37%*	-	-	-	*8.9*	0.54	*320*	320
dwelling occupied (avg. 50% m²)*	*33*	*63%*	*15.1*	2.27	1133	*8.9*	0.54	*160*	1291
Habitable spaces total	**66**	**100%**			**1133**			***480***	**1613**
Exhaust spaces				*m³/h*			*m³/h*		
Kitchen unit	7	9%	2.2	72.0	156	21.8	14.4	314	469
Bathroom	9	4%	1.0	36.0	36	23.0	7.2	166	202
Toilet	2	1%	0.2	36.0	9	23.8	7.2	172	181
Exhaust spaces total	**18**	**14%**			**200**			**652**	**852**
Hall	9								
Total	***93***				***1333***			***1132***	***2465***
Average *m³/h.m² Aheated*	*2465 / 24h / 93m² = **1.11** m³/h.m² Aheated*								
with best demand control (-20%) *with re-use supply air (-25%)*	***qopt*** *= 1.1 * 0.8 * 0.75=* ***0.67*** *m³/h.m² Aheated*								

*=on average 60% of inhabitants present in 50% of the occupied non-exhaust space

Table 2 shows that all the living (habitable) spaces make up 66m² of the dwelling and that the dwelling is empty 37% of the time (8.9 h/day). And when it is occupied (63% of the time or 15.1h per day), the inhabitants only occupy half (33 m²) of the living space surface area at the time (living room, bedrooms, etc.). Then, using optimal air exchange rates, in m³/h per m² heated surface A_{heated} for non-exhaust spaces discussed in the previous paragraph, the air exchange per day in occupied and non-occupied periods is assessed and summed to find the total non-exhaust spaces air exchange of 1613 m³/day.

For exhaust spaces, the floor area is not part of the calculation and is only given for information. The air exchange per day in occupied and non-occupied periods is calculated from the hours per day and optimal air exchange rates, in m³/h, during occupied and non-occupied periods. The total air exchange in exhaust spaces is found to be 852 m³/day.

[11] NEN1087 Task Group, Indicatieve Beoordelingsmethode Ventilatie Prestatie (Indicative Assessment method Ventilation Performance, in Dutch), Informative Annex to the Netherlands standard NEN 1087:2020, Delft 2020.

Combining exhaust and non-exhaust area values, a total of 2465 m³/day is found for the average dwelling with 93m² heated floor area. On average this gives 1.11 m³/h per m² A_{heated}[12] that is ideally needed for a category II ventilation performance for a ventilation system that is capable of *'inducing the right air exchange rates in the right place at the right time'* .

Please note this value relates to ventilation systems that:

- do not reuse the supply airflow rates in habitable spaces for the wet spaces, and;
- do not use load dependent controls for the habitable spaces (capable of adjusting airflow to the actual occupancy of 60% (see table 2)).

This means that the total minimal required standard airflow rate of 103 m³/h can be further reduced by:

1. Applying ventilation systems that reuse the air supplied in habitable spaces for the air exchange (extraction) in wet spaces, in which case the extract airflows in unoccupied wet spaces (652 m²/day) can be supplied from the HS, saving on average (652/2465) 25% (factor 0.75 below).
2. Applying sensors capable of determining the number of inhabitants in habitable spaces and adjusting the flowrates accordingly. With this an extra saving of around 20% on the total average AER over the dwelling can be achieved (factor 0.8 below).

The ultimate benchmark for comparing the *efficacy*[13] (or effectiveness) of the ventilation system in this average airtight EU-dwelling thus becomes:

q_{opt} = 1.1 * 0.8 * 0.75= **0.67 m³/h per m² A_{heated}**

Systems that result in higher air exchange rates than this q_{opt} (0.26 air changes per hour ACH), use more air for ventilation purposes than would strictly be necessary in an optimal situation and thereby waste more energy.[14]

For non-ducted (local) RVUs the optimal flow rates are 0.18 m³/h.m² in HS and 0.13 m³/h.m² in ES. For non-ducted (local) RVUs, 3 units are assumed for ES and 3 for HS. Note that for the q_{opt} of ducted RVUs there is the option of using the same exhaust air twice, i.e. first in a habitable space and then in a wet space. Non-ducted BVUs don't have that option and thus – when using only non-ducted units for the whole dwelling ventilation—the total q_{opt} of using non-ducted RVUs for the whole dwelling will be higher.

[12] 103 m³/h or 0.43 ACH for the average EU dwelling

[13] Efficacy is the ability to perform a task to a satisfactory or expected degree

[14] Note that ventilation systems that can compensate for useful infiltration (e.g. systems with CO_2 sensors in HS) may need even lower flowrates than this average flowrate of 62 m³/h. Assuming an average useful infiltration for a n50=4 dwelling of 0.16 m³/h per m² of habitable space, the minimal required airflow for the perfect system is reduced by 0.16/0.67 = 24%, resulting in an average hourly flowrate of 47 m³/h. As this situation cannot be predicted it will not be taken into account in the legislation.

2.3.3 Natural ventilation flow rate q_{ref}

The **natural ventilation flow rate q_{ref}** is discussed in Annex I. Amongst others, it shows that the average natural ventilation rate q_{ref} currently set at a default of 2.2 m³/h.m² should be increased to 2.5 m³/h.m² (rounded value) to properly represent the building stock having natural ventilation systems. The infiltration rate is, both for natural and mechanically assisted ventilation systems an important element as discussed in Annex 1. To reach the IAQ-benchmark, the natural ventilation system --using only the driving force of a passive stack (vertical duct from wet space extraction point to the roof)—requires abundant infiltration and/or natural air supply grids to reach the required IAQ-level. Mechanical ventilation systems can function with only a fraction of that infiltration rate to reach the same IAQ-level.

2.3.4 Reference flow rate q_{net}

As argued in Task 3, section 1.2, the reference flow rates q_{net} (as well as the declared flow rate q_{sys} of the system at hand discussed hereafter), can be assessed using the **Ventilation Performance Assessment (VPA)** tool[15] [16] developed for the European Ventilation Industry Association EVIA and based upon long-term surveys in the Netherlands and other Member States regarding the actual ventilation air exchange in residential dwellings.[17] [18] [19] [20]

The average technology for a whole dwelling is a ducted central unidirectional ventilation unit (UVU) with manual control (*CTRL*=1). The VPA-tool calculated that, in order to achieve the IAQ-benchmark with such a technology, the unit needs a flow rate q_{net} 1.97 m³/h/m².

Non-ducted (local) units need a flow rate q_{net} of 0.26 m³/h/m² when ventilating the exhaust space and 0.39 m³/h/m² in the habitable space to meet the IAQ-benchmark. It is assumed that three non-ducted local ventilation units are in the exhaust space and three non-ducted units are in the habitable spaces necessary to achieve to full dwelling ventilation.

[15] This method is based on the methodology that was developed by the University of Gent and VHK and is meant to assess the ventilation performance of residential ventilation systems on the basis of the technical characteristics of the ventilation provisions that are selected.

[16] Van Holsteijn, R.C.A., Laverge, J., Li, W.L., Methodology for Assessing the Air-Exchange Performance of Residential Ventilation Systems, Proceedings of the 38th AIVC Conference, 2017, Nottingham, United Kingdom.

[17] Consortium MONICAIR, Final Report WP1a, Results of a monitoring study into the Indoor Air Quality and energy efficiency of residential ventilation systems, December 2014. Results of a full year monitoring study concerning the ventilation performance in the various rooms of a dwelling, comparing 11 different building code compliant ventilation systems in the Netherlands.

[18] Tappler, P., Hutter, H.P., Hengsberger, H., Ringer, W. (2014), Lüftung 3.0 – Bewohnergesundheit und Raumluftqualtität in neu errichteten energieefficienten Wohnhäusern, Österreichisches Institut für Baubiologie und Bauökologie (IBO), Wien, Austria.

[19] McGill, G.M., Oyedele, L.O., Keeffe, G.K., McAllister, K.M., Sharpe, T. (2015), Bedroom Environmental Conditions in Airtight Mechanically Ventilated Dwellings, Conference Proceedings Healthy Buildings Europe May 2015, The Netherlands, Paper ID548.

[20] Sharpe, T., McGill, G., Gupta,R., Gregg, M., Mawditt, I., (2016), Characteristics and Performance of MVHR Systems, A meta study of MVHR systems used in the Innovative UK Building Performance Evaluation Programme, Report published by Fourwalls Consultants, MEARU and Oxford Brookes University.

2.3.5 Unit flow rate q_{sys}

Similar to the actual average flow rate q_{net}, the flow rate q_{sys} of a ventilation unit meeting the IAQ-benchmark with any control technology can be determined using the VPA-tool. The outcomes of a wide range of control technologies were assessed and compared with the BaseCase q_{net} (1.97), with $CTRL=q_{sys}/q_{net}$, to determine the look-up table for the $CTRL$-factors (see Tables 3 and 4).

In the case of a non-ducted (local) unit the formula is the same $CTRL=q_{sys}/q_{net}$ but for further calculations the CTRL-factor requires an additional correction for flow-sensitivity, using the multiplier fs; the q_{net} values for non-ducted units are as mentioned before, i.e. 0.39 for HS and 0.26 for ES.

fs : flow-sensitivity correction factor for local RVUs, determined with the formulas:

- For periodical operating fans : $fs = 1 + (v + qvio)/2$
- For continuous operating fans : $fs = (1 + v)$

Where

v = airflow sensitivity to pressure variations in %

$qvio$ = indoor/outdoor airtightness RVU with fans switched off related to qvmax in %

2.3.6 CTRL-factor

With the look-up table in the regulation, there is no longer any need for q_{sys} and the CTRL-factor can be found identifying whether the RVU-system is [ducted or non-ducted], where ducted airflow control types can be [central/zonal/local] and the control-input in the habitable spaces can be [a manual switch, a clock, central/zonal/local ES-type VDC[21] sensor(s) or HS-type VDC sensor(s)]. ES-type sensors measure humidity, VOCs and/or motion (yes/no). HS-type sensors measure CO_2 concentrations, occupancy (preferably intensity) and optionally VOCs as additional parameters. The control-type for ventilation in exhaust spaces plays no decisive role in determining the CTRL-factor for the RVU.
Airflow(s) of ducted units are [Unidirectional (UVU) or Bidirectional (BVU)], where subtype BVU1 has air supply in HS and subtype BVU2 has air supply in connecting spaces (e.g. hallway).

The non-ducted units inherently only have [local] airflow control and [local] control-inputs of the same types as the ducted units. Here it matters for the CTRL-factors whether the unit is serving the [exhaust space or the habitable space]. Also, the flow sensitivity fs is part of the equation for the CTRL-factor. Airflow(s) of the (Local) non-ducted units can be Unidirectional (L-UVU) or Bidirectional (L-BVU). In the latter case, there are also bidirectional units that have a constant ('balanced') flow control L-BVUc and thus a better CTRL-factor. The same goes for the ducted BVU1c and BVU2c In general, the BVUs have a filter-compensation factor of 20% and 6% internal leakage, but the L-BVUc, BVU1c and BVU2c have a filter-compensation-factor ≤1% and internal leakage ≤3%.

[21] ventilation demand control

Table 3. CTRL factors for ducted ventilation units (serving ES and HS)

VDC-devices/sensors /switches		**Airflow control**				
		RVU with central airflow control				
Extract Spaces	***Habitable Spaces***	UVU	BVU*1*	BVU*1c*		
manual,	no control or manual	**1.00**	**0.95**	**0.75**	***default***	
or any VDC-ES	clock, central VDC-ES	0.95	0.90	0.70		
	zonal VDC-ES or central VDC-HS	0.90	0.85	0.65		
	local VDC-ES or zonal VDC-HS	0.85	0.80	0.60		
	local VDC-HS	0.80	0.65	0.50		
		RVU with zonal airflow control				
Extract Spaces	***Habitable Spaces***	UVU	BVU*1*	BVU*1c*		
manual,	no control or manual	0.95	0.90	0.75		
or any VDC-ES	clock per zone	0.90	0.85	0.65		
	zonal VDC-ES	0.80	0.75	0.60		
	local VDC-ES or zonal VDC-HS	0.75	0.70	0.55		
	local VDC-HS	0.65	0.60	0.45		
		RVU with local airflow control				
Extract Spaces	***Habitable Spaces***	UVU	BVU*1*	BVU*1c*	BVU*2*	BVU*2c*
manual,	manual	0.95	0.80	0.65	0.95	0.95
or any VDC-ES	clock per room	0.85	0.75	0.60	0.90	0.80
	local VDC-ES	0.70	0.70	0.55	0.80	0.60
	local VDC-HS	0.45	0.50	0.35	0.70	0.50

Table 4. CTRL factors for non-ducted (local) ventilation units

Non-ducted (local) RVUs serving Extract Spaces only (incl. basic ventilation)						
Extract Spaces	***Habitable Spaces***	*L*-UVU	*L*-BVU	*L*-BVU*c*		
manual	n.a.	1.00*fs				
clock	n.a.	0.95*fs				
local VDC-HS	n.a.	0.85*fs				
local VDC-ES	n.a.	0.70*fs				
Non-ducted (local) RVUs serving Habitable Spaces only (incl. basic ventilation)						
Extract Spaces	***Habitable Spaces***	*L*-UVU	*L*-BVU	*L*-BVU*c*		
n.a.	manual	0.95*fs	0.95*fs	0.95*fs		
n.a.	clock	0.85*fs	0.90*fs	0.80*fs		
n.a.	local VDC-ES	0.70*fs	0.80*fs	0.60*fs		
n.a.	local VDC-HS	0.45*fs	0.70*fs	0.50*fs		

2.3.7 Average flow rate q_v

All the previous flow rates are defined to meet the IAQ-benchmark, but of course there is also the actual average flow rate of the unit q_v in m³/h per m² A_{heated} with a Ventilation Performance that typically will be much lower than the Ventilation Performance at the IAQ-benchmark. This value of q_v will be used in the assessment of the base cases (as most ventilation units do not reach the IAQ-benchmark in real life). Further clarification can be found in Chapters 3, as well as in Annex 4.

2.3.8 Ventilation Performance Indicator

The CTRL-factor, q_{net} and q_{ref} can be used to calculate the SEC and with the q_{opt} for calculation of a Ventilation Performance Indicator e.g. to be used in an energy label. The *Ventilation Performance indicator* ***VPI*** is defined as:

for ducted units $VPI=q_{opt}/(q_{net}*CTRL)$

for non-ducted units $VPI=q_{opt}/(q_{net}*fs*CTRL)$.

3 Ventilation Performance of base cases

3.1 Base Cases

This section presents the ventilation performance, average flow rates and boundary conditions required to describe the environmental and economic aspects of VU types placed on the market. As laid down in the MEErP the VU types sold and used in the Union are assessed as base cases, representative of products placed on the market today. The base cases are based upon the preceding preparatory studies for ventilation products for residential applications (Lot 10) :

- Ecodesign ENER Lot 10 – residential ventilation: Philippe Riviere et al, Study on residential ventilation - Final report (after SH comments), ARMINES France, February 2009;
- Ecodesign ENTR Lot 6 - Air-conditioning and ventilation systems: Philippe Riviere et al, Final Report Task 4, Definition Base Cases Ventilation Systems for non-residential and collective residential applications, ARMINES, VHK, BRE, June 2012;

The residential ventilation products or base cases covered by the former Lot 10 study and the present study are included in this report as follows:

Table 5. Residential VU types

ENER Lot 10 designation	Base Case or designation in present report	Basis for performance and efficacy	Airflow-control1)	Ventilation controls2)
DV/window continuous DV/wall continuous	UVU <100 m³/h for Extract Spaces or Habitable Spaces	Section 0	ES: Local HS: Local	ES: Manual HS: Manual
DV/window intermittent DV/wall intermittent DV/hood intermittent	excluded (see note 3)			
ICV contin. 2 speeds	UVU 100-250 m³/h	Section 3.3.3	Central	Manual
DV&HR continuous	BVU <100 m³/h	Section 3.3.2	Local	Manual
ICV&HR continuous	BVU 100-250 m³/h	Section 3.3.4	Central	Manual
CCV	UVU 250-1000 m³/h	Section 3.3.5	Central	Clock
CCV&HR	BVU 250-1000 m³/h	Section 3.3.5	Central	Clock

Notes:
1). Level at which the mechanical airflow can be varied (central, zone or local (room))
2). Type and location of the VDC-devices/sensor/switches that determine the (high/low) operation of the VU
3). VUs that cannot ventilate continuously (are always switched off after a certain period) are not considered ventilation units (and thus excluded from the assessment). Hoods are covered under a different regulation for energy labelling[22] and ecodesign[23] and excluded from the assessment

[22] Commission Delegated Regulation (EU) No 65/2014 of 1 October 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of domestic ovens and range hoods (Text with EEA relevance) OJ L 29, 31.1.2014

[23] Commission Regulation (EU) No 66/2014 of 14 January 2014 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for domestic ovens, hobs and range hoods (Text with EEA relevance) OJ L 29, 31.1.2014

Note that collective VUs between 250 and 1000 m³/h are considered NRVUs in the VU-Regulation.

For the non-residential ventilation products the same base cases for ventilation products in the former Lot 6 study are kept. Only the naming is changed to make this more consistent overall.

Table 6. Non-residential VU types

ENTR Lot 6 designation	Base Case or designation in present report	Basis for performance and efficacy	Airflow-control[1)]	Ventilation controls[2)]
CEXH	UVU > 1000 m³/h	Section 3.3.5	Central	Clock
CHRV	BVU 2500-5500 m³/h	Section 3.4	Central	Clock
AHU-S	AHU 5500 m³/h	Section 3.4		Clock
AHU-M	AHU 14500 m³/h	Section 3.4		Clock
AHU-L	AHU 50000 m³/h	Section 3.4		Clock

Notes:
1). Level at which the mechanical airflow can be varied (central, zone or local (room))
2). Type and location of the VDC-devices/sensor/switches that determine the (high/low) operation of the VU

The value of 100, 250, 1000, etc. indicate the category limits in terms of nominal flow rate in m³/h (qv). The actual flow rate is chosen roughly to be 30-40% lower than these limits (see Annex 4).

3.2 Boundary conditions

Based on the assessments and calculations described in the previous sections, and existing studies on average airtightness values of the EU-building stock, the following reference parameters have been defined for the existing building stock.

Building air tightness for assessment of ventilation performance of mechanical ventilation systems is determined to be on average n50 = 4 (for design options, see Report Task 6, it is assessed at n50 = 2, reflecting expected improvements in building envelope).

The number of local UVUs and BVUs is assessed at 3 units per home (heated space area 100 m²).

The performance values are indicative for year 2010, as this is close to the characteristics of the average products in stock (average life is assumed to be 17 years). Sales and stock volume relate to year 2015.

The default values for q_{opt} and q_{net} from the previous chapter are summarised in

Table 7.

Table 7. Default values for q_{opt} and q_{net} per VU types

	Ducted RVU [m³/h/m²]	**Non-ducted RVU-HS*** [m³/h/m²]	**Non-ducted RVU-ES*** [m³/h/m²]
q_{net}	1.97	0.39	0.26
q_{opt}	0.67	0.18	0.13

* For non-ducted (local) RVUs, 3 units are assumed for ES and 3 for HS. Note that q_{opt} of ducted RVUs there is the option of using the same exhaust air twice, i.e. first in a habitable and then in a wet space. With non-ducted RVUs don't have that option and thus –when using only non-ducted units for the whole dwelling ventilation—the total q_{opt} of non-ducted RVUs will be higher.

These characteristics are used to find the CTRL-factor.

3.3 Residential ventilation systems

3.3.1 Performance Local UVUs: UVU100

Non-ducted local extract ventilation units are gradually gaining market share in the renovation market mainly because ductwork is not needed, making installation less invasive. Unlike bathroom and toilet UVUs, these units provide continuous (or intermittent) basic extract ventilation 24 hours a day, seven days a week. These units can be used for whole house ventilation (similar to the central UVU, in which case often more than one local UVU is required as well as natural supply provisions in habitable spaces), or as extract-units for wet spaces only, in which case habitable spaces require their own supply and exhaust ventilation provisions. Finally, these local UVUs can also be used in habitable spaces. In that case both extract or supply UVUs can be used.

A specific characteristic for non-ducted UVUs concerns the flow-sensitivity *(fs)*. Wall mounted units may be sensitive to pressure variations over the façade and may introduce additional leakages when the indoor/outdoor airtightness is low during the off-periods of intermittent operation. These characteristics may influence ventilation performance and the energy performance of the units.

For whole house applications (similar to central UVU), please see section 3.3.3 for their performance parameters and design options). For ES-only applications, see table 6. And for HS-only applications, see table 7.

Table 8. Performance UVU100 for ES (base case and design options)

UVU/100/ES : Base case *fs* = 1.1 Non-ducted local UVU for extract spaces					
Airflow control	Local fan (3 local UVUs assumed per average dwelling)				
Ventilation controls ES	Manual Switch for UVU in ES				
Ventilation controls HS	n.a.				
Performance parameters					
qv ($m^3/h/m^2$)	qsys ($m^3/h/m^2$)	*qopt* ($m^3/h/m^2$)	*qnet* ($m^3/h/m^2$)	CTRL**fs*	VPI ES
0.22	0.29	*0.13*	*0.26*	1.00*1.1=1.1	45%
Design option A *fs<1+1% fs* = 1.01					
Airflow control	Local fan				
Ventilation controls ES	Local RH (Relative Humidity sensor)				
Ventilation controls HS	n.a.				
Performance parameters					
qv	qsys	*qopt*	*qnet*	CTRL**fs*	VPI ES
0.17	0.18	*0.13*	*0.26*	0.70*1.01=0.71	72%

Table 9. Performance UVU100 for HS (base case and design options)

UVU/100/HS : Base case fs=1.1 Non-ducted local UVU for habitable spaces					
Airflow control	Local fan (3 local UVUs assumed per average dwelling)				
Ventilation controls ES	n.a.				
Ventilation controls HS	Manual Switch for UVU in HS				
Performance parameters					
qv	qsys	*qopt*	*qnet*	CTRL**fs*	VPI
0.18	0.41	*0.18*	*0.39*	0.95*1.1=1.05	44%
Design option A *fs=1.01*					
Airflow control	Local fan (3 local UVUs assumed per average dwelling)				
Ventilation controls ES	n.a.				
Ventilation controls HS	Local CO2 control for UVU in HS				
Performance parameters					
qv	qsys	qopt	qnet	CTRL**fs*	VPI HS
0.18	0.18	0.18	0.39	0.45*1.01=0.45	100%

3.3.2 Performance Local BVUs: BVU100

The non-ducted local bidirectional ventilation units with heat recovery are also gradually gaining market share in the renovation market because ductwork is not needed, making installation less invasive. They provide continuous (or intermittent) basic ventilation for 24 hours a day, seven days a week. These units are mainly used for habitable spaces where thermal comfort issues are important topics.

A specific characteristic of non-ducted BVUs concerns the flow-sensitivity (*fs*). Wall mounted units may be sensitive to pressure variations over the façade and may introduce additional leakages when the indoor/outdoor airtightness is low during the off-periods of intermittent operations. These characteristics may influence ventilation performance and the energy performance of the units. As base case, a BVU100_HS unit is selected having default internal leakages of 6% and a filter clogging correction factor of 20% and a flow sensitivity *(fs)* of 5%. The newer BVUs that are offered on the market have lower internal leakages, airflow balance control and improved ventilation demand control options, all leading to a higher ventilation performance, a lower CTRL-factor and higher efficacy values.

Table 10. Performance BVU100 for HS (base case and design options)

BVU/100 : Base case (*fs=1.10*) Non-ducted local BVU for a habitable space (extraction and supply in HS)					
Airflow control		Local fan(s)			
Ventilation controls ES		n.a.			
Ventilation controls HS		Manual switch			
Performance parameters					
qv	*qsys*	*qopt*	*qnet*	CTRL**fs*	VPI
0.20	0.41	*0.18*	*0.39*	0.95*1.1=1.05	44%
Design option A (internal leakage=6%; filter clogging correction=20%; *fs=1.10)*					
Airflow control		Local fan(s)			
Ventilation controls ES		n.a.			
Ventilation controls HS		Local RH			
Performance parameters					
qv	*qsys*	qopt	qnet	CTRL**fs*	VPI
0.29	0.34	0.18	0.39	0.80*1.1=0.88	53%
Design option B (internal leakage=6%; filter clogging correction=20%; *fs=1.10)*					
Airflow control		Local fan(s)			
Ventilation controls ES		n.a.			
Ventilation controls HS		Local CO2			
Performance parameters					
qv	*qsys*	*qopt*	*qnet*	*CTRL*fs*	*VPI*
0.24	0.30	0.18	0.39	0.70*1.1=0.77	60%
Design option C (internal leakage=3%; filter clogging correction=1%; *fs=1.01)*					
Airflow control		Local fan(s)			
Ventilation controls ES		n.a.			
Ventilation controls HS		Local CO2			
Performance parameters					
qv	*qsys*	*qopt*	*qnet*	*CTRL*fs*	*VPI*
0.20	0.20	0.18	0.39	0.50*1.01=0.51	90%

3.3.3 Performance Central Extract UVUs: UVU250

Central extract UVUs are the most widely used mechanical ventilation units. The majority of these units are combined with manual switches in the kitchen and/or the bathroom and control the speed settings of the fan. This version is selected as base case for the UVU250. Some countries also apply constant flow UVUs (VUs with no differentiation in high and low airflows). Depending on their average airflow per m², such units may result in a higher ventilation performance but their CTRL factor is inherently high and efficacy low and further improvement of these parameters is not possible.

Newer UVUs that are offered on the market have improved control options, leading to a higher ventilation performance in ES and HS, a lower CTRL-factor and higher efficacy values.

Table 11. Performance UVU250 (base case and design options)

UVU/250 : Base case Central Extract UVU ES for whole dwelling (to be combined with ventilation grids in HS)					
Airflow control[1)]		Central fan with *fixed* extraction valves in all ES			
Ventilation controls ES		Switch for UVU in kitchen and/or bathroom			
Ventilation controls HS		No controls for UVU; manual control of ventilation grids			
Performance parameters					
qv	qsys	qopt	qnet	CTRL	VPI
0.58	1.97	0.67	1.97	1.00	34%
Design option A					
Airflow control[1)]		Central fan with *controllable* extraction valves in all ES			
Ventilation controls ES		RH in kitchen and bathroom, PIR in toilet			
Ventilation controls HS		Zonal RH-measurement controlling UVU; manual control vent. grids			
Performance parameters					
qv	qsys	qopt	qnet	CTRL	VPI
1.00	1.58	0.67	1.97	0.80	42%
Design option B					
Airflow control[1)]		Central fan with *fixed* extraction valves in all ES			
Ventilation controls ES		RH in kitchen and bathroom, PIR in toilet			
Ventilation controls HS		Local CO_2-measurement controlling UVU; manual control grids			
Performance parameters					
qv	qsys	qopt	qnet	CTRL	VPI
1.15	1.58	0.67	1.97	0.80	42%
Design option C : Central UVU ES&HS					
Airflow control[1)]		Central fan with *controllable* extraction valves in all ES & HS			
Ventilation controls ES		RH in kitchen and bathroom, PIR in toilet			
Ventilation controls HS		Local CO_2-measurement controlling UVU; manual control grids			
Performance parameters					
qv	qsys	qopt	qnet	CTRL	VPI
0.90	0.89	0.67	1.97	0.45	76%
[1)]. Level at which the mechanical airflow can be varied (central, zone or local (room))					

3.3.4 Performance and Efficacy Central BVUs: BVU250

Central bidirectional ventilation units with heat recovery are gradually gaining market share. The most commonly used central BVU is the unit with manual switches in kitchen and/or bathroom that control the speed settings of the fan. BVUs have internal leakages and supply filters with increased pressure drop over time. As base case a BVU250 unit is selected having default internal leakages of 6% and a filter clogging correction factor of 20%.

The newer BVUs that are offered on the market have lower internal leakages, airflow balance control and improved ventilation demand control options, all leading to a higher ventilation performance in ES and HS, a lower CTRL-factor and higher efficacy values.

Table 12. Performance BVU250 (base case and design options)

BVU250 : Base case (internal leakage=6%, filter clogging correction=20%) Central BVU for whole dwelling (extraction in HS and supply in HS)					
Airflow control[1)]		Central fan with *fixed* valves in all ES and HS			
Ventilation controls ES		Switch for BVU in kitchen and/or bathroom			
Ventilation controls HS		No controls for BVU			
Performance parameters					
qv	qsys	qopt	qnet	CTRL	VPI
0.54	1.87	0.67	1.97	0.95	36%
Design option A					
Airflow control[1)]		Central fan with *fixed* valves in all ES and HS			
Ventilation controls ES		RH in kitchen and bathroom, PIR in toilet			
Ventilation controls HS		Local CO_2-measurement controlling BVU			
Performance parameters					
qv	qsys	qopt	qnet	CTRL	VPI
1.15	1.28	0.67	1.97	0.65	52%
Design option B BVU250 with internal leakage≤3%, filter clogging correction=0% (constant flow)					
Airflow control[1)]		Central fan with *fixed* valves in all ES and HS			
Ventilation controls ES		RH in kitchen and bathroom, PIR in toilet			
Ventilation controls HS		Local CO_2-measurement controlling BVU			
Performance parameters					
qv	qsys	qopt	qnet	CTRL	VPI
0.89	0.98	0.67	1.97	0.50	68%
Design option C BVU250 with internal leakage≤3%, filter clogging correction=0% (constant flow)					
Airflow control[1)]		Central fan with *controllable* extraction valves in all ES & HS			
Ventilation controls ES		RH in kitchen and bathroom, PIR in toilet			
Ventilation controls HS		Local CO_2-measurement controlling BVU			
Performance parameters					
qv	qsys	qopt	qnet	CTRL	VPI
0.70	0.70	0.67	1.97	0.35	96%
[1)]. Level at which the mechanical airflow can be varied (central, zone or local (room))					

3.3.5 Performance and Efficacy of collective RVUs

UVUs and BVUs of over 250 m³/h up to (and beyond) 1000 m³/h are considered to be a representative base case unit for collective residential applications. Groups of four to five apartments can be served with units of up to 1000 m³/h. The larger units UVU>1000 and BVU2500 serve an even larger number of individual apartments. By far the largest part of the residential apartment buildings uses these larger collective unidirectional extract units. The traditional control option here is to use a clock for increasing the flowrate during the morning and the evening periods, when the wet rooms (bathroom, kitchens and toilets) are more frequently used. Beyond these periods, the flowrates are reduced. Smarter control options to further improve the ventilation performance in the habitable spaces are possible with controllable valves per dwelling; such solutions require continuous negative pressure in the central exhaust duct and a continuous surplus pressure in the central supply ducts. Dwelling- and even room- specific sensors that control the valves can further improve ventilation performance in both the extract and habitable spaces while simultaneously reduce the airflow needed to achieve this.

For indications on the performance and efficacy of the collective RVUs, reference is made to table 9 and 10.

3.4 Non-residential ventilation systems

Five non-residential ventilation units are distinguished:

1. NR-UVU/>1000
2. NR-BVU/2500
3. AHU/S
4. AHU/M
5. AHU/L

The first two are also discussed in the previous section as collective residential unit. But these units are also used for non-residential applications where generally higher design airflow rates are required. Also, according to the definition in the Regulation ventilation units above 1000 m³/h are denominated as non-residential ventilation units and treated differently. For these reasons these units are also addressed in this section with adjusted calculations

Contrary to the residential applications described in the previous sections, no reference is made here to a specific reference ventilation performance. This implies that for these NRVUs it is assumed that comparable ventilation performances are achieved irrespective of the types of controls used. It also implies that the calculated energy consumption will be more in line with real-life energy consumption. For non-residential ventilation systems where usually the operation of the ventilation unit is controlled by building automation control systems and such like (i.e. not by the occupants), the topic ventilation performance is considered less problematic compared to residential applications.

For base case NRVUs a default CTRL-factor is assumed of 0.48 (NRVUs with variable speed motor controls and a clock program for the ventilation demand control).

3.5 Defining reference parameters

The environmental and economic (life cycle cost) assessment of base cases are based upon the air exchange rates (for habitable (HS) and exhaust (ES) spaces) as calculated in the preceding sections.

Annex 4 presents the additional parameters used to calculate the main inputs in the environmental and economic assessment shown in Table 13

Table 13. Main inputs/outputs for average flow rate of base cases

Base Case	Related heated space	Nominal flowrate q_{nom}	SPI @nom.flow	SFPtotal @nom.flow	Average flowrate q_v	Average flowrate	Real-life CTRL-factor q_v/q_{nom}
	m²	m³/h	W/m³/h	W/m³/s	m³/h/m²	m³/h	
UVU/100/ES	100	60	0.20		0.22		0.37
UVU/100/HS	100	60	0.20		0.18		0.25
BVU/100/HS	100	60	0.40		0.20		0.33
UVU/250	100	180	0.30		0.58		0.32
BVU/250	100	180	0.45		0.54		0.30
UVU/1000	400	720	0.30		0.61		0.34
BVU/1000	400	720	0.45		0.61		0.34
UVU/>1000	833	1500	0.30		0.61		0.34
BVU/2500	1250	2250	0.45		0.61		0.34
AHU-S	1111	4000		1985		1920	0.48
AHU-M	2778	10000		2703		4800	0.48
AHU-L	9722	35000		3167		16800	0.48

The average power consumption is calculated as 0.15 times the nominal flow rate times the SPI at nominal flow, plus 0.85 times real life CTRL factor to the power of the motor exponent (value 1 to 2) times the nominal flow rate times the SPI at nominal flow. The average annual electricity consumption is calculated as the average power of fan + controls * 8760 hours per year plus defrosting energy (which is electric).

Table 14. Calculated electricity and (indirect) fuel consumption of base cases

Base Case	Avg. annual electric power VU	Annual electricity consumption VU	Average space heating energy loss per VU	Average additional annual space heating energy loss natural infiltration
	W	kWh_e/a	kWh_fuel/a	kWh_fuel/a
UVU/100/ES	4	36	542	263
UVU/100/HS	3	27	370	263
BVU/100/HS	8	121	172	263
UVU/250	16	145	1429	2370
BVU/250	23	276	266	1938
UVU/1000	69	610	6012	9481
BVU/1000	103	1230	1202	7752
UVU/>1000	143	1261	12524	19751
BVU/2500	322	3825	3757	24225

AHU-S	508	4963	26490	21533
AHU-M	1730	16435	66226	53833
AHU-L	7095	66622	231789	188415

All the above values apply to the 'Average' climate condition.

4 Environmental analysis

The following sections describe the inputs for the Ecoreport per phase of the product life cycle, from production (including resource extraction and assembly) to distribution, use and end-of-life.

As the calculation of life cycle costs in Chapter 5 for non-residential units is different to residential units (mainly because of in/exclusion of VAT) this led to the introduction of additional base cases for the UVU 1000, BVU 1000, UVU >1000 and BVU 2500 ventilation units by splitting them up in residential and non-residential applications. Units of max. 250 m3/h are by definition residential and AHUs are by definition non-residential. As the economic calculations are linked to environmental calculations, the output of the calculations show these additional base cases (split up into residential and non-residential).

The division is not shown in the inputs for the production and distribution phase, and EOL phase in order not to repeat the same information. For the use-phase differences occur for environmental parameters (electricity consumption, and primary energy loss from heating) as non-residential ventilation units may serve different heated areas, and economic parameters (costs, sales and stock).

4.1 Changes to Ecoreport 2013

The environmental analysis in this report is based upon the EcoReport tool, which has a predefined set of impact indicators per resource consumed or per life cycle activity. The Ecoreport version used is from 2013, but some indicators and calculations have been updated (as per the review study for the revisions of the space, combination and water heaters regulations 811/2013, 812/2013, 813/2013 and 814/2013) and the excel worksheets have been modified to accommodate the many base cases.

The environmental analysis in this Task 5 is based on the EcoReport tool 2014 specifically developed for use in Ecodesign preparatory studies and revised in 2014[24]. However, the Ecoreport 2014 has been modified to better suit the needs of this Task and to remove some inconsistences. The modifications include [25]:

1. In indicator row #68 to #74 in worksheet Data2 the basis of inputs was revised (now on fuel in, instead heat out), and NOx emissions of gas and oil fired appliances were revised (and also that of condensate as process water).
2. ROW 243 in worksheet Uitrekensheet was covering energy/impacts from consumption during use only, and Unit indicator #87 Mini-van diesel (for service/repair transports) was omitted. ROW 254 of Uitrekensheet was added to values in ROW 243;

[24] See https://ec.europa.eu/docsroom/documents/5308/attachments/1/translations available on https://ec.europa.eu/growth/industry/sustainability/ecodesign_en (Support tools for experts)

[25] See also the Task 5 reports of the Review Studies for Space, Combination and Water Heaters, available at: www.ecoboiler-review.eu

3. indicator #93 was introduced by subtracting the impacts from reuse/recover /recycling processes (indicator #93) from the possible benefits from re-use as calculated in sheet Data3 for bulk and tec plastics only.
4. EOL mass fractions to reuse, recycling, recovery (Ecoreport inputs pos.nr. 263 to 267 have been updated;
5. Unit indicator #93 (plastics re-use impacts), reflecting impacts from the recycling processes itself (not to be confused with credits) has been implemented.

Table 15. NOx emissions per GJ or kWh energy input (GCV)

Input energy	**Original Ecoreport 2014 value**	**Additional categories:**		
		"pre-mix."	*"internal combustion"*	*"fuel cell"*
	(MEErP 2014 shows multiple indicators for efficiency levels)	pre-mix burners, non-internal combustion engines (Stirling, sorption), and similar technologies	internal combustion engines (as in Otto- and Diesel cycles, for gas and oil)	gas-fired fuel cell (based on natural gas)
gas	80 mg/kWh = 15.52 g/GJ	40 mg/kWh = 7.7 g/GJ [26]	240 mg/kWh = 46.7 g/GJ	0.3 g/GJ [27] = 1 mg/kWh
oil	~500 mg/kWh = 97 g/GJ	120 mg/kWh = 23.3 g/GJ[28]	420 mg/kWh = 81.7 g/GJ	(n.a.)

Ventilation units were not part of the pilot phase of the development of Product Environmental Footprints (PEFs) nor have Product Environmental Footprint Category Rules (PEFCRs) been established for ventilation units [29].

4.2 Production

The Ecoreport calculation of the production-phase covers resource extraction and production, including assembly and starts with a bill-of-materials of the product. The impacts of these materials include impacts from resource extraction (see MEErP update 2011 and 2013) and the production of the raw or semi-finished materials themselves (plastics production, steel

[26] Source: Jean Schweitzer, Per G. Kristense, Evaluation of the NOx emissions of the Danish population of gas boilers below 120 kW, Project Report, Danish Gas Technology Centre, October 2014. The DGC report concludes for 'new' boilers an average emission of 0.42/0.77/1.16 kg/year for buildings with an energy input (gas consumption) of 10000/20000/30000 kWh/year (table page 52 and table 3-4) . This translates to average 40 mg/kWh gas input, and is in line with ecodesign requirements as introduced by 813/2013. The assumption is that the NOx emissions as calculated from tests (weighted average of emissions at full and several part load capacities) is representative for actual emissions.

[27] Source: Catalog of CHP Technologies, Section 6. Technology characterization - Fuel cells, US EPA, March 2015. The value is the simple average of all technologies covered by Table 6-5. For PEMFC and SOFC the NOx value shown may be considered uncharacteristically high, but the error (given unknown fuel cell technologies to be applied) is considered acceptable.

[28] The assumption is that oil boilers also meet the ecodesign requirements in place since 2013 (implemented 2015) and that the NOx emissions as calculated from tests (weighted average of emissions at full and several part load capacities) is representative for actual emissions.

[29] http://ec.europa.eu/environment/eussd/smgp/ef_pilots.htm

production) and losses occurring during production and assembly (such as injection moulding, steel forming, etc.).

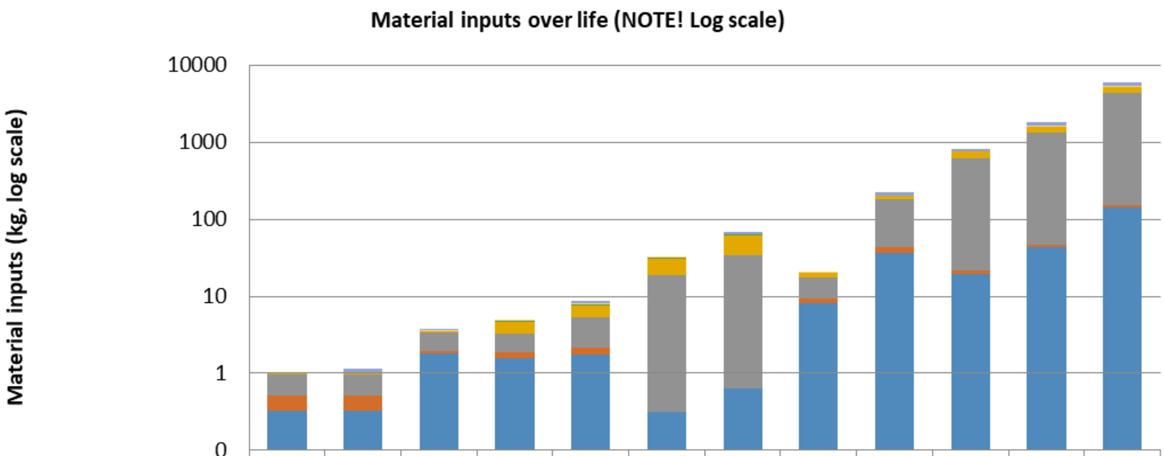
The bill-of-materials of the base cases are as defined in the preceding preparatory studies as these are considered to be of sufficient quality. Stakeholders have not indicated that this information is not representative anymore, and no updated information has been received.

Table 16 Material inputs (incl. repair)

Material category / VU type		UVU/ 100/ ES	UVU/ 100/ HS	BVU/ 100/ HS	UVU/ 250	BVU/ 250	UVU/ 1000	BVU/ 1000	UVU/ >1000	BVU/ 2500	AHU -S	AHU -M	AHU - L
Sector		R	R	R	R	R	R+NR	R+NR	R+NR	R+NR	NR	NR	NR
Bulk plastics	kg	0.3	0.3	1.8	1.6	1.7	0.3	0.6	8.1	35.9	19.8	42.8	142
Tec plastics	kg	0.2	0.2	0.1	0.3	0.5	-	-	1.3	6.8	1.7	3.7	12.0
Ferro	kg	0.5	0.5	1.4	1.4	3.1	18.3	33.9	8.1	139	605	1,290	4,190
Non-Ferro	kg	0.0	0.0	0.2	1.4	2.3	12.3	27.0	2.4	17.1	127	271	881
Coatings	kg	-	-	-	-	-	-	-	-	-	-	-	-
Electronics	kg	0.0	0.0	-	0.1	0.2	0.6	1.3	0.5	0.8	1.0	1.5	2.0
Misc.	kg	-	-	-	-	-	-	-	-	-	-	-	-
Refrigerants	kg	-	-	-	-	-	-	-	-	-	-	-	-
Hg	kg	-	-	-	-	-	-	-	-	-	-	-	-
Repair	kg	0.0	0.0	0.1	0.1	0.2	0.6	1.3	0.4	4.0	15.1	32.2	117
Water (m^3)	kg	-	-	-	-	-	-	-	-	-	-	-	612.0

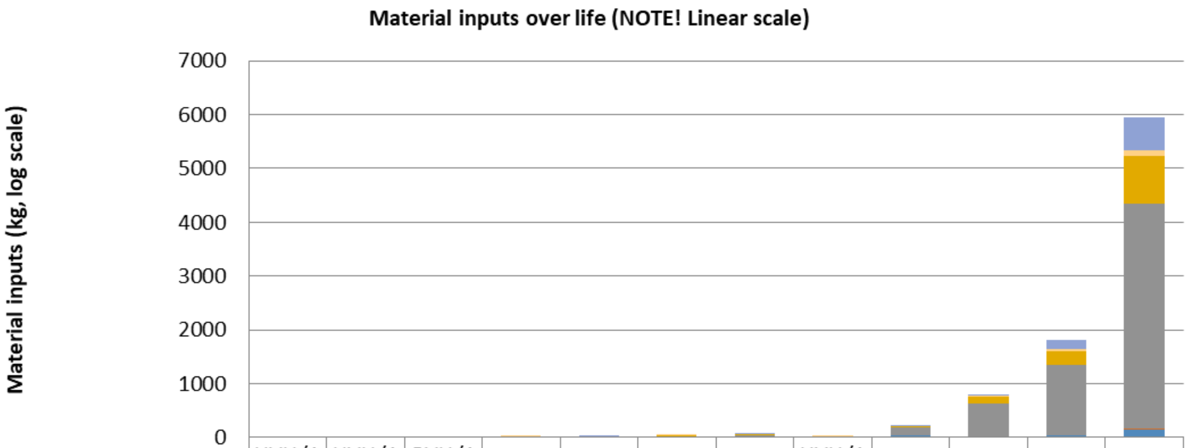
Added to material inputs are impacts from production facilities and storage. The impacts of the latter are based on the volume of the product (for calculation see the section 'Distribution' below). An overview of material inputs per base case is provided below.

Figure 2 Material inputs per base case (kg over life, log scale)



	UVU/100/ES/average	UVU/100/HS/average	BVU/100/HS/average	UVU/250/average	BVU/250/average	UVU/1000/average	BVU/1000/average	UVU/1000+/average	BVU/2500/average	AHU-S/average	AHU-M/average	AHU-L/average
Consumables kg	-	0.1	0.1	-	0.6	-	3.8	-	17.0	34.0	170.0	612.0
Repair (use phase) kg	0.0	0.0	0.1	0.1	0.2	0.6	1.3	0.4	4.3	15.8	35.6	116.8
Hg kg	-	-	-	-	-	-	-	-	-	-	-	-
Refrigerants kg	-	-	-	-	-	-	-	-	-	-	-	-
Misc. kg	-	-	-	-	-	-	-	-	-	-	-	-
Electronics kg	0.0	0.0	-	0.1	0.2	0.6	1.3	0.5	0.8	1.0	1.5	2.0
Coatings kg	-	-	-	-	-	-	-	-	-	-	-	-
Non-ferro kg	0.0	0.0	0.2	1.4	2.3	12.3	27.0	2.4	17.1	127.3	271.4	881.4
Ferro kg	0.5	0.5	1.4	1.4	3.1	18.3	33.9	8.1	139.3	605.0	1,290.	4,190.
Tec plastics kg	0.2	0.2	0.1	0.3	0.5	-	-	1.3	6.8	1.7	3.7	12.0
Bulk plastics kg	0.3	0.3	1.8	1.6	1.7	0.3	0.6	8.1	35.9	19.8	42.8	141.7

Figure 3 Material inputs per base case (kg over life, linear scale)



	UVU/100/ES/average	UVU/100/HS/average	BVU/100/HS/average	UVU/250/average	BVU/250/average	UVU/1000/average	BVU/1000/average	UVU/1000+/average	BVU/2500/average	AHU-S/average	AHU-M/average	AHU-L/average
Consumables kg	-	0.1	0.1	-	0.6	-	3.8	-	17.0	34.0	170.0	612.0
Repair (use phase) kg	0.0	0.0	0.1	0.1	0.2	0.6	1.3	0.4	4.3	15.8	35.6	116.8
Hg kg	-	-	-	-	-	-	-	-	-	-	-	-
Refrigerants kg	-	-	-	-	-	-	-	-	-	-	-	-
Misc. kg	-	-	-	-	-	-	-	-	-	-	-	-
Electronics kg	0.0	0.0	-	0.1	0.2	0.6	1.3	0.5	0.8	1.0	1.5	2.0
Coatings kg	-	-	-	-	-	-	-	-	-	-	-	-
Non-ferro kg	0.0	0.0	0.2	1.4	2.3	12.3	27.0	2.4	17.1	127.3	271.4	881.4
Ferro kg	0.5	0.5	1.4	1.4	3.1	18.3	33.9	8.1	139.3	605.0	1,290.	4,190.
Tec plastics kg	0.2	0.2	0.1	0.3	0.5	-	-	1.3	6.8	1.7	3.7	12.0
Bulk plastics kg	0.3	0.3	1.8	1.6	1.7	0.3	0.6	8.1	35.9	19.8	42.8	141.7

4.3 Distribution

The impacts of the distribution phase cover impacts related to distribution from manufacturing site to storage in wholesale and retail (warehouses) and are calculated using the default impacts per m³ installed product, plus impacts for storage per unit of product.

The Ecoreport impacts for installed products such as VUs are per unit of volume. For ventilation products this is derived from the product mass (of bill of materials) using:

*volume (m³) = 0.005*mass (kg)^1.02.*

These values are based upon an assessment of over 60 VUs ranging from 200 to 8000 m³/h and data from the preceding studies.

Figure 4 Storage and transport volume by product mass

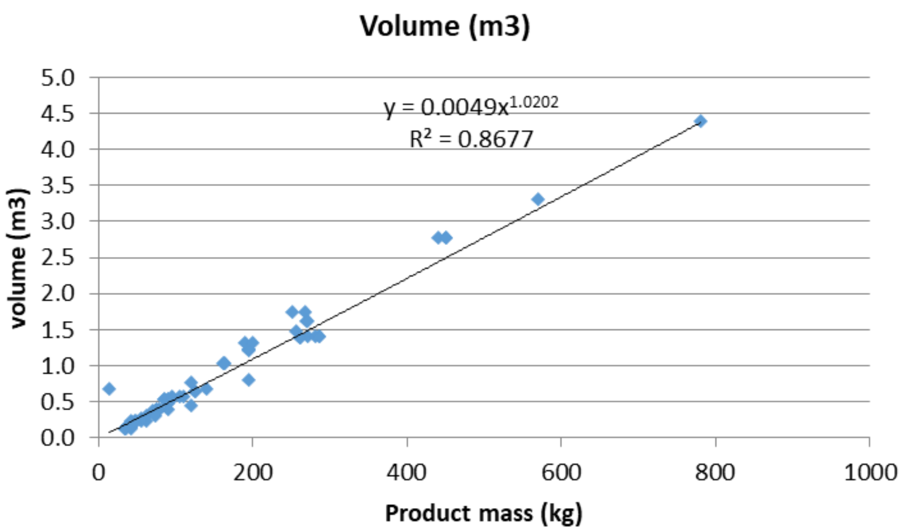


Table 17 Average storage and transport volume per base case

VU type	UVU/ 100/ ES	UVU/ 100/H S	BVU/ 100/H S	UVU/ 250	BVU/ 250	UVU/ 1000	BVU/ 1000	UVU/ >1000	BVU/ 2500	AHU-S	AHU-M	AHU-L
Volume (m^3)	0.005	0.005	0.02	0.03	0.05	0.19	0.38	0.12	1.25	4.85	10.50	34.90

The base case volume determines the impacts attributed to the base cases. The impacts are shown in the overall assessment together with the other life cycle phases.

4.4 Use phase

The use-phase inputs have been thoroughly updated, taking into account the performance and efficacy analysis in the preceding chapters in this Task 5 report. The energy consumption of ventilation products entails a direct consumption (electricity for motors and controls) and an indirect fuel "consumption" as ventilated air represents an energy content, in particular during the heating season.

Other impacts in the use-phase are related to use of consumables (filters) and service/ maintenance/ repair (materials and visits).

4.4.1 Electricity consumption due to ventilation

The electricity consumption is calculated as the average power consumption times the 8760 hours per year plus defrosting energy (only BVUs) as calculated in Chapters 3 and 4.

Defrosting is done electrically. Defrost hours and preheating temperature difference for the 'average' climate are 168 h/yr and 2.4 ºC (for 'warmer' 0 h/yr and 0 degrees and for 'colder' 1003 h/yr and 5.2 degrees respectively).

4.4.2 Heating energy due to ventilation

The ventilation losses or the loss of energy due to exchange of conditioned air are calculated on the basis of the reference air flow rates for the mechanical part and the infiltration part (together they provide the full ventilation function).

The ventilation losses are based upon an average heating season of 5112 h/a with an average temperature difference between indoor and outdoor conditions of 9.5 ºC for (for warmer and colder conditions the season duration is respectively 4392 h/a and 6552 h/a and 5 and 14.5 degrees respectively). The average specific energy content of the air exchanged is 0.00034 kWh/m³*K.

The ventilation losses due to the mechanical component are included in the environmental assessment. It is assumed that the losses are compensated by a modern low NOx gas fired space heater. The efficiency of the average space heater (value for 2020) is chosen as 75%.

Note that the total ventilation losses include infiltration losses determined by building envelope characteristics which are not controlled by mechanical ventilation system design and control. The infiltration rate for mechanically ventilated spaces is based on buildings with n50=4. Although natural ventilation or infiltration contributes to the ventilation performance indicator (VPI) and the ventilation losses need to be compensated by the heating system, they are not included in the present environment assessment as these losses cannot be attributed to the mechanical ventilation system.

Table 18 Main use phase inputs

Base case	Sector	Heated floor space	Annual electricity consumption VU	Avg. space heating energy loss per VU	Avg.additional annual space heating energy loss natural infiltration (information only)
		m^2	kWh_e/a	kWh_fuel/a	kWh_fuel/a
R-UVU100ES	R	33	28	463	263
R-UVU100HS	R	33	24	579	263
R-BVU100HS	R	33	79	193	263
R-UVU250	R	100	121	1946	2370
R-BVU250	R	100	231	381	1938
R-UVU1000	R	400	603	9165	9481
NR-UVU1000	NR	400	603	9165	9481
R-BVU1000	R	400	1142	1681	7752
NR-BVU1000	NR	400	1142	1681	7752
R-UVU>1000	R	833	1130	15809	19751
NR-UVU>1000	NR	400	537	17029	9481
R-BVU2500	R	1250	3551	5252	24225
NR-BVU2500	NR	500	1856	5322	9690
NR-AHU-S	NR	1050	4401	19222	20349
NR-AHU-M	NR	2500	13751	45767	48450
NR-AHU-L	NR	7000	44079	128146	135659

4.4.3 Consumables

Filter consumption is in kg per annum and based on the preparatory study for non-residential units (Lot 6 DG GROW, Task 4. p.24). The resulting trend line has been used to calculate expected filter consumption for smaller/residential BVUs.

Figure 5. Filter consumption by flow rate

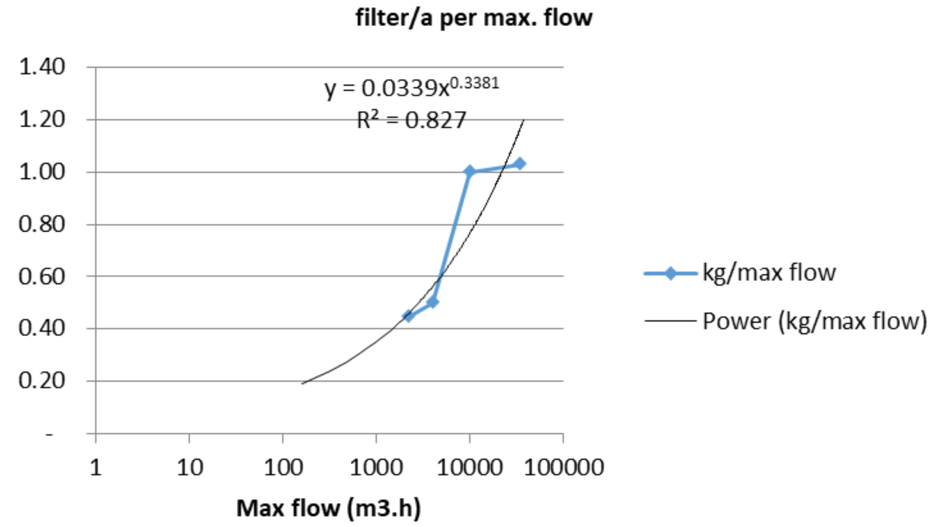


Table 19. Filter consumption per base case

Filter consumption	Filter mass	Filter change	Filter consumption
	kg/filter	filters/a	kg/y
UVU/100/ES			0
UVU/100/HS			0.01
BVU/100/HS			0.01
UVU/250			0
BVU/250			0.04
UVU/1000			0
BVU/1000			0.23
UVU/>1000			0
BVU/2500	1	1	1.00
AHU-S	2	1	2.00
AHU-M	5	2	10.00
AHU-L	6	6	36.00

In the Ecoreport tool filters have been entered as the equivalent to 'vacuum cleaner filter bags' as the closest equivalent impact indicator.

4.4.4 Service and repair

Servicing, maintenance and repair involves a number of trips by service personnel and material inputs for repairs.

For the service trips an estimate on the frequency of visits (how many years apart) is made. Each visit is assumed to require 50 km of transport by (delivery) van. The kilometres travelled over product life are indicated in the table below.

For materials for repairs a default value of 2% of total material input is assumed. The resulting kg's over life are shown in the table below.

Table 20. Service transport and repairs per base case

Category	Service frequency	Service transport	Repair	
	years between visits	km/life	% of mass	kg/life
UVU/100/ES	10	85	2%	0.02
UVU/100/HS	10	85	2%	0.02
BVU/100/HS	9	94	2%	0.07
UVU/250	5	170	2%	0.09
BVU/250	5	170	2%	0.17
UVU/1000	3	283	2%	0.63
BVU/1000	3	283	2%	1.30
UVU/>1000	2	425	2%	0.41
BVU/2500	2	425	2%	4.34
AHU-S	1	850	2%	15.78
AHU-M	1	850	2%	35.59
AHU-L	1	850	2%	116.79

The product life of all VUs is set at 17 years.

4.5 End-of-life phase

VUs are considered to fall within the scope of the WEEE Directive 2012/19/EU as *"Electric fans"* and are mentioned under *"1. Large household appliances"* in Annex II *"Indicative list of EEE which falls within the categories of Annex I"* for the transitional period, in that Directive. It is expected that VUs are covered by the present scope either as 'small' or 'large equipment' (Annex III). As Member States implement the WEEE in their national provisions regarding the treatment of this waste, it could be that the actual scope differs per Member State.

In 2017, fifteen EU Member States attained or surpassed the 45% target for collection of waste electrical and electronic equipment, with four further Member States very close to the target[30]. The average EU collection rate in 2017 was close to 40%. As of 2019, Member states must collect 65% of EEE put on the market [31] (WEEE 2012/19/EU Article 7). The WEEE

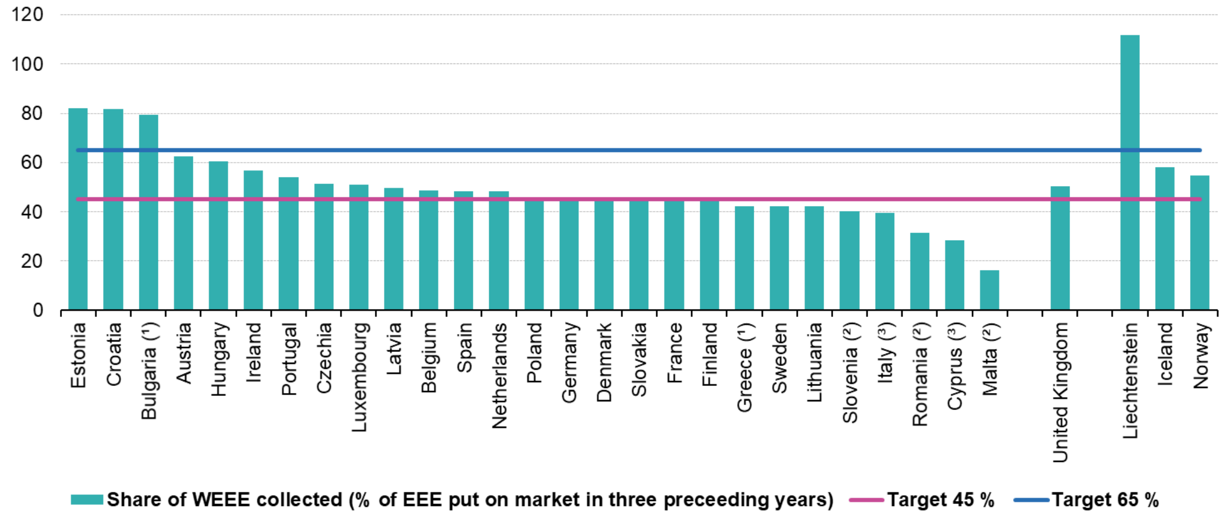
[30] https://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics_-_electrical_and_electronic_equipment#Collection_of_WEEE_by_country

[31] Or 85% of WEEE generated on the territory of that Member State. Member States will be able to choose which one of these two equivalent ways to measure the target they wish to report [https://ec.europa.eu/eurostat/documents/342366/351758/Target-Rates-WEEE]

Directive requires that member states achieve an 85% recovery rate for 'large equipment 'and 75% for 'small equipment', of which 80% and 55% respectively have to be prepared for re-use or recycling.

Figure 6. Total collection rate for WEEE, by MS, 2017[32]

(% of the average weight of EEE put on the market in the three preceding years 2015-2017)



Note: ranked on 'Share of WEEE collected...' data

(¹) Definition differs.

(²) Data on collection 2016 intstead of 2017; % of average weight of EEE put on the market 2014-2016

(³) Data on collection 2015 intstead of 2017; % of average weight of EEE put on the market 2013-2015

Source: Eurostat (online data code: env_waselee)

For the end-of-life phase an update of recovery rates has been applied. In this assessment it is assumed that by 2020 some 50% (not 65%) of products is collected through formal waste systems and receives formal treatment in accordance with WEEE requirements, and that the other 50% is treated informally. The reason being that the recovery rate for the EU as a whole in 2017 was close to just 40% and the recovery rates are changing only slowly. This also includes the assumption that ventilation products are not always removed from decommissioned buildings and may end up in construction & demolition waste with fewer options for material recovery especially for electronics and plastics (ferrous metals and some non-ferrous metals are easily recoverable so here similar recovery rates are assumed). Note that there is a general lack of data about actual 'removal' (for recovery) of ventilation systems, or technical systems in general, from building and demolition waste, even if protocols for handling such wastes exists in many member states[33].

The recovery rates (differentiated into recovery and recycling) and rates for discarded materials are presented in Annex 3- Recovery rates.

[32] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Total_collection_rate_for_waste_electrical_and_electronic_equipment,_2017_(%25_of_the_average_weight_of_EEE_put_on_the_market_in_the_three_preceding_years_(2015-2017)).png

[33] EU Construction & Demolition Waste Management Protocol, Ecorys, September 2016

4.6 Overview of environmental impacts per base case

The following graphs present the impacts of the life cycle phases for the base cases as calculated using the Ecoreport material and process indicators.

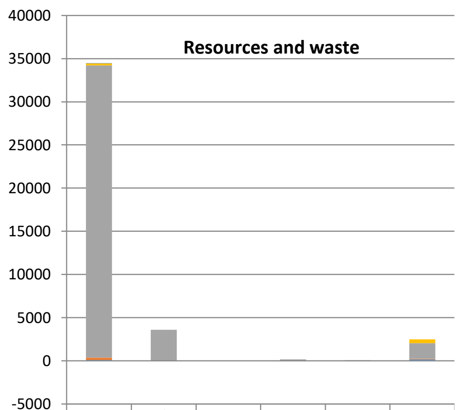
The graphs show that for resource consumption and waste the use phase is most often dominant. For greenhouse gas emissions the use phase (grey bar segment) again dominates. For acidification and VOCs the distribution phase of smaller VUs is relevant for, but as VU size grows the use phase again starts to dominate. Reduction of distribution emissions is most importantly achieved by regulating emissions of vehicles as the size of ventilation units is of secondary importance.

Emissions to water are dominated by the use phase and end-of-life phase (disposal debit are impacts). The credits for material recovery (avoided impacts) are not sufficient to recuperate end-of-life impacts.

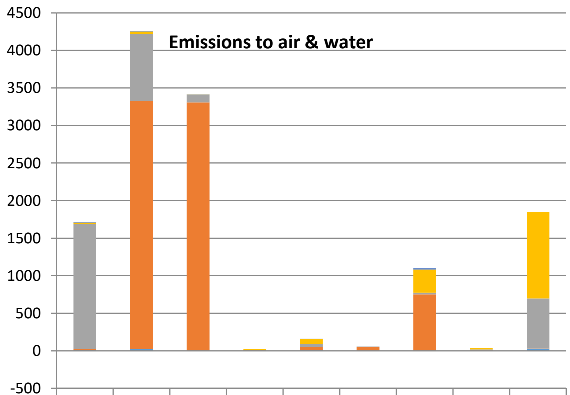
Figure 7 Resource consumption and emissions to air and water per base case

(see graphs following pages)

R-UVU/100/ES

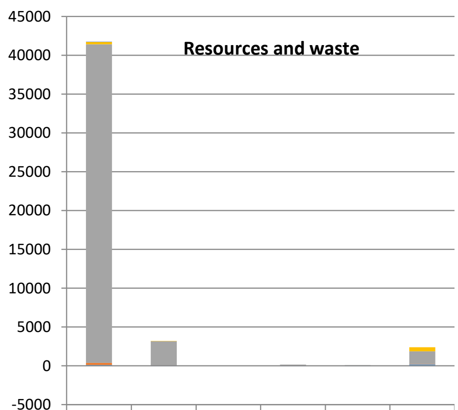


	Total energy (MJ)	o/w electricity (MJ prim.)	Water / process (ltr)	Water / cooling (ltr)	Waste / haz. (g)	Waste / non-haz. (g)
EOL/credit	2	0	0	0	0	-1
EOL/debet	240	0	0	0	0	415
Use(incl. cons.)	33883	3552	0	158	56	1830
Distribution	264	0	0	0	1	55
Production	84	17	0	8	1	164

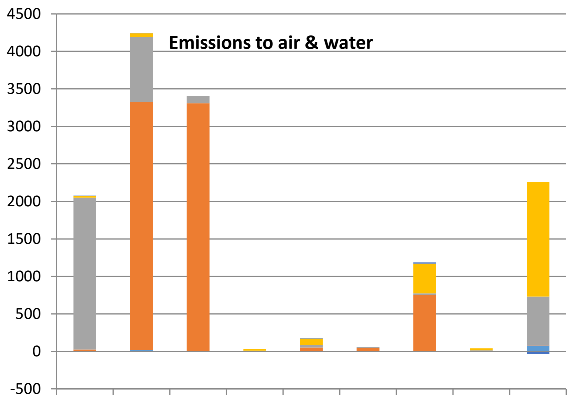


	Green h.gas (kg CO2 eq.)	Acidif (g SO2 eq.)	VOCs (g)	POPs (ng i-Tec.)	HMs/air (mg Ni eq.)	PAHs (mg Ni eq.)	PMs (g)	HMs/aq. (mg Hg/20)	Eutroph./aq. (g PO4)
EOL/credit	0	0	0	0	0	0	17	0	-1
EOL/debet	18	35	1	16	67	0	308	20	1149
Use(incl. cons.)	1662	891	99	8	36	9	22	15	671
Distribution	20	3307	3307	0	47	44	750	0	1
Production	6	20	0	2	6	3	2	0	26

R-UVU/100/HS

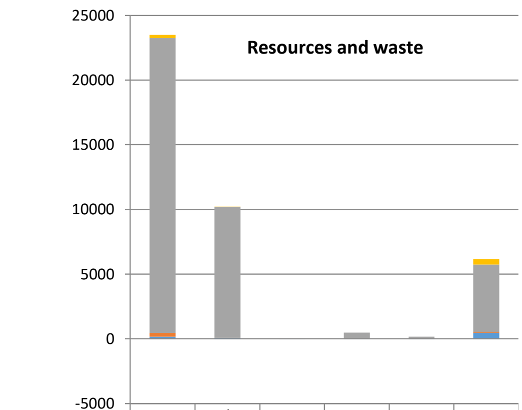


	Total energy (MJ)	o/w electricity (MJ prim.)	Water / process (ltr)	Water / cooling (ltr)	Waste / haz. (g)	Waste / non-haz. (g)
EOL/credit	0	0	0	0	0	-5
EOL/debet	310	0	0	0	0	528
Use(incl. cons.)	41051	3134	0	139	49	1622
Distribution	264	0	0	0	1	55
Production	87	18	0	8	1	170

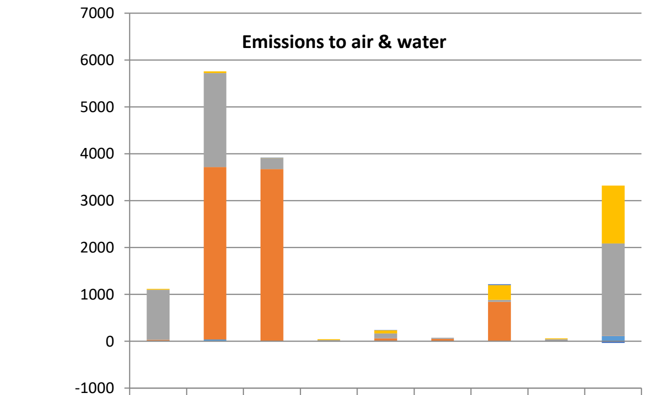


	Green h.gas (kg CO2 eq.)	Acidif (g SO2 eq.)	VOCs (g)	POPs (ng i-Tec.)	HMs/air (mg Ni eq.)	PAHs (mg Ni eq.)	PMs (g)	HMs/aq. (mg Hg/20)	Eutroph./aq. (g PO4)
EOL/credit	0	0	0	0	0	0	17	0	-33
EOL/debet	23	45	1	20	86	0	395	26	1529
Use(incl. cons.)	2022	868	95	7	32	8	22	13	647
Distribution	20	3307	3307	0	47	44	750	0	1
Production	7	21	0	2	6	3	2	0	81

R-BVU/100/HS

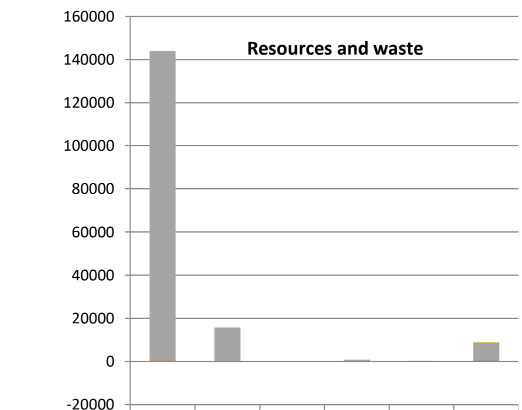


	Total energy (MJ)	o/w electricity (MJ prim.)	Water / process (ltr)	Water / cooling (ltr)	Waste / haz. (g)	Waste / non-haz. (g)
EOL/credit	0	-1	0	-1	0	-9
EOL/debet	248	0	0	0	0	425
Use(incl. cons.)	22806	10138	0	451	160	5231
Distribution	286	0	0	0	1	55
Production	162	63	1	29	1	444

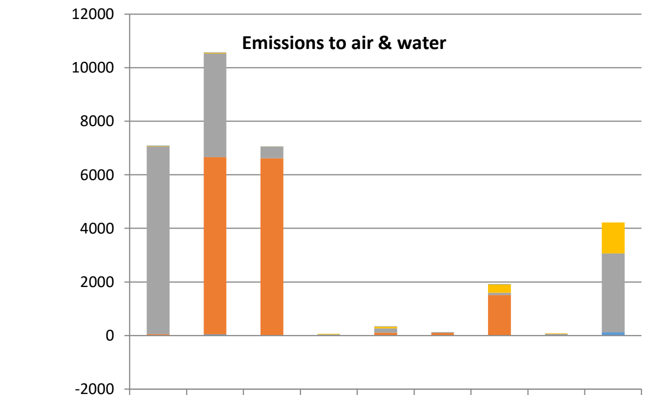


	Green h.gas (kg CO2 eq.)	Acidif (g SO2 eq.)	VOCs (g)	POPs (ng i-Tec.)	HMs/air (mg Ni eq.)	PAHs (mg Ni eq.)	PMs (g)	HMs/aq. (mg Hg/20)	Eutroph./aq. (g PO4)
EOL/credit	0	0	0	0	0	0	17	0	-34
EOL/debet	18	36	1	16	69	0	316	21	1234
Use(incl. cons.)	1064	2007	235	24	103	24	44	44	1970
Distribution	22	3674	3674	0	52	49	833	0	1
Production	11	39	0	4	12	3	4	0	114

R-UVU/250

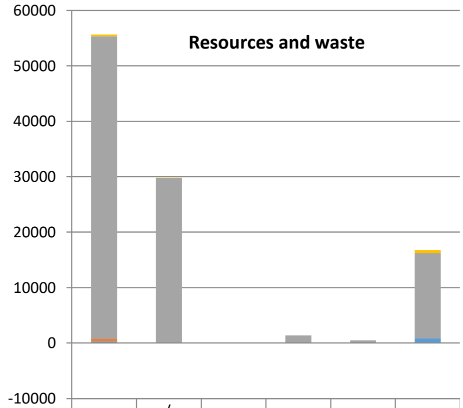


	Total energy (MJ)	o/w electricity (MJ prim.)	Water / process (ltr)	Water / cooling (ltr)	Waste / haz. (g)	Waste / non-haz. (g)
EOL/credit	1	-1	0	-1	0	-7
EOL/debet	240	0	0	0	0	415
Use(incl. cons.)	143008	15553	0	691	245	8015
Distribution	468	0	0	0	1	55
Production	187	72	2	36	2	535

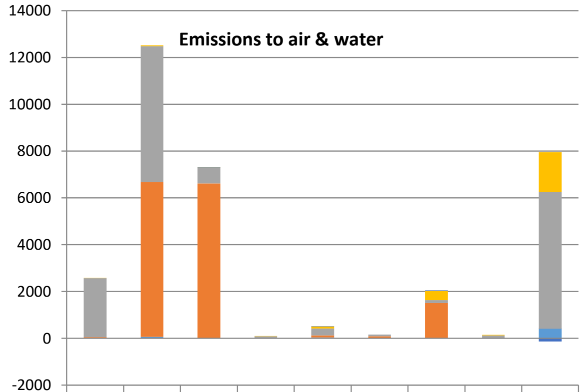


	Green h.gas (kg CO2 eq.)	Acidif (g SO2 eq.)	VOCs (g)	POPs (ng i-Tec.)	HMs/air (mg Ni eq.)	PAHs (mg Ni eq.)	PMs (g)	HMs/aq. (mg Hg/20)	Eutroph./aq. (g PO4)
EOL/credit	0	0	0	0	0	0	17	0	-4
EOL/debet	18	35	1	16	67	0	308	20	1149
Use(incl. cons.)	7012	3862	431	36	157	40	94	67	2938
Distribution	36	6613	6613	0	91	88	1500	0	1
Production	12	47	0	7	19	3	6	1	132

R-BVU/250

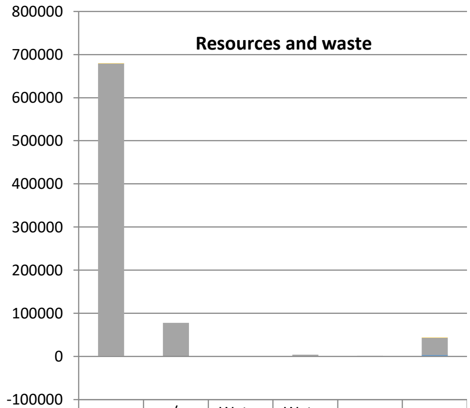


	Total energy (MJ)	o/w electricity (MJ prim.)	Water / process (ltr)	Water / cooling (ltr)	Waste / haz. (g)	Waste / non-haz. (g)
EOL/credit	-7	-2	0	-1	0	-27
EOL/debet	319	1	0	0	0	528
Use(incl. cons.)	54628	29701	0	1320	469	15332
Distribution	468	0	0	0	1	55
Production	266	107	3	53	2	845

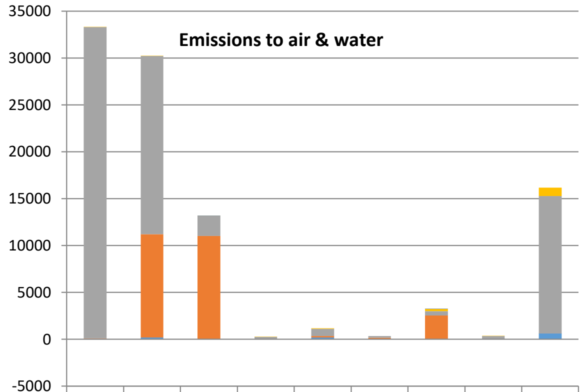


	Greenh.gas (kg CO2 eq.)	Acidif (g SO2 eq.)	VOCs (g)	POPs (ng i-Tec.)	HMs/air (mg Ni eq.)	PAHs (mg Ni eq.)	PMs (g)	HMs/aq. (mg Hg/20)	Eutroph./aq. (g PO4)
EOL/credit	0	-2	0	0	0	0	17	0	-133
EOL/debet	23	47	1	20	86	0	395	26	1695
Use(incl. cons.)	2510	5793	680	69	300	70	125	128	5830
Distribution	36	6613	6613	0	91	88	1500	0	1
Production	17	67	0	14	34	3	10	1	421

R-UVU/1000

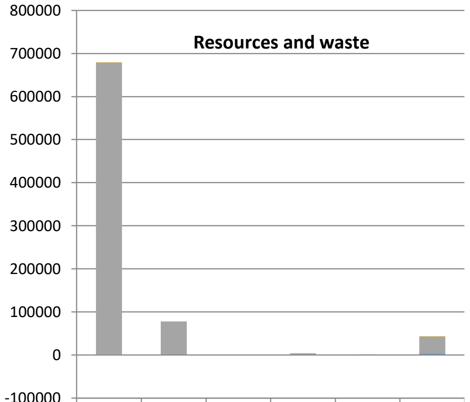


	Total energy (MJ)	o/w electricity (MJ prim.)	Water / process (ltr)	Water / cooling (ltr)	Waste / haz. (g)	Waste / non-haz. (g)
EOL/credit	-7	-4	0	-2	0	-53
EOL/debet	189	0	0	0	0	331
Use(incl. cons.)	677675	77505	0	3445	1223	39941
Distribution	741	0	0	0	1	55
Production	673	308	12	150	4	2857

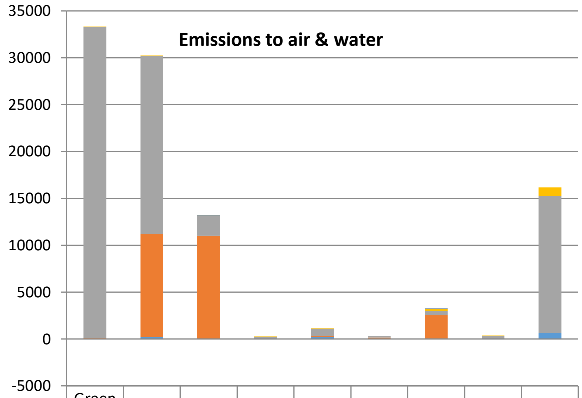


	Greenh.gas (kg CO2 eq.)	Acidif (g SO2 eq.)	VOCs (g)	POPs (ng i-Tec.)	HMs/air (mg Ni eq.)	PAHs (mg Ni eq.)	PMs (g)	HMs/aq. (mg Hg/20)	Eutroph./aq. (g PO4)
EOL/credit	0	-2	0	-1	-2	-1	17	0	-9
EOL/debet	14	27	1	12	53	0	243	16	906
Use(incl. cons.)	33202	18993	2124	181	784	196	461	334	14640
Distribution	57	11022	11022	0	150	147	2499	0	1
Production	41	179	2	78	184	6	31	6	632

NR-UVU/1000

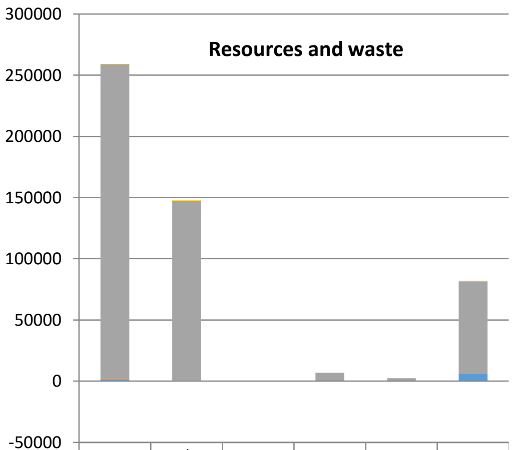


	Total energy (MJ)	o/w electricity (MJ prim.)	Water / process (ltr)	Water / cooling (ltr)	Waste / haz. (g)	Waste / non-haz. (g)
EOL/credit	-7	-4	0	-2	0	-53
EOL/debet	189	0	0	0	0	331
Use(incl. cons.)	677675	77505	0	3445	1223	39941
Distribution	741	0	0	0	1	55
Production	673	308	12	150	4	2857

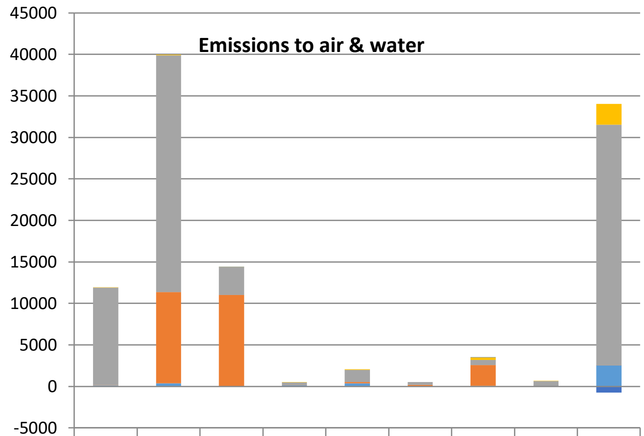


	Green h.gas (kg CO2 eq.)	Acidif (g SO2 eq.)	VOCs (g)	POPs (ng i-Tec.)	HMs/air (mg Ni eq.)	PAHs (mg Ni eq.)	PMs (g)	HMs/aq. (mg Hg/20)	Eutroph./aq. (g PO4)
EOL/credit	0	-2	0	-1	-2	-1	17	0	-9
EOL/debet	14	27	1	12	53	0	243	16	906
Use(incl. cons.)	33202	18993	2124	181	784	196	461	334	14640
Distribution	57	11022	11022	0	150	147	2499	0	1
Production	41	179	2	78	184	6	31	6	632

R-BVU/1000

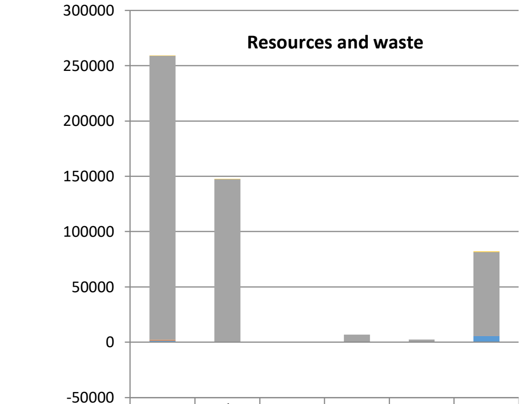


	Total energy (MJ)	o/w electricity (MJ prim.)	Water / process (ltr)	Water / cooling (ltr)	Waste / haz. (g)	Waste / non-haz. (g)
EOL/credit	-54	-10	-1	-3	0	-189
EOL/debet	322	4	0	0	0	444
Use(incl. cons.)	256917	146793	0	6524	2316	75796
Distribution	741	0	0	0	1	55
Production	1338	609	24	295	7	5712

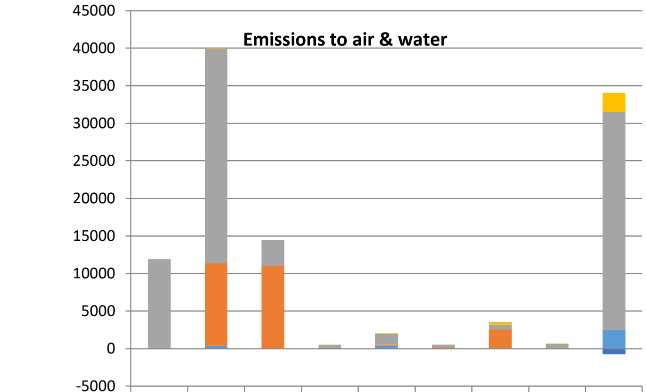


	Green h.gas (kg CO2 eq.)	Acidif (g SO2 eq.)	VOCs (g)	POPs (ng i-Tec.)	HMs/air (mg Ni eq.)	PAHs (mg Ni eq.)	PMs (g)	HMs/aq. (mg Hg/20)	Eutroph./aq. (g PO4)
EOL/credit	-3	-13	0	-2	-4	-1	16	-1	-748
EOL/debet	19	51	1	17	72	0	330	22	2499
Use(incl. cons.)	11752	28538	3350	343	1484	345	615	632	28995
Distribution	57	11022	11022	0	150	147	2499	0	1
Production	80	353	4	153	358	9	62	13	2519

NR-BVU/1000

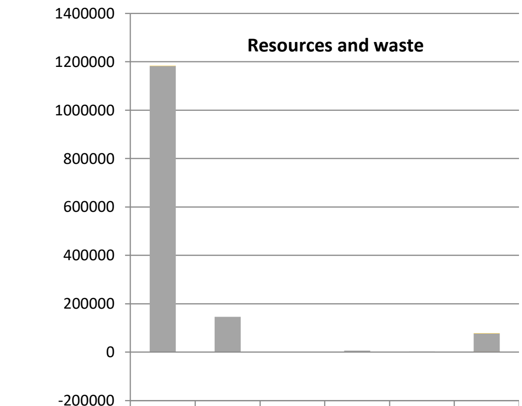


	Total energy (MJ)	o/w electricity (MJ prim.)	Water / process (ltr)	Water / cooling (ltr)	Waste / haz. (g)	Waste / non-haz. (g)
EOL/credit	-54	-10	-1	-3	0	-189
EOL/debet	322	4	0	0	0	444
Use(incl. cons.)	256917	146793	0	6524	2316	75796
Distribution	741	0	0	0	1	55
Production	1338	609	24	295	7	5712

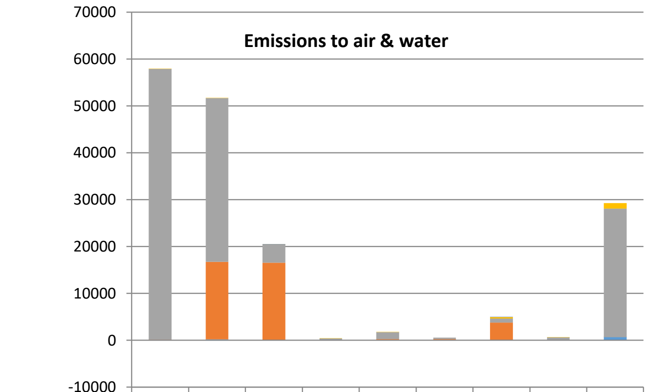


	Greenh.gas (kg CO2 eq.)	Acidif (g SO2 eq.)	VOCs (g)	POPs (ng i-Tec.)	HMs/air (mg Ni eq.)	PAHs (mg Ni eq.)	PMs (g)	HMs/aq. (mg Hg/20)	Eutroph./aq. (g PO4)
EOL/credit	-3	-13	0	-2	-4	-1	16	-1	-748
EOL/debet	19	51	1	17	72	0	330	22	2499
Use(incl. cons.)	11752	28538	3350	343	1484	345	615	632	28995
Distribution	57	11022	11022	0	150	147	2499	0	1
Production	80	353	4	153	358	9	62	13	2519

R-UVU/>1000

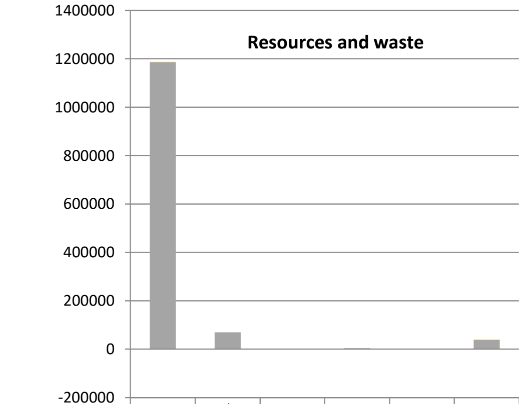


	Total energy (MJ)	o/w electricity (MJ prim.)	Water / process (ltr)	Water / cooling (ltr)	Waste / haz. (g)	Waste / non-haz. (g)
EOL/credit	-6	-4	0	-3	0	-33
EOL/debet	240	0	0	0	0	415
Use(incl. cons.)	1180489	145250	0	6456	2292	74852
Distribution	1082	0	0	0	1	55
Production	666	325	11	167	3	2144

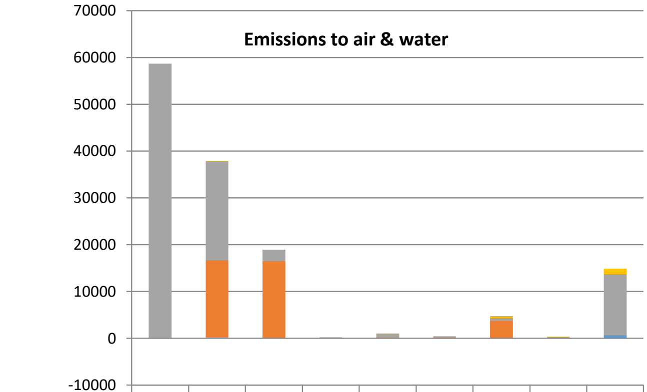


	Greenh.gas (kg CO2 eq.)	Acidif (g SO2 eq.)	VOCs (g)	POPs (ng i-Tec.)	HMs/air (mg Ni eq.)	PAHs (mg Ni eq.)	PMs (g)	HMs/aq. (mg Hg/20)	Eutroph./aq. (g PO4)
EOL/credit	0	-2	0	0	0	0	17	0	-19
EOL/debet	18	35	1	16	67	0	308	20	1149
Use(incl. cons.)	57764	34944	3922	339	1469	365	841	625	27436
Distribution	83	16533	16533	0	224	221	3749	0	1
Production	40	171	1	24	58	4	29	2	661

NR-UVU/>1000

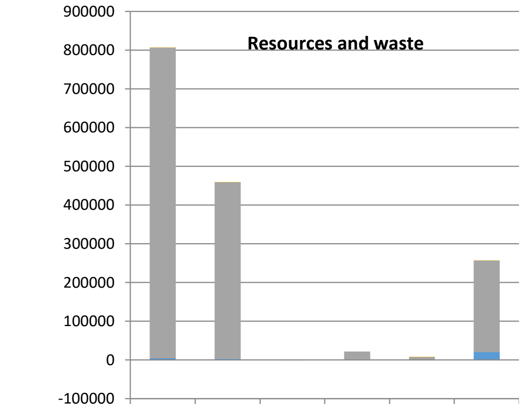


	Total energy (MJ)	o/w electricity (MJ prim.)	Water / process (ltr)	Water / cooling (ltr)	Waste / haz. (g)	Waste / non-haz. (g)
EOL/credit	-6	-4	0	-3	0	-33
EOL/debet	240	0	0	0	0	415
Use(incl. cons.)	1184167	69013	0	3067	1089	35565
Distribution	1082	0	0	0	1	55
Production	666	325	11	167	3	2144

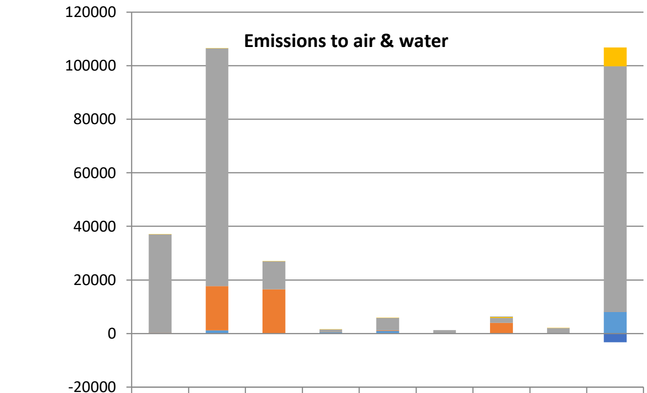


	Green h.gas (kg CO2 eq.)	Acidif (g SO2 eq.)	VOCs (g)	POPs (ng i-Tec.)	HMs/air (mg Ni eq.)	PAHs (mg Ni eq.)	PMs (g)	HMs/aq. (mg Hg/20)	Eutroph./aq. (g PO4)
EOL/credit	0	-2	0	0	0	0	17	0	-19
EOL/debet	18	35	1	16	67	0	308	20	1149
Use(incl. cons.)	58491	21124	2272	161	698	189	556	297	13036
Distribution	83	16533	16533	0	224	221	3749	0	1
Production	40	171	1	24	58	4	29	2	661

R-BVU/2500

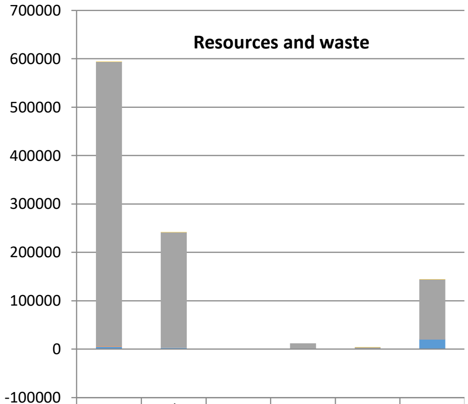


	Total energy (MJ)	o/w electricity (MJ prim.)	Water / process (ltr)	Water / cooling (ltr)	Waste / haz. (g)	Waste / non-haz. (g)
EOL/credit	-220	-41	-1	-18	-1	-746
EOL/debet	589	17	0	0	0	528
Use(incl. cons.)	800553	456340	0	20281	7200	235816
Distribution	1082	0	0	0	1	55
Production	4940	2636	47	1182	7	20506

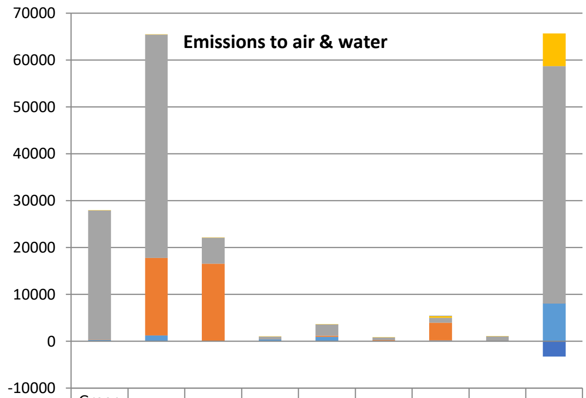


	Green h.gas (kg CO2 eq.)	Acidif (g SO2 eq.)	VOCs (g)	POPs (ng i-Tec.)	HMs/air (mg Ni eq.)	PAHs (mg Ni eq.)	PMs (g)	HMs/aq. (mg Hg/20)	Eutroph./aq. (g PO4)
EOL/credit	-13	-49	0	-7	-11	-1	14	-1	-3260
EOL/debet	23	103	1	20	87	0	395	26	6987
Use(incl. cons.)	36627	88747	10417	1065	4614	1073	1912	1964	91707
Distribution	83	16533	16533	0	224	221	3749	0	1
Production	283	1216	5	411	951	8	186	32	8108

NR-BVU/2500

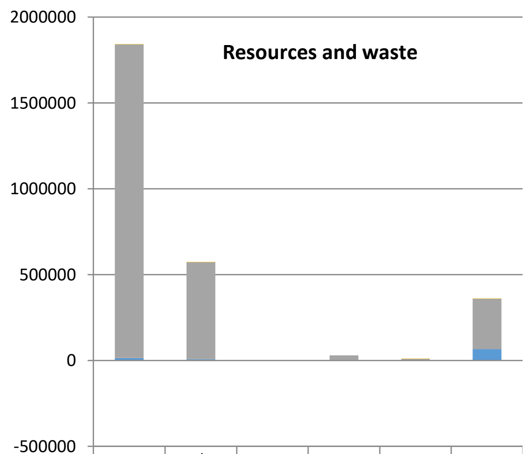


	Total energy (MJ)	o/w electricity (MJ prim.)	Water / process (ltr)	Water / cooling (ltr)	Waste / haz. (g)	Waste / non-haz. (g)
EOL/credit	-220	-41	-1	-18	-1	-746
EOL/debet	589	17	0	0	0	528
Use(incl. cons.)	587327	238576	0	10603	3764	123595
Distribution	1082	0	0	0	1	55
Production	4940	2636	47	1182	7	20506

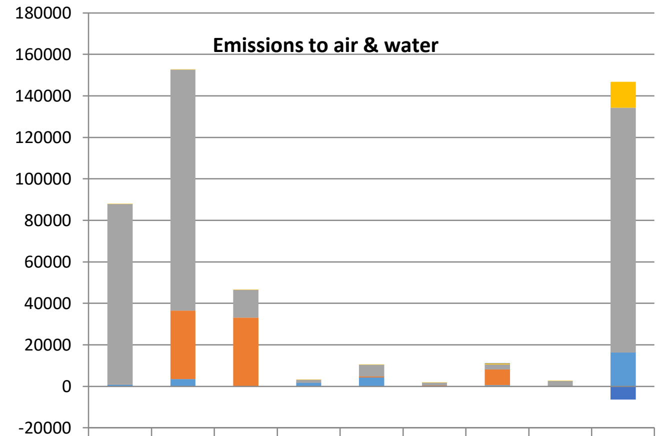


	Green h.gas (kg CO2 eq.)	Acidif (g SO2 eq.)	VOCs (g)	POPs (ng i-Tec.)	HMs/air (mg Ni eq.)	PAHs (mg Ni eq.)	PMs (g)	HMs/aq. (mg Hg/20)	Eutroph./aq. (g PO4)
EOL/credit	-13	-49	0	-7	-11	-1	14	-1	-3260
EOL/debet	23	103	1	20	87	0	395	26	6987
Use(incl. cons.)	27558	47647	5556	557	2412	565	1042	1027	50573
Distribution	83	16533	16533	0	224	221	3749	0	1
Production	283	1216	5	411	951	8	186	32	8108

AHU-S

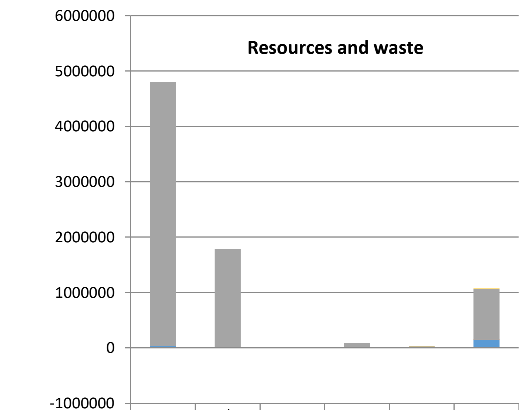


	Total energy (MJ)	o/w electricity (MJ prim.)	Water / process (ltr)	Water / cooling (ltr)	Waste / haz. (g)	Waste / non-haz. (g)
EOL/credit	-498	-106	-2	-37	-1	-2106
EOL/debet	872	34	0	0	1	528
Use(incl. cons.)	1824866	565605	0	25136	8924	292772
Distribution	2106	0	0	0	1	56
Production	13827	7500	113	3169	16	67281

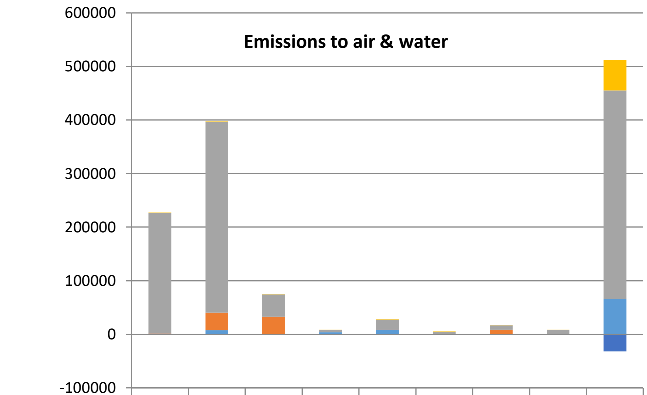


	Green h.gas (kg CO2 eq.)	Acidif (g SO2 eq.)	VOCs (g)	POPs (ng i-Tec.)	HMs/air (mg Ni eq.)	PAHs (mg Ni eq.)	PMs (g)	HMs/aq. (mg Hg/20)	Eutroph./aq. (g PO4)
EOL/credit	-29	-120	0	-30	-51	-4	9	-5	-6453
EOL/debet	23	161	1	20	87	0	395	26	12499
Use(incl. cons.)	86872	116076	13456	1320	5719	1351	2579	2435	117855
Distribution	162	33065	33065	0	445	442	7498	0	1
Production	796	3447	18	1821	4200	17	528	141	16361

AHU-M

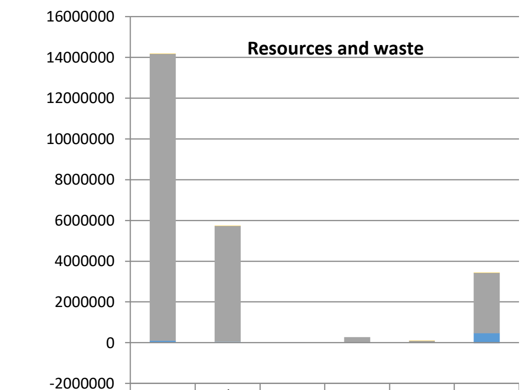


	Total energy (MJ)	o/w electricity (MJ prim.)	Water / process (ltr)	Water / cooling (ltr)	Waste / haz. (g)	Waste / non-haz. (g)
EOL/credit	-1995	-281	-3	-79	-3	-6662
EOL/debet	3129	170	0	0	4	528
Use(incl. cons.)	4767056	1767427	0	78545	27887	917298
Distribution	2108	0	0	0	1	57
Production	30985	16103	232	6743	33	147192

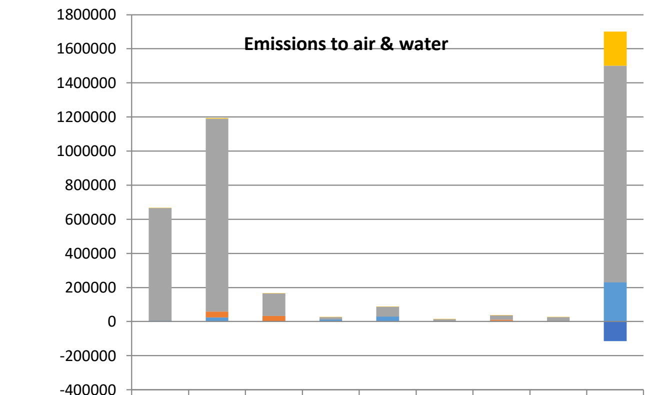


	Green h.gas (kg CO2 eq.)	Acidif (g SO2 eq.)	VOCs (g)	POPs (ng i-Tec.)	HMs/air (mg Ni eq.)	PAHs (mg Ni eq.)	PMs (g)	HMs/aq. (mg Hg/20)	Eutroph./aq. (g PO4)
EOL/credit	-117	-449	0	-64	-110	-9	0	-10	-31965
EOL/debet	23	629	1	21	89	0	396	27	56597
Use(incl. cons.)	224880	356135	41432	4125	17872	4200	7824	7608	388938
Distribution	162	33065	33065	0	445	442	7500	0	2
Production	1783	7644	36	3884	8954	32	1118	301	66062

AHU-L



	Total energy (MJ)	o/w electricity (MJ prim.)	Water / process (ltr)	Water / cooling (ltr)	Waste / haz. (g)	Waste / non-haz. (g)
EOL/credit	-7050	-945	-9	-257	-10	-22969
EOL/debet	10466	611	0	0	14	528
Use(incl. cons.)	14066695	5665612	0	251778	89395	2943023
Distribution	2116	0	0	0	1	61
Production	101249	52415	720	21829	95	480298



	Green h.gas (kg CO2 eq.)	Acidif (g SO2 eq.)	VOCs (g)	POPs (ng i-Tec.)	HMs/air (mg Ni eq.)	PAHs (mg Ni eq.)	PMs (g)	HMs/aq. (mg Hg/20)	Eutroph./aq. (g PO4)
EOL/credit	-414	-1576	-2	-209	-357	-28	-38	-32	-114973
EOL/debet	23	2147	1	24	97	1	398	30	199917
Use(incl. cons.)	660391	1133019	132016	13222	57290	13431	24774	24389	1268499
Distribution	163	33065	33065	0	445	442	7505	0	2
Production	5818	24889	112	12613	29070	90	3593	977	231983

A detailed overview of all calculated impacts (and costs) of base cases is shown in Annex 3.

5 Economic analysis

This Chapter of the Task 5 report presents an updated life cycle cost analysis of the (base cases of) ventilation products.

The life cycle cost analysis describes the costs over the complete life cycle of the base cases and includes purchase, installation, operational costs (energy & servicing/maintenance) and end-of-life costs. The goal is to identify the total costs of operation of the products and to provide a basis for the EU-wide assessment of costs associated with the production, use and disposal of these products (the EU-wide impact and costs are presented in Chapter 7).

5.1 Purchase & installation costs

The purchase costs and installation costs of VUs are based upon information in the Task 2 report. VAT is 20% for residential ventilation units.

Table 21. Purchase costs

Base case	Nominal flow rate (m³/h)	Purchase price (incl. VAT)	Source
R-UVU100ES	60	190	Task 2, Table 32, p.84
R-UVU100HS	60	190	Task 2, Table 35, p.89
R-BVU100HS	180	544	Task 2, Table 30, p.83
R-UVU250	180	486	Task 2, Table 33, p.86
R-BVU250	720	1619	Task 2, Table 30, p.83
R-UVU1000	720	382	Task 2, Table 33, p.86
NR-UVU1000	see residential	318	see residential
R-BVU1000	1500	2058	Task 2, Table 31, p.83
NR-BVU1000	see residential	1715	see residential
R-UVU>1000	2250	750	Task 2, Table 34, p.87
NR-UVU>1000	see residential	625	see residential
R-BVU2500	4000	5582	Task 2, Table 36, p.90
NR-BVU2500	see residential	4652	see residential
NR-AHU-S	10000	9563	Task 2, Section 4.2.7, p.91
NR-AHU-M	35000	13254	Task 2, Section 4.2.7, p.91

The installation costs are based on the previous assessments corrected for the 2015 monetary value. These earlier assessments provided information for installation costs for replacement (NRVU only) and new built and renovation (RVU and NRVU). A very large part of the new built and renovation costs however covers the creation of a ventilation system infrastructure (exhaust ducts, inlet ducts, building envelope openings, terminal equipment) which last longer than the single ventilation product itself.

Assuming a residential building life of average 75 years and 50 years for non-residential buildings (acknowledging that the spread in building life is vast) the building will experience one 1st time installation and 3 VU replacements in residential buildings (together spanning 75 years) and 2 VU replacements in non-residential buildings for 50 years building life. Summing the installation costs ('non-recurring') and subsequent replacement costs ('recurring') and dividing these by the total number of VUs installed over that building life, this results on average ('combined') installation costs per VU as shown below.

Table 22. Installation costs

Base case	Vent. infra-structure life	Installation replacement (incl. VAT, 2015 euros)	Installation new built (incl. VAT, 2015 euros)	Installation renovated (incl. VAT, 2015 euros)	Combined installation costs over VU life (incl. VAT, 2015 euros)
	(yr)	(EUR/#)	(EUR/#)	(EUR/#)	(EUR/#)
R-UVU100ES	75	62.5	62.5	62.5	80
R-UVU100HS	75	63	63	63	80
R-BVU100HS	75	75	224	224	136
R-UVU250	75	75	784	1200	345
R-BVU250	75	108	1741	2479	682
R-UVU1000	75	108	1170	1793.0	511
NR-UVU1000	50	108	1170	1793.0	612
R-BVU1000	75	133	2605	3712.0	992
NR-BVU1000	50	133	2605	3712.0	1207
R-UVU>1000	75	260	5000	6200	1783
NR-UVU>1000	50	260	5000	6200	2164
R-BVU2500	75	2200	18900	21200	7654
NR-BVU2500	50	2200	18900	21200	9017
NR-AHU-S	50	2930	87885	98469	34610
NR-AHU-M	50	4680	238500	267300	90666
R-UVU100ES	50	8820	745200	834480	277366

The installation costs (over product life) as % of life cycle costs range from 7% for the smallest R-UVUs up to 70%-80% for the largest AHUs.

5.2 Servicing, maintenance and repair costs

Maintenance (and repair and/or servicing) includes e.g. filter replacement, cleaning of fans, ducts, valves and grills, and small repairs. The costs are as established in the preceding studies, with values corrected to 2015 monetary value.

Table 23 Maintenance costs

Base case	Maintenance / repair costs (EUR/a)	Source	Maintenance / repair costs (EUR/life)
R-UVU100ES	2	Task 2, Table 39, p.92	41
R-UVU100HS	2		41
R-BVU100HS	22		449
R-UVU250	10		204
R-BVU250	52		1061
R-UVU1000	41		836
NR-UVU1000	34		581
R-BVU1000	94		1907

NR-BVU1000	78	1325
R-UVU>1000	72	1469
NR-UVU>1000	60	1020
R-BVU2500	135	2754
NR-BVU2500	113	1913
NR-AHU-S	191	3247
NR-AHU-M	652	11084
NR-AHU-L	2739	46563

5.3 Energy costs (direct and indirect)

Direct energy costs from electricity consumption are based upon the 2020 electricity tariff for residential consumers of 0.21 EUR/kWh_elec, and 0.171 EUR/kWh_elec for non-residential consumers.

The indirect energy consumption is the loss of energy due to the air exchange of conditioned air. It is assumed that incoming unconditioned air (corrected for heat recovery) is heated by a gas space heater with an efficiency of 75% [34]. The 2015 gas tariff for residential consumers is 0.076 EUR/kWh_fuel and 0.058 EUR/kWh for non-residential consumers.

The electricity and fuel/gas consumption (for infiltration air and/or mechanically displaced air) is presented in Section 4.4 of this report. The resulting electricity and fuel costs of the base cases over their life are shown below (for average climate conditions).

Table 24 Energy costs for base cases

Base case	Electricity costs, incl. VAT	Fuel costs (indirect, for heating) mechanical only, incl. VAT
	(EUR/life)	(EUR/life)
R-UVU100ES	118	718
R-UVU100HS	104	897
R-BVU100HS	337	300
R-UVU250	517	3016
R-BVU250	988	590
R-UVU1000	2577	14204
NR-UVU1000	1752	9043
R-BVU1000	4881	2605
NR-BVU1000	3317	1658
R-UVU>1000	4830	24501
NR-UVU>1000	1560	16803
R-BVU2500	15175	8140

[34] In chapter 6 of the Task 7 report of the review study on space heaters, the average boiler energy efficiency of the stock in 2016 was 74%. In Regulation 1253/2014 a space heater efficiency is 75%. This is considered adequate.

NR-BVU2500	5391	5251
NR-AHU-S	12782	18966
NR-AHU-M	39939	45157
NR-AHU-L	128026	126441

5.4 End-of-life costs

The following paragraphs are an attempt to quantify costs associated with the removal and treatment of VU waste, based upon generic but known waste treatment recovery rates and estimates for recovery value.

The potential monetary benefits of recovery are calculated on the basis of scrap metal value. Prices for scrap metal have been retrieved from scrap metal dealers which usually follow day trading tariffs (prices can differ from day to day)[35].

Table 25 Scrap metal value (June 2020)

Ecoreport material[36]	Scrap value (EUR/kg)
22_St sheet galv.	0.08
23_St tube/profile	0.1
24_Cast iron	0.05
25_Ferrite	0.05
26_Stainless 18/8 coil	0.6
27_Al sheet/extrusion (kg)	0.4
28_Al die cast	0.4
29_Cu winding wire	1.3
30_Cu wire	2.5
31_Cu tube/sheet	3.7
32_CuZn38 cast	2.35
98_Controller board	0.3

Given the fairly high percentages assumed for metal recycling it can be assumed that the potential scrap value is within 90-95% of the value shown above. Note that the recycling rates for the base cases are not 100% but closer to 96% for ferrous and 90% for non-ferrous materials (see Annex 3 – Recovery rates)

The EOL costs include besides the scrap value also the costs for scrap handling (for collection & transport, for pre-treatment & final processing). The WEEE Directive requires Member States to set up a structure so that funds are raised to ensure proper treatment of EEE placed on the market. In many Member States this takes the form of a surcharge on top of the purchase costs to be spent on treatment of discarded products of the same kind. The applicability and amount of the surcharge however may differ per Member State. In the Netherlands (VLA) this surcharge is 0.05 EUR/kg with a maximum of EUR 47.50 per

[35] Scrap metal value has been assessed using apps from Lion Metals and Krommenhoek Metals (both Rotterdam, Netherlands), June 2020. The prices are an estimated average of the two sources and an estimate in case the description of metal in the app and in Ecoreport appear different.

[36] The numbers refer to Ecoreport codes for materials.

ventilation unit[37]. When applied to the mass of the base cases it shows that these costs represent at maximum 0.2% of the purchase costs.

Alternatively there is the thinkstep B2BWEEE scheme, which mentions costs of GBP 110 per tonne (equivalent to 121 EUR/1000kg, or 0.121/kg, excl. transport and VAT) plus various annual fees[38]. Applying this value results in EOL costs that are maximum 0.04% of LCC costs (for smaller VUs) or a benefit of 0.21% of LCC costs (scrap value lowers LCC costs, for larger VUs).

The profitability of WEEE treatment is dependent on many factors, many beyond the sphere of influence by product design (labour costs, costs for technology for sorting and separation (inc. removal of hazardous or valuable parts/materials), recovery value (also in relation to prices of raw materials) , overhead costs etc.).

It is not known if the surcharge by VLA or B2BWEEE already includes the scrap value. If this charge includes recovery value, there are no net financial gains in waste treatment, only costs.

Even if for the LCC the actual recovery costs, including or excluding recovery value, are negligible as they represent 0.4% of value at maximum, for actual recycling to happen, the absolute recycling costs/benefits are relevant. Assuming the WEEE treatment costs do not include recovery value, recovery costs of 0.05 EUR/kg result in a net financial gain for all products. With treatment costs at 0.121 EUR/kg products weighing more than 3 kg result in net financial benefits: Smaller products are a cost factor.

Table 26. EOL costs (treatment) and benefits (scrap value) per ventilation unit

Category	Costs for treatment EUR/life	Benefits from scrap value (negative value is benefit) EUR/life
R-UVU100ES	€0.05	-€0.06
R-UVU100HS	€0.05	-€0.06
R-BVU100HS	€0.17	-€0.38
R-UVU250	€0.23	-€0.94
R-BVU250	€0.38	-€1.62
R-UVU1000	€1.55	-€8.08
NR-UVU1000	€1.55	-€8.08
R-BVU1000	€3.08	-€17.39
NR-BVU1000	€3.08	-€17.39
R-UVU>1000	€1.00	-€3.17
NR-UVU>1000	€1.00	-€3.17
R-BVU2500	€9.80	-€22.24
NR-BVU2500	€9.80	-€22.24
NR-AHU-S	€37.00	-€154.89
NR-AHU-M	€47.00	-€330.10
NR-AHU-L	€47.00	-€1,071.24

[37] https://www.orcon.nl/vla-leden-gaan-opnieuw-verwijderingsbijdrage-heffen-ventilatiesystemen/

[38] https://b2bweee-scheme.com/services/pricing

5.5 Life cycle costs

The combined costs for purchase (including installation and EoL), energy (electricity and indirect heating costs from ventilation losses by mechanical ventilation) and servicing/maintenance/repair (including filter replacement) make up the life cycle costs.

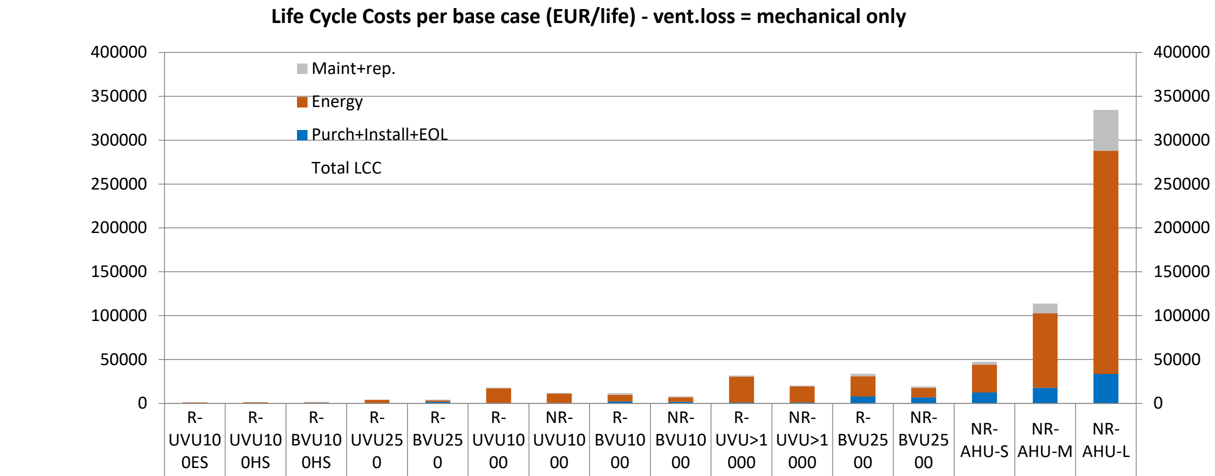
Table 27. Life cycle costs per ventilation unit

Category	Purch+Install+EOL, incl. VAT (EUR/life)	Energy, incl. VAT (EUR/life)	Maint+rep., incl. VAT (EUR/life)	Total LCC, incl. VAT (EUR/life)
R-UVU100ES	252	836	41	1129
R-UVU100HS	252	1002	41	1294
R-BVU100HS	618	637	449	1704
R-UVU250	560	3534	204	4298
R-BVU250	1726	1577	1061	4364
R-UVU1000	482	16781	836	18100
NR-UVU1000	420	10795	581	11795
R-BVU1000	2174	7486	1907	11568
NR-BVU1000	1834	4976	1325	8134
R-UVU>1000	1007	29331	1469	31807
NR-UVU>1000	883	18362	1020	20265
R-BVU2500	7767	23315	2754	33836
NR-BVU2500	6840	10642	1913	19394
NR-AHU-S	12375	31748	3247	47370
NR-AHU-M	17651	85096	11084	113831
NR-AHU-L	33476	254467	46563	334505

The energy costs are calculated for the air exchange through the VU only (infiltration losses excluded).

The absolute LCC are shown in Figure 8 below.

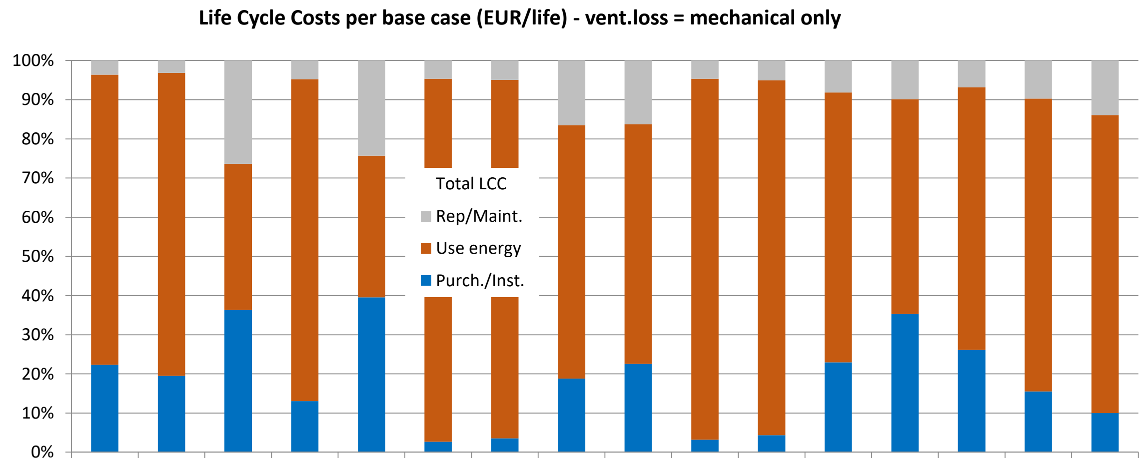
Figure 8 Life cycle costs per base case / absolute



	R-UVU100ES	R-UVU100HS	R-BVU100HS	R-UVU250	R-BVU250	R-UVU1000	NR-UVU1000	R-BVU1000	NR-BVU1000	R-UVU>1000	NR-UVU>1000	R-BVU2500	NR-BVU2500	NR-AHU-S	NR-AHU-M	NR-AHU-L
Maint+rep.	41	41	449	204	1061	836	581	1907	1325	1469	1020	2754	1913	3247	11084	46563
Energy	836	1002	637	3534	1577	16781	10795	7486	4976	29331	18362	23315	10642	31748	85096	254467
Purch+Install+EOL	252	252	618	560	1726	482	420	2174	1834	1007	883	7767	6840	12375	17651	33476
Total LCC	1129	1294	1704	4298	4364	18100	11795	11568	8134	31807	20265	33836	19394	47370	113831	334505

The relative costs show the relevance of the purchase / installation or maintenance costs (costs for filters). For BVU base cases the purchase and installation can reach beyond the 30% of LCC, to almost 40%, also because of much lower use costs (indirect costs for heating) for VUs using heat recovery.

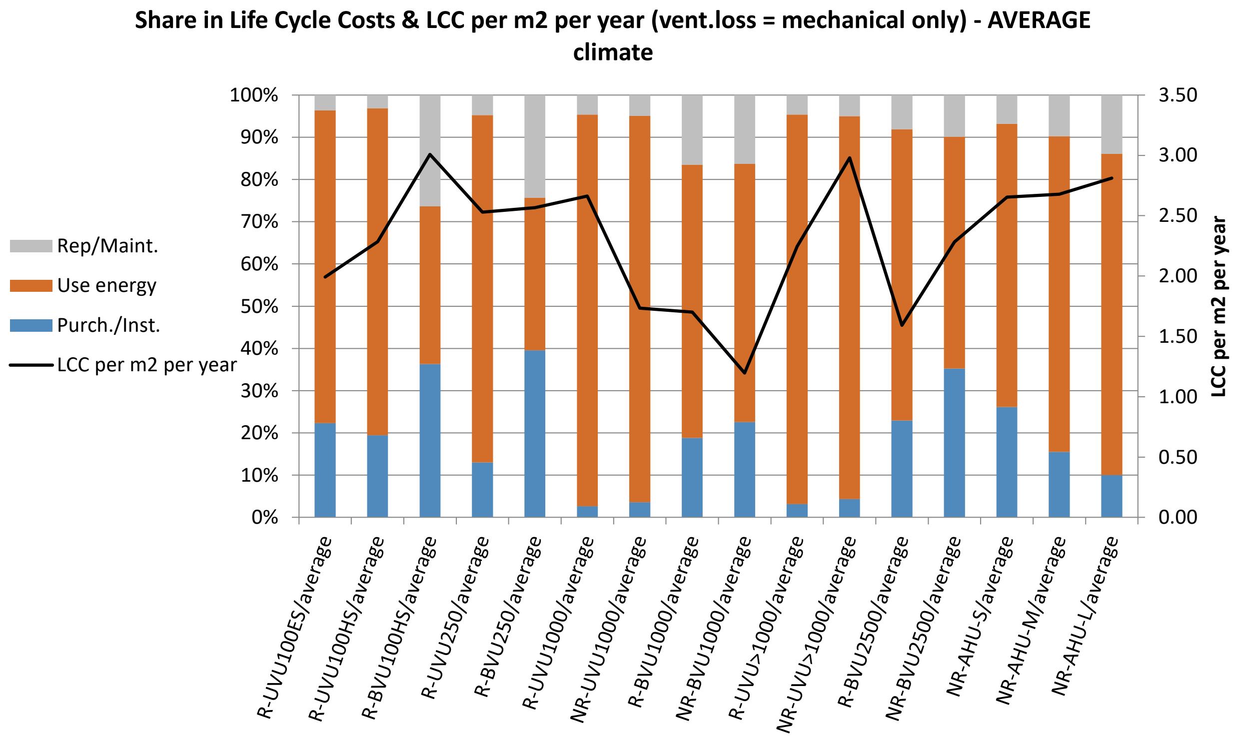
Figure 9 Life cycle costs per base case / relative



	R-UVU100ES	R-UVU100HS	R-BVU100HS	R-UVU250	R-BVU250	R-UVU1000	NR-UVU1000	R-BVU1000	NR-BVU1000	R-UVU>1000	NR-UVU>1000	R-BVU2500	NR-BVU2500	NR-AHU-S	NR-AHU-M	NR-AHU-L
Total LCC	1129	1294	1704	4298	4364	18100	11795	11568	8134	31807	20265	33836	19394	47370	113831	334505
Rep/Maint.	4%	3%	26%	5%	24%	5%	5%	16%	16%	5%	5%	8%	10%	7%	10%	14%
Use energy	74%	77%	37%	82%	36%	93%	92%	65%	61%	92%	91%	69%	55%	67%	75%	76%
Purch./Inst.	22%	19%	36%	13%	40%	3%	4%	19%	23%	3%	4%	23%	35%	26%	16%	10%

Obviously the LCC for larger systems are higher as they are more powerful and last longer. Dividing costs per m² heated floor space and lifetime of the equipment shows the relative costs (per year, per m^2 heated area).

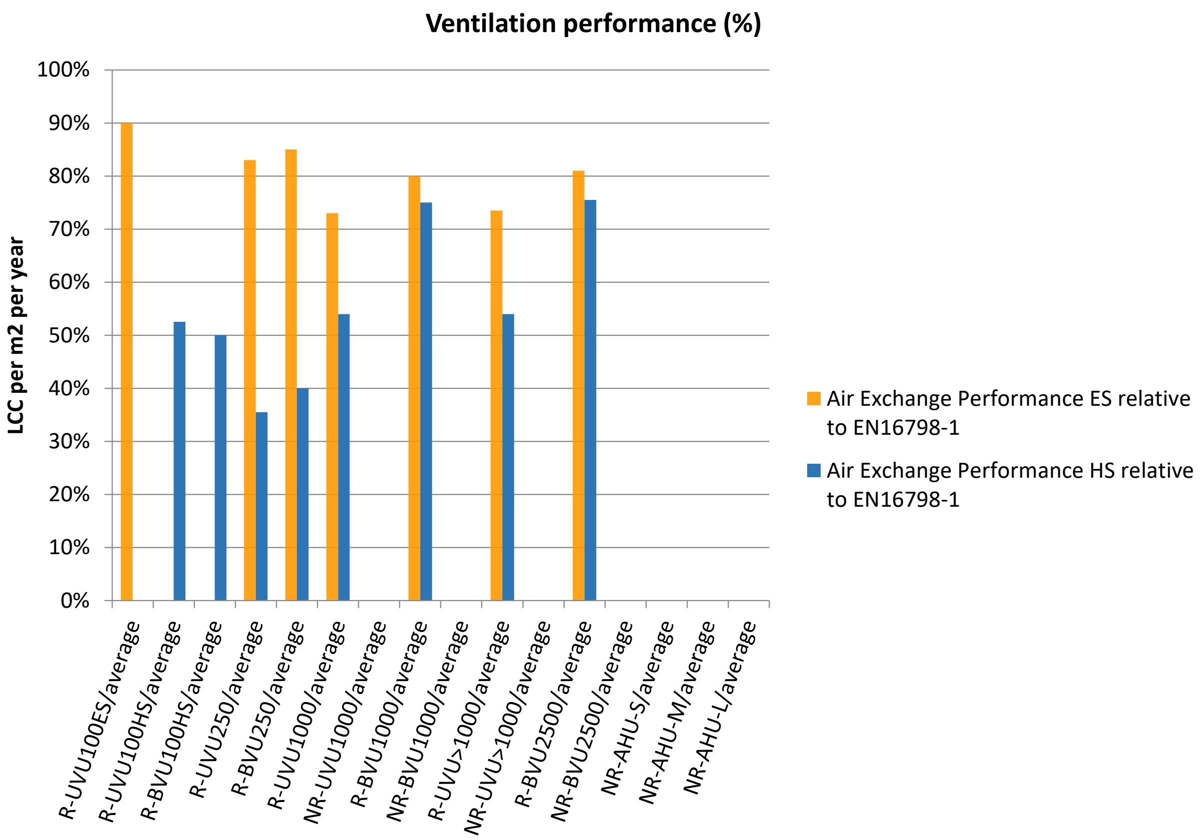
Figure 10 Relative Life cycle costs per base case and costs per m²/a



The graph shows that the lowest LCC per m2 per year are for the mid-sized BVUs (max. 250 m^2/h and max. 1000 m^2/h). The non-residential BVU 2500 has higher costs because of the smaller floor area it services.

The ventilation performance of the residential base cases, calculated for habitable (HS) and exhaust spaces (ES) is presented below.

Figure 11. Ventilation performance ES & HS



Note that because the base cases have different ventilation performances, a ranking (best to worst) on impacts or costs is not appropriate. A detailed overview of costs (and impacts) of all base cases is shown in Annex 4 – Impacts and costs per base case.

6 Impacts and costs at EU level

In this chapter the impacts and costs per unit identified in the previous chapters are combined with the sales and stock figures (units sold/installed) to present impacts and costs for the whole EU.

6.1 Comparison with EU Total impacts (normalisation)

The calculation shows that the annual impacts of the ventilation units installed and operating in the EU27 (year 2015), represent 1.9% of total annual EU primary energy demand in 2015 (this includes energy consumption by space heaters to compensate mechanical ventilation losses, but not losses from infiltration) and 1.2% of the total annual EU electricity consumption in 2015. A related impact are greenhouse gas emissions (GHG) at 1.3% of the EU27 total of 2015. The main environmental parameter is therefore direct and indirect energy consumption of ventilation units during the use phase.

Resource consumption of plastics, ferrous and non-ferrous metals is 0.3%, 1.3% and 3.3% respectively of the EU28 totals (of 2013).

Table 28. EU totals and normalisation

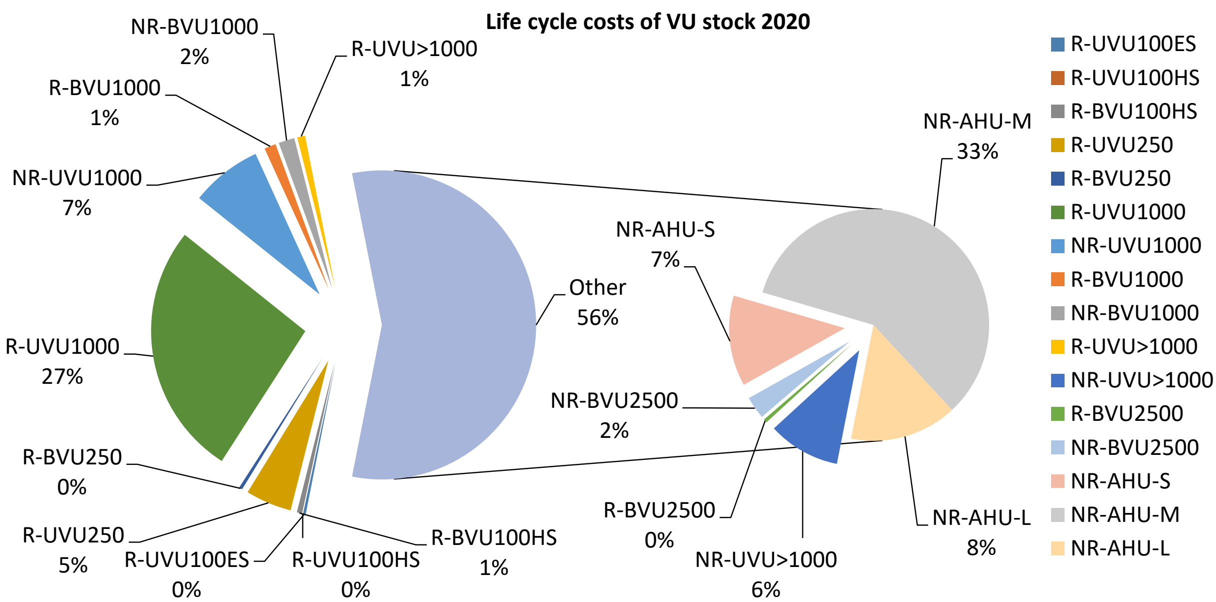
Environmental impact category	Unit	Totals of all base cases combined (stock)	Totals for EU28[39]	Base cases as % of EU totals
Materials				
Plastics	Mt	0.28	48	0.3%
Ferrous metals	Mt	7.39	206	1.3%
Non-ferrous metals	Mt	1.60	20	3.3%
Other resources & waste				
Total Energy (GER)	PJ	1,733	56.520 [40]	1.9%
of which, electricity	TWh_elec	80.35	2,800 [41]	1.2%
Water (process)*	mln.m3	79.1	247,000	0.0%
Waste, hazardous/ incinerated*	kton	0.36	2,947	0.1%
Waste, non-haz./ landfill*	Mt	9.51	89	0.2%
Emissions (Air)				
Greenhouse Gases in GWP100	mt CO2eq.	82	3,900 [42]	1.3%
Acidifying agents (AP)	kt SO2eq.	0.14	22,432	0.0%
Volatile Org. Compounds (VOC)	kt	0.01	8,951	0.0%
Persistent Org. Pollutants (POP)	g i-Teq.	1.37	2,212	0.0%
Heavy Metals (HM)	ton Ni eq.	9.30	5,903	0.1%
PAHs	ton Ni eq.	1.61	1,369	0.1%
Particulate Matter (PM, dust)	kt	0.01	3,522	0.0%
Emissions (Water)				
Heavy Metals (HM)	ton Hg/20	2.70	12,853	0.0%

[39] EU Values for primary energy, electricity consumption and greenhouse gas emissions have been updated to 2015 values, for EU27, excluding UK. The other values are as in the MEErP 2013 reports.
[40] Value for 2015, source: https://ec.europa.eu/eurostat/statistics-explained/index.php?title= Energy_saving_statistics
[41] Value for 2015, source: https://ec.europa.eu/eurostat/statistics-explained/ index.php?title= Electricity_production,_consumption_and_market_overview#Electricity_generation
[42] Value for 2015, source: Ref: https://ec.europa.eu/eurostat/statistics-explained/index.php?title= Greenhouse_gas_emission_statistics_-_emission_inventories

6.2 Life cycle costs at EU level

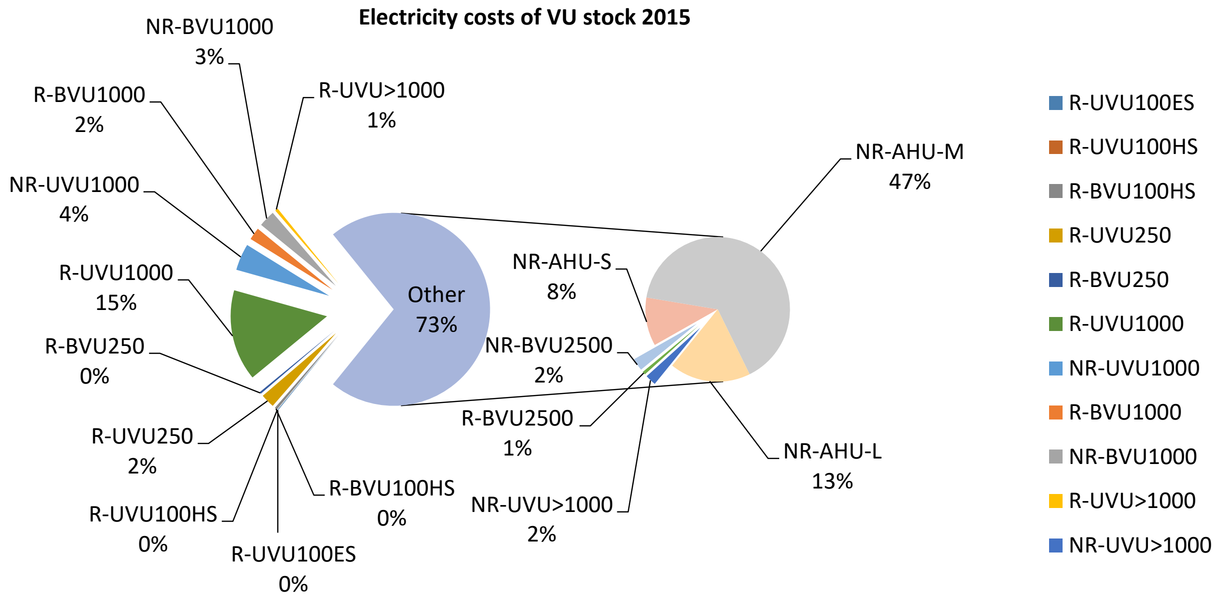
The life cycle costs of the ventilation units installed in the EU27 (note: this is not the total annual expenditure, but rather the total cost of ownership of the present (2015) stock, expressed on annual basis) are dominated by the AHUs: the AHU-M makes up almost 33% of overall EU LCC, followed by AHU-L at 8%, the AHU-S at 7% and the residential UVU/1000 m3/h at 27% which combined represent 75% of overall combined EU life cycle costs. Note that this covers only costs related to ventilation units and does not include costs from infiltration (uncontrolled ventilation) nor natural ventilation.

Figure 12. Life cycle costs of stock of VU in EU



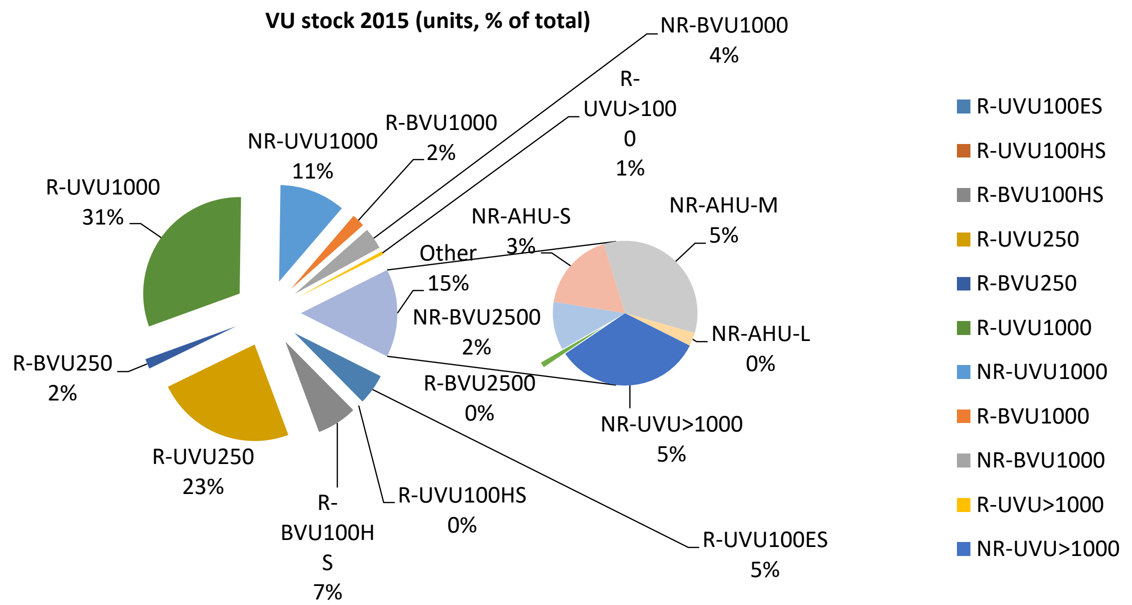
The electricity costs of the EU stock of VUs are dominated by AHUs representing 68% of total VU electricity costs.

Figure 13. Electricity costs of stock of VU in EU



This is in sharp contrast with the actual units in operation, where AHUs represent only 8% of the total units in stock.

Figure 14. Share in stock of VU in EU



Annex 1 – Performance Natural Ventilation systems

Infiltration

One of the new elements in a more sophisticated approach for assessment of energy efficiency of ventilation units is infiltration, not only as part of the natural ventilation but also as part of mechanical ventilation systems. Infiltration always occurs and - depending on the airtightness of the building- can result in high or low infiltration air flows.

Infiltration is defined as '*the uncontrolled flow of air into a space through adventitious or unintentional gaps and cracks in the building envelope. The rate of air infiltration is dependent on the porosity of the building shell and the magnitude of the natural driving forces of wind and temperature'. The corresponding loss of air from an enclosed space is termed 'exfiltration'.* [43]

In an ideal situation, mechanical ventilation fills in the ventilation performance that is not taken care of by infiltration. Unfortunately, for most ventilation systems this not the case. On the contrary, in buildings using mechanical extract UVUs, infiltration rates reduce the authority of the mechanical ventilation system with a risk of impairing the ventilation performance.

The reason is that leaky facades reduce the fan-induced airflow rates that enter through dedicated ventilation grids that are installed in habitable spaces; this reduces the ventilation performance in habitable spaces.

The mechanical ventilation performance of the unit and ventilation through infiltration are thus very much intertwined concepts, requiring careful partitioning and assessment where one or the other truly contribute usefully to the ventilation performance.

The magnitude of the infiltration airflows depends upon:

- the airtightness of the building;
- the average wind pressure on the façade (which depends on location/shielding and height of the building) and
- the size or capacity of the stack ducts, adding an extra pressure difference over the facades.

The airtightness of the building is often given as the hourly airflow leakage (m^3/h) as a fraction of the heated interior volume (m^3) at a certain pressure difference. Most common is a pressure difference of 50 Pa and the leakage factor is *n50*. For instance, an *n50* value of 0.6/h –which is used e.g. for passive houses-- means that 60% of the heated interior volume of a building is escaping per hour at 50 Pa pressure difference.

[43] Source: Air Infiltration and Ventilation Centre. https://www.aivc.org/resources/faqs

Alternatively, in some countries like the Netherlands, the air leakage is also expressed at a pressure difference of 10 Pa over the building shell. This factor *qv10* is expressed in dm³/s/m² and equals a wind force 2 (Beaufort), whereas the *n50* equals a wind force 4 or 5 Beaufort.

Air permeability of buildings is usually measured with a so-called 'blower-door test' [44], whereby a pressure difference is induced by a blower that is mounted in the door-hole of a building/dwelling space.

The strength of natural driving forces, like wind pressure and thermal buoyancy, is unpredictable and will sometimes not exist or not be helpful. For instance, when the outdoor temperature is higher than the indoor temperature, there is no thermal buoyancy to drive the air renewal and if there is no wind there is of course no wind-pressure to drive the air renewal.

When using average reference values for natural infiltration, these will relate to a (Gaussian) probability distribution, indicating that during long periods of time this infiltration is not enough to deliver the requested supply of airflows for ventilation purposes, impairing the ventilation performance. Vice versa, also during considerable periods of time, the infiltration rates will be higher than the requested ventilation rates and thus energy is wasted.

Nonetheless, assuming an average wind speed of 3.50 m/s (Beaufort ~2.5, creating an average wind pressure of around 1 Pa over the façade) and assuming an additional pressure difference of on average 1.5 Pa that is induced by the passive stack, average infiltration rates can be calculated (using standard equations) for the average EU dwellings[45] with different airtightness values (see Table 29).

Table 29. Average infiltration rates at various buildings airtightness levels (calculated for an EU-average dwelling) at 2.5 Pa pressure difference (sum of wind and PSV) over the façade.

		AIRTIGHTNESS n50 and average infiltration rates						
Average Infiltration	unit	**10**	**8**	**6**	**4**	**2**	**1**	**0.5**
Total over dwelling	l/s	79.81	63.85	47.89	31.93	15.96	7.98	3.99
Total over dwelling	m³/h	287	230	172	115	57	29	14
Per m² heated space	l/s/m² Atot	0.86	0.69	0.52	0.35	0.17	0.09	0.04
	m³/h/m² Atot	3.11	2.49	1.87	1.24	0.62	0.31	0.16

The average airtightness of naturally ventilated buildings varies between n50=4 and n50=10 and higher (present building stock). Due to their climates, the higher n50-values (leakier buildings) are typically found in Southern Member States and the lower n50 values (air tighter buildings) in Northern Member States. When airtightness values drop below n50=8 (q_{v10}=2), infiltration related to leakages may no longer be enough to achieve acceptable IAQ-levels.

[44] EN-ISO 9972:2015 Thermal performance of buildings - Determination of air permeability of buildings - Fan pressurization method

[45] Average EU dwelling: Aheated = 92.4 m², Ahabitable = 66 m², No of HS =3, No of ES = 3, open kitchen

This is the reason behind the use of natural supply grids, increasing the amount of air that naturally enters the habitable spaces of a dwelling/building.

The table above illustrates that average airflows related to natural infiltration vary (depending on the airtightness of the building) between 3.11 to 0.16 m³ per square meter of heated space, which constitutes a difference in infiltration airflows of nearly 95%.

A similar table can be drafted for natural ventilation systems that use natural supply grids in the habitable spaces. Assuming the same average conditions as for infiltration calculations, the natural supply airflows in the habitable spaces can be calculated. The following additional information of the natural supply grids is necessary for the assessment:

- capacity of the natural supply grids (in l/s/m² or m³/s/m²);
- the pressure difference at which this capacity is determined;
- are they wind pressure controlled or not?

Since building codes on this topic differ per country, the following averaged values will be used:

- installed capacity supply grids: qvmax 0.5 l/s/m² Ahab, determined at 5Pa
- grids are not wind pressure controlled

Table 30. Average infiltration and ventilation-grid airflows at various buildings airtightness levels (calculated for an EU-average dwelling) at 2.5 Pa pressure difference (sum of wind and PSV induced pressure) over the façade

		AIRTIGHTNESS n50 and average infiltration rates						
Average Infiltration	unit	10	8	6	4	2	1	0.5
Total over dwelling	l/s	79.8	63.8	47. 9	31.9	16.0	8.0	4.0
Total over dwelling	m³/h	287	230	172	115	57	29	14
Per m² heated space	l/s/m² Atot	0.86	0.69	0.52	0.35	0.17	0.09	0.04
Per m² heated space	m³/h/m² Atot	3.11	2.49	1.87	1.24	0.62	0.31	0.16
Supply airflow grids	unit	Inst. capacity and avg. supply airflow through ventilation grids						
Installed grid cap.@5 Pa	l/s/m² Ahab			0.50	0.50	0.50	0.50	0.50
	m³/h/m² Ahab			1.80	1.80	1.80	1.80	1.80
Airflow grids @2.5	m³/h/m² Ahab			1.27	1.27	1.27	1.27	1.27
Per m² heated space	m³/h/m² Atot			0.91	0.91	0.91	0.91	0.91
Total average airflow	unit	Total average airflow through infiltration and ventilation grids						
Per m² heated space	m³/h/m² Atot	3.11	2.49	2.77	2.15	1.53	1.22	1.06
Total over dwelling	m³/h	287	230	256	199	141	113	98

The total average airflows in natural ventilated buildings range from around 3.10 m³/h/m² for leaky buildings to around 1.1 m³/h/m² for extreme airtight buildings.

The reference airflow rate for natural ventilation systems that is currently used in the EU 1253/2014 Regulation is **2.2** $m^3/h/m^2$. This corresponds fairly well with the values calculated in the table above for dwellings with an airtightness of around n50 = 4, having an average airflow of 2.15 $m^3/h/m^2$. However, over 65% of the existing building stock using natural ventilation (around 70% of the total buildings stock uses natural ventilation) dates from before 1990 and, despite post-insulation, will not achieve n50 values of an average of 4. Based on various information and papers on this topic, it is estimated that the average n50 of all existing buildings having natural ventilation systems is around 7,5 and the related infiltration and ventilation airflow is around **2.5** m^3/h per m^2 of heated space [46].

Whether these natural airflows sufficiently contribute to the actual ventilation performance remains to be seen. In general, it is assumed that, since these natural ventilation systems comply with national building codes (that were valid in the year of construction), these systems also deliver the required ventilation performance.

As explained in section 1.2 of the Task 3 report, apart from the generic parameter ACH (average Air Change per Hour over the whole dwelling), ventilation performance has not yet been a specific topic in the overall assessment of ventilation systems. Neither for mechanical ventilation, nor for natural ventilation systems.

The airflow rates coming from infiltration and ventilation grids as calculated in the table above (last two rows), are airflow rates that on average occur in naturally ventilated dwellings. This means that they can be used for assessing the energy performance of natural ventilation systems. They cannot be used however, for determining the ventilation performance, because for that a closer look into the coincidence of occupancy and actually occurring airflow rates in the occupied spaces is necessary.

Since the use of an energy performance figure for ventilation systems makes no sense when the performance related to its primary function (air exchange- or ventilation performance) is not known, a method for assessing the ventilation performance is very much required. It should be avoided that the most energy efficient ventilation unit is the one that does not move any air (has the poorest ventilation performance).

[46] Rounded value, actually 2.48 m^3/h per m^2; a value that is also used in this report

Natural ventilation performance

Based on the method described in chapter 2, the air exchange performance *AEP* (a.k.a. *ventilation performance* or the *efficacy*) of natural ventilation systems can now be further assessed, for habitable and wet (exhaust) spaces separately.

Table 31. Average airflows and Performances of natural ventilation systems in dwellings with varying airtightness values

		AIRTIGHTNESS n50 and related average infiltration rates						
Average Infiltration	unit	10	8	6	4	2	1	0,5
Per m² heated space	m³/h/m² Atot	3,11	2,49	1,87	1,24	0,62	0,31	0,16
Per m² habitable space	m³/h/m² Ahab	2,18	1,74	1,31	0,87	0,44	0,22	0,11
Useful infiltration for AEP (50%)	m³/h/m² Ahab	1,09	0,87	0,65	0,44	0,22	0,11	0,05
Supply airflow through grids	unit	Inst. capacity and avg. supply airflow through ventilation grids						
Airflow grids @2.5	m³/h/m² Ahab	n.a.	n.a.	1,27	1,27	1,27	1,27	1,27
Useful airflow for AEP (10e Perc.)	m³/h/m² Ahab	n.a.	n.a.	0,64	0,64	0,64	0,64	0,64
fctrl;presence: 50.5%	m³/h/m² Ahab	n.a.	n.a.	0,32	0,32	0,32	0,32	0,32
fctrl;absence: 32.5%	m³/h/m² Ahab	n.a.	n.a.	0,21	0,21	0,21	0,21	0,21
Air Exchange Performance HS	unit	Calculating Air Exchange Performance Habitable Spaces						
Total prob. airflow HS presence	m³/h/m² Ahab	1,09	0,87	0,97	0,76	0,54	0,43	0,38
Reference airflow HS presence	m³/h/m² Ahab	2,26	2,26	2,26	2,26	2,26	2,26	2,26
AEP HS presence	%	48%	39%	43%	33%	24%	19%	17%
Total prob. airflow HS absence	m³/h/m² Ahab	1.09	0.87	0.86	0.64	0.42	0.32	0.26
Reference airflow HS absence	m³/h/m² Ahab	0,54	0,54	0,54	0,54	0,54	0,54	0,54
AEP HS absence	%	202%	161%	159%	119%	79%	58%	48%
AEP HS	%	**51%**	**40%**	**45%**	**34%**	**23%**	**18%**	**15%**
Air Exchange Performance ES [1)]	unit	Calculating Air Exchange Performance Exhaust Spaces						
Total prob. airflow ES presence	m³/h	144	115	128	99	71	56	49
Total ref. airflow ES presence	m³/h	144	144	144	144	144	144	144
AEP ES presence	%	100%	80%	89%	69%	49%	39%	34%
Total airflow ES absence	m³/h	144	115	128	99	71	56	49
Total ref. airflow ES absence	m³/h	29	29	29	29	29	29	29
AEP ES absence	%	499%	399%	445%	345%	245%	195%	170%
AEP ES	%	**120%**	**100%**	**109%**	**89%**	**64%**	**49%**	**41%**

Summary

Average AER dwelling	m³/h/m² Atot	3,11	2,49	2,77	2,15	1,53	1,22	1,06
	ACH	1,20	0,96	1,07	0,83	0,59	0,47	0,41
AEP Habitable Spaces	%	51%	40%	45%	34%	24%	18%	16%
AEP Exhaust (wet) Spaces	%	120%	100%	109%	89%	64%	49%	41%

1) For determining the AEP for Exhaust Spaces, it is assumed that all (or the majority) of the supply airflows leave the building through passive stacks situated in the wet rooms, and the capacity of the passive stacks is properly dimensioned. If this is not the case, AEP ES values will be worse than calculated here.

Ventilation Performance (AEP) for Exhaust Spaces

The conclusions regarding the Ventilation Performance in exhaust spaces of naturally ventilated dwellings based on the assessment illustrated in Table 31 are the following:

Observations regarding AEP ES figures in

1. When n50 ≥ 8 : Infiltration rates are sufficient for category II AEP in ES (AEP ES ≥ 100%).
2. When 4<n50< 8: Additional ventilation grids in HS are necessary for category II AEP ES; in which case AEP values between 89% and 109% are achieved.
3. When n50 ≤ 4: Despite ventilation grids in HS, ventilation performance in ES does not comply with category II. Additional mechanical extract provision in ES that at least operate during presence, are necessary to achieve category II AEP in ES.

It is assumed that, since bad ventilation performance in wet spaces becomes noticeable and often also becomes visible (fungi, mildew, bad smells, moisture damage, etc.), ventilation provisions will eventually, most probably be adjusted when these become noticed e.g. by installing toilet-, kitchen-, and/or bathroom fans, that can be switched on and off at will.

With an increase in the airtightness values of the existing buildings stock, this self-regulating mechanism may very well provide the explanation for the huge stock and market for toilet- kitchen and bathroom fans for both residential and non-residential applications that was identified in the Task 2 report.

The assumptions for this assessment are that all (or the majority) of the airflows leave the building through passive stacks situated in the wet spaces of the dwelling and that the individual capacities of the passive stacks are properly dimensioned.

If these conditions are not met, AEP ES values could actually be lower.

Ventilation Performance (AEP) for Habitable Spaces

For habitable spaces, the figures in Table 31 regarding the AEP in HS indicate that natural ventilation systems do not achieve category II ventilation performance levels in any of the dwellings, regardless of the airtightness values. The leakiest dwelling (n50 = 10), provides an AEP HS that is at best half (51%) of the category II AEP HS.

It has been found in various real-life monitoring studies, that in habitable spaces the reference airflows are often not achieved, and CO_2 concentrations can rise far above limit values of 1200 ppm and even of 2000 ppm. This is not only the case in naturally ventilated dwellings, but also in dwellings with certain mechanical ventilation systems. Nonetheless, these assessment results in table 31 are in line with the findings in real life.

An important distinction with the AEP in exhaust spaces, is the fact that bad AEP in HS is generally not noticed nor visible. Gradually deteriorating IAQ-levels are not perceived by the inhabitants, because humans gradually adapt their sensory system to these worsening IAQ-levels. This means that there is no self-correcting mechanism at work here and inhabitants are actually exposed to higher pollutant concentrations than the ones obtained when category II ventilation rates would actually be achieved.

The fact that inhabitants do not detect this, does not imply that it is not harmful to their health and wellbeing. As explained in the Task 3 report, section 2.8.5 (Impact IAQ human wellbeing and performance), considerably lower ventilation rates than the ones belonging to IAQ category II, may significantly diminish people's wellbeing as well as their performance levels.

One could even say that – in the current practice where average ACH over the dwelling is the key parameter - ventilation performance in habitable spaces is not really a topic and is certainly insufficiently highlighted in the overall assessment of ventilation systems. But as there is increasing evidence that the air exchange performance of ventilation systems in habitable spaces is insufficient and that it influences people's health and wellbeing, it should become a relevant topic for future assessments. Especially with an EPBD rightly targeted at increasing the airtightness and insulation levels of the existing building stock, ventilation systems and their actual air exchange performance in the various habitable rooms of a building will need serious and increased attention to prevent large scale IAQ-related problems. What the figures in table 31 in any case clearly show is, that upgrading the building shell cannot be done without upgrading the ventilation system. System adjustments will be necessary to secure the AEP in renovated airtight buildings.

Efficacy natural ventilation systems

The efficacy of a ventilation system is the ratio of the total airflow needed to achieve Category II ventilation performance and the total airflow that the perfect ventilation system needs to achieve the same performance.
As indicated in Section 2, the perfect ventilation system only needs 0.67 m³/h per m² of heated space to achieve A_{heated}. Natural ventilation systems (having no or limited controls) will on average need much higher ventilation rates to achieve a category II ventilation performance.

Using the data from Table 31, the efficacy of natural ventilation systems can be calculated for habitable spaces and exhaust spaces.

Table 32. Control efficacy of natural ventilation systems

AIRTIGHTNESS n50 and related average infiltration rates

Average natural airflows	unit	10	8	6	4	2	1	0,5
Average infiltration	$m^3/h/m^2$ A_{tot}	3.11	2.49	1.87	1.24	0.62	0.31	0.16
Average airflow grids	$m^3/h/m^2$ A_{tot}			0.91	0.91	0.91	0.91	0.91
Total	$m^3/h/m^2$ A_{tot}	3.11	2.49	2.77	2.15	1.53	1.22	1.06
CTRL Efficacy HS presence								
Share of total induced in HS	$m^3/h/m^2$ A_{hab}	2.18	1.74	2.58	2.14	1.71	1.49	1.38
Efficacy regarding place	%	50%	50%	66%	71%	80%	87%	93%
Of which during presence HS	$m^3/h/m^2$ A_{hab}	1.09	0.87	0.97	0.76	0.54	0.43	0.38
Efficacy regarding time	%	50%	50%	38%	35%	32%	29%	27%
Overall CTRL-efficacy HS pres.	%	25%	25%	25%	25%	25%	25%	25%
CTRL Efficacy ES presence								
Share of total induced in ES	m^3/h	287	230	256	199	141	113	98
Efficacy regarding place	%	100%	100%	100%	100%	100%	100%	100%
Of which during presence ES	m^3/h	144	115	128	99	71	56	49
Efficacy regarding time	%	50%	50%	50%	50%	50%	50%	50%
Overall CTRL-efficacy ES pres.	%	50%	50%	50%	50%	50%	50%	50%

The calculations in Table 32 indicate that the average CTRL-efficacy (or effectiveness) for fully natural ventilation systems is about 25% for habitable spaces and about 50% for wet spaces during periods of occupancy.

This means that during presence natural ventilation systems need about 1/25% =4 x more airflow than the reference airflow of 2.26 m^3/h per square meter of habitable space, to achieve a category II ventilation performance.

For wet spaces, natural ventilation systems need about 1/50% = 2 x higher airflow rates than the reference values for presence.

During absence, these CTRL-efficacy figures will roughly be the same, but in this case the airflows do <u>not</u> need an increase to achieve category II performance. The average occurring air exchanges are already high enough to compensate for these low CTRL-efficacies (see table

31). In most cases, the airflows during absence are even too high. This means that with proper ventilation provisions and controls, the airflow rates during absence can be reduced significantly without compromising the ventilation performance. It also means a significant amount of heating energy can be saved.

Saving potential naturally ventilated dwellings

To assess the saving potential in airflow rates (and related heating energy) over the whole dwelling, a simple comparison is made in the table below. The table compares the airflows and the ventilation performance of a natural system in an average existing dwelling where n50=4 (reference airflow is 2.15 m³/h/m², ratio = 1), with the ideal system applied to dwellings with various airtightness values and with the passive stack replaced by mechanical exhaust. This reduces the average pressure difference over the façade during absence by about 1.5 Pa and thus lowers infiltration rates by about 37%.

Table 33. Comparing overall airflows and performance levels of naturally ventilated dwellings with ideally ventilated dwellings

Type of ventilation system	n50	Infiltration	Ventilation airflow	Overall airflow	Airflow Ratio	AEP ES	AEP HS
		m³/h/m² Atot	m³/h/m² Atot	m³/h/m² Atot		%	%
Natural ventilation system with grids	6	1.87	0.91	2.78	*1.3*	109%	45%
Natural vent. system with grids	**4**	**1.24**	**0.91**	**2.15**	***1***	**89%**	**34%**
Natural ventilation system with grids	2	0.62	0.91	1.53	*0.71*	64%	23%
Perfect ventilation system	4	0,78	0.67	1.45	*0.67*	100%	100%
Perfect ventilation system	2	0.39	0.67	1.06	*0.49*	100%	100%
Perfect ventilation system	0.5	0.10	0.67	0.77	*0.36*	100%	100%

Main conclusions regarding Ventilation Performance and saving potential:

1. As long as natural ventilation systems are used, the airtightness of the dwelling should not be lower than n50=4 to prevent unacceptable ventilation performances in ES. These systems will however result in low performance levels in the habitable spaces.
2. When airtightness levels of the dwellings are further reduced to values below 4, the ventilation systems must also be upgraded to ensure acceptable IAQ-levels. This should be made mandatory.
3. With upgraded or new ventilation systems, the ventilation performance in habitable and in wet spaces can be further increased. The extent to which this occurs , depends on the type of ventilation system used.
4. If in an existing dwelling where n50 = 4, the natural ventilation system is replaced by the ideal ventilation system (removing or lifting passive stacks effects in the ES), the ventilation performance can be increased to category II levels while the overall

average airflow is reduced by about **33%** (from 2.15 to 1.45 m³/h = 0,70 m³/h per square meter of heated space).

5. The maximum savings can be achieved, when the airtightness of the dwelling is minimized to n50 = 0.5 and the ventilation system is replaced by the ideal system. Compared to the reference, the overall airflow is reduced from 2.15 m³/h to 0.77 m³/h per square meter of heated space, of which 0.67 m³/h relates to the ideal ventilation system.

This represents a maximum saving potential of **64%** on space heating energy for ventilation/infiltration losses, while at the same time the ventilation performance can be improved to category II performance levels.

Annex 2 – Input base case calculations ventilation performance

UVU/100/ES		
Related heated space	m²	100
nr.units/100m² dwelling	-	3
Nominal flowrate	m³/h	60
SPI @nom.flow	W/m³/h	0.20
Motor control	-	multi speed
Ventilation controls Extract Spaces	-	manual
Electr. power for any additional CTRLs	W	0
Average flowrate per UVU/100/ES qv	m³/h/m²	0.22
	m³/h	22
Real-life CTRL-factor	-	0.37
Heat recovery (ηt)	%	0%
Qdefr for avg climate per VU	kWh/m²/a	0
Assumed average n50	-	*4*
Avg additional natural airflow per VU	m³/h/m²	*0.11*
Avg. annual electric power per VU	W	4.06
Annual electricity consumption per VU	kWhe/a	36
Avg. space heating energy loss per VU	kWh/a	542
TOTAL PRIMARY ENERGY CONSUMPTION PER VU	kWh/a	617
Avg.add.annual space heating energy loss natural infiltration per VU	kWh/a	263
Share ref.space heating energy loss (nat.vent = 2.48m³/h/m²) for ES	kWh/a	2455
Avg. space heating energy savings compared to reference per VU	kWh/a	13
TOTAL PRIMARY ENERGY SAVINGS PER VU compared to reference	kWh/a	-62
Air Exchange Performance ES relative to EN16798-1	%	80%

UVU/100/HS		
Related heated space	m²	100
nr.units/100m² dwelling	-	3
Nominal flowrate	m³/h	60
SPI @nom.flow	W/m³/h	0.20
Motor control	-	multi speed
Ventilation controls Extract Spaces	-	manual
Electr. power for any additional CTRLs	W	0
Average flowrate	m³/h/m²	0.18
	m³/h	18
Real-life CTRL-factor	-	0.30
Heat recovery (ηt)	%	0%
Qdefr for avg climate per VU	kWh/m²/a	0
Assumed average n50	-	*4*
Avg additional natural airflow per VU	m³/h/m²	*0.11*
Avg. annual electric power VU	W	3.48
Annual electricity consumption VU	kWhe/a	30
Avg. space heating energy loss VU	kWh/a	443
TOTAL PRIMARY ENERGY CONSUMPTION PER VU	kWh/a	507
Avg.add.an. space heating energy loss natural infiltration	kWh/a	263
Share ref.space heating energy loss (nat.vent = 2.48m³/h/m²) for HS	kWh/a	3655
Avg. space heating energy savings compared to reference per VU	kWh/a	511
TOTAL PRIMARY ENERGY SAVINGS PER VU compared to reference	kWh/a	447
Air Exchange Performance HS relative to EN16798-1	%	30%

BVU/100/HS			
	Related heated space	m²	100
	nr.units/100m² dwelling	-	3
	Nominal flowrate	m³/h	60
	SPI @nom.flow	W/m³/h	0.40
	Motor control	-	multi speed
	Balance control	-	no
	Internal leakage	-	≥6%
	Ventilation controls Habitable Spaces	-	manual
	Electr. power for any additional CTRLs	W	0
	Average flowrate	m³/h/m²	0.20
		m³/h	20
	Real-life CTRL-factor	-	0.33
	Heat recovery (ηt)	%	65%
	Qdefr for avg climate per VU	kWh/m²/a	0.26
	Assumed average n50	-	4
	Avg additional natural airflow per VU	m³/h/m²	*0.11*
	Avg. annual electric power VU	W	8
	Annual electricity consumption VU	kWhe/a	121
	Avg. space heating energy loss VU	kWh/a	172
	TOTAL PRIMARY ENERGY CONSUMPTION PER VU	kWh/a	366
	Avg.add.an. space heating energy loss natural infiltration	kWh/a	263
	Share ref.space heating energy loss (nat.vent = 2.48m³/h/m²) for HS	kWh/a	3655
	Avg. space heating energy savings compared to reference per VU	kWh/a	782
	TOTAL PRIMARY ENERGY SAVINGS PER VU compared to reference	kWh/a	589
	Air Exchange Performance HS relative to EN16798-1	%	25%

UVU/250			
	Related heated space	m²	100
	nr.units/100m² dwelling	-	1
	Nominal flowrate	m³/h	180
	SPI @nom.flow	W/m³/h	0.30
	Motor control	-	multi speed
	Directly extracts air from:		ES
	Flow control	-	central
	Ventilation controls Extract Spaces	-	RH-central
	Ventilation controls Habitable Spaces	-	RH-central
	Electr. power for any additional CTRLs	W	0
	Average flowrate	m³/h/m²	0.58
		m³/h	58
	Real-life CTRL-factor	-	0.32
	Heat recovery (ηt)	%	0%
	Qdefr for avg climate per VU	kWh/m²/a	0.00
	Assumed average n50	-	4
	Avg additional natural airflow per VU	m³/h/m²	*0.96*
	Avg. annual electric power VU	W	16
	Annual electricity consumption VU	kWhe/a	145
	Avg. space heating energy loss VU	kWh/a	1429
	TOTAL PRIMARY ENERGY CONSUMPTION PER VU	kWh/a	1732
	Avg.add.an. space heating energy loss natural infiltration	kWh/a	2370
	Reference space heating energy loss (nat.vent = 2.48m³/h/m²)	kWh/a	6109
	Avg. space heating energy savings compared to reference	kWh/a	2310
	TOTAL PRIMARY ENERGY SAVINGS PER VU compared to reference	kWh/a	2007
	Air Exchange Performance ES relative to EN16798-1	%	66%
	Air Exchange Performance HS relative to EN16798-1	%	27%

BVU/250		
Related heated space	m²	100
nr.units/100m² dwelling	-	1
Nominal flowrate	m³/h	180
SPI @nom.flow	W/m³/h	0.45
Motor control		multi speed
Balance control	-	no
Internal leakage	-	≥6%
Flow control	-	central
Ventilation controls Extract Spaces	-	RH-central
Ventilation controls Habitable Spaces	-	RH-central
Electr. power for any additional CTRLs	W	0
Average flowrate	m³/h/m²	0.54
	m³/h	54
Real-life CTRL-factor	-	0.30
Heat recovery (ηt)	%	80%
Qdefr for avg climate per VU	kWh/m²/a	0.71
Assumed average n50	-	4
Avg additional natural airflow per VU	m³/h/m²	*0.79*
Avg. annual electric power VU	W	23
Annual electricity consumption VU	kWhe/a	276
Avg. space heating energy loss VU	kWh/a	266
TOTAL PRIMARY ENERGY CONSUMPTION PER VU	kWh/a	846
Avg.add.an. space heating energy loss natural infiltration	kWh/a	1938
Reference space heating energy loss (nat.vent = 2.48m³/h/m²)	kWh/a	6109
Avg. space heating energy savings compared to reference	kWh/a	3905
TOTAL PRIMARY ENERGY SAVINGS PER VU compared to reference	kWh/a	3325
Air Exchange Performance ES relative to EN16798-1	%	70%
Air Exchange Performance HS relative to EN16798-1	%	30%

UVU/1000		
Related heated space	m²	400
nr.units/100m² dwelling	-	0.25
Nominal flowrate	m³/h	720
SPI @nom.flow	W/m³/h	0.30
Motor control		multi speed
Directly extracts air from:		ES
Flow control		central
Add. power consumption fans due to constant pressure in ducts	W	0.00
Ventilation controls Extract Spaces	-	clock
Ventilation controls Habitable Spaces	-	none
Electr. power for any additional CTRLs	W	1
Average flowrate	m³/h/m²	0.61
	m³/h	244
Real-life CTRL-factor	-	0.34
Heat recovery (ηt)	%	0%
Qdefr for avg climate per VU	kWh/m²/a	0
Assumed average n50	-	4
Avg additional natural airflow per VU	m³/h/m²	*0.96*
Avg. annual electric power VU	W	69
Annual electricity consumption VU	kWhe/a	610
Avg. space heating energy loss VU	kWh/a	6012
TOTAL PRIMARY ENERGY CONSUMPTION PER VU	kWh/a	7292
Avg.add.an. space heating energy loss natural infiltration	kWh/a	9481
Reference space heating energy loss (nat.vent = 2.48m³/h/m²)	kWh/a	24437
Avg. space heating energy savings compared to reference	kWh/a	8945
TOTAL PRIMARY ENERGY SAVINGS PER VU compared to reference	kWh/a	7664
Air Exchange Performance ES relative to EN16798-1	%	66%
Air Exchange Performance HS relative to EN16798-1	%	22%

BVU/1000			
	Related heated space	m²	400
	nr.units/100m² dwelling	-	0.25
	Nominal flowrate	m³/h	720
	SPI @nom.flow	W/m³/h	0.45
	Motor control		multi speed
	Balance control	-	no
	Internal leakage	-	≥6%
	Flow control	-	central
	Add. power consumption fans due to constant pressure in ducts	W	0.00
	Ventilation controls Extract Spaces	-	clock
	Ventilation controls Habitable Spaces	-	none
	Electr. power for any additional CTRLs	W	1
	Average flowrate	m³/h/m²	0.61
		m³/h	244
	Real-life CTRL-factor	-	0.34
	Heat recovery (ηt)	%	80%
	Qdefr for avg climate per VU	kWh/m²/a	0.80
	Assumed average n50	-	4
	Avg additional natural airflow per VU	m³/h/m²	*0.79*
	Avg. annual electric power VU	W	103
	Annual electricity consumption VU	kWhe/a	1230
	Avg. space heating energy loss VU	kWh/a	1202
	TOTAL PRIMARY ENERGY CONSUMPTION PER VU	kWh/a	3785
	Avg.add.an. space heating energy loss natural infiltration	kWh/a	7752
	Reference space heating energy loss (nat.vent = 2.48m³/h/m²)	kWh/a	24437
	Avg. space heating energy savings compared to reference	kWh/a	15483
	TOTAL PRIMARY ENERGY SAVINGS PER VU compared to reference	kWh/a	12900
	Air Exchange Performance ES relative to EN16798-1	%	66%
	Air Exchange Performance HS relative to EN16798-1	%	27%

UVU/>1000			
	Related heated space	m²	833
	nr.units/100m² dwelling	-	0.12
	Nominal flowrate	m³/h	1500
	SPI @nom.flow	W/m³/h	0.30
	Motor control		multi speed
	Flow control	-	central
	Add. power consumption fans due to constant pressure in ducts	W	
	Ventilation controls Extract Spaces	-	clock
	Ventilation controls Habitable Spaces	-	none
	Electr. power for any additional CTRLs	W	1
	Average flowrate	m³/h/m²	0.61
		m³/h	508
	Real-life CTRL-factor	-	0.34
	Heat recovery (ηt)	%	0%
	Qdefr for avg climate per VU	kWh/m²/a	0
	Assumed average n50	-	4
	Avg additional natural airflow per VU	m³/h/m²	*0.96*
	Avg. annual electric power VU	W	143
	Annual electricity consumption VU	kWhe/a	1261
	Avg. space heating energy loss VU	kWh/a	12524
	TOTAL PRIMARY ENERGY CONSUMPTION PER VU	kWh/a	15172
	Avg.add.an. space heating energy loss natural infiltration	kWh/a	19751
	Reference space heating energy loss (nat.vent = 2.48m³/h/m²)	kWh/a	50911
	Avg. space heating energy savings compared to reference	kWh/a	18636
	TOTAL PRIMARY ENERGY SAVINGS PER VU compared to reference	kWh/a	15987
	Air Exchange Performance ES relative to EN16798-1	%	66%
	Air Exchange Performance HS relative to EN16798-1	%	22%

BVU/2500		
Related heated space	m²	1250
nr.units/100m² dwelling	-	0.08
Nominal flowrate	m³/h	2250
SPI @nom.flow	W/m³/h	0.45
Motor control		multispeed
Balance control	-	no
Internal leakage	-	≥6%
Flow control	-	central
Ventilation controls Extract Spaces	-	clock
Ventilation controls Habitable Spaces	-	none
Electr. power for any additional CTRLs	W	1
Average flowrate	m³/h/m²	0.61
	m³/h	763
Real-life CTRL-factor	-	0.34
Heat recovery (ηt)	%	80%
Qdefr for avg climate per VU	kWh/m²/a	0.80
Assumed average n50	-	4
Avg additional natural airflow per VU	m³/h/m²	*0.79*
Avg. annual electric power VU	W	322
Annual electricity consumption VU	kWhe/a	3825
Avg. space heating energy loss VU	kWh/a	3757
TOTAL PRIMARY ENERGY CONSUMPTION PER VU	kWh/a	11790
Avg.add.an. space heating energy loss natural infiltration	kWh/a	24225
Reference space heating energy loss (nat.vent = 2.48m³/h/m²)	kWh/a	76366
Avg. space heating energy savings compared to reference	kWh/a	48384
TOTAL PRIMARY ENERGY SAVINGS PER VU compared to reference	kWh/a	40352
Air Exchange Performance ES relative to EN16798-1	%	66%
Air Exchange Performance HS relative to EN16798-1	%	27%

AHU-S with HR		
Related heated space	m²	1111
Nominal flowrate	m³/h	4000
Design ΔPext	pa	244
Design ΔPint	pa	292
Power output P_{vent} in watts for	W	1191
Fan system efficiency @nom.flow	%	54%
$P_{el;design}$	W	2206
SFP_{total} @nom.flow	W/m³/s	1985
SFP_{int} @ nom.flow	W/m³/s	1081
Motor control		variable speed
Internal leakage	-	
Ventilation controls	-	clock
Average flowrate	m³/h	1920
Real-life CTRL-factor	-	0.48
Heat recovery (ηt)	%	44%
Qdefr for avg climate per VU	kWh/m³/a	0.27
Assumed average n50	-	4
Avg additional natural airflow per VU	m³/h/m²	*0.79*
Avg. annual electric power VU	W	508
Annual electricity consumption VU	kWhe/a	4963
Avg. space heating energy loss VU	kWh/a	26490
TOTAL PRIMARY ENERGY CONSUMPTION PER VU	kWh/a	36913
Avg.add.an. space heating energy loss natural infiltration	kWh/a	21533
Reference space heating energy loss (nat.vent = 2.48m³/h/m²)	kWh/a	67881
Avg. space heating energy savings compared to reference	kWh/a	19858
TOTAL PRIMARY ENERGY SAVINGS PER VU compared to reference	kWh/a	9435

AHU-M with HR			
	Related heated space	m²	2778
	Nominal flowrate	m³/h	10000
	Design ΔPext	pa	450
	Design ΔPint	pa	334
	Power output P_{vent} in watts for	W	4356
	Fan system efficiency @nom.flow	%	58%
	$P_{el;design}$	W	7510
	SFP_{total} @nom.flow	W/m³/s	2703
	SFP_{int} @ nom.flow	W/m³/s	1152
	Motor control		variable speed
	Internal leakage	-	
	Ventilation controls	-	clock
	Average flowrate	m³/h	4800
	Real-life CTRL-factor	-	0.48
	Heat recovery (ηt)	%	44%
	Qdefr for avg climate per VU	kWh/m³/a	0.27
	Assumed average n50	-	4
	Avg additional natural airflow per VU	m³/h/m²	*0.79*
	Avg. annual electric power VU	W	1730
	Annual electricity consumption VU	kWhe/a	16435
	Avg. space heating energy loss VU	kWh/a	66226
	TOTAL PRIMARY ENERGY CONSUMPTION PER VU	kWh/a	100738
	Avg.add.an. space heating energy loss natural infiltration	kWh/a	53833
	Reference space heating energy loss (nat.vent = 2.48m³/h/m²)	kWh/a	169703
	Avg. space heating energy savings compared to reference	kWh/a	49644
	TOTAL PRIMARY ENERGY SAVINGS PER VU compared to reference	kWh/a	15132

AHU-L with HR			
	Related heated space		9722
	Nominal flowrate	m³/h	35000
	Design ΔPext	pa	575
	Design ΔPint	pa	391
	Power output P_{vent} in watts for	W	18783
	Fan system efficiency @nom.flow	%	61%
	$P_{el;design}$	W	30792
	SFP_{total} @nom.flow	W/m³/s	3167
	SFP_{int} @ nom.flow	W/m³/s	1282
	Motor control		variable speed
	Internal leakage	-	
	Ventilation controls	-	clock
	Average flowrate	m³/h	16800
	Real-life CTRL-factor	-	0.48
	Heat recovery (ηt)	%	44%
	Qdefr for avg climate per VU	kWh/m³/a	0.27
	Assumed average n50	-	4
	Avg additional natural airflow per VU	m³/h/m²	*0.79*
	Avg. annual electric power VU	W	7095
	Annual electricity consumption VU	kWhe/a	66622
	Avg. space heating energy loss VU	kWh/a	231789
	TOTAL PRIMARY ENERGY CONSUMPTION PER VU	kWh/a	371695
	Avg.add.an. space heating energy loss natural infiltration	kWh/a	188415
	Reference space heating energy loss (nat.vent = 2.48m³/h/m²)	kWh/a	593960
	Avg. space heating energy savings compared to reference	kWh/a	173756
	TOTAL PRIMARY ENERGY SAVINGS PER VU compared to reference	kWh/a	33850

Annex 3 – Recovery rates

Table 34. Recovery (and recycling) rates

Type of recovery																
	Formal						Informal						Total			
Collection rate	**50%**						**50%**									
Recovery activity	**Preprocessing yield**	**Final processing**				**Disposed**	**Preprocessing yield**	**Final processing**				**Disposed**	**Recycled**	**Recovered**	**Disposal**	**50%**
		Recyc yield	Recov yield	% Recycl	% Recover			Recyc yield	Recov yield	% Recycl	% Recover				Incinerate	Landfill
Bulk Plastics	80%	32%	32%	13%	13%	24%	0%	0%	0%	0%	0%	50%	13%	13%	37%	37%
TecPlastics	80%	0%	63%	0%	25%	25%	0%	0%	0%	0%	0%	50%	0%	25%	37%	37%
Ferro	98%	98%	0%	48%	0%	2%	98%	98%	0%	48%	0%	2%	96%	0%	0%	4%
Non-ferro	95%	95%	0%	45%	0%	5%	95%	95%	0%	45%	0%	5%	90%	0%	0%	10%
Coating	80%	0%	50%	0%	20%	30%	0%	0%	0%	0%	0%	50%	0%	20%	40%	40%
Electronics	20%	10%	80%	1%	8%	41%	20%	0%	0%	0%	0%	50%	1%	8%	46%	46%
Misc. , excluding refrigant & Hg	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	0%	50%	0%	0%	50%	50%
Refrigerant	60%	0%	100%	0%	30%	20%	0%	0%	100%	0%	0%	50%	0%	30%	70%	0%
Hg (mercury), in mg/unit	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	0%	50%	0%	0%	50%	50%
Repair / extra	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	0%	50%	0%	0%	50%	50%
Consumables / auxiliaries	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	0%	50%	0%	0%	50%	50%

Annex 4 – Impacts and costs per base case

Table 35. Environmental impacts over life and life cycle costs per base case

Impacts per base case		R-UVU100ES	R-UVU100HS	R-BVU100HS	R-UVU250	R-BVU250	R-UVU1000	NR-UVU1000	R-BVU1000	NR-BVU1000
Total material input	kg	1	1	4	5	8	32	32	63	63
to discarded	kg	0	1	2	2	3	3	3	11	11
to recovered	kg	-1	-1	-2	-3	-6	-29	-29	-57	-57
stock balance	kg	0	0	0	0	0	0	0	0	0
Other resource use										
Total energy (MJ_prim)	MJ_prim	34472	41712	23502	143904	55674	679271	679271	259264	259264
o/w electricity (MJ_prim)	MJ_prim	3569	3152	10200	15624	29806	77809	77809	147396	147396
Water / process (ltr)	ltr	0	0	1	2	3	12	12	23	23
Water / cooling (ltr)	ltr	166	148	479	727	1372	3593	3593	6816	6816
Waste / haz. (g)	g	58	52	162	248	471	1228	1228	2324	2324
Waste / non-haz. (g)	g	2463	2370	6146	9013	16733	43131	43131	81818	81818
Emissions to air										
GHG Greenhouse gases (kg CO2 eq.)	kg CO2 eq.	1707	2072	1114	7078	2585	33314	33314	11905	11905
AP Acidification (g SO2 eq.)	g SO2 eq.	4253	4240	5756	10557	12519	30218	30218	39951	39951
VOC Volatile Organic Compounds (g)	g	3407	3403	3910	7045	7294	13148	13148	14377	14377
POP Persistent Organic Pollutants (ng i-Tec)	ng i-Tec.	26	29	44	59	103	271	271	510	510
HMs Heavy Metals to air (mg Ni eq.)	mg Ni eq.	156	171	236	335	512	1169	1169	2061	2061
PAHs Polycyclic Aromatic Hydrocarbons (mg Ni eq.)	mg Ni eq.	56	55	76	131	162	349	349	500	500
PM Particulate Matter (g)	g	1099	1186	1215	1926	2047	3251	3251	3522	3522

Impacts per base case		R-UVU100ES	R-UVU100HS	R-BVU100HS	R-UVU250	R-BVU250	R-UVU1000	NR-UVU1000	R-BVU1000	NR-BVU1000
Emissions to water										
HMs Heavy Metals to water (mg Hg/20)	mg Hg/20	36	40	65	88	155	356	356	665	665
EP Eutrophication Potential (g PO4)	g PO4	1846	2225	3285	4216	7815	16172	16172	33267	33267
Life Cycle Costs										
Product price	EUR	158	158	453	405	1349	318	318	1715	1715
Installation	EUR	63	63	75	75	108	108	108	133	133
Fuels	EUR	598	748	250	2514	492	11838	9045	2174	1661
Electricity	EUR	98	87	281	431	823	2148	1752	4068	3317
Repair & Maintenance	EUR	34	34	374	170	884	697	581	1590	1325
EOL	EUR	0	0	0	-1	-2	-8	-8	-17	-17
Total LCC	EUR	951	1089	1433	3594	3655	15101	11795	9662	8134

Table 36. Environmental impacts over life and life cycle costs per base case (continued)

Impacts per base case		R-UVU>1000	NR-UVU>1000	R-BVU2500	NR-BVU2500	NR-AHU-S	NR-AHU-M	NR-AHU-L
		average	average	average	average	average	average	average
Total material input	kg	20	20	200	200	755	1610	5228
to discarded	kg	8	8	61	61	103	319	1097
to recovered	kg	-12	-12	-160	-160	-702	-1496	-4859
stock balance	kg	0	0	0	0	0	0	0
Other resource use								
Total energy (MJ_prim)	MJ_prim	1182471	1186149	806945	593718	1841173	4801284	14173476
o/w electricity (MJ_prim)	MJ_prim	145571	69334	458952	241188	573033	1783418	5717694
Water / process (ltr)	ltr	11	11	46	46	111	229	710

Impacts per base case		**R-UVU>1000**	**NR-UVU>1000**	**R-BVU2500**	**NR-BVU2500**	**NR-AHU-S**	**NR-AHU-M**	**NR-AHU-L**
Water / cooling (ltr)	ltr	6620	3232	21445	11767	28268	85208	273349
Waste / haz. (g)	g	2296	1093	7209	3773	8942	27923	89496
Waste / non-haz. (g)	g	77433	38146	256159	143938	358531	1058414	3400941
Emissions to air								
GHG Greenhouse gases (kg CO2 eq.)	kg CO2 eq.	57905	58631	37004	27934	87824	226731	665980
AP Acidification (g SO2 eq.)	g SO2 eq.	51681	37860	106550	65450	152629	397024	1191544
VOC Volatile Organic Compounds (g)	g	20457	18807	26955	22095	46539	74534	165193
POP Persistent Organic Pollutants (ng i-Tec)	ng i-Tec.	378	201	1490	981	3131	7965	25651
HMs Heavy Metals to air (mg Ni eq.)	mg Ni eq.	1818	1047	5864	3662	10400	27250	86545
PAHs Polycyclic Aromatic Hydrocarbons (mg Ni eq.)	mg Ni eq.	590	415	1302	794	1807	4666	13937
PM Particulate Matter (g)	g	4944	4659	6257	5387	11010	16837	36232
Emissions to water								
HMs Heavy Metals to water (mg Hg/20)	mg Hg/20	647	319	2021	1084	2597	7926	25364
EP Eutrophication Potential (g PO4)	g PO4	29229	14829	103543	62410	140262	479635	1585428
Life Cycle Costs								
Product price	EUR	625	625	4652	4652	9563	13254	25680
Installation	EUR	260	260	2200	2200	2930	4680	8820
Fuels	EUR	20418	16804	6793	5261	19003	45236	126697
Electricity	EUR	4025	1560	12645	5391	12782	39939	128026
Repair & Maintenance	EUR	1224	1020	2295	1913	3247	11084	46563
EOL	EUR	-3	-3	-22	-22	-155	-330	-1071

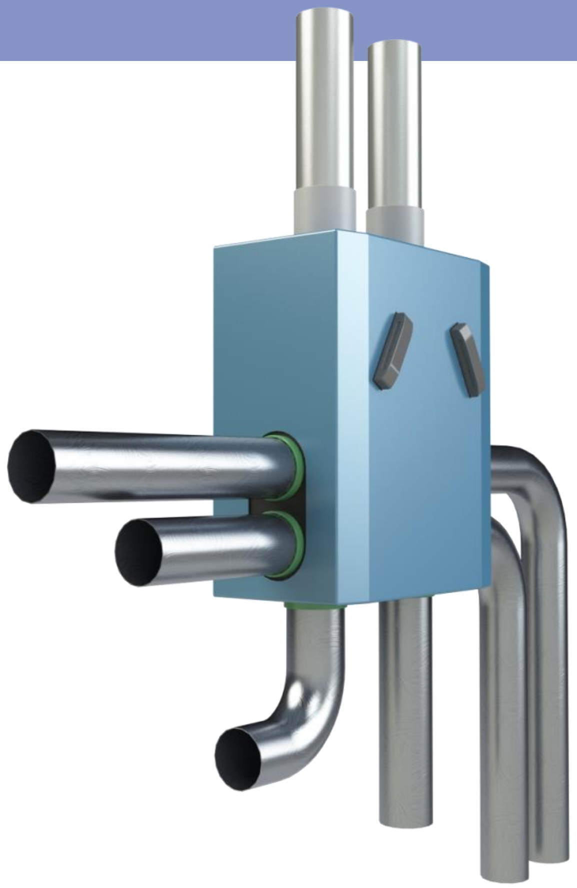
Impacts per base case		R-UVU>1000	NR-UVU>1000	R-BVU2500	NR-BVU2500	NR-AHU-S	NR-AHU-M	NR-AHU-L
Total LCC	EUR	26549	20265	28563	19394	47370	113863	334715

Table 37. Environmental impacts at EU level (stock EU27)

EU normalisation		R-UVU100ES	R-UVU100HS	R-BVU100HS	R-UVU250	R-BVU250	R-UVU1000	NR-UVU1000	R-BVU1000	NR-BVU1000	R-UVU>1000	NR-UVU>1000	R-BVU2500	NR-BVU2500	NR-AHU-S	NR-AHU-M	NR-AHU-L	Base Cases totals	EU(27) total	Share BC in EU
Materials																				
Plastics	Mt	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.01	0.06	0.02	**0.1**	**48**	0.3%
Ferrous metals	Mt	0.00	0.00	0.00	0.01	0.00	0.13	0.05	0.02	0.03	0.00	0.01	0.01	0.05	0.37	1.53	0.43	**2.6**	**206**	1.3%
Non-ferrous metals	Mt	0.00	0.00	0.00	0.01	0.00	0.09	0.03	0.01	0.02	0.00	0.00	0.00	0.01	0.08	0.32	0.09	**0.7**	**20**	3.3%
Other resources & waste																				
Total Energy (GER)	PJ	2.47	0.00	2.20	46.79	1.29	289.39	103.90	7.88	12.91	8.91	80.43	1.98	13.11	66.87	335.88	86.22	**1,060**	**56,520**	3.1%
of which, electricity	TWh_elec	0.03	0.00	0.13	0.67	0.09	4.38	1.57	0.59	0.97	0.15	0.62	0.15	0.70	2.75	16.50	4.60	**34**	**2,800**	2.9%
% of EU electricity		0.00%	0.00%	0.00%	0.02%	0.00%	0.16%	0.06%	0.02%	0.03%	0.01%	0.02%	0.01%	0.03%	0.10%	0.59%	0.16%			
Water (process)*	mln.m3	0.03	0.00	0.09	0.70	0.08	4.96	1.78	0.70	1.15	0.08	0.73	0.11	1.02	4.03	16.03	4.32	**36**	**247,000**	0.0%
Waste, hazardous/ incinerated*	kt	0.00	0.00	0.02	0.08	0.01	0.52	0.19	0.07	0.12	0.02	0.07	0.02	0.08	0.32	1.95	0.54	**4.0**	**2,947**	0.3%
Waste, non-haz./ landfill*	Mt	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.02	**0.2**	**89**	0.4%
Emissions (Air)																				
Greenhouse Gases in GWP100	mt CO2eq.	0.12	0.00	0.10	2.30	0.06	14.19	5.10	0.36	0.59	0.44	3.98	0.09	0.62	3.19	15.86	4.05	**51**	**3,900**	2.1%
Acidifying agents (AP)	kt SO2eq.	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.01	**0.1**	**22,432**	0.0%
Volatile Org. Compounds (VOC)	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**	**8,951**	0.0%
Persistent Org. Pollutants (POP)	g i-Teq.	0.00	0.00	0.00	0.02	0.00	0.03	0.02	0.01	0.01	0.00	0.03	0.00	0.00	0.05	0.07	0.02	**0.3**	**2,212**	0.1%
Heavy Metals (HM)	ton Ni eq.	0.01	0.00	0.02	0.11	0.01	0.50	0.18	0.06	0.10	0.01	0.07	0.01	0.08	0.38	1.91	0.53	**4.0**	**5,903**	0.2%
PAHs	ton Ni eq.	0.00	0.00	0.01	0.04	0.00	0.15	0.05	0.02	0.02	0.00	0.03	0.00	0.02	0.07	0.33	0.08	**0.8**	**1,369**	0.1%
Particulate Matter (PM, dust)	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**	**3,522**	0.0%
Emissions (Water)																				
Heavy Metals (HM)	ton Hg/20	0.00	0.00	0.01	0.03	0.00	0.15	0.05	0.02	0.03	0.00	0.02	0.00	0.02	0.09	0.55	0.15	**1,2**	**12,853**	0.0%

Ventilation Units

Ecodesign and Energy Labelling



Preparatory Review Study

Phase 1.1 and phase 1.2

Final Report

TASK 6. Options

Review study on Regulations EU 1253/2014 (Ecodesign requirements for ventilation units) and EU 1254/2014 (energy labelling of residential ventilation units)

Prepared by
VHK, Delft (NL), for the
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August 2020

Grow

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Specific contract: No 681/PP/GRO/IMA/18/1131/10204-SI2.798223
Contract starting date: February 5th 2019

Cover: Ventilation unit [picture VHK 2019].

This study was ordered and paid for by the European Commission, Directorate-General Grow.

Executive summary Technologies

This is the draft Task 6 report of the preparatory review study on the Ecodesign Commission Regulation (EU) No. 1253/2014 and Energy Label Commission Delegated Regulation (EU) No. 1254/2014 for Ventilation Units.

This Task 6 report deals with options for improving the existing regulation, or – more specifically – with proposals for both design and regulatory options. The assessment of design options is required to determine whether best available technologies and related product improvements can lead to further environmental and energy savings without increasing lifecycle costs. The proposed regulatory options are intended to build upon that and further refine the requirements set in the regulations.

Chapter 1 describes the design options that are identified for achieving better ventilation performance and better energy performance. Reference to all energy calculations for RVUs is the Category II ventilation performance as described in Task 5. The base cases as defined in the Task 5 report will serve as a starting point for the design options. For all design options the parameters that determine the ventilation and energy performances are listed. Based on that, their annual electricity consumption is calculated as well as the space heating energy consumption related to the air exchanges induced by the VU. Finally, the annual energy savings and related cost savings are calculated compared to the reference unit. With an estimate of the price increase of the design option, the simple payback period and life cycle costs, savings can be calculated. Product cost estimates have been derived from the Task 2 and Task 5 reports and energy rates from the Ecodesign Impact Accounting (status December 2019). For ventilation units that require infra-structural adjustments (ductwork in the building) that have longer lifecycles (e.g. 50 years) than the ventilation units, only a representative part of these installation costs are calculated per VU.
The main findings of the design options analyses relate to the understanding that with a reference ventilation performance as a benchmark, not only can significant energy savings be achieved when smart controls and higher electrical-heat recovery efficiencies are applied, but also that in many cases (especially in cold and average climates) these design options result in lower lifecycle costs.
For individual dwellings, a primary energy consumption of only 4,55 kWh/m²/a in an average climate and 5,82 kWh/m²/a in a cold climate is needed to achieve category II ventilation performance when smart state-of-the art BVUs are applied. Compared to the average 2010 reference UVU with a simple manual control, the savings can be as high as 51 kWh/m²/a in an average climate and up to 84 kWh/m²/a in a cold climate, with corresponding lifecycle cost savings of € 29 /m² and € 68 respectively.
Smart state-of-the-art UVUs also result in a reduced primary energy consumption; such a unit consumes 24.4 kWh/m²/a in an average climate and 40,6 kWh/m²/a in a warm climate to achieve category II ventilation performance. Again compared to the average 2010 reference UVU with a simple manual control, the savings can be as high as 32 kWh/m²/a in an average climate and up to 50 kWh/m²/a in a cold climate, with corresponding lifecycle cost savings of € 33 /m² and € 54 respectively.
In the warm climate, the smart state-of-the-art UVU offers the lowest lifecycle cost, with savings of up to €14/m², and a reduction of 16 kWh/m²/a on primary energy. For collective RVUs, the lifecycle cost savings can even go up due to the reduced investment cost per dwelling.
For NRVUs the picture that arises is similar but less pronounced due to the fact that for these applications it is assumed that despite the control types, the requested ventilation performance will in practice be achieved.

All in all, the main conclusion to draw is that the better VU-types in both the residential and non-residential sectors is both economically and environmentally sound and should therefore be promoted; it is also strongly advisable from the IAQ and public health point of view.

Chapter 2 further elaborates on the subject matter and scope. Following discussions with the stakeholder three scope-extensions are proposed. As regards the scope-exclusions, clearer descriptions and definitions are proposed for exclusions that give rise to questions in the market.

Chapter 3 describes the regulatory options that are proposed for the revised regulations for residential ventilation units. It covers both regulatory issues related to ecodesign and energy labelling and provides clear proposals for adjusting both the existing regulations, based on the ongoing discussions with the various stakeholders. Topics that are covered are: *ventilation performance, extended list of CTRL factors, adjusted sec-formula, filters and their energy consumption, including humidity recovery, limit values BVU-leakages, indoor/outdoor airtightness, frost-protection, energy label and verification tolerances*.

In the same manner, chapter 4 covers the regulatory options that are proposed for the non-residential ventilation units. The main topics that are covered under this section are: *including humidity recovery, minimum requirements HRS-efficiency, minimum requirements* SFP_{int}*, filters and minimum requirements as regards their energy consumption, filters and information requirements, controls, BVU-leakages, frost protection, working point unknown, issue of casing fans and verification tolerances.*

Finally, in chapter 5, some topics concerning the regulation text and their interpretation are further clarified.

Preface

This draft Task 6 report covers the current status of the work that has been done for Phase 1.1 and phase 1.2 of the Review Study, comprising the Technical Analysis and the update of the Preparatory studies. According to the Terms of Reference (T.o.R.) Phase 1.1 shall assess the items listed in Article 8 of Regulation 1253/2014 (Ecodesign of Ventilation Units) and Article 7 of Regulation 1254/2014 (Energy Labelling of Residential Ventilation Units), being:

a) the need to set requirements on air leakage rates in the light of technological progress;
b) the possible extension of the scope of Regulation 1253/2014 to cover unidirectional units with an electric power input of less than 30 W, and bidirectional units with a total electric power input for the fans of less than 30 W per air stream;
c) the verification tolerances set out in Annex VI of Regulation 1253/2014;
d) the appropriateness of taking into account the effects of low-energy consuming filters on the energy efficiency;
e) the need to add a further tier with tightened Ecodesign requirements;
f) the possible inclusion of other ventilation units, notably of non-residential units and of units with a total electric power input smaller to 30 W under Regulation 1254/2014;
g) the specific energy consumption calculation and classes for demand controlled unidirectional and bidirectional ventilation unit (in this respect it would be very relevant to provide, if possible, an estimate of the efficiency and energy labelling levels of the installed base of residential and non-residential ventilation units in the European Union (EU).

According to the Terms of Reference the following additional items need to be analysed:

h) the influence of the ambient conditions and the climatic zones in the EU on the quantitative requirements for heat recovery;
i) the need for specific provisions (and related formulation) on historic or listed buildings where the lack of space available can make it challenging to fit in ventilation units compliant with the two Regulations;
j) the need for (further) clarification on the nature of 'box fans' and 'roof fans', in particular concerning their compliance with the two Regulations and the fans Ecodesign regulation 327/2011;
k) the need/feasibility to impose quantitative requirements on the maximum internal leakage for bidirectional ventilation units, as well as the need/feasibility for correction factors for the declared thermal efficiency of residential ventilation units, based on the internal leakage rate;
l) an introduction, in the text of the two Regulations (e.g. in the definitions of unidirectional and bidirectional ventilation units), of the clarifications contained in the 'Question on a combination of a supply UVU and an exhaust UVU being considered as a BVU (11-2016)2';
m) an improved/increased description of the definition of 'nominal flow rate' of non-residential ventilation units;
n) improvements/changes in the definition of 'ventilation unit', with particular regard to the inclusion/exclusion of ventilation units for industrial applications (on the basis of FAQ 10 of the 'Guidelines accompanying Regulation (EU) No 1254/2014

with regard to the energy labelling of residential ventilation units and Regulation (EU) No 1253/2014 with regard to Ecodesign requirements for ventilation units';

o) the application and potential improvement of the requirement on the provision of instructions for the effective material recycling of the ventilation units (as in Annex IV - point 3 - of the Regulation 1253/2014);

p) other clarification requests from stakeholder in the context of the stakeholder consultation process.

And finally, if needed, the existing 'Guidelines accompanying Regulation (EU) No. 1254/2014 with regard to the energy labelling of residential ventilation units and Regulation (EU) No 1253/2014 with regard to Ecodesign requirements for ventilation units' will be updated.

In the subsequent phase 1.2 the Preparatory Studies are updated, where, according to the T.o.R. at least the following additional items need to be addressed:

1) the identification of potential new functional parameters at product level, in particular concerning the indoor air quality where relevant and feasible;
2) resource efficiency aspects3 - most likely disassembly, recyclability, reparability, durability and content of Critical Raw Materials (CRM), following the adoption of the Circular Economy Package in December 2015 and the new Ecodesign Working Plan 2016-2019. This includes the analysis of requirements already set (on the instruction of material recycling), their effectiveness in promoting the resource efficiency of ventilation unit and the identification of additional and/or more ambitious requirements, where relevant (e.g. in the content of CRM in magnets);
3) the potential inclusion in the analysis of smart controls and demand control options (such as, but not limited to, solutions for building/home energy management system based on the European standards SAREF/SAREF4ENER).

The study is carried out as a supplement to already existing preparatory studies for Lot 6 and Lot 10, indicating topics that have already been addressed will not be addressed again, unless there are new elements to be reported.

This sub-report on Task 6, specifically deals with updating data regarding Design Options and proposes the options for improving the existing regulations.

Acronyms and units

Acronyms

AC/DC	Alternating/Direct Current
ADCO	Administrative Co-operation
AHRI	American Air Conditioning, Heating and Refrigeration Institute
AMCA	Air Movement and Control Association
ATEX	ATmosphères EXplosibles
BC	Backward Curved
BVU	Bidirectional Ventilation Unit
CECED	European Committee of Domestic Equipment Manufacturers
CEN	European Committee for Standardization
CFD	Computer Fluid Dynamics
CIRCA	Communication and Information Resource Centre
CLP	Classification, Labelling and Packaging (Regulation)
DigitalEurope	Association representing the digital technology industry in Europe
DoC	Document of Conformity
DoE	US Department of Energy
EC	Electronically Commutating
EN	European Norm
EPEE	European Partnership for Energy and the Environment
Eurovent	Association of European refrigeration, air conditioning, air handling, heating and ventilation industry
EVIA	European Ventilation Industry Association
FC	Forward Curved
GWh	Giga Watt hour 109 Wh
HNL	Howden Netherlands
HRS	Heat Recovery System
ICSMS	Information and Communication System on Market Surveillance
ISO	International Standardisation Organisation
JBCE	Japan Business Council in Europe
JRAIA	Japan Refrigeration and Air Conditioning Industry Association
N	Efficiency grade
NRVU	Non-Residential Ventilation Unit
RAC	Run Around Coil
RAPEX	EU Rapid Alert System
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (Regulation)
RoHS	Restriction of Hazardous Substances (directive)
RVU	Residential Ventilation Unit
rpm	rounds per minute (unit for fan rotation speed)
TC	Technical Committee (in ISO, CEN, etc.)
TWh	Tera Watt hour 1012 Wh
UVU	Unidirectional Ventilation Unit
VU	Ventilation Unit
WEEE	Waste of electrical and electronic equipment (directive)
WG	Working Group (of a TC)
yr	year

Parameters

A	floor surface area building [m²]
cair	specific heat air [Wh/ m³.K]
Q	heat/energy [kWh]
q	hourly air exchange [$m^3.h^{-1}$/ m³]
rec	ventilation recovery rate [-]
S	shell surface area building [m²]
SV	shell surface/volume ratio building
t	heating season hours [h]
T_{in}	Indoor temperature [°C]
T_{out}	outdoor temperature [°C]
U	insulation value in [W/K. m²]
V	heated building volume [m³]
ΔT	Indoor-outdoor temperature difference [°C]
η	efficiency [-]

Units

€	Euro
°C	degree Celsius
a	annum (year)
bn	billion (1000 million)
CO_2	carbon-dioxide (equivalent)
h	hours
K	degree Kelvin
kWh	kilo Watt hour
m	metre or million
m²	square metre
m³	cubic metre
Pa	Pascal
W	Watt

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1. Design Options

1.1 Introduction

The design options that are identified in the paragraphs below pursue two goals:

1. to comply with category II ventilation performance
2. to minimize energy consumption

In that sense, the energy consumption that is calculated in this section, may not always coincide with real life energy consumption where the required ventilation performance is not always achieved. It is considered essential however, that the energy performance of ventilation units is compared to a reference ventilation performance. This approach therefore differs from the previous study where similar ventilation performance was implicitly assumed.

As a starting point for the design options, the base cases as defined in the Task 5 report will be used, as well as the suggestions mentioned here (Chapter 3.2 of this Task 5) to improve ventilation performance (i.e. efficacy). For all design options the parameters that determine the ventilation and energy performance are listed. Based on that, their annual electricity consumption is calculated, as well as the space heating energy consumption related to the air exchanges induced by the VU. Finally, the annual energy savings and related cost savings are calculated compared to the reference unit. With an estimate of the price increase of the design option, the simple payback period and life cycle costs savings can be calculated. Product cost estimates have been derived from the Task 2 and Task 5 reports and energy rates from the Ecodesign Impact Accounting (status December 2019). For ventilation units that require infra-structural adjustments (ductwork in the building) and with longer lifecycles (e.g. 50 years) than the ventilation units, only a representative part of these installation costs are calculated per VU.

1.2 Non-ducted (local) RVU

Non-ducted local ventilation units are gaining a share in the renovation market due to their lower installation costs compared to central ducted ventilation units. In the preparatory study of 2010, such units were mentioned under the best not yet available technology (BNAT) options (being a new trend at the time), but over the year their applications increased. These local units may have a specific product characteristic that may influence the ventilation performance as well as the energy performance of the units, which is the flow sensitivity (*fs*). Wall-mounted units may be sensitive to pressure variations over the façade and may introduce additional leakages in the building shell. These characteristics influence both performances and are therefore included in the assessment of the design options.

Three versions of these non-ducted (local) RVUs are distinguished (see Task 5), all with their own design options:

1. UVU/100/ES : Local extract unit serving ES only (additional units for HS are required)
2. UVU/100/HS : Local UVU serving HS only (additional units for ES are required)
3. BVU/100/HS : Local BVU serving HS only (additional units for ES are required)

1.2.1 UVU/100/ES

These local extract units are intended to only serve extract or wet spaces (ES). This means that for the habitable spaces, additional ventilation units are required. The unit allows for ventilation rates needed to comply with building codes (minimum installed capacity for ES) and applies the base load ventilation rates as a default minimum (i.e. cannot be switched off).

Reference unit
As a reference for the average installed unit, a manually controlled UVU with an SPI of 0.20 w/m³/h is selected. Its flow sensitivity factor is 1.15 and the unit has 3 different rotational speeds.
To achieve the reference ventilation performance in extract spaces, this unit requires an average flowrate of 31 m³/h, consumes €167 worth of electricity and €901 space heating energy cost over its lifetime for an average climate. A natural ventilation system requires around 10% more space heating energy cost and also has a lower ventilation performance.
The total lifecycle cost of this reference UVU/100/ES which includes product and installation costs, is calculated to be €1279 for the average climate, €692 for the warm climate and €1949 for the cold climate.

Design Options

The three design options indicated in

Table 1 have lower SPI-values, improved motor controls, lower flow sensitivity factors and better ventilation controls. The term VDC-ES refers to ventilation demand controls that are specifically suited for exhaust spaces (ES). For bathrooms this could be an RH-sensor, for toilets e.g. a TVOC-sensor or passive infra-red (PIR) sensor (with overrun-option), or a combination of suitable sensors. Because of these ventilation demand control devices, the design options not only require lower flowrates to achieve the same reference ventilation performance, but the electricity consumption is also reduced. Design option III requires an average flowrate of 19 m³/h, consumes €38 electricity and €554 space heating energy cost over its lifetime for the average climate.

Even by including product and installation costs (which are estimated relatively high in order not to overestimate lifecycle savings), design option III has the lowest lifecycle costs with €915 for the average climate, €549 for the warm climate and €1322 for the cold climate; the related LCC savings per local unit when compared to the reference unit are €369, €143 and €628 respectively. Payback periods for all three design options are less than 5 years.

Table 1. Performance, consumption and lifecycle cost design options UVU/100/ES

UVU/100/ES				DESIGN OPTIONS		
Parameter	**unit**	**Nat. vent.**	**Reference**	**I**	**II**	**III**
Performance data						
Nominal and reference flowrate	[m^3/h]	-	100/70	100/70	100/70	100/70
Airflow control	[-]	-	local	local	local	local
VDC[1] ES	[-]	-	manual	manual	VDC-ES	VDC-ES
VDC HS	[-]	-	n.a.	n.a.	n.a.	n.a.
CTRL factor @reference AEP	[-]	-	1.00	1.00	0.70	0.70
Flow sensitivity *: fs*	[-]	-	1.15	1.05	1.05	1.01
Avg flowrate for reference AEP [2]	[m^3/h]	34	31	28	20	19
VPI [3]	[-]	-	0.30	0.32	0.46	0.48
AEP ES @ CTRL factor	[%]	89%	100%	100%	100%	100%
AEP HS @ CTRL factor	[%]	-	n.a.	n.a.	n.a.	n.a.
SPI	[$W/m^3/h$]	-	0.20	0.10	0.10	0.05
Motor control type	[-]	-	multi speed	multi speed	variable speed	variable speed
Power consumption external VDC	[W]	-	0	0	1	1
Energy recovery ratio	[%]	-	0%	0%	0%	0%
Qdefrost for average climate	[kWh/a]	-	0	0	0	0
Consumption data (SEC)						
Annual electricity consumption	[kWh_e/a]	-	47	23	16	11
Annual space heating energy loss						
- for average climate	[kWh_{pr}/a]	836	757	691	484	466
- for warm climate	[kWh_{pr}/a]	291	264	241	169	162
- for cold climate	[kWh_{pr}/a]	1457	1320	1205	844	812
Sec value for avg climate	[$kWh/m^2/a$]			-0.95	-3.17	-3.48
Financial data						
Product cost (VAT excl.)	[€]		€ 118	€ 118	€ 198	€ 198
Installation cost (VAT excl.)	[€]		€ 58	€ 67	€ 67	€ 67
Total investment (VAT incl.)	[€]	€ 50	€ 211	€ 222	€ 318	€ 318
Electricity cost over lifetime (@21ct/kWh)	[€]		€ 167	€ 84	€ 59	€ 38
Total space heating energy cost over lifetime						
- for average climate (@7ct/kWh)	[€]	€ 994	€ 901	€ 823	€ 576	€ 554
- for warm climate	[€]	€ 346	€ 314	€ 286	€ 201	€ 193
- for cold climate	[€]	€ 1734	€ 1571	€ 1435	€ 1004	€ 966
Total lifecycle cost (LCC)						
- for average climate	[€]	€ 1044	€ 1279	€ 1128	€ 952	€ 910
- for warm climate	[€]	€ 396	€ 692	€ 592	€ 577	€ 549
- for cold climate	[€]	€ 1784	€ 1949	€ 1740	€ 1381	€ 1322

Improvements vs natural ventilation	LCC electr.	LCC space heating energy savings			Investment	payback yrs	€ LCC savings
	savings	average	warm	cold	increase	for average climate	
Design Option I	-€ 84	€ 172	€ 60	€ 299	€ 172	33.21	-€ 84
Design Option II	-€ 59	€ 418	€ 146	€ 730	€ 268	12.66	€ 92
Design Option III	-€ 38	€ 440	€ 153	€ 768	€ 268	11.32	€ 134

Improvements vs reference unit	LCC electr.	LCC space heating energy savings			Investment	payback yrs	€ LCC savings
	savings	average	warm	cold	increase	for average climate	
Design Option I	€ 84	€ 78	€ 27	€ 137	€ 11	1.13	€ 151
Design Option II	€ 109	€ 325	€ 113	€ 567	€ 107	4.19	€ 327
Design Option III	€ 129	€ 347	€ 121	€ 605	€ 107	3.81	€ 369

1) VDC= ventilation demand controls; ES refers to exhaust spaces; HS refers to habitable spaces.
2) Average flowrate is determined for the reference Air Exchange Performance (AEP), following Category II of EN16798-1 (except for natural vent. systems). For local units the average flowrate is determined assuming three UVU/100/ES per average dwelling.
3) VPI = Ventilation Perfromance Index = Ratio of the flow rate needed for the ideal/perfect VU and the VU concerned to achieve Category II ventilation performance for a whole dwelling

Note: data in this table only relates to category II ventilation performance of the exhaust ('wet') spaces ES. For evaluating and comparing lifecycle cost of a whole house, additional data as regards the ventilation solutions for habitable ('living') spaces HS are needed.

1.2.2 UVU/100/HS

These local extract units are intended to serve only habitable spaces. This means that for the extract or wet spaces, additional ventilation units are required. The unit allows for ventilation rates needed to comply with building codes (minimum installed capacity for HS) and applies the base load ventilation rates as a default minimum i.e. they cannot be switched off.

Reference unit

As a reference for the average installed unit, a manually controlled UVU with an SPI of 0.20 w/m³/h is selected. Its flow sensitivity factor is 1.15 and the unit has 3 different rotational speeds.

To achieve the reference ventilation performance in extract spaces, this unit requires an average flowrate of 43 m³/h, consumes €226 of electricity and €1247 space heating energy costs over its lifetime (for average climate). A natural ventilation system requires around 15% more space heating energy costs and also has a considerably lower ventilation performance in living spaces. Including product and installation costs, the total lifecycle costs of this reference UVU/100/HS is calculated at €1684 for the average climate, €871 for the warm climate and €2612 for the cold climate.

Design Options

The three design options indicated in Table 2 have lower SPI-values, improved motor controls, lower flow sensitivity factors and better ventilation controls. The term VDC-HS refers to ventilation demand controls that are specifically suited for habitable spaces (HS). CO_2-sensors for instance are adequate VDC-HS devices that not only detect the presence of people but also their number ; methods of occupancy detection that also enable detecting the number of people present are equally suitable. Using such VDC-HS devices, the design options not only require lower flowrates to achieve the same reference ventilation performance but they also reduce the electricity consumption. Design options II and III require an average flowrate of 18 m³/h. Design options III consumes €49 of electricity and €519 of space heating energy costs over its lifetime for an average climate.

Even by including product and installation costs (which are estimated to be relatively high in order not to overestimate lifecycle savings), the design option III still has the lowest lifecycle costs of €946 for the average climate, €608 for the warm climate and €1332 for the cold climate; the related LCC-savings per local unit when compared to the reference unit are €738, €264 and €1280 respectively. Payback periods for all three design options are about 3 years. As regards the ventilation performance, the VPI increases from 43% for the reference unit to 100% for design option III.

When comparing UVU/100/HS with BVU/100/HS, the total lifecycle costs for BVU are lower in cold climates but for warm climates the UVU has the lowest lifecycle costs. For an average climate this depends uoon the types of UVU and BVU that are being compared.

Table 2. Performance, consumption and lifecycle cost design options UVU/100/HS

UVU/100/HS				DESIGN OPTIONS		
Parameter	**unit**	**Nat. vent.**	**Reference**	**I**	**II**	**III**
Performance data						
Nominal and reference flowrate	[m^3/h]	-	100/70	100/70	100/70	100/70
Airflow control	[-]	-	local	local	local	local
VDC[1] ES	[-]	-	n.a.	n.a.	n.a.	n.a.
VDC HS	[-]	-	manual	VDC-ES	VDC-HS	VDC-HS
CTRL factor @reference AEP	[-]	-	0.95	0.70	0.45	0.45
Flow sensitivity *: fs*	[-]	-	1.15	1.10	1.05	1.01
Avg flowrate for reference AEP [2]	[m^3/h]	49	43	30	18	18
VPI [3]	[-]	-	0.31	0.44	0.72	0.75
AEP ES @ CTRL factor	[%]	89%	n.a.	n.a.	n.a.	n.a.
AEP HS @ CTRL factor	[%]	34%	100%	100%	100%	100%
SPI	[W/m^3/h]	-	0.20	0.10	0.10	0.05
Motor control type	[-]	-	multi speed	variable speed	variable speed	variable speed
Power consumption external VDC	[W]	-	0	0	1	1
Energy recovery ratio	[%]	-	0%	0%	0%	0%
Qdefrost for average climate	[kWh/a]	-	0	0	0	0
Consumption data (SEC)						
Annual electricity consumption	[kWh_e/a]	-	63	17	17	14
Annual space heating energy loss						
- for average climate	[kWh_{pr}/a]	1218	1048	739	453	436
- for warm climate	[kWh_{pr}/a]	424	365	257	158	152
- for cold climate	[kWh_{pr}/a]	2123	1828	1288	790	760
Sec value for avg climate	[kWh/m^2/a]			-4.44	-7.28	-7.53
Financial data						
Product cost (VAT excl.)	[€]		€ 118	€ 198	€ 248	€ 248
Installation cost (VAT excl.)	[€]		€ 58	€ 58	€ 67	€ 67
Total investment (VAT incl.)	[€]	€ 50	€ 211	€ 307	€ 378	€ 378
Electricity cost over lifetime (@21ct/kWh)	[€]		€ 226	€ 60	€ 61	€ 49
Total space heating energy cost over lifetime						
- for average climate (@7ct/kWh)	[€]	€ 1449	€ 1247	€ 879	€ 539	€ 519
- for warm climate	[€]	€ 505	€ 434	€ 306	€ 188	€ 181
- for cold climate	[€]	€ 2526	€ 2175	€ 1533	€ 941	€ 905
Total lifecycle cost (LCC)						
- for average climate	[€]	€ 1499	€ 1684	€ 1246	€ 979	€ 946
- for warm climate	[€]	€ 555	€ 871	€ 673	€ 627	€ 608
- for cold climate	[€]	€ 2576	€ 2612	€ 1900	€ 1380	€ 1332

Improvements vs natural ventilation	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs for average climate	€ LCC savings for average climate
Design Option I	-€ 60	€ 570	€ 198	€ 993	€ 257	8.57	€ 253
Design Option II	-€ 61	€ 909	€ 317	€ 1586	€ 328	6.57	€ 520
Design Option III	-€ 49	€ 930	€ 324	€ 1622	€ 328	6.33	€ 553

Improvements vs reference unit	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs for average climate	€ LCC savings for average climate
Design Option I	€ 166	€ 368	€ 128	€ 642	€ 96	3.06	€ 438
Design Option II	€ 164	€ 708	€ 246	€ 1234	€ 167	3.25	€ 705
Design Option III	€ 177	€ 728	€ 254	€ 1270	€ 167	3.13	€ 738

[1] VDC= ventilation demand controls; ES refers to exhaust spaces; HS refers to habitable spaces.
[2] Average flowrate is determined for the reference Air Exchange Performance (AEP), following Category II of EN16798-1 (except for natural vent. systems). For local units the average flowrate is determined assuming three UVU/100/HS per average dwelling.
[3] VPI = Ventilation Perfromance Index = Ratio of the flow rate needed for the ideal/perfect VU and the VU concerned to achieve Category II ventilation performance for a whole dwelling

Note: data in this table only relates to category II ventilation performance of the habitable ('living') spaces HS. To evaluate and compare lifecycle costs of a whole house, additional data as regards the ventilation solutions for exhaust ('wet') spaces ES are needed.

1.2.3 BVU/100/HS

These local BVUs are intended to serve only habitable spaces. For the extract or wet spaces, additional ventilation units are therefore required. The unit allows for ventilation rates needed to comply with building codes (minimum installed capacity for HS) and applies the base load ventilation rates as a default minimum (i.e. cannot be switched off).

Reference unit
As a reference for the average installed unit, a manually controlled BVU with an SPI of 0.35 w/m³/h is selected. Its airflow balance is not controlled, the internal leakage is around 20% (not uncommon for local BVUs), flow sensitivity factor is 1.15 and the unit has 3 different rotational speeds. The energy recovery ratio of the reference unit is set at 65% (incorporating corrections for internal leakages and flow sensitivity).
To achieve the reference ventilation performance in extract spaces, this unit requires an average flowrate of 43 m³/h, consumes €661 of electricity and €437 of space heating energy cost over its lifetime for an average climate. A natural ventilation system requires over 3 times more space heating energy cost and also has a considerably lower ventilation performance. Including product and installation costs, the total lifecycle cost of this reference BVU/100/HS is calculated at €1823 for the average climate, €1538 for the warm climate and €2147 for the cold climate.

Design Options
The three design options indicated in Table 3 have one or more improved specifications among which lower SPI-values, improved motor controls, lower flow sensitivity factors and better ventilation controls. Also, the internal leakages are reduced and the energy recovery ratio is further improved. Note that the energy recovery efficiency values are relatively low compared to figures mentioned in sales documentation because they are corrected for internal leakages and flow sensitivity. The term VDC-HS refers to ventilation demand controls that are specifically suited for habitable spaces (HS). CO_2-sensors for instance are adequate VDC-HS devices that not only detect the presence of people but also their number ; methods of occupancy detection that also enable detecting the number of people present are equally suitable. Using such VDC-HS devices, the design options not only require lower flowrates to achieve the same reference ventilation performance, but they also reduce the electricity consumption. .
Design options II and III require average flowrates of 29 and 20 m³/h respectively. Design option III consumes only €113 of electricity and €90 of space heating energy costs over its lifetime for an average climate.
As regards the ventilation performance, the VPI increases from 43% for the reference unit, to 90% for design option III.

Even by including product and installation costs (which are estimated to be relatively high in order not to overestimate lifecycle savings), the design option III has the lowest lifecycle cost with €1108 for the average climate, €1049 for the warm climate and €1175 for the cold climate; the related LCC savings per local unit when compared to the reference unit are €714, €488 and €972 respectively. Payback periods for all three design options are less than 4 years.

Table 3. Performance, consumption and lifecycle cost design options BVU/100/HS

BVU/100/HS				DESIGN OPTIONS		
Parameter	**unit**	**Nat. vent.**	**Reference**	**I**	**II**	**III**
Performance data						
Nominal and reference flowrate	[m³/h]	-	100/70	100/70	100/70	100/70
Airflow control	[-]	-	local	local	local	local
Balance control	[-]	-	no	no	no	yes
Internal leakage	[-]	-	≥6%	≥6%	≥6%	<3%
VDC[1] ES	[-]	-	n.a.	n.a.	n.a.	n.a.
VDC HS	[-]	-	manual	VDC-ES	VDC-HS	VDC-HS
CTRL factor @reference AEP	[-]	-	0.95	0.80	0.70	0.50
Flow sensitivity *: fs*	[-]	-	1.15	1.10	1.05	1.05
Avg flowrate for reference AEP [2]	[m³/h]	49	43	34	29	20
VPI [3]	[-]	-	0.31	0.39	0.46	0.65
AEP ES @ CTRL factor	[%]	89%	n.a.	n.a.	n.a.	n.a.
AEP HS @ CTRL factor	[%]	34%	100%	100%	100%	100%
SPI	[W/m³/h]	-	0.35	0.25	0.20	0.15
Motor control type	[-]	-	multi speed	multi speed	variable speed	variable speed
Power consumption external VDC	[W]	-	0	0	1	1
Energy recovery ratio	[%]	-	65%	70%	75%	85%
Qdefrost for average climate	[kWh/a]	-	26	17	7	4
Consumption data (SEC)						
Annual electricity consumption	[kWh_e/a]	-	185	89	56	32
Annual space heating energy loss						
- for average climate	[kWh_{pr}/a]	1218	367	253	176	76
- for warm climate	[kWh_{pr}/a]	424	128	88	61	26
- for cold climate	[kWh_{pr}/a]	2123	640	442	307	132
Sec value for avg climate	[kWh/m²/a]		-4.62	-7.78	-9.24	-10.75
Financial data						
Product cost (VAT excl.)	[€]		€ 403	€ 453	€ 553	€ 553
Installation cost (VAT excl.)	[€]		€ 201	€ 201	€ 201	€ 201
Total investment (VAT incl.)	[€]	€ 50	€ 725	€ 785	€ 905	€ 905
Electricity cost over lifetime (@21ct/kWh)	[€]		€ 661	€ 316	€ 200	€ 113
Total space heating energy cost over lifetime						
- for average climate (@7ct/kWh)	[€]	€ 1449	€ 437	€ 301	€ 210	€ 90
- for warm climate	[€]	€ 505	€ 152	€ 105	€ 73	€ 31
- for cold climate	[€]	€ 2526	€ 761	€ 526	€ 366	€ 157
Total lifecycle cost (LCC)						
- for average climate	[€]	€ 1499	€ 1823	€ 1402	€ 1314	€ 1108
- for warm climate	[€]	€ 555	€ 1538	€ 1206	€ 1177	€ 1049
- for cold climate	[€]	€ 2576	€ 2147	€ 1627	€ 1470	€ 1175

Improvements vs natural ventilation	LCC electr.	LCC space heating energy savings			Investment	payback yrs	€ LCC savings
	savings	average	warm	cold	increase	for average climate	
Design Option I	-€ 316	€ 1147	€ 400	€ 2001	€ 735	15.03	€ 96
Design Option II	-€ 200	€ 1239	€ 431	€ 2161	€ 855	13.98	€ 185
Design Option III	-€ 113	€ 1359	€ 473	€ 2370	€ 855	11.67	€ 391

Improvements vs reference unit	LCC electr.	LCC space heating energy savings			Investment	payback yrs	€ LCC savings
	savings	average	warm	cold	increase	for average climate	
Design Option I	€ 345	€ 135	€ 47	€ 236	€ 60	2.12	€ 420
Design Option II	€ 462	€ 227	€ 79	€ 395	€ 180	4.45	€ 508
Design Option III	€ 548	€ 347	€ 121	€ 604	€ 180	3.42	€ 714

[1] VDC= ventilation demand controls; ES refers to exhaust spaces; HS refers to habitable spaces.

[2] Average flowrate is determined for the reference Air Exchange Performance (AEP), following Category II of EN16798-1 (except for natural vent. systems). For local units the average flowrate is determined assuming three BVU/100/HS per average dwelling.

[3] VPI = Ventilation Perfromance Index = Ratio of the flow rate needed for the ideal/perfect VU and the VU concerned to achieve Category II ventilation performance for a whole dwelling

Note: data in this table only relates to category II ventilation performance of the habitable ('living') spaces HS. To evaluate and compare lifecycle costs of a whole house, additional data as regards the ventilation solutions for exhaust ('wet') spaces ES are needed.

1.3 Ducted (central) RVU

Ducted residential ventilation units that serve one dwelling (also called central RVUs), are the most commonly applied systems in detached and terraced dwellings and renovated apartments. Two versions of ducted RVUs are distinguished (see also Task 5 Report), both with their own design options:

1. UVU/250
2. BVU/250

1.3.1 UVU/250

These units are intended to serve both extract spaces and habitable spaces. Using ducts, the central UVU directly extracts from all wet spaces (ES) while fresh air is supplied to habitable spaces through ventilation grids. The unit allows for ventilation rates needed to comply with the buildings codes regarding minimum required capacity for both the exhaust and habitable spaces and applies the base load ventilation rates as a default minimum. The unit cannot be switched off.

Reference unit
A unit with an SPI of 0.30 W/m³/h and an additional central RH-sensor (next to the manual 3-way switch in the kitchen and in the bathroom) will serve as a reference for calculating the design options for the UVU/250. The unit can supply three preselected flowrates and can extract air directly from the wet spaces only, using fixed extraction valves.
To achieve reference ventilation performance, this reference unit requires an average ventilation rate of 187 m³/h, consumes €1711 of electricity and €5487 of space heating energy over its lifetime in an average climate; a natural ventilation system would in this case, incur €7330 of space heating energy costs and with a lower ventilation performance. Including product and installation costs, the total lifecycle costs of this reference unit is €8102 in the average climate, €4526 in the warm climate and €12.182 in the cold climate.

Design Options
Table 4 indicates the design options and related improvements in product specifications. Initial improvements relate to the VDC-controls. All three design options have local RH/PIR sensors in the wet rooms and local CO_2-sensors in the habitable spaces which considerably improve the control behaviour of the unit leading to higher efficacy values and lower average airflow rates. Additionally, the SPI-values and motor controls are improved. Finally, for design option III, the direct extraction of air is extended to the habitable spaces as well, using controllable valves in all spaces with which the extracted airflow can be adjusted per individual room. Design option III requires average flowrates of 89 m³/h, consumes €432 of electricity and €2599 of space heating energy over its lifetime for an average climate.
As regards the ventilation performance, the VPI increases from 36% for the reference unit, to 76% for design option III.

Including product and installation costs, design option III has the lowest lifecycle costs of €4787 for the average climate, €3093 for the warm climate and €6720 for
the cold climate; the related LCC-savings per unit when compared to the reference unit are €3315, €1433 and €5462 respectively. Payback periods for all three design options are less than 5 years.

Table 4. Performance, consumption and lifecycle cost design options UVU/250

UVU/250				DESIGN OPTIONS		
Parameter	**unit**	**Nat. vent.**	**Reference**	**I**	**II**	**III**
Performance data						
Nominal and reference flowrate	[m³/h]	-	250/175	250/175	250/175	250/175
Directly extracts air from:			ES	ES	ES	ES and HS
Airflow control	[-]	-	central	central	central	local with valves
VDC[1] ES	[-]	-	central VDC-ES	local VDC-ES	local VDC-ES	local VDC-ES
VDC HS	[-]	-	central VDC-ES	local VDC-HS	local VDC-HS	local VDC-HS
CTRL factor @reference AEP	[-]	-	0.95	0.80	0.80	0.45
Flow sensitivity *: fs*	[-]	-	1.00	1.00	1.00	1.00
Avg flowrate for reference AEP [2]	[m³/h]	250	187	158	158	89
VPI [3]	[-]	-	0.36	0.43	0.43	0.76
AEP ES @ CTRL factor	[%]	89%	100%	100%	100%	100%
AEP HS @ CTRL factor	[%]	34%	100%	100%	100%	100%
SPI	[W/m³/h]	-	0.30	0.10	0.05	0.05
Motor control type	[-]	-	multi speed	variable speed	variable speed	variable speed
Power consumption external VDC	[W]	-	0.00	4.00	4.00	6.00
Energy recovery ratio	[%]	-	0%	0%	0%	0%
Qdefrost for average climate	[kWh/a]	-	0.00	0.00	0.00	0.00
Consumption data (SEC)						
Annual electricity consumption	[kWh_e/a]	-	479	179	124	121
Annual space heating energy loss						
- for average climate	[kWh_{pr}/a]	6159	4611	3883	3883	2184
- for warm climate	[kWh_{pr}/a]	2145	1606	1352	1352	761
- for cold climate	[kWh_{pr}/a]	10740	8040	6770	6770	3808
Sec value for avg climate	[kWh/m²/a]		-5.42	-19.00	-20.16	-37.21
Financial data						
Product cost (VAT excl.)	[€]		€ 300	€ 710	€ 710	€ 1010
Installation cost (VAT excl.)	[€]		€ 453	€ 453	€ 453	€ 453
Total investment (VAT incl.)	[€]	€ 150	€ 904	€ 1396	€ 1396	€ 1756
Electricity cost over lifetime (@21ct/kWh)	[€]		€ 1711	€ 641	€ 444	€ 432
Total space heating energy cost over lifetime						
- for average climate (@7ct/kWh)	[€]	€ 7330	€ 5487	€ 4621	€ 4621	€ 2599
- for warm climate	[€]	€ 2552	€ 1911	€ 1609	€ 1609	€ 905
- for cold climate	[€]	€ 12780	€ 9567	€ 8057	€ 8057	€ 4532
Total lifecycle cost (LCC)						
- for average climate	[€]	€ 7480	€ 8102	€ 6657	€ 6460	€ 4787
- for warm climate	[€]	€ 2702	€ 4526	€ 3645	€ 3448	€ 3093
- for cold climate	[€]	€ 12930	€ 12182	€ 10093	€ 9896	€ 6720

Improvements vs natural ventilation	LCC electr.	LCC space heating energy savings			Investment	payback yrs	€ LCC savings
	savings	average	warm	cold	increase	for average climate	
Design Option I	-€ 641	€ 2709	€ 943	€ 4724	€ 1246	10.24	€ 823
Design Option II	-€ 444	€ 2709	€ 943	€ 4724	€ 1246	9.35	€ 1020
Design Option III	-€ 432	€ 4731	€ 1647	€ 8248	€ 1606	6.35	€ 2693

Improvements vs reference unit	LCC electr.	LCC space heating energy savings			Investment	payback yrs	€ LCC savings
	savings	average	warm	cold	increase	for average climate	
Design Option I	€ 1071	€ 866	€ 302	€ 1511	€ 492	4.32	€ 1445
Design Option II	€ 1268	€ 866	€ 302	€ 1511	€ 492	3.92	€ 1642
Design Option III	€ 1279	€ 2888	€ 1006	€ 5035	€ 852	3.48	€ 3315

[1] VDC= ventilation demand controls; ES refers to exhaust spaces; HS refers to habitable spaces.
[2] Average flowrate is determined for the reference Air Exchange Performance (AEP), following Category II of EN16798-1 (except for natural vent. systems). For local units the average flowrate is determined assuming three BVU/100/HS per average dwelling.
[3] VPI = Ventilation Perfromance Index = Ratio of the flow rate needed for the ideal/perfect VU and the VU concerned to achieve Category II ventilation performance for a whole dwelling

1.3.2 BVU/250

These units are intended to serve both the extract spaces and the habitable spaces. Using ducts, air is mechanically extracted from all wet spaces (ES) and similarly fresh air is mechanically supplied to all the habitable spaces. A heat exchanger in the BVU transfers the thermal energy from the used and extracted air to the fresh supply of air.
The unit allows for ventilation rates needed to comply with the buildings codes regarding minimum required capacity for both the exhaust and habitable spaces and applies the base load ventilation rates as a default minimum. The unit cannot be switched off.

Reference unit
A unit with an SPI of 0.45 W/m³/h and an additional central RH-sensor (next to the manual 3-way switch in the kitchen and in the bathroom) will serve as a reference for calculating the design options for the BVU/250. The unit can supply three preselected flowrates and extracts and supplies air using fixed supply and exhaust grilles. The unit has no flow balance control and its total leakages are about 20%. Reference energy recovery ratio is set at 70% to compensate for these leakages.
To achieve reference ventilation performance, this reference unit requires an average ventilation rate of 177 m³/h, consumes €3124 of electricity and €1559 of space heating energy over its lifetime for an average climate; a natural ventilation system would in this case need €7330 of space heating energy costs and with a lower ventilation performance. Including product and installation costs, the total lifecycle cost of this reference unit is €7981 for the average climate, €6965 for the warm climate and €9141 for the cold climate.

Design Options
Table 5 indicates the design options and related improvements in product specifications. Initial improvements relate to the VDC-controls. All three design options have local RH/PIR-sensors in wet rooms and local CO_2 sensors in habitable spaces, which considerably improve the control behaviour of the unit, leading to higher efficacy values and lower average airflow rates. Additionally, the SPI-values and motor controls are improved. Internal leakages are reduced to below 3% and the energy recovery ratio is further increased. Finally, the airflow control is further improved, using zonal adjustable valves in design option II and local adjustable valves in all spaces for design option III.
Design option III requires average flowrates of 69 m³/h, consumes €487 of electricity and €202 of space heating energy over its lifetime for an average climate.
As regards the ventilation performance, the VPI increases from 38% for the reference unit, to 100% for design option III.

Including product and installation costs, design option III – even though it has the lowest energy costs – does not have the lowest lifecycle costs. It is design option I that has the lowest lifecycle costs with €4978 for the average climate, €4601 for the warm climate and €5407 for the cold climate; the related LCC savings per unit when compared to the reference unit are €3004, €2364 and €3734 respectively. Payback periods for all three design options are within 5 years.

Table 5. Performance, consumption and lifecycle cost design options BVU/250

BVU/250				DESIGN OPTIONS		
Parameter	**unit**	**Nat. vent.**	**Reference**	**I**	**II**	**III**
Performance data						
Nominal and reference flowrate	[m^3/h]	-	250/175	250/175	250/175	250/175
Airflow control	[-]	-	central	central	zonal with valves	local with valves
Balance control	[-]		no	yes	yes	yes
Internal leakage	[-]		≥6%	<3%	<3%	<3%
VDC[1] ES	[-]	-	central VDC-ES	local VDC-ES	local VDC-ES	local VDC-ES
VDC HS	[-]	-	central VDC-ES	local VDC-HS	local VDC-HS	local VDC-HS
CTRL factor @reference AEP	[-]	-	0.90	0.50	0.45	0.35
Flow sensitivity *: fs*	[-]	-	1.00	1.00	1.00	1.00
Avg flowrate for reference AEP [2]	[m^3/h]	250	177	99	89	69
VPI [3]	[-]	-	0.38	0.68	0.76	1.00
AEP ES @ CTRL factor	[%]	89%	100%	100%	100%	100%
AEP HS @ CTRL factor	[%]	34%	100%	100%	100%	100%
SPI	[W/m^3/h]	-	0.45	0.20	0.20	0.15
Motor control type	[-]	-	multi speed	variable speed	variable speed	variable speed
Power consumption external VDC	[W]	-	0.00	3.00	5.00	5.00
Energy recovery ratio	[%]	-	70%	80%	85%	90%
Qdefrost for average climate	[kWh/a]	-	71	25	23	20
Consumption data (SEC)						
Annual electricity consumption	[kWh_e/a]	-	875	164	180	136
Annual space heating energy loss						
- for average climate	[kWh_{pr}/a]	6159	1310	485	328	170
- for warm climate	[kWh_{pr}/a]	2145	456	169	114	59
- for cold climate	[kWh_{pr}/a]	10740	2285	846	571	296
Sec value for avg climate	[kWh/m^2/a]		-30.11	-53.29	-54.54	-57.03
Financial data						
Product cost (VAT excl.)	[€]		€ 1234	€ 1664	€ 1964	€ 2264
Installation cost (VAT excl.)	[€]		€ 1514	€ 1514	€ 1514	€ 1514
Total investment (VAT incl.)	[€]	€ 150	€ 3298	€ 3814	€ 4174	€ 4534
Electricity cost over lifetime (@21ct/kWh)	[€]		€ 3124	€ 586	€ 642	€ 487
Total space heating energy cost over lifetime						
- for average climate (@7ct/kWh)	[€]	€ 7330	€ 1559	€ 578	€ 390	€ 202
- for warm climate	[€]	€ 2552	€ 543	€ 201	€ 136	€ 70
- for cold climate	[€]	€ 12780	€ 2719	€ 1007	€ 680	€ 352
Total lifecycle cost (LCC)						
- for average climate	[€]	€ 7480	€ 7981	€ 4978	€ 5205	€ 5222
- for warm climate	[€]	€ 2702	€ 6965	€ 4601	€ 4951	€ 5091
- for cold climate	[€]	€ 12930	€ 9141	€ 5407	€ 5495	€ 5373

Improvements vs natural ventilation	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs for average climate	€ LCC savings for average climate
Design Option I	-€ 586	€ 6752	€ 2351	€ 11773	€ 3664	10.10	€ 2502
Design Option II	-€ 642	€ 6940	€ 2416	€ 12100	€ 4024	10.86	€ 2274
Design Option III	-€ 487	€ 7127	€ 2482	€ 12428	€ 4384	11.22	€ 2257

Improvements vs reference unit	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs for average climate	€ LCC savings for average climate
Design Option I	€ 2538	€ 982	€ 342	€ 1712	€ 516	2.49	€ 3004
Design Option II	€ 2483	€ 1170	€ 407	€ 2039	€ 876	4.08	€ 2776
Design Option III	€ 2638	€ 1357	€ 473	€ 2367	€ 1236	5.26	€ 2759

[1] VDC= ventilation demand controls; ES refers to exhaust spaces; HS refers to habitable spaces.
[2] Average flowrate is determined for the reference Air Exchange Performance (AEP), following Category II of EN16798-1 (except for natural vent. systems). For local units the average flowrate is determined assuming three BVU/100/HS per average dwelling.
[3] VPI = Ventilation Perfromance Index = Ratio of the flow rate needed for the ideal/perfect VU and the VU concerned to achieve Category II ventilation performance for a whole dwelling

1.4 Collective ventilation units

When apartments are built or renovated, collective ventilation systems are often considered. Collective UVUs or BVUs are placed in or on top of the building that serve multiple apartments using a centralized duct system. Although the focus is on residential applications, the units are also used for non-residential applications (small offices, commercial buildings etc.). Following the base cases described in Task 5, the subsequent collective ventilation units are distinguished, each with their own design options:

3. UVU/1000
4. BVU/1000
5. UVU/1000+
6. BVU/2500

1.4.1 UVU/1000

Like the UVU/250, these collective units are intended to serve both the extract spaces and the habitable spaces in dwellings. Using a central duct in the building (and possibly some additional ducting per individual dwelling), the central UVU directly extracts from all wet spaces (ES) while fresh air is supplied to the habitable spaces through ventilation grids. The unit allows for ventilation rates needed to comply with the buildings codes regarding minimum required capacity for both the exhaust and habitable spaces for all dwellings attached and applies the base load ventilation rates as a default minimum. The unit cannot be switched off.

Reference unit
A unit with an SPI of 0.30 W/m³/h, a variable speed motor control and a clock programme that switches from low to higher ventilation rates when most of the extract spaces (ES) are used (e.g. for a couple of hours in the morning and in the evening), and when most inhabitants are assumed to be present (during night time). The unit extracts air directly from the wet spaces only, using fixed extraction grilles.
To achieve reference ventilation performance, this reference unit requires an average ventilation rate of 749 m³/h, consumes €6734 of electricity and €21.948 of space heating energy over its lifetime for an average climate; natural ventilation systems would need, in this case, €29.319 of space heating energy costs and with a lower ventilation performance. Including product and installation costs, the total lifecycle costs of this reference unit is €29.789 for the average climate, €15.483 for the warm climate and €46.110 for the cold climate.

Design Options
Table 6 indicates the design options and related improvements in product specifications. Initial improvements relate to the SPI-value that is improved from 0.30 to 0.10. For the second design option, the fixed extraction valves are replaced by controllable valves in all ES that are controlled by local VDC-ES devices (e.g. RH- and/or PIR sensors). This solution requires a constant under-pressure in the central extract duct for which the fan uses additional power. For the third design option, local VDC-HS devices are added in all habitable spaces that also control the valves in the ES. As regards the ventilation performance, the VPI increases from 36% for the reference unit, to 52% for design option III.

Design option III requires average flowrates of 512 m³/h, consumes €2705 of electricity and €15.017 of space heating energy over its lifetime for an average climate.
Including product and installation costs, the design option III has the lowest lifecycle cost of €22.368 for the average climate, €12.580 for the warm climate and €33.536 for the cold climate; the related LCC-savings per unit when compared to the reference unit are €7420, €2903 and €12574 respectively. Payback periods for all three design options are within 6 years.

Table 6. Performance, consumption and lifecycle cost design options UVU/1000

UVU/1000				DESIGN OPTIONS		
Parameter	**unit**	**Nat. vent.**	**Reference**	**I**	**II**	**III**
Performance data						
Nominal and reference flowrate	[m^3/h]	-	1000/700	1000/700	1000/700	1000/700
Directly extracts air from:			ES	ES	ES	ES
Airflow control	[-]	-	central	central	zonal (valves in ES)	zonal (valves in ES)
Power consumption fans due to constant pressure in ducts		-	0.00	0.00	9.60	12.80
VDC[1)] in ES	[-]	-	clock	clock	local VDC-ES	local VDC-ES
VDC in HS	[-]	-	clock	clock	zonal VDC-ES	local VDC-HS
CTRL factor @reference AEP	[-]	-	0.95	0.95	0.80	0.65
Flow sensitivity *: fs*	[-]	-	1.00	1.00	1.00	1.00
Avg flowrate for reference AEP [2)]	[m^3/h]	1000	749	749	630	512
VPI [3)]	[-]	-	0.36	0.36	0.43	0.52
AEP ES @ CTRL factor	[%]	89%	100%	100%	100%	100%
AEP HS @ CTRL factor	[%]	34%	100%	100%	100%	100%
SPI	[W/m^3/h]	-	0.30	0.10	0.10	0.10
Motor control type	[-]	-	variable speed	variable speed	variable speed	variable speed
Power consumption external VDC	[W]	-	1.00	1.00	2.20	14.20
Energy recovery ratio	[%]	-	0%	0%	0%	0%
Qdefrost for average climate	[kWh/a]	-	0.00	0.00	0.00	0.00
Consumption data (SEC)						
Annual electricity consumption	[kWh_e/a]	-	1886	640	645	758
Annual space heating energy loss						
- for average climate	[kWh_{pr}/a]	24637	18444	18444	15531	12619
- for warm climate	[kWh_{pr}/a]	8579	6422	6422	5408	4394
- for cold climate	[kWh_{pr}/a]	42959	32159	32159	27081	22004
Sec value for avg climate	[kWh/m^2/a]		-5.58	-12.12	-19.38	-26.07
Financial data						
Product cost (VAT excl.)	[€]		€ 388	€ 425	€ 2188	€ 3388
Installation cost (VAT excl.)	[€]		€ 550	€ 550	€ 550	€ 550
Total investment (VAT incl.)	[€]	€ 600	€ 1107	€ 1151	€ 3231	€ 4647
Electricity cost over lifetime (@21ct/kWh)	[€]		€ 6734	€ 2286	€ 2304	€ 2705
Total space heating energy cost over lifetime						
- for average climate (@7ct/kWh)	[€]	€ 29319	€ 21948	€ 21948	€ 18482	€ 15017
- for warm climate	[€]	€ 10209	€ 7642	€ 7642	€ 6436	€ 5229
- for cold climate	[€]	€ 51121	€ 38269	€ 38269	€ 32227	€ 26184
Total lifecycle cost (LCC)						
- for average climate	[€]	€ 29919	€ 29789	€ 25384	€ 24017	€ 22368
- for warm climate	[€]	€ 10809	€ 15483	€ 11079	€ 11971	€ 12580
- for cold climate	[€]	€ 51721	€ 46110	€ 41705	€ 37762	€ 33536

Improvements vs natural ventilation	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs	€ LCC savings for average climate
Design Option I	-€ 2286	€ 7371	€ 2567	€ 12852	€ 551	1.84	€ 4535
Design Option II	-€ 2304	€ 10836	€ 3773	€ 18894	€ 2631	5.24	€ 5901
Design Option III	-€ 2705	€ 14302	€ 4980	€ 24937	€ 4047	5.93	€ 7550

Improvements vs reference unit	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs	€ LCC savings for average climate
Design Option I	€ 4448	€ -	€ -	€ -	€ 44	0.17	€ 4404
Design Option II	€ 4430	€ 3465	€ 1207	€ 6043	€ 2124	4.57	€ 5771
Design Option III	€ 4029	€ 6931	€ 2413	€ 12085	€ 3540	5.49	€ 7420

1) VDC= ventilation demand controls; ES refers to exhaust spaces; HS refers to habitable spaces.

2) Average flowrate is determined for the reference Air Exchange Performance (AEP), following Category II of EN16798-1 (except for natural vent. systems). For local units the average flowrate is determined assuming three BVU/100/HS per average dwelling.

3) VPI = Ventilation Perfromance Index = Ratio of the flow rate needed for the ideal/perfect VU and the VU concerned to achieve Category II ventilation performance for a whole dwelling

1.4.2 BVU/1000

Like the BVU/250, these collective units are intended to serve both the extract spaces and the habitable spaces in the dwellings that are connected to the unit. Using central ducts in the building (and possibly some additional ducting per individual dwelling), the central BVU mechanically extracts air from all wet spaces (ES) and mechanically supplies fresh air to all habitable spaces. A heat exchanger in the BVU transfers the thermal energy from the used and extracted air to the fresh supply of air.
The unit allows for ventilation rates needed to comply with the buildings codes regarding minimum required capacity for both the exhaust and habitable spaces and applies the base load ventilation rates as a default minimum. The unit cannot be switched off.

Reference unit
A unit with an SPI of 0.45 W/m³/h, multispeed speed motor drive and a clock program that switches from low to higher ventilation rates when the majority of the extract spaces (ES) is used (e.g. for a couple of hours in the morning and in the evening), and when most inhabitants are assumed to be present (during night time). The unit extracts air directly from the wet spaces and supplies air into the habitable spaces using fixed extract and supply grilles. The unit has no flow balance control and its total leakages are above 6%. Reference energy recovery ratio is set at 70% to compensate for total leakages.
To achieve reference ventilation performance, this reference unit requires an average ventilation rate of about 709 m³/h, consumes €12.559 of electricity and €6238 of space heating energy over its lifetime for an average climate; a natural ventilation system would, in this case, need €29.319 of space heating energy costs and would have a lower ventilation performance. Including product and installation costs, the total lifecycle costs of this reference unit would be €23.322 for the average climate, €19.256 for the warm climate and €27.961 for the cold climate.

Design Options
Table 7 indicates the design options and related improvements in product specifications. Initial improvements relate to the SPI-value which is upgraded to state-of-the-art level of 0.20 w/m³/h. Also, the total leakage rates are reduced to values below 3% and the energy recovery ratio is improved. Design option II applies zonal flow rates controls and local VDC-ES devices in all the extract spaces. Design options III employs controllable valves in all spaces and local VDC-HS devices for controlling the valves in the HS. The design options that use controllable valves, require a constant over- or under pressure in the central duct for which the fan uses additional power.
Design option III requires average flowrates of 276 m³/h, consumes €2699 of electricity and €809 of space heating energy over its lifetime in an average climate.
As regards the ventilation performance, the VPI increases from 38% for the reference unit, to 100% for design option III.

Even though it has the lowest product and installation costs, design option III does not have the lowest lifecycle costs. It is design option I that has the lowest lifecycle costs at €10.156 for the average climate, €8575 for the warm climate and €11.960 for the cold climate; the related LCC savings per unit when compared to the reference unit are €13.166, €10.681 and €16.001 respectively. Payback periods for all three design options are within 6 years.

Table 7. Performance, consumption and lifecycle cost design options BVU/1000

BVU/1000				DESIGN OPTIONS		
Parameter	**unit**	**Nat. vent.**	**Reference**	**I**	**II**	**III**
Performance data						
Nominal and reference flowrate	[m³/h]	-	1000/700	1000/700	1000/700	1000/700
Airflow control	[-]	-	central	central	zonal with valves	valves in ES &HS
Power consumption fans due to constant pressure in ducts		-	0.00	0.00	9.06	15.56
Balance control	[-]		no	yes	yes	yes
Internal leakage	[-]		≥6%	<3%	<3%	<3%
VDC[1] ES	[-]	-	clock	clock	local VDC-ES	local VDC-ES
VDC HS	[-]	-	clock	clock	zonal VDC-ES	local VDC-HS
CTRL factor @reference AEP	[-]	-	0.90	0.70	0.60	0.35
Flow sensitivity *: fs*	[-]	-	1.00	1.00	1.00	1.00
Avg flowrate for reference AEP [2]	[m³/h]	1000	709	552	473	276
VPI [3]	[-]	-	0.38	0.49	0.57	1.00
AEP ES @ CTRL factor	[%]	89%	100%	100%	100%	100%
AEP HS @ CTRL factor	[%]	34%	100%	100%	100%	100%
SPI	[W/m³/h]	-	0.45	0.20	0.20	0.20
Motor control type	[-]	-	multi speed	variable speed	variable speed	variable speed
Power consumption external VDC	[W]	-	1.00	1.00	2.20	14.20
Energy recovery ratio	[%]	-	70%	85%	87%	90%
Qdefrost for average climate	[kWh/a]	-	320	108	95	81
Consumption data (SEC)						
Annual electricity consumption	[kWh_e/a]	-	3518	840	817	756
Annual space heating energy loss						
- for average climate	[kWh_{pr}/a]	24637	5242	2039	1514	680
- for warm climate	[kWh_{pr}/a]	8579	1825	710	527	237
- for cold climate	[kWh_{pr}/a]	42959	9140	3554	2640	1185
Sec value for avg climate	[kWh/m²/a]		-30.02	-52.09	-53.52	-55.93
Financial data						
Product cost (VAT excl.)	[€]		€ 1625	€ 1805	€ 3605	€ 6005
Installation cost (VAT excl.)	[€]		€ 2344	€ 2344	€ 2344	€ 2344
Total investment (VAT incl.)	[€]	€ 600	€ 4525	€ 4730	€ 6782	€ 9518
Electricity cost over lifetime (@21ct/kWh)	[€]		€ 12559	€ 3000	€ 2917	€ 2699
Total space heating energy cost over lifetime						
- for average climate (@7ct/kWh)	[€]	€ 29319	€ 6238	€ 2426	€ 1802	€ 809
- for warm climate	[€]	€ 10209	€ 2172	€ 845	€ 627	€ 282
- for cold climate	[€]	€ 51121	€ 10877	€ 4230	€ 3142	€ 1410
Total lifecycle cost (LCC)						
- for average climate	[€]	€ 29919	€ 23322	€ 10156	€ 11500	€ 13025
- for warm climate	[€]	€ 10809	€ 19256	€ 8575	€ 10326	€ 12498
- for cold climate	[€]	€ 51721	€ 27961	€ 11960	€ 12841	€ 13627

Improvements vs natural ventilation	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs	€ LCC savings
						for average climate	
Design Option I	-€ 3000	€ 26893	€ 9364	€ 46891	€ 4130	2.94	€ 19763
Design Option II	-€ 2917	€ 27517	€ 9581	€ 47979	€ 6182	4.27	€ 18418
Design Option III	-€ 2699	€ 28510	€ 9927	€ 49711	€ 8918	5.87	€ 16893

Improvements vs reference unit	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs	€ LCC savings
						for average climate	
Design Option I	€ 9559	€ 3812	€ 1327	€ 6647	€ 205	0.26	€ 13166
Design Option II	€ 9643	€ 4436	€ 1545	€ 7734	€ 2257	2.73	€ 11821
Design Option III	€ 9861	€ 5429	€ 1890	€ 9467	€ 4993	5.55	€ 10297

[1] VDC= ventilation demand controls; ES refers to exhaust spaces; HS refers to habitable spaces.
[2] Average flowrate is determined for the reference Air Exchange Performance (AEP), following Category II of EN16798-1 (except for natural vent. systems). For local units the average flowrate is determined assuming three BVU/100/HS per average dwelling.
[3] VPI = Ventilation Perfromance Index = Ratio of the flow rate needed for the ideal/perfect VU and the VU concerned to achieve Category II ventilation performance for a whole dwelling

1.4.3 UVU/1000+

Like the UVU/250, these collective units are intended to serve both the extract spaces and the habitable spaces in dwellings that are connected to the unit. Using a central duct in the building (and possibly some additional ducting per individual dwelling), the central UVU directly extracts from all wet spaces (ES) while fresh air is supplied to the habitable spaces through ventilation grids. The unit allows for ventilation rates needed to comply with the buildings codes regarding minimum required capacity for both the exhaust and habitable spaces for all dwellings attached, and applies the base load ventilation rates as a default minimum (i.e. the unit cannot be switched off). The used values for this unit relates to applications for 8 to 10 apartments.

<u>Reference unit</u>

A unit with an SPI of 0.30 W/m³/h, multi speed motor control and a clock program that switches from low to higher ventilation rates when the majority of the extract spaces (ES) is used (e.g. for a couple of hours in the morning and in the evening), and when most inhabitants are assumed to be present (during night time). The unit extracts air directly from wet spaces only, using fixed extraction grilles.
To achieve reference ventilation performance, this reference unit requires an average ventilation rate of 1560 m³/h, consumes €14.323 of electricity and € 45.725 of space heating energy over its lifetime (for an average climate; natural ventilation systems would, in this case, need €61.080 of space heating energy costs and they would have a lower ventilation performance). Including product and installation costs, the total lifecycle cost of this reference unit is €62.078 for the average climate, €32.375 for the warm climate and €96.081 for the cold climate.

<u>Design Options</u>

Table 8 indicates the design options and related improvements in product specifications. Initial improvements relate to the SPI-value from 0.30 to 0.10 and the multi speed drive that is replaced by a variable speed drive. For the second design option, the fixed extraction valves are replaced by controllable valves in all ES, these are controlled by local VDC-ES devices (e.g. RH- and/or PIR sensors). This solution requires a constant under-pressure in the central extract duct for which the fan uses additional power. For the third design option local VDC-HS devices are added to all habitable spaces and are also able to control the valves in the ES.
Design option III requires average flowrates of 1067 m³/h, consumes €5568 of electricity and €31.285 of space heating energy over its lifetime for an average climate.
As regards the ventilation performance, the VPI increases from 36% for the reference unit, to 52% for design option III.

Including product and installation costs, design option III has the lowest lifecycle costs at €45.073 for the average climate, €24.682 for the warm climate and €68.338 for the cold climate; the related LCC savings per unit when compared to the reference unit are €17.005, €7593 and €27,742 respectively. Payback periods for all three design options are within 5 years.

Table 8. Performance, consumption and lifecycle cost design options UVU/1000+

UVU/1000+				DESIGN OPTIONS		
Parameter	**unit**	**Nat. vent.**	**Reference**	**I**	**II**	**III**
Performance data						
Nominal and reference flowrate	[m^3/h]	-	2150/1500	2150/1500	2150/1500	2150/1500
Directly extracts air from:			ES	ES	ES	ES
Airflow control	[-]	-	central	central	zonal (valves in ES)	zonal (valves in ES)
Power consumption fans due to constant pressure in ducts		-	0.00	0.00	20.00	26.67
VDC[1] ES	[-]	-	clock	clock	local VDC-ES	local VDC-ES
VDC HS	[-]	-	clock	clock	zonal VDC-ES	local VDC-HS
CTRL factor @reference AEP	[-]	-	0.90	0.90	0.80	0.65
Flow sensitivity *: fs*	[-]	-	1.00	1.00	1.00	1.00
Avg flowrate for reference AEP [2]	[m^3/h]	2083	1478	1478	1313	1067
VPI [3]	[-]	-	0.38	0.38	0.43	0.52
AEP ES @ CTRL factor	[%]	89%	100%	100%	100%	100%
AEP HS @ CTRL factor	[%]	34%	100%	100%	100%	100%
SPI	[W/m^3/h]	-	0.30	0.10	0.10	0.10
Motor control type	[-]	-	multi speed	variable speed	variable speed	variable speed
Power consumption external VDC	[W]	-	1.00	1.00	3.50	28.50
Energy recovery ratio	[%]	-	0%	0%	0%	0%
Qdefrost for average climate	[kWh/a]	-	0.00	0.00	0.00	0.00
Consumption data (SEC)						
Annual electricity consumption	[kWh_e/a]	-	3701	1182	1326	1560
Annual space heating energy loss						
- for average climate	[kWh_{pr}/a]	51328	36402	36402	32357	26290
- for warm climate	[kWh_{pr}/a]	17873	12675	12675	11267	9154
- for cold climate	[kWh_{pr}/a]	89498	63472	63472	56419	45841
Sec value for avg climate	[kWh/m^2/a]		-8.59	-14.93	-19.42	-26.12
Financial data						
Product cost (VAT excl.)	[€]		€ 530	€ 720	€ 4320	€ 6720
Installation cost (VAT excl.)	[€]		€ 1500	€ 1500	€ 1500	€ 1500
Total investment (VAT incl.)	[€]	€ 1200	€ 2030	€ 2220	€ 5820	€ 8220
Electricity cost over lifetime (@21ct/kWh)	[€]		€ 13212	€ 4220	€ 4734	€ 5568
Total space heating energy cost over lifetime						
- for average climate (@7ct/kWh)	[€]	€ 61080	€ 43318	€ 43318	€ 38505	€ 31285
- for warm climate	[€]	€ 21268	€ 15084	€ 15084	€ 13408	€ 10894
- for cold climate	[€]	€ 106502	€ 75531	€ 75531	€ 67139	€ 54550
Total lifecycle cost (LCC)						
- for average climate	[€]	€ 62280	€ 58560	€ 49758	€ 49059	€ 45073
- for warm climate	[€]	€ 22468	€ 30326	€ 21524	€ 23961	€ 24682
- for cold climate	[€]	€ 107702	€ 90774	€ 81972	€ 77693	€ 68338

Improvements vs natural ventilation	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs for average climate	€ LCC savings for average climate
Design Option I	-€ 4220	€ 17762	€ 6185	€ 30971	€ 1020	1.28	€ 12522
Design Option II	-€ 4734	€ 22575	€ 7861	€ 39363	€ 4620	4.40	€ 13222
Design Option III	-€ 5568	€ 29795	€ 10375	€ 51952	€ 7020	4.93	€ 17207

Improvements vs reference unit	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs for average climate	€ LCC savings for average climate
Design Option I	€ 8992	€ -	€ -	€ -	€ 190	0.36	€ 8802
Design Option II	€ 8479	€ 4813	€ 1676	€ 8392	€ 3790	4.85	€ 9502
Design Option III	€ 7644	€ 12033	€ 4190	€ 20981	€ 6190	5.35	€ 13487

[1] VDC= ventilation demand controls; ES refers to exhaust spaces; HS refers to habitable spaces.
[2] Average flowrate is determined for the reference Air Exchange Performance (AEP), following Category II of EN16798-1 (except for natural vent. systems). For local units the average flowrate is determined assuming three BVU/100/HS per average dwelling.
[3] VPI = Ventilation Perfromance Index = Ratio of the flow rate needed for the ideal/perfect VU and the VU concerned to achieve Category II ventilation performance for a whole dwelling

1.4.4 BVU/2500

Like the BVU/250, these collective units are intended to serve both the extract spaces and the habitable spaces in the dwellings that are connected to the unit. Using central ducts in the building (and possibly some additional ducting per individual dwelling), the central BVU mechanically extracts air from all wet spaces (ES) and mechanically supplies fresh air to all habitable spaces. A heat exchanger in the BVU transfers the thermal energy from the used and extracted air to the fresh supply of air.
The unit allows for ventilation rates needed to comply with the buildings codes regarding minimum required capacity for both the exhaust and habitable spaces and applies the base load ventilation rates as a default minimum (i.e. cannot be switched off). The used values for this unit relates to applications for 12 to 15.

Reference unit

A unit with an SPI of 0.45 W/m³/h, multispeed speed motor drive and a clock program that switches from low to higher ventilation rates when the majority of the extract spaces (ES) is used (e.g. for a couple of hours in the morning and in the evening), and when most inhabitants are assumed to be present (during night time). The unit extracts air directly from wet spaces and supplies air to habitable spaces using fixed extract and supply grilles. The unit has no flow balance control and its total leakages are above 6%. Reference energy recovery ratio is set at 70% to compensate for total leakages.
To achieve reference ventilation performance, this reference unit requires an average ventilation rate of around 2339 m³/h, consumes €42.143 of electricity and €20.576 of space heating energy over its lifetime for an average climate; a natural ventilation system would in this case need €91.621 of space heating energy costs and would have a lower ventilation performance. Including product and installation costs, the total lifecycle costs of this reference unit is €82.219 for the average climate, €68.807 for the warm climate and €97.520 for the cold climate.

Design Options

Table 9 indicates the design options and related improvements in product specifications. Initial improvements relate to the SPI-value which is upgraded to the state-of-the-art level of 0.20 w/m³/h. Also, the total leakage rates are reduced to values below 3% and the energy recovery ratio is improved. Design option II applies zonal flow rates controls and local VDC-ES devices in all of the extract spaces. Design options III employs controllable valves in all spaces and local VDC-HS devices for controlling the valves in the HS. The design options that use controllable valves, require a constant over- or under pressure in the central duct for which the fan uses additional power.
Design option III requires average flowrates of 862 m³/h, consumes € 304 of electricity and €2527 of space heating energy over its lifetime for an average climate.
As regards the ventilation performance, the VPI increases from 36% for the reference unit, to 100% for design option III.

Even though it has the lowest product and installation costs, design option III does not have the lowest lifecycle costs. It is design option I that has the lowest lifecycle costs of €38.221 for the average climate, €33.280 for the warm climate and €43,858 for the cold climate; the related LCC-savings per unit when compared to the reference unit are €43.998, €35.527 and €53.662 respectively. Payback periods for all three design options are within 5 years.

Table 9. Performance, consumption and lifecycle cost design options BVU/2500

BVU/2500				DESIGN OPTIONS		
Parameter	**unit**	**Nat. vent.**	**Reference**	**I**	**II**	**III**
Performance data						
Nominal and reference flowrate	[m^3/h]	-	3500/2450	3500/2450	3500/2450	3500/2450
Airflow control	[-]	-	central	central	zonal (valves in ES)	local (valves ES &HS)
Power consumption fans due to constant pressure in ducts		-	0.00	0.00	28.30	48.61
Balance control	[-]		no	yes	yes	yes
Internal leakage	[-]		≥6%	<3%	<3%	<3%
VDC[1] ES	[-]	-	clock	clock	local VDC-ES	local VDC-ES
VDC HS	[-]	-	clock	clock	zonal RH	local VDC-HS
CTRL factor @reference AEP	[-]	-	0.90	0.70	0.60	0.35
Flow sensitivity : *fs*	[-]	-	1.00	1.00	1.00	1.00
Avg flowrate for reference AEP [2]	[m^3/h]	3125	2216	1724	1478	862
VPI [3]	[-]	-	0.38	0.49	0.57	1.00
AEP ES @ CTRL factor	[%]	89%	100%	100%	100%	100%
AEP HS @ CTRL factor	[%]	34%	100%	100%	100%	100%
SPI	[W/m^3/h]	-	0.45	0.20	0.20	0.20
Motor control type	[-]	-	multispeed	variable speed	variable speed	variable speed
Power consumption external VDC	[W]	-	1.00	1.00	4.68	42.18
Energy recovery ratio	[%]	-	70%	85%	87%	90%
Qdefrost for average climate	[kWh/a]	-	999	667	296	255
Consumption data (SEC)						
Annual electricity consumption	[kWh_e/a]	-	10957	3035	2027	1486
Annual space heating energy loss						
- for average climate	[kWh_{pr}/a]	76992	16381	6370	4732	2123
- for warm climate	[kWh_{pr}/a]	26809	5704	2218	1648	739
- for cold climate	[kWh_{pr}/a]	134247	28562	11108	8251	3703
Sec value for avg climate	[kWh/m^2/a]		-30.08	-51.40	-54.40	-57.40
Financial data						
Product cost (VAT excl.)	[€]		€ 4500	€ 4804	€ 10429	€ 17929
Installation cost (VAT excl.)	[€]		€ 15000	€ 15000	€ 15000	€ 15000
Total investment (VAT incl.)	[€]	€ 1800	€ 19500	€ 19804	€ 25429	€ 32929
Electricity cost over lifetime (@21ct/kWh)	[€]		€ 39117	€ 10836	€ 7236	€ 5304
Total space heating energy cost over lifetime						
- for average climate (@7ct/kWh)	[€]	€ 91621	€ 19493	€ 7581	€ 5631	€ 2527
- for warm climate	[€]	€ 31903	€ 6788	€ 2640	€ 1961	€ 880
- for cold climate	[€]	€ 159753	€ 33989	€ 13218	€ 9819	€ 4406
Total lifecycle cost (LCC)						
- for average climate	[€]	€ 93421	€ 78110	€ 38221	€ 38296	€ 40759
- for warm climate	[€]	€ 33703	€ 65405	€ 33280	€ 34625	€ 39112
- for cold climate	[€]	€ 159753	€ 92606	€ 43858	€ 42484	€ 42639

Improvements vs natural ventilation	LCC electr.	LCC space heating energy savings			Investment	payback yrs	€ LCC savings
	savings	average	warm	cold	increase	for average climate	
Design Option I	-€ 10836	€ 84040	€ 29263	€ 146535	€ 18004	4.18	€ 55199
Design Option II	-€ 7236	€ 85989	€ 29942	€ 149934	€ 23629	5.10	€ 55125
Design Option III	-€ 5304	€ 89094	€ 31023	€ 155347	€ 31129	6.32	€ 52661

Improvements vs reference unit	LCC electr.	LCC space heating energy savings			Investment	payback yrs	€ LCC savings
	savings	average	warm	cold	increase	for average climate	
Design Option I	€ 28281	€ 11913	€ 4148	€ 20771	€ 304	0.13	€ 39889
Design Option II	€ 31882	€ 13862	€ 4827	€ 24170	€ 5929	2.20	€ 39814
Design Option III	€ 33814	€ 16966	€ 5908	€ 29583	€ 13429	4.50	€ 37351

[1] VDC= ventilation demand controls; ES refers to exhaust spaces; HS refers to habitable spaces.
[2] Average flowrate is determined for the reference Air Exchange Performance (AEP), following Category II of EN16798-1 (except for natural vent. systems). For local units the average flowrate is determined assuming three BVU/100/HS per average dwelling.
[3] VPI = Ventilation Perfromance Index = Ratio of the flow rate needed for the ideal/perfect VU and the VU concerned to achieve Category II ventilation performance for a whole dwelling

1.5 Non-residential ventilation units

Following the base cases described in Task 5, five non-residential ventilation units are distinguished, each with its own design options. The first two are also discussed in the previous section as collective residential unit. As already indicated there, these units are also used for non-residential applications where generally higher design airflow rates are required. Furthermore, according to the definition in the Regulation ventilation units above 1000 m³/h denominated non-residential ventilation units and treated differently. For these reasons, these units are also addressed in this section with adjusted calculations

7. NR-UVU/1000+
8. NR-BVU/2500
9. AHU/S
10. AHU/M
11. AHU/L

Contrary to the residential applications described in the previous sections, no reference is made here to a specific reference ventilation performance. This implies that for these NRVUs it is assumed that comparable ventilation performances are achieved irrespective of the types of controls used. It also implies that the calculated energy consumption will be more in line with real-life energy consumption. For non-residential ventilation systems where the operation of the ventilation unit is usually controlled by clock-programmes, building automation control systems and such like (i.e. those not run by the occupants), the topic ventilation performance is considered less problematic compared to residential applications.

1.5.1 NR-UVU/1000+

Reference unit

The reference unit has a fan efficiency of 25%, a variable speed motor control and an SFPint of 320 W/m³/s, representing the average 2010 sold units.

Using a clock control, this reference unit delivers an average ventilation rate of around 720 m³/h, consumes €1975 of electricity and €18,094 of space heating energy over its lifetime for an average climate. Including product and installation costs, the total lifecycle costs of this reference unit is €22.098 for the average climate, €11.355 for the warm climate and €40.812 for the cold climate.

Design Options

For the design options presented in table 10 the fan efficiency is further improved from 35% for design option I to 50% for design option III; the ΔPint is further improved by enhancing the in- and outlet design of the unit. In design option III, valves are introduced in combination with VDC-devices. This option allows for local load dependent ventilation control, and further reduces the average airflow without compromising the ventilation performance.

Including product- and installation costs, design option III brings the lowest lifecycle costs for cold climates (€35.654, saving €5225 compared to the reference unit). Design option II that has the lowest lifecycle costs for warm and average climates at €21.383 for the average climate, €10.639 for the warm climate with both saving €716 compared to the reference unit.

Table 10. Performance, consumption and lifecycle cost design options NR-UVU/1000+

NR-UVU/1000+				DESIGN OPTIONS		
Parameter	**unit**	**Nat. vent.**	**Reference**	**I**	**II**	**III**
Performance data						
Nominal flowrate	[m^3/s]	-	0.42	0.42	0.42	0.42
Design Δpext	[pa]	-	154	154	154	154
Design Δpint	[pa]	-	40	40	35	30
Fan system efficiency @nom.flow	[%]	-	25%	35%	45%	50%
Pel;design	[kW]	-	323	231	175	153
Balance control	[-]		n.a.	n.a.	n.a.	n.a.
Internal leakage	[-]		n.a.	n.a.	n.a.	n.a.
Motor control type	[-]	-	variable speed	variable speed	variable speed	variable speed
Ventilation Demand Controls	[-]	-	clock	clock	clock	VDC+valves
CTRL-factor			0.48	0.48	0.48	0.35
Avg flowrate	[m^3/h]	1042	720	720	720	525
SFPint @ nominal flow	[$W/m^3/s$]	-	320	229	156	120
SFPtot @ nominal flow	[$W/m^3/s$]		776	554	420	368
Energy recovery ratio	[%]	-	0%	0%	0%	0%
Qdefrost for average climate	[$kWh/m^3/a$]	-	0.00	0.00	0.00	0.00
Consumption data						
Annual electricity consumption	[kWh_e/a]	-	653	466	353	165
Annual space heating energy loss						
- for average climate	[kWh_{pr}/a]	25664	17739	17739	17739	12935
- for warm climate	[kWh_{pr}/a]	8936	6177	6177	6177	4504
- for cold climate	[kWh_{pr}/a]	44749	30930	30930	30930	22553
Financial data						
Product cost (VAT excl.)	[€]		€ 530	€ 720	€ 720	€ 6720
Installation cost (VAT excl.)	[€]		€ 1500	€ 1500	€ 1500	€ 1500
Total investment (VAT incl.)	[€]	€ 1800	€ 2030	€ 2220	€ 2220	€ 8220
Electricity cost over lifetime (@18ct/kWh)	[€]		€ 1975	€ 1411	€ 1069	€ 498
Total space heating energy cost over lifetime						
- for average climate (@6ct/kWh)	[€]	€ 26177	€ 18094	€ 18094	€ 18094	€ 13193
- for warm climate	[€]	€ 9115	€ 7350	€ 7350	€ 7350	€ 5360
- for cold climate	[€]	€ 45644	€ 36807	€ 36807	€ 36807	€ 26839
Total lifecycle cost (LCC)						
- for average climate	[€]	€ 27977	€ 22098	€ 21724	€ 21383	€ 21911
- for warm climate	[€]	€ 10915	€ 11355	€ 10981	€ 10639	€ 14078
- for cold climate	[€]	€ 47444	€ 40812	€ 40438	€ 40096	€ 35556

Improvements vs natural ventilation	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs for average climate	€ LCC savings for average climate
Design Option I	-€ 1411	€ 8084	€ 1765	€ 8837	€ 420	1.07	€ 6253
Design Option II	-€ 1069	€ 8084	€ 1765	€ 8837	€ 420	1.02	€ 6595
Design Option III	-€ 498	€ 12984	€ 3755	€ 18805	€ 6420	8.74	€ 6066

Improvements vs reference unit	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs for average climate	€ LCC savings for average climate
Design Option I	€ 564	€ -	€ -	€ -	€ 190	5.72	€ 374
Design Option II	€ 906	€ -	€ -	€ -	€ 190	3.57	€ 716
Design Option III	€ 1477	€ 4900	€ 1991	€ 9969	€ 6190	16.50	€ 187

1.5.2 NR-BVU/2500

Reference unit

The reference unit has a fan efficiency of 35%, a variable speed motor control and an SFPint of 800 W/m³/s, representing the average 2010 sold units.

Using a clock control, this reference unit delivers an average ventilation rate of around 1080 m³/h, consumes €7776 of electricity and €8142 of space heating energy over its lifetime for an average climate. Including product and installation costs, the total lifecycle costs of this reference unit is €35.418 for the average climate, €30.584 for the warm climate and €43.839 for the cold climate.

Design Options

For the design options presented in table 11 the fan efficiency is further improved from 40% for design option I to 50% for design option III; the ΔPint is further improved by enhancing the in- and outlet design of the unit and by applying more energy efficient filters. In design option III, valves are introduced in combination with VDC-devices. This option allows for local load dependent ventilation control, and further reduces the average airflow without compromising the ventilation performance. Finally, the heat recovery efficiency figures are further improved to 85% of design option I and 90% for design option II and III.

Although it has the lowest energy costs for both and product and installation costs, design option III does not have the lowest lifecycle costs. Design option II that has the lowest lifecycle cost at €28.899 for the average climate, €26.482 for the warm climate and €33.110 for the cold climate; lifecycle cost savings are €6518, €4102 and €10.730 respectively.

Table 11. Performance, consumption and lifecycle cost design options NR-BVU/2500

NR-BVU/2500				DESIGN OPTIONS		
Parameter	**unit**	**Nat. vent.**	**Reference**	**I**	**II**	**III**
Performance data						
Nominal flowrate	[m³/s]	-	0.63	0.63	0.63	0.63
Design Δpext	[pa]	-	160	160	160	160
Design Δpint	[pa]	-	140	140	120	110
Fan system efficiency @nom.flow	[%]	-	35%	40%	45%	50%
Pel;design	[kW]	-	1071	938	778	675
Balance control	[-]		yes	yes	yes	yes
Internal leakage	[-]		<3%	<3%	<3%	<3%
Motor control type	[-]	-	variable speed	variable speed	variable speed	variable speed
Ventilation Demand Controls	[-]	-	clock	clock	clock	VDC+valves
CTRL-factor			0.48	0.48	0.48	0.35
Average flowrate	[m³/h]	1563	1080	1080	1080	788
SFPint @ nominal flow	[W/m³/s]	-	800	700	533	440
SFPtot @ nominal flow	[W/m³/s]		1714	1500	1244	1080
Energy recovery ratio	[%]	-	70%	85%	90%	90%
Qdefrost for average climate	[kWh/a]	-	0.38	0.08	0.06	0.06
Consumption data						
Annual electricity consumption	[kWh_e/a]	-	2570	2071	1660	772
Annual space heating energy loss						
- for average climate	[kWh_{pr}/a]	38496	7983	5322	3991	1940
- for warm climate	[kWh_{pr}/a]	13404	2780	1853	1390	676
- for cold climate	[kWh_{pr}/a]	67123	13919	9279	6959	3383
Financial data						
Product cost (VAT excl.)	[€]		€ 4500	€ 4804	€ 4804	€ 17929
Installation cost (VAT excl.)	[€]		€ 15000	€ 15000	€ 15000	€ 15000
Total investment (VAT incl.)	[€]	€ 1800	€ 19500	€ 19804	€ 19804	€ 32929
Electricity cost over lifetime (@18ct/kWh)	[€]		€ 7776	€ 6266	€ 5024	€ 2337
Total space heating energy cost over lifetime						
- for average climate (@6ct/kWh)	[€]	€ 39266	€ 8142	€ 5428	€ 4071	€ 1979
- for warm climate	[€]	€ 13673	€ 3308	€ 2205	€ 1654	€ 804
- for cold climate	[€]	€ 68466	€ 16563	€ 11042	€ 8282	€ 4026
Total lifecycle cost (LCC)						
- for average climate	[€]	€ 41066	€ 35418	€ 31498	€ 28899	€ 37245
- for warm climate	[€]	€ 15473	€ 30584	€ 28275	€ 26482	€ 36070
- for cold climate	[€]	€ 70266	€ 43839	€ 37112	€ 33110	€ 39292

Improvements vs natural ventilation	LCC electr.	LCC space heating energy savings			Investment	payback yrs	€ LCC savings
	savings	average	warm	cold	increase	for average climate	
Design Option I	-€ 6266	€ 33838	€ 11467	€ 57424	€ 18004	11.10	€ 9568
Design Option II	-€ 5024	€ 35195	€ 12019	€ 60184	€ 18004	10.14	€ 12167
Design Option III	-€ 2337	€ 37287	€ 12869	€ 64440	€ 31129	15.14	€ 3820

Improvements vs reference unit	LCC electr.	LCC space heating energy savings			Investment	payback yrs	€ LCC savings
	savings	average	warm	cold	increase	for average climate	
Design Option I	€ 1510	€ 2714	€ 1103	€ 5521	€ 304	1.22	€ 3920
Design Option II	€ 2752	€ 4071	€ 1654	€ 8282	€ 304	0.76	€ 6519
Design Option III	€ 5439	€ 6163	€ 2504	€ 12537	€ 13429	19.68	-€ 1827

1.5.3 AHU/S

Reference unit

The reference unit has a fan efficiency of 54%, a variable speed motor control, an SFPint of 1081 W/m³/s and an average energy recovery ratio of 44%, representing the average 2010 sold units with run-around and recuperative HR systems and a share having no HRS-systems at all.

Using a clock control, this fictitious reference unit delivers an average ventilation rate of around 1920 m³/h, consumes €15.663 of electricity and €27.020 of space heating energy over its lifetime for an average climate. Total installation costs are averaged over new built projects (30%), renovation projects (30%) and replacements (40%). Including product and installation costs, the total lifecycle cost of this reference unit is €111.446 for the average climate, €95.402 for the warm climate and €139.391 for the cold climate.

Design Options

For the design options presented in table 12 the fan efficiency is further improved from 58% for design option I to 62% for design option III; the ΔPint is further reduced by enhancing the in- and outlet design of the unit, by applying more energy efficient filters and reducing the face velocity. In design option III, valves are introduced in combination with VDC-devices. This option allows for local load dependent ventilation control and further reduces the average airflow without compromising the ventilation performance. Finally, the heat recovery efficiency figures are further improved to 70% for design option I and 73% and 75% for design option II and III respectively.

Including product and installation costs, design option III has the lowest lifecycle costs with €89.548 for the average climate, €84.325 for the warm climate and €98.465 for the cold climate; lifecycle cost savings are €21.898, €11.077 and €40.746 respectively.

Table 12. Performance, consumption and lifecycle cost design options AHU/S

AHU-S				DESIGN OPTIONS		
Parameter	**unit**	**Nat. vent.**	**Reference**	**I**	**II**	**III**
Performance data						
Nominal flowrate	[m^3/s]	-	1.11	1.11	1.11	1.11
Design Δpext	[pa]	-	244	244	244	244
Design Δpint	[pa]	-	292	250	220	220
Fan system efficiency @nom.flow	[%]	-	54%	58%	60%	62%
Pel;design	[kW]	-	2.21	1.89	1.72	1.66
Balance control	[-]		yes	yes	yes	yes
Internal leakage	[-]		<3%	<3%	<3%	<3%
Motor control type	[-]	-	variable speed	variable speed	variable speed	variable speed
Ventilation Demand Controls	[-]	-	clock	clock	clock	VDC+valves
CTRL-factor			0.48	0.48	0.48	0.35
Avg flowrate	[m^3/h]	2778	1920	1920	1920	1400
SFPint @ nominal flow	[$W/m^3/s$]	-	1081	862	733	710
SFPtot @ nominal flow	[$W/m^3/s$]		1985	1703	1547	1497
Energy recovery ratio	[%]	-	44%	70%	73%	75%
Qdefrost for average climate	[kWh/a]	-	419	184	93	68
Consumption data						
Annual electricity consumption	[kWh_e/a]	-	5176	4138	3629	1870
Annual space heating energy loss						
- for average climate	[kWh_{pr}/a]	68437	26490	14191	12772	8623
- for warm climate	[kWh_{pr}/a]	23830	9224	4941	4447	3003
- for cold climate	[kWh_{pr}/a]	119330	46189	24744	22270	15036
Financial data						
Product cost (VAT excl.)	[€]		€ 8363	€ 11578	€ 12221	€ 14693
Installation cost (VAT excl.)	[€]		€ 60400	€ 60400	€ 60400	€ 60400
Total investment (VAT incl.)	[€]	€ 1800	€ 68763	€ 71978	€ 72621	€ 75093
Electricity cost over lifetime (@18ct/kWh)	[€]		€ 15663	€ 12520	€ 10983	€ 5659
Total space heating energy cost over lifetime						
- for average climate (@6ct/kWh)	[€]	€ 69806	€ 27020	€ 14475	€ 13028	€ 8796
- for warm climate	[€]	€ 24307	€ 10977	€ 5880	€ 5292	€ 3573
- for cold climate	[€]	€ 121717	€ 54965	€ 29446	€ 26501	€ 17892
Total lifecycle cost (LCC)						
- for average climate	[€]	€ 71606	€ 111446	€ 98973	€ 96631	€ 89548
- for warm climate	[€]	€ 26107	€ 95402	€ 90378	€ 88896	€ 84325
- for cold climate	[€]	€ 123517	€ 139391	€ 113944	€ 110105	€ 98645

Improvements vs natural ventilation	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs for average climate	€ LCC savings for average climate
Design Option I	-€ 12520	€ 55331	€ 18426	€ 92271	€ 70178	27.87	-€ 27367
Design Option II	-€ 10983	€ 56779	€ 19014	€ 95216	€ 70821	26.29	-€ 25025
Design Option III	-€ 5659	€ 61011	€ 20734	€ 103824	€ 73293	22.51	-€ 17942

Improvements vs reference unit	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs for average climate	€ LCC savings for average climate
Design Option I	€ 3142	€ 12545	€ 5096	€ 25520	€ 3215	3.48	€ 12472
Design Option II	€ 4680	€ 13993	€ 5684	€ 28464	€ 3858	3.51	€ 14815
Design Option III	€ 10003	€ 18224	€ 7403	€ 37073	€ 6330	3.81	€ 21898

1.5.4 AHU/M

Reference unit

The reference unit has a fan efficiency of 58%, a variable speed motor control, an SFPint of 1152 W/m³/s and an average energy recovery ratio of 44%, representing the average 2010 sold units with run-around and recuperative HR systems and a share having no HRS-systems at all.

Using a clock control, this fictitious reference unit delivers an average ventilation rate of around 4800 m³/h, consumes €49.731 of electricity and €67.550 of space heating energy over its lifetime for an average climate. Total installation costs are averaged over new built projects (25%), renovation projects (25%) and replacements (50%). Including product and installation costs, the total lifecycle costs of this reference unit is €272.554 for the average climate, €232.446 for the warm climate and €342.418 for the cold climate.

Design Options

For the design options presented in table 13 the fan efficiency is further improved from 60% for design option I to 65% for design option III; the ΔPint is further reduced by enhancing the in- and outlet design of the unit, by applying more energy efficient filters and reducing the face velocity. In design option III, valves are introduced in combination with VDC-devices. This option allows for local load dependent ventilation control, and further reduces the average airflow without compromising the ventilation performance. Finally, the heat recovery efficiency figures are further improved to 70% for design option I and 73% and 75% for design option II and III respectively.

Including product- and installation cost, design option III has the lowest lifecycle cost with €206.936 for the average climate, €193.880 for the warm climate, and €229.678 for the cold climate; lifecycle cost savings are €65.618, €38.566 and €112.740 respectively.

Table 13. Performance, consumption and lifecycle cost design options AHU/M

AHU-M				DESIGN OPTIONS		
Parameter	**unit**	**Nat. vent.**	**Reference**	**I**	**II**	**III**
Performance data						
Nominal flowrate	[m^3/s]	-	2.78	2.78	2.78	2.78
Design Δpext	[pa]	-	450	450	450	450
Design Δpint	[pa]	-	334	260	230	230
Fan system efficiency @nom.flow	[%]	-	58%	60%	63%	65%
Pel;design	[kW]	-	7.51	6.57	6.00	5.81
Balance control	[-]		yes	yes	yes	yes
Internal leakage	[-]		<3%	<3%	<3%	<3%
Motor control type	[-]	-	variable speed	variable speed	variable speed	variable speed
Ventilation Demand Controls	[-]	-	clock	clock	clock	VDC+valves
CTRL-factor			0.48	0.48	0.48	0.35
Avg flowrate	[m^3/h]	6944	4800	4800	4800	3500
SFPint @ nominal flow	[W/m^3/s]	-	1152	867	730	708
SFPtot @ nominal flow	[W/m^3/s]		2703	2367	2159	2092
Energy recovery ratio	[%]	-	44%	70%	73%	75%
Qdefrost for average climate	[kWh/a]	-	740	494	251	251
Consumption data						
Annual electricity consumption	[kWh_e/a]	-	16435	14123	12536	6553
Annual space heating energy loss						
- for average climate	[kWh_{pr}/a]	171093	66226	35478	31930	21558
- for warm climate	[kWh_{pr}/a]	59575	23060	12354	11118	7506
- for cold climate	[kWh_{pr}/a]	298326	115474	61861	55675	37589
Financial data						
Product cost (VAT excl.)	[€]		€ 12173	€ 15981	€ 17378	€ 22019
Installation cost (VAT excl.)	[€]		€ 143100	€ 143100	€ 143100	€ 143100
Total investment (VAT incl.)	[€]	€ 1800	€ 155273	€ 159081	€ 160478	€ 165119
Electricity cost over lifetime (@18ct/kWh)	[€]		€ 49731	€ 42735	€ 37933	€ 19828
Total space heating energy cost over lifetime						
- for average climate (@6ct/kWh)	[€]	€ 174515	€ 67550	€ 36188	€ 32569	€ 21989
- for warm climate	[€]	€ 60767	€ 27441	€ 14701	€ 13231	€ 8933
- for cold climate	[€]	€ 304292	€ 137413	€ 73614	€ 66253	€ 44731
Total lifecycle cost (LCC)						
- for average climate	[€]	€ 176315	€ 272554	€ 238004	€ 230980	€ 206936
- for warm climate	[€]	€ 62567	€ 232446	€ 216517	€ 211642	€ 193880
- for cold climate	[€]	€ 306092	€ 342418	€ 275431	€ 264664	€ 229678

Improvements vs natural ventilation	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs for average climate	€ LCC savings for average climate
Design Option I	-€ 42735	€ 138328	€ 46066	€ 230678	€ 157281	27.97	-€ 61688
Design Option II	-€ 37933	€ 141947	€ 47536	€ 238039	€ 158678	25.93	-€ 54664
Design Option III	-€ 19828	€ 152526	€ 51834	€ 259561	€ 163319	20.92	-€ 30621

Improvements vs reference unit	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs for average climate	€ LCC savings for average climate
Design Option I	€ 6996	€ 31363	€ 12741	€ 63799	€ 3808	1.69	€ 34551
Design Option II	€ 11798	€ 34981	€ 14211	€ 71161	€ 5205	1.89	€ 41575
Design Option III	€ 29903	€ 45561	€ 18509	€ 92683	€ 9846	2.22	€ 65618

1.5.5 AHU/L

Reference unit

The reference unit has a fan efficiency of 61%, a variable speed motor control, an SFPint of 1282 W/m³/s and an average energy recovery ratio of 44%, representing the average 2010 sold units with run-around and recuperative HR systems and a share having no HRS-systems at all.

Using a clock control, this fictitious reference unit delivers an average ventilation rate of around 16,800 m³/h, consumes €201.597 of electricity and €236.425 of space heating energy over its lifetime for an average climate. Total installation costs are averaged over new built projects (25%), renovation projects (25%) and replacements (50%). Including product and installation costs, the total lifecycle cost of this reference unit is €1.021.656 for the average climate, €881.276 for the warm climate and €1.266.178 for the cold climate.

Design Options

For the design options presented in table 14 the fan efficiency is further improved from 65% for design option I to 70% for design option III; the ΔPint is further reduced by enhancing the in- and outlet design of the unit, by applying more energy efficient filters and reducing the face velocity. In design option III, valves are introduced in combination with VDC-devices. This option allows for local load dependent ventilation control, and further reduces the average airflow without compromising the ventilation performance. Finally, the heat recovery efficiency figures are further improved to 70% for design option I and 73% and 75% for design option II and III respectively.

Including product and installation costs, design option III has the lowest lifecycle cost with €757.222 for the average climate, €711.526 for the warm climate, and €836.819 for the cold climate; related lifecycle cost savings are €264.434, €169.750 and €429.359 respectively.

Table 14. Performance, consumption and lifecycle cost design options AHU/L

AHU-L				DESIGN OPTIONS		
Parameter	**unit**	**Nat. vent.**	**Reference**	**I**	**II**	**III**
Performance data						
Nominal flowrate	[m^3/3]	-	9.72	9.72	9.72	9.72
Design Δpext	[pa]	-	575	575	575	575
Design Δpint	[pa]	-	391	300	270	270
Fan system efficiency @nom.flow	[%]	-	61%	65%	68%	70%
Pel;design	[kW]	-	30.79	26.18	24.16	23.47
Balance control	[-]		yes	yes	yes	yes
Internal leakage	[-]		<3%	<3%	<3%	<3%
Motor control type	[-]	-	variable speed	variable speed	variable speed	variable speed
Ventilation Demand Controls	[-]	-	clock	clock	clock	VDC+valves
CTRL-factor			0.48	0.48	0.48	0.35
Avg flowrate	[m^3/h]	24306	16800	16800	16800	12250
SFPint @ nominal flow	[W/m^3/s]	-	1282	923	794	771
SFPtot @ nominal flow	[W/m^3/s]		3167	2692	2485	2414
Energy recovery ratio	[%]	-	44%	70%	73%	75%
Qdefrost for average climate	[kWh/a]	-	2589	1730	877	877
Consumption data						
Annual electricity consumption	[kWh_e/a]	-	66622	55819	50283	26293
Annual space heating energy loss						
- for average climate	[kWh_{pr}/a]	598827	231789	124173	111756	75452
- for warm climate	[kWh_{pr}/a]	208514	80710	43237	38914	26273
- for cold climate	[kWh_{pr}/a]	1044140	404157	216513	194862	131562
Financial data						
Product cost (VAT excl.)	[€]		€ 29009	€ 36232	€ 38866	€ 46073
Installation cost (VAT excl.)	[€]		€ 554625	€ 554625	€ 554625	€ 554625
Total investment (VAT incl.)	[€]	€ 1800	€ 583634	€ 590857	€ 593491	€ 600698
Electricity cost over lifetime (@18ct/kWh)	[€]		€ 201597	€ 168909	€ 152156	€ 79563
Total space heating energy cost over lifetime						
- for average climate (@6ct/kWh)	[€]	€ 610804	€ 236425	€ 126656	€ 113991	€ 76961
- for warm climate	[€]	€ 212684	€ 96045	€ 51453	€ 46307	€ 31265
- for cold climate	[€]	€ 1065023	€ 480947	€ 257650	€ 231885	€ 156558
Total lifecycle cost (LCC)						
- for average climate	[€]	€ 612604	€ 1021656	€ 886423	€ 859638	€ 757222
- for warm climate	[€]	€ 214484	€ 881276	€ 811219	€ 791955	€ 711526
- for cold climate	[€]	€ 1066823	€ 1266178	€ 1017417	€ 977533	€ 836819

Improvements vs natural ventilation	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs for average climate	€ LCC savings for average climate
Design Option I	-€ 168909	€ 484148	€ 161232	€ 807372	€ 589057	31.77	-€ 273819
Design Option II	-€ 152156	€ 496813	€ 166377	€ 833137	€ 591691	29.18	-€ 247034
Design Option III	-€ 79563	€ 533843	€ 181420	€ 908464	€ 598898	22.41	-€ 144619

Improvements vs reference unit	LCC electr. savings	LCC space heating energy savings average	warm	cold	Investment increase	payback yrs for average climate	€ LCC savings for average climate
Design Option I	€ 32688	€ 109769	€ 44592	€ 223297	€ 7223	0.86	€ 135234
Design Option II	€ 49441	€ 122434	€ 49737	€ 249062	€ 9857	0.97	€ 162018
Design Option III	€ 122034	€ 159464	€ 64780	€ 324389	€ 17064	1.03	€ 264434

1.6 Summary Design Option Savings

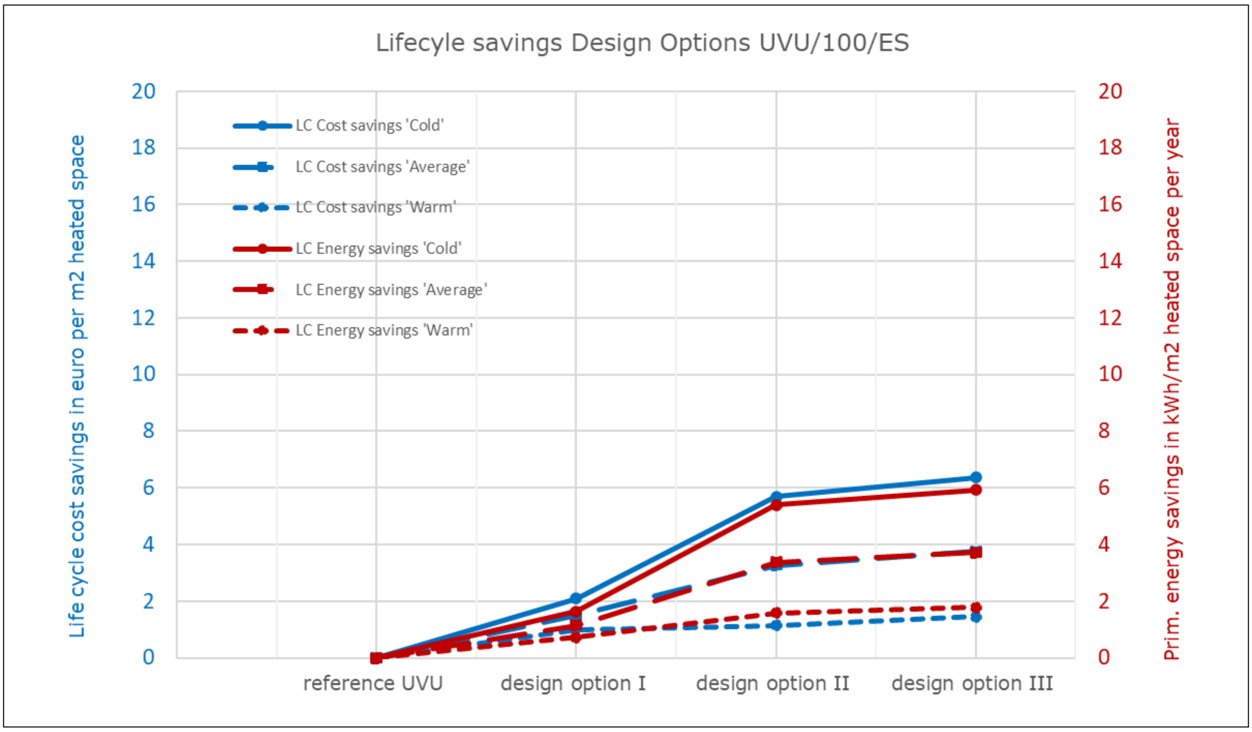
1.6.1 Non-ducted (local) RVUs

UVU/100/ES

For all climate zones, all three design options achieve energy and costsavings as well as acceptable payback periods, indicating that setting minimum requirements above the reference level (manual control, SPI = 0.2 W/m³/h, *fs* = 1.15) for these units can be considered (see table below.

Table 15. Summary UVU/100/ES

	Electricity savings per year		Heating energy savings per year		Total primary energy savings per year		Investment increase	payback time	Lifecycle cost		Lifecycle cost savings	
									per unit	per m2	per unit	per m2
	[kWhe/unit]	[€/unit]	[kWh/unit]	[€/unit]	[kWh]	[kWh/m²]	[€/unit]	[yr]	[€]	[€/m²]	[€]	[€/m²]
UVU/100/ES	average climate											
reference UVU	-	-	-	-	-	-	-	-	€ 1279	€ 12.79	-	-
design option I	23	€ 5	66	€ 5	115	1.2	10.8	1.1	€ 1128	€ 11.28	€ 151	€ 1.51
design option II	30	€ 6	273	€ 19	337	3.4	106.8	4.2	€ 952	€ 9.52	€ 327	€ 3.27
design option III	36	€ 8	296	€ 21	372	3.7	106.8	3.8	€ 905	€ 9.05	€ 375	€ 3.75
	warm climate											
reference UVU	-	-	-	-	-	-	-	-	€ 692	€ 6.92	-	-
design option I	23	€ 5	23	€ 2	72	0.7	10.8	1.7	€ 592	€ 5.92	€ 100	€ 1.00
design option II	30	€ 6	95	€ 7	159	1.6	106.8	8.2	€ 577	€ 5.77	€ 115	€ 1.15
design option III	36	€ 8	103	€ 7	179	1.8	106.8	7.2	€ 547	€ 5.47	€ 145	€ 1.45
	cold climate											
reference UVU	-	-	-	-	-	-	-	-	€ 1949	€ 19.49	-	-
design option I	23	€ 5	115	€ 8	164	1.6	10.8	0.8	€ 1740	€ 17.40	€ 209	€ 2.09
design option II	30	€ 6	476	€ 33	540	5.4	106.8	2.7	€ 1381	€ 13.81	€ 569	€ 5.69
design option III	36	€ 8	517	€ 36	593	5.9	106.8	2.4	€ 1312	€ 13.12	€ 637	€ 6.37



RVU/100/HS

For all climate zones, all three design options of the non-ducted UVU/100/HS achieve energy and cost savings and acceptable payback periods. This is not the case however for non-ducted BVU/100/HS (see table 17). Although they achieve the highest energy savings compared to the reference UVU/100/HS (up to 10 kWh/m²/a for average climate, up to 4 for warm and up to 17 kWh/m²/a for cold climate), the total life cycle costs may increase. This is especially the case for the warm climate .
In summary: with assumed product, installation and energy prices, the UVU/100/HS design option III, is the unit with the least lifecycle costs for the warm and average climate. The BVU/100/HS design option III offers the lowest lifecycle costs for the cold climates.

Table 16. Summary UVU/100/HS

	Electricity savings per year		Heating energy savings per year		Total primary energy savings per year		Investment increase	payback time	Lifecycle cost		Lifecycle cost savings	
									per unit	per m2	per unit	per m2
	[kWhe/unit]	[€/unit]	[kWh/unit]	[€/unit]	[kWh]	[kWh/m²]	[€/unit]	[yr]	[€]	[€/m²]	[€]	[€/m²]
UVU/100/HS	average climate											
reference UVU	-	-	-	-	-	-	-		€ 1684	€ 16.84	-	-
design option I	46	€ 10	309	€ 22	407	4.1	96.0	3.1	€ 1246	€ 12.46	€ 438	€ 4.38
design option II	46	€ 10	595	€ 42	692	6.9	166.8	3.3	€ 979	€ 9.79	€ 705	€ 7.05
design option III	49	€ 10	612	€ 43	716	7.2	166.8	3.1	€ 946	€ 9.46	€ 738	€ 7.38
	warm climate											
reference UVU	-	-	-	-	-	-	-		€ 871	€ 8.71	-	-
design option I	46	€ 10	108	€ 8	205	2.1	96.0	5.5	€ 673	€ 6.73	€ 198	€ 1.98
design option II	46	€ 10	207	€ 14	304	3.0	166.8	6.9	€ 627	€ 6.27	€ 244	€ 2.44
design option III	49	€ 10	213	€ 15	317	3.2	166.8	6.6	€ 608	€ 6.08	€ 264	€ 2.64
	cold climate											
reference UVU	-	-	-	-	-	-	-		€ 2612	€ 26.12	-	-
design option I	46	€ 10	540	€ 38	637	6.4	96.0	2.0	€ 1900	€ 19.00	€ 712	€ 7.12
design option II	46	€ 10	1037	€ 73	1134	11.3	166.8	2.0	€ 1380	€ 13.80	€ 1232	€ 12.32
design option III	49	€ 10	1067	€ 75	1171	11.7	166.8	2.0	€ 1332	€ 13.32	€ 1280	€ 12.80

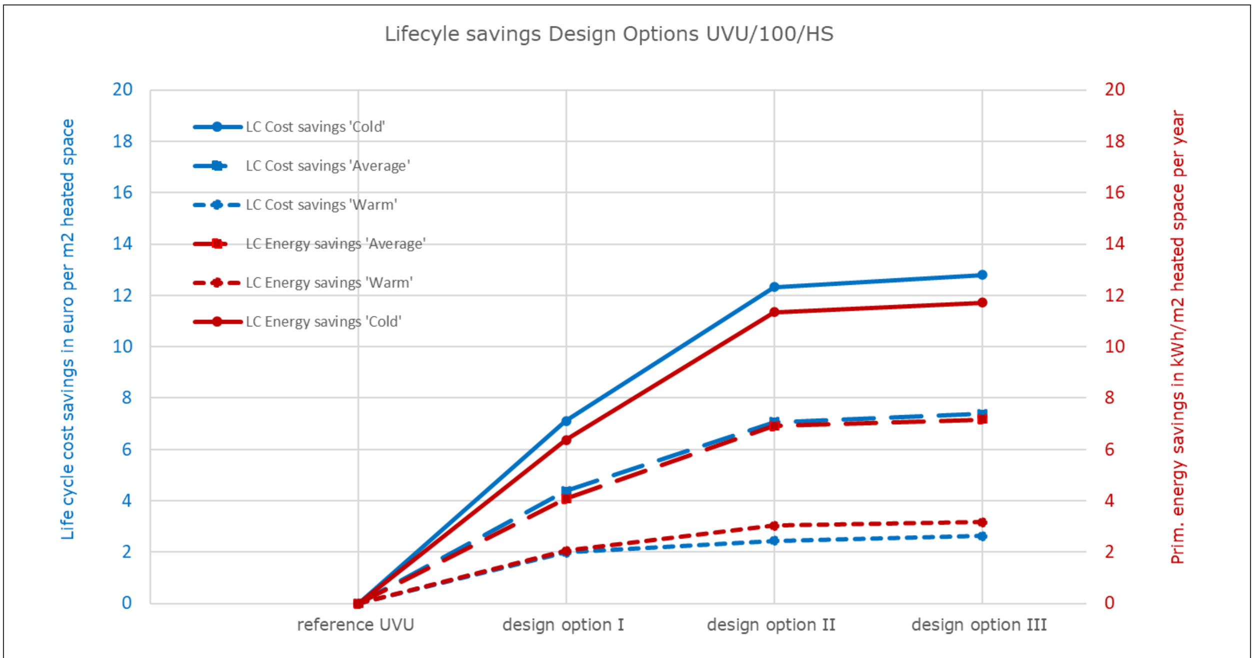
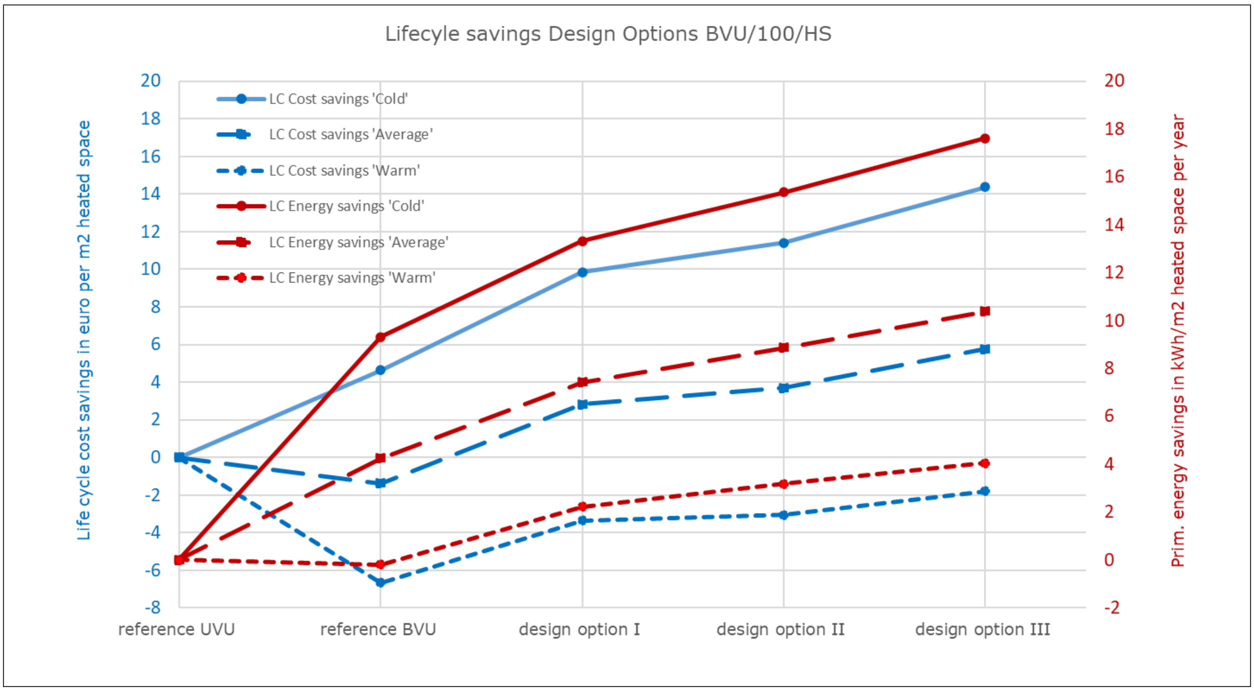


Table 17. Summary BVU/100/HS

	Electricity savings per year		Heating energy savings per year		Total primary energy savings per year		Investment increase	payback time	Lifecycle cost		Lifecycle cost savings	
									per unit	per m2	per unit	per m2
	[kWhe/unit]	[€/unit]	[kWh/unit]	[€/unit]	[kWh]	[kWh/m^2]	[€/unit]	[yr]	[€]	[€/m^2]	[€]	[€/m^2]
BVU/100/HS	average climate											
reference UVU	-	-	-	-	-	-	-		€ 1684	€ 16.84	-	-
reference BVU	-122	-€ 26	681	€ 48	425	4.3	514	23.3	€ 1823	€ 18.23	-€ 138	-€ 1.38
design option I	-25	-€ 5	795	€ 56	742	7.4	574	11.4	€ 1402	€ 14.02	€ 282	€ 2.82
design option II	7	€ 2	872	€ 61	887	8.9	694	11.1	€ 1314	€ 13.14	€ 370	€ 3.70
design option III	31	€ 7	973	€ 68	1039	10.4	694	9.3	€ 1108	€ 11.08	€ 576	€ 5.76
	warm climate											
reference UVU	-	-	-	-	-	-	-		€ 871	€ 8.71	-	-
reference BVU	-122	-€ 26	237	€ 17	-19	-0.2	514	-57.0	€ 1538	€ 15.38	-€ 667	-€ 6.67
design option I	-25	-€ 5	277	€ 19	223	2.2	574	40.9	€ 1206	€ 12.06	-€ 335	-€ 3.35
design option II	7	€ 2	304	€ 21	319	3.2	694	30.4	€ 1177	€ 11.77	-€ 306	-€ 3.06
design option III	31	€ 7	339	€ 24	405	4.0	694	22.9	€ 1049	€ 10.49	-€ 178	-€ 1.78
	cold climate											
reference UVU	-	-	-	-	-	-	-		€ 2612	€ 26.12	-	-
reference BVU	-122	-€ 26	1188	€ 83	932	9.3	514	8.9	€ 2147	€ 21.47	€ 464	€ 4.64
design option I	-25	-€ 5	1386	€ 97	1333	13.3	574	6.3	€ 1627	€ 16.27	€ 985	€ 9.85
design option II	7	€ 2	1520	€ 106	1536	15.4	694	6.4	€ 1470	€ 14.70	€ 1142	€ 11.42
design option III	31	€ 7	1696	€ 119	1762	17.6	694	5.5	€ 1175	€ 11.75	€ 1437	€ 14.37



The graph shows that in terms of lifecycle costs, the reference BVU cannot be considered an improvement vis a vis the reference UVU in warm and average climates. For warm climates, none of the design options for BVU/100/HS reduce the lifecycle costs, despite the energy savings.

1.6.2 Ducted (central) RVUs

RVU/250

For all climate zones, all three design options of the ducted UVU/250 achieve energy and cost savings and acceptable payback periods. This is only partly the case for ducted BVU/250 (see next page). Although they achieve the highest energy savings compared to the reference UVU/250 (up to 51 kWh/m²/a for an average climate, up to 22.7 for warm and up to 84.6 kWh/m²/a for a cold climate), the total life cycle costs may increase. This is especially the case for the warm climate.
In summary: with assumed product, installation and energy prices, UVUs have the lowest lifecycle costs in warm climates and only design option III of the UVU/250 offers the least lifecycle costs for the average climate (design options I and II of the UVU/250 result in higher lifecycle costs compared to BVU/250). All BVU/250 design options offer the lower lifecycle costs for the cold climates compared to UVU/250.

Table 18. Summary UVU/250

	Electricity savings per year		Heating energy savings per year		Total primary energy savings per year		Investment increase	payback time	Lifecycle cost		Lifecycle cost savings	
									per unit	per m2	per unit	per m2
	[kWhe/unit]	[€/unit]	[kWh/unit]	[€/unit]	[kWh]	[kWh/m²]	[€/unit]	[yr]	[€]	[€/m²]	[€]	[€/m²]
UVU/250	average climate											
reference UVU	-	-	-	-	-	-	-		€ 8102	€ 81.02	-	-
design option I	300	€ 63	728	€ 51	1358	13.6	492.0	4.3	€ 6657	€ 66.57	€ 1445	€ 14.45
design option II	355	€ 75	728	€ 51	1474	14.7	492.0	3.9	€ 6460	€ 64.60	€ 1642	€ 16.42
design option III	358	€ 75	2427	€ 170	3179	31.8	852.0	3.5	€ 4787	€ 47.87	€ 3315	€ 33.15
	warm climate											
reference UVU	-	-	-	-	-	-	-		€ 4526	€ 45.26	-	-
design option I	300	€ 63	254	€ 18	883	8.8	492.0	6.1	€ 3645	€ 36.45	€ 880	€ 8.80
design option II	355	€ 75	254	€ 18	999	10.0	492.0	5.3	€ 3448	€ 34.48	€ 1077	€ 10.77
design option III	358	€ 75	845	€ 59	1598	16.0	852.0	6.3	€ 3093	€ 30.93	€ 1433	€ 14.33
	cold climate											
reference UVU	-	-	-	-	-	-	-		€ 12182	€ 121.82	-	-
design option I	300	€ 63	1269	€ 89	1899	19.0	492.0	3.2	€ 10093	€ 100.93	€ 2089	€ 20.89
design option II	355	€ 75	1269	€ 89	2015	20.2	492.0	3.0	€ 9896	€ 98.96	€ 2286	€ 22.86
design option III	358	€ 75	4231	€ 296	4984	49.8	852.0	2.3	€ 6720	€ 67.20	€ 5463	€ 54.63

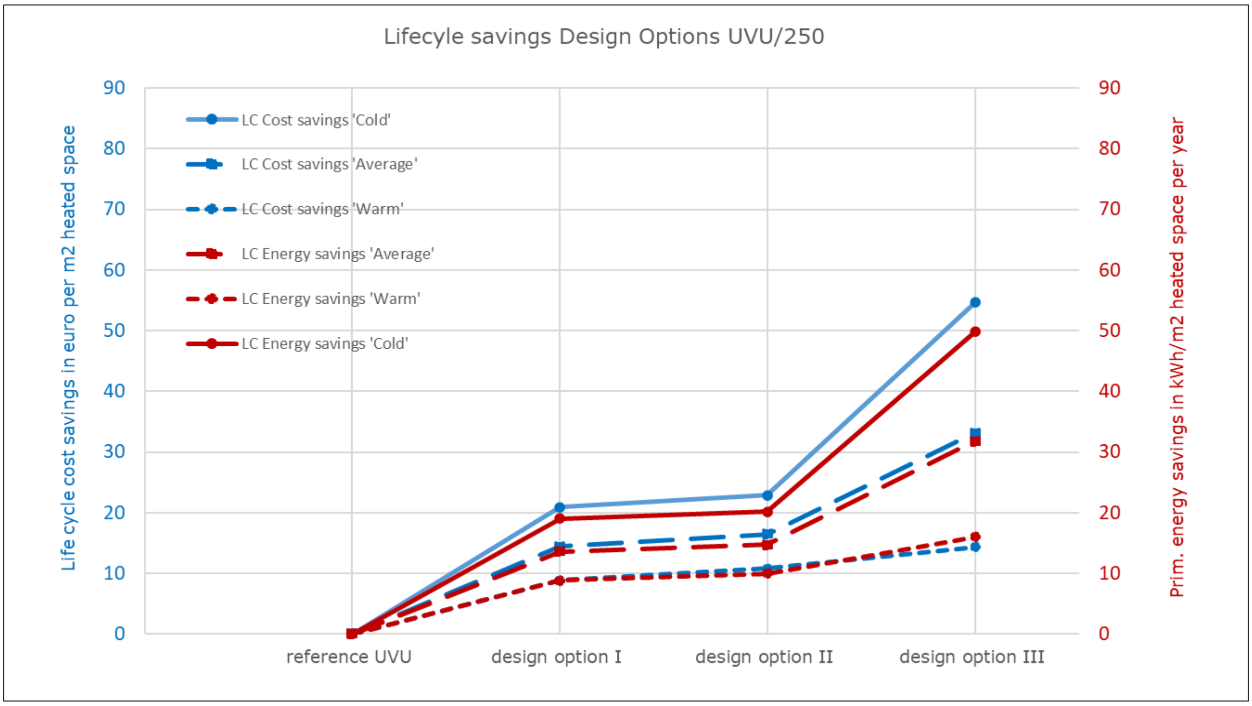
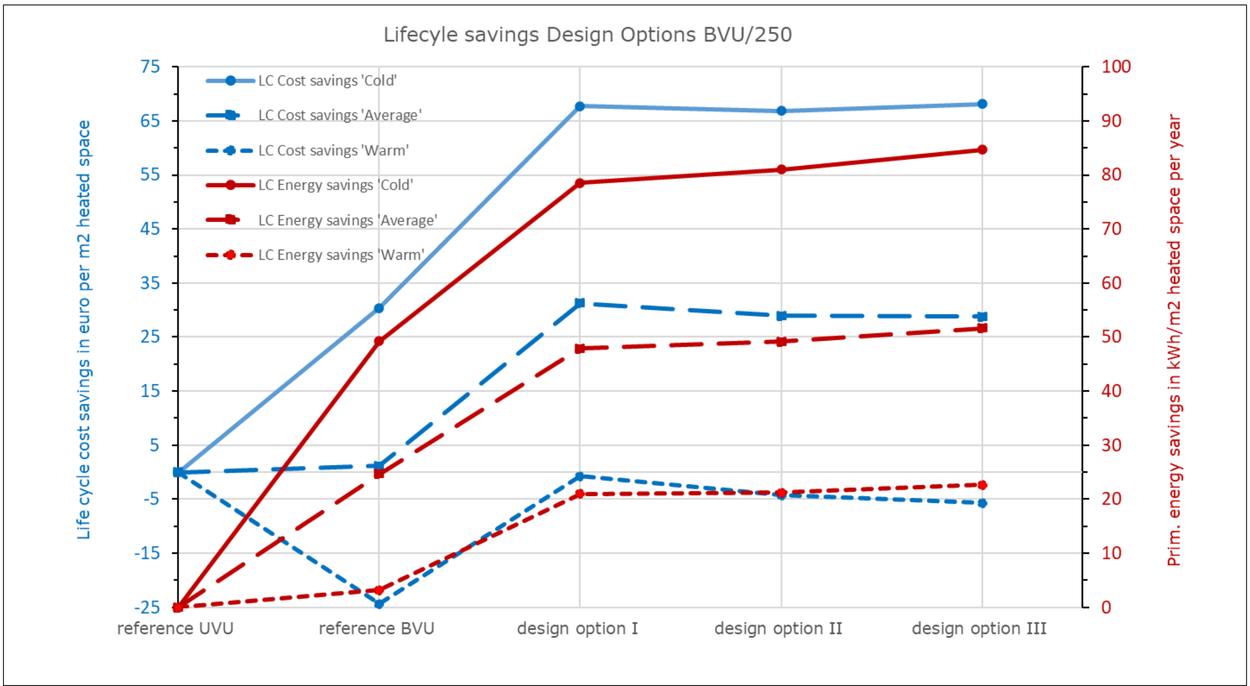


Table 19. Summary BVU/250

	Electricity savings per year		Heating energy savings per year		Total primary energy savings per year		Investment increase	payback time	Lifecycle cost		Lifecycle cost savings	
									per unit	per m2	per unit	per m2
	[kWhe/unit]	[€/unit]	[kWh/unit]	[€/unit]	[kWh]	[kWh/m²]	[€/unit]	[yr]	[€]	[€/m²]	[€]	[€/m²]
BVU/250	average climate											
reference UVU	-	-	-	-	-	-	-		€ 8102	€ 81.02	-	-
reference BVU	-396	-€ 83	3300	€ 231	2469	24.7	2394	16.2	€ 7981	€ 79.81	€ 120	€ 1.20
design option I	315	€ 66	4126	€ 289	4787	47.9	2910	8.2	€ 4978	€ 49.78	€ 3124	€ 31.24
design option II	300	€ 63	4283	€ 300	4913	49.1	3270	9.0	€ 5205	€ 52.05	€ 2897	€ 28.97
design option III	343	€ 72	4441	€ 311	5161	51.6	3630	9.5	€ 5222	€ 52.22	€ 2879	€ 28.79
	warm climate											
reference UVU	-	-	-	-	-	-	-		€ 4526	€ 45.26	-	-
reference BVU	-396	-€ 83	1149	€ 80	318	3.2	2394	-894.7	€ 6965	€ 69.65	-€ 2439	-€ 24.39
design option I	315	€ 66	1437	€ 101	2098	21.0	2910	17.5	€ 4601	€ 46.01	-€ 76	-€ 0.76
design option II	300	€ 63	1491	€ 104	2121	21.2	3270	19.5	€ 4951	€ 49.51	-€ 425	-€ 4.25
design option III	343	€ 72	1546	€ 108	2267	22.7	3630	20.1	€ 5091	€ 50.91	-€ 565	-€ 5.65
	cold climate											
reference UVU	-	-	-	-	-	-	-		€ 12182	€ 121.82	-	-
reference BVU	-396	-€ 83	5755	€ 403	4924	49.2	2394	7.5	€ 9141	€ 91.41	€ 3041	€ 30.41
design option I	315	€ 66	7193	€ 504	7855	78.6	2910	5.1	€ 5407	€ 54.07	€ 6775	€ 67.75
design option II	300	€ 63	7469	€ 523	8098	81.0	3270	5.6	€ 5495	€ 54.95	€ 6687	€ 66.87
design option III	343	€ 72	7744	€ 542	8464	84.6	3630	5.9	€ 5373	€ 53.73	€ 6810	€ 68.10



As the graph shows, all design options result in energy savings. For warm climates however, lifecycle costs increase.

1.6.3 Collective ducted RVUs

RVU/1000

Energy savings of up to 20 kWh/m²/a for an average climate, 11 for warm and 31 kWh/m²/a for cold climate can be achieved with the proposed design options, while simultaneously reducing the total lifecycle costs when compared to the reference unit. The BVU/1000 (see Table 21), achieves considerably higher energy savings and also reduces total lifecycle costs noticeably (expect for the reference BVU in warm climates, which is not considered an improvement compared to the reference UVU). These differences in BVU savings compared to RVU/250 mainly relates to the energy-cost/investment-cost ratio, which is higher for RVU/1000 units.

Table 20. Summary UVU/1000

	Electricity savings per year		Heating energy savings per year		Total primary energy savings per year		Investment increase	payback time	Lifecycle cost		Lifecycle cost savings	
									per unit	per m2	per unit	per m2
	[kWhe/unit]	[€/unit]	[kWh/unit]	[€/unit]	[kWh]	[kWh/m²]	[€/unit]	[yr]	[€]	[€/m²]	[€]	[€/m²]
UVU/1000	average climate											
reference UVU	-	-	-	-	-	-	-		€ 29789	€ 74.47	-	-
design option I	1246	€ 262	0	€ -	2617	6.5	43.7	0.2	€ 25384	€ 63.46	€ 4404	€ 11.01
design option II	1228	€ 258	2912	€ 204	5491	13.7	2124.0	4.6	€ 24063	€ 60.16	€ 5726	€ 14.31
design option III	1129	€ 237	5824	€ 408	8194	20.5	3540.0	5.5	€ 22368	€ 55.92	€ 7420	€ 18.55
	warm climate											
reference UVU	-	-	-	-	-	-	-		€ 15483	€ 38.71	-	-
design option I	1246	€ 262	0	€ -	2617	6.5	43.7	0.2	€ 11079	€ 27.70	€ 4404	€ 11.01
design option II	1228	€ 258	1014	€ 71	3593	9.0	2124.0	6.5	€ 12016	€ 30.04	€ 3467	€ 8.67
design option III	1129	€ 237	2028	€ 142	4398	11.0	3540.0	9.3	€ 12580	€ 31.45	€ 2903	€ 7.26
	cold climate											
reference UVU	-	-	-	-	-	-	-		€ 46110	€ 115.27	-	-
design option I	1246	€ 262	0	€ -	2617	6.5	43.7	0.2	€ 41705	€ 104.26	€ 4404	€ 11.01
design option II	1228	€ 258	5078	€ 355	7657	19.1	2124.0	3.5	€ 37807	€ 94.52	€ 8303	€ 20.76
design option III	1129	€ 237	10155	€ 711	12526	31.3	3540.0	3.7	€ 33536	€ 83.84	€ 12574	€ 31.44

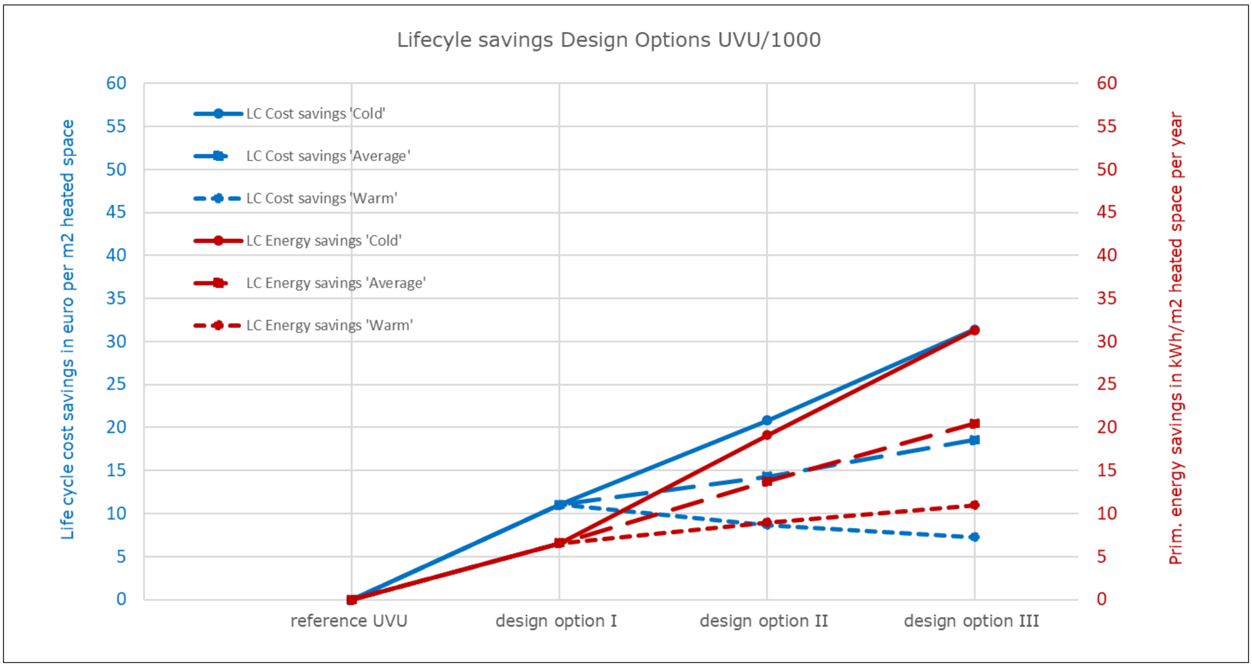
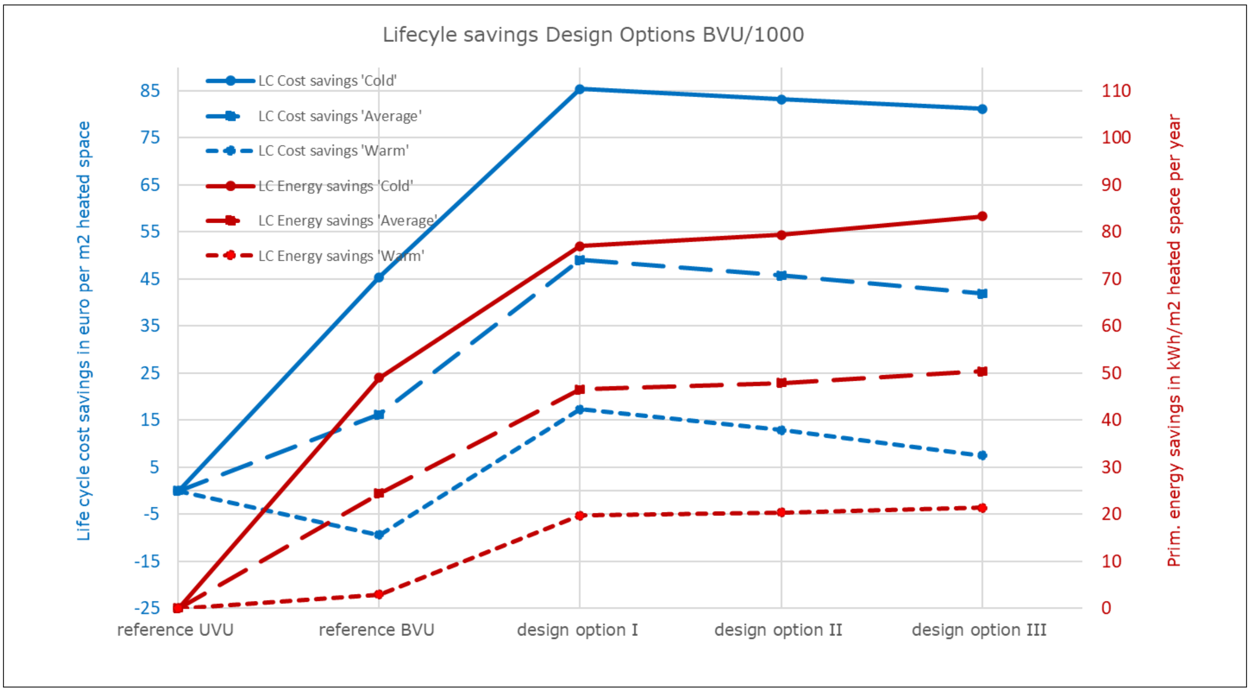


Table 21. Summary BVU/1000

	Electricity savings per year		Heating energy savings per year		Total primary energy savings per year		Investment increase	payback time	Lifecycle cost		Lifecycle cost savings	
									per unit	per m2	per unit	per m2
	[kWhe/unit]	[€/unit]	[kWh/unit]	[€/unit]	[kWh]	[kWh/m²]	[€/unit]	[yr]	[€]	[€/m²]	[€]	[€/m²]
BVU/1000	average climate											
reference UVU	-	-	-	-	-	-	-		€ 29789	€ 74.47	-	-
reference BVU	-1632	-€ 343	13202	€ 924	9775	24.4	3418	5.9	€ 23322	€ 58.30	€ 6467	€ 16.17
design option I	1046	€ 220	16405	€ 1148	18601	46.5	3623	2.6	€ 10156	€ 25.39	€ 19633	€ 49.08
design option II	972	€ 204	16803	€ 1176	18845	47.1	5675	4.1	€ 11996	€ 29.99	€ 17792	€ 44.48
design option III	1130	€ 237	17764	€ 1243	20138	50.3	8411	5.7	€ 13025	€ 32.56	€ 16763	€ 41.91
	warm climate											
reference UVU	-	-	-	-	-	-	-		€ 15483	€ 38.71	-	-
reference BVU	-1632	-€ 343	4597	€ 322	1170	2.9	3418	-163.5	€ 19256	€ 48.14	-€ 3773	-€ 9.43
design option I	1046	€ 220	5712	€ 400	7909	19.8	3623	5.8	€ 8575	€ 21.44	€ 6908	€ 17.27
design option II	972	€ 204	5851	€ 410	7893	19.7	5675	9.2	€ 10724	€ 26.81	€ 4759	€ 11.90
design option III	1130	€ 237	6186	€ 433	8559	21.4	8411	12.5	€ 12498	€ 31.25	€ 2985	€ 7.46
	cold climate											
reference UVU	-	-	-	-	-	-	-		€ 46110	€ 115.27	-	-
reference BVU	-1632	-€ 343	23019	€ 1611	19592	49.0	3418	2.7	€ 27961	€ 69.90	€ 18149	€ 45.37
design option I	1046	€ 220	28605	€ 2002	30801	77.0	3623	1.6	€ 11960	€ 29.90	€ 34150	€ 85.37
design option II	972	€ 204	29299	€ 2051	31341	78.4	5675	2.5	€ 13448	€ 33.62	€ 32662	€ 81.66
design option III	1130	€ 237	30974	€ 2168	33348	83.4	8411	3.5	€ 13627	€ 34.07	€ 32483	€ 81.21



A similar picture also arises with regards to energy savings and lifecycle cost savings:for collective residential units with even higher nominal flowrates (UVU/1000+ and BVU/25000). The design options of the BVU versions achieve the least lifecycle costs at the highest energy savings per m² of heated surface.

1.6.4 Non-residential ventilation units

<u>NR-UVUs and BVUs</u>

For the non-residential units, no reference is made to a specific ventilation performance. This implies that for these NRVUs it is assumed that comparable ventilation performances are achieved irrespective of the types of controls used.

The design option II of the NR-UVU/1000+ with improved fan system efficiency and lower ΔPint yields the lowest lifecycle costs for average and cold climates as well as some energy savings per m² heated space compared to the reference UVU. The design options of NR-BVU/2500 (see table 23) offer even lower lifecycle costs per m^2 for buildings in cold and average climates combined with significant energy savings; design option II offer the lowest lifecycle costs for average and cold climates compared to the reference UVU. The main difference with the assessment of the residential VUs is the fact that with NRVUs it is assumed that all required airflows (high during presence and low during absence) are always achieved, irrespective of the type of controls. Any differences in total daily airflows relate to differences in the amount of 'over'-ventilation. The effect of controls on the average airflow is set using a fixed value 0.48 for units with clock-controls and variable speed motor controls, and a value of 0.35 for units that have the proper VDC-devices (ventilation demand control).

Table 22. Summary non-residential UVU/1000+

	Electricity savings per year		Heating energy savings per year		Total primary energy savings per year		Investment increase	payback time	Lifecycle cost		Lifecycle cost savings	
									per unit	per m2	per unit	per m2
	[kWhe/unit]	[€/unit]	[kWh/unit]	[€/unit]	[kWh]	[kWh/m^2]	[€/unit]	[yr]	[€]	[€/m^2]	[€]	[€/m^2]
NR-UVU/1000+	average climate											
reference UVU	-	-	-	-	-	-	-		€ 22098	€ 53.04	-	-
design option I	299	€ 53	0	€ -	629	1.5	190.0	3.6	€ 21724	€ 52.14	€ 374	€ 0.90
design option II	488	€ 87	0	€ -	1025	2.5	190.0	2.2	€ 21383	€ 51.32	€ 716	€ 1.72
design option III	653	€ 116	4804	€ 288	6175	14.8	6190.0	15.3	€ 21911	€ 52.59	€ 187	€ 0.45
	warm climate											
reference UVU	-	-	-	-	-	-	-		€ 11355	€ 27.25	-	-
design option I	299	€ 53	0	€ -	629	1.5	190.0	3.6	€ 10981	€ 26.35	€ 374	€ 0.90
design option II	488	€ 87	0	€ -	1025	2.5	190.0	2.2	€ 10639	€ 25.53	€ 716	€ 1.72
design option III	653	€ 116	1673	€ 100	3043	7.3	6190.0	28.6	€ 14078	€ 33.79	-€ 2722	-€ 6.53
	cold climate											
reference UVU	-	-	-	-	-	-	-		€ 40812	€ 97.95	-	-
design option I	299	€ 53	0	€ -	629	1.5	190.0	3.6	€ 40438	€ 97.05	€ 374	€ 0.90
design option II	488	€ 87	0	€ -	1025	2.5	190.0	2.2	€ 40096	€ 96.23	€ 716	€ 1.72
design option III	653	€ 116	8377	€ 503	9747	23.4	6190.0	10.0	€ 35556	€ 85.34	€ 5255	€ 12.61

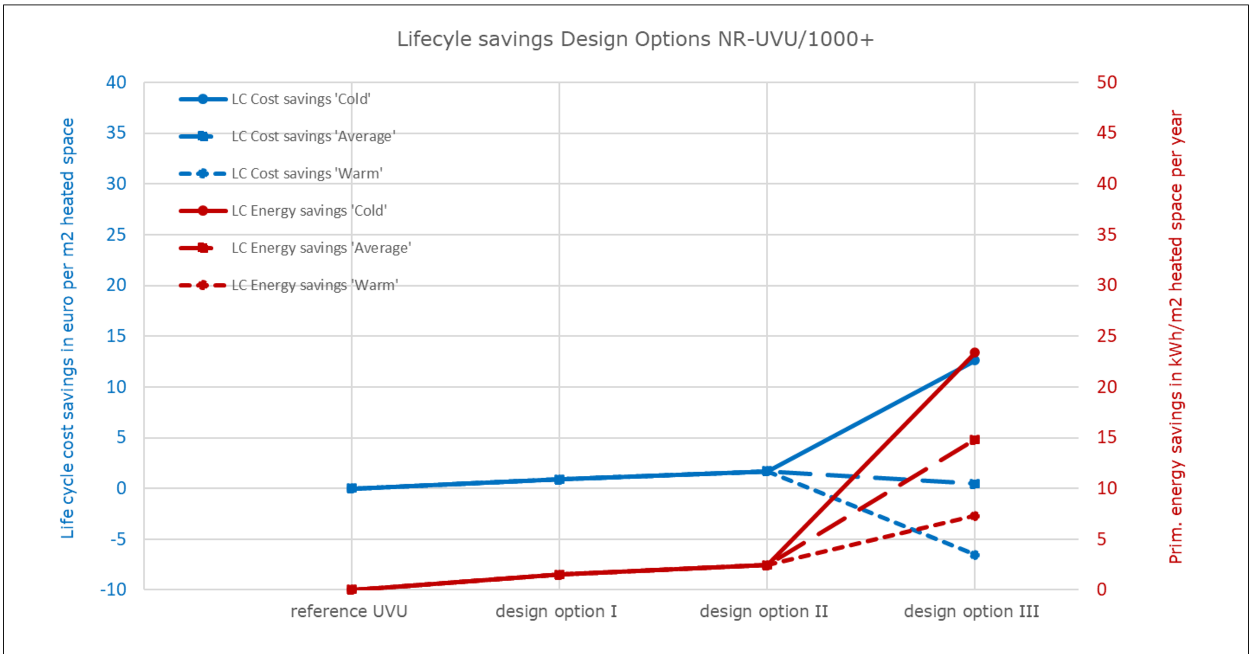
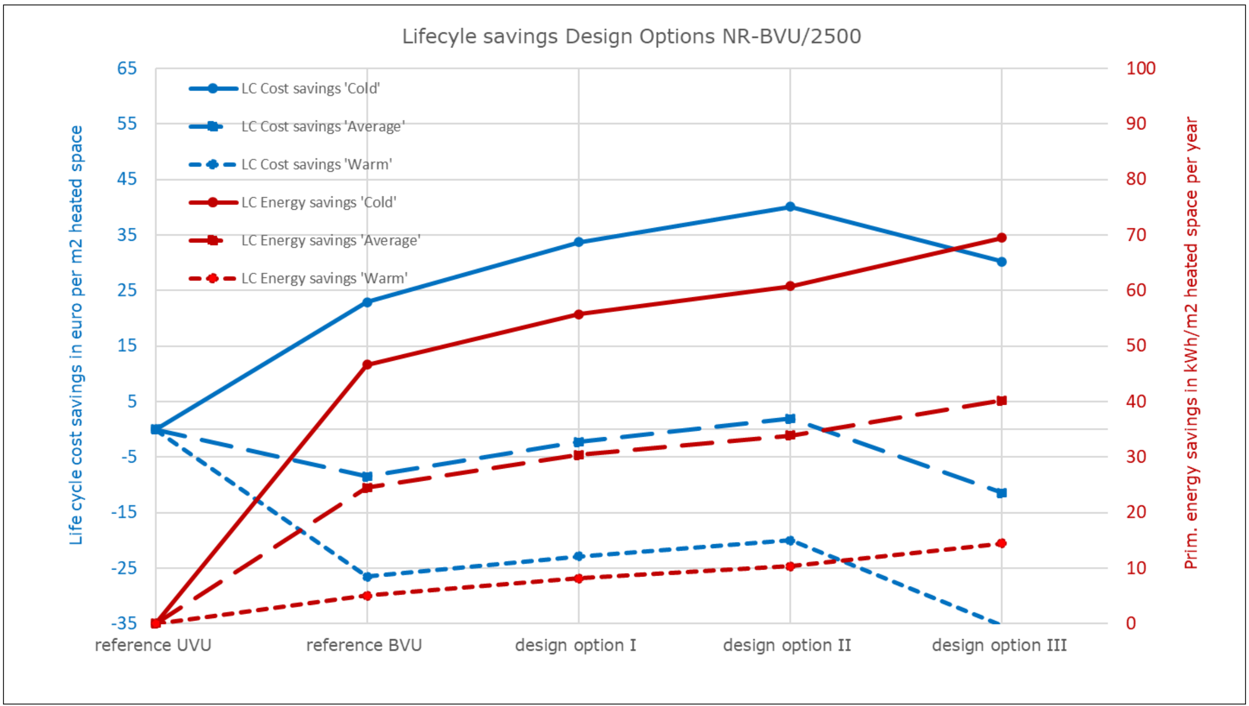


Table 23. Summary non-residential BVU/2500

	Electricity savings per year		Heating energy savings per year		Total primary energy savings per year		Investment increase	payback time	Lifecycle cost		Lifecycle cost savings	
									per unit	per m2	per unit	per m2
	[kWhe/unit]	[€/unit]	[kWh/unit]	[€/unit]	[kWh]	[kWh/m²]	[€/unit]	[yr]	[€]	[€/m²]	[€]	[€/m²]
NR-BVU/2500	average climate											
reference UVU	-	-	-	-	-	-	-		€ 30103	€ 48.16	-	-
reference BVU	-1591	-€ 283	18626	€ 1304	15285	24.5	16455	16.1	€ 35418	€ 56.67	-€ 5316	-€ 8.51
design option I	-1092	-€ 194	21287	€ 1490	18994	30.4	16759	12.9	€ 31498	€ 50.40	-€ 1395	-€ 2.23
design option II	-681	-€ 121	22617	€ 1583	21186	33.9	16759	11.5	€ 28899	€ 46.24	€ 1204	€ 1.93
design option III	206	€ 37	24668	€ 1727	25102	40.2	29884	16.9	€ 37245	€ 59.59	-€ 7143	-€ 11.43
	warm climate											
reference UVU	-	-	-	-	-	-	-		€ 13988	€ 22.38	-	-
reference BVU	-1591	-€ 283	6486	€ 454	3145	5.0	16455	96.3	€ 30584	€ 48.93	-€ 16596	-€ 26.55
design option I	-1092	-€ 194	7412	€ 519	5119	8.2	16759	51.6	€ 28275	€ 45.24	-€ 14287	-€ 22.86
design option II	-681	-€ 121	7875	€ 551	6444	10.3	16759	39.0	€ 26482	€ 42.37	-€ 12494	-€ 19.99
design option III	206	€ 37	8590	€ 601	9023	14.4	29884	46.8	€ 36070	€ 57.71	-€ 22083	-€ 35.33
	cold climate											
reference UVU	-	-	-	-	-	-	-		€ 58173	€ 93.08	-	-
reference BVU	-1591	-€ 283	32477	€ 2273	29136	46.6	16455	8.3	€ 43839	€ 70.14	€ 14333	€ 22.93
design option I	-1092	-€ 194	37116	€ 2598	34824	55.7	16759	7.0	€ 37112	€ 59.38	€ 21061	€ 33.70
design option II	-681	-€ 121	39436	€ 2761	38005	60.8	16759	6.3	€ 33110	€ 52.98	€ 25063	€ 40.10
design option III	206	€ 37	43013	€ 3011	43446	69.5	29884	9.8	€ 39292	€ 62.87	€ 18881	€ 30.21



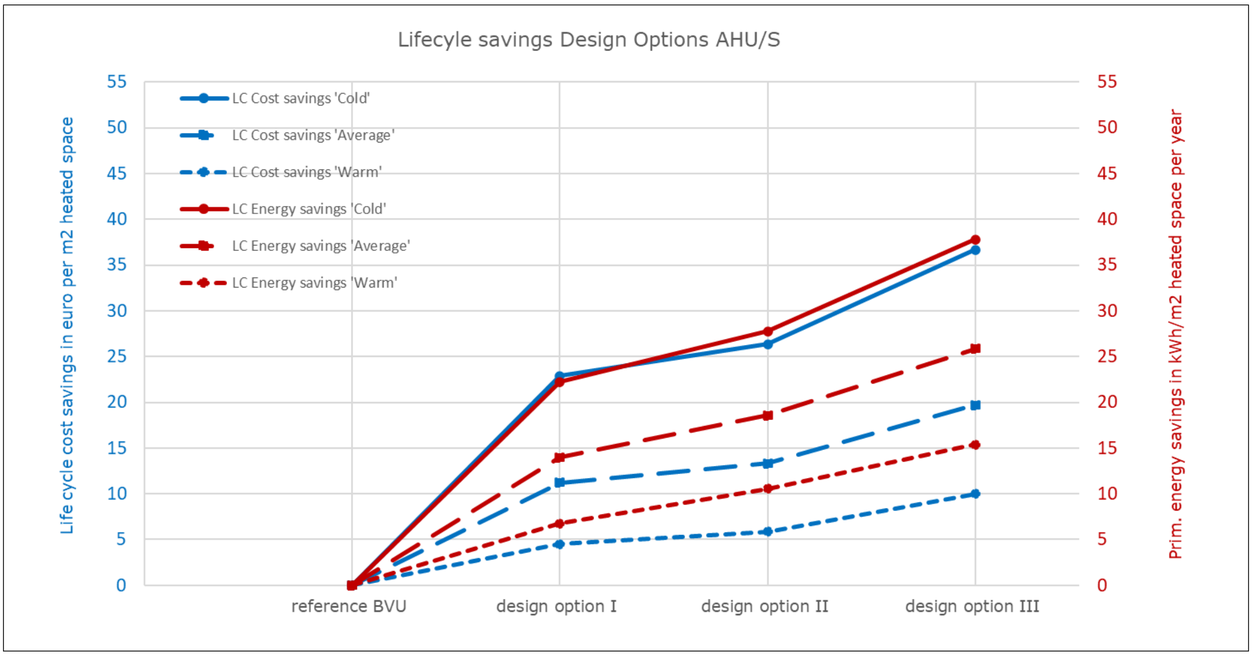
AHUs

For AHUs (Air Handling Units) the same principle applies with regard to the assessment of the ventilation performance: all airflows are considered useful. With regard to total installation costs, a weighted average s of new-built, renovation and replacement is used to determine the value. Since the installation costs are by far the largest component in the total investment (the infrastructure (ductwork etc.) of AHUs is also used for air heating and cooling), this largely influences the results of the LCC calculations: the total lifecycle costs compared to ventilation only systems will be higher. Because for AHUs having both supply and exhaust airflows, a heat recovery system is required, there is no reference to UVUs here.

Even with the assumed limited improvement for DCV-devices (the CTRL factor is 0.35 compared to 0.48), design option III has the least lifecycle costs in all climates. The increase in product costs of about 6300 euros (from about 8360 euros to 14.700 euros) can be recovered rapidly with reduced yearly energy costs.

Table 24. Summary AHU/S

	Electricity savings per year		Heating energy savings per year		Total primary energy savings per year		Investment increase	payback time	Lifecycle cost		Lifecycle cost savings	
									per unit	per m2	per unit	per m2
	[kWhe/unit]	[€/unit]	[kWh/unit]	[€/unit]	[kWh]	[kWh/m²]	[€/unit]	[yr]	[€]	[€/m²]	[€]	[€/m²]
AHU/S	average climate											
reference BVU	-	-	-	-	-	-	-		€ 111446	€ 100.30	-	-
design option I	1547	€ 275	12299	€ 738	15547	14.0	3215.0	3.2	€ 98973	€ 89.08	€ 12472	€ 11.23
design option II	3306	€ 588	13718	€ 823	20660	18.6	3858.0	2.7	€ 96631	€ 86.97	€ 14815	€ 13.33
design option III	5176	€ 921	17867	€ 1072	28737	25.9	6330.0	3.2	€ 89548	€ 80.59	€ 21898	€ 19.71
	warm climate											
reference BVU	-	-	-	-	-	-	-		€ 95402	€ 85.86	-	-
design option I	1547	€ 275	4283	€ 257	7530	6.8	3215.0	6.0	€ 90378	€ 81.34	€ 5024	€ 4.52
design option II	3306	€ 588	4777	€ 287	11719	10.5	3858.0	4.4	€ 88896	€ 80.01	€ 6506	€ 5.86
design option III	5176	€ 921	6221	€ 373	17091	15.4	6330.0	4.9	€ 84325	€ 75.89	€ 11077	€ 9.97
	cold climate											
reference BVU	-	-	-	-	-	-	-		€ 139391	€ 125.45	-	-
design option I	1547	€ 275	21445	€ 1287	24693	22.2	3215.0	2.1	€ 113944	€ 102.55	€ 25447	€ 22.90
design option II	3306	€ 588	23920	€ 1435	30862	27.8	3858.0	1.9	€ 110105	€ 99.09	€ 29286	€ 26.36
design option III	5176	€ 921	31154	€ 1869	42023	37.8	6330.0	2.3	€ 98645	€ 88.78	€ 40746	€ 36.67



For AHU/M and AHU/L a similar picture emerges (see Table 25, Table 26).

Table 25. Summary AHU/M

	Electricity savings per year		Heating energy savings per year		Total primary energy savings per year		Investment increase	payback time	Lifecycle cost		Lifecycle cost savings	
									per unit	per m2	per unit	per m2
	[kWhe/unit]	[€/unit]	[kWh/unit]	[€/unit]	[kWh]	[kWh/m²]	[€/unit]	[yr]	[€]	[€/m²]	[€]	[€/m²]
AHU/M	average climate											
reference BVU	-	-	-	-	-	-	-		€ 272554	€ 98.12	-	-
design option I	3899	€ 694	30748	€ 1845	38935	14.0	3808.0	1.5	€ 238004	€ 85.68	€ 34551	€ 12.44
design option II	9882	€ 1759	34295	€ 2058	55048	19.8	5205.0	1.4	€ 230980	€ 83.15	€ 41575	€ 14.97
design option III	16435	€ 2925	44668	€ 2680	79181	28.5	9846.0	1.8	€ 206936	€ 74.50	€ 65618	€ 23.62
	warm climate											
reference BVU	-	-	-	-	-	-	-		€ 232446	€ 83.68	-	-
design option I	3899	€ 694	10706	€ 642	18894	6.8	3808.0	2.8	€ 216517	€ 21.65	€ 15929	€ 5.73
design option II	9882	€ 1759	11942	€ 717	32694	11.8	5205.0	2.1	€ 211642	€ 76.19	€ 20804	€ 7.49
design option III	16435	€ 2925	15553	€ 933	50066	18.0	9846.0	2.6	€ 193880	€ 69.80	€ 38566	€ 13.88
	cold climate											
reference BVU	-	-	-	-	-	-	-		€ 342418	€ 123.27	-	-
design option I	3899	€ 694	53613	€ 3217	61801	22.2	3808.0	1.0	€ 275431	€ 99.16	€ 66987	€ 24.12
design option II	9882	€ 1759	59799	€ 3588	80551	29.0	5205.0	1.0	€ 264664	€ 95.28	€ 77754	€ 27.99
design option III	16435	€ 2925	77884	€ 4673	112397	40.5	9846.0	1.3	€ 229678	€ 82.68	€ 112740	€ 40.59

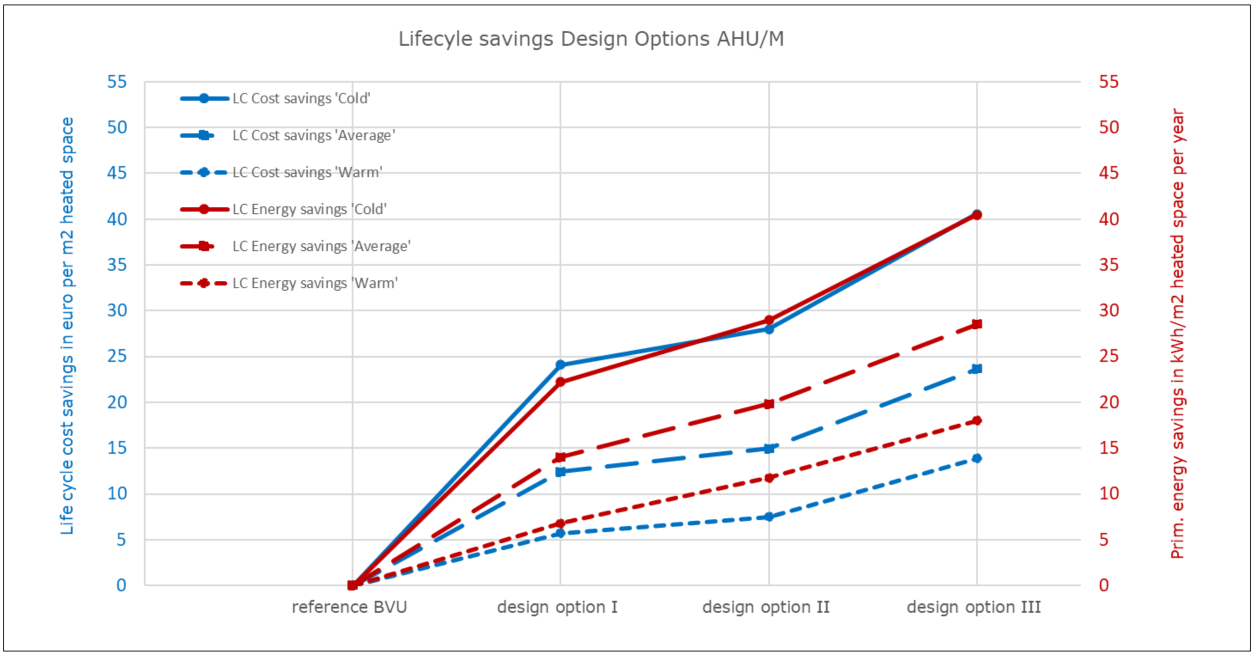
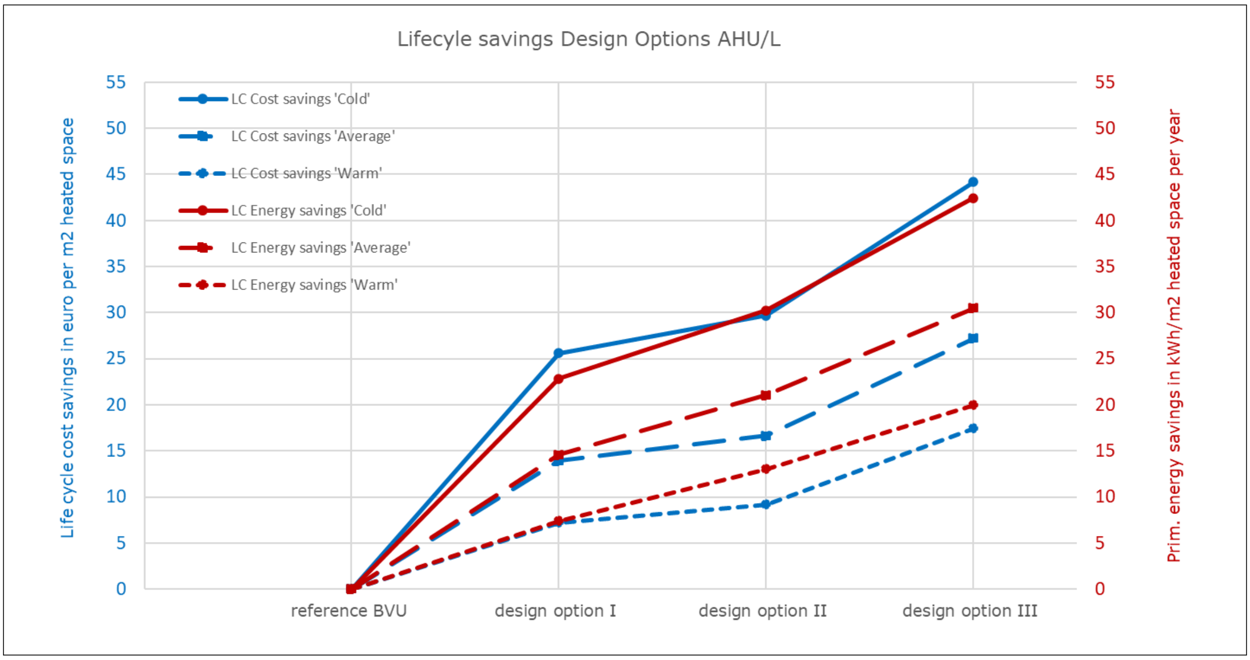


Table 26. Summary AHU/L

	Electricity savings per year		Heating energy savings per year		Total primary energy savings per year		Investment increase	payback time	Lifecycle cost		Lifecycle cost savings	
									per unit	per m2	per unit	per m2
	[kWhe/unit]	[€/unit]	[kWh/unit]	[€/unit]	[kWh]	[kWh/m²]	[€/unit]	[yr]	[€]	[€/m²]	[€]	[€/m²]
AHU/L	average climate											
reference BVU	-	-	-	-	-	-	-		€ 1021656	€ 105.08	-	-
design option I	16339	€ 2908	107616	€ 6457	141928	14.6	7223.0	0.8	€ 886423	€ 91.17	€ 135234	€ 13.91
design option II	40329	€ 7178	120034	€ 7202	204724	21.1	9857.0	0.7	€ 859638	€ 88.42	€ 162018	€ 16.66
design option III	66622	€ 11859	156337	€ 9380	296243	30.5	17064.0	0.8	€ 757222	€ 77.89	€ 264434	€ 27.20
	warm climate											
reference BVU	-	-	-	-	-	-	-		€ 881276	€ 90.65	-	-
design option I	16339	€ 2908	37472	€ 2248	71784	7.4	7223.0	1.4	€ 811219	€ 83.44	€ 70057	€ 7.21
design option II	40329	€ 7178	41796	€ 2508	126486	13.0	9857.0	1.0	€ 791955	€ 81.46	€ 89321	€ 9.19
design option III	66622	€ 11859	54437	€ 3266	194343	20.0	17064.0	1.1	€ 711526	€ 73.19	€ 169750	€ 17.46
	cold climate											
reference BVU	-	-	-	-	-	-	-		€ 1266178	€ 130.24	-	-
design option I	16339	€ 2908	187644	€ 11259	221956	22.8	7223.0	0.5	€ 1017417	€ 104.65	€ 248762	€ 25.59
design option II	40329	€ 7178	209296	€ 12558	293986	30.2	9857.0	0.5	€ 977533	€ 100.55	€ 288646	€ 29.69
design option III	66622	€ 11859	272596	€ 16356	412501	42.4	17064.0	0.6	€ 836819	€ 86.07	€ 429359	€ 44.16



2. Subject matter and Scope

2.1 Proposed exclusions

In consultation with stakeholders, the following additional exclusions and related formulations to the Regulation are proposed:

2.1.1 AHUs, primarily used for air heating and/or cooling

The following text is proposed:

'This Regulation shall not apply to AHUs that are primarily used for air heating and/or cooling, having also a connection to the outdoor (i.e. a ventilation function) with a supply/exhaust air flow rate in regular heating operation (whenever using heat recovery) below 10% of the total declared air flow rate'.

In other words: maximum outdoor air intake is always below 10% of the total airflow (recirculation + outdoor) of the unit.

<u>Stakeholder views</u>

Stakeholders generally agree with this additional exclusion and related formulation. Few comments were submitted:

Spain: fears that this exclusion may represent a loophole.

Eurovent: members believe that, with a clear declaration (in the technical fiche) stating that the maximum outdoor airflow in winter conditions (during heating season) remains below 10%, loopholes are avoided.

2.1.2 VUs used for replacing old units in historic buildings

The following text is proposed:

'This Regulation shall not apply to ventilation units which are exclusively specified as operating in a building officially protected as part of a designated environment or because of its special architectural or historical merit, in so far as installation of a ventilation unit compliant with this Regulation would unacceptably alter the building's character or appearance'

<u>Stakeholder views:</u>

Stakeholders generally agree with this additional exclusion and related formulation.
Some additional comments/clarifications were submitted:

Spain: Historical or special building should be included in a National Catalogues of Historical Buildings; otherwise the 1253 should be applied.

Eurovent: A review of the approach to historic landmark buildings at the national level reveals, that all EU Member States seem to have a legal regime protecting historical buildings and monuments, including a register and a national conservation authority. Examples of relevant existing legislation in different EU Member States are presented in Annex I of Eurovent's

position paper No. PP-2019-11-27. At the national level, there appears to be no ambiguity as to which buildings are historic landmarks and which are not.
Examples of regulatory exceptions of historic landmark buildings in EU legislation already exist. Article 4(2)(a) of Directive 2010/31/EU on the energy performance of buildings, for example, permits Members States not to apply the requirements laid out in Article 4(1) to "buildings officially protected as part of a designated environment or because of their special architectural or historical merit, in so far as compliance with certain minimum energy performance requirements would unacceptably alter their character or appearance".

RLT-Herstellerverband: In the case of historic buildings, this can be circumvented relatively easily by official confirmation in most member countries. In countries where such a mechanism does not exist, however, objective framework conditions, for example the age of the building or a statement by building historians, should be worked towards.
In the case of existing buildings, this is much more problematic. The conclusion suggests that confirmation from the client about an economic unreasonableness is quickly given. However, the many projects, in which a renovation of the plant technology is completely dispensed with, cannot be denied. Here, further considerations are worthwhile as to how these systems can be considered and loopholes can be avoided at the same time.

EVIA: EVIA welcomes the recognition of the specific issues presented by historic and listed buildings. They highlight the point that the same aspects are also applicable in refurbishments where space limitations are a constraint. Manufacturers are reporting that in many cases, refurbishment is prevented due to space limitations with the implication that existing inefficient AHUs are not replaced. EVIA reiterates that the principle of Declaration of Intended Use would solve these issues.

The question is raised whether a procedure can be developed that facilitates this additional exclusion for buildings having a technical room with limited space that can be used by manufacturers and checked by market surveillance.

2.1.3 VUs used exclusively for dehumidification and de-chlorination of spaces

The following text is proposed:

'This Regulation shall not apply to ventilation units which are exclusively intended for dehumidification and/or de-chlorination of spaces that are not designed for human occupancy'

Stakeholder views

Stakeholders generally agree with this additional exclusion and related formulation. The following additional comments were submitted.

Eurovent, EVIA, Spain, RLT: Swimming pools are in the scope because they are intended for human occupation.

2.1.4 UVUs not classified as range hoods but used in commercial kitchen hoods

The following text is proposed:

'This Regulation shall not apply to UVUs equipped with at least one impeller, one motor and a casing, exclusively designed for operation in a commercial kitchen ventilation hood AND not covered in the scope of Commission Regulation EU 66/2014.

Stakeholder views

EVIA: This exclusion underlines issues related to the definition of box and roof fans. The current definition of ventilation lacks clarity and as a result it is possible that box fans might be considered as a non-ventilation application and out of the scope. A separate EVIA proposal on box and roof fans proposes a solution to this issue.

Polverini (EC): Excluding commercial kitchen hoods is already agreed upon; this would only be a formality. .

2.1.5 Other

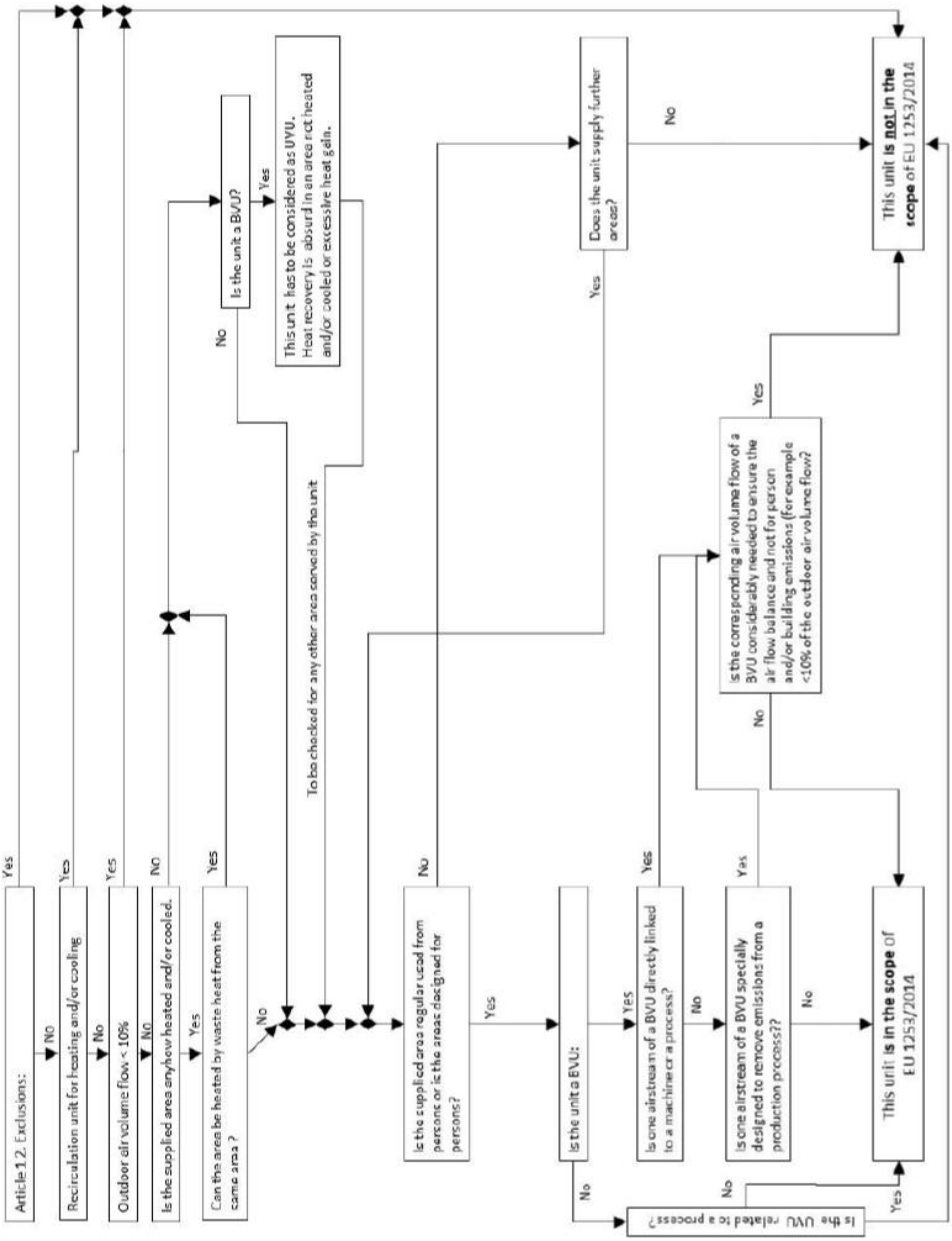
In cases of doubt and regarding the exclusions in general, stakeholders propose to use the decision tree[1] displayed on the next page, to help decide whether a VU is covered by the regulation.

Stakeholder views

Eurovent: In the opinion of Eurovent, an unambiguous list of exemptions should include the following applications:

- units for ventilation, cooling or heating machines or processes situated in spaces which are not normally occupied by people;
- applications with excessive heat;
- applications with high extract air humidity in industrial washing processes;
- process applications with large amounts of particles in Extract air;
- applications with cold room temperatures;
- rooftop units, which are an integral part of the EU Regulation 2016/2281.

[1] EVIA/Eurovent Guidance Document on Ecodesign requirements for ventilation units Release 3 – 10th Feb. 2017 - Including EVIA, Eurovent and EU Commission comments


Article 1.2. Exclusions:
Yes
No
Recirculation unit for heating and/or cooling
Yes
No
Outdoor air volume flow < 10%
Yes
No
Is the supplied area anyhow heated and/or cooled.
No
Yes
Can the area be heated by waste heat from the same area ?
Yes
No
Is the unit a BVU?
No
Yes
This unit has to be considered as UVU.
Heat recovery is absurd in an area not heated and/or cooled or excessive heat gain.
To be checked for any other area served by the unit
Is the supplied area regular used from persons or is the areas designed for persons?
No
Yes
Is the unit a BVU:
No
Yes
Is the UVU related to a process?
No
Yes
Is one airstream of a BVU directly linked to a machine or a process?
Yes
No
Is one airstream of a BVU specially designed to remove emissions from a production process??
Yes
No
Is the corresponding air volume flow of a BVU considerably needed to ensure the air flow balance and not for person and/or building emissions (for example <10% of the outdoor air volume flow?
No
Yes
Does the unit supply further areas?
Yes
No
This unit **is in the scope** of EU 1253/2014
This unit **is not in the scope** of EU 1253/2014

2.2 Possible Scope Extensions

In consultation with stakeholders, the following scope extensions and related formulations to the Regulation are proposed:

2.2.1 Include VUs < 30W per airstream

Article 8 of EU 1253/2014 and article 7 of EU 1254/2014 ask for an assessment of the need to extend the scope of both Regulations for ventilation units with an electric power input of less than 30 W per air stream.

For the Ecodesign Regulation this assessment relates to both UVUs and BVUs with power inputs of < 30 watts per airstream. For energy labelling it would mean an extension with only UVUs < 30 watts.

<u>Include VUs with electric power input < 30 W per airstream in EU 1253/2014:</u>

Based on the feedback received from stakeholders, it is proposed to extend the scope of the Ecodesign Regulation with VUs below 30 watts per airstream that are intended for continuous operation.
It is therefore proposed to remove the current exclusion 2. (a) and (b) in Article 1 of the EU 1253/2014 Regulation, stating that UVUs and BVUs with an electric power input < 30 W per airstream are excluded from the scope (except for information requirements).

Instead, an exclusion for discontinuous UVUs below 30 W is included. The following text is proposed (text recommended by EVIA):

'This Regulation shall not apply to a single room exhaust ventilation unit with an electric power input < 30 watts, that are exclusively specified as operating occasionally to ventilate either one bathroom or one toilet (rest room) by means of an external switch (for example light switch) or built-in motion sensor and/or timer, and do not have the technical possibility to continuously ventilate these spaces by applying either constant or intermittent air flows (i.e. units are always switched off after a certain period), except for information requirements.

<u>Include UVUs with electric power input < 30 W per airstream EU 1254/2014:</u>

It is proposed to also extend the scope of the Energy Labelling Regulation with UVUs below 30 W that are intended for continuous operation (BVUs below 30 watts per airstream were already included).

It is therefore proposed to remove the current exclusion 2. (a) in Article 1 of the EU 1254/2014 Regulation, stating that UVUs with an electric power input < 30 W per airstream are excluded from the scope (except for information requirements).

Instead, an exclusion for discontinuous UVUs below 30 W is included. The following text is proposed (text recommended by EVIA):

'This Regulation shall not apply to a single room exhaust ventilation unit with an electric power input < 30 watts, that are exclusively specified as operating occasionally to ventilate either one bathroom or one toilet (rest room) by means of an external switch (for example light switch) or built-in motion sensor and/or timer, and do not have the technical possibility

to continuously ventilate these spaces by applying either constant or intermittent air flows (i.e. units are always switched off after a certain period), except for information requirements.

Stakeholder views regarding scope extension <30 watts

Stakeholders generally agree with this scope extension and the new formulated exclusion. The following additional comments were submitted.

ECOS: ECOS supports the extension of the scope to include VUs with < 30 W per exhaust, especially considering the current potential loophole described in the study report.

Eurovent: Eurovent considers these products should be regulated. This would level the playing field, even though the energy impact might not be significant. The current exclusion makes it possible to place on the market low energy-efficient products and circumvent ecodesign requirements.

EVIA: EVIA agrees with this scope extension and indicates that a change of the 30 W limit should not have implications for products, which are not intended for residential ventilation. Such implications could e.g. occur in the following cases:

- need for refurbishments in applications with limited space (wall openings, fire restrictions);acoustic requirements in cases where acoustics have lower relevance or higher levels (temporary use, non-residential applications below 250 m³/h).

EVIA continues to prefer maintaining a suitable limit in the EU 1253 revision for minimum requirements, because the energy impact is low and these units < 30 W are typically not designed as a ventilation unit according to the definition used in the regulation.
EVIA would agree to lower the electrical power input in the labelling directive EU 1254 for unidirectional residential ventilation units that provide ventilation according to the definition, meaning all continually running units in analogy with BVU.

Germany: a particularly concerned product group in this context, relates to extract fans (UVUs) especially designed to discharge the extract air of up to 30 toilets and bathrooms of a multi-family dwelling into a common duct by means of over pressure. Consequently, these fans must have a compact design and feature tight non-return dampers within their casing to avoid return flow of exhaust air. Furthermore, to ensure a sufficient air flow for all toilets and bathrooms under all pressure conditions in the exhaust duct at any time, these special fans need to provide a constant air flow characteristic with very limited permissible deviations. In Germany, these fans are third-party certified and regularly monitored according to the DIN standard 18017-3. Because of all the demands and boundary conditions of this particular application, the especially designed UVUs can’t fulfil all eco-design requirements of EU1253 and should therefore be exempt from requirements.

Spain: Spain agrees with this extension of the scope but does not see the need to exclude here the special exhaust UVUs (exhaust fans for common exhaust ducts with an over-pressure (German request)).

Mitsubishi Electric, JBCE JRAIA: argues that VUs below 30 W should be added to the scope in two tiers; first tier: power input limit is 20 W; second tier: power input limit is 15 W.
They also state that VUs below 30 W do not need to comply with the Ecodesign requirements regarding VSD, thermal bypass facility and filter change warning signal.

Aldes: Aldes is of the opinion that all fans should be included, even the incidentally used toilet and bathroom fans. Such fans are numerous, provide high airflows and generally have low efficiencies. If an exemption is to be made, it should indeed be the intermittent fans, provided they automatically switch off (switching capability must be built in the fan (no separate delivery).

2.2.2 BVUs having a heat exchanger and heat pump for heat recovery

Article 1, item 2.(g) of the current Regulation, excludes from the scope ventilation units which include a heat exchanger and a heat pump for heat recovery or allowing heat transfer or extraction being additional to that of the heat recovery system.

This also means that BVUs having a heat exchanger and an additional heat pump for recovering heat from the ventilation exhaust air to the ventilation supply air, are not in the scope. This exemption creates a loophole for ventilation units with an additional (low grade) heat pump, because they do not need to comply with the regulations.

It is therefore proposed to include in the scope 'BVUs having a heat exchanger and a heat pump for recovering heat from ventilation exhaust air to ventilation supply air.'

For the time being, asking for information requirement should be enough.
The information that must be provided here still needs to be determined together with the stakeholders.

Future revisions must investigate what test and calculation methods are appropriate for these products and whether specific minimum requirements are appropriate. It is therefore also proposed to put this product in the review clause of the new Regulation (a proposal for test methods for BVUs having a heat exchanger and an additional heat pump for recovering heat from the ventilation exhaust air to the ventilation supply air, has been included in the prEN 13141-7:2019, but the test however relates to an operating mode with the heat pump switched off).

<u>Stakeholder views</u>

Eurovent: Eurovent states that this exclusion 2.(g) should be erased and NRVUs including a heat exchanger and a heat pump for heat recovery should be covered in the scope of Regulation 1253/2014. The same should apply to NRVUs that only use the heat pump for heat recovery. Minimum requirements of this kind of unit should consider the energy impact of the heat pump and additional pressure drop over an evaporator and a condenser. Eurovent is looking into specific evaluation methods for these products.

DTI: DTI proposes a formulation that states that only multifunctional VUs can be categorized as heat exchangers, meaning that the supply air temperature must not exceed the extract air temperature. Nonetheless, DTI acknowledges that such a definition will not avoid loopholes.

Talteka: The Finnish Building Services Industries and Trade Organization, states that these units should be included. However, the thermal efficiency requirement can be set only for those conditions for which there is a method that can be used for verification of the requirement. At the moment, there is only a method for situations where no heating or cooling is injected into the RAC-circuit. Talteka is in favour of an approach that allows for situations where heating or cooling is injected. However, there are no known activities in any standardization committee for including this kind of a method in its standardization programme. Talteka has prepared an initial proposal on how to do this in its r position paper (Talteka's comments 20191220 and appendix). The proposal is based on the concept of determining the correct amounts of active cooling/heating that is needed to achieve supply air temperature efficiencies of 100% (or in other words, supply air temperature = exhaust air temperature).

2.2.3 Multifunctional Residential BVUs

It is proposed to include Multifunctional Residential BVUs (residential BVUs that have one or more other functions in addition to ventilation, e.g. space heating/cooling, DHW) in the Review Clause of the revised VU Regulations EU 1253 and EU1254.

Multifunctional residential BVUs are defined as units that are designed and supplied as a complete package with mount instructions, covering packages that contain at least one or more casings, supply and exhaust air fans, air filters, common control system and one or more of the following three additional components: air to water heat pump; air to air heat pump; air-to-air heat exchanger and additional heating/cooling functions next to its primary function ventilation with heat recovery.
As indicated in the Task 1 report, products are eligible for measures if they are economically significant, have a significant environmental impact and represent a significant saving potential. Currently is it estimated that the sales figures of these multifunctional BVUs are below 15000 units a year. Recent estimates from Eurovent for 2017 do not go beyond 4000 units. The preliminary assessment in this Task 1 is, that the EU-saving potential in the short term is not enough to justify an extension of the scope per 2020/2021, but that it certainly is recommended to anticipate future extensions by providing a proposal for a method for rating these multifunctional BVUs under the VU-Regulations EU 1253/2014 and EU 1254/2014.

It is recommended however, to include performance data of these multifunctional residential BVUs according to EN 16573, in the information requirements.
In the Task 3 report the study team recommends the following approach:

1. Only multifunctional residential BVU-packages (MF-BVUs) that fulfil these multiple functions completely (as in no other products from a third party are needed to meet the declared capacity of the functions that are offered by the MF-BVU, (heat-load/cool-load/dhw-tapping pattern, and the ventilation needs)) can reside under the regulations.
2. The manufacturer specifies at what specific average ventilation airflow rates qv,MF,ref (in m³/h/m²) the multifunctional unit should operate to achieve its optimum overall energy performance and its declared heat/cool-load and/or dhw-pattern.
3. The contribution of the energy recovery from ventilation to the other heating functions (DHW, hydronic/heating, air heating/cooling) are determined at the reference ventilation rate of the MF-BVU, which corresponds to 70% of its maximum ventilation capacity.
4. Test institute tests and confirms that the supplied ventilation controls and related options for control-settings are in line with and facilitate the specified specific average ventilation airflow rates qv,MF,ref (in m³/h/m²).
5. The energy performance of the ventilation functions of the MF-BVU is determined with the SEC-formula from the EU 1253/2014 regulation, using for the CTRL-factor the value that is ascertained with the formula: CTRL = qv,MF,ref / qref .

<u>Stakeholder views</u>

Five of the leading European industry associations in the sector (EPEE, EHPA, Eurovent, EVIA and EHI) share common concerns over the approach taken to the integration of multifunctional units within the EU's framework for Energy Related Products (ERP).
In particular, they have reservations on the proposal outlined in the Task 7 Final Report1 on the revision of EU 206/2012 (Small air conditioners and comfortsfans) to extend the scope to include ventilation exhaust air-to-air heat pumps and air conditioners whose rated capacity is

≤ 12 kW. According to these European Industry Associations, multifunctional bidirectional ventilation units (two fans), having the primary function of ventilating the dwelling or building and delivering energy contributions to additional functions like space heating, cooling and/or domestic hot water should be included in the Regulations for ventilation units (EU 1253/2014 and EU 1254/2014) and not in the proposed revised scope of EU 206/2012.

DTI: DTI agrees with including MF-BVUs in the Ventilation Unit Regulations

Nilan A/S: Nilan also agrees that they should be included in the EU 1253/2014 and 1254/2014, as the market for these products is increasing. The fact that they are now not included, poses the following problems:

- hese kinds of units are sold on the same market and in competition with standard ventilation units;
- buyers do not have the opportunity to compare these different technologies with each other by energy label and SEC calculations
- it is a distortion of competition that these units are not included in 1253/2014, as they do not have an energy label or ecodesign data. As a result, these buyers of ventilation units with heat pumps do not receive subsidies, which in fact promotes units without a heat pump although the MR-BVU may in fact be a better solution;
- we sell more units with a heat pump in countries where cooling is a demand because of a warmer climate, but also in countries where cooling does not normally occur , we have experienced a higher demand for cooling;
- there is no control over the energy consumption of units sold with heat pumps as they are not covered by any regulations at the moment.

Uniclima: for multi-functional ventilation units fitted with a heat pump, we think that it is too early to introduce Ecodesign requirements. As a start and in coherence with the direction taken for RVU multifunctional units, information dissemination would be a first step, ideally based upon a used and comprehensive standard.

JBCE JRAIA: The Japanese Business Council Europe disagrees with including a multifunctional unit with a heat pump in scope. The opposing reason is that GROW-Lot6 is a standard for ventilation fans; BVU with a heat pump and BVU without it have different functions in the first place, making comparison with the same index very difficult. If BVUs equipped with a heat pump are the target device, we think that a new standard for them is necessary.

3. Regulatory Options RVUs

3.1 Ventilation Performance

Ventilation Performance is not properly addressed yet in the current VU Regulation. It is proposed to include two performance indicators on the Energy Label:

1. Ventilation Performance Indicator (VPI)
2. Filter type / filter class

Ad 1)
The VPI is an indicator for the air exchange performance of the VU. More precisely, it is an 'indicator of the system's ability to induce the correct air exchange rates in the right place at the right time'. The references for the correct air exchange rates needed during presence and absence are derived from EN 16798-1, Annex B, Category II).
It is based on an assessment of the technical features of the VU-type, its co-supplied controls and its associated room based air exchange provisions. For a Ventilation Unit without co-supplied controls, a default basic controls (manual switch) will be assumed. This means that only controls that are co-supplied and invoiced by the manufacturer qualify for the VPI assessment.
The Ventilation Performance Indicator can be calculated by determining the ratio of the minimum required AER for achieving 100% AEP and the actual AER needed for the ventilation system at hand (including controls) to achieve the 100% AEP. This ratio can also be referred to as 'airflow efficacy' because it addresses the effectiveness of the airflows that are induced in a dwelling in relation to its occupancy schedule.

It is proposed to develop and use a predefined and aggregated VPI-table, covering the ventilation performance indicators for the various ventilation package types that are offered on the market and to include this table as an annex to the RVU-regulations. See Annex 2 for a proposal of the VP-Indicators.

Ad 2)
The filter type (filter class) used for the supply air is a direct indicator of the quality of the supplied air. It has to be determined what indicator shall be used here (ISO 16890 indications, the old EN 779 indicators, or other?).

<u>Stakeholder views</u>

ECOS: We agree with the need to have the ventilation performance of the unit displayed next to the energy label. As mentioned, it does not make sense to display the energy efficiency without information on the performance. Proposal: Indicate the performance of the ventilation unit on the energy label.

EVIA: EVIA welcomes the introduction of the assessment method for determining the ventilation performance aspects for residential ventilation. This is a step forward for good performance ventilation. Future support will mainly depend upon the way the actual implementation (and its simplicity) is proposed.

Eurovent: Eurovent can support this proposal when the following conditions are met: 1) the methodology that is used is profoundly clarified, 2) the methodology is transparent, reliable and validated.

Renson: Renson welcomes the introduction of the assessment method for determining the ventilation performance for residential ventilation.

DTI: DTI finds the ventilation performance method developed by the consultants for EVIA interesting and would like to see it as a part of the regulation and the label (like other air treatment parametres that influences the IAQ). But for now, DTI cannot yet support it for the following reasons: 1) Missing proof of concept; 2) It strongly depends upon the air-exchange provisions which is on a system/building level and not part of the delivery from the manufacturer; 3) Ventilation performance further depends upon the temperature difference between the supply air and the room, the airflow, the room geometry and the size, and the location of provisions which cannot be known in advance.

With regard to displaying the filter type, some manufacturers are in favour of using the ISO 16890 indications, while others prefer the ABC..G classification because it is more understandable to consumers.

3.2 New list of CTRL-factors

It is proposed to replace the list of CTRL-factors currently used in the regulation.

Table 27. CTRL-factors existing Regulation

	CTRL-factor
Manual control	1.00
Clock control	0.95
Central DCV	0.85
Local DCV	0.65

These CTRL-factors do not relate to any reference regarding ventilation performance and furthermore they do not sufficiently discriminate the control systems that are currently on the market. It is therefore recommended to introduce a new and larger table with CTRL-factors, covering the wide range of VU-package currently offered on the market for which the CTRL-factors are determined based on a fixed reference ventilation performance (according to category II, following Annex B of the EN 16798-1).
Only then, the energy performance indicators resulting from the SEC-formula, can be compared to each other (see Task 3 section 1.5.1).

The CTRL-factor will be assessed on the basis of the technical features of the VU-type, its co-supplied controls and its associated room-based air exchange provisions. For a Ventilation Unit without co-supplied controls, a default basic controls (manual switch) will be assumed. This means that only controls that are co-supplied and invoiced by the manufacturer qualify for the CTRL-factor assessment.

The CTRL-factor can be calculated by determining the ratio of the AER needed for the ventilation system at hand to achieve 100% AEP and the reference AER for a selected reference ventilation system. This reference ventilation system relates to the simplest control option for the VU and hand, i.e. manual control.

See Annex 1 for a proposal for a new and extended list of CTRL-factors, which in its current version represents the latest status of this CTRL-list following feedback from stakeholders.

Stakeholder views

EVIA: EVIA welcomes the introduction of the assessment method for determining the CTRL-factor of residential ventilation. But the assessment method shall not be used to recalculate other, more system orientated data and corrections. EVIA stresses that the extended CTRL-table must remain of a generic nature and cover all possible VUs.

Eurovent: Eurovent will support this proposal when the following conditions are met: 1) the methodology that is used is profoundly clarified. 2) the methodology is transparent, reliable and validated. Questions arise though for situations where controls are added in a later stage in the supply chain (e.g. by the installer) which is out of the control of the manufacturer.

VHK: member states indicate that the current system (where a declaration for the applicable CTRL-factor suffices) does not work because in practice the best CTRL-factors are declared but related controls are not installed.
The new proposal entails that all companies that put RVUs on the market can offer their units with or without controls (same as today), the difference being that now they need to organize the invoicing of the complete package (i.e. including controls ordered by the client). The logistics of possible additional control packages can be outsourced, as long as the specification of the controls and the related invoicing is done by the company that puts the RVUs on the market. Such an approach is already being applied in the boiler and water heating market.

3.3 Adjustments SEC-formula

The formula currently used in the Regulation for calculating the specific energy savings of a VU in relation to a fully naturally ventilated building, is presented in the box below.

Table 28. SEC formula existing Regulation

$$SEC = t_a \cdot pef \cdot q_{net} \cdot MISC \cdot CTRL^x \cdot SPI - t_h \cdot \Delta T_h \cdot \eta_h^{-1} \cdot c_{air} \cdot (q_{ref} - q_{net} \cdot CTRL \cdot MISC \cdot (1 - \eta_t)) + Q_{defr}$$

3.3.1 Additional references natural ventilation rates q_{ref} needed

The term q_{ref} in this formula is the 'reference natural ventilation rate' which is set at 2.2 m³/h per square metre of heated space. This is the average AER of a naturally ventilated dwelling (using passive stack – infiltration – natural supply grids air vents), and is used for both the habitable spaces and the wet spaces. In other words, this 2.2 value is used as reference airflow for calculating the energy savings of whole house RVUs.

Because - as indicated in the Task 5 report - it is proposed to base this reference natural ventilation rate on a value that refers to and includes the total infiltration airflows of the existing naturally ventilated building stock and because we are now also assessing local RVUs, some modifications regarding q_{ref} are needed:

1. q_{ref} is adjusted: the average total airflow (including infiltration) of naturally ventilated EU building stock is 2.50 m³/h per square metre of heated space;
2. additional q_{ref} values are needed for non-ducted RVUs; for a correct comparison of the energy performance or SEC-value of non-ducted RVUs with ducted RVUs, these values preferably relate to the q_{ref} of ducted units (= 2.50 m³/h/m²). Since with non-ducted (local) RVUs, roughly 60% of the total airflow in a dwelling is used/needed for habitable

spaces, and 40% for wet spaces (see also Task 5 report), the following values are proposed:

Table 29. Proposed values for q_{ref}

	q_{ref} whole house [m³/h/m²]	q_{ref} per local RVU* [m³/h/m²]
for whole house	2.50	
share for habitable spaces	1.50	0.50
share for wet spaces	1.00	0.34

* Assuming 3 local RVU-ES and 3 local RVU-HS

3.3.2 Adjusted and additional values needed for qnet

Applying a fixed reference for the ventilation performance, results in another value for the net ventilation requirement 'q_{net}', than currently used in the Regulation.
Currently the value q_{net} =1.3 m³/h per square metre of heated space is used. But when the reference MEV-ventilation system (which is defined as a basic central extract UVU for wet spaces with a manual switch in the kitchen, combined with natural supply provisions in the habitable spaces) must achieve this reference category II ventilation performance (following Annex B of the EN 16798-1), a net ventilation requirement of q_{net} =1.97 m³/h per square metre of heated space is needed.
Also for the local BVUs and UVUs corresponding values are determined, based on the application of basic manual controls for such units. The following values are proposed:

Table 30. Proposed values for q_{net}

	q_{net} whole house [m³/h/m²]	q_{net} per local RVU* [m³/h/m²]
for whole house	1.97	
share for habitable spaces	1.18	0.39
share for wet spaces	0.79	0.26

* Assuming 3 local RVU-ES and 3 local RVU-HS

3.3.3 Deleting 'MISC'

MISC is defined in the current Regulation as an aggregated general typology factor, incorporating factors for ventilation effectiveness, duct leakages and infiltration. Values for MISC are 1.1 for ducted units and 1.21 for non-ducted units.
Because the assessment method for the CTRL-factor already incorporates these factors and even additional factors (e.g. internal leakage, filter compensation), it is proposed to skip this MISC-parameter.

An initial assessment of the achievable CTRL-factors shows, that the probable lowest value is about 0.35, indicating that ventilation airflows (achieving category II ventilation performance) may range from 0.35 * 1.97 = 0.69 m³/h per square meter of heated space to 1.0 * 1.97 = 1.97 m³/h/m².

The current regulation accommodates the lowest ventilation airflow (without reference to a ventilation performance) of MISC * CTRL * q_{net} = 1.1 * 0.65 * 1.30 = 0.93 m³/h per square metr of heated space and a highest airflow rate of 1.1 * 1.30 = 1.43 m³/h/m².

These calculations show that the new proposal allows for a slight reduction of the lowest threshold value (from 0.93 to 0.69 m³/h/m²), but also facilitates a larger differentiation between systems which can be used to promote smart and better performing ventilation systems.

3.3.4 Adjusted definition for ηt

It is proposed to use temperature efficiency values in the SEC-formula that are corrected for internal and external leakages, for indoor and outdoor mixing and for airflow sensitivity, following the FprEN13142.
Or, in other words, η5 is to be used instead of η0 for ηt. In addition, it is proposed to replace this ηt by ηe, being the symbol for the total recovered energy (thermal and humidity).

3.3.5 Energy frost protection depends on actual airflow

The SEC formula employs a fixed value Qdefr for indicating the energy consumption for frost protection that only depends on the climate zone for which the SEC-calculations are made (5.82, 0.45 and 0.0 kWh/a/m² for cold, average and warm climate respectively).

These values however should relate to the actual airflow that the VU induces, or in other words, the Qdefr value must be multiplied with the CTRL-factor.

<u>Stakeholder views</u>

Regarding MISC AND INF-factors

Annex F of the FprEN 13142:2019: by means of Annex F in the latest FprEN 13142, it is claimed that the current values for the MISC do not reflect the real aspects of cascading VUs in dwellings. The term 'cascading' is not further explained in this context but it is assumed that the term is used to indicate the difference between a central RVU and several decentralized BVUs and its effect on the overall airflow in a dwelling.
To reflect the estimated effect of cascading, stakeholders propose adjusted value for the MISC factor: 1.0 for UVUs and central BVUs, and 1.5 to 2.0 for a local (non-ducted) BVU (instead of the previous values 1.1 for ducted and 1.21 for non-dusted).

In the same draft standard (also Annex F), it is also proposed to include a new parameter 'INF' into the SEC-formula. Stakeholders believe that the current values for MISC do not sufficiently address the topic infiltration. They feel that the impact of the over or under pressure in the building (induced by UVU-systems) on the in-/exfiltration rates is not adequately accounted for in comparison to BVUs that result in a neutral pressure in the building. Stakeholders therefore propose to include a new parameter 'INF' into the SEC-formula, in addition to the MISC-factor.
This INF-factor is used to increase the qref (reference natural ventilation rate per m² heated floor area (in m³/h/m²)) having a default value of 2.2 m³/h/m². See also informative Annex F of the FprEN 13142:2019.

This additional INF parameter only influences the SEC-value for exhaust ventilation systems and supply ventilation systems, but not for balanced ventilation systems. The values proposed are: 0.10 for cold climates, 0.18 for average climates and 0.36 for warm climates.

DTI: If the MISC is adjusted according to the proposal, it means that non-ducted units will have a very difficult task of staying in the market. Even though that ducted VU is often the best solution, sometimes and depending on the building, it is not possible to make balanced ventilation with ducted VU units and an alternative is therefore needed. In our opinion, it will decrease the development if it is difficult for the non-ducted units to achieve a good energy label (A to B). We do not therefore support the adjustments to MISC.

In summary, stakeholders indicate that these modifications as proposed in Annex F should be incorporated into the revised Regulation.

Regarding ηt

Eurovent: Eurovent supports the proposal to correct temperature efficiency for leakages (ηt = η5 instead of η0). But it also asserts that a discussion to find correct values for η5 is needed. In our view, the current proposal of η5 in the harmonized FprEN 13142 does not correctly take account of the leakage test method (pressure test, in-duct tracer gas test or chamber tracer gas test). There is a common understanding among experts that the results of these methods cannot be directly compared. This situation could lead to inconsistencies in the evaluation and rating of RVUs.

EVIA: EVIA agrees with using η5 instead of η0 but insists on strictly using the measurement procedure and correction procedures presented in standards EN 13141 and EN 13142. These procedures are well established and the pressure method is, where applicable, a cost-effective way to ensure good quality.
The correction of thermal efficiency presented in EN 13142 table was the result of an intensive debate with all stakeholders and has wide acceptance in the market.
EVIA recommends maintaining the current test methods as described in EN 13141 standards, which reflect a good balance of easy and cost-effective testing to ensure good product quality.
This means:
the pressure method applies to classify the external and internal leakages of category I heat exchanger units, as well as the external leakages of category II heat exchangers.
The tracer gas method applies to classify external and internal leakages of category II heat exchanger units by using the chamber method as well as the internal leakages of category II heat exchangers by using the duct method.

Reaction study team

The effect of the INF-factor is, that the SEC values for UVUs will be increased (they will achieve higher savings) relative to BVUs by (depending on the climate zone) about 10% for cold, 18% for average or 36% for warm climates. The effect of the adjusted MISC-factor is that local BVUs are even further degraded compared to the other RVU types s by a factor of about 1.5 to 2.0.

Legitimacy for these adjustments in the relative position between UVUs and BVUs is found in the differences in infiltration airflow and overall airflow in the dwelling.

The following arguments can be made against these proposals:

1. New ventilation systems do not rely on infiltration for their air supply but use dedicated air supply provisions, either natural (ventilation grids) or mechanical. The

main reason is that the airtightness of new and renovated dwellings is considerably increased. Using infiltration as an upgrade for UVUs is therefore not a very future-proof approach.

2. Airtightness of a building is not a characteristic of the ventilation system, but a given condition of the building. The purpose is to assess the performance of the ventilation system, irrespective of the dwelling it is applied to .
3. When determining the performance of VUs, it is preferred to use the same reference for all VU types, in order to be able to make a comparison. Using different reference ventilation rates is not a very practical approach.
4. With increased infiltration rates, the authority of the ventilation system is reduced, or in other words, its ventilation performance is impaired. This means that with low airtightness values, higher UVU ventilation flows are necessary to achieve reference ventilation performance. It also means that bigger infiltration airflows are generated, of which a large part (>50%) do not enter the dwelling through the habitable spaces, implying an increase of untargeted air exchanges.
5. Concerning the adjusted MISC-values, it is not clear what is meant with cascading and how it effects the performance of the local BVUs. Local BVUs are normally used in habitable spaces, combined with local or central extract UVUs in wet spaces. The air exchange efficiencies of local BVUs are considered sufficient (see Task 4 report) and with the local of central extract UVUs in wet rooms, the airflows through the dwelling (including connecting spaces) is also considered. So, the purpose of this adjusted MISC-value is not sufficiently explained nor substantiated.

All in all, instead of an increase in the ventilation performance of UVUs, the over or under pressure caused by UVU-systems indeed lead to increased infiltration rates. However, this results in a reduced ventilation performance and an increase in the energy consumption.

It is therefore recommended not to follow annex F of the FprEN 13142:2019.
Instead, it is proposed to use the Ventilation Performance Assessment Tool (VPA-Tool) as described in Task 3, section 1.2.1 to determine the impact of airtightness, leakages and infiltration on the ventilation and the energy performance of the VU, since all these aspects are integrated in the VPA-Method, including the double use of air (air used to ventilate habitable spaces is also used for wet spaces) as is the case with certain UVU-systems.

2nd round Stakeholder views

Aldes: argues that UVUs indeed create an additional (over or under-) pressure over the façade, but that this in fact reduces the infiltration flows instead of increasing them because a pressure barrier is created.

3.4 Filters and their energy consumption

Currently, the energy impact of clean filters is included in the Regulations for RVUs and NRVUs. When the maximum flowrate is determined, the VU must be completely installed (e.g. including clean filters); see also EU 1353/2014, Article 2, definition (4).
For RVUs however, no corrections are prescribed in case filters which are not present. This most probably means that a lot of bidirectional RVUs are tested without filters, leading to somewhat higher declared flowrates and somewhat lower SPI-values.
In real-life, filters have a significant impact on the SPI and the related annual power consumption. Depending on the filter class, the filter size (= air velocity over the filter media) and the filter resistance characteristic at growing dust loads, the pressure drop over a filter

can easily increase by a factor 7 from, for instance, 30 Pa for the clean filter to above 200 Pa when filters are not replaced regularly.

It is therefore proposed to make it mandatory to include the filters in the VUs when they are offered for testing. If no filters are provided by the manufacturer, the unit cannot be tested. With regard to the information requirements for RVUs, it is proposed to include the following information on filters:

- filter classes used for supply and exhaust;
- filter-velocity;
- clean pressure drop;
- final pressure drop and related expected filter change intervals;
- power consumption of used/full filters in case they are not exchanged;
- filter by-pass leakage indication.

For the future it is suggested to develop a separate energy label for filters, preferably in analogy with the method developed by Eurovent for filters used in NRVUs. With such a label, energy consumption of filters remains a topic for all future replacement and purchase times. Currently, this is not possible due to the filter test facilities that are all designed for high flow rates, large filter sizes and mainly non-residential application.

3.5 Including humidity recovery

Recovery of latent heat and humidity can be advantageous. Especially in warm climate zones, recovery of latent heat and humidity is an asset since it can significantly reduce the energy needed for cooling, when compared to sensible heat recovery only.
In average and colder climates, recovery of humidity will lower the risk of frozen heat exchangers and will help increase the humidity levels of indoor air during winter periods. For these reasons, industry associations are in favour of including this humidity recovery feature into the revised Regulations. Their proposal is to use an energy efficiency parameter 'ηe' instead of the temperature efficiency 'ηt', and to apply the limit values for energy recovery to ηe instead of ηt, with $\eta e = \eta t + c * \eta x\_c$

It is therefore proposed to include humidity recovery features into the revised Regulations, using the formula (as proposed by EVIA):

$$\eta_e = \eta_t + 0.08 * \eta_{x\_c}$$

where

η_e	=	efficiency of the total recovered energy (thermal + humidity)
η_t	=	efficiency of the thermal heat recovery (sensible heat)
η_{x_c}	=	efficiency of the humidity recovery (to be tested acc. to FprEN 13141-7 or FprEN 13141-8)

Including humidity recovery into the revised regulations represents an important step. Not because it makes the application of heat/energy-recovery in warmer climates more viable (which is indeed the case), but because it is also introduces a new topic into the discussion, namely a potential carry-over of contaminants and micro biological contamination in enthalpy exchangers for both regenerative and recuperative types of exchangers.

Further discussions with stakeholders will be necessary to determine whether minimum limit values on the contaminant carry-over for the various exchanger materials are required.

Stakeholder views

DTI: DTI can support the proposal from EVIA, if the heat recovery does not exceed 100% and that the amount of recovered moisture can be controlled by the VU control system.

Eurovent: in the first Position Paper of March 2019, Eurovent has proposed considering humidity recovery for NRVUs. It was motivated energy-wise, since in applications involving control of indoor air humidity, the use of enthalpy heat exchangers leads to significant energy savings (for humidification and dehumidification). In residential applications, the indoor humidity control is not a typical case. The proposed approach to compensate for temperature efficiency by humidity efficiency might result (particularly in a cold climate where a very high temperature efficiency is required) in insufficient (too low) temperature of supply air leaving the exchanger. However, given that the moisture recovery lowers the HRS freezing temperature limit and improves IEQ, Eurovent would support this proposal provided the bonus factor in the ηe formula is adjusted to the climate conditions. Eurovent will submit a clarified position and a proposal for adjustment.

Heatex: Heatex supports the implementation of the requirement of humidity recovery and thus total recovered energy efficiency.

3.6 Reference pressure parameters

Two topics regarding reference pressure are discussed here. The first deals with the reference external pressure that is to be used for determining the reference airflow of an RVU. The second topic relates to the proposal to use a more specific definition of external pressure that looks at the total external pressure and not only the static external pressure.

3.6.1 Reference external pressure difference

For RVUs the SEC-value is calculated based on the Specific Power Input (SPI) measured at the reference airflow rate. For ducted RVUs, this reference airflow rate corresponds to at least 70% of the maximum airflow rate measured at 50 pascal external pressure difference. Based on this value the energy class of the RVU is determined (G to A+).

Over the last couples of years , the practice has been to select an RVU on the basis of the energy label and this has not always resulted in a real-life energy consumption that is coherent to the labelling scheme. This is due to the fact that the external pressure difference in the field differs from the reference that is set at 50 Pa (for a further explanation, see Task 3 Section 1.8.2).

It is therefore proposed to use a mathematical function that relates the applicable reference external pressure to the maximum declared flowrate, instead of a fixed reference external pressure of 50 Pa at which the reference flowrate is to be determined.
The proposed mathematical function for determining the reference external pressure difference is :

$$\Delta P_{s,ext.} = 6.32 * q_{max}^{0.5}$$

Stakeholder views

Eurovent: Eurovent supports the principle of adjusting the applicable reference external pressure to the declared maximum flowrate instead of using the fixed value of 50 Pa and to determine the reference flowrate accordingly. We maintain that there should be a clear distinction between the maximum working point and the reference working point.

EVIA: EVIA insists upon keeping the current procedure for reference and maximum flow as described in EN 13141 and EN 13142. Industry has made huge efforts to clarify this issue but the effect and the benefit of the new proposal cannot be understood.
It is clear that real life pressure in duct systems influence performance but the proposal shown does not solve this issue. EVIA contend that the proposal will open additional loopholes.

MITSUBISHI ELECTRIC: does not support this proposal. This is because a manufacturer can select its own reference external pressure, making it difficult to compare performance values across different manufacturers. It is not only the duct diameter, but also the layout of ductwork, distribution boxes and materials that influence the external pressure difference. Therefore, MITSUBISHI ELECTRIC supports keeping the current procedure for the reference and maximum flow as described in EN13141 and EN13142.

EU AMCA: prefers to keep the current reference external pressure of 50 Pa.

2VV: the idea of external static pressure depending on airflow is in principle good. Bigger airflow requires a larger duct system with increased pressure drop. The proposed mathematical function needs to be adjusted to relate to reasonable values for the external reference pressure. Proposed mathematical function: ΔPs,ext. = 6.32 * qmax0.5

After long discussions it is was decided to keep the existing method: 'using a fixed value of 50 Pa external pressure difference.'

3.6.2 Reference pressure parameters

Current regulations use the parameter 'external static pressure difference' ΔPs,ext in the energy efficiency assessment of RVUs and NRVUs. This parameter however does not consider the dynamic pressure at inlet and/or outlet of the ventilation unit as a component in the energy transformation from electric energy (input) to flow energy (output). This can lead to an incorrect assessment of the energy efficiency of ventilation units (see Task 3, Section 1.8.3 for further explanation).

It is proposed to use the following pressure parameters in the EU regulation for ventilation units for determining the reference point for the energy efficiency assessment:

Pus : unit static pressure as difference between static pressure at unit outlet and total pressure at unit inlet
pu : unit pressure as difference between total pressure at unit outlet and total pressure at unit inlet

These pressure parameters lead to a single and unambiguous reference point. The pressure parameters are in full analogy to the pressure parameters pf and pfs for fans according to ISO 5801 and shall be linked to the intended installation category of the ventilation according to the following table:

Installation category			**Example (ventilation unit)**	**Pressure parameter RVU, NRVU**	Pressure parameter Fans *)
A	free inlet / free outlet		**wall fan with casing**	p_{us}	p_{fs}
B	free inlet / ducted outlet		**„toilet fan“ (box fan)**	p_u	p_f
C	ducted inlet / free outlet		**roof fan**	p_{us}	p_{fs}
D	ducted inlet / ducted outlet		**duct fan, air handling unit**	p_u	p_f

<u>Stakeholder views</u>

Stakeholders are in favour of using pus and pu parameters.

3.7 Limit values BVU leakages

Currently there are no limit values for BVU leakages. There is only an information requirement regarding this topic (see EU 1253/2014 Annex IV, item 1(o) and 1(p).
Leakages inside a bidirectional ventilation unit (BVU) will compromise the ventilation capacity of the unit because outdoor supply flowrates and/or exhaust air flowrates are not in conformity with the specifications of the product. Leakages will also influence the heat recovery performance. Anecdotal reports on leakage rates for non-ducted local BVUs mention leakages of up to 40%, indicating that these unintended airflows can have a significant impact on the key performances of such ventilation units. Apart from information requirements, the current Regulations EU 1253/2014 and 1254/2014 do not consider leakages or mixing when determining the heat recovery performance, the SPI and the outdoor supply air flowrate of RVUs.

It is therefore proposed to introduce the following limit values for Internal and External BVU-leakages:

For ducted BVUs, following FprEN 13141-7 (table 4)

- Class A2 (<7%) when pressurization test is used
- Class C3 (<4%) when in-duct tracer gas test is used
- Class B3 (<6%) when the chamber tracer gas test is used

For non-ducted BVUs, following FprEN 13141-8

- Class U2 (<7%)

It is also proposed to correct the declared outdoor supply and indoor exhaust mass-flows for these leakages.

Stakeholder views

Eurovent: Eurovent supports the introduction of limit values for BVU leakages. Taking into consideration the current status of standardization, they agree with the proposed limit classes for ducted BVUs. Given that method C is not considered reliable enough if the external leakage is high, we propose to set, in addition, a limit for class B3 if the chamber tracer gas is used. Since the proposed limits for the leakage are low, Eurovent does not support the proposal to correct the declared outdoor supply and indoor exhaust mass-flows for these leakages. In the opinion of Eurovent members, the energy impact is reflected in heat recovery, thus introducing a correction of ηt due to leakages (η5) is enough. Moreover, we firmly express our opinion, that a unified method for leakages test (most preferably pressure based) of ducted BVUs should be developed to ensure comparable evaluation of any unit (as a 'black box') regardless of the HRS type.
For Residential Ventilation Units i.e. with the maximum flow rate in the range of 250 m³/h to 1000 m³/h and declared by the manufacturer as intended exclusively for use in residential application, the leakage rating should still be performed acc. to EN 13141-7.

DTI: Based on the available test data, it is recommended that the maximum allowable leakage is A1 in accordance with table 4, prEN13141-7 which corresponds to a leakage of ≤ 3%. This leakage is archivable for the majority of the RVUs on the market today and the manufacturers should be able to comply with this, without further problems or significant extra costs.

Furthermore, it is recommended to use only one test method for all RVUs regardless of whether the unit is ducted or non-ducted and regardless of the heat exchanger type. It is recommended to use the pressurization test because the test method is relatively simple, reliable and reproducible. In addition, the costs for the test setup and instruments are relatively low.
Regarding the non-ducted units: DTI has no profound experience with the non-ducted RVUs and therefore it is recommended to follow the prEN13141-8:2019.

EU AMCA: A common internal leakage test method for recuperative and regenerative heat exchangers needs to be determined first before further discussing any changes.
EU-AMCA is against this proposition, as it is not possible to control the external pressure drop of the system.

VKE: The regulation has indeed not specified a maximum limit for leakage. However, it has identified which standards should be the basis for RVU regarding temperature efficiency (EN 13141-7). In EN 13141-7, the maximum leak limit is set for the efficiency tests to be considered reliable so indirectly there is already a maximum limit. The problem here is that you have different testing methods that are not fully consistent and the limits for these can seem very unfair at closer examination.

There is now a suggestion, which could prove a good idea, that based upon leakage classes, a bonus/penalty could be given relative to the different contexts. However, given how the table for limit values is established, it is a major concern.

It may even be that these requirements put rotor technology (regenerative heat exchanger) out of play as there are very strict requirements to stay within the maximum limit. In addition to this, the testing methods for rotor technology (rotating regenerators) are expensive and complicated compared to the pressure test method used for counter-current, In this case we would need a more uniform test and requirements.
The same principle is also valid for EN 13142, EN 13141-8 and a correction for leakages is suggested. The method for testing should be harmonised/made comparable and the limits should be aligned in accordance with this.
We would like to emphasize that the methods/limit levels should be tested/evaluated and should preferably result in a simplified test that can be used for all types of heat exchangers (carry-over leakages can be calculated). Then we could have one single table for all heat

changers. The limit values today are set to what is just possible to cope with a regenerative heat exchanger, as the carry-over leakages account for the bulk of leaks in modern AHUs with higher requirements for efficiency degrees. To give higher energy efficiency we need larger rotors, which again gives more carry-over leakages.

Reaction study team

All leakage tests are to be determined before the temperature ratio test is performed. When the temperature ratios of the residential BVUs are determined according to FprEN 13141-7 and FprEN13141-8 (referred to as η0), no corrections are made to compensate for the leakages. Only the mass flows shall be balanced within max. 3% before determining the temperature efficiency of the BVU. If the mass flow differences are > 3% (cannot be further adjusted), the unit is declared unbalanced and the imbalance shall be reported.

3.8 Indoor/outdoor airtightness and airflow sensitivity

Indoor/outdoor airtightness and airflow sensitivity are two typical parameters that can be associated with non-ducted (local) ventilation units. The FprEN 13141-8 uses the following definitions:

Indoor/outdoor airtightness (qvio) :
Maximum air volume flow at static pressure difference of -20 Pa and +20 Pa corresponding to the setting when the fans are "OFF" and all additional shutters are closed.

Airflow sensitivity (v):
Maximum relative deviation of the maximum airflow qvmax due to static pressure differences of -20 Pa and +20 Pa.

Explaining the influence of low indoor/outdoor airtightness:
Local non-ducted ventilation units require openings in the building shell through which the ventilation air (supply and/or exhaust) can be transported. Such openings in the building shell may also reduce the airtightness of the building, resulting in higher infiltration rates and higher energy consumption for space heating; it may also negatively affect the effectiveness of the ventilation.

Explaining the influence of high airflow sensitivity:
Local non-ducted RVUs often use low-pressure (axial) fans because they don't have to deal with higher pressure differences associated with ductwork. Unfortunately, these low-pressure fans are also more receptive to pressure differences over the façade. This means, that the actual flowrates achieved by the local non-ducted RVUs can be dependent upon the pressure differences over the building shell. Local non-ducted RVUs that are highly sensitive to pressure differences, will not always be able to deliver the requested airflows. This means that airflows are either too high or too low. In other words, either energy is wasted or the IAQ is compromised. In addition, if a heat recovery system is used in these non-ducted RVUs, its efficiency or temperature ratio will also be compromised, because the airflows will be far from balanced.
To account for these influences on the ventilation performance and the energy performance, it is proposed to correct the CTRL-factor for both these parameters:

Corrections for the combined effect of airflow-sensitivity 'v' and the indoor/outdoor airtightness 'qvio', are to be based upon multiplier '*fs*' *fs* : flow-sensitivity correction factor for non-ducted (local) RVUs, determined with the formulae:

- For periodical operating fans : $fs = 1+ (v + q_{vio})/2$
- For continuous operating fans : $fs = (1 + v)$

Where
v = airflow sensitivity to pressure variations in %
q_{vio} *= indoor/outdoor airtightness RVU with fans switched off related to* q_{vmax} *in %*

Stakeholder views

EVIA: EVIA strongly recommends the use of EN 13142 for correction only at the product level.

DTI: Non-ducted VUs have difficulties in remaining at a high heat recovery value when they are tested with ±20 Pa according to air flow sensitivity, which means that the HR can be reduced from 80 % to eg. 50 %, which has a huge influence on the SEC.
In our opinion, the thermal efficiency of the heat recovery should not be corrected according to airflow sensitivity as described in the prEN 13142, because it does not follow the intention of the energy label and reduces the reached energy label significantly. The thermal efficiency of the heat recovery is not reduced by the fact that the flow of the product is reduced by a wind impact. It will be the flow and total number of Joules over the year that will be recovered, which is partly dealt with by the SEC. Therefore, we do not support the correction of the HRS according to airflow sensitivity.

Reaction study team

This proposal of the study team relates to an adjustment of the CTRL-factor in the SEC-formula, not to an adjustment of the temperature efficiency ηt.

3.9 Frost protection

Currently the energy that is involved for frost protection of BVUs (Qdefr in the SEC-formula) is determined (based on electric resistance heating principle) with the default formula:

$$Q_{defr} = t_{defr} * \Delta T_{defr} * c_{air} * q_{net} * pef$$

Where

Q_{defr} = the annual heating energy per m² of heat floor area for defrosting [kWh/m²/a]
t_{defr} = the duration of the defrosting period in hours per year, i.e. when the outdoor temperature is below -4°C
ΔT_{defr} = is the average difference between the outdoor temperature and -4°C during frosting period

Current default values for Q_{defr} are 5.82, 0.45 and 0.0 kWh/a/m² for cold, average and warm climates respectively.

As numerous defrosting strategies are applied to the market and all have different impacts on related energy consumptions and available supply airflows, stakeholders propose, by

means of the FprEN 13142:2019 an alternative method for calculating the energy consumption for defrosting.
However, in view of its complexity and given its impact on the total energy consumption for ventilation, stakeholders were invited to suggest a more simplified approach to this.

The table below is a proposal for such a simplified approach, drafted in consultation with professor H. Huber, Institute of Building Technology and Energy IGE, Lucerne University of Applied Sciences.

Table 31. Default Qdefr values for various frost protection strategies acc. to FprEN13142

Frost protection strategy	Explanation	Qdefr in kWh/m²/a PEF=2.1, CTRL=1, $\eta_5{}^1$=0.75 qnet=1,97 m³/h/m² setpoint=-3°C, x = 2		
		Cold	Average	Warm
E1	Electric preheating; 1 stage, controlled by outdoor temperature inlet in ventilation unit	40.40	4.95	0.00
E2	Electric preheating; 2 stage, controlled by outdoor temperature inlet in ventilation unit	22.57	2.17	0.00
E3	Electric preheating; stepless variable, controlled by outdoor temperature inlet in ventilation unit	8.64	1.10	0.00
E4	Electric preheating; stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	7.16	0.96	0.00
L1	Lowering supply air flow rate; ventilator shut off	n.a.	2.77	0.00
L2	Lowering supply air flow rate; stepless variable, controlled by outdoor temperature inlet in ventilation unit	n.a.	0.63	0.00
L3	Lowering supply air flow rate; stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	n.a.	0.58	0.00
I1	Increasing exhaust air flow rate; ventilator shut off	n.a.	2.77	0.00
I2	Increasing exhaust air flow rate; stepless variable, controlled by outdoor temperature inlet in ventilation unit	n.a.	1.50	0.00
I3	Increasing exhaust air flow rate; stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	n.a.	1.26	0.00
B1	Bypass for defrosting; Bypass full open	n.a.	2.77	0.00
B2	Bypass for defrosting; stepless variable, controlled by outdoor temperature inlet in ventilation unit	n.a.	0.63	0.00
B3	Bypass for defrosting; stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	n.a.	0.58	0.00
η_5 = recovered thermal energy, corrected for leakages, mixing and airflow sensitivity, following FprEN 13142				

Stakeholder views

EVIA: EVIA supports the invitation to work out a simplified approach to defrosting aspects based on EN 13142. They propose to extend mandatory information requirements with information on the type of defrosting strategy to which this is applied and modify the calculation method of energy use for defrosting, following annex F of prEN 13142:2019.

Eurovent: Eurovent is in favour of indicating what the impact of the defrosting strategy is on the energy consumption provided it would be simple and easy to implement. According to prof. Huber, the author of the approach proposed in FprEN 13142:2019, the current method for correcting SEC might be simplified by selecting the variant of a blacklist or a whitelist. The idea behind this method is to indicate which frost protection strategies have a relevant impact on energy and therefore can lead to a reduction of an energy class. Furthermore, the criteria for functionality of acceptable defrosting strategies should include the outdoor temperature range at which a unit can properly operate (continuous and balanced air flows and the acceptable limit for a minimum supply of air temperature).

As an alternative approach, Eurovent proposes to include a simple information requirement for BVUs and to add a symbol on the energy label to inform the end-user on whether the unit has passed the cold climate test, has failed the test, or has not been tested. For outside temperatures down to -15°C the cold climate test according to EN 13141-7 might be used. For units operating in a very cold climate (e.g. northern Scandinavia) a lower testing temperature would be necessary.

Following the stakeholder discussion on the subject, Eurovent proposes that for Residential Ventilation Units, a simple information requirement in the Regulation and the addition of a symbol on the energy label should be included, both of which should inform the end-user of whether the unit passed the cold climate test according to EN 13141-7, did not pass the test, or was not tested.

Heatex: freezing in an HR unit is predominantly caused by low ambient temperatures. But another factor is the thermal efficiency of the heat exchanger since it will have an impact on the amount of condensate. A higher thermal efficiency results in more condensate and once freezing occurs more energy is required to defrost the unit. A consequence would be increased operation in bypass mode or increasing preheating of ambient air. Heatex suspect a modified minimum thermal efficiency requirement will have an impact on the amount of energy used for defrosting in relation to the increased heat recovered. Heatex suggest that the impact on increased freezing issues is investigated.

Talteka: in FprEN 13142:2019 it is referred to as an approach for calculating the energy consumption for defrosting. The methods listed in the pre-standard do not reflect the applicable methods in cold and arctic climates. Defrosting the air into the rooms must be done at a temperature that does not cause problems. For example, a method that allows for shutting down supply air for defrosting and causing an imbalanced ventilation cannot be allowed. On the other hand, the standard mentions that defrosting with by-pass is not applicable in a cold climate. However, by-pass with supply air heating to a safe level is a commonly used method for defrosting.
Talteka maintains its position for a need to indicate what the impact of the defrosting strategy will be on the energy consumption of all kinds of ventilation units. The approach proposed in FprEN 13142 should be simplified and adapted to better include the need in cold and arctic climates.

Reaction study team

The common denominator so far is, that the Information Requirements for RVUs in Annex IV must be amended with information regarding the type of defrosting strategy that is applied to the BVU as well as its suitability for colder climates and its energy impact.
Also, for strategies not mentioned in the table with default values, the EN 13142 can be used because it provides a methodology for calculating Qdefr values for strategies not mentioned in the table.

With all the proposed adjustments to the existing SEC formula incorporated, the new SEC-formula becomes:

$$SEC = t_a \cdot pef \cdot q_{net} \cdot CTRL^x \cdot SPI - t_h \cdot \Delta T_h \cdot \eta_h^{-1} \cdot c_{air} \cdot (q_{ref} - q_{net} \cdot CTRL \cdot (1-\eta_e)) + CTRL * Q_{defr}$$

where

- *SEC* is Specific Energy Consumption-savings for ventilation per m² heated floor area of a dwelling or building [kWh/(m².a)], compared to a fully naturally ventilated residential building;
- t_a is annual operating hours [h/a];
- *pef* is primary energy factor for electric power generation and distribution [-];
- q_{net} is net ventilation rate demand per m² heated floor area [m³/h.m²];
- *CTRL* is ventilation control factor [-] (see Annex 1);
- *x* is an exponent that takes into account non-linearity between thermal energy and electricity saving, depending on motor and drive characteristics [-];
- *SPI* is Specific Power Input [kW/(m³/h)];
- t_h is total hours heating season [h];
- ΔT_h is the average difference in indoor (19°C) and outdoor temperature over a heating season, minus 3K correction for solar and internal gains [K];
- η_h is the average space heating efficiency [-];
- c_{air} is the specific heat capacity of air at constant pressure and density [kWh/(m³ K)];
- q_{ref} is the reference natural ventilation rate per m² heated floor area [m³/h.m²];
- η_e is the total energy efficiency of energy recovery system [-], including both thermal and humidity recovery and including corrections for BVU-leakages;
- Q_{defr} is the annual heating energy per m² heated floor area [kWh/m².a] for frost protection with CTRL-factor =1, to be taken from Table 31 where default values for qdefr are given based on the frost protection strategy that is used in the BVU; Q_{defr} applies only to bidirectional units with recuperative heat exchanger; for unidirectional units or units with regenerative heat exchanger is $Q_{defr} = 0$;
- t_{defr} is the duration of the defrosting period, i.e. when the outdoor temperature is below -3°C in [h/a];
- ΔT_{defr} is the average difference in K between the outdoor temperature and -3°C during defrosting period.

SPI and η_t are values derived from tests and calculation methods.

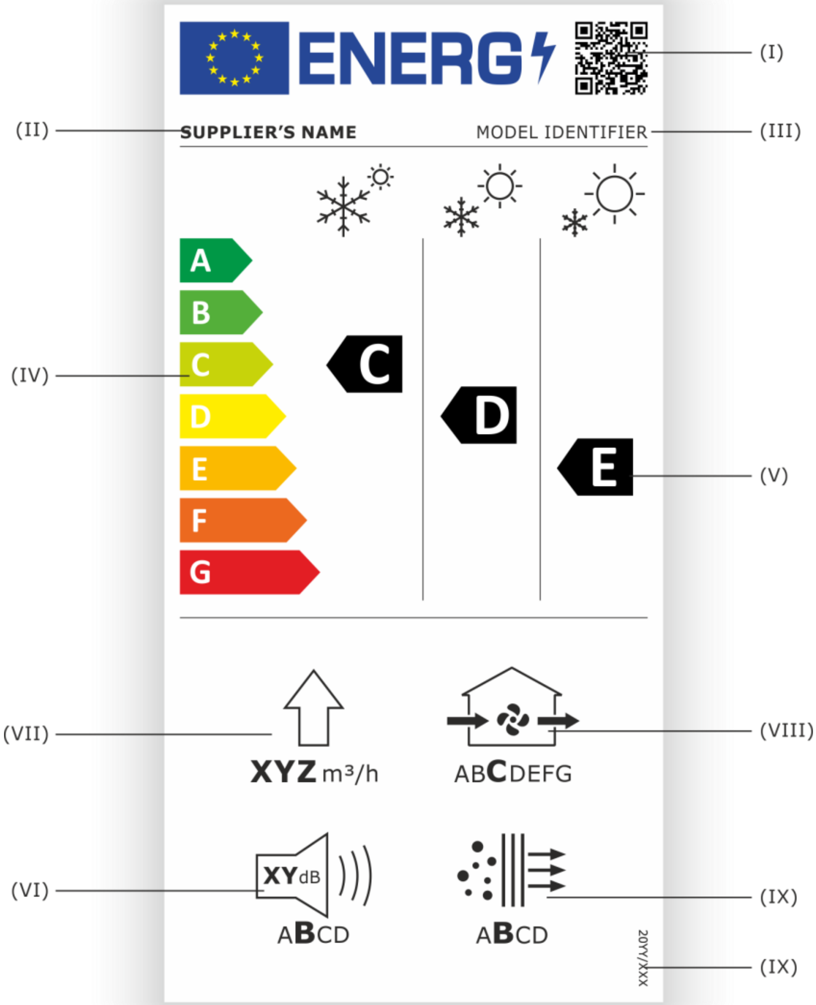
3.10 Adjustments Energy Label

The following proposals are submitted for adjusting the Energy Label.

3.10.1 Show effect of outdoor climate on energy savings

The absolute energy savings that can be achieved with RVUs largely depend on the temperature difference between indoors and outdoors. Currently, only the energy savings related to the average climate are displayed on the label. To present more differentiated information on the label, it is proposed to display the energy class (based on a new SEC-formula) for three average outdoor temperature levels on the Energy Label (label lay-out comparable to the Energy Label for room air conditioners).

Example of differentiated information of energy classes on the Energy Label.



Stakeholder views

ECOS: ECOS supports the decision to display the different SEC on the energy label based on climate zones considering the impact that the climate can have on heat recovery.

Eurovent and EVIA also support this proposal.

3.10.2 Add filter type

The type of supply filter that is used, provides important information regarding the quality of the air that will be supplied to the dwelling. It is therefore proposed to add information regarding the type (if any) of supply filter that is used.

Stakeholder views

Stakeholders in general support this proposal.

An important remark relates to the fact that showing the filter type on the energy label must not lead to consumer interpretation that worse or no filter classification would imply a bad RVU. After all, if ODA (outdoor air quality) is good, in principle no energy consuming filters would be needed to secure the quality of the supply air (i.e. filters are primarily needed for the HR-unit).

3.10.3 Sound power level

Currently, the sound power level that is mentioned on the energy label (see picture below), relates to the sound power level generated at reference airflow and is displayed next to the maximum flowrate of the unit. This is misleading.
A proposal is to display the sound power level at maximum flowrate of the unit.

Stakeholder views

The topic was further discussed and the majority favours using the sound power level at reference airflow

3.10.4 Add Ventilation Performance Indicator

The core function of a Ventilation Unit is to provide 'the required air exchange rates in the right place at the right time'.
With the proposed VPA-method for determining the CTRL-factor, an indicator is obtained for the control efficacy of the Ventilation Unit Package that is put on the market. The lower the CTRL-factor, the higher the control efficacy and the higher the ability of the VU system to achieve the correct air exchange rates in the right place at the right time. A VPI-indicator (discriminating e.g. using six classes) can be derived from this and can be displayed on the label.

Stakeholder views

During the meeting on March 5th in Brussels (with participants Evia, Eurovent, Policy Officer DG Grow, and VHK), this practical proposal for determining the VP-indicator was discussed. Evia acknowledges that this could be a simple and practical way to derive at a VP-Indicator. But they also mention the option to first start with a voluntary Ventilation Performance Label and gain experience. Eurovent still notes that further explanation and validation will be needed. The Policy Officer hopes that if the opportunities are there for considerable improvements of the regulation, they should be used, as the next review will be after 5 years.

3.10.5 Adjustment Label classes

There are several reasons for adjusting the label classes for RVUs:

1. Primary Energy Factor (PEF)
   The Primary Energy Factor (PEF) is changed to 2.1 instead of 2.5. This means that maximum theoretical efficiency for electric heat generators is raised by 19% (e.g. Joule effect generators 47.6% instead of 40%). But ambition level of Ecodesign should remain the same, which means that Ecodesign limits are adjusted accordingly.
2. Revised q_{net}
   Changing the net ventilation requirement from 1.3 m³/h into 1.97 m³/h per square metre of heated space will lead to adjusted SEC-values which also might require adjustment of the label classes.
   Furthermore, additional label classes will be needed for the two local RVUs (local BVUs serving habitable spaces only, and local continuous UVUs serving wet spaces only).
3. New table for the CTRL-factor
   Changing the CTRL-factors will result in adjusted SEC-values, which may lead to adjustment of the label classes.

Based on the adjusted SEC-formula, the new q_{net} and Q_{defr} values, and proposed CTRL-values in Annex 1, the following label classes are proposed for the average climate:

Table 32. Energy efficiency classes of ducted RVUs

SEC in kWh/a.m²			
Energy Efficiency Class	**Cold climate**	**Average climate**	**Warm climate**
A		SEC ≤ -60	
B		-60≤SEC<-50	
C		-50≤SEC<-40	
D		-40≤SEC<-30	
E		-30≤SEC<-20	
F		-20≤SEC<-10	
G		-10≤SEC	

Table 33. Energy efficiency classes of non-ducted RVUs

SEC in kWh/a.m²			
Energy Efficiency Class	**Cold climate**	**Average climate**	**Warm climate**
A		SEC ≤ -12.5	
B		-12.5≤SEC<-10	
C		-10≤SEC<-7.5	
D		-7.5≤SEC<-5	
E		-5≤SEC<-2.5	
F		-2.5≤SEC<0	
G		0≤SEC	

Once an agreement has been reached on the new table with CTRL-factors (Annex 1), the proposal can be further complemented with classes for the other climates.

3.11 Verification tolerances

It is stated by some stakeholders that the current verification tolerance of 7% on the SPI is too difficult to achieve. 10% would be more in line with real life situations.

Also with regard to the 2 dB tolerance on sound power levels, this is considered to be too strict. Fan suppliers already use higher tolerances and furthermore, the test rig and the accuracy with which flow rates can be fine-tuned play a significant role. It is proposed to change this tolerance on sound power level to 3 dB.

4. Regulatory Options NRVUs

4.1 Including humidity recovery

Recovery of latent heat and humidity can be advantageous. Especially in warm climate zones recovery of latent heat and humidity is an asset since it can significantly reduce the energy needed for cooling, when compared to sensible heat recovery only.
In average and colder climates, recovery of humidity will lower the risk of frozen heat exchangers and will help increase the humidity levels of indoor air during winter periods. For these reasons, industry associations are in favour of including this humidity recovery feature into the revised Regulations. Their proposal is to use an energy efficiency parameter 'ηe' instead of the temperature efficiency 'ηt', and to apply the limit values for energy recovery to ηe instead of ηt, with ηe = ηt + c * ηx_c.

It is therefore proposed to include humidity recovery features into the revised Regulations, using the formula (as proposed by EVIA and Eurovent):

$$\eta_{e\_nrvu} = \eta_{t\_nrvu} + 0.08 * \eta_{x\_c}$$

where

η_{e_nrvu}	=	efficiency of the total recovered energy (sensible + humidity)
η_{t_nrvu}	=	efficiency of the thermal heat recovery (sensible heat)
η_{x_c}	=	efficiency of the humidity recovery for cooling conditions, defined as per prEN308 (exhaust air 25°C DB/18°C WB, outdoor air 35°C DB)

Including humidity recovery into the revised regulations represents an important step. Not because it makes the application of heat/energy-recovery in warmer climates more viable (which is indeed the case), but because it also introduces a new topic into the discussion, namely a potential carry-over of contaminants and micro biological contamination in enthalpy exchangers for both regenerative and recuperative types of exchangers.
Further discussions with stakeholders will be necessary to determine whether minimum limit values on the contaminant carry-over for the various exchanger materials are required.

Stakeholder views

Eurovent: Eurovent members are of the opinion that moisture recovery should be considered in the Ecodesign requirements to better match the performance of a unit to the actual ambient climate conditions and the application type. However, exchangers for moisture recovery feature higher pressure drops compared to exchangers for sensitive heat recovery only. Since the current Ecodesign benchmarks consider only the thermal efficiency, units which must be equipped with moisture recovery exchangers (sorption rotors, enthalpy plate exchangers) due to system design requirements, are at a disadvantage. Taking into consideration the above, Eurovent suggests introducing separate minimum requirements for the HRS featuring only recovery of sensible heat and for the HRS offering both the sensible heat recovery and the moisture recovery under summer conditions. For the sensible-only heat recovery systems, the minimum requirements (ηt) should remain as they are in the current Regulation. For sensible and humidity heat recovery systems Eurovent proposes to set minimum requirements for the overall energy recovery ηe .

Based on the Eurovent members' expertise, they suggest setting the following requirement for the minimum efficiency of energy recovery η_{e_nrvu} at 75%. In addition it is proposed to include an efficiency bonus of E = (η_{e_nrvu} – 0.73) * 3000.

The value of 0.73 in the formula for the efficiency bonus (E) is proposed because of the additional pressure drop given by treatment for moisture transfer under non-condensing conditions.
This approach provides for optimum adjustment of η_{t_nrvu} and η_{x_c} in warm climate countries (or applications), where the recovery of moisture is more relevant than recovery of sensible heat, yet still ensuring appropriate recovery of energy. By modifying the efficiency bonus (E) calculation, it also allows for higher air pressure drop typical for moisture recovery HRS.[2]

EVIA and DTI: both agree with the Eurovent proposals.

Heatex: Aluminium rotor heat exchanger can transfer low levels of humidity. If they must reach the minimum requirements for the total energy efficiency (η_{e_nrvu}) they might be excluded from the market. Heatex suggest basing the minimum requirement on the region with the highest potential; middle Europe (France, Benelux, Germany, Poland). An alternative would be to use climate zones and to differentiate between the minimum requirement.

4.2 Minimum requirements HRS efficiency

The study team received a lot of feedback from stakeholders on their initial and challenging proposals to increase the minimum requirements for thermal efficiency to 77%. The general opinion is that such a new minimum requirement would lead to more applications where the extra power consumption due to increased pressure drops over the heat exchanger, cannot be compensated for by the heat and/or cold recovery within the given operating time of the NRVU. In other words, stakeholders fear that the total number of applications where the Regulation can actually save energy, will be reduced when the minimum requirements for thermal efficiency is further increased to 77%.

Based on the feedback and following the recommendations of the industry associations, the following alternative proposal is presented which includes:

- a higher minimum requirement (75%) for HR-units providing both thermal and moisture recovery;
- an adjusted calculation of the efficiency bonus E, which is no longer based on a linear function and has become a multiplier instead of a stand-alone value;
- an adjusted (more stringent) efficiency bonus for RACs.

4.2.1 Primary track

Thermal and moisture recovery systems in BVUs
Minimum energy efficiency η_{e_nrvu} is 75%, and the efficiency bonus
$E = \eta_{e\ nrvu} /(1- \eta_{e\ nrvu}) /0.73*(1- 0.73)$ if the efficiency is at least 73%, otherwise E = 1

Thermal recovery only systems in BVUs (RACs excluded)
Minimum thermal efficiency η_{t_nrvu} is 73%, and the efficiency bonus
$E = \eta_{t\ nrvu} /(1- \eta_{tnrvu}) /0.73*(1- 0.73)$ if the efficiency is at least 73%, otherwise E = 1

Run-around recovery systems in BVUs
Minimum energy efficiency η_{t_nrvu} is 68%, and the efficiency bonus
$E = \eta_{t\ nrvu} /(1- \eta_{tnrvu}) /0.73*(1- 0.73)$ if the efficiency is at least 73%, otherwise E = 1

[2] See also calculations provided by Eurovent on this topic, in their updated consolidated Position Paper, dated PP-2019-11-22, which can be found on the project website https://www.ecoventilation-review.eu/documents.htm .

4.2.2 Parallel track

Parallel to this proposal it was decided to explore the possibilities of the option to set application-specific minimum requirements for HRS-efficiencies under Ecodesign, a bit further. This further exploration not only involves the legal implications (what is possible under the Ecodesign Regulation), but also the ways in which the proposal could be applied in the market as simply as possible i.e. without hampering the activities of the market surveillance authorities and conformity assessment.

The idea here is, that when minimum requirements could be somewhat tailored to specific applications (e.g. related to average outdoor temperatures (and possibly indoor temperatures and/or operating times), energy and financial savings can be further optimized. Such application specific requirements can relate to both the 'η' and 'SFP', because optimization involves both parameters.

By going into greater detail, the approach could consist of the following: custom-made[3] non-residential ventilation units (i.e. those which are not mass-produced, but are directly installed on site on the basis of customer specifications) would have to be compliant with a requirement on the heat recovery efficiency which would not be a fixed value, as it is today, but a value depending on:

A. indoor temperature of the building,
B. outdoor temperature and
C. hours or operation per year.

Some of this information is already available, at least for certain buildings, as reporting obligations under the EPBD (Energy performance of buildings directive).
This would have the effect of 'adapting' the stringency of the requirement to the climate of the area where the ventilation units are installed, implying that 'bigger' (therefore more costly) heat recovery systems would be only needed for cold climates.
In order for this solution to be operationalized, a direct relationship (in the form of a formula) between the heat recovery efficiency and the abovementioned factors (indoor temperature of the building, outdoor temperature and hours or operation per year) shall be made available.
The work that has been done on this topic by Hochschule Trier and the University of Kassel (Prof. Dr. Kaup and Prof. Knissel)[4],[5] is considered very useful in that respect, and can perhaps be used as an intermediate tool for arriving at the envisaged simplified scheme.

Based on the work done by Prof. Kaup, the following equation is proposed here: <u>For non-residential BVUs for which working point **is known**</u>.

The minimum required thermal efficiency $\eta_{t\_nrvu\_min}$ of custom made NRVUs is:

$$\eta_{t\_nrvu} = -1{,}02302*ODA - 0{,}05813*ODA^2 - 0{,}00134\ ODA^3 + 3{,}936274*EXT - 0{,}07118*EXT^2 + 0{,}004494*OT - 2{,}3*10^{-7}*OT^2$$

where

[3] A custom-made unit is made on a one-off basis according to individual customer specification and is not equivalent to other units.

[4] Kaup, C., Knissel, J., European Study on heat recovery in non-residential buildings

[5] Kaup, C., Mehrdimensionale und relationale Optimierung der Wärmerückgewinnung, Teil 1 und Teil 2.

- ODA is the minimum outdoor temperature in winter at the installation site, valid range[6]: -15°C to 2,5 °C
- EXT is the exhaust air temperature (from the building), valid range: 18°C to 24 °C
- OT is the operating hours of the ventilation unit, in h/y, valid range: 2.350 to 8.760 h/a).

The DG-Grow policy officer will further explore the options in consultation with EPBD-colleagues and relevant ADCO-groups.

The minimum requirements for the various HRS-types mentioned in section 4.2.1 are the values that are proposed in case this parallel track discussed in section 4.2.2 for bespoke units proves not to be feasible. For BVUs for which the working point is unknown, the requirements proposed in section 4.2.1 are applicable.

4.3 Minimum requirements for SFPint

Following the recommendations from the industry associations, the following formulae are proposed with regard to the minimum requirements for SFP_{int}:

a)

For BVUs having an ERS equipped with a heat exchanger designed for thermal energy recovery either with or without humidity recovery, except for run-around ERS, the maximum internal specific fan power (SFP_{int_limit}) in W/(m³/s) is:

$460*E*C + F_{sup} + F_{exh}$ if $q_{nom} \geq 2$ m³/s and

$760*E*C - 300*q_{nom}/2 + F_{sup} + F_{exh}$ if $q_{nom} < 2$ m³/s,

b)

For BVUs having a run-around ERS, the maximum internal specific fan power (SFP_{int_limit}) in W/(m³/s) is:

$960*E*C + F_{sup} + F_{exh}$ if $q_{nom} \geq 2$ m³/s and

$1260*E*C - 300*q_{nom}/2 + F_{sup} + F_{exh}$ if $q_{nom} < 2$ m³/s,

c)

For UVUs intended to be used with filters

SPFint-limit = Fsup (or Fexh)

[6] The valid ranges are the ones used when developing the formula and include most of the EU operating conditions. For cases where higher or lower ODA values are applicable the limit values of -15 °C and + 2.5 °C are to be used.

where

E = efficiency multiplier
C = control bonus multiplier (see section 4.6)

F_{sup} is the default *supply filter correction* value for the required filter-class supply filter in Pa as indicated in Table 34.

F_{exh} is the default *exhaust filter correction* value for the required filter-class exhaust filter in Pa as indicated in Table 34.

Fsup and Fexh values are to be taken from the table below, representing the proposed SFP values for the various filters, to be used in the first Tier of the revised Regulation.

Table 34. Filter correction values

	Filter class acc. to EN ISO 16890 and proposed F -values							
Filter class EN 779	ISO ePM1		ISO ePM2,5		ISO ePM10		ISO Coarse	
		F SFP		*F* SFP		*F* SFP		*F* SFP
G4							≥ 60%	**70**
M5					≥ 50%	**120**		
M6			≥ 50%	**135**				
F7	≥ 50%	**150**						
F8	≥ 70%	**185**						
F9	≥ 80%	**210**						

More filter efficiency classes can be added to the list with F factors in the Regulation, having a clear reference the new ISO 16890 standard and related definitions. This approach differentiates more clearly the power consumption related to the initial pressure difference of the filter section. It also allows to set separate limit values for filters and encourages the development of more energy efficient filters.

Stakeholder views

In general, stakeholders agree with this approach. Actual F-values proposed in the table still might need further discussion.

4.4 Filters and energy consumption

Initial proposals to address this topic of the energy consumption of filters was based upon defining limit values for the individual parameters that influence the energy consumption of a filter over their life cycle (e.g. filter velocity, final pressure drop of the filter, filter size). Various comments were received relating to this approach, indicating that it could hamper innovation and impair certain filter technologies.

For that reason this approach is no longer pursued and an alternative method is proposed that directly relates to energy consumption of the filter and is based upon the methodology developed by Eurovent and laid down in Eurovent Recommendation 4/21 – 2019 ‘Energy Efficiency Evaluation of Air Filters for General Ventilation Purposes’.

This Recommendation 4/11-2019 provides a comprehensive methodology for determining the reference energy consumption of a filter based on the dust holding capacity test defined in EN ISO 16890 part 3. This approach allows an estimate of the real-life performance of a filter to be made. The amount of the testing dust corresponds to a period of one year of operation. The reference energy consumption is tested for the nominal air flow rate (3400 m^3/h @592x592) and can then be recalculated for different air flows using a new simple method presented in the latest edition of the Recommendation 4/21 (November 2019).

Based on this methodology and under the Eurovent Certita Certification Programme, the Annual Energy Consumption (AEC) in kWh/year is determined (see also Table 8 in Section 1.8.1 in the Task 3 Report). For each filter class according to EN ISO 16890:2016, energy efficiency class limits for six classes (class A+ to class E) are determined, measured at 0.944 m^3/s. The classification is based on the ISO efficiency rating and the related Annual Energy Consumption in kWh/year.

According to Eurovent Market Intelligence over 80% of the filters placed on the EU market are certified under this programme. About 47% of the filters tested are rated under energy efficiency class D and E. The remaining 53% is class C or higher.

Following the recommendations of Eurovent, it is proposed to further investigate the option to use this method and set the minimum requirement for Annual Energy Consumption (AEC) of filters to class limit values (in terms of kWh/year) belonging to class C, for each filter-type.

To accommodate this, the filter supplier declares the maximum flowrate at which the filter can still achieve the energy consumption limit values related to class C. Because the energy consumption is rated at nominal flowrate (3400 m^3/h), and NRVUs very often operate at lower than nominal airflows, filters falling under class D or E could still be used, provided the maximum airflow of the RVU is sufficiently lower than the nominal flowrate (of 3400 m^3/h). For filters having the lowest energy class E, a minimum requirement on filter media velocity is still necessary (because recalculation is not possible) and set to 1.2 m/s. At these face velocities, ΔPs over filters are very low.
The supplier of the NRVU is responsible for using/selecting compliant filters.

This approach would result in the following table with limit values for the maximum allowable annual energy consumption (AEC) of any filters in the NRVU at nominal flowrate (see Table 35).

Table 35. Limit values for annual energy consumption (AEC) of filters

Filter class	Limit values AEC filters in kWh/y		
	ePM1 and ePM1, min ≥ 50%	ePM2.5 and ePM2.5, min ≥ 50%	ePM10 ≥ 50%
50% & 55%	1400	1300	750
60% & 65%	1450	1350	850
70% & 75%	1550	1400	900
80% & 85%	1800	1500	1000
> 90%	1900	1600	1400

Preliminary stakeholder views

Uniclima: Uniclima states that Eurovent's latest proposal is better than the first proposal. However, the following comments on this new proposal are given:
Eurovent 4/21 recommendation (25 Nov 2019) describes the method of calculating the energy consumption of the filters: at 3400 m³/h, taking hypotheses on a fan efficiency (0,5) and an operating time (6000h/year) to go from measurements in ΔP to an indicator in kWh/year. The document also makes it possible to calculate a consumption at another flow by ratio of flows and ΔP. Problematic, the formula is very approximate and not very accurate if we move too far from 3400 m³/h. Using this energy classification for the purpose of reducing the consumption of AHUs in their use has several limitations:
Only applies to filters with nominal flow 3400 m³/h, transposition to different flow rates is not proven; the formula given by Eurovent 4/21 has a limited and unknown range of application
The artificial fouling obtained in the laboratory is not representative of actual fouling (see extract below from a CETIAT study).
The classification is the property of Eurovent Certita Certification (RS4 / C / 001-2019).
This indicator is an intrinsic property of the filter, it is linked to a mass of dust generated, unrelated to actual conditions of use. The energy consumption of the AHU due to clogging of the filters depends upon various real-life use factors that are not all accounted for in this methodology.

EVIA: EVIA supports the proposal tabled by Eurovent's filter group, to specify the energy consumption as a criterion.

4.5 Filters and information requirements

In addition, it is proposed to expand upon the information requirements regarding filters for NRVUs (ANNEX V, item 1 (p) with the following items:

- filter classes used for supply and exhaust;
- filter clean pressure drop;
- filter final pressure drop and related expected filter change intervals; pPower consumption of used/full filters in case they are not exchanged or alternatively the energy performance of the filter.

4.6 Controls

Since smart controls can significantly reduce the amount of energy needed for ventilation, encouraging the use of smart controls may be considered a complementary method, next to utilizing the last percentages on the parameters 'η' and 'SFP'.
A bonus on the SFPint, limit is proposed as a means to encourage that. This approach offers an alternative for situations where the default η' and 'SFP' limits would result in uneconomic application of the HR-system. The bonus scheme is to be determined with stakeholders.

The proposal is to allow a reduction on limit values for SFPint-limit for nonresidential BVUs that have smart controls that are co-supplied with the NRVUs (≥ IDA-C5, following table 12 of EN 16798-3)

Stakeholder views

EVIA: EVIA welcomes the intention to include a controls bonus. The controls shall only be granted for SFPint. EVIA would like to participate in further discussions to specify the controls to be used for the bonus and will table a concrete proposal in the context of the ongoing review.

Eurovent: Eurovent proposes to introduce minimum requirements for control systems. This approach has distinct advantages over alternatives developed by other stakeholders proposing an SFP_{INT} bonus for controls.
The latter proposal would allow less efficient units to be placed on the market provided they have a compliant control system. The intent of the Eurovent proposal is to enable the revised 1253/2014 to make further efficiency gains by way of control system requirements, not to provide alternative ways to reach the same level of efficiency. To further increase the energy efficiency, safety, and quality of ventilation units, Eurovent's members ask the European Commission to require that each NRVU placed on the European market must be equipped with a control system which fulfils the minimum requirements outlined below.

For UVUs

- Communicate with Building Management Systems by either receiving analogue and/or digital systems
- Manage the fresh air supply through demand control
  - Tier 1: At least by time or presence, or through an automatic control linked to the air quality determined by at least one sensor (e.g. temperature, humidity, fine dust, CO_2)
  - Tier 2: Through an automatic control linked to the air quality determined by at least one sensor
- Speed control the fans (this is already a requirement within the current Regulation)
- Monitor filter dust (this is already a requirement within the current Regulation)
- Monitor core information
  - Tier 1: Malfunctions concerning the fan(s)
  - Tier 2: Current technical data on e.g. airflows, temperatures and power consumption

For BVUs

- Communicate with Building Management Systems by either receiving analogue and/or digital systems
- Manage the fresh air supply through demand control
  - Tier 1: At least by time or presence, or through an automatic control linked to the air quality determined by at least one sensor (e.g. temperature, humidity, fine dust, CO_2)
  - Tier 2: Through an automatic control linked to the air quality determined by at least one sensor
- Speed control the fans (already a requirement within the current Regulation)
- Monitor filter dust (already a requirement within the current Regulation)
- Continuously control the heat recovery efficiency depending on the actually demanded supply air temperature (adjustable thermal bypass facility; thermal bypass requirements are already being dealt with within the current Regulation
- Monitor core information
  - Tier 1: Malfunctions concerning the fan(s) and heat recovery system(s)
  - Tier 2: Current technical data as, for instance, airflows, temperature and power consumption

I Incorporating these minimum requirements into the future Regulation, would ensure that all ventilation units placed on the European market meet essential quality criteria. Furthermore, and most importantly, it would make it much more likely that a unit performs as envisaged by the Ecodesign regulation not only on paper, but also in real-life conditions.

The verification of minimum controller requirements by market surveillance authorities can be easily ensured through a documentation review. All controller functions have to be described in the documentation of a ventilation unit.

RLT Hersteller Verband: the RLT manufacturer association basically supports the proposal to give a bonus for the use of an adequate control technology, which meets certain minimum requirements. Specifically, therefore, the association recommends, when using such a device, to grant a bonus to the SFPlimit value of 25%. Instead of referring to a fixed class from EN 16798-3, Table 10, the use of the following minimum properties is proposed:

Requirements for a control (function):

- control unit/device controller is supplied by the manufacturer;
- demand-driven, stepless control of the volumetric flow, using: measurement of the volumetric flow in the device, at least in Supply air ductwork and Exhaust air ductwork; variable adjustment of the speed is delivered from the manufacturer; interface of the controlled variable (external) or suitable sensor (internal) is present;
- needs-based, continuous control of the heat/cooling recovery power: Continuous adjustment of thermal performance (including icing protection); circulation flow optimisation; Sensor technology.

Monitor requirements:

- supply air temperature at device outlet;
- interface for downloading the data for the monitoring;
- filters: differential sensors to determine the loading degree of the respective particulate filter, continuous measurement of the current filter pressure loss;
- fans information: volume flow, static pressure increase of the respective air line, consumed electrical power (W) of the drive, consumed electrical energy (Wh) of the drive, operating hours;
- Heat Recovery Unit (HRU).

Aldes: The possibility of a Multi Speed Drive shall be removed because it is not as efficient as Variable Speed Drive. VSD (Frequency inverter or EC motors) shall be mandatory for all NRVU. VU factory equipped with VSD shall have a 5% bonus because the VSD is more efficient when it is set by the manufacturer.

Talteka: In conjunction with taking smart controls into account when assessing the performance of a ventilation unit it would be necessary to clarify the responsibilities of actors in fixing the CE-marking. It should be the responsibility of a manufacturer to equip the ventilation unit with automation that fulfils at least the minimum requirements. Talteka sees the additional bonus scheme as a good approach to improving the energy efficiency of ventilation units but also, a clear definition of product and description of responsibilities are needed.

ECOS: Considering the impact of adequate control, proposal 1 (setting minimum control requirements) seems preferable to proposal 2 (the bonus system) and we would like to see this option investigated. Proposal: investigate the possibility of having minimum control requirements in further task reports.

During the 2nd stakeholder meeting of May 2020, this topic was extensively discussed. Especially two different approaches (minimum requirements versus bonus system) generated a lot of comments. Since many AHUs are still delivered without controls (clients prefer to solve the control issues through themselves or other companies), a small majority opts for the bonus-approach, because it does not force companies to change their policies while at the same time offers them the options for improvement.

It is therefore proposed to introduce a 'control-bonus' C, for AHUs with co-supplied controls according to the table below (note: only one C1-value can be selected).

Table 36. Proposed values for the control bonus C.

Smart control options included in NRVU-package		***C = C1*C2***
Regarding controls and VDC-readiness		***C1***
1	Interface for allowing VDC-devices	1,05
2	Time or presence related ventilation controls	1,10
3	Ventilation Demand Control -devices	1,15
Regarding monitoring functions		***C2***
4	Monitoring of flowrates, electrical power, electricity consumption, supply air temperature, filter pressure drop, interface for downloading monitoring data	1.1

4.7 BVU-Leakages (NRVUs)

Task 3 reports that, apart from a mandatory notification in the Information Requirements, the current Regulations EU 1253/2014 and 1254/2014 do not consider leakages or mixing when determining the heat recovery performance, the SPI and SFP and the outdoor supply air flowrate of RVUs and NRVUs. Also, the terminologies, definitions and test methods that are used to assess the various types of leakages and leakage rates are not very consistent. The various standards do not use the same terms and definitions but furthermore, the Regulations work with a different terminology and descriptions. In addition, the proposals for how to compensate for these various leakage types is not very consistent.

Proposals for adjusting the leakages related definitions (following proposal Task 3 Report):

<u>Required supply flowrate</u>: (new parameter, new definition):
'the required design outdoor flow rate of an NRVU – BVU at standard air conditions 20°C and 101.325 Pa, whereby the unit is installed complete (e.g. including filters) and according to the manufacturer instructions.

<u>Nominal flowrate (adjusted)</u>:
'the declared design flow rate of an NRVU distributed to and/or extracted from the building, including any leakages or any pressure balancing flow, at standard air conditions 20°C and 101.325 Pa, whereby the unit is installed complete (e.g. including filters) and according to the manufacturer instructions.

<u>Internal leakage (adjusted);</u>
'the air leakage inside the casing between supply and exhaust airflows when the unit is operated at nominal flow rate and designed pressure relations. The Internal leakage rate is quantified with Outdoor Air Correction Factor (OACF) defined as the Ratio of outdoor air flow measured in outdoor duct to supply air flow measure in supply air duct, where internal leakage rate is OACF-1.

Term 'Carry over' to be replaced by 'Exhaust air leakage rate':
'the percentage of the exhaust air which is returned to supply air for a heat exchanger when the unit is operated at nominal flow rate, measured at the supply air duct. The exhaust air leakage is calculated or measured at actual design pressure conditions and reference air volume flow. "Exhaust air leakage" is quantified with Exhaust Air Transfer Ratio (EATR).

To limit the effects internal and external leakages might have on ventilation performance, it is proposed to set minimal requirements on leakages, following the proposal put forward by Eurovent:

a) Set Minimum Leakage Requirements for NRVUs:

a.1) External leakages (applicable to NRVUs with flowrates > 1000 m³/h

- For negative pressure (to be tested at -400Pa) : 1,32 l/s/m²
- For positive pressure (to be tested at +700Pa) : 1,90 l/s/m²
- For NRVUs with flowrates between 250 – 1000 m³/h, maximum pressure using the static pressure of the fan at maximum stated nominal air flow is used.
  m² relates to the outer surface of the NRVU

a.2) EATR (applicable to all Heat Recovery sections except RACs)

- Maximum allowable EATR at design conditions: ≤5%
- For EATR < 1% no additional compensation action required
- For EATR between 1 and 5%, the nominal supply flowrate shall be increased with the EATR-percentage to compensate for the exhaust air leakage at design conditions and to ensure that the required supply flowrate is delivered.

a.3) For NRVUs including a RAC (with common wall between supply and extract air)

- EATR < 0,1%

a.4) OACF

- At design conditions OACF must be within the range 0.90 tot 1.10

In addition, it is proposed to further discuss the need for corrections on mass flows and related measurements.

b) Correct mass flows and related measurements due to internal leakages

b.1) regarding SFPint

- SFPint shall include all impacts of internal (OACF and EATR) and external leakages at nominal conditions to ensure that the required outdoor air supply flowrate and extract flowrate will be delivered. These impacts include increased airflow pressure losses.

b.2) regarding EATR and supply flowrate

- Actual supply flowrate must be increased to ensure it contains the correct outdoor flow. As a result, the power consumption of the supply fan will increase, the related pressure drop will increase and the heat recovery temperature ratio may decrease.

b.3) regarding EATR and extract flowrate

- When EATR ≤ 1%, no action is required
- When EATR > 1%, adjust the extracted airflow rate qextr = qreq* (1+ EATR)

These adjustments are needed to maintain airflow balance in the building.

b.4) regarding OACF

- When calculating the power consumption of the supply and exhaust air fan, the respective fan shall be calculated taking into consideration the possible increased airflow as well as all increased pressure drops due to the influence of increased airflows (the heat recovery temperature efficiency will be marginally affected) and/or increased pressure drops due to the actual differential pressure between supply and extract air side (will impact on e.g. plate heat exchangers).

Stakeholder views

EVIA: EVIA proposes to limit the leakage and EATR/OACF (as minimum requirement, reference pressure shall be specified according to EN 308 revised).
A recalculation of flows and heat recovery performance would be disproportionately expensive. Furthermore, any controls and checks will be impossible for market surveillance or other involved parties.
Leakages and correction of heat recovery, depend upon:

- pressure in supply and exhaust area;
- position of leakages;
- air volume flows etc.

Even identical units would have different performance data in their specific surroundings.

DTI: it is recommended to use the calculation in accordance to EN308 and that the maximal allowable external leakage must not exceed 3% with the declared nominal flow as reference. This is more relevant in accordance to the regulation to calculate the leakage with the declared nominal flow as reference, because one NRVU can be declared at more than one nominal air flow. Furthermore, the leakage as a percentage is more related to the actual operational point than the total surface area of the NRVU.

Mitsubishi Electric: MITSUBISHI ELECTRIC proposes the following:
"1.32 l/s/m² @ 400 Pa negative pressure", "1.90 l/s/m² @ 700 Pa positive pressure" for the product where maximum pressure exceeds 400Pa/700Pa.
"1.90 l/s/m² @ designed pressure" for the product where maximum pressure does not exceed 400Pa.
The method should include "design pressure" the same as OACF and EATR for the product which does not operate at 400Pa/700Pa. The leakage of the design condition is the actual usage leakage (low static pressure products will never operate at such high static pressure (400Pa or 700Pa)).

Regarding the test methods regarding leakages several comments were made.

EU AMCA: A common internal leakage test method for recuperative and regenerative heat exchangers should be used before further discussing any changes.

JBCE JRAIA: We consider that using the static pressure test method under conditions not reflecting the actual operating point of the product, could hinder the energy-saving and material-saving properties of products leading to over-speculation of products. We do understand however that this method has the advantage of being easy and less costly to implement.
As for a solution to this, we believe that the international standard ISO16494 should be "added" to the reference standards as a reliable leakage measurement method, along with a simple method for measuring internal leakages and external leakages by the current static

pressure method. If adding ISO16494 is accepted by other stakeholders, we support the proposed content. It is also proposed to give an incentive (bonus) to an evaluation index (for example, for SFP) according to the leakage reduction rate based on the current level.

ISO 16494 provides a method that can simultaneously measure external leakage and internal leakage during the designed operating conditions of each product. Among them, there is the definition of Unit Exhaust Air Transfer Ration (UEATR), which is expressed by the equation (1) (see standard).
When the internal leakage is higher, the temperature exchange efficiency improves. Considering the internal leakage as the efficiency, it becomes a product that promotes air leakage and goes against energy savings, so in order to eliminate this unwanted influence, the UEATR is used and the temperature exchange efficiency is calculated to correct this perverse effect using the following formula (2).
By using this efficiency value for calculation of SFP, which is an energy saving index, it becomes possible to make a fair comparison in terms of product performance including leakage. In this case, it is necessary to set an upper limit value or a lower limit value for leakage, because the leakage ratio is already included in the efficiency.
The currently proposed evaluation of the static pressure method requires that internal leakage should be less than 5% and the external leakage should be less than a certain value (1.32 or 1.90 l/s/m²). The actual value of the external leakage varies depending on the product form, but it assumes 0%, and then UEATR becomes 5% (=5%+0%). The products evaluated by the static pressure method can be evaluated using the above formula (2), then finally both method results can be compared fairly.

Based on the discussions, the initial proposal as regards minimum requirements for BVU leakages, is:

- The maximum external leakage when tested using static pressure differences according to Table 37:
  - For NRVUs with negative pressure: 1,32 l/s/m²
  - For NRVUs with positive pressure: 1,90 l/s/m²

- the maximum static internal leakage for recuperative heat exchangers when tested using static pressure differences according to Table 37 shall be 3%.

  if the static internal leakage >3%, the EATR and OACF shall be determined and their values shall comply with the minimum requirements for EATR and OACF;
- the maximum EATR at nominal flow and nominal pressure is 5%. For recuperative heat exchangers these values only need to be checked when the static internal leakage >3%;

- the OACF at nominal flow and nominal pressure must be within 0.90 and 1.10. For recuperative heat exchangers these values only need to be checked when the static internal leakage >3%.

Table 37. Test pressure for determining NRVU-leakages

For measuring external leakage	Static ΔP
NRVUs with nominal static pressures < - 400 Pa	-400 Pa
NRVUs with nominal static pressures ≥ - 400 Pa	nominal pressure
NRVUs with nominal static pressures > +700 Pa	700 Pa
NRVUs with nominal static pressures ≤ +700 Pa	nominal pressure
For measuring static internal leakage	**Static ΔP**
Recuperative NRVUs	+250 and -250 Pa

4.8 Frost protection

For Non-Residential BVUs it is proposed to determine the required defrosting/frost prevention energy per climate zone (cold, average, warm) and include the results in the information requirements of the regulation. The determination of the required defrosting/frost prevention energy is preferably based on a simplified calculation method, using common reference conditions like climate zone, operating time, temperature and moisture content of the extract air. The calculation method should also take into account the control logic that is used for the defrosting function.

Stakeholder views

EVIA:EVIA proposes to keep things as they are and not to consider defrosting because it is only relevant to cold climates and defrosting will furthermore cause condensing aspects and further complex considerations in the heat recovery systems. The energy consumption impact might be only 2%, but this would be higher with the minimum requirements on thermal efficiency.

Eurovent: The current methodology of the energy efficiency assessment for NRVUs does not distinguish a type of HRS applied in a ventilation unit in terms of its sensitivity to freezing. This could lead to confusing conclusions, particularly when comparing ventilation units operating in cold climate countries. To ensure a continuous, undisturbed operation of the exchanger in cold climate conditions, additional energy for defrosting might need to be supplied. This is not covered in the current Ecodesign benchmark for NRVUs.

To provide for a level-playing field for all manufacturers, Eurovent suggests including in the information request (Annex V of the Regulation) an indication of the annual energy consumption for defrosting, attributable to applied HRS, most preferably expressed in kWh/a.

- The displayed defrosting energy should be determined based on a simplified calculation method for common reference conditions (climate zone, operating time, temperature and moisture content of extract air)
- Considered climate zones should be the same as already applied in the assessment for RVUs (cold, average, warm)
- The calculation method should take into consideration the defrosting strategy and control logic (either offered by an integrated control system or provided for in a manufacturer's manual)

Figures calculated separately for each climate zone should be presented in the information requirements.

During the 2nd stakeholder meeting of May 2020 this topic was further discussed. Stakeholders do not agree that there is a need to declare the energy consumption of frost protection. They do agree however, that the information requirements must clearly declare the type of frost protection strategy that is applied (if any), at what outdoor temperature frost protection becomes necessary and whether the AHU is suited for cold climates.

4.9 Working point unknown

Proposal: For NRVUs for which the actual working point is not known at the time, the unit is placed on the market (as is the case for mass-produced NRVUs), the manufacturers can declare an area (in a Q/ΔP-graph), defined by multiple Q/ΔP-values for which the SFPint-values meet the requirements or the regulations (see also Guidelines accompanying the EU1253 and 1254 regulations, oct.2016).

Stakeholder views

EVIA: it should be clarified that a graph with area of compliancy is only mandatory, if individual calculation is not provided. Manufacturers shall provide information to be compliant with regulation.

4.10 Issue on Box and roof fans

Box and roof fans (in short casing fans) may or may not be declared as ventilation units. When declared as ventilation units they need to comply with the more stringent EU 1253/2014 and EU 1253/2014; when declared as fans, they need to comply with the somewhat less stringent Fan Regulation 327/2011. The products however appear identical (although impeller types may be different), which in practice means that box and roof fans declared as fans are used for ventilation purposes. This introduces a loophole.

A second problem relates to the fact that manufacturers beforehand do not know what the box and roof fans will be used for and which Regulation applies. The formal procedure would be to test according to both regulations and declare whether a casing fan can be used as a ventilation unit or not. This will most probably not solve the loophole problem in the market.

Stakeholders would preferably like to adjust the Fan Regulation 327/2011 regarding the topic casing fans. Since the finalization of revised fan regulation is pending and the time for amendments has expired, EVIA proposes for the time being, to specifically and explicitly treat these box and roof fans (and duct- and tube- fans) in a separate Annex, under the VU-Regulations.

EVIA is working on a proposal for this separate Annex. Provisional status of this Annex as provided by EVIA is depicted below:

<u>Proposal for Annex</u>

Ecodesign requirements for Casing Fans (CF) for non-residential ventilation application without air treatment ('Casing Fan' being the umbrella term for box, roof, duct and tube fans, and casing being the element being additional to the stator of a fan).

Ecodesign Requirements Casing Fans

1.
The ecodesign requirements for Casing Fan (CF) are set out below, using definitions in Article 2 and Annex I of regulation xxx/xxx (revision of 327/2011)

$\eta_{CF,min}$ = 0.0456 * LN(Pe) – 0.105 + (0.78* N) where Pe < 10 kW

$\eta_{CF,min}$ = 0.011 * LN(Pe) – 0.026 + (0.78* N) where Pe ≥ 10 kW

Table 38. N values for CF-impeller types

Casing fan type	Measurement category	Pressure	N rev	N 327/2011
Foreward curved and radial < 5kW	A,C	Static	0,52	0,44
	B,D	Total	0,57	0,49
Forward curved and radial ≥5kW, Backward curved	A,C	Static	0,64	0,61 -0,62
	B,D	Total	0,67	0,64
Axial fans	A,C	Static	0,5	0,4
	B,D	Total	0,64	0,58
Mixed flow fans	A,C	Static	0,57 + 0,07· (α –45)/25	
	B,D	Total	0,67	

2.
Casing fans used as UVU without air treatment (except dual use units) shall be equipped with a multi speed drive or a variable speed drive.

Justification: the current level of requirements for dual use units with regard to control equipment shall not be increased.

3.
This requirement is decreased by 15 % for Casing Fans which are eligible to the control/DCV bonus and add 10% if the Casing Fan is eligible to the Monitoring bonus (see separate EVIA proposition).

4.
The minimum energy efficiency requirements shall apply from *yy,mm,dd*

5.
The product information requirements on UVU without air treatment on how they must be displayed are as set out in Annex III of regulation xxx/xxx (revision of 327/2011). These requirements shall apply from xxx

6.
Compliance with ecodesign requirements shall be measured and calculated in accordance with requirements of regulation xxx/xxx (revision of 327/2011) and related EN standards.

EVIA proposes that in a later stage, during a next revision of the Fan Regulation, this Annex on Casing Fans is to be included. According to EVIA, the actual differences in efficiencies of the Casing Fans between the original VU-Regulation and the here proposed Annex, is limited.

The study team point out that there are differences in the resulting minimum required η_{vu} and that such an annex in the revised EN1253/2014 should not lead to reduced energy savings.

	η_{vu} EN1253/2014	η_{CF} [1)] CF-Annex (Rev. EU327)
P = 10 kW	56.3%	52.1%
P = 20 kW	60.6%	52.9%
P = 30 kW	63.1%	53.4%
1) N value for casing fan = 0.67		

Furthermore, a part of the problem (not knowing beforehand what requirement applies) that remains due to item No. 2 of this provisional Annex (casing fans used as UVU). A solution here could be to make this requirement of multi speed or variable speed drive mandatory for all casing fans.

Another important question that was raised relates to whether it is at all legally possible to insert an annex regarding casing fans (for general purposes) into a regulation intended for van ventilation units only.

Helios: In their latest written comments on the 2nd stakeholder meeting, Helios proposes to set limit values for casing fans in this separate CF Annex that are equal to the EU 1253/2014 requirements:

Requirement on static efficiency at best efficiency point (BEP) for Cat A and Cat C casing fans:

$\eta_{CF,stat,target}$ = 6,2% × LN(Pe) + 39% , where Pe <= 30 kW

$\eta_{CF,stat,target}$ = 60,1% , where Pe > 30 kW

Requirement on total efficiency at BEP for Cat B and Cat D casing fans:

$\eta_{CF,tot,target}$ = 6,2% × LN(Pe) + 42% , where Pe <= 30 kW

$\eta_{CF,tot,target}$ = 63,1% , where Pe > 30 kW

Further discussions will be necessary before a final decision can be made regarding the topic of casing fans.

4.11 Verification tolerances

A related comment comes from VKE, stating that the verification tolerances (set at 2 dB for NRVUs) are too strict. The fact is that two different fans can vary within +/-1 dB which is considered perfectly normal.

5. Clarifications in Regulation Text

Apart from regulatory options several text and definition issues were discussed with stakeholders.

5.1 Definition Ventilation Unit

It is proposed to change the definition used in the Regulation for Ventilation Units (VUs) into:

'ventilation units (VU)' means an electricity driven appliance equipped with at least one impeller, one motor and a casing and intended to replace indoor air with outdoor air, when the indoor air is utilized/polluted due to presence of human beings and their use of the building including emissions from building materials, decorative and interior product and equipment.

Stakeholder views

Stakeholders in general agree that this new definition is a clear improvement of the existing one. Some stakeholders however comment that the definition:

- should also state that the VUs' purpose is to exchange indoor air with outdoor air (not purifying air);
- should relate to an extended purpose of ventilation (removing unwanted heat gains, removing contaminants from any other source;
- should be expanded to indicate that the utilized air is replaced by treated air and that this treatment can constitute one or more of the following: filtration, heat recovery, cooling, heating, humidification.

Response study team

The basic function of ventilation is 'keeping indoor pollutant concentrations on an acceptable level for its occupants and to protect the buildings from (moisture) damage by exchanging indoor air with outdoor air'. Passive additional functions (filtration, heat recovery) can be added to this basic ventilation function, because it does not affect or alter its primary function (exchanging indoor air with outdoor air for the purpose of …….). Active functions like heating, cooling and humidification however, not only add new functions to the ventilation function, but also largely interfere with other existing Regulations like the ones for heating and cooling. Also, the function 'removing unwanted heat gains' actually relates to 'ventilative cooling', for which other requirements apply than those for ventilation only.

Furthermore, the proposed extension 'removing contaminants from any other source' is difficult from a definition perspective. What are the 'other sources', how to define them, and is it not so that in most cases these pollutant concentrations coming from 'other sources' are better tackled with dedicated measures (like the kitchen hood)?

The definition above is adjusted compared to the previous one in order to further clarify that indoor air is replaced by outdoor air.

5.2 Clarification toxic environment

It is proposed to adjust the text currently used for Exclusions f. (v) in Article I of the EU1253.

Current text:

'Units exclusively specified as operating in toxic, highly corrosive or flammable environments or environments with abrasive substances'.

Proposed amended text:

'Units exclusively specified as operating in toxic, highly corrosive or flammable environments or environments with abrasive substances' and are exclusively designed for abstract of air from such an environment without any purpose of ventilation (e.g. an extract air unit for a laboratory fume hood or a technical extraction system of a machinery).

This means that still only ventilation units that are exclusively designed for application within production processes are excluded; no other units (for example: a ventilation unit that also can be used for the office has to comply with the regulation).

A question that needs answering: is this exclusion feasible in the sense that it relates to a verifiable technical feature and does not create a loophole?

Stakeholder views

EVIA: Harmonization with fans standard EN 17166 and the fan regulation should be pursued.

EU AMCA: The issue should be further discussed to determine whether this is a verifiable technical feature.

5.3 Other

Many amendments and clarifications regarding the existing Regulatory text were proposed by stakeholders. They will not be summarized in this Task 6 report. They will be integrated in the draft Working Document.

Annex 1. List *CTRL*-factors

Proposal for the extended list of CTRL-factors:

CTRL factors for ducted ventilation units (serving ES and HS)

VDC-devices/sensors /switches		**Airflow control**				
		RVU with central airflow control				
Extract Spaces	***Habitable Spaces***	UVU	BVU*1*	BVU*1c*		
manual, or any VDC-ES	no control or manual	**1.00**	**0.95**	**0.75**	***default***	
	clock, central VDC-ES	0.95	0.90	0.70		
	zonal VDC-ES or central VDC-HS	0.90	0.85	0.65		
	local VDC-ES or zonal VDC-HS	0.85	0.80	0.60		
	local VDC-HS	0.80	0.65	0.50		
		RVU with zonal airflow control				
Extract Spaces	***Habitable Spaces***	UVU	BVU*1*	BVU*1c*		
manual, or any VDC-ES	no control or manual	0.95	0.90	0.75		
	clock per zone	0.90	0.85	0.65		
	zonal VDC-ES	0.80	0.75	0.60		
	local VDC-ES or zonal VDC-HS	0.75	0.70	0.55		
	local VDC-HS	0.65	0.60	0.45		
		RVU with local airflow control				
Extract Spaces	***Habitable Spaces***	UVU	BVU*1*	BVU*1c*	BVU*2*	BVU*2c*
manual, or any VDC-ES	manual	0.95	0.80	0.65	0.95	0.95
	clock per room	0.85	0.75	0.60	0.90	0.80
	local VDC-ES	0.70	0.70	0.55	0.80	0.60
	local VDC-HS	0.45	0.50	0.35	0.70	0.50

CTRL factors for non-ducted (local) ventilation units

Non-ducted (local) RVUs serving Extract Spaces only (incl. basic ventilation)						
Extract Spaces	***Habitable Spaces***	*L*-UVU	*L*-BVU	*L*-BVU*c*		
manual	n.a.	1.00**fs*				
clock	n.a.	0.95**fs*				
local VDC-HS	n.a.	0.85**fs*				
local VDC-ES	n.a.	0.70**fs*				
Non-ducted (local) RVUs serving Habitable Spaces only (incl. basic ventilation)						
Extract Spaces	***Habitable Spaces***	*L*-UVU	*L*-BVU	*L*-BVU*c*		
n.a.	manual	0.95**fs*	0.95**fs*	0.95**fs*		
n.a.	clock	0.85**fs*	0.90**fs*	0.80**fs*		
n.a.	local VDC-ES	0.70**fs*	0.80**fs*	0.60**fs*		
n.a.	local VDC-HS	0.45**fs*	0.70**fs*	0.50**fs*		

The CTRL-factor can be found identifying whether the RVU-system is [ducted or non-ducted], where ducted airflow control types can be [central/zonal/local] and the control-input in the habitable spaces can be [a manual switch, a clock, central/zonal/local ES-type VDC[7] sensor(s) or HS-type VDC sensor(s)]. ES-type sensors measure humidity, VOCs and/or motion (yes/no). HS-type sensors measure CO_2, occupancy (preferably intensity) and optionally VOCs as additional parameters. The control-type of ventilation in exhaust spaces plays no decisive role in determining the CTRL-factor for the RVU.
Airflow(s) of ducted units are [Unidirectional (UVU) or Bidirectional (BVU)], where subtype BVU1 has air supply in HS and air extraction in ES, and subtype BVU2 has air supply in connecting spaces (e.g. hallway) and extraction in ES and HS.

The non-ducted units inherently only have [local] airflow control and [local] control-inputs of the same types as the ducted units. Here it matters for the CTRL-factors whether the unit is serving the [exhaust space or the habitable space]. Also, the flow sensitivity *fs* is part of the equation for the CTRL-factor. Airflow(s) of the (local) non-ducted units can be Unidirectional

[7] ventilation demand control

(L-UVU) or Bidirectional (L-BVU). In the latter case, there are also bidirectional units that have a constant ('balanced') flow control L-BVUc and thus a better CTRL-factor. The same goes for the ducted BVU1c and BVU2c. In general, the BVUs have a filter-compensation factor of 20% and 6% internal leakage, but the L-BVUc, BVU1c and BVU2c have a filter-compensation-factor ≤1% and internal leakage ≤3%.

Annex 2. VPI classification

Proposal for Ventilation Performance Indicator RVUs

Proposal for Ventilation Performance Indicator: VPI (or Airflow Efficacy)

Formula for determining VPI:

For ducted RVUs : $VPI = q_{opt} / (q_{net} * CTRL)$

For non-ducted RVUs : $VPI = q_{opt} / (q_{net} * fs * CTRL)$

Where

q_{net} : is the net ventilation requirement per m² of heated floor area that the *reference* RVU needs for achieving Category II ventilation performance

q_{opt} : is the ventilation requirement per m² of heated floor area that the *ideal/optimized* RVU needs for achieving Category II ventilation performance

fs : flow-sensitivity correction factor for non-ducted (local) RVUs, determined with the formulae:

- For periodical operating fans : $fs = 1 + (v + q_{vio}) / 2$
- For continuous operating fans : $fs = (1 + v)$

Where

v = airflow sensitivity to pressure variations in %

q_{vio} *= indoor/outdoor airtightness RVU with fans switched off related to* q_{vmax} *in %*

Because in the residential sector, ventilation performance in particular, is an issue in habitable spaces (HS) rather than in extract or wet spaces (ES), it is proposed to exclude the non-ducted RVU-ES from the VPI-declaration.

Default values for q_{net} and q_{opt} and proposed VPI-classes

Table 39. Default values q_{net} and q_{opt}

	Ducted RVU [m³/h/m²]	**Non-ducted RVU-HS*** [m³/h/m²]
q_{net}	1.97	0.39
q_{opt}	0.67	0.18

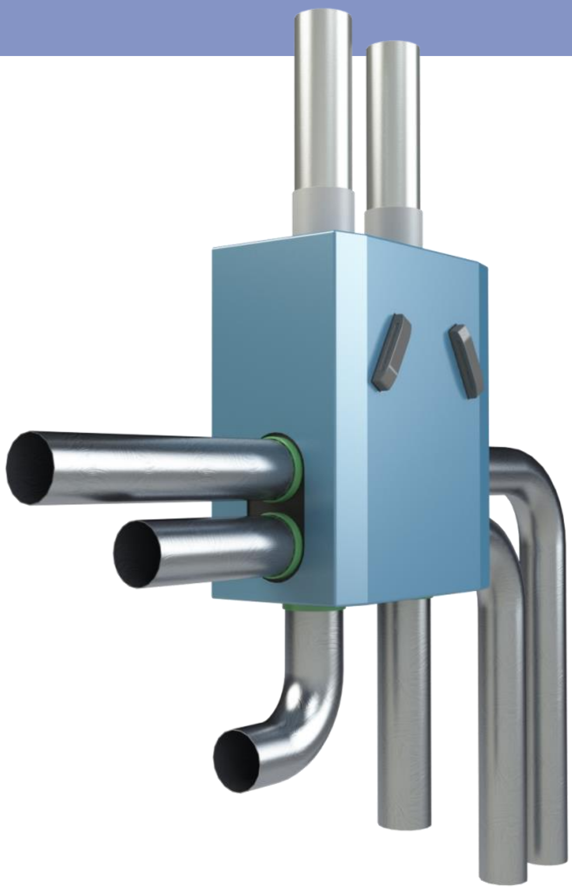
* For non-ducted (local) RVUs 3 units are assumed for HS

Table 40. Proposed VP classes

VPI -value	**Class**
$0.8 \leq VPI \leq 1.0$	A
$0.7 \leq VPI < 0.8$	B
$0.6 \leq VPI < 0.7$	C
$0.5 \leq VPI < 0.6$	D
$0.4 \leq VPI < 0.5$	E
$\leq VPI < 0.4$	F

Ventilation Units

Ecodesign and Energy Labelling



Preparatory Review Study

Phase 1.1 and phase 1.2

Final Report

TASK 7. Scenarios

Review study on Regulations EU 1253/2014 (Ecodesign requirements for ventilation units) and EU 1254/2014 (energy labelling of residential ventilation units)

Prepared by
VHK, Delft (NL), for the
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August 2020

GROW

[empty on purpose]

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Project website: www.ecoventilation-review.eu

Specific contract: No 681/PP/GRO/IMA/18/1131/10204-SI2.798223

Contract starting date: February 5th 2019

Cover: Ventilation unit [picture VHK 2019].

This study was ordered and paid for by the European Commission, Directorate-General Grow.

Executive summary

Scope

The scope of this Task 7 report is to perform a scenario analysis, i.e. to analyse the evolution over time of environmental and socio-economic impacts due to policy options for the review of Commission Regulation (EU) No. 1253/2014 (ecodesign ventilation units) and Commission Delegated Regulation (EU) No. 1254/2014 (energy labelling of ventilation units). The impacts include energy consumption, GHG-emissions, monetary impacts for users and businesses, and associated jobs. The scenarios analysed are:

- **Business-as-Usual ('BAU') scenario**: no new policy options, existing regulation remain unchanged.

- **Intermediate policy scenario 'ECO0.3'**: adopts a series of undisputed design measures in the review, amongst which (a) scope extension to >30W, (b) minimum requirements on internal BVU-leakages, (c) inclusion of humidity recovery, (d) adjusted calculation for frost protection, (e) correction of temperature efficiency for BVU-leakages, (f) adjusted minimum requirements (SEC, SFP and energy recovery ratio).

- **'ECO' scenario**: ventures into a more ambitious approach as regards the proposed Ventilation Performance Index (VPI), i.e. aiming for true and effective improvement of the air exchange rate for a better indoor air quality. For the residential sector, two variants of the ECO-scenario have been analysed:
  1) **'ECO with ECO-VPI**: a preferential scenario with a vastly improved ventilation performance at the expense of less energy savings,
  2) **'ECO with BAU-VPI**: an alternative scenario with the current (BAU) ventilation performance but with a higher energy saving.

- **Reference ('BAU0') scenario**: reflects the situation if regulations 1253/2014 and 1254/2014 would not have been adopted. The comparison of 'BAU0' and 'BAU' provides the change in impacts due to the existing regulations.

The changes in impacts for the ECO-scenarios compared to the BAU-scenario are analysed. This comparison captures the effects of improvements in electrical efficiency, of improvements in heat recovery efficiency, of decreases in mechanical flow rate due to improved flow controls, and of increases in mechanical flow rate required to obtain a better VPI (where applicable). However, this comparison does not capture the changes in impact when passing from (uncontrolled) natural ventilation (window openings, stack vents, infiltration) to (controlled) mechanical ventilation.

Therefore, in addition, the difference in impacts between the use of mechanical ventilation and the use of natural ventilation is assessed for each scenario, both for the stock of ventilation unit appliances and for the entire stock of residential dwellings and non-residential buildings.

Methodology and inputs

The scenario analysis follows the MEErP[1], and more in particular the methodology of the Ecodesign Impact Accounting (EIA)[2]. The inputs for the calculations, e.g. dwelling/building areas, sales, lifetimes, loads (user demand for product output), (real-life) efficiencies, prices, rates, etc. are taken from the information presented in the preceding task reports. The analysis covers the period 1990-2050, with additional inputs for sales and efficiencies going back as far as 1970 to enable realistic stock calculations from 1990 onwards. The analysis is performed for EU27 (excluding UK).

The analysis considers 9 base cases for residential ventilation units and 7 base cases for non-residential ventilation units (details in section 1.2).

Results for the VU-stock without considering remaining natural infiltration

These results (Table 1, Table 2, Figure 1) consider the primary energy for VU electricity consumption (PEF 2.5 until 2020; PEF 2.1 from 2021), and the space heating energy required to compensate for mechanical ventilation heat losses, not counting any remaining natural infiltration.

The total primary energy consumption of the VU stock according to the BAU-scenario will rise from 330 TWh in 2015 to 371 TWh in 2040 and to 406 TWh in 2050, primarily due to the increase of the number of buildings (heated surface) that are going to be equipped with ventilation units.

The ECO0.3 scenario with its total primary energy use of 363 TWh in 2040 and 395 TWh in 2050, delivers limited energy savings of 7 TWh in 2040 and 12 TWh in 2050.

The ECO-scenario (with ECO-VPI) results in an improved ventilation performance, a lower total energy use and improved savings compared to ECO0.3: 24 TWh in 2040 and 39 TWh in 2050. The average ventilation performance (VPI) is expected to increase from 0.34 in 2015 to approximately 0.51 in 2050, which would be a significant future accomplishment of the proposed revised regulation. This improvement will be at the expense of (extra) energy savings (Table 2): In the variant ECO-scenario using the same VPI as BAU (no improved ventilation performance), the savings are higher: 39 TWh in 2040 and 60 TWh in 2050.

[1] https://ec.europa.eu/docsroom/documents/26525

[2] Wierda, L., Kemna, R. et al. (VHK), Ecodesign Impact Accounting, VHK for EC DG ENER C.3, 2013-2018. https://ec.europa.eu/energy/en/studies/ecodesign-impact-accounting-0

Table 1. EU27 total primary energy consumption by the VU stock: primary energy for VU electricity consumption (PEF 2.5 until 2020; PEF 2.1 afterwards), and space heating energy required to compensate for mechanical ventilation heat losses (not counting remaining infiltration).

Primary energy VU stock (TWh/a)	1990	2000	2010	2015	2020	2030	2040	2050
BAU	167	226	306	330	341	337	371	406
ECO0.3	167	226	306	330	341	334	363	395
ECO (RVUs /BAU-VPI)	167	226	306	330	341	324	331	347
ECO (RVUs /ECO-VPI)	167	226	306	330	341	329	347	368

Table 2. EU27 total primary energy savings versus BAU and VPI for residential

Primary energy savings versus BAU (TWh/a)	1990	2000	2010	2015	2020	2030	2040	2050
ECO0.3	0	0	0	0	0	2	7	12
ECO (with RVUs having BAU-VPI)	0	0	0	0	0	12	39	60
VPI RVUs	*0.34*	*0.34*	*0.35*	*0.36*	*0.37*	*0.39*	*0.41*	*0.42*
ECO (with RVUs having ECO-VPI)	0	0	0	0	0	7	24	39
VPI RVUs	*0.34*	*0.34*	*0.35*	*0.36*	*0.37*	*0.42*	*0.47*	*0.51*

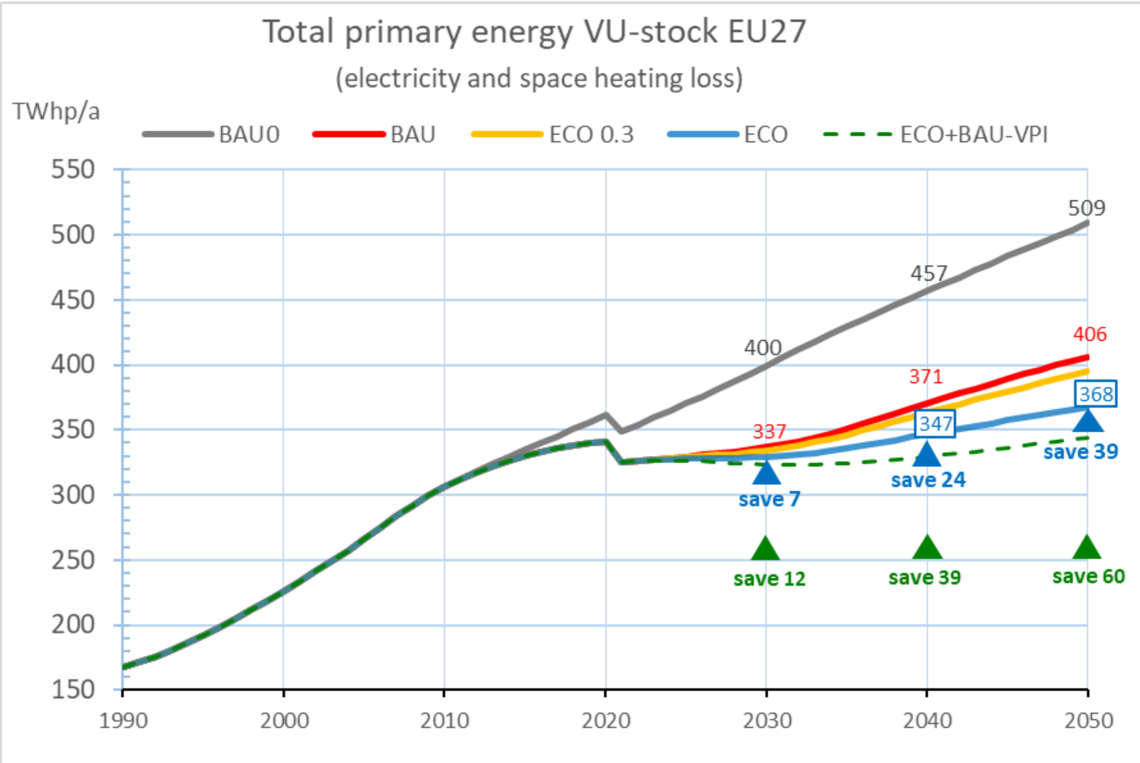

Figure 1. EU27 total primary energy consumption by the VU stock: primary energy for VU electricity consumption (PEF 2.5 until 2020; PEF 2.1 afterwards) plus space heating energy required to compensate for mechanical ventilation heat losses (not counting remaining infiltration).

Results for the VU-stock when also considering remaining natural infiltration

Figure 2 gives the gross primary energy consumption of the total VU-stock, including the infiltration that remains in the buildings the VUs are installed in. This infiltration causes additional heat losses that have to be compensated by additional space heating energy. The infiltration is the same for all VU-scenarios and consequently it does not affect the differences between scenarios (the savings). An average n50 of 2 for dwellings renovated or newly constructed beyond 2020 is used, an average n50 of 4 for 2010 and an average n50 of 6 for 2000 and before [3].

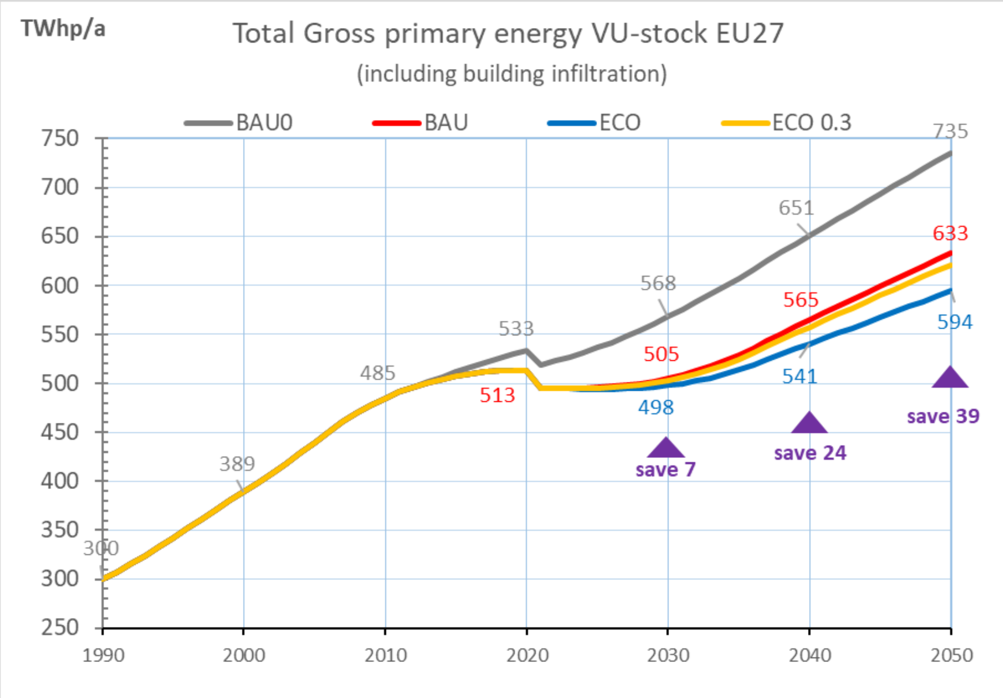

Figure 2. Gross primary energy for ventilation and infiltration in EU27 VU-building stock. Compared to Figure 1 this adds primary energy for space heating required to compensate for infiltration heat losses.

Results for the VU-stock when subtracting replaced natural ventilation

For renovation projects and newly constructed buildings that include the installation of VUs, it is assumed that the airtightness levels are improved and related infiltration rates decline to values that are typical for the year of realization (see n50 values above). This means that, in the cases of new construction and renovation, the installation of mechanical ventilation avoids the space heating energy that would otherwise have been required to compensate for reference natural ventilation heat losses (corresponding to

[3] A common measure for infiltration –also referred to as the air-tightness of a building, is n50. This is the air exchange per hour over the inner volume of the dwelling (ACH in m3/h) at an indoor/outdoor pressure difference of 50 Pa.

2.5 $m^3/h/m^2$). For VUs that replace existing VUs, no avoidance of natural ventilation heat losses is accounted.

Subtracting the avoided space heating energy losses for installation of mechanical VUs in new construction and renovation from the gross primary energy consumption of the VU-stock presented above, the net primary energy effect of Figure 3 is obtained. Also in this case, the avoided natural ventilation heat losses are the same for all scenarios, so the differences between the scenarios (the savings) are not affected.

Replacement of natural ventilation systems in renovation projects has by far the largest offsetting effect here. The ambitious but clear path of the EPBD towards a low and zero-emission building stock in the EU by 2050 is a clear driver behind the renovation activities in the existing building stock.
Nevertheless, the ECO-scenario does not take into account that all of the existing buildings will be renovated by 2050, but assumes that about 30% of the stock still needs to be renovated by 2050.

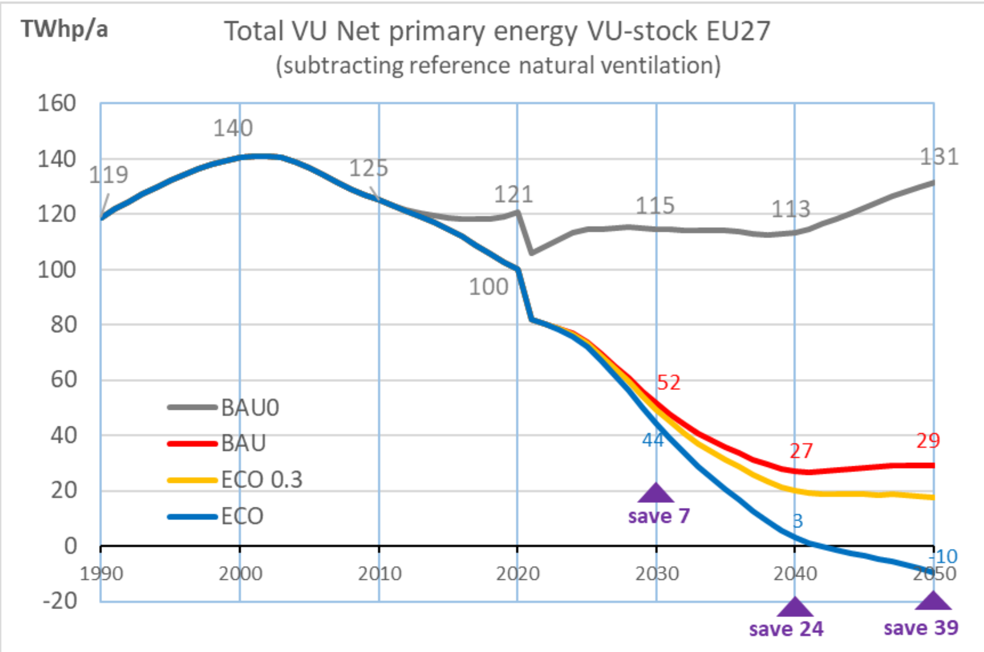

Figure 3. EU27 Total Net primary energy effect of the VU-stock. Compared to Figure 2 this subtracts, for the cases of new construction and renovation, the space heating energy required to compensate for reference natural ventilation heat losses that would have occurred if no mechanical ventilation had been installed.

Results for the entire building stock

Figure 4 and Table 3 illustrate that the total primary energy consumption for ventilation and residual infiltration for the total EU27 building stock (including all dwellings and buildings, with or without VU) will gradually decline from 2015 onwards, despite an expansion of the total building surface of almost 10% (from 27 526 million m^2 in 2015 to 30 131 million m^2 in 2050).

The specific primary energy consumption in kWh/m^2/a is reduced from 63.4 kWh/m^2/a in 1990 to 37.8 kWh/m^2/a in 2050. A reduction of 40%. With 1990 as reference the total savings are 771 TWh in 2050; with 2015 as reference the savings amount to 567 TWh in 2050. The savings per m^2 of heated surface are the result of the increased penetration of improved mechanical ventilation units and related improvements to the buildings and dwelling shells.

Table 3. Primary energy ventilation and infiltration in total EU27 building stock

	unit	**1990**	**2000**	**2010**	**2015**	**2020**	**2030**	**2040**	**2050**
Total heated surface	Mm2	20384	23039	26312	27526	28291	29280	29789	30131
Total primary energy EU27 buildings stock - BAU	TWh/a	1292	1435	1547	1558	1528	1391	1282	1178
Total primary energy EU27 buildings stock - ECO03	TWh/a	1292	1435	1547	1558	1528	1389	1275	1166
Total primary energy EU27 buildings stock - ECO	TWh/a	1292	1435	1547	1558	1528	1383	1258	1139
Specific primary energy consumption - ECO	kWh/ m^2/a	*63.4*	*62.3*	*58.8*	*56.6*	*54.0*	*47.2*	*42.2*	*37.8*
Savings compared to 1990 reference: 63.4 kWh/m^2/a	TWh/a	0	26	120	186	265	473	630	771
Savings compared to 2015 reference: 56.6 kWh/m^2/a	TWh/a	0	0	0	0	73	274	429	567

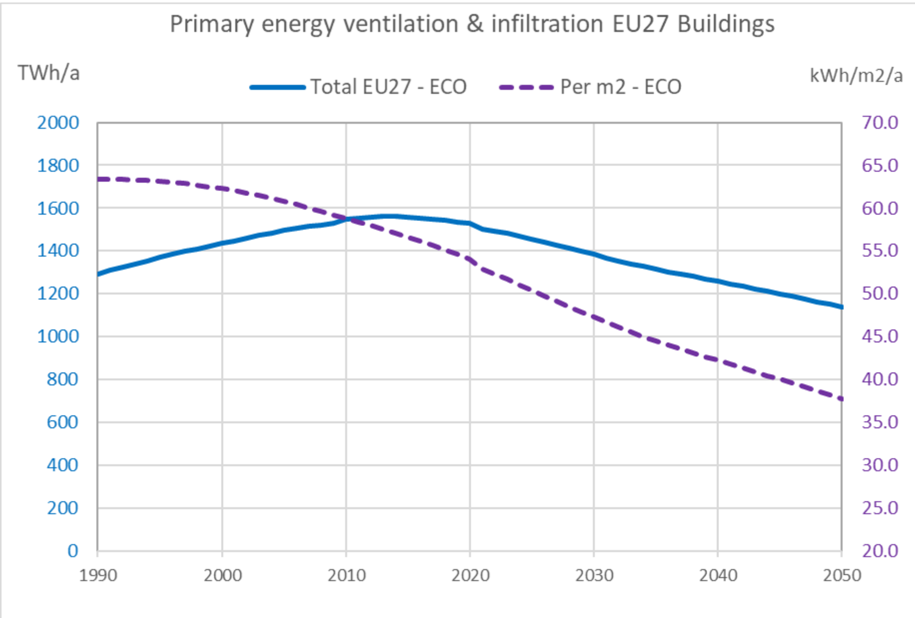

Figure 4. Primary energy for ventilation of the EU27 buildings stock

Greenhouse gas emissions

Total EU27 net avoided GHG-emissions for the VU appliance stock (subtracting contributions from avoided space heating to compensate for natural ventilation losses in the case of new construction and renovation) in the ECO-scenario versus the BAU scenario are 4 MtCO2eq/a in 2040 and 6 MtCO2eq/a in 2050. In the ECO0.3 scenario the avoided emissions in the same years reduce to respectively 1 and 2 MtCO2eq/a.

User expense

In the BAU-scenario, total EU27 user expenditure related to VUs increases from 27 bn euros/a in 2020, to 29 in 2030 and further up to 34 bn euros/a in 2050. This increase is mainly due to an increase in the VU-sales and -stock quantities.

In the ECO-scenario, the total user expenditure initially increases compared to BAU, by 0.6 bn euros in 2030 (negative savings shown in the graph). This is an investment in better-performing VUs, which initially are more expensive. In later years the ECO-expenditure is lower than in BAU: 0.7 bn euros lower in 2040 and 2.4 bn euros lower in 2050. This is due to higher average electrical and heat recovery efficiency, and to improved control of the ventilation airflows, leading to lower energy costs. In the ECO0.3 scenario the expenditure savings versus BAU would be reduced to 0.7 bn euros/a in 2050. These overall cost reductions come together with an improvement in the ventilation performance index.

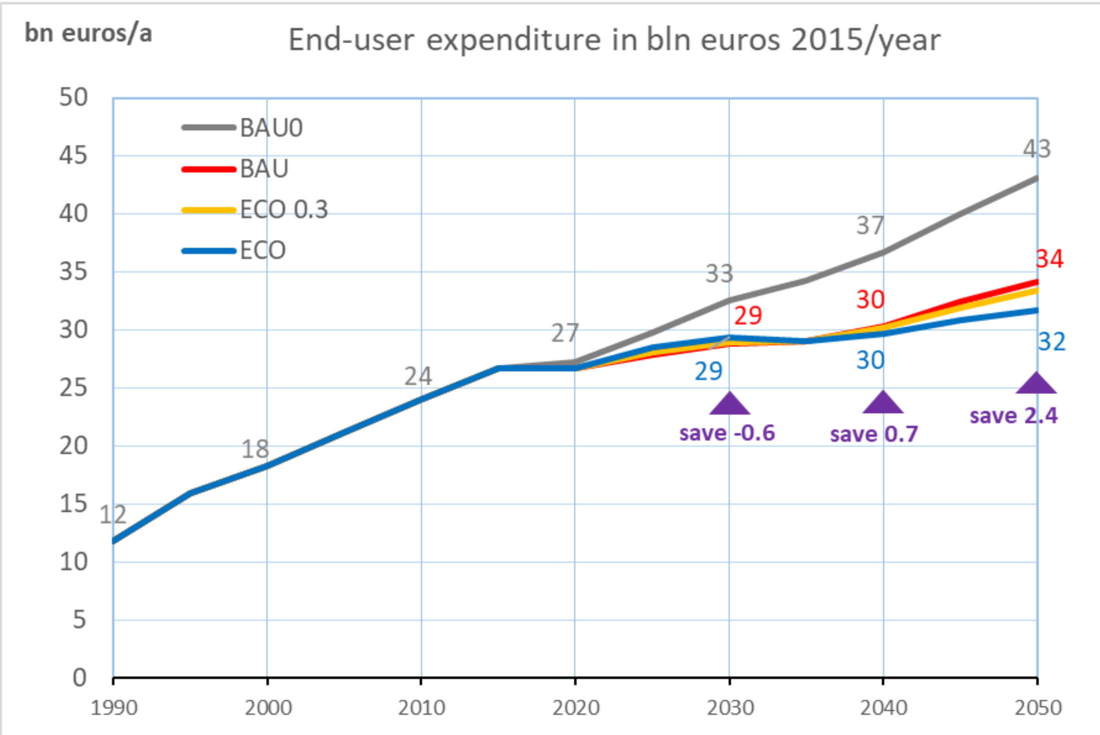

Figure 5: EU27 total user expense (in bn 2015 euros/a) related to the acquisition and use of Ventilation Units, for the four scenarios considered.

Business revenues and jobs

The additional business revenues in ECO versus BAU are 1.1 bn euros in 2030 and 1.5 bn euros in 2050. In ECO0.3 the 2050 value would reduce to 0.4 bn euros.

As regards associated jobs, in the BAU-scenario in 2020 the estimate is 242 thousand jobs associated with the sale, installation and maintenance of ventilation units. Without new measures, this is projected to increase to 278 thousand in 2030 and 377 in 2050. While installation and maintenance jobs are most likely all inside EU27, a share of the industry jobs would be expected to be outside EU27. In the ECO-scenario, 17 thousand additional jobs are created in 2030 and 23 thousand additional in 2050. This would drop to 7 thousand additional jobs in 2050 in the ECO0.3 scenario.

Acronyms and units

Acronyms

AC/DC	Alternating/Direct Current
ADCO	Administrative Co-operation
AHRI	American Air Conditioning, Heating and Refrigeration Institute
AMCA	Air Movement and Control Association
ATEX	ATmosphères EXplosibles
BC	Backward Curved
BVU	Bidirectional Ventilation Unit
CECED	European Committee of Domestic Equipment Manufacturers
CEN	European Committee for Standardization
CFD	Computer Fluid Dynamics
CIRCA	Communication and Information Resource Centre
CLP	Classification, Labelling and Packaging (Regulation)
DigitalEurope	Association representing the digital technology industry in Europe
DoC	Document of Conformity
DoE	US Department of Energy
EC	Electronically Commutating
EN	European Norm
EPEE	European Partnership for Energy and the Environment
Eurovent	Association of European refrigeration, air conditioning, air handling, heating and ventilation industry
EVIA	European Ventilation Industry Association
FC	Forward Curved
GWh	Giga Watt hour 10^9 Wh
HNL	Howden Netherlands
HRS	Heat Recovery System
ICSMS	Information and Communication System on Market Surveillance
ISO	International Standardisation Organisation
JBCE	Japan Business Council in Europe
JRAIA	Japan Refrigeration and Air Conditioning Industry Association
N	Efficiency grade
NRVU	Non-Residential Ventilation Unit
RAC	Run Around Coil
RAPEX	EU Rapid Alert System
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (Regulation)
RoHS	Restriction of Hazardous Substances (directive)
RVU	Residential Ventilation Unit
rpm	rounds per minute (unit for fan rotation speed)
TC	Technical Committee (in ISO, CEN, etc.)
TWh	Tera Watt hour 1012 Wh
UVU	Unidirectional Ventilation Unit
VU	Ventilation Unit
WEEE	Waste of electrical and electronic equipment (directive)
WG	Working Group (of a TC)
yr	year

Parameters

A	floor surface area building [m²]
c_{air}	specific heat air [Wh/ m³.K]
Q	heat/energy [kWh]
q	hourly air exchange [$m^3.h^{-1}/ m^3$]
rec	ventilation recovery rate [-]
S	shell surface area building [m²]
SV	shell surface/volume ratio building
t	heating season hours [h]
T_{in}	Indoor temperature [°C]
T_{out}	outdoor temperature [°C]
U	insulation value in [W/K. m²]
V	heated building volume [m³]
ΔT	Indoor-outdoor temperature difference [°C]
η	efficiency [-]

Units

€	Euro
°C	degree Celsius
a	annum (year)
bn	billion (1000 million)
CO_2	carbon-dioxide (equivalent)
h	hours
K	degree Kelvin
kWh	kilo Watt hour
m	metre or million
m^2	square metre
m^3	cubic metre
Pa	Pascal
W	Watt

Table of Contents

1 Introduction

1.1 Scope

The scope of Task 7 is to perform a scenario analysis, i.e. to analyse the evolution over time of environmental and socio-economic impacts due to policy options for the review of Ecodesign and/or Energy Label regulations for ventilation units EU 1254/2014 (Energy Label, EL) and EU 1253/2014 (Ecodesign, ED). The impacts include energy consumption, GHG-emissions, monetary impacts for users and businesses, and associated jobs. The policy options include the Business-as-Usual ('BAU') scenario, an intermediate policy scenario 'ECO0.3' and an ambitious 'ECO' scenario.

The BAU-scenario reflects continuation of the current situation with projections up to 2050. The ECO0.3 and ECO policy scenarios build on the Least Life Cycle Cost (LLCC) design options from Task 6 for the base cases defined in Task 5. Details are given in Annex 2. In the ECO0.3 scenario a series of undisputed design measures is adopted in the review, whereas the ECO scenario also ventures into a more ambitious approach as regards the proposed Ventilation Performance Index (VPI), i.e. aiming for true and effective improvement of the air exchange rate for a better indoor air quality.

For the ECO-scenario there are two scenarios: 1) a preferential scenario with a vastly improved ventilation performance at the expense of less extra energy savings, or 2) an alternative scenario with the current ventilation (BAU) performance but with a higher energy saving.

The first scenario assumes that the market actors will react to the proposed Ecodesign and Energy Label measures and choose ventilation unit types and controls leading to a better VPI. The alternative scenario assumes that installers and consumers are set in their ways and will not or only slightly change their purchasing and installation habits for mechanical ventilation units. These two scenarios fit the two interrelated strategies where a review could solve the current ventilation problems: 1) inadequate ventilation performance and 2) untapped potential for further energy saving.

Finally, Task 7 also includes a 'BAU0' scenario. For the sake of an evaluation of the effectiveness of the current measures in the context of Better Regulation Fitness Check, this scenario revisits the 2014 Business-as-Usual scenario, i.e. the scenario before the introduction of the ventilation unit regulations EU 1254/2014 (Energy Label, EL) and EU 1253/2014 (Ecodesign, ED). Note that 'BAU0' is numerically not identical to the BAU scenario in the 2014 Impact Assessment (IA) study, because there have been substantial new insights in market developments and space heating data. But 'BAU0' does mimic the 2014 IA BAU scenario in terms of efficiency projections.

This Task 7 follows the MEErP-prescription for this task, but also draws the boundaries of the impact assessment considerably wider, including not only scenarios for the ventilation unit product but also the impact of the ongoing switch from a building stock that in majority still uses natural ventilation (window openings, stack vents, infiltration) to mechanical ventilation. Scenario analyses are performed both on the complete EU27-buildings stock (including natural ventilation and infiltration) and on the EU27 VU appliance stock. By doing so, the effect of the increased penetration of mechanical ventilation units on the total space heating energy demand of the growing EU27 building stock can also be assessed.

1.2 Methodology

The scenario analysis follows the MEErP[4], and more in particular the methodology of the Ecodesign Impact Accounting (EIA)[5]. The inputs for the calculations, e.g. sales, lifetimes, loads (user demand for product output), (real-life) efficiencies, prices, rates, etc. are taken from the information presented in the preceding task reports. The analysis covers the period 1990-2050, with additional inputs for sales and efficiencies going back as far as 1970 to enable realistic stock calculations from 1990 onwards. The analysis is performed for EU27 (excluding UK). Table 1 gives a survey of the base cases considered in the scenario analysis for residential ventilation units. Table 2 lists the considered base cases for non-residential ventilation units.

Table 4. Base cases Residential VUs, individual and collective

No	Name	RVU-type	Nominal flowrate m^3/h	Airflow-control1)	Ventilation controls2)
1	UVU/100/ES	Local extract UVU for ES only	60	Local	Manual
2	UVU/100/HS	Local extract UVU for HS only	60	Local	Manual
2	BVU/100	Local BVU for HS only	60	Local	Manual
3	UVU/250	Central extract UVU for whole dwelling	180	Central	Manual
4	BVU/250	Central BVU for whole dwelling	180	Central	Manual
5	UVU/1000	Collective central extract UVU	720	Central	Clock
6	BVU/1000	Collective central BVU	720	Central	Clock
7	UVU/1000+	Collective central extract UVU	1500	Central	Clock
8	BVU/2500	Collective central BVU	2250	Central	Clock

1). Level at which the mechanical airflow can be varied (central, zone or local (room))
2). Type and location of the VDC-devices/sensor/switches that determine the operation (high/low switching) of the ventilation unit.

[4] https://ec.europa.eu/docsroom/documents/26525

[5] Wierda, L., Kemna, R. et al. (VHK), Ecodesign Impact Accounting, VHK for EC DG ENER C.3, 2013-2018. https://ec.europa.eu/energy/en/studies/ecodesign-impact-accounting-0

Table 5. Base cases non-residential VUs

No	Name	RVU-type	Nominal flowrate	Airflow-control1)	Ventilation controls2)
9	NR-UVU/1000	Central extract UVU, small	720	Central	Clock
10	NR-BVU/1000	Central BVU, small	720	Central	Clock
11	NR-UVU/1000+	Central extract UVU	1500	Central	Clock
12	NR-BVU/2500	Central BVU	2250	Central	Clock
13	AHU/S	Air Handling Unit Small	4000	Central	Clock
14	AHU/M	Air Handling Unit Medium	10.000	Central	Clock
15	AHU/L	Air Handling Unit Large	35.000	Central	Clock

1). Level at which the mechanical airflow can be varied (central, zone or local (room))

2). Type and location of the VDC-devices/sensor/switches that determine the operation (high/low switching) of the ventilation unit.

1.3 Report Structure

This Task 7 report contains, after this introductory chapter 1, separate chapters per parameter, i.e. sales, stock, load (demand for ventilation), energy efficiency, energy consumption, GHG-emission, user expense, business revenues and jobs. Each of these chapters presents data for the BAU-scenario, the ECO-scenario, the ECO0.3 scenario and the differences BAU-ECO (savings, change in impacts). Data for the BAU0-scenario are not discussed in detail, but shown as reference in figures comparing scenario results.

2 Sales

The accuracy of Prodcom data for this product group is very limited, due partly to ambiguous definitions. Complete time-histories and projections on sales and stock of ventilation units are available from older (2012) Ecodesign studies, as summarized in the Ecodesign Impact Accounting. For recent years there are only fragmented data (one country, one year, etc.) and no projections for e.g. the impact of the strong decrease in new buildings following the 2008 financial crisis, or following the provisions of the 2018 recast of the Energy Performance of Buildings Directive (EPBD), i.e. all new-built to be NZEB (Nearly-Zero Energy Building) by 2020, and the entire EU27 stock of buildings to be NZEB by 2050.

Therefore, in particular for the future projections of the sales and stock of ventilation units, the study team developed a Buildings-Ventilation Model (BVM), linking the sales of VUs to the number of new-built and renovated residential dwellings and non-residential buildings (see Task 2 report). The most important model assumptions are:

- 60% of the 2015 residential dwelling stock will be renovated by 2050. This % varies per country, from 46% to 69%. The EU average annual renovation rate necessary to reach this is 0.6% in 2015, 1.6% in 2030 and 2.6% in 2050.
- 45% of the 2015 non-residential building stock will be renovated by 2050. The EU average annual renovation rate necessary to reach this is 0.7% in 2015, 1.4% in 2030 and 1.4% in 2050.
- The share of new-built or renovated residential dwellings installing a certain type of VU in the period 2025-2050 is given per country by Table 1 in the Task 2 report.
- For the non-residential sector, the distribution share of new-built or renovated non-residential building area covered by the various VU-types is given by Table 2 in the Task 2 report. In addition to these distribution shares it is assumed that 80% of new-built building area will install a VU, and 60% of the renovated building area.

The sales quantities for ventilation units derived in Task 2 have been used in the scenario analysis. The sales are the same for all scenarios. What differs between the scenarios (starting from 2023) are the sales shares, for a given VU-type, of the 2020 base case design and of the design options. These sales shares have been used to compute sales-weighted average loads and efficiencies that differ per scenario (chapters 4 and 5).

For the ECO- and ECO0.3 scenarios these sales shares are indicated in Annex 1 and 2 respectively and show that the sales share of the design options increases with time, but more in the ECO-scenario than in the ECO0.3 scenario. The proposed measures for RVUs (Task 6) are expected to further promote the sales of units that provide better ventilation performance vis-à-vis lower energy consumption (i.e. the design options). RVUs with better energy labels (i.e. lower SEC-values) and higher VPI-classifications will gain increased market shares as a result of the proposed new energy-label scheme. For non-residential ventilation units the proposed adjustments in the Ecodesign Regulation will result in higher shares of NRVUs with improved application specific optimisations with regard to the SFP values and energy recovery ratios.

Sales of Residential Ventilation Units

As derived in Task 2, in 2015 a total of 1.2 mln VUs were sold for the EU27 residential sector. Of these, 0.3 mln were for new-built dwellings, 0.3 mln for renovated dwellings and 0.6 mln were replacement sales. The large majority were CUVUs (0.8 mln units, 72%). BVUs represented 20% of the sales: 0.23 mln units, of which 0.08 mln CBVU (> 100 m3/h) and 0.15 mln LBVU (< 100 m3/h). Continuously operating LUVUs represented 7% of the market (0.09 mln units).

Starting from 2020, due to the measures in the EPBD (all new-built dwellings NZEB by 2020; entire EU dwelling stock NZEB by 2050), a strong increase in sales of VUs is projected. This increase is driven mainly by the sales for renovated dwellings that are projected to continue to increase up to 2050. Sales for new-built and renovated dwellings show a strong increase in the period 2020-2025. In later years, sales for new-built stabilize or decrease due to the gradual reduction of the number of new-built dwellings. Sales for renovated dwellings continue to increase also after 2025. Given the increase in sales from 2020, and the assumed average lifetime of VUs of 17 years, starting from 2037 there is a strong increase in replacement sales. The increase in sales mainly regards BVUs (with heat recovery), that pass from 0.23 mln in 2015 to 2.4 mln in 2030 and 5.3 mln in 2050. In comparison, sales for CUVUs are projected to remain relatively stable: around 1 mln units per year over the entire period.

Figure 6 shows the RVU total sales quantities for the period 1990-2050. For a split in new-built, renovation and replacement, and details for each of the base cases of Table 4, see the Task 2 report.

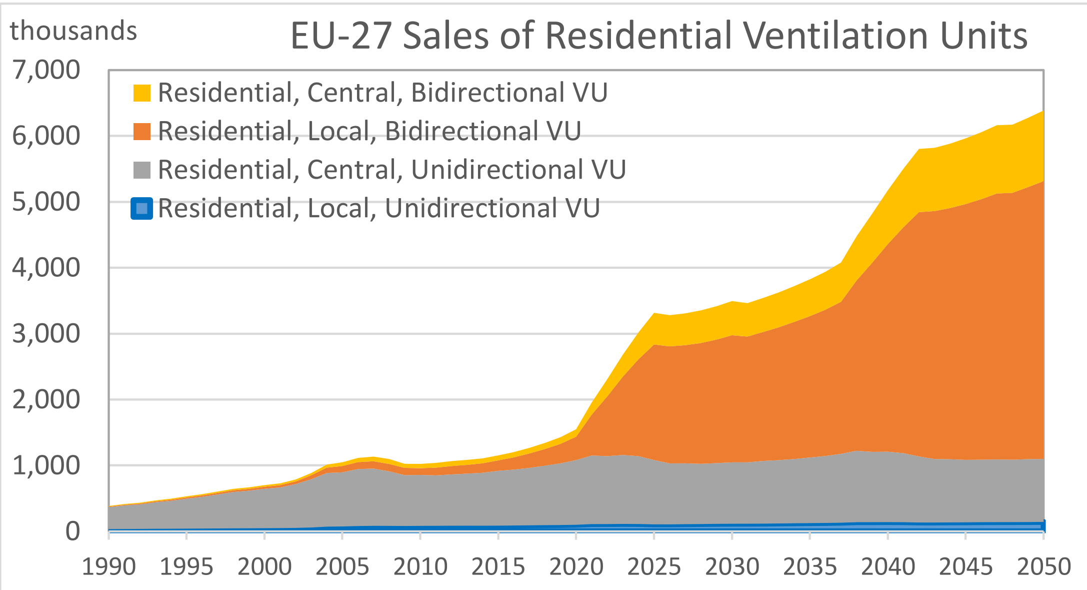

Figure 6. EU27 Total Sales of Ventilation Units for residential dwellings (thousands)
(source: VHK 2020, BVM model)

Sales of Non-Residential Ventilation Units

As derived in Task 2, in 2015 a total of 487 thousand VUs were sold for the EU27 non-residential sector. Of these, 122 thousand (25%) were for new-built buildings, 85 thousand (17%) for renovated buildings, and 280 thousand (57%) were replacement sales. Central Balanced solutions (CBVU/CHRV and AHU) represented 52% of the market (251 thousand units) and Central Unidirectional (CUVU/CEXH) another 48% (236 thousand units).

Due to the measures in the EPBD (entire EU building stock NZEB by 2050), a continuing increase in sales of NRVUs is projected. This increase is driven both by new-construction and by renovation. In particular the sales of BVUs and AHUs (most with heat recovery) are expected to increase from 251 thousand units in 2015 to 365 thousand in 2030 and 517 thousand in 2050. Sales of CUVUs are expected to remain relatively stable: between 216 and 247 thousand units per year over the entire 2015-2050 period.

Figure 7 shows the NRVU total sales quantities for the period 1990-2050. For a split in new-built, renovation and replacement, and other details, see the Task 2 report.

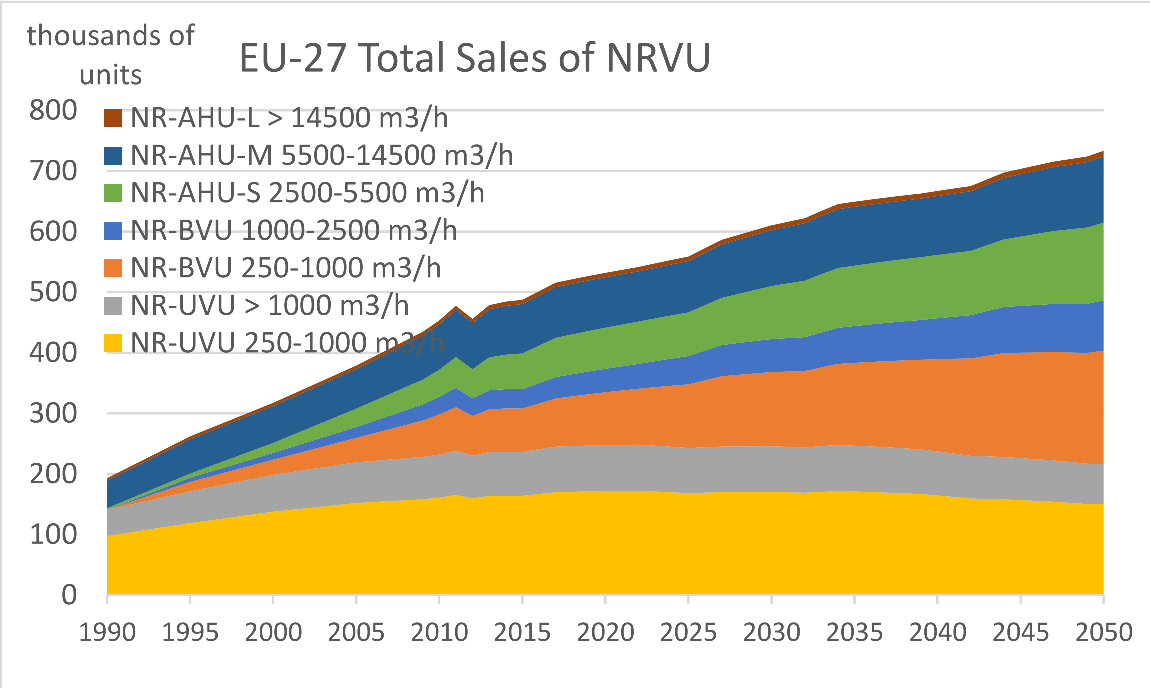

Figure 7. EU27 Total Sales of Ventilation Units for non-residential buildings (thousands)
(source: VHK 2020, BVM model)

3 Stock

The stock is the quantity of ventilation units that is installed and operating in EU27. In the analysis methodology, the stock in a given year is calculated as the sum of the sales over lifetime preceding years, i.e. summing the units sold in earlier years that have not yet reached their end-of-life. For example, for a base case that has a 17 year lifetime, the stock in 2010 is the sum of the sales over years 1994-2010.

The stocks derived in the Task 2 report have been used for the scenario analysis. As sales are the same for all scenarios, so are the stocks.

Stock of Residential Ventilation Units

As derived in Task 2 and shown in Figure 8, in 2015 the total stock of VUs for continuous operation used in the residential sector amounted to 16.6 mln units. The large majority were UVUs (14.1 mln units, 85%), mainly Central UVUs > 100 m3/h (12.9 mln, 77%). BVUs represented 15% of the stock (2.5 mln units), mainly Local BVUs < 100 m3/h (1.6 mln, 9.5%).

In 2015, 20% of the total EU27 area of permanently occupied dwellings used a CUVU, and 2% a CBVU. The share of area covered by continuously operating Local VUs was less than 1%. Overall, around 23% of the dwelling area used some kind of mechanical ventilation. This implies that 77% had no mechanical ventilation (except non-continuous local UVU for toilet, bathroom, kitchen, etc.).

Due to the increase in sales, the share of permanently occupied dwelling area using CBVUs is projected to increase from 2% in 2015 to 7% in 2030 and 22% in 2050. Local BVUs are projected to increase their covered area share from 0.3% in 2015 to 10% in 2050. CUVUs slightly increase their share of covered dwelling area from 20% in 2015 to 25% in 2050. As a result, 34% of permanently occupied residential dwelling area uses some kind of mechanical ventilation in 2030, and in 2050 this is projected to further increase to 58%.

For further details on the RVU stock, see the Task 2 report.

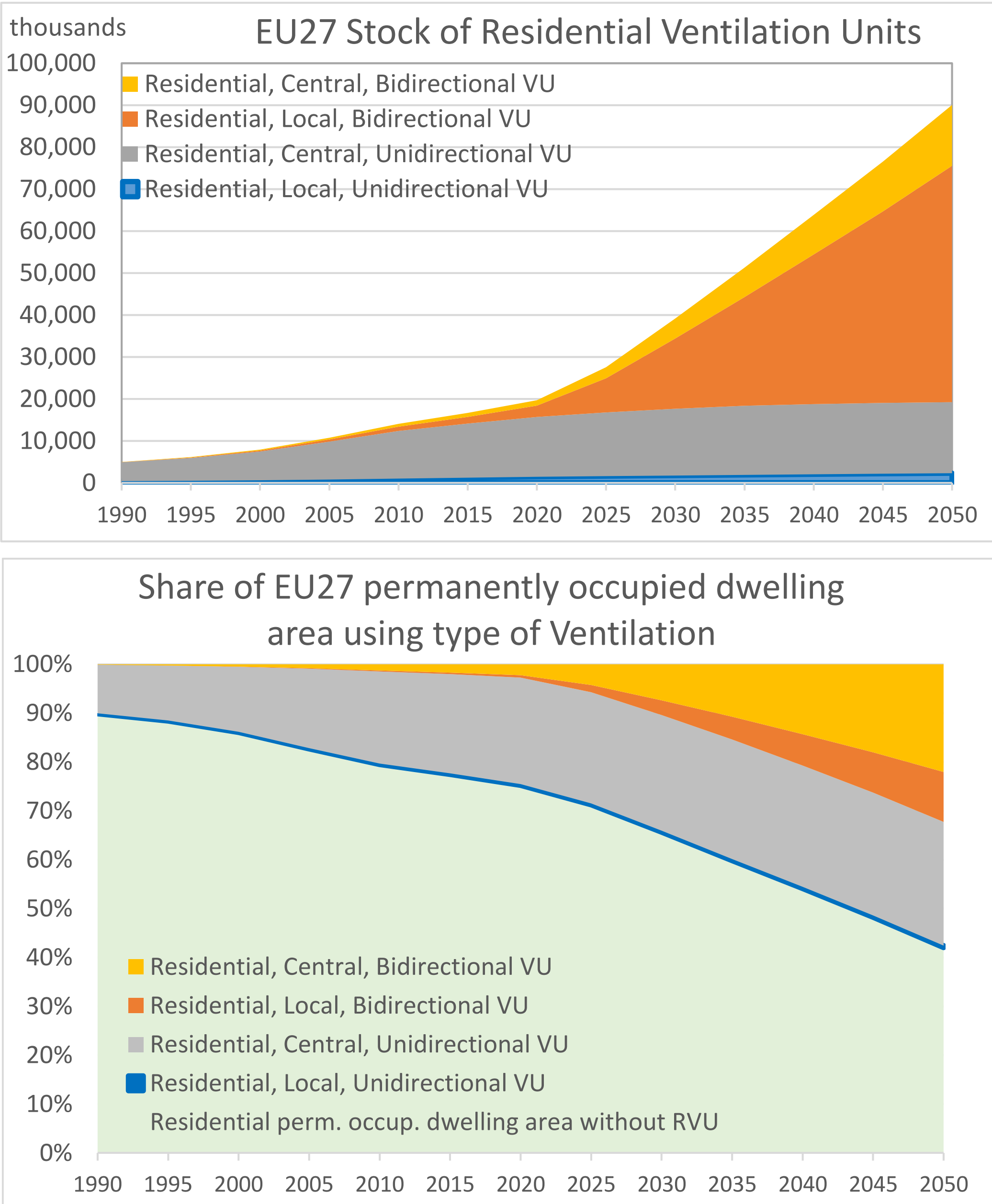

Figure 8. Total EU27 stock of residential ventilation units and share of EU27 residential dwelling area using a certain type of ventilation

Stock of Non-Residential Ventilation Units

As derived in Task 2 and shown in Figure 9, in 2015 the total EU27 stock of VUs for continuous operation in the non-residential sector amounted to 6.9 mln units. Of these, 3.8 mln (55%) were Central Unidirectional units (CUVU/CEXH) and 1.2 mln (18%) Central Balanced units (CBVU/CHRV). Air Handling Units represented 27% of the stock (1.9 mln units).

In 2015, 15% of the non-residential building area used a CUVU and another 5% a CBVU, while 43% used an Air Handling Unit. Overall, 64% of the non-residential building area used some kind of mechanical ventilation. This implies that 36% of the building area had no continuously operating mechanical ventilation.

Due to the increase in sales of VUs, the share of non-residential building area using CBVUs is projected to increase to 9% in 2030 and to 14% in 2050. In parallel, the share of area covered by AHUs increases from 43% in 2015, to 53% in 2030 and 62% in 2050. The share of non-residential building area using CUVUs is projected to slightly decrease over the 2015-2050 period, from 15% to 13%. As a result, 78% of non-residential building area uses some kind of mechanical ventilation in 2030, and this is projected to further increase to 90% in 2050.

For further details on the NRVU stock, see the Task 2 report.

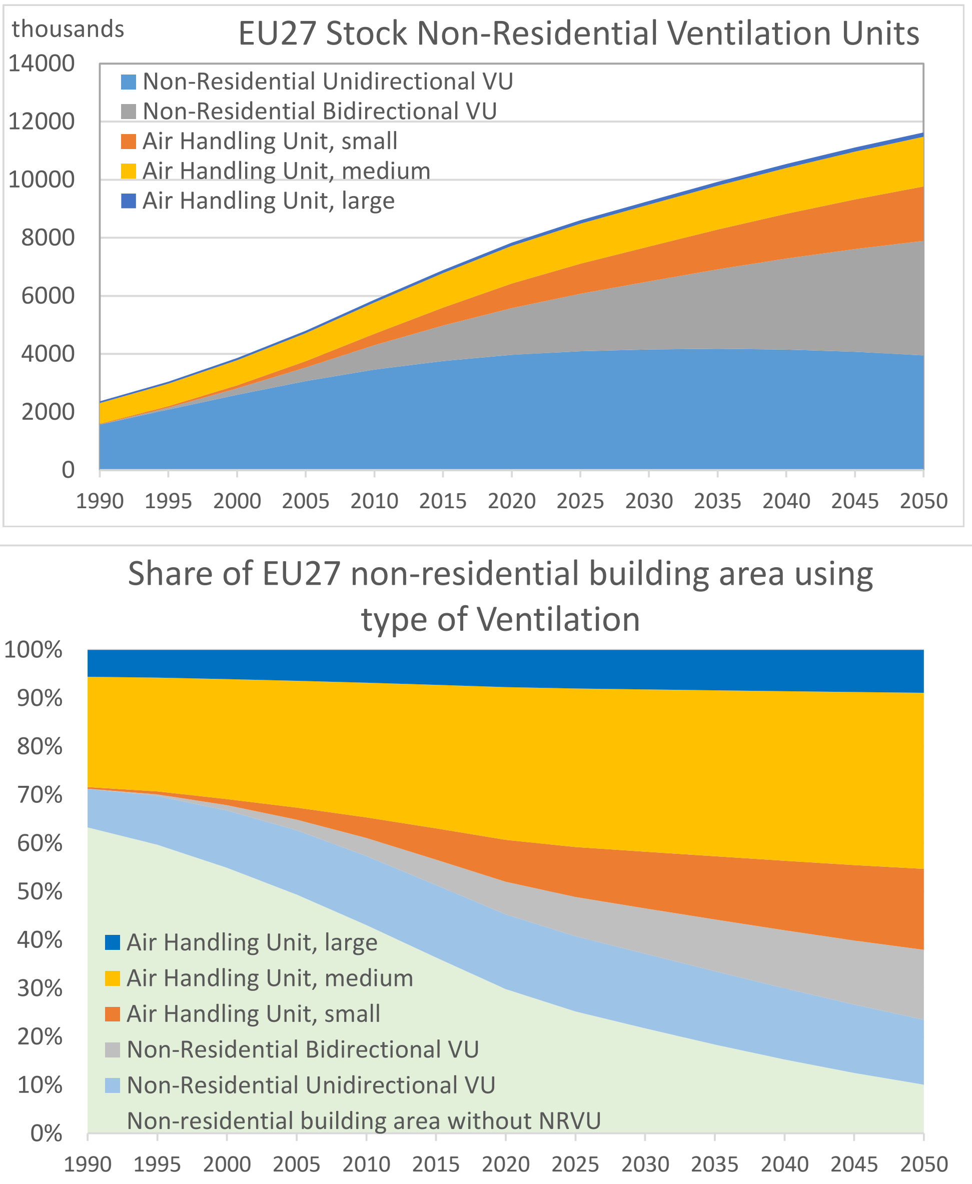

Figure 9. Total EU27 stock of non-residential ventilation units and share of EU27 non-residential building area using a certain type of ventilation

(source: VHK 2020, BVM model)

4 Load

The load is the optimal average ventilation flow rate 'q_{opt}' required, at the right time and place[6], for a healthy indoor climate[7]. It is expressed in hourly air exchange in m^3/h per m^2 heated surface at a given average height, but can also be calculated in m^3/h per m^3 heated volume, per year instead of per hour, for a single dwelling or for the whole of the EU building stock.

With some additional parameters it can also be used to estimate the average space heating loss due to ventilation, e.g. per year for the whole of the EU. The above definition of the load is a benchmark for 100% ventilation performance index VPI at a minimum loss of ventilation-related space heating energy. It is a universal benchmark, which applies independently of the air exchange typology, mechanical or natural ventilation, and allows a fair comparison between the two. Infiltration, i.e. the air flows through –largely unintentional– openings in the building shell, play an important role in both and will be defined as part of the ventilation load. A common measure for infiltration –also referred to as the air-tightness of a building, is n50. This is the air exchange per hour over the inner volume of the dwelling (A_{CH} in m^3/h) at an indoor/outdoor pressure difference of 50 Pa. Also, some other space heating defaults are needed for the calculation.[8] The end-result will be called the *'net (ventilation) space heating load'*.

As will also be illustrated in the following sections, this is not the actual space heating demand due to ventilation but merely an 'ideal' benchmark for the energy demand related to optimized ventilation and minimal infiltration in dwellings and buildings (without considering heat recovery), to be used for later reference (e.g. for assessing the theoretical maximum saving potential in the EU-dwelling stock).

Residential sector

The load can be calculated by using the qopt (= 0.67 m3/h/m2)9 as default flowrate for ventilation and using a minimum infiltration rate of 0.31 m3/h/m2 that is typical for an average dwelling airtightness of n50 =1 10 (infiltration occurs even in the best airtight buildings), to determine the net heat load for ventilation.

All calculations are related to the square metres of heated space of permanently occupied dwellings in the residential sector (average height 2.6m). The total surface of heated space

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[6] E.g. depending on use ('wet spaces' like kitchen, bathroom, toilet or not) and when the room is occupied by people or not.

[7] Defined in EN16798-1:2019, Category II (1200 ppm indoors). See Task 5.

[8] The ventilation losses are based upon an average heating season of 4910 h/a, with an average temperature difference between indoor and outdoor conditions of 10.94 ºC for (for warmer and colder conditions the season duration is respectively 3590 h/a and 6446 h/a and 5.21 and 14.53 degrees). These are the climate bin hours from Annex A of EN 14825 and also the values proposed in the 'Working Document on Ventilation Units (review EU1253/2014)'. They are slightly different from those in the current Ecodesign space heating regulation(s). The average specific energy content of the air exchanged is 0.00034 $kWh/m^3 \cdot K$. An average space heating energy efficiency of 75% is assumed.

[9] See Task 5 section 2.3.2

[10] n50 is the air exchange per hour over the inner volume of the dwelling (ACH in m3/h) at an indoor/outdoor pressure difference of 50 Pa.

of permanently occupied dwellings is derived from the Building-Ventilation Model (see Task 2), as are the percentages of dwelling surface that use residential ventilation units (RVUs).

As can be concluded from Table 6 and Figure 10, the increase in the number of dwellings over the years will also increase the net space heating energy demand for ventilation in EU27 in the residential sector from 303 TWh in 1990 to 423 TWh in 2015 and to around 444 TWh in 2050. These figures relate to all buildings, i.e. naturally and mechanically ventilated.

Looking only at net space heating load for dwellings using mechanical ventilation, this will increase more rapidly, due to the growing share of residential dwellings using mechanical instead of natural ventilation; this share is expected to rise from 10% in 1990, to 23% in 2015 and to around 58% in 2050.

As a result, the net space heating load related to the EU27 dwelling stock using RVU appliances increases from 30 TWh in 1990, to 97 TWh in 2015 and will further increase to approximately 257 TWh in 2050.

Table 6. Net ventilation heat load and space heating demand in residential sector EU27

NET VENTILATION LOAD EU27 RESIDENTIAL	unit	1990	2000	2010	2015	2020	2030	2040	2050
Net ventilation need: q_{opt}	$m^3/h/m^2$	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Total heated surface perm. occupied dwellings A	Mm^2	12562	14309	16627	17510	18027	18519	18531	18375
Net ventilation heat load Q_v	TWh/a	156	177	206	217	223	229	229	227
Reference minimal infiltration (n50 =1) q_{inf}	$m^3/h/m^2$	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Minimal infiltration heat load Q_{inf}	TWh/a	72	82	95	100	103	106	106	105
Total net heat load for opt. vent & min. infiltr. Qvtot	TWh/a	227	259	301	317	326	335	336	333
NET SPACE HEATING DEMAND EU27 RESIDENTIAL	unit	**1990**	**2000**	**2010**	**2015**	**2020**	**2030**	**2040**	**2050**
Assumed average energy recovery ratio VU	%	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Average space heating efficiency	%	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*
Net space heating demand ventilation Q_{hopt}	TWh/a	207	236	274	289	298	306	306	303
Space heating demand residual infiltration Q_{hint}	TWh/a	96	109	127	134	138	141	142	140
Total net space heating energy demand Q_{htot}	TWh/a	**303**	**345**	**401**	**423**	**435**	**447**	**447**	**444**
of which: for dwellings using natural ventilation	%	90%	86%	79%	77%	75%	66%	54%	42%
	TWh/a	*273*	*297*	*317*	*326*	*326*	*295*	*242*	*186*
of which: for dwellings using RVUs	%	10%	14%	21%	23%	25%	34%	46%	58%
	TWh/a	*30*	*48*	*84*	*97*	*109*	*152*	*206*	*257*

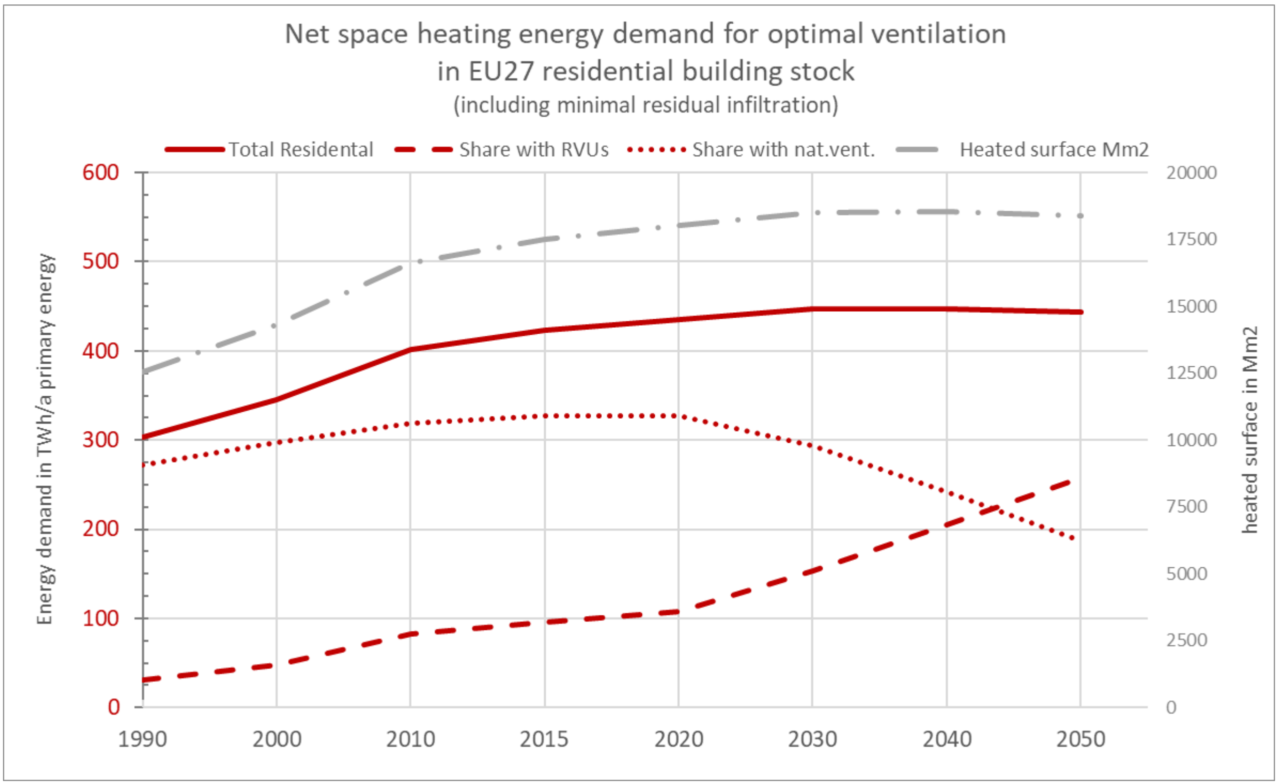


Figure 10. Net space heating energy demand EU27 residential building stock

Non-residential sector

As is the case for the residential sector, the net load can be calculated by using the qopt (= 1.26 $m^3/h/m^2$)[11] as default flowrate for ventilation and using a minimum infiltration rate of 0.31 $m^3/h/m^2$ to determine the net heat load for ventilation.

The total surface of heated space of non-residential buildings is derived from the Building Ventilation Model (see Task 2), as are the percentages of building surface that use NRVUs. The total heated surface in non-residential buildings rises from 7 822 million m^2 in 1990 to approximately 10 016 million m^2 in 2015. After that it is expected to further increase to approximately 11 756 million m^2 in 2050.

As can be derived from Table 7 and Figure 11, the increase in total heated surface (number of non-residential buildings) over the years, will also increase the net space heating energy load for ventilation from 303 TWh in 1990 to 387 TWh in 2015 and to approximately 455 TWh in 2050.

Looking only at net space heating energy load for buildings using NRVUs, this will increase more rapidly, due to the growing number of buildings using mechanical ventilation, which is expected to rise from 37% in 1990 to 64% in 2015 and to around 90% in 2050. As a result, the net space heating energy load related to the EU27 building stock using NRVU appliances increases from 112 TWh in 1990 to 248 TWh in 2015 and will further increase to about 409 TWh in 2050.

[11] Design ventilation rate according to EN 16798-1 Category II is 1.4 l/s per m2 room = 1.4*3.6/1.4 =3.6 m3/h/m2 Aheated. Multiplying this with the best control factor for NRVUs (=0.35), gives 1.26 m3/h/m2

Table 7. Net ventilation heat load and space heating demand in non-residential sector EU27

NET VENTILATION LOAD EU27 NON-RESIDENTIAL	unit	**1990**	**2000**	**2010**	**2015**	**2020**	**2030**	**2040**	**2050**
Net ventilation need: q_{opt}	m³/h/m²	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26
Total heated surface non-residential buildings	Mm2	7822	8730	9685	10016	10264	10761	11258	11756
Net ventilation heat load	TWh/a	182	203	225	233	239	251	262	274
Assumed reference minimal infiltration	m³/h/m²	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Minimal infiltration heat load	TWh/a	45	50	55	57	59	62	64	67
Total net heat load for opt. vent & min. infiltr.	TWh/a	227	253	281	291	298	312	327	341
NET SPACE HEATING DEMAND EU27 NON-RESIDENTIAL	unit	**1990**	**2000**	**2010**	**2015**	**2020**	**2030**	**2040**	**2050**
Assumed average energy recovery ratio VU	%	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Average space heating efficiency	%	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*
Net space heating energy demand ventilation	TWh/a	243	271	301	311	319	334	349	365
Space heating energy demand minimal infiltration	TWh/a	60	67	74	76	78	82	86	90
Total net space heating energy demand	TWh/a	**303**	**338**	**375**	**387**	**397**	**416**	**435**	**455**
of which: for dwellings using natural ventilation	%	63%	55%	43%	36%	30%	22%	15%	10%
	TWh/a	*191*	*186*	*161*	*139*	*119*	*92*	*65*	*45*
of which: for dwellings using NRVUs	%	37%	45%	57%	64%	70%	78%	85%	90%
	TWh/a	*112*	*152*	*214*	*248*	*278*	*325*	*370*	*409*

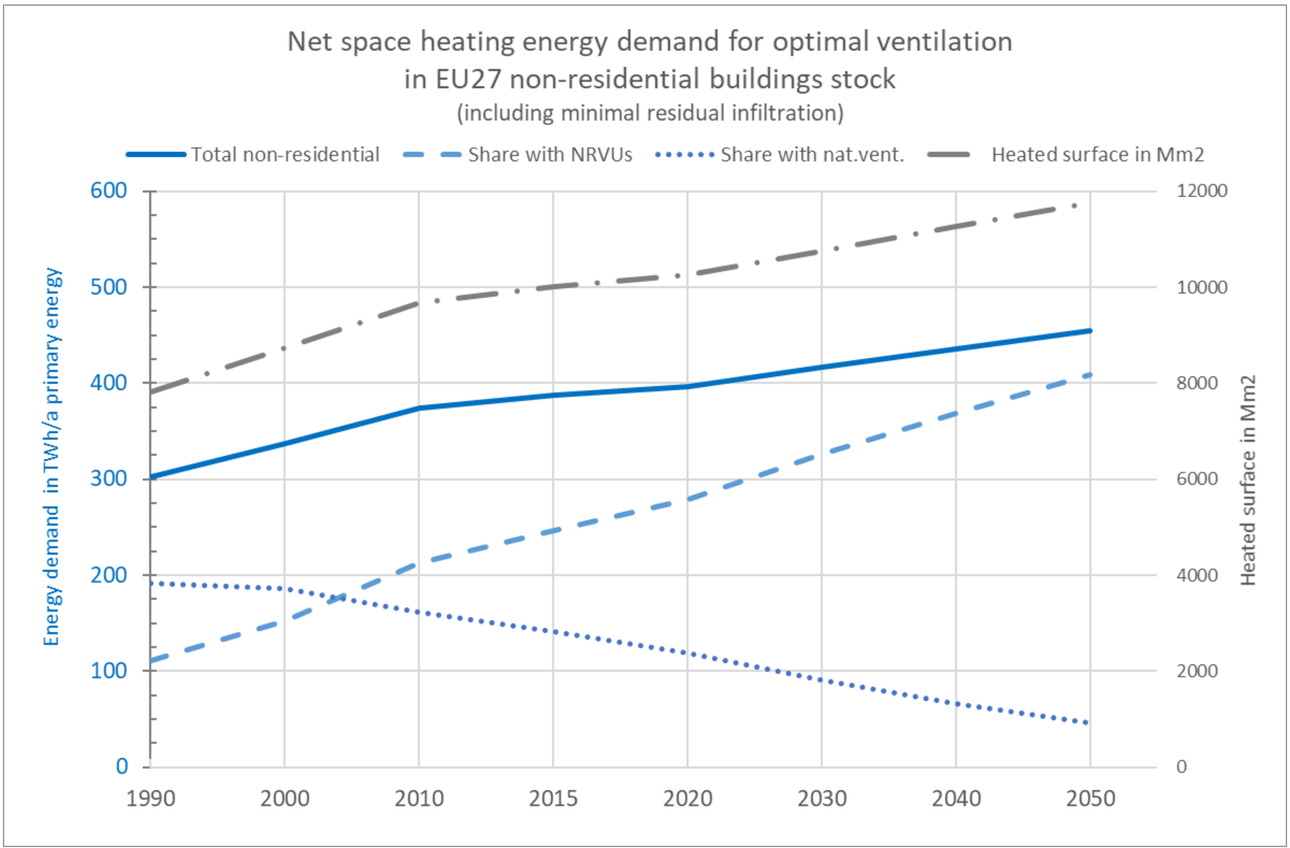


Figure 11. Net space heating energy demand EU27 non-residential building stock

Total NET LOAD EU27

For the total EU27 building stock (residential plus non-residential), the annual net space heating load for ventilation rises from 606 TWh in 1990 to 810 TWh in 2015 and is expected to further increase to 898 TWh in 2050, due to an increase in the building stock surface.

Table 8. Net space-heating energy demand for ventilation in EU27 building stock

	unit	1990	2000	2010	2015	2020	2030	2040	2050
Total NET space heating energy demand	TWh/a	606	683	776	810	832	863	883	898
Of which for residential buildings	TWh/a	303	345	401	423	435	447	447	444
for share residential buildings using RVUs	TWh/a	31	48	82	95	108	154	205	257
Of which for non- residential buidings	TWh/a	303	338	375	387	397	416	435	455
for share non-residential buildings using NRVUs	TWh/a	112	152	214	248	278	325	370	409
Total NET space heating energy demand buildings with VUs	TWh/a	143	200	296	343	386	478	576	666

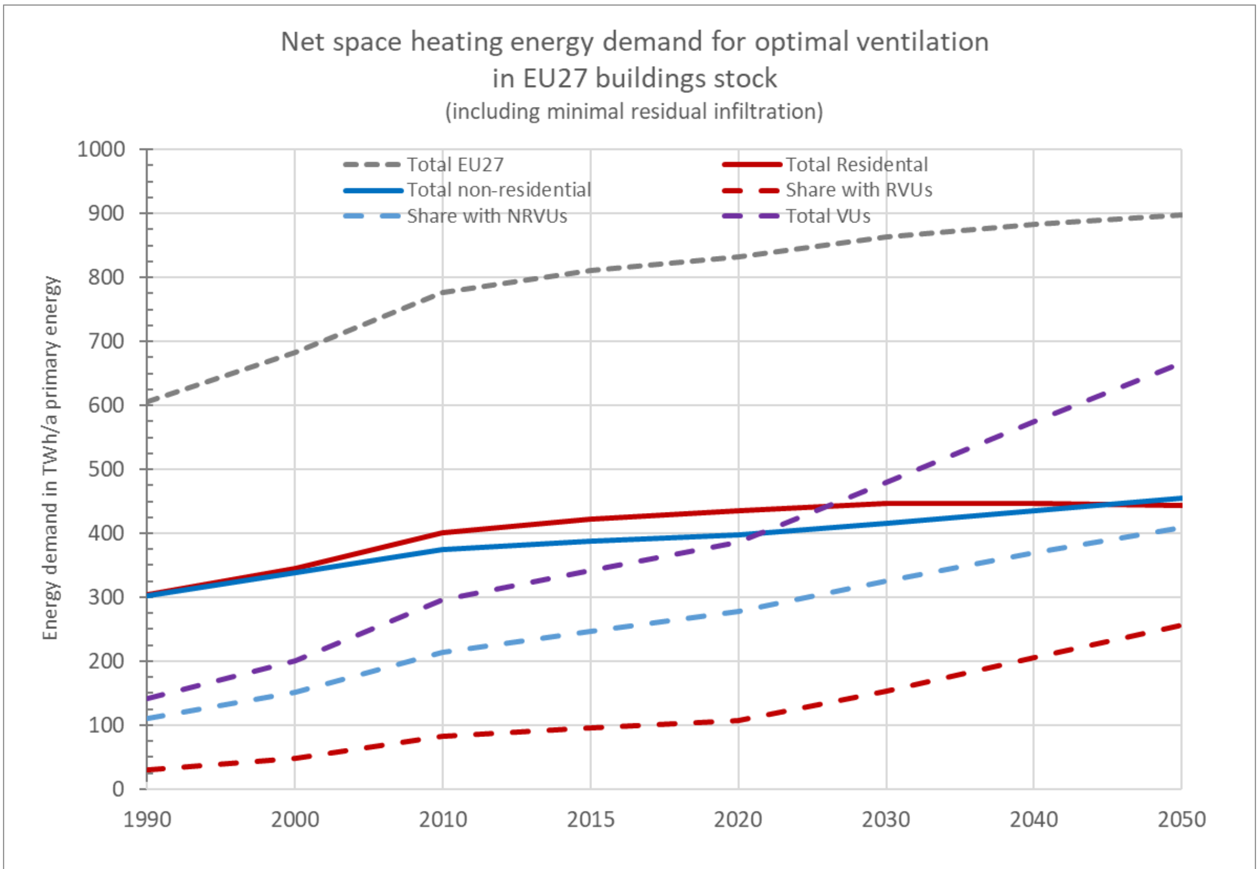


Figure 12. Total net space heating energy demand EU27 building stock

The net space heating energy load for the mechanically ventilated building stock increases from 142 TWh in 1990 to 345 TWh in 2015 and is expected to further rise to 666 TWh in 2050, when approximately 75% of the total heated surface will be using mechanical ventilation units.

5 Efficiency and ventilation effectiveness

The key parameters determining the energy efficiency of ventilation units are:

- the SPI (for RVUs) and SFP (for NRVUs), which are indicators of the electrical efficiency of the ventilation units;
- the energy recovery ratio of the heat recovery system, its internal leakages and the defrosting strategy that is used (if any);
- the flow controls and ventilation demand controls that are co-delivered with the VU and which determine the ventilation effectiveness of the unit.

Together, these parameters can be used to determine the average energy- and ventilation performance parameters per type of VU per square meter of heated building space, expressed in:

1. Total average electricity consumption per m^2 of heated space (including any electricity consumption for co-delivered controls): Q_{el} in kWh$_e$/m^2/a
2. Total average mechanical ventilation rate per m^2 of heated space : q_v in m^3/h/m^2
3. Total average space heating energy demand for average climate: Q_h in kWh/m^2/a
4. The ventilation effectiveness or ventilation performance: VPI[12] in %

For the various base cases and design options these four parameters were calculated. They are summarised in Table 9. For the technical product specifications of the base cases and design options, including the VPI, please refer to Task 6 and Annex 1.

It is important to note here that the table below refers to the average flow rate q_v (average real-life flow that may be expected for the VU with the co-delivered controls), whilst the tables in Task 6 refer to q_{sys}, which is the flow rate the VU-configuration at hand needs to achieve category II ventilation performance.

Table 9. Energy and ventilation performance parameters per m^2 heated space

	base case				reference 2020				design option I				design option II				design option III			
	q_v	Q_{el}	Q_h	*VPI*	q_v	Q_{el}	Q_h	*VPI*	q_v	Q_{el}	Q_h	*VPI*	q_v	Q_{el}	Q_h	*VPI*	q_v	Q_{el}	Q_h	*VPI*
	m^3/h/m^2	kWh$_e$/m^2/a	kWh/m^2/a	-	m^3/h/m^2	kWh$_e$/m^2/a	kWh/m^2/a	-	m^3/h/m^2	kWh$_e$/m^2/a	kWh/m^2/a	-	m^3/h/m^2	kWh$_e$/m^2/a	kWh/m^2/a	-	m^3/h/m^2	kWh$_e$/m^2/a	kWh/m^2/a	-
RVUs																				
UVU/100/ES	0.22	0.36	5.42	0.30	0.22	0.18	5.42	0.32	0.16	0.20	3.84	0.44	0.16	0.14	3.84	0.48				
UVU/100/HS	0.18	0.30	4.43	0.31	0.29	0.18	7.14	0.44	0.18	0.21	4.43	0.72	0.18	0.15	4.48	0.75				
BVU/100/HS	0.20	0.84	1.72	0.31	0.29	0.74	2.14	0.39	0.24	0.46	1.40	0.46	0.15	0.29	0.55	0.65				
UVU/250	0.58	1.45	14.3	0.36	1.00	0.98	24.6	0.38	1.15	1.14	28.4	0.43	1.15	0.74	28.4	0.43	0.90	0.81	22.2	0.76
BVU/250	0.54	2.76	4.0	0.38	0.86	1.86	3.6	0.52	0.86	1.60	4.3	0.68	0.78	1.64	2.9	0.76	0.70	1.30	1.7	0.97
UVU/1000	0.93	1.80	22.9	0.36	0.93	1.21	22.9	0.36	0.93	0.62	22.9	0.36	0.86	0.80	21.3	0.43	1.15	1.38	28.4	0.52
BVU/1000	0.61	3.07	4.5	0.38	0.93	2.64	3.9	0.49	0.93	1.48	3.4	0.49	0.82	1.51	2.6	0.57	0.70	1.73	1.7	0.97
UVU/1000+	0.93	2.21	22.9	0.36	0.93	1.20	22.9	0.36	0.93	0.60	22.9	0.36	0.86	0.79	21.3	0.43	1.15	1.37	28.4	0.52
BVU/2500	0.61	3.06	4.5	0.38	0.93	2.62	3.9	0.49	0.93	1.73	3.4	0.49	0.82	1.49	2.6	0.57	0.70	1.72	1.7	0.97

[12] As explained in Task3 and Task 5, ventilation is about inducing 'the right air exchanges in the right place at the right time'. Depending on the type of VU and the type of controls that are used, VUs are more capable or less capable of achieving this ideal ventilation strategy. The VPI is an indicator for this capability.

NRVUs																				
NR-UVU/1000+	1.73	1.57	42.6	n.a.	1.73	1.12	42.6	n.a.	1.73	0.85	42.6	n.a.	1.26	0.39	31.0	n.a.				.
NR-BVU/2500	1.73	4.11	12.8	n.a	1.73	3.11	8.51	n.a	1.73	2.66	6.39	n.a	1.26	1.24	3.10	n.a				
AHU/S	1.73	4.66	23.8	n.a	1.73	3.72	12.8	n.a	1.73	3.27	11.5	n.a	1.26	1.68	7.8	n.a				
AHU/M	1.73	5.92	23.8	n.a	1.73	5.08	12.8	n.a	1.73	4.51	11.5	n.a	1.26	2.36	7.8	n.a				
AHU/L	1.73	6.85	23.8	n.a	1.73	5.74	12.8	n.a	1.73	5.17	11.5	n.a	1.26	2.70	7.8	n.a				

For the complete stock of VU-appliances, year specific stock averages for all four performance parameters are calculated from the stock-compositions (mix of base case design and design options) that result from the various scenarios. The stock-compositions of the ECO- and ECO0.3-scenario are based on Annex 1 and 2 that provide the sales share of base case units and the various design options over the years. The BAU-scenario is mainly based on the 2015-2020 base case specifications, and the BAU0 scenario on the 2000 and 2010 base case specifications.

6 Energy consumption

Using the stock-average performance parameters explained in the previous chapters, the overall primary energy consumption for the total VU-stock can be calculated for BAU0, BAU, ECO and ECO0.3 scenarios.

Paragraph 6.1 concerns the primary energy consumption of the VU appliance stock. The calculations are done for the residential sector and non-residential sector separately. For the residential sector, stock-averages for the VPI-indicators are also calculated, showing the change over time in residential ventilation performance.

Paragraph 6.2 gives an overall picture of the energy consumption of ventilation for the total EU27-building stock, and calculates the total energy consumption of the building stock for natural ventilation, infiltration and mechanical ventilation.

As already indicated in chapter 4, the average infiltration is a vital component for the air supply in naturally ventilated buildings and in mechanically ventilated buildings they result in residual airflows that may influence the ventilation performance. For these reasons it is more logical to integrate infiltration in the energy consumption related to ventilation instead of adding them to the transmission losses of the buildings. Also, by including residual infiltration, calculations regarding the savings vis-à-vis naturally ventilated dwellings will be more accurate.

6.1 EU27 energy consumption related to VU-appliances

6.1.1 Energy consumption of residential VUs

BAU-scenario

Table 10. Energy consumption RVU stock in EU27 according BAU

ENERGY CONSUMPTION EU27 RVUs- BAU	unit	1990	2000	2010	2015	2020	2030	2040	2050
Stock average mechanical ventilation : q_v	$m^3/h/m^2$	0.60	0.60	0.70	0.77	0.84	0.92	0.92	0.91
Stock average Electricity consumption	$kWh_e/m^2/a$	2.11	2.17	2.06	1.93	1.72	1.58	1.69	1.78
Share heated surface with RVUs	%	10%	14%	21%	23%	25%	34%	46%	58%
Heated surface of dwellings with RVUs	Mm^2	1273	1996	3411	3948	4467	6363	8505	10654
Stock average ventilation heat load RVUs	TWh/a	14	22	44	56	69	108	144	180
Primary energy factor	-	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.1*	*2.1*	*2.1*
Average energy recovery ratio VU-stock	%	*1%*	*2%*	*4%*	*5%*	*7%*	*23%*	*35%*	*43%*
Average space heating efficiency	%	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*
Space heating energy demand for RVUs	TWh/a	19	29	56	71	86	110	125	136
Primary energy consumption for electricity	TWh/a	7	11	18	19	19	21	30	40
Primary energy ventilation for RVU stock	TWh/a	**25**	**40**	**74**	**90**	**105**	**131**	**155**	**176**
Stock Average Ventilation Performance Index	-	0.34	0.34	0.35	0.36	0.37	0.39	0.41	0.42

ECO-scenario with VPI identical to BAU-level

As indicated in the Task 6 report, the design options used in the calculations of the ECO-scenario are intended to pursue two goals:

1. Comply with category II ventilation performance
2. Minimize energy consumption for ventilation

Obviously, there is a trade-off between the two goals. Depending of the type of RVU, an increase in ventilation performance may lead to an increased average airflow rate and a related higher energy consumption (and vice versa). In order to compare the energy consumption between BAU and ECO on the same basis, the VPI-levels need to be comparable. For that reason, two calculations are performed. The first calculates the energy consumption of the ECO-scenario keeping the VPI-levels identical. The second calculation correlates to the energy consumption related to the actual VPI-levels that are achieved with the ECO-scenario.

Table 11. Energy consumption RVU stock in EU27 according ECO with BAU-VPI

ENERGY CONSUMPTION EU27 RVUs - ECO	unit	**1990**	**2000**	**2010**	**2015**	**2020**	**2030**	**2040**	**2050**
Stock average mechanical ventilation : q_v	m³/h/m²	0.60	0.60	0.70	0.77	0.84	0.88	0.82	0.77
Stock average Electricity consumption	kWhₑ/m²/a	2.11	2.17	2.06	1.93	1.72	1.44	1.35	1.31
Share heated surface with RVUs	%	10%	14%	21%	23%	25%	34%	46%	58%
Heated surface of dwellings with RVUs	Mm²	1273	1996	3411	3948	4467	6363	8505	10654
Stock average ventilation heat load RVUs	TWh/a	14	22	44	56	69	103	129	152
Primary energy factor	-	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.1*	*2.1*	*2.1*
Average energy recovery ratio VU-stock	%	*1%*	*2%*	*4%*	*5%*	*7%*	*23%*	*35%*	*43%*
Average space heating efficiency	%	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*
Space heating energy demand for RVUs	TWh/a	19	29	56	71	86	106	112	115
Primary energy consumption for electricity	TWh/a	7	11	18	19	19	19	24	29
Primary energy ventilation for RVU stock	TWh/a	**25**	**40**	**74**	**90**	**105**	**125**	**136**	**144**
Stock Average Ventilation Performance Index	-	0.34	0.34	0.35	0.36	0.37	0.39	0.41	0.42

ECO-scenario with ECO-VPI-level

Table 12. Energy consumption RVU stock in EU27 according ECO with ECO-VPI

ENERGY CONSUMPTION EU27 RVUs- ECO	unit	**1990**	**2000**	**2010**	**2015**	**2020**	**2030**	**2040**	**2050**
Stock average mechanical ventilation : q_v	m³/h/m²	0.60	0.60	0.70	0.77	0.84	0.91	0.90	0.87
Stock average Electricity consumption	kWhₑ/m²/a	2.11	2.17	2.06	1.93	1.72	1.48	1.46	1.45
Share heated surface with RVUs	%	10%	14%	21%	23%	25%	34%	46%	58%
Heated surface of dwellings with RVUs	Mm²	1273	1996	3411	3948	4467	6363	8505	10654
Stock average ventilation heat load RVUs	TWh/a	14	22	44	56	69	107	142	172
Primary energy factor	*pef*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.1*	*2.1*	*2.1*
Average energy recovery ratio VU-stock	%	*1%*	*2%*	*4%*	*5%*	*7%*	*23%*	*34%*	*42%*
Average space heating efficiency	%	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*
Space heating energy demand for RVUs	TWh/a	19	29	56	71	86	110	125	133
Primary energy consumption for electricity	TWh/a	7	11	18	19	19	20	26	32
Primary energy ventilation for RVU stock	TWh/a	**25**	**40**	**74**	**90**	**105**	**130**	**151**	**165**
Stock Average Ventilation Performance Index	-	0.34	0.34	0.35	0.36	0.37	0.42	0.47	0.51

ECO0.3-scenario

ENERGY CONSUMPTION RVUs EU27 -ECO03	unit	**1990**	**2000**	**2010**	**2015**	**2020**	**2030**	**2040**	**2050**
Stock average mechanical ventilation : q_v	$m^3/h/m^2$	0.60	0.60	0.70	0.77	0.84	0.92	0.91	0.90
Stock average Electricity consumption	$kWh_e/m^2/a$	2.11	2.17	2.06	1.93	1.72	1.55	1.62	1.68
Share heated surface with RVUs	%	10%	14%	21%	23%	25%	34%	46%	58%
Heated surface of dwellings with RVUs	Mm^2	1273	1996	3411	3948	4467	6363	8505	10654
Stock average ventilation heat load RVUs	TWh/a	14	22	44	56	69	108	144	177
Primary energy factor	-	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.1*	*2.1*	*2.1*
Average energy recovery ratio VU-stock	%	*1%*	*2%*	*4%*	*5%*	*7%*	*23%*	*35%*	*43%*
Average space heating efficiency	%	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*
Space heating energy demand for RVUs	TWh/a	19	29	56	71	86	110	124	134
Primary energy consumption for electricity	TWh/a	7	11	18	19	19	21	29	38
Primary energy ventilation for RVU stock	TWh/a	**25**	**40**	**74**	**90**	**105**	**131**	**154**	**172**
Stock Average Ventilation Performance Index	-	0.34	0.34	0.35	0.36	0.37	0.39	0.41	0.42

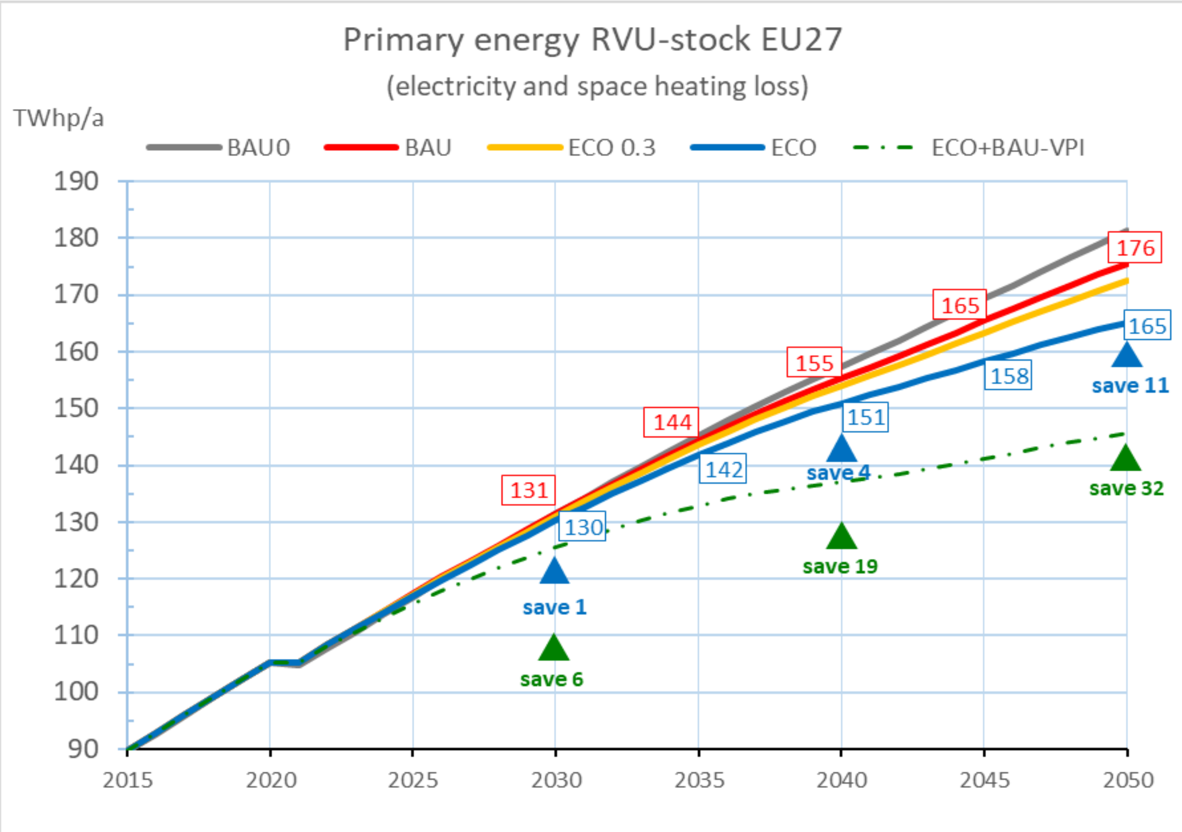


Figure 13. Primary energy RVU-stock EU27

Summary RVUs

The total primary energy consumption of the RVU-stock according to the BAU scenario is expected to increase from 90 TWh in 2015 to 176 TWh in 2050. According to the ECO scenario with BAU-level VPI's the energy consumption is expected to increase from 90 TWh in 2015 to about 144 TWh in 2050 and according to the ECO0.3-scenario from 90 to 172 TWh/a in 2050.

Table 13. Savings RVUs in 2020-2050 compared to BAU

	unit	2020	2030	2040	2050
ECO03	TWh/a	0	0	2	4
ECO with BAU-VPI	TWh/a	0	6	19	32
VPI	-	*0.37*	*0.39*	*0.41*	*0.42*
ECO with improved VPI	TWh/a	0	1	4	11
VPI	-	*0.37*	*0.42*	*0.47*	*0.51*

The ECO-scenario assuming BAU-VPI levels achieves savings of about 6 TWh/a in 2030, rising to 19 TWh in 2040 and 32 TWh in 2050. The ECO0.3 scenario results in reduced savings of 2 TWh in 2040 and 4 TWh in 2050 with VPI levels remaining similar to the BAU-scenario.

The ECO-scenario that results in improved VPI-levels, still saves 4 TWh in 2040 and 11 TWh in 2050.

6.1.2 Energy consumption of non-residential VUs

BAU-scenario

ENERGY CONSUMPTION NRVUs - BAU	unit	1990	2000	2010	2015	2020	2030	2040	2050
Stock average mechanical ventilation : q_v	m3/h/m2	1.56	1.51	1.51	1.52	1.54	1.55	1.55	1.55
Stock average Electricity consumption	$kWh_e/m2/a$	8.40	7.88	6.56	5.58	4.72	3.99	3.87	3.84
Share heated surface with NRVUs	%	37%	45%	57%	64%	70%	78%	85%	90%
Heated surface of buildings with NRVUs	Mm2	2872	3934	5513	6373	7202	8423	9538	10572
Stock average ventilation heat load NRVUs	TWh/a	83	110	153	179	205	242	274	303
Primary energy factor	-	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.1*	*2.1*	*2.1*
Average energy recovery ratio VU-stock	%	*26%*	*26%*	*30%*	*37%*	*45%*	*58%*	*62%*	*64%*
Average space heating efficiency	%	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*
Space heating energy demand for NRVUs	TWh/a	82	109	142	152	150	135	138	146
Primary energy consumption for electricity	TWh/a	60	77	90	89	85	71	77	85
Prim. energy ventilation for NRVU stock	TWh/a	**142**	**186**	**233**	**241**	**235**	**205**	**215**	**231**

ECO-scenario

ENERGY CONSUMPTION NRVUs - ECO	unit	1990	2000	2010	2015	2020	2030	2040	2050
Stock average mechanical ventilation : q_v	m3/h/m2	1.56	1.51	1.51	1.52	1.54	1.53	1.49	1.46
Stock average Electricity consumption	$kWh_e/m^2/a$	8.40	7.88	6.56	5.58	4.72	3.82	3.37	3.20
Share heated surface with NRVUs	%	37%	45%	57%	64%	70%	78%	85%	90%
Heated surface of buildings with NRVUs		2872	3934	5513	6373	7202	8423	9538	10572
Stock average ventilation heat load NRVUs	TWh/a	83	110	153	179	205	238	262	286
Primary energy factor	-	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.1*	*2.1*	*2.1*
Average energy recovery ratio VU-stock	%	*26%*	*26%*	*30%*	*37%*	*45%*	*59%*	*63%*	*65%*
Average space heating efficiency	%	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*
Space heating energy demand for NRVUs	TWh/a	82	109	142	152	150	132	128	132
Primary energy consumption for electricity	TWh/a	60	77	90	89	85	68	68	71
Primary energy consumption for NRVU stock	TWh/a	**142**	**186**	**233**	**241**	**235**	**199**	**196**	**203**

ECO0.3-scenario

ENERGY CONSUMPTION NRVUs - ECO03	unit	1990	2000	2010	2015	2020	2030	2040	2050
Stock average mechanical ventilation : q_v	m3/h/m2	1.56	1.51	1.51	1.52	1.54	1.55	1.53	1.52
Stock average Electricity consumption	$kWh_e/m^2/a$	8.40	7.88	6.56	5.58	4.72	3.94	3.72	3.65
Share heated surface with NRVUs	%	37%	45%	57%	64%	70%	78%	85%	90%
Heated surface of buildings with NRVUs	Mm2	2872	3934	5513	6373	7202	8423	9538	10572
Stock average ventilation heat load NRVUs	TWh/a	83	110	153	179	205	241	270	298
Primary energy factor	-	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.1*	*2.1*	*2.1*
Average energy recovery ratio VU-stock	%	*26%*	*26%*	*30%*	*37%*	*45%*	*58%*	*63%*	*64%*
Average space heating efficiency	%	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*	*75%*
Space heating energy demand for NRVUs	TWh/a	82	109	142	152	150	134	135	141
Primary energy consumption for electricity	TWh/a	60	77	90	89	85	70	75	81
Primary energy consumption for NRVU stock	TWh/a	**142**	**186**	**233**	**241**	**235**	**203**	**209**	**222**

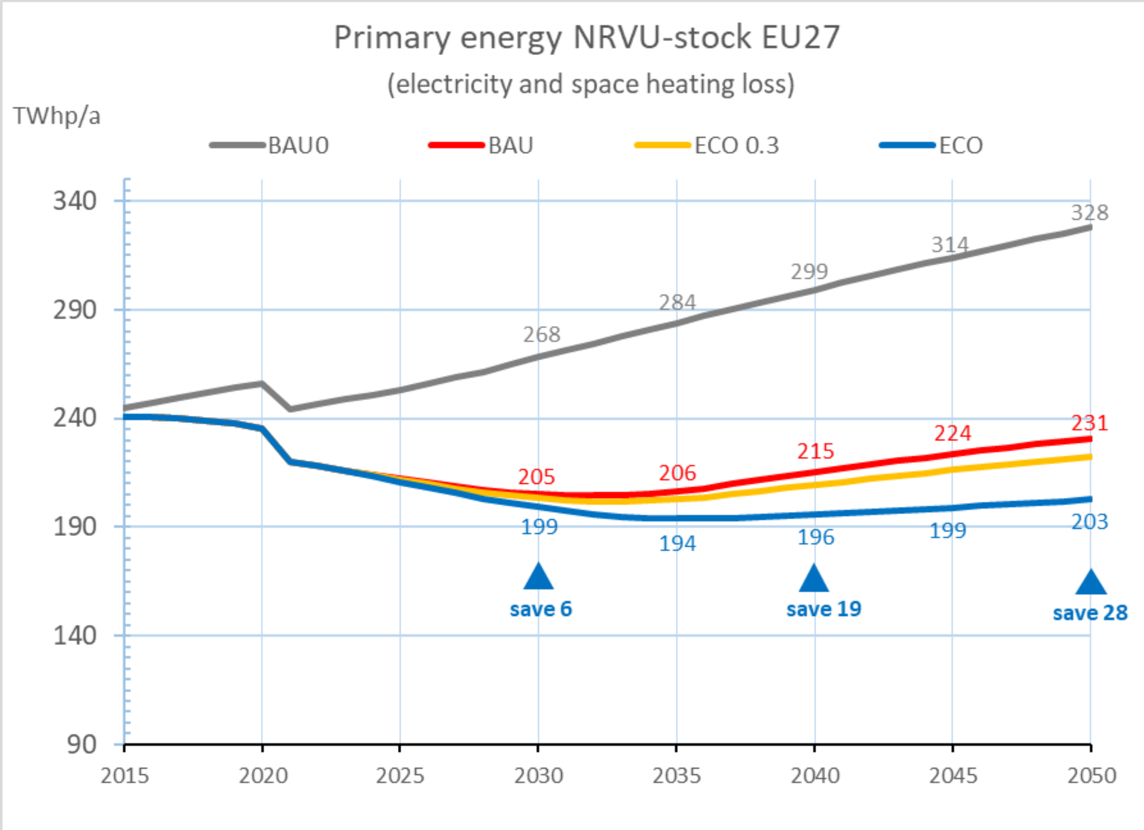


Figure 14. Primary energy NRVU-stock EU27

Summary NRVUs

The total primary energy consumption of the NRVU-stock according to the BAU scenario is expected to decrease from 241 TWh in 2015 to 231 TWh in 2050. According to the ECO scenario the energy consumption is expected to further decrease from 241 TWh in 2015 to 203 TWh in 2050 and according to the ECO0.3-scenario from 241 to 222 TWh/a in 2050.

Table 14. Savings NRVUs in 2020-2050 compared to BAU

	unit	2020	2030	2040	2050
ECO03	TWh/a	0	2	6	9
ECO	TWh/a	0	6	19	28

The ECO-scenario achieves savings of about 6 TWh/a in 2030, rising to 19 TWh in 2040 and 28 TWh in 2050. The ECO0.3 scenario results in reduced savings of 2 TWh in 2030, 6 TWh in 2040 and 9 TWh in 2050.

6.1.3 Energy consumption of all VUs

The total primary energy consumption of the whole EU27 VU appliance stock (residential plus non-residential) is summarized in Figure 15 and Figure 16.

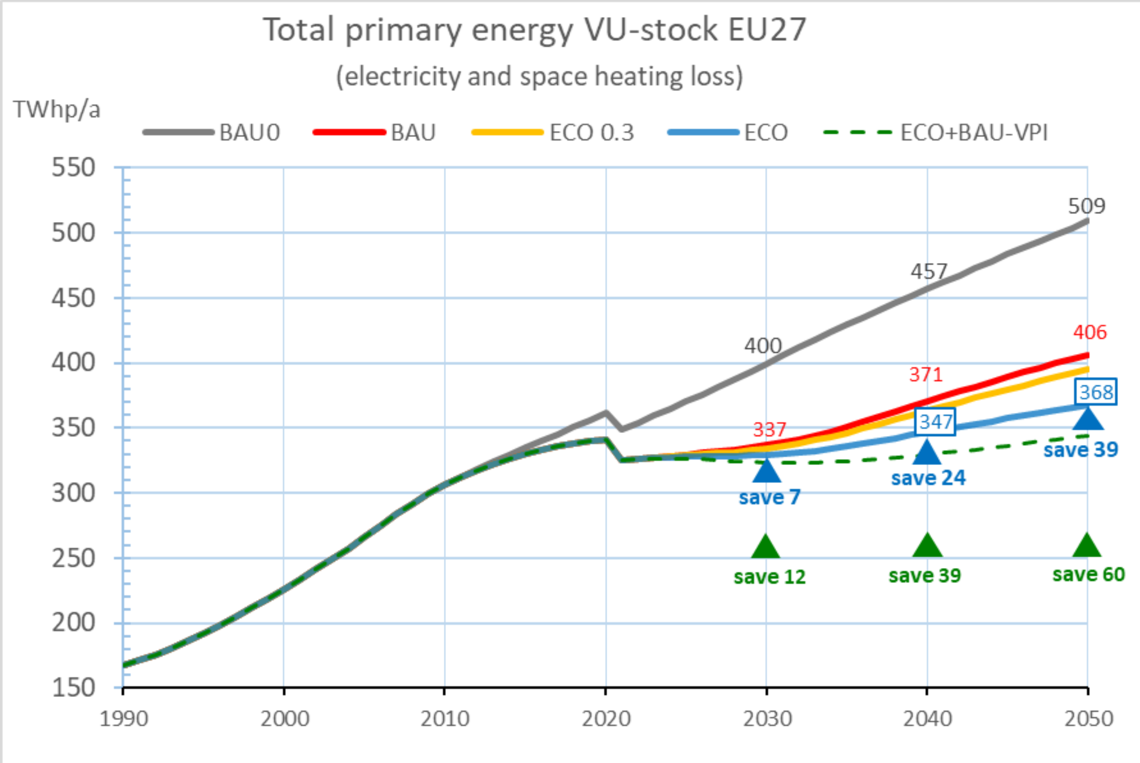


Figure 15. Total primary energy consumption of total VU appliance stock EU27

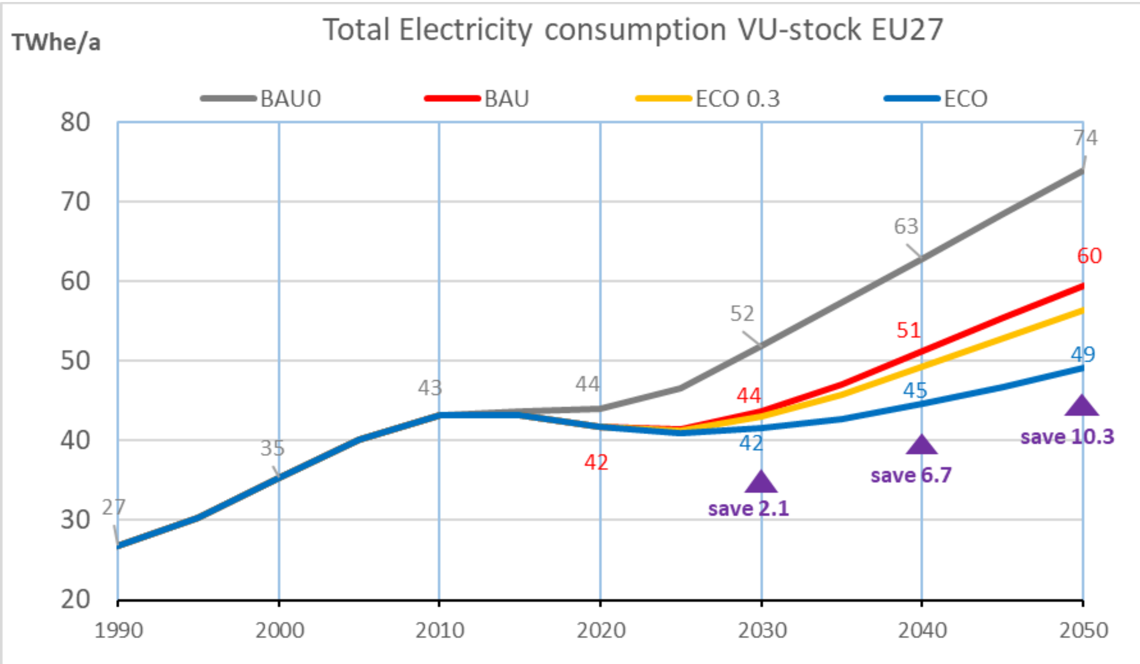


Figure 16. Total electricity consumption of VU appliance stock EU27

The total primary energy consumption, the savings, and the VPI for the RVUs of the whole EU27 VU appliance stock are also summarized in Table 15 and Table 16.

Table 15. Primary energy total VU appliance stock EU27

	unit	1990	2000	2010	2015	2020	2030	2040	2050
Primary energy VU stock - BAU	TWh/a	167	226	306	330	341	337	371	406
Primary energy VU stock - ECO0.3	TWh/a	167	226	306	330	341	334	363	395
Primary energy VU stock - ECO (RVUs /BAU-VPI)	TWh/a	167	226	306	330	341	324	331	347
Primary energy VU stock with improved VPI									
Primary energy VU stock - ECO (RVUs /ECO-VPI)	*TWh/a*	*167*	*226*	*306*	*330*	*341*	*329*	*347*	*368*

Table 16. Summary energy savings and VPI

ECO0.3 versus BAU	TWh/a	0	0	0	0	0	2	7	12
ECO versus BAU (with RVUs having BAU-VPI)	TWh/a	0	0	0	0	0	12	39	60
VPI RVUs	-	*0.34*	*0.34*	*0.35*	*0.36*	*0.37*	*0.39*	*0.41*	*0.42*
Savings VU-stock versus BAU with improved VPI									
ECO versus BAU (with RVUs having ECO-VPI)	TWh/a	0	0	0	0	0	7	24	39
VPI RVUs	-	*0.34*	*0.34*	*0.35*	*0.36*	*0.37*	*0.42*	*0.47*	*0.51*

The total primary energy consumption of the VU stock according to the BAU-scenario will rise from 330 TWh in 2015 to 371 TWh in 2040 and to 406 TWh in 2050, primarily due to the increase of the number of buildings (heated surface) that are going to be equipped with ventilation units.

The ECO0.3 scenario with its total primary energy use of 363 TWh in 2040 and 395 TWh, delivers limited saving of 7 TWh in 2040 and 12 TWh in 2050.

The ECO-scenario results in an improved ventilation performance, a lower total energy use and improved savings compared to ECO0.3: 24 TWh in 2040 and 39 TWh in 2050. The average ventilation performance (VPI) is expected to increase from 0.34 in 2015 to approximately 0.51 in 2050, which would be a significant future accomplishment of the proposed revised regulation. This improvement will be at the expense of (extra) energy savings (see Table 16).

Comparing the primary energy use of the ECO-scenario using the same VPI as BAU, the savings are higher: 39 TWh in 2040 and 60 TWh in 2050.

6.2 Energy consumption for ventilation by EU27 Building Stock

This paragraph gives an overall picture of the energy consumption of ventilation for the total EU27-building stock, and calculates the total energy consumption of the buildings stock for natural ventilation, infiltration and mechanical ventilation.

As already indicated in chapter 4, the average infiltration is a vital component for the air supply in naturally ventilated buildings, and in mechanically ventilated buildings it results in residual airflows that may influence the ventilation performance. For these reasons it is more logical to integrate infiltration in the energy consumption related to ventilation instead of adding them to the transmission losses of the buildings. Also, by including residual infiltration, calculations regarding the savings vis-à-vis naturally ventilated dwellings will be more accurate.

6.2.1 Energy for the EU27 Stock of residential dwellings

Naturally ventilated dwellings

The share of naturally ventilated dwellings is included in the calculations. For natural ventilation systems a default q_v of 2.50 m^3/h/m^2 is used (see Task 5), leading to an average space heating energy demand (average climate) Q_h of 61.6 kWh/m^2/a.

As indicated in Table 17, the energy consumption of the share of naturally ventilated dwellings will decrease over time, due to their declining stock. In 2015 natural ventilation (having a share of 77% of the residential building stock) consumes about 830 TWh per year; in 2050 it is expected to decline to approximately 475 TWh, representing 42% of the dwelling stock. As indicated in Task 5, the ventilation performance is on average low, especially due to the lower air exchange rates that are achieved during presence in the habitable spaces.

Table 17. Energy consumption natural ventilated dwellings EU27

Primary energy NATURALLY VENTILATED DWELLINGS EU27	unit	1990	2000	2010	2015	2020	2030	2040	2050
Reference airflow natural ventilation: q_{ref}	m^3/h/m^2	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Share heated surface with natural ventilation	%	90%	86%	79%	77%	75%	66%	54%	42%
Total heated surface nat. ventilated dwellings	Mm^2	11306	12306	13135	13483	13520	12223	10007	7718
Space heating energy consumption	TWh/a	**696**	**758**	**809**	**830**	**833**	**753**	**616**	**475**
Average Ventilation Performance Index	-	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

Mechanically ventilated dwellings

For the mechanically ventilated dwellings, the calculations regarding total primary energy depend on the scenario selected. The calculations for the BAU-scenario and the ECO-scenario are given in tables below. In dwellings with mechanically ventilation units, infiltration will still occur. Depending on the year in which a building or dwelling is renovated or newly constructed and equipped with a certain type of VU, the average air-tightness and related infiltration levels will be adjusted accordingly. An average n50 of 2 for dwellings renovated or newly constructed beyond 2020 has been used, an average n50 of 4 for 2010 and an average n50 of 6 for 2000 and before; values are interpolated in intermediate years. Based on this, the stock averages for infiltration are calculated and the related space heating energy demand is added to the primary energy consumption of the ventilation units.

BAU-Scenario

The total primary energy consumption for ventilation and infiltration of the dwelling stock with RVUs according to the BAU scenario is expected to increase from 157 TWh in 2015 to approximately 286 TWh in 2050, due to the increase in the number of dwellings that are ventilated by RVUs, which rises from 3948 Mm^2 in 2015 to 10654 Mm^2 in 2050.

The average ventilation performance is expected to increase from 0.34 in 2015 to 0.42 in 2050 (illustrating that the air exchange rates in the extract spaces (ES) are generally considered adequate, but the exchange rates in the habitable spaces during presence are still substandard).

Table 18. Energy consumption dwellings with RVUs in EU27 according BAU

Primary energy DWELLINGS with RVUs - BAU	unit	1990	2000	2010	2015	2020	2030	2040	2050
Heated surface of dwellings with RVUs	Mm^2	1273	1996	3411	3948	4467	6363	8505	10654
Primary energy ventilation for RVU stock	TWh/a	**25**	**40**	**74**	**90**	**105**	**131**	**155**	**176**
Stock average residual infiltration	$m^3/h/m^2$	1.30	1.10	0.80	0.69	0.60	0.45	0.45	0.45
Residual infiltration heat load	TWh/a	30	41	51	51	49	53	66	83
Primary energy demand infiltration	TWh/a	40	54	67	67	66	70	88	110
Total primary energy for ventilation and infiltration in dwellings with RVUs	TWh/a	**66**	**94**	**141**	**157**	**171**	**202**	**243**	**286**
Stock Average Ventilation Performance Index	-	0.34	0.34	0.35	0.36	0.37	0.39	0.41	0.42

ECO-scenario

For the ECO-scenario, the calculations are based on the version with the improved VPI, which is the preferred scenario. The total primary energy consumption for ventilation and infiltration of the dwelling stock with the RVUs according to the ECO scenario with improved VPI's is expected to increase from 157 TWh in 2015 to about 275 TWh in 2050.

Table 19. Energy consumption dwellings with RVUs in EU27 according ECO with ECO-VPI

Primary energy DWELLINGS with RVUs - ECO	unit	1990	2000	2010	2015	2020	2030	2040	2050
Heated surface of dwellings with RVUs	Mm^2	1273	1996	3411	3948	4467	6363	8505	10654
Primary energy ventilation for RVU stock	TWh/a	**25**	**40**	**74**	**90**	**105**	**130**	**151**	**165**
Stock avg. residual infiltr. dwellings with RVUs)	$m^3/h/m^2$	1.30	1.10	0.80	0.69	0.60	0.45	0.45	0.45
Residual infiltration heat load	TWh/a	30	41	51	51	49	53	66	83
Primary energy demand infiltration	TWh/a	40	54	67	67	66	70	88	110
Total primary energy for ventilation and infiltration in dwellings with RVUs	TWh/a	**66**	**94**	**141**	**157**	**171**	**201**	**239**	**275**
Stock Average Ventilation Performance Index	-	0.34	0.34	0.35	0.36	0.37	0.42	0.47	0.52

Total EU27 dwellings

The total energy consumption of ventilation and infiltration (natural and mechanical) in the residential EU27 building stock is given in the table below. According to the BAU-scenario, the total energy consumption for ventilation and residual infiltration increases from 761 in 1990 to 992 TWh in 2020, and after that gradually decreases again to 761 TWh in 2050. In the ECO-scenario with BAU-VPI the total energy consumption for ventilation and residual infiltration decreases some further to 730 TWh in 2050.

Table 20. Total primary energy consumption in residential dwelling stock EU27

	unit	1990	2000	2010	2015	2020	2030	2040	2050
Prim. energy consumption BAU-scenario	TWh/a	761	852	955	992	1006	951	861	761
Prim. energy consumption ECO-scenario/BAU-VPI		761	852	955	992	1006	944	841	730
Prim. energy consumption ECO-scenario/ ECO-VPI	TWh/a	761	852	955	992	1006	949	856	751

It is important to understand here that the savings calculated in Table 16 only relate to the savings of the BAU-scenario compared to the ECO-scenario and therefore only relate to changes in composition of the VU-appliance stock.

Significantly larger savings are achieved when natural ventilation systems are replaced by mechanical ventilation systems. The general procedure when renovating older dwellings is, to install a mechanical ventilation unit and simultaneously improve the insulation- and airtightness values of the dwelling. These savings are not visible when only scenarios for the VU-stock are compared to each other.

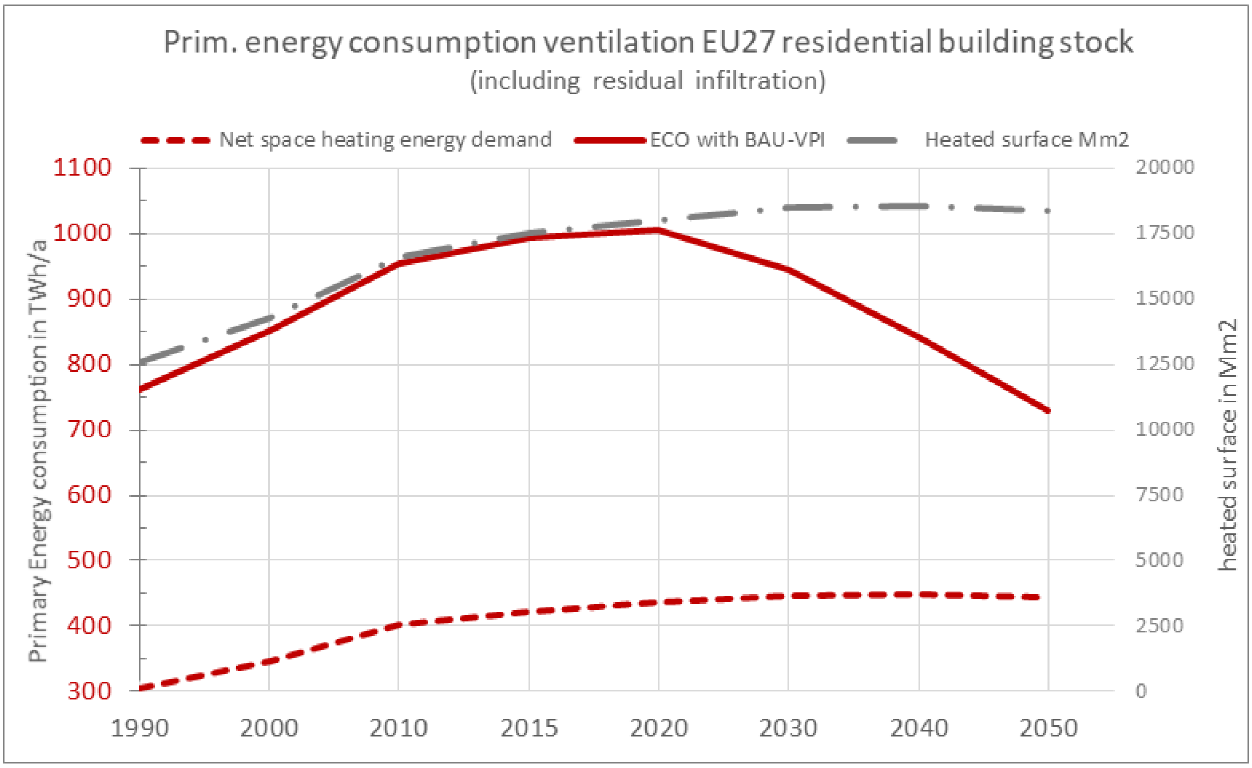


Figure 17. Primary energy consumption ventilation EU27 dwelling stock acc. ECO-scenario

Figure 17 illustrates, that – although the total heated surface is expanding - the primary energy consumption for ventilation (including residual infiltration) is decreasing considerably. The total heated surface in the residential sector increases with about 47% from 12562 in 1990 to 18375 million m^2 in 2050. The total primary energy consumption for ventilation, however, remains practically the same in both years. This indicates that the primary energy consumption per m^2 of heated surface for ventilation decreases considerably, due to the increased penetration of mechanical ventilation units and related improvements to the dwelling shell. In 1990 the specific primary energy consumption was 60.6 kWh/m^2/a and is projected to be 39.7 kWh/m^2/a in 2050. A reduction of over 34%.

Table 21. Savings on primary energy consumption per m^2 of heated surface res. dwellings

	unit	1990	2000	2010	2015	2020	2030	2040	2050
Heated surface perm. occupied dwellings EU27	Mm2	12562	14309	16627	17510	18027	18519	18531	18375
Prim. energy consumption **ECO**- /BAU-VPI	TWh/a	761	852	955	992	1006	944	841	730
Specific prim.energy consumption in kWh/m^2/a	kWh/m^2/a	60.6	59.6	57.4	56.7	55.8	51.0	45.4	39.7
Savings versus nat.ventilation: 61.6 kWh/m^2/a	TWh/a	13	29	69	86	104	197	300	402
Savings versus 1990 reference: 60.6 kWh/m^2/a	TWh/a	0	15	53	69	86	178	282	384

Total savings that are thus achieved amount to 402 TWh/a when compared to natural ventilation, and to 384 when compared to the 1990 reference value of the specific energy consumption per m^2. Figure 18 gives the shares in the total energy consumption for EU27 dwelling stock, subdivided in natural ventilation, mechanical ventilation and electricity.

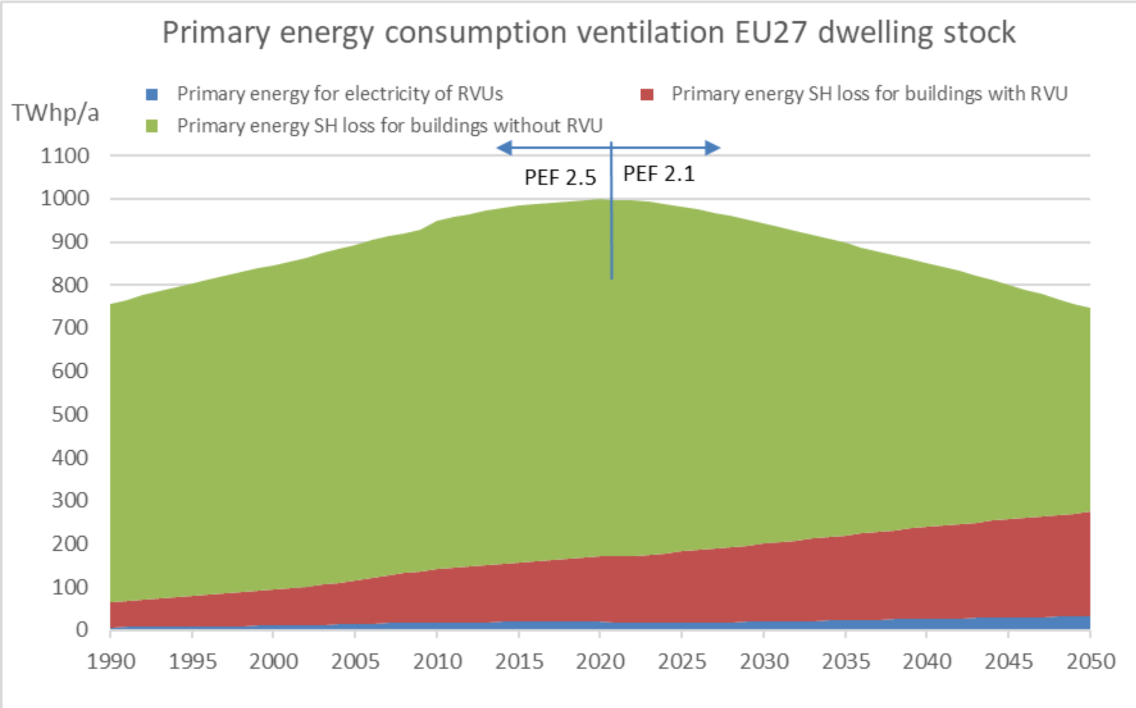


Figure 18. Allocation of EU27 dwelling stock energy consumption for ventilation for ECO

6.2.2 Energy for the EU27 Stock of non-residential buildings

Naturally ventilated buildings

The energy consumption of the share of naturally ventilated non-residential buildings will decrease over time, due to their declining stock. In 2015 natural ventilation (having a share of 36% of the non-residential building stock) consumed about 223 TWh per year; in 2050 it is expected to decline to approximately 72 TWh, representing 10% of the building stock.

Table 22. Energy consumption natural ventilated buildings EU27

Primary energy Naturally ventilated BUILDINGS	unit	1990	2000	2010	2015	2020	2030	2040	2050
Reference airflow natural ventilation: q_{ref}	$m^3/h/m^2$	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Share heated surface with natural ventilation	%	63%	55%	43%	36%	30%	22%	15%	10%
Total heated surface nat. ventilated buildings	Mm2	4950	4796	4172	3643	3062	2338	1720	1184
Space heating energy consumption	TWh/a	302	293	255	223	187	143	105	72

Mechanically ventilated buildings

For the mechanically ventilated non-residential buildings, the calculations regarding total primary energy depend on the scenario that is selected. The calculations for the BAU-scenario and the ECO-scenario are given in tables below.

BAU-Scenario

The total primary energy consumption of non-residential buildings with NRVUs according to the BAU scenario is expected to decrease from 350 TWh in 2015 to 348 TWh in 2050. The expected increase in energy consumption due to the increase in heated surface served by NRVUs is compensated by the improved energy-performance of the NRVUs.

Table 23. Energy consumption buildings with NRVUs in EU27 according BAU

Primary energy BUILDINGS with NRVUs - BAU	unit	1990	2000	2010	2015	2020	2030	2040	2050
Heated surface of buildings with NRVUs	Mm2	2872	3934	5513	6373	7202	8423	9538	10572
Primary energy ventilation for NRVU stock	TWh/a	**142**	**186**	**233**	**241**	**235**	**205**	**215**	**231**
Stock avg. residual infiltr. buildings with NRVUs	$m^3/h/m^2$	1.30	1.13	0.82	0.70	0.60	0.47	0.45	0.45
Residual infiltration heat load	TWh/a	69	82	84	82	80	74	79	88
Primary energy demand infiltration	TWh/a	92	109	111	109	106	98	106	117
Total primary energy for ventilation and infiltration in buildings with NRVUs	TWh/a	**234**	**295**	**344**	**350**	**342**	**303**	**321**	**348**

ECO-Scenario

According to the ECO-scenario the total primary energy consumption of non-residential buildings with NRVUs is expected to decrease from 350 TWh in 2015 to 320 TWh in 2050. Despite the increase in heated surface served by NRVUs the energy consumption is declining with 30 TWh, due to a further improvement of the energy-performance of the NRVUs.

Table 24. Energy consumption buildings with NRVUs in EU27 according ECO

Primary energy BUILDINGS with NRVUs - ECO	unit	1990	2000	2010	2015	2020	2030	2040	2050
Heated surface of buildings with NRVUs	Mm2	2872	3934	5513	6373	7202	8423	9538	10572
Primary energy ventilation for NRVU stock	TWh/a	**142**	**186**	**233**	**241**	**235**	**199**	**196**	**203**
Stock avg. residual infiltr. buildings with NRVUs	m³/h/m²	1.30	1.13	0.82	0.70	0.60	0.47	0.45	0.45
Residual infiltration heat load	TWh/a	69	82	84	82	80	74	79	88
Primary energy demand infiltration	TWh/a	92	109	111	109	106	98	106	117
Total primary energy for ventilation and infiltration in buildings with NRVUs	TWh/a	**234**	**295**	**344**	**350**	**342**	**297**	**301**	**320**

Total non-residential EU27 buildings

The total energy consumption of ventilation (natural and mechanical) in the non-residential EU27 building stock is given in the table below. According to the BAU-scenario, the total energy consumption for ventilation and residual infiltration increases from 536 in 1990 to 599 TWh in 2010, and after that gradually decreases again to 420 TWh in 2050. In the ECO-scenario the total energy consumption for ventilation and residual infiltration decreases some further to 392 TWh in 2050, saving approximately 20 TWh in 2040 and 28 TWh in 2050, compared to the BAU-scenario.

Table 25. Total primary energy consumption in non-residential building stock EU27

	unit	1990	2000	2010	2015	2020	2030	2040	2050
Prim. energy consumptions BAU-scenario	TWh/a	536	588	599	573	529	446	426	420
Prim. energy consumptions ECO-scenario	TWh/a	536	588	599	573	529	440	406	392

As already explained for the residential sector, these savings only relate to the changes in the composition of the NRVU-appliance stock. The savings that are achieved by the increased penetration of NRVUs through e.g. building renovation projects are not visible here. Figure 19 shows that, despite an increasing heated surface, the primary energy consumption for ventilation (including residual infiltration) is decreasing to values even below the net space heating energy demand. This is caused by the increased penetration of heat recovery and its improved efficiency, which reduces the energy consumption below the net space heating demand that is based on net air exchanges without heat recovery.

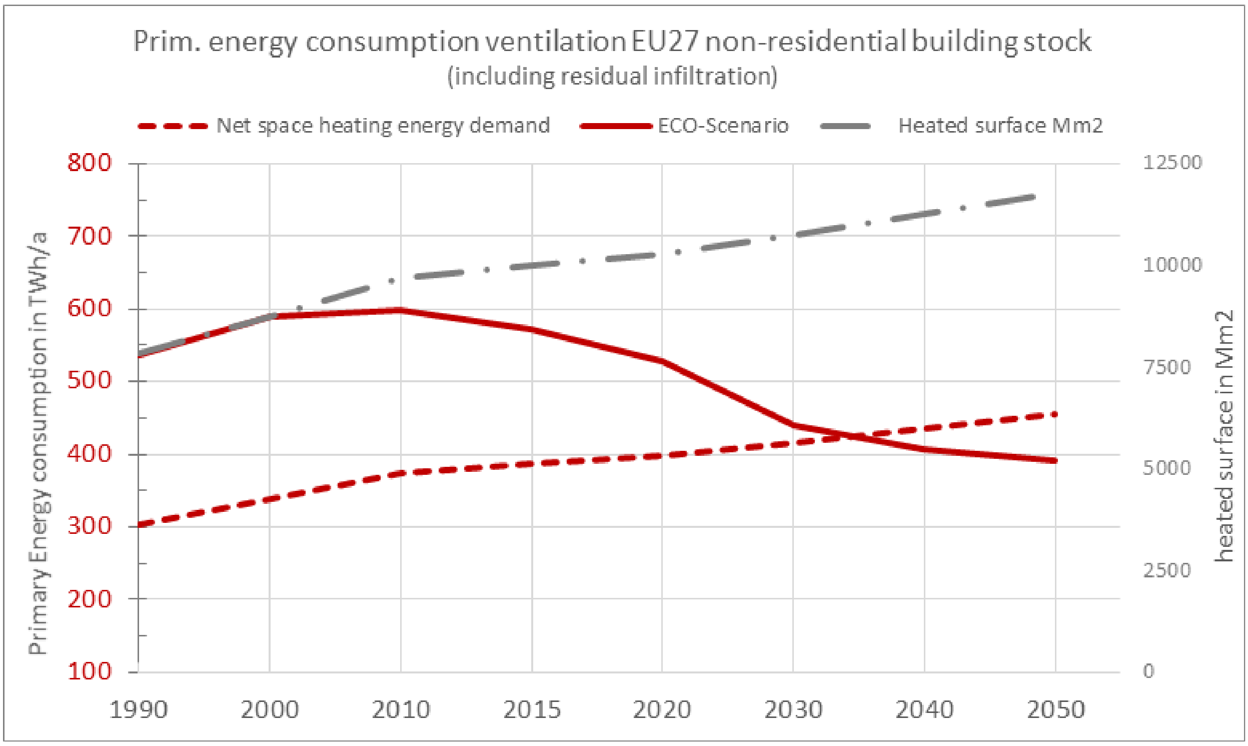


Figure 19. Primary energy consumption ventilation EU27 NR Buildings Stock acc. ECO

This indicates that the primary energy consumption per m² of heated surface for ventilation decreases considerably, due to the increased penetration of improved mechanical ventilation units and related improvements to the dwelling shell.

Table 26 shows that in 1990 the specific primary energy consumption is 68.6 kWh/m²/a and 33.4 kWh/m²/a in 2050. A reduction of over 50%.

Table 26. Savings on primary energy consumption per m² heated surface NR-buildings

	unit	1990	2000	2010	2015	2020	2030	2040	2050
Total surface heated non-res. buildings EU27	Mm2	7822	8730	9685	10016	10264	10761	11258	11756
Prim. energy consumption buildings stock **ECO**	TWh/a	536	588	599	573	529	440	406	392
Specific prim.energy consumption in kWh/m²/a	kWh/m²/a	68.6	67.4	61.8	57.2	51.5	40.9	36.1	33.4
Savings versus natural ventilation: 61.6 kWh/m²/a	TWh/a	-55	-51	-2	44	103	223	287	332
Savings versus 1990 reference: 68.6 kWh/m2/a	TWh/a	0	10	65	114	175	298	366	414

Total savings that are thus achieved amount to 332 TWh/a when compared to natural ventilation, and to 414 TWh when compared to the 1990 reference value of the specific energy consumption per m² (i.e. 68.6 kWh/m²/a).

Figure 19 gives the shares in the total energy consumption for EU27 non-residential building stock, subdivided in natural ventilation, mechanical ventilation and electricity.

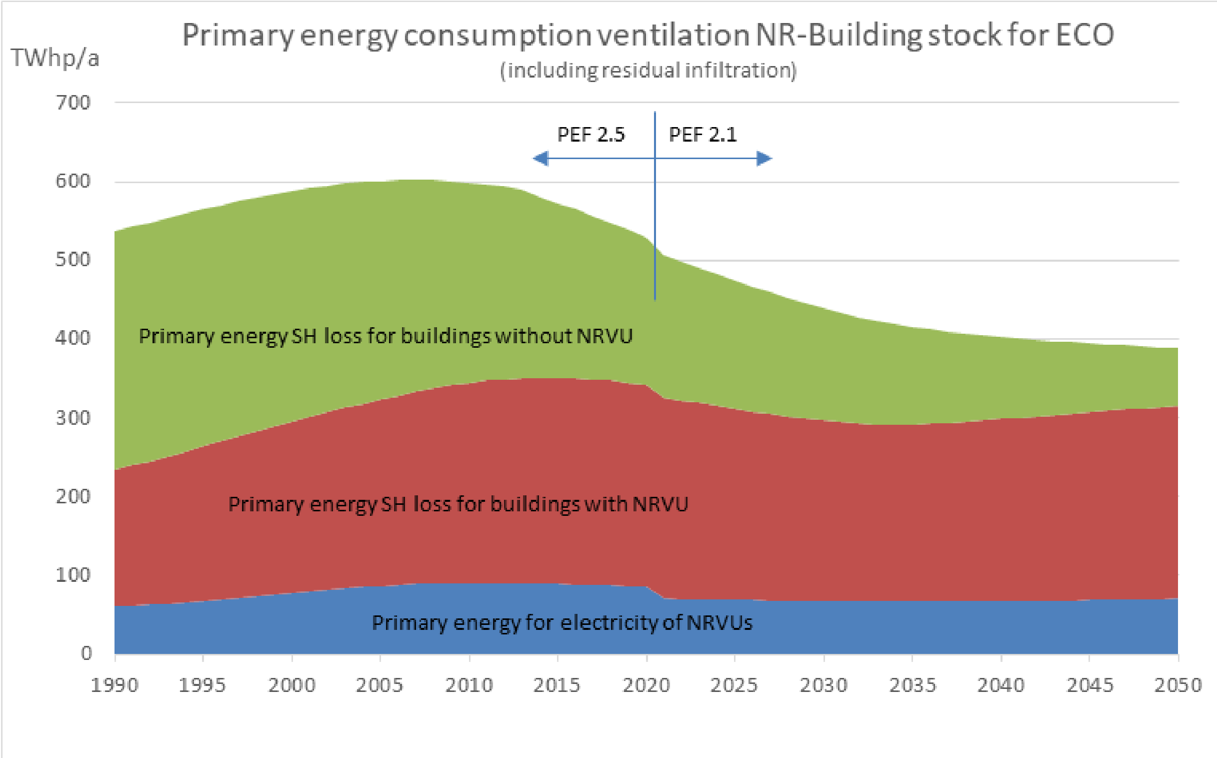


Figure 20. Allocation of EU27 NR-buildings stock energy consumption for ventilation for ECO

6.2.3 Total residential and non-residential building stock EU27

Figure 21 and Table 27 illustrate that the total primary energy consumption for ventilation and residual infiltration for the total EU27-building stock will gradually decline from 2015 onwards, despite an expansion of the total building surface of almost 10% (from 27 526 million m^2 in 2015 to 30 131 million m^2 in 2050).

Table 27. Primary energy ventilation and infiltration in total EU27 building stock

	unit	1990	2000	2010	2015	2020	2030	2040	2050
Total heated surface	Mm2	20384	23039	26312	27526	28291	29280	29789	30131
Total primary energy EU27 buildings stock - BAU	TWh/a	1292	1435	1547	1558	1528	1391	1282	1178
Total primary energy EU27 buildings stock - ECO03	TWh/a	1292	1435	1547	1558	1528	1389	1275	1166
Total primary energy EU27 buildings stock - ECO	TWh/a	1292	1435	1547	1558	1528	1383	1258	1139
Specific primary energy consumption - ECO	kWh/m²/a	*63.4*	*62.3*	*58.8*	*56.6*	*54.0*	*47.2*	*42.2*	*37.8*
Savings compared to 1990 reference: 63.4 kWh/m²/a	TWh/a	0	26	120	186	265	473	630	771
Savings compared to 2015 reference: 56.6 kWh/m²/a	TWh/a	0	0	0	0	73	274	429	567

The specific primary energy consumption in kWh/m^2/a is reduced from 63.4 kWh/m^2/a in 1990 to 37.8 kWh/m^2/a in 2050. A reduction of 40%. With 1990 as reference the total savings are 771 TWh in 2050; with 2015 as reference the savings amount to 567 TWh in 2050. Such savings per m^2 of heated surface are the result of the increased penetration of improved mechanical ventilation units and related improvements to the buildings and dwelling shells.

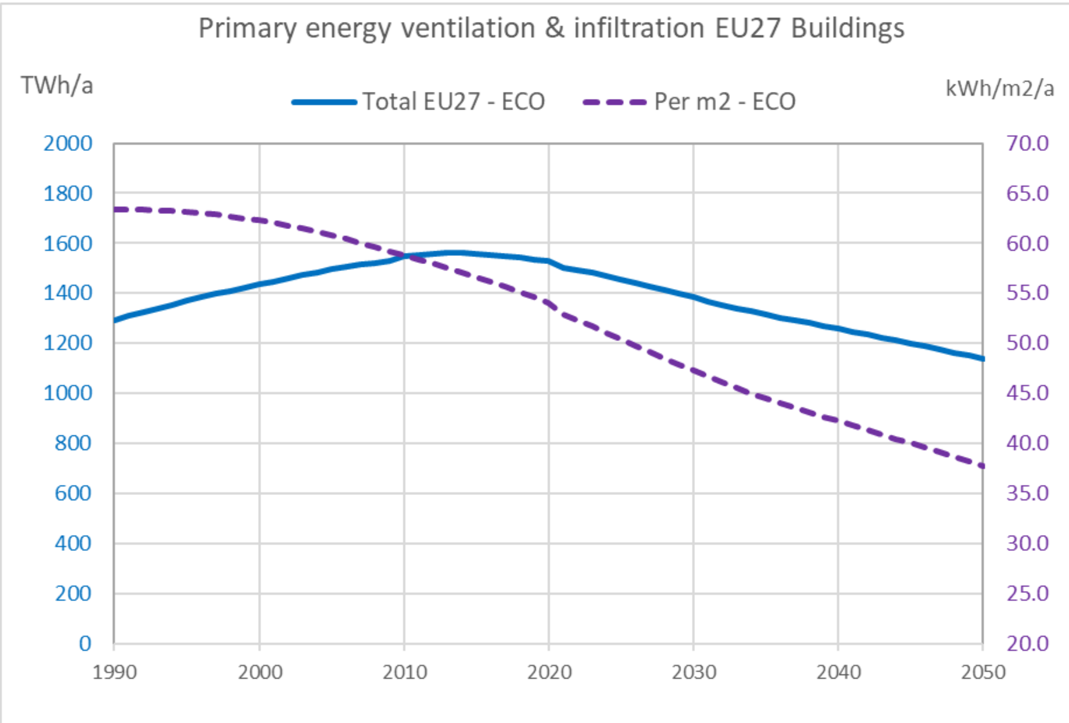


Figure 21. Primary energy for ventilation of the EU27 buildings stock

Figure 22 gives the gross primary energy consumption of the total VU-stock, including the infiltration that remains in the buildings the VUs are installed in. It is assumed here, that only for renovation projects and newly constructed buildings that include the installation of VUs, the airtightness levels are improved and related infiltration rates decline to values that are typical for the year of realization. An average n50 of 2 for dwellings renovated or newly constructed beyond 2020 is used, an average n50 of 4 for 2010 and an average n50 of 6 for 2000 and before; values are interpolated in intermediate years. Based on this, the stock averages for infiltration are calculated and the related space heating energy demand is added to the primary energy consumption of the ventilation units.

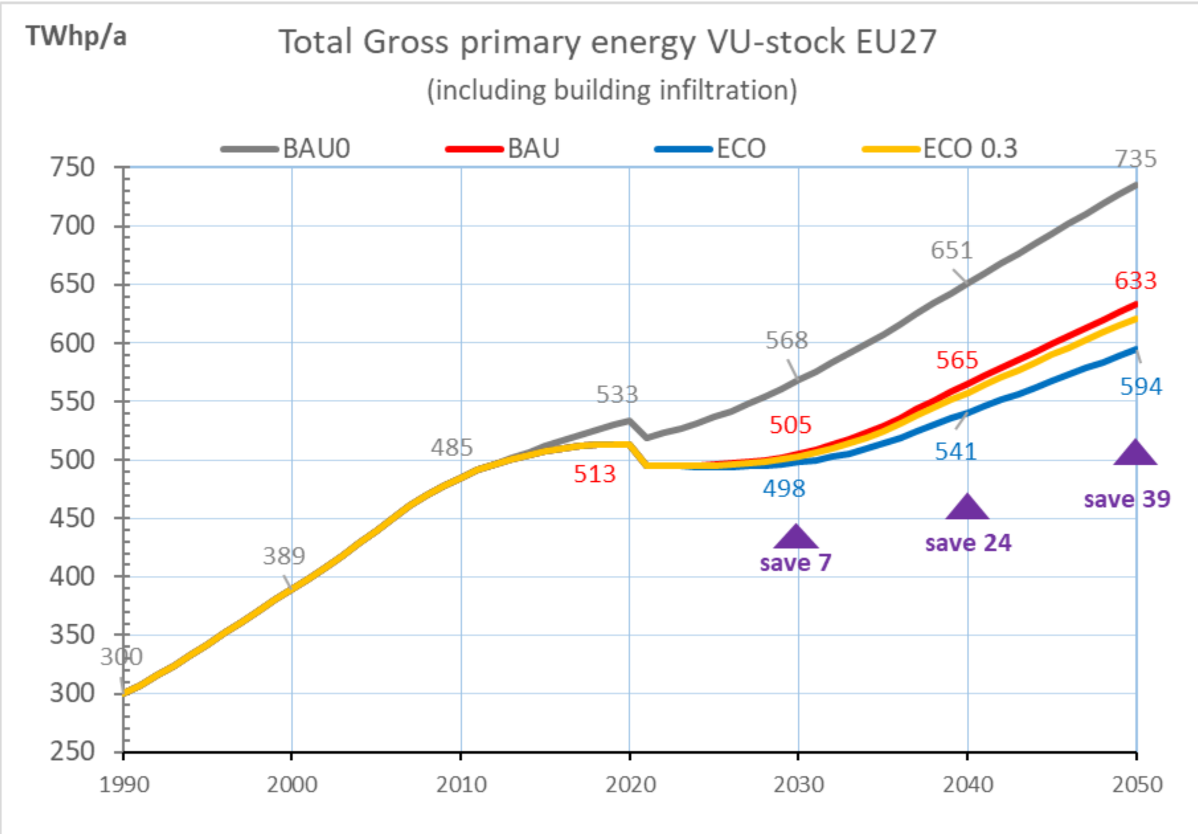


Figure 22. Gross primary energy for ventilation and infiltration in EU27 VU-building stock

A part of this EU27 VU-stock replaces natural ventilation systems. For this particular share, the reference natural ventilation (of 2.50 $m^3/h/m^2$) is replaced by a more effective mechanical ventilation system and simultaneously the infiltration rates are reduced because of a renovated or improved buildings shell. The result of this effect is illustrated in Figure 23.

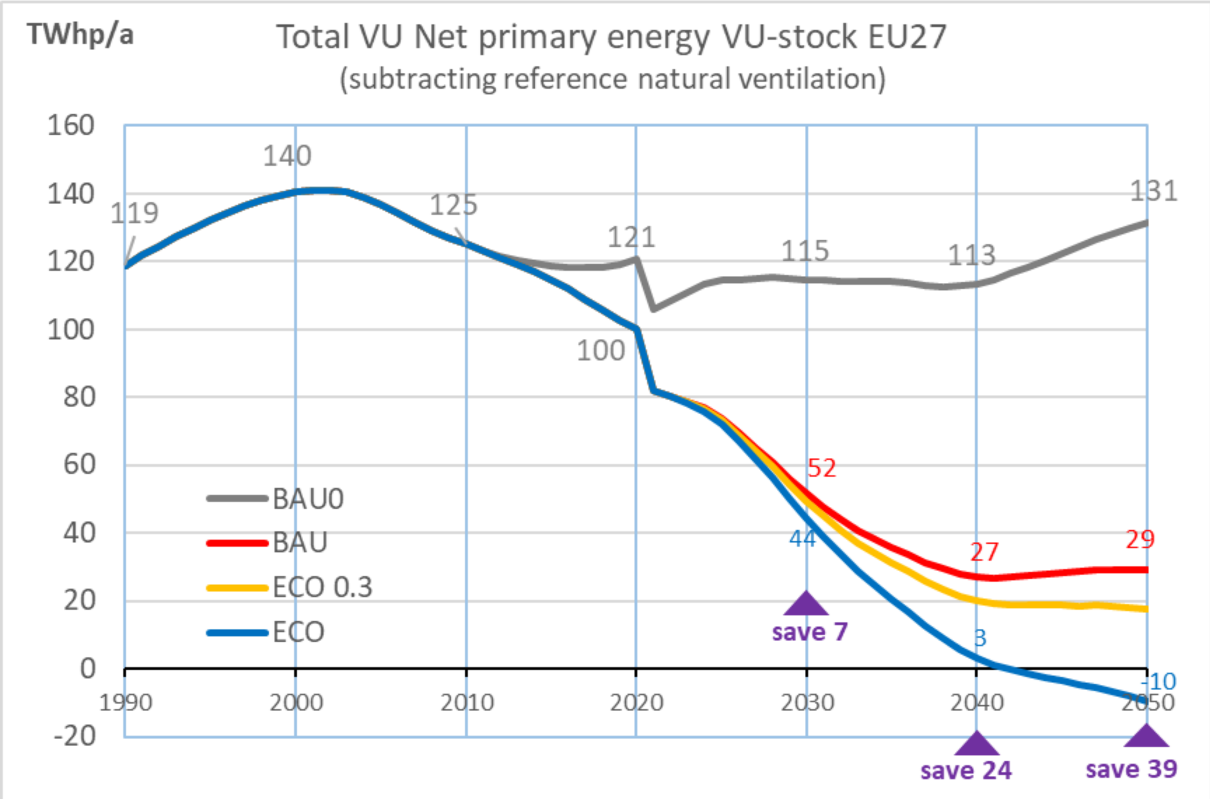


Figure 23. Total Net primary energy effect VU-stock EU27

Figure 23 represents the overall energy effect of the increased penetration of mechanical ventilation units in the EU27 building stock. The growing energy use related to the expanding stock VU of appliances (see Figure 15) is more than compensated by the following effects:

1. replacement of natural ventilation systems in a large share of the existing building stock (i.e. in renovation projects) combined with improvement or renovation of the building shell, resulting in a considerable reduction of the average ventilation and infiltration airflow rates
2. improvement of the ventilation effectiveness
3. improvement of the energy recovery ratio (further saving on space heating energy)
4. reduction of the electricity consumption.

Replacement of natural ventilation systems in renovation projects has by far the largest offsetting effect here. The ambitious but clear path of the EPBD towards a low and zero-emission building stock in the EU by 2050 is a clear driver behind the renovation activities in the existing building stock.
Nevertheless, the ECO-scenario does not take into account that all of the existing buildings will be renovated by 2050, but assumes that about 30% of the stock still needs to be renovated by 2050.

7 GHG emissions

Greenhouse gas (GHG) emissions related to the use of ventilation units are computed multiplying the VU-related energy consumption by Global Warming Potential (GWP) factors depending on the type of energy consumed.

For electricity, the GWP factor from the Ecodesign Impact Accounting (EIA) is used. This factor derives from information in the MEErP, and decreases with the years, reflecting changes in the electricity generation, from 0.50 $kgCO_2eq/kWh$ in 1990, to 0.40 in 2015, 0.34 in 2030 and 0.26 $kgCO_2eq/kWh$ in 2050.

For space heating energy related to VUs, the use of a mix of 80% gas and 20% heating oil is assumed, leading to a GWP of 0.21 $kgCO_2eq/kWh$ (NCV). This value is constant over the years and is the same as used in EIA.

The net GHG emissions per scenario shown in Figure 24 and Table 28 include the emissions due to:

- Electricity consumption of the VU itself,
- Space heating energy required to compensate heat losses due to mechanical ventilation airflows (including the reduction of those losses due to heat recovery by the VU, where applicable),
- Space heating energy required to compensate heat losses due to residual infiltration in dwellings/buildings using a VU,
- Space heating energy avoided by using a VU instead of reference natural ventilation. This is accounted as a negative contribution. A reference airflow of 2.48 $m^3/h/m^2$ is used for newly built or renovated dwellings/buildings installing a VU. For VUs replacing like-for-like existing VUs, where there is no new avoidance of space heating energy, the reference is set identical to the residual infiltration.

The GHG emissions shown here do not include those due to space heating energy required to compensate for heat losses due to natural ventilation and infiltration in dwellings/buildings without a VU. In addition, only emissions during the use-phase are taken into account here (see Task 5 for emissions in other life-phases).

In the BAU-scenario (with existing regulations), total EU27 GHG emissions related to the use of VUs decrease from 21 $MtCO_2eq/a$ in 2010, to 15 in 2020, to 6 in 2030 and further down to -5 $MtCO_2eq/a$ in 2050. The negative value indicates that, compared to the reference of natural ventilation and infiltration, the implementation of VUs leads to a net reduction of the emissions.

In the ECO-scenario (including proposed measures of Task 6), the GHG emissions are reduced compared to the BAU-scenario by 1.3 $MtCO_2eq/a$ in 2030 and 6.3 $MtCO_2eq/a$ in 2050. This reflects improvements in the average electrical efficiency of the VUs, and improvements in the heat recovery efficiency. In the ECO0.3 scenario the emissions savings versus BAU would be reduced to 1.9 $MtCO_2eq/a$ in 2050. The reduction of the emissions occurs in parallel to an improvement in ventilation performance.

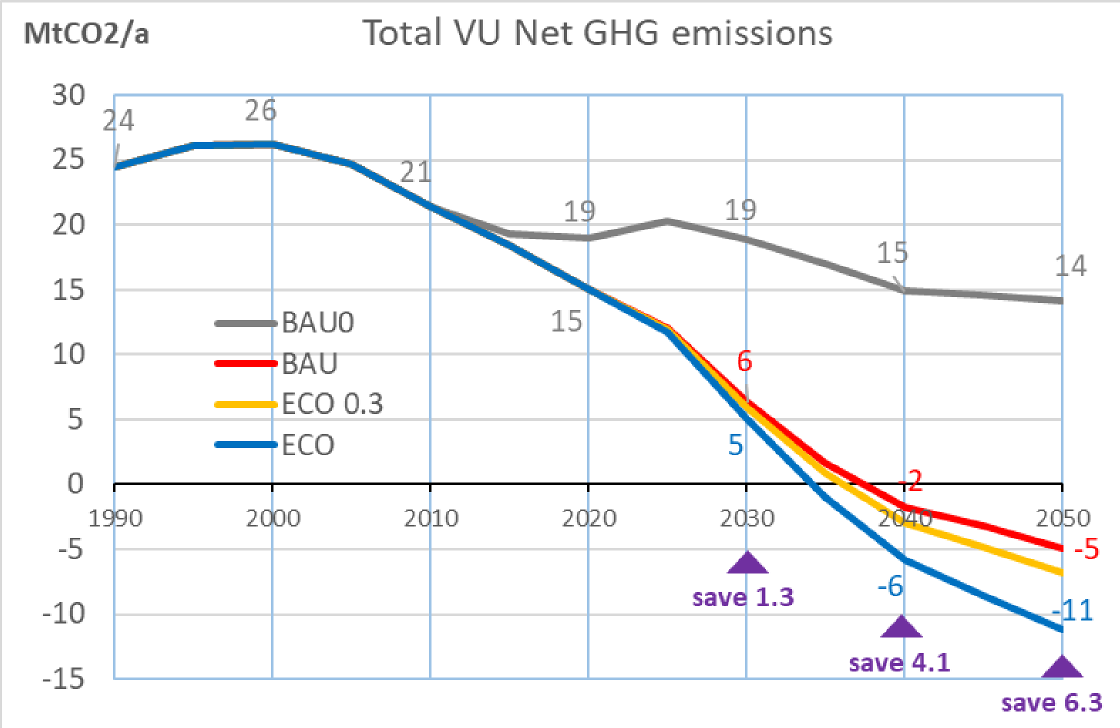


Figure 24: EU27 total net GHG emissions (in MtCO2eq/a) related to the use of Ventilation Units, for the four scenarios considered.

Table 28: EU27 total net GHG emissions (in MtCO2eq/a) related to the use of Ventilation Units, subdivided by source, comparing results for the BAU and ECO scenarios (top) or the BAU and ECO0.3 scenarios (bottom).

BAU vs ECO	**2020**	**2030**			**2040**			**2050**		
	BAU	**BAU**	**ECO**	**inc**	**BAU**	**ECO**	**inc**	**BAU**	**ECO**	**inc**
Net GHG emissions (total)	**15**	**6**	**5**	**-1.3**	**-2**	**-6**	**-4.1**	**-5**	**-11**	**-6.3**
o/w from electricity	*16*	*15*	*14*	*-0.7*	*15*	*13*	*-2.0*	*15*	*13*	*-2.7*
o/w from space heating (mech.vent.)	*50*	*52*	*51*	*-0.6*	*56*	*54*	*-2.1*	*60*	*56*	*-3.6*
o/w from space heating (infiltration balance)	*-51*	*-61*	*-61*	*0.0*	*-73*	*-73*	*0.0*	*-80*	*-80*	*0.0*

BAU vs ECO0.3	**2020**	**2030**			**2040**			**2050**		
	BAU	**BAU**	**ECO 0.3**	**inc**	**BAU**	**ECO 0.3**	**inc**	**BAU**	**ECO 0.3**	**inc**
Net GHG emissions (total)	**15**	**6**	**6**	**-0.4**	**-2**	**-3**	**-1.2**	**-5**	**-7**	**-1.9**
o/w from electricity	*16*	*15*	*15*	*-0.2*	*15*	*15*	*-0.6*	*15*	*15*	*-0.8*
o/w from space heating (mech.vent.)	*50*	*52*	*52*	*-0.2*	*56*	*55*	*-0.6*	*60*	*59*	*-1.1*
o/w from space heating (infiltration balance)	*-51*	*-61*	*-61*	*0.0*	*-73*	*-73*	*0.0*	*-80*	*-80*	*0.0*

o/w = of which; inc = increment in ECO or ECO0.3 versus BAU of the same year (reduction if negative)

8 User expense

The total user expense related to ventilation units is the sum of acquisition costs, energy costs and maintenance cost. All expenses are reported in 2015 euros and include 20% VAT for the residential sector.

Acquisition costs include purchase costs for the ventilation appliance itself (including co-delivered controls where applicable), installation materials (ducts, grills, etc.), and installation labour costs. The latter two depend on the type of installation, i.e. in new-built, in renovated, or as a like-for-like replacement. The basic costs per unit, for the base case design and for the design options, are taken from Task 2 and Task 5.

The BAU-scenario essentially considers the unit costs for the 2015-2020 base case design. The ECO-scenario deviates from the BAU-scenario starting from 2023, and considers the sales-weighted average unit costs for the assumed mix of base case design and (more expensive) design options (Annex 1). For the ECO0.3 scenario, 30% of the unit cost increase from BAU to ECO is applied. For purchase cost increases, a reduction due to learning effects and increasing quantities is considered, varying per VU type from 0.9%/a to 0.4%/a (values derived from EIA, based on previous Ecodesign studies).

Unit costs are multiplied by the VU-sales in a given year (split in new-built, renovation and replacement) to obtain the total EU27 annual acquisition costs.

Energy costs are computed multiplying the energy consumption related to VUs by a corresponding energy rate (euros/kWh) depending on the type of energy consumed. Separate rates are used for the residential sector, the tertiary/services sector, the industry sector and the other sector (e.g. agriculture, forestry, fishing). For the RVUs, 100% residential use is assumed. For the NRVUs and AHUs, 86% tertiary, 12% industry and 2% other is used.

The rates for electricity and heating fuel (80% gas; 20% oil) from the EIA have been applied (Table 29). Until 2018 these rates derive from Eurostat. For later years, an annual increase of 1% (on top of inflation) is assumed for electricity and 1.5% for heating fuel, which is close to the projections in the PRIMES 2016 reference scenario.

Table 29: Rates per usage sector for electricity and heating fuel (80% gas; 20% oil). In 2015 euros per kWh (NCV for fuel); incl. 20% VAT for residential.

Energy rates in 2015 € / kWh	1990	2010	2015	2020	2025	2030	2035	2040	2045	2050
Electricity										
Residential	0.202	0.184	0.210	0.207	0.217	0.229	0.240	0.253	0.265	0.279
Industry	0.128	0.112	0.119	0.117	0.123	0.129	0.136	0.143	0.150	0.158
Tertiary & Other	0.176	0.159	0.178	0.175	0.184	0.194	0.204	0.214	0.225	0.237
Heating fuel (80% gas, 20% oil)										
Residential	0.054	0.068	0.075	0.071	0.076	0.082	0.088	0.095	0.103	0.111
Industry	0.029	0.043	0.043	0.040	0.043	0.046	0.050	0.054	0.058	0.062
Tertiary & Other	0.043	0.056	0.060	0.056	0.061	0.065	0.070	0.076	0.082	0.088

Unit maintenance costs per year have been derived from data in Task 2 and Task 5. These quantities are multiplied by the VU-stock in a given year to obtain the total EU27 maintenance costs for VUs.

The total user expense (acquisition + energy cost + maintenance) for the four different scenarios is shown in Figure 25 and Table 30.

In the BAU-scenario (with existing regulations), total EU27 expenditure related to VUs increases from 24 bn euros/a in 2010, to 27 in 2020, to 29 in 2030 and further up to 34 bn euros/a in 2050. This increase is mainly due to an increase in the VU-sales and -stock quantities.

In the ECO-scenario (including proposed measures of Task 6), the total user expenditure initially increases compared to BAU, by 0.6 bn euros in 2030 (negative savings shown in the graph). This is an investment in better-performing VUs, which initially are more expensive. In later years the ECO-expenditure is lower than in BAU: 0.7 bn euros lower in 2040 and 2.4 bn euros lower in 2050. This is due to higher average electrical and heat recovery efficiency, and to improved control of the ventilation airflows, leading to lower energy costs. In the ECO0.3 scenario the expenditure savings versus BAU would be reduced to 0.7 bn euros/a in 2050. These overall cost reductions come together with an improvement in the ventilation performance.

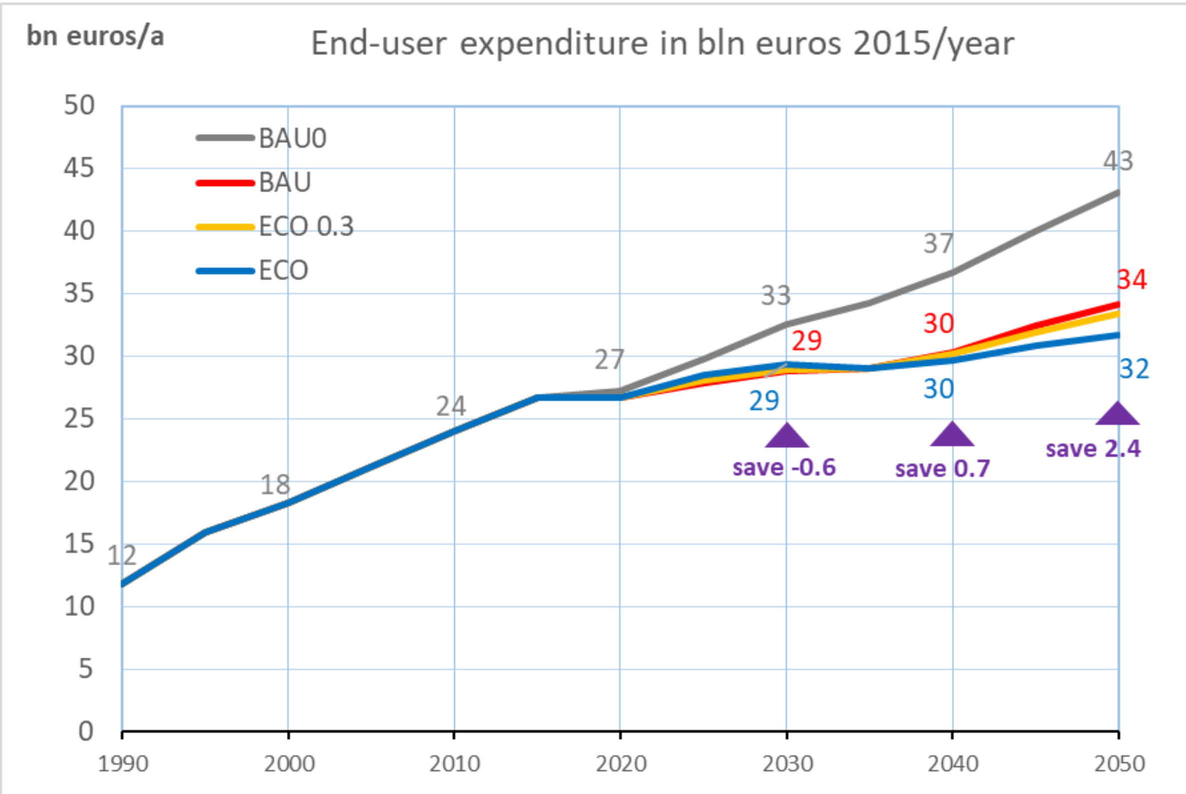


Figure 25: EU27 total user expense (in bn 2015 euros/a) related to the acquisition and use of Ventilation Units, for the four scenarios considered.

Table 30: EU27 total user expense (in bn 2015 euros/a) related to the acquisition and use of Ventilation Units, subdivided by cost source, comparing results for the BAU and ECO scenarios (top) or the BAU and ECO0.3 scenarios (bottom).

BAU vs ECO	2020	2030			2040			2050		
	BAU	BAU	ECO	inc	BAU	ECO	inc	BAU	ECO	inc
User expense (total)	**27**	**29**	**29**	**0.6**	**30**	**30**	**-0.7**	**34**	**32**	**-2.4**
o/w Acquisition costs (incl. installation)	*18*	*20*	*22*	*1.2*	*23*	*24*	*1.5*	*25*	*27*	*1.7*
o/w Energy costs (electricity)	*7*	*9*	*8*	*-0.4*	*11*	*10*	*-1.5*	*15*	*12*	*-2.5*
o/w Energy costs (SH mech.vent.)	*14*	*18*	*17*	*-0.2*	*22*	*21*	*-0.7*	*27*	*26*	*-1.5*
o/w Energy costs (SH infiltration balance)	*-15*	*-21*	*-21*	*0.0*	*-30*	*-30*	*0.0*	*-38*	*-38*	*0.0*
o/w Maintenance costs	*2*	*3*	*3*	*0.0*	*4*	*4*	*0.0*	*5*	*5*	*0.0*

BAU vs ECO0.3	2020	2030			2040			2050		
	BAU	BAU	ECO 0.3	inc	BAU	ECO 0.3	inc	BAU	ECO 0.3	inc
User expense (total)	**27**	**29**	**29**	**0.2**	**30**	**30**	**-0.2**	**34**	**33**	**-0.7**
o/w Acquisition costs (incl. installation)	*18*	*20*	*21*	*0.4*	*23*	*23*	*0.5*	*25*	*26*	*0.5*
o/w Energy costs (electricity)	*7*	*9*	*8*	*-0.1*	*11*	*11*	*-0.4*	*15*	*14*	*-0.8*
o/w Energy costs (SH mech.vent.)	*14*	*18*	*17*	*-0.1*	*22*	*22*	*-0.2*	*27*	*27*	*-0.5*
o/w Energy costs (SH infiltration balance)	*-15*	*-21*	*-21*	*0.0*	*-30*	*-30*	*0.0*	*-38*	*-38*	*0.0*
o/w Maintenance costs	*2*	*3*	*3*	*0.0*	*4*	*4*	*0.0*	*5*	*5*	*0.0*

o/w = of which; inc = increment in ECO or ECO0.3 versus BAU of the same year (additional expense if positive); SH = Space Heating

9 Business revenues and jobs

Revenues for the maintenance sector derive directly from the maintenance costs, removing the portion of VAT. Corresponding jobs are estimated dividing the revenues by 108 000 euros of sector revenue per employee (source: EIA).

Revenues for the installation sector (in mln 2015 euros) derive directly from the installation labour costs, removing the portion of VAT. Corresponding jobs are estimated dividing the revenues by 108 000 euros/employee (source: EIA).

Purchase costs and installation material costs lead to revenue for the industry-, retail- and wholesale-sectors. For residential VUs, 17% of these costs is VAT, while 17% is assumed to be retail-, 16% wholesale- and 50% industry-revenue. For non-residential VUs, 0% is VAT, 10% retail revenue, 10% wholesale and 80% industry. Corresponding jobs are estimated dividing the industry revenues by 54 000 euros of sector revenue per employee (covering 1/3 manufacturing, 1/3 services, 1/3 OEM). For retail, 65 000 euros/employee is used, and for wholesale 270 000 euros/employee. (source: EIA).

Total EU27 business revenues (in bn euros 2015) and jobs (in thousands) associated with the sale, installation and maintenance of ventilation units are reported in Figure 26 and Table 31.

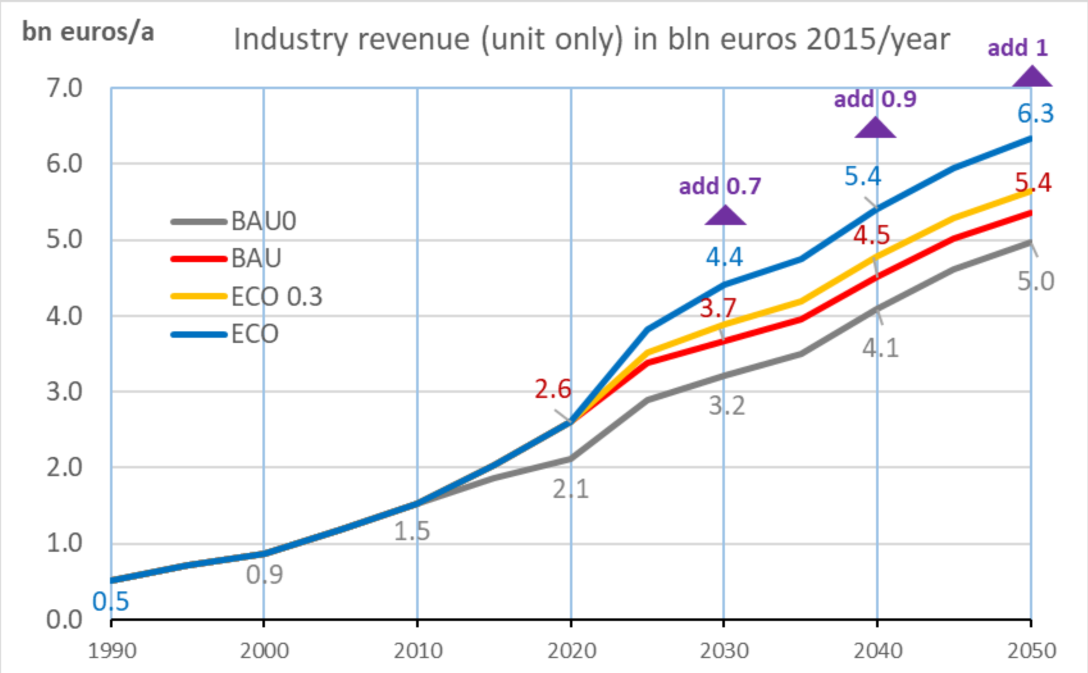
The graphs show industry revenues for the units only (excluding installation materials) and for units and installation materials together. The differences between the scenarios (additional revenues) are the same in both cases: installation material costs are assumed to be the same in all scenarios. Industry revenues (incl. installation materials) are approximately one third of the total business revenues. Installation revenues (from labour only) have the highest share.

In the BAU-scenario (with existing regulations), total EU27 industry revenues related to VUs (units only) increase from 1.5 bn euros/a in 2010, to 2.6 in 2020, to 3.7 in 2030 and further up to 5.4 bn euros/a in 2050. This increase is mainly due to an increase in the VU-sales quantities.

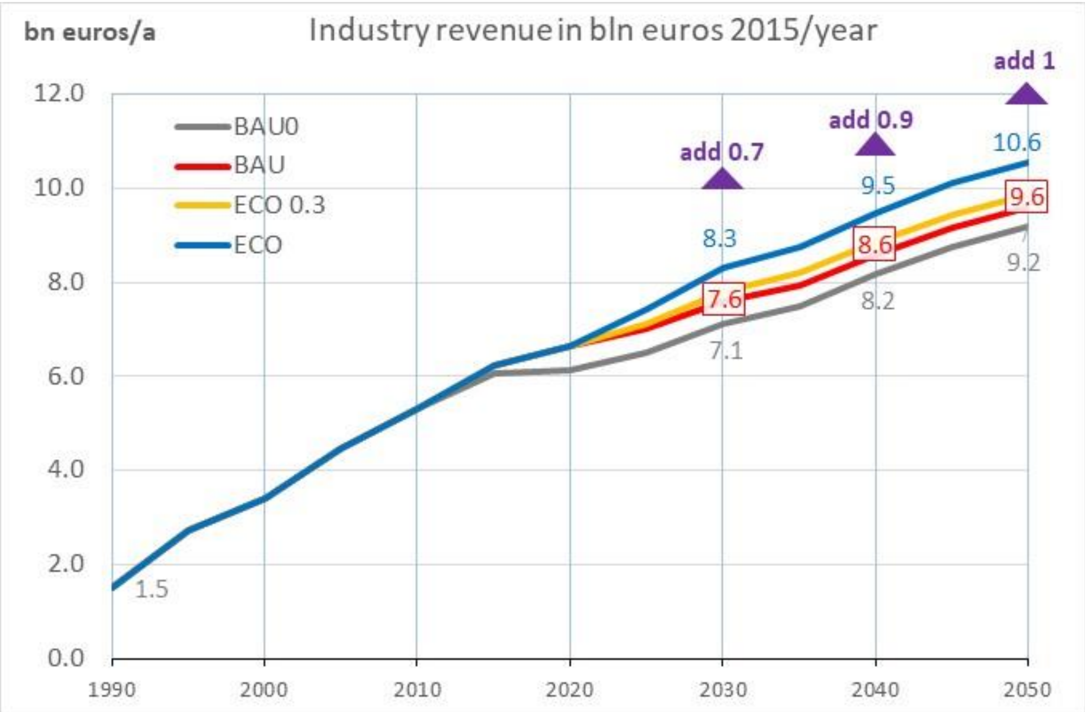
In the ECO-scenario (including proposed measures of Task 6), the total industry revenues are higher than in BAU, by 0.7 bn euros in 2030, and 1.0 bn euros in 2050. This is due to the higher average purchase cost for better-performing VUs in the ECO-scenario. In the ECO0.3 scenario the additional industry revenue versus BAU would be reduced to 0.3 bn euros/a in 2050.

Considering the total of business revenues, the additional revenues in ECO versus BAU are 1.1 bn euros in 2030 and 1.5 bn euros in 2050. In ECO0.3 the 2050 value would reduce to 0.4 bn euros.

As regards associated jobs, in the BAU-scenario in 2020 the estimate is 242 thousand jobs associated with the sale, installation and maintenance of ventilation units. Without new measures, this is projected to increase to 278 thousand in 2030 and 377 in 2050. While installation and maintenance jobs are most likely all inside EU27, a share of the industry jobs would be expected to be outside EU27. In the ECO-scenario, 17 thousand additional jobs are created in 2030 and 23 thousand additional in 2050. This would drop to 7 thousand additional jobs in 2050 in the ECO0.3 scenario.



This excludes installation materials



This includes installation materials

Figure 26: EU27 industry revenue (in bn 2015 euros/a), for the four scenarios considered. The bottom graph includes sales of Ventilation Units and associated installation materials, the top graph is for the units only.

Table 31: EU27 total business revenues (in bn 2015 euros/a) and associated jobs (thousands) related to the acquisition, installation and maintenance of ventilation units, subdivided by business sector, comparing results for BAU and ECO scenarios (top) or BAU and ECO0.3 scenarios (bottom).

BAU vs ECO	2020	2030			2040			2050		
	BAU	BAU	ECO	inc	BAU	ECO	inc	BAU	ECO	inc
Business revenue (total, bn euros)	**19.4**	**22.3**	**23.4**	**1.1**	**25.4**	**26.8**	**1.3**	**28.5**	**30.0**	**1.5**
o/w Industry (incl. installation materials)	*6.6*	*7.6*	*8.3*	*0.7*	*8.6*	*9.5*	*0.9*	*9.6*	*10.6*	*1.0*
o/w Wholesale (incl. install. mat.)	*1.0*	*1.3*	*1.4*	*0.2*	*1.5*	*1.7*	*0.2*	*1.8*	*2.0*	*0.2*
o/w Retail (incl. install. mat.)	*1.0*	*1.3*	*1.5*	*0.2*	*1.6*	*1.8*	*0.2*	*1.8*	*2.0*	*0.2*
o/w Installation (install. labour only)	*8.8*	*9.3*	*9.3*	*0.0*	*9.9*	*10.0*	*0.0*	*10.6*	*10.6*	*0.0*
o/w Maintenance	*2.1*	*2.9*	*2.9*	*0.0*	*3.8*	*3.8*	*0.0*	*4.7*	*4.7*	*0.0*
Associated jobs (total, thousands)	**242**	**278**	**295**	**17.1**	**316**	**337**	**20.9**	**354**	**377**	**22.9**
o/w Industry (incl. installation materials)	*123*	*141*	*154*	*13.6*	*159*	*176*	*16.6*	*178*	*196*	*18.2*
o/w Wholesale (incl. install. mat.)	*4*	*5*	*5*	*0.6*	*6*	*6*	*0.8*	*6*	*7*	*0.8*
o/w Retail (incl. install. mat.)	*15*	*20*	*23*	*2.8*	*24*	*28*	*3.4*	*28*	*32*	*3.7*
o/w Installation (install. labour only)	*81*	*86*	*86*	*0.1*	*92*	*92*	*0.1*	*98*	*99*	*0.1*
o/w Maintenance	*19*	*27*	*27*	*0.0*	*35*	*35*	*0.0*	*44*	*44*	*0.0*

BAU vs ECO0.3	2020	2030			2040			2050		
	BAU	BAU	ECO 0.3	inc	BAU	ECO 0.3	inc	BAU	ECO 0.3	inc
Business revenue (total, bn euros)	**19.4**	**22.3**	**22.7**	**0.3**	**25.4**	**25.8**	**0.4**	**28.5**	**29.0**	**0.4**
o/w Industry (incl. installation materials)	*6.6*	*7.6*	*7.8*	*0.2*	*8.6*	*8.9*	*0.3*	*9.6*	*9.9*	*0.3*
o/w Wholesale (incl. install. mat.)	*1.0*	*1.3*	*1.3*	*0.1*	*1.5*	*1.6*	*0.1*	*1.8*	*1.8*	*0.1*
o/w Retail (incl. install. mat.)	*1.0*	*1.3*	*1.4*	*0.1*	*1.6*	*1.6*	*0.1*	*1.8*	*1.9*	*0.1*
o/w Installation (install. labour only)	*8.8*	*9.3*	*9.3*	*0.0*	*9.9*	*9.9*	*0.0*	*10.6*	*10.6*	*0.0*
o/w Maintenance	*2.1*	*2.9*	*2.9*	*0.0*	*3.8*	*3.8*	*0.0*	*4.7*	*4.7*	*0.0*
Associated jobs (total, thousands)	**242**	**278**	**283**	**5.1**	**316**	**322**	**6.3**	**354**	**361**	**6.9**
o/w Industry (incl. installation materials)	*123*	*141*	*145*	*4.1*	*159*	*164*	*5.0*	*178*	*183*	*5.5*
o/w Wholesale (incl. install. mat.)	*4*	*5*	*5*	*0.2*	*6*	*6*	*0.2*	*6*	*7*	*0.3*
o/w Retail (incl. install. mat.)	*15*	*20*	*21*	*0.8*	*24*	*25*	*1.0*	*28*	*29*	*1.1*
o/w Installation (install. labour only)	*81*	*86*	*86*	*0.0*	*92*	*92*	*0.0*	*98*	*98*	*0.0*
o/w Maintenance	*19*	*27*	*27*	*0.0*	*35*	*35*	*0.0*	*44*	*44*	*0.0*

o/w = of which; inc = increment in ECO or ECO0.3 versus BAU of the same year (additional revenue if positive)

Annex 1. ECO-scenario

Shares of VU design options in future sales of the ECO-scenario

ECO scenario									
Share of design options in annual sales (with interpolation in between years)									
Non-ducted (local) RVUs									
	average	energy use		*CTRL*fs*	VPI	**2020**	**2023**	**2030**	**2050**
UVU/100/ES (3 units per 100m^2)	m^3/h	kWh$_{el}$/a	kWh$_{SH\ PR}$/a			*Share in annual sales UVU/100/ES*			
BaseCase 2020	15.6	20	384	0.74	-	*100%*	*90%*	*60%*	*20%*
Design Option I	15.6	14	384	0.70	-	0%	10%	40%	80%
							interpolation		
UVU/100/HS (3 units per 100m^2)	m^3/h	kWh$_{el}$/a	kWh$_{SH\ PR}$/a	[-]	[-]	*Share in annual sales UVU/100/HS*			
BaseCase 2020	29	18	714	0.77	0.54	*100%*	*80%*	*50%*	*15%*
Design Option I	18	21	443	0.47	0.93	0%	10%	20%	40%
Design Option II	18	15	443	0.45	1.00	0%	10%	30%	45%
							interpolation		
UVU/100/HS (3 units per 100m^2)	m^3/h	kWh$_{el}$/a	kWh$_{SH\ PR}$/a	[-]	[-]	*Share in annual sales BVU/100/HS*			
BaseCase 2020	29	74	214	0.77	0.54	*100%*	*80%*	*50%*	*10%*
Design Option I	24	46	148	0.53	0.84	0%	10%	20%	40%
Design Option II	15	29	55	0.35	1.00	0%	10%	30%	50%
Ducted RVUs									
	average	energy use		*CTRL*	VPI	**2020**	**2023**	**2030**	**2050**
UVU/250 (100 m^2)	m^3/h	kWh$_{el}$/a	kWh$_{SH\ PR}$/a	[-]	[-]	*Share in annual sales UVU/250*			
BaseCase 2020	100	98	2464	0.90	0.38	*100%*	*75%*	*55%*	*30%*
Design Option I	115	114	2838	0.80	0.43	0%	10%	10%	15%
Design Option II	115	74	2838	0.80	0.43	0%	10%	20%	30%
Design Option III	90	81	2217	0.45	0.76	0%	5%	15%	25%
BVU/250 (100 m^2)	m^3/h	kWh$_{el}$/a	kWh$_{SH}$/a	[-]	[-]	*Share in annual sales BVU/250*			
BaseCase 2020	86	186	362	0.60	0.57	*100%*	*75%*	*45%*	*10%*
Design Option I	86	160	426	0.50	0.68	0%	10%	20%	35%
Design Option II	78	164	289	0.45	0.76	0%	10%	20%	35%
Design Option III	70	130	172	0.35	0.97	0%	5%	15%	20%
Ducted Collective RVUs									
	average	energy use		*CTRL*	VPI	**2020**	**2023**	**2030**	**2050**
UVU/1000 (400 m^2)	m^3/h	kWh$_{el}$/a	kWh$_{SH\ PR}$/a	[-]	[-]	*Share in annual sales UVU/1000*			
BaseCase 2020	372	484	9165	0.95	0.36	*100%*	*75%*	*50%*	*30%*
Design Option I	372	246	9165	0.95	0.36	0%	10%	15%	20%
Design Option II	372	348	9165	0.90	0.38	0%	10%	20%	30%
Design Option III	460	663	11353	0.65	0.52	0%	5%	15%	20%
BVU/1000 (400 m^2)	m^3/h	kWh$_{el}$/a	kWh$_{SH\ PR}$/a	[-]	[-]	*Share in annual sales BVU/1000*			
BaseCase 2020	372	1054	1558	0.70	0.49	*100%*	*75%*	*55%*	*35%*
Design Option I	372	592	1375	0.70	0.49	0%	10%	20%	30%
Design Option II	326	602	1044	0.65	0.52	0%	10%	15%	20%
Design Option III	280	694	690	0.35	0.97	0%	5%	10%	15%
UVU/1000+ (833 m^2)	m^3/h	kWh$_{el}$/a	kWh$_{SH\ PR}$/a	[-]	[-]	*Share in annual sales UVU/1000+*			
BaseCase 2020	775	999	19094	0.95	0.36	*100%*	*75%*	*50%*	*30%*
Design Option I	775	504	19094	0.95	0.36	0%	10%	15%	20%
Design Option II	775	714	19094	0.90	0.38	0%	10%	20%	30%
Design Option III	960	1371	23652	0.65	0.52	0%	5%	15%	20%
BVU/2500 (1250 m^2)	m^3/h	kWh$_{el}$/a	kWh$_{SH\ PR}$/a	[-]	[-]	*Share in annual sales BVU/2500*			
BaseCase 2020	1163	3276	4869	0.70	0.49	*100%*	*75%*	*55%*	*35%*
Design Option I	1163	2162	4296	0.70	0.49	0%	10%	20%	30%
Design Option II	1019	1864	3263	0.65	0.52	0%	10%	15%	20%
Design Option III	875	2148	2156	0.35	0.97	0%	5%	10%	15%

NRVUs									
	average	Energy use		*CTRL*		**2020**	**2023**	**2030**	**2050**
NR-UVU/1000+ (417 m^2)	$m^3/h/m^2$	kWh_{el}/a	kWh_{SH_PR}/a	[-]		*Share in annual sales UVU/250*			
BaseCase 2020	720	585	17739	0.48		*100%*	*85%*	*50%*	*20%*
Design Option I	720	414	17739	0.48		0%	10%	30%	50%
Design Option II	525	197	12935	0.35		0%	5%	20%	30%
NR-BVU/2500 (625 m^2)	$m^3/h/m^2$	kWh_{el}/a	kWh_{SH_PR}/a	[-]		*Share in annual sales UVU/250*			
BaseCase 2020	1080	2071	5322	0.48		*100%*	*85%*	*50%*	*20%*
Design Option I	1080	1660	3991	0.48		0%	10%	30%	50%
Design Option II	788	772	1940	0.35		0%	5%	20%	30%
AHU-S (1110 m^2)	$m^3/h/m^2$	kWh_{el}/a	kWh_{SH_PR}/a	[-]		*Share in annual sales UVU/250*			
BaseCase 2020	1920	4138	14191	0.48		*100%*	*85%*	*50%*	*20%*
Design Option I	1920	3629	12772	0.48		0%	10%	30%	50%
Design Option II	1400	1870	8623	0.35		0%	5%	20%	30%
AHU-M (2778 m2)	$m^3/h/m^2$	kWh_{el}/a	kWh_{SH_PR}/a	[-]		*Share in annual sales UVU/250*			
BaseCase 2020	4800	14123	35478	0.48		*100%*	*85%*	*50%*	*20%*
Design Option I	4800	12536	31930	0.48		0%	10%	30%	50%
Design Option II	3500	6553	21558	0.35		0%	5%	20%	30%
AHU-L (9722 m^2)	$m^3/h/m^2$	kWh_{el}/a	kWh_{SH_PR}/a	[-]		*Share in annual sales UVU/250*			
BaseCase 2020	16800	55819	124173	0.48		*100%*	*85%*	*50%*	*20%*
Design Option I	16800	50283	111756	0.48		0%	10%	30%	50%
Design Option II	12250	26293	75452	0.35		0%	5%	20%	30%

Annex 2. ECO03 scenario

Shares of VU design options in future sales of the ECO03 scenario

ECO_0.3 scenario

Share of design options in annual sales (with interpolation in between years)

Non-ducted (local) RVUs

	average	energy use		CTRL*fs	VPI	2020	2023	2030	2050
UVU/100/ES (3 units per 100m²)	m^3/h	kWh_{el}/a	kWh_{SH_PR}/a			Share in annual sales UVU/100/ES			
BaseCase 2020	15.6	20	384	0.74	-	*100%*	*100%*	*90%*	*80%*
Design Option I	15.6	14	384	0.70	-	0%	0%	10%	20%
							interpolation		
UVU/100/HS (3 units per 100m²)	m^3/h	kWh_{el}/a	kWh_{SH_PR}/a	[-]	[-]	Share in annual sales UVU/100/HS			
BaseCase 2020	29	18	714	0.77	0.54	*100%*	*100%*	*85%*	*70%*
Design Option I	18	21	443	0.47	0.93	0%	0%	10%	20%
Design Option II	18	15	443	0.45	1.00	0%	0%	5%	10%
							interpolation		
UVU/100/HS (3 units per 100m²)	m^3/h	kWh_{el}/a	kWh_{SH_PR}/a	[-]	[-]	Share in annual sales BVU/100/HS			
BaseCase 2020	29	74	214	0.77	0.54	*100%*	*100%*	*85%*	*70%*
Design Option I	24	46	148	0.53	0.84	0%	0%	10%	20%
Design Option II	15	29	55	0.35	1.00	0%	0%	5%	10%

Ducted RVUs

	average	energy use		CTRL	VPI	2020	2023	2030	2050
UVU/250 (100 m²)	m^3/h	kWh_{el}/a	kWh_{SH_PR}/a	[-]	[-]	Share in annual sales UVU/250			
BaseCase 2020	100	98	2464	0.90	0.38	*100%*	*100%*	*90%*	*75%*
Design Option I	115	114	2838	0.80	0.43	0%	0%	5%	10%
Design Option II	115	74	2838	0.80	0.43	0%	0%	5%	10%
Design Option III	90	81	2217	0.45	0.76	0%	0%	0%	5%
BVU/250 (100 m²)	m^3/h	kWh_{el}/a	kWh_{SH}/a	[-]	[-]	Share in annual sales BVU/250			
BaseCase 2020	86	186	362	0.60	0.57	*100%*	*100%*	*90%*	*75%*
Design Option I	86	160	426	0.50	0.68	0%	0%	5%	10%
Design Option II	78	164	289	0.45	0.76	0%	0%	5%	10%
Design Option III	70	130	172	0.35	0.97	0%	0%	0%	5%

Ducted Collective RVUs

	average	energy use		CTRL	VPI	2020	2023	2030	2050
UVU/1000 (400 m²)	m^3/h	kWh_{el}/a	kWh_{SH_PR}/a	[-]	[-]	Share in annual sales UVU/1000			
BaseCase 2020	372	484	9165	0.95	0.36	*100%*	*100%*	*90%*	*75%*
Design Option I	372	246	9165	0.95	0.36	0%	0%	5%	10%
Design Option II	372	348	9165	0.90	0.38	0%	0%	5%	10%
Design Option III	460	663	11353	0.65	0.52	0%	0%	0%	5%
BVU/1000 (400 m²)	m^3/h	kWh_{el}/a	kWh_{SH_PR}/a	[-]	[-]	Share in annual sales BVU/1000			
BaseCase 2020	372	1054	1558	0.70	0.49	*100%*	*100%*	*90%*	*75%*
Design Option I	372	592	1375	0.70	0.49	0%	0%	5%	10%
Design Option II	326	602	1044	0.65	0.52	0%	0%	5%	10%
Design Option III	280	694	690	0.35	0.97	0%	0%	0%	5%
UVU/1000+ (833 m²)	m^3/h	kWh_{el}/a	kWh_{SH_PR}/a	[-]	[-]	Share in annual sales UVU/1000+			
BaseCase 2020	775	999	19094	0.95	0.36	*100%*	*100%*	*90%*	*75%*
Design Option I	775	504	19094	0.95	0.36	0%	0%	5%	10%
Design Option II	775	714	19094	0.90	0.38	0%	0%	5%	10%
Design Option III	960	1371	23652	0.65	0.52	0%	0%	0%	5%
BVU/2500 (1250 m²)	m^3/h	kWh_{el}/a	kWh_{SH_PR}/a	[-]	[-]	Share in annual sales BVU/2500			
BaseCase 2020	1163	3276	4869	0.70	0.49	*100%*	*100%*	*90%*	*75%*
Design Option I	1163	2162	4296	0.70	0.49	0%	0%	5%	10%
Design Option II	1019	1864	3263	0.65	0.52	0%	0%	5%	10%
Design Option III	875	2148	2156	0.35	0.97	0%	0%	0%	5%

NRVUs									
	average flowrate	Energy use		*CTRL*		**2020**	**2023**	**2030**	**2050**
NR-UVU/1000+ (417 m^2)	m^3/h/m^2	kWh$_{el}$/a	kWh$_{SH_PR}$/a	[-]		*Share in annual sales UVU/250*			
BaseCase 2020	720	585	17739	0.48		*100%*	*100%*	*88%*	*75%*
Design Option I	720	414	17739	0.48		0%	0%	10%	20%
Design Option II	525	197	12935	0.35		0%	0%	2%	5%
NR-BVU/2500 (625 m^2)	m^3/h/m^2	kWh$_{el}$/a	kWh$_{SH_PR}$/a	[-]		*Share in annual sales UVU/250*			
BaseCase 2020	1080	2071	5322	0.48		*100%*	*100%*	*88%*	*75%*
Design Option I	1080	1660	3991	0.48		0%	0%	10%	20%
Design Option II	788	772	1940	0.35		0%	0%	2%	5%
AHU-S (1110 m^2)	m^3/h/m^2	kWh$_{el}$/a	kWh$_{SH_PR}$/a	[-]		*Share in annual sales UVU/250*			
BaseCase 2020	1920	4138	14191	0.48		*100%*	*100%*	*88%*	*75%*
Design Option I	1920	3629	12772	0.48		0%	0%	10%	20%
Design Option II	1400	1870	8623	0.35		0%	0%	2%	5%
AHU-M (2778 m2)	m^3/h/m^2	kWh$_{el}$/a	kWh$_{SH_PR}$/a	[-]		*Share in annual sales UVU/250*			
BaseCase 2020	4800	14123	35478	0.48		*100%*	*100%*	*88%*	*75%*
Design Option I	4800	12536	31930	0.48		0%	0%	10%	20%
Design Option II	3500	6553	21558	0.35		0%	0%	2%	5%
AHU-L (9722 m^2)	m^3/h/m^2	kWh$_{el}$/a	kWh$_{SH_PR}$/a	[-]		*Share in annual sales UVU/250*			
BaseCase 2020	16800	55819	124173	0.48		*100%*	*100%*	*88%*	*75%*
Design Option I	16800	50283	111756	0.48		0%	0%	10%	20%
Design Option II	12250	26293	75452	0.35		0%	0%	2%	5%

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ET-02-20-534-EN-N

Publications Office
of the European Union

doi: 10.2873/254887
ISBN 978-92-76-20667-5