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Final report – Technical study on the possible introduction of inspection of stand-alone ventilation systems in buildings

[Written by INIVE and BPIE]
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Final report – Technical study on the possible introduction of inspection of stand-alone ventilation systems in buildings

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PART 1

EXISTING REGULATIONS, STANDARDS AND GUIDELINES ON THE INSPECTION OF VENTILATION SYSTEMS, AND OTHER RELEVANT INITIATIVES AND PROJECTS

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More information on the European Union is available on http://europa.eu/

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Executive Summary

Article 19a of Directive 2018/844, includes the requirement for the Commission to perform, before 2020, a feasibility study to clarify the possibilities and timeline for introducing two aspects in order to improve buildings' energy performance:

- The inspection of stand-alone ventilation systems and
- An optional building renovation passport.

This technical study is contracted to a consortium formed by INIVE and BPIE who, together with a broad range of experts in the required fields, will provide technical support to the Directorate-General for Energy of the European Commission for investigating the different elements covered by the feasibility study. This technical study is coordinated by INIVE EEIG and runs from 18 December 2018 until 17 December 2019.

The first part of this technical study will 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:

- An analysis of the stock of ventilation systems in EU buildings, including their technical characteristics, the distribution systems and foreseen evolution of the stock;
- 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;
- 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.

This report covers the second objective. It provides a review of existing regulations, schemes, guidelines and standards on the inspection of stand-alone ventilation systems, and other relevant initiatives and projects.

A total of 81 items has been found and analysed. A detailed analysis was carried out for a selection of 34 of them, seen as the most interesting or representative ones.

Most of the identified items do not only cover inspection. They often describe installation, commissioning or maintenance guidelines or requirements, including an inspection part.

The identified items include:

- regulations in 12 EU countries, a part of them being dedicated to workplaces,
- 11 European standards and some national standards in the EU and outside the EU,
- a wide range of guidelines (47 items) 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. Standards and guidelines for the inspection of ductwork airtightness have been specifically listed and analysed.

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 and database, clear design, installation and commissioning procedures, training/qualification/certification of the competence of professionals, increase of occupants awareness and use of smart ventilation systems.

1. Introduction

1.1 Context

The publication on 19 June 2018 of the amended EPBD - Directive 2018/844 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency - represents the first major step towards the implementation of the Commission's Clean Energy for all Europeans package.

Article 19a of Directive 2018/844 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency includes the requirement for the Commission to perform, before 2020, a feasibility study to clarify the possibilities and timeline for introducing two aspects in order to improve buildings' energy performance:

- The inspection of stand-alone ventilation systems and
- An optional building renovation passport

"The Commission shall, before 2020, conclude a feasibility study, clarifying the possibilities and timeline to introduce the inspection of stand-alone ventilation systems and an optional building renovation passport that is complementary to the energy performance certificates, in order to provide a long-term, step-by-step renovation roadmap for a specific building based on quality criteria, following an energy audit, and outlining relevant measures and renovations that could improve the energy performance".

This technical study is contracted to a consortium formed by INIVE and BPIE who, together with a broad range of experts in the required fields, will provide technical support to the Directorate-General for Energy of the European Commission for investigating the different elements covered by the feasibility study mandated under Article 19a of the amended EPBD. This technical study is coordinated by INIVE EEIG and runs from 19 December 2018 until 18 December 2019.

The first part of this technical study should assess the relevance and feasibility to introduce EU provisions (legislative and non-legislative) 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.

Directive 2018/844/EU, articles 14 and 15, already extends the requirements of the EPBD on the inspection of heating and air-conditioning systems to the inspection of combined heating and ventilation systems, and combined air-conditioning and ventilation systems.

This technical study aims to investigate the relevance and feasibility of the inspection of stand-alone ventilation systems, and other related measures. In this study, stand-alone ventilation systems are defined as ventilation systems whose sole function is to ventilate a building.

The study is also providing an overview of the stock of ventilation systems installed in Europe and related technological trends, as well as a review of mandatory and voluntary inspection schemes of ventilation systems in buildings, at EU and national levels. It will further assess the relevance, feasibility and overall impacts of introducing EU measures in relation to the inspection of stand-alone ventilation systems in buildings (e.g. development or improvement of technical standards, preparation of guidelines and identification and sharing of best practices, or extension of mandatory regular inspections to stand-alone ventilation systems under the EPBD).

1.2 Overall objectives

The objectives regarding inspection of stand-alone ventilation systems are to deliver

- An analysis of the stock of ventilation systems in EU buildings, including their technical characteristics, the distribution systems and foreseen evolution of the stock;
- 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;
- 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.

This report covers the second objective, by providing a review of existing regulations, standards, guidelines and other initiatives about the inspection of stand-alone ventilation systems in buildings, at EU and non EU level.

The report has been prepared by INIVE-CETIAT with inputs from:

- INIVE-BBRI, BCCA, CEREMA, EPB Consulting Group, PLEIAQ and REHVA,

with contributions from:

- INIVE-TNO and SuLVI,

and information provided by:

- EVIA and Eurovent.

1.3 Scope

The European standard EN 12792 "Ventilation for buildings - Symbols, terminology and graphical symbols" (2003) defines ventilation as: "Designed supply and removal of air to and from a treated space".

In the AIVC Glossary (Limb, 1992), ventilation is defined as "the process of supplying or removing air, by natural or mechanical means to and from a space".

Natural ventilation is defined as "ventilation through leakage paths (infiltration) and openings (ventilation) in the building which relies on pressure differences without any fan" (EN 12792). It includes airing (ventilation by window opening), cross ventilation (resulting from wind pressures on the facades) and shaft ventilation (using a vertical or inclined duct to generate stack effect).

Mechanical ventilation is defined by AIVC (Limb, 1992) as "ventilation by means of one or more fans".

This survey covers:

- Stand-alone ventilation systems, i.e. systems whose sole function is to ventilate a building; the inspection of combined heating and ventilation systems, and of combined air-conditioning and ventilation systems is covered by articles 14 and 15 of Directive 2018/844/EU

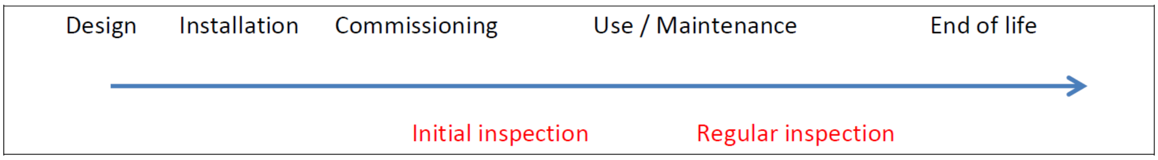
Examples:
In our scope: balanced ventilation system with heat recovery
Out of our scope: air handling unit with heating/cooling coils

- Ventilation systems in residential and non-residential buildings, except industrial buildings
- Newly-installed ventilation systems in new, renovated or existing buildings
- Ventilation systems already installed and in operation in existing buildings
- All types of stand-alone ventilation systems: mechanical, natural, hybrid together with their controls. Airing (i.e. natural ventilation by window opening) is out of our scope since it does not rely on components dedicated to ventilation (air inlets, air outlets, etc.).
- Initial or regular inspection(s)
- Various levels of inspection: from simple visual check based on a check-list to exhaustive measurements on the installed system
- Various inspection objectives: checking of good operation, ductwork airtightness, energy efficiency, air flow-rates, indoor air quality, thermal comfort, system cleanliness, noise level, etc.
- Inspections operated by installers, maintenance workers, independent inspectors or others

Inspection of a ventilation system has several possible understandings:

- looking at it carefully;
- viewing it closely in critical appraisal;
- checking or testing it against established standards;
- examining it officially;
- visiting it to check that everything is correct and legal.

The European standard EN 16798-17 defines inspection as the "examination of a technical building system including at least collection of documents, on-site visual checks, and a report with recommendations".



This work does not cover:

- Protocols that only measure indoor air quality without looking at the ventilation system
- Protocols of commissioning that do not include an inspection part
- Protocols of maintenance that do not include an inspection part: for example, a maintenance procedure that would only require to clean the fan and to replace filters is not considered
- Inspection of systems for smoke exhaust in case of a fire

2. Methodology

The work consisted of the following 9 actions:

1. Inventory of existing regulations, guidelines, standards and other related initiatives in the EU
2. Inventory of existing regulations, guidelines, standards and other related initiatives in other regions of the world
3. Analysis of legal issues and sanctions
4. Analysis and report in standard format of existing regulations, guidelines, standards and other related initiatives
5. Synthesis of information available within the EPBD CA
6. Synthesis of information from EU projects
7. Synthesis of information from international projects (e.g. IEA)
8. Synthesis of information from national projects
9. Preparation of this report

The inventory (actions 1 and 2) relies on:

- a survey (see Annex 11) among national European associations of HVAC engineers that are members of REHVA (in Belgium, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Latvia, Lithuania, Moldova, The Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom);
- internet search and collection of information via websites of the relevant organisations;
- a survey among national European associations of HVAC engineers that are members of REHVA;
- contacts with the two main European associations of ventilation system manufacturers, EVIA and Eurovent;
- information and questions to the country representatives in the AIVC (Air Infiltration and Ventilation Centre);
- mail and phone contacts with identified persons in the covered countries;
- two dedicated sessions in the 27-28 March 2019 AIVC Workshop in Dublin, allowing sharing information with invited speakers and participants (see Annex 12).

This report will present:

- the overview of existing regulations, standards, guidelines on the inspection of ventilation systems
- the overview of existing regulations, standards, guidelines on the inspection of ductwork airtightness
- other information linked to the inspection of stand-alone ventilation systems, including information from other sources than regulations, standards and guidelines and information on alternatives to the inspection
- an analysis of existing regulations, standards, guidelines and other initiatives.

Detailed results are presented in the following Annexes:

- Annex 1 shows the detailed result of the inventory.
- Existing regulations are analysed and detailed in Annexes 2 and 3
- Existing standards are analysed and detailed in Annexes 4 and 5

- Existing guidelines are analysed and detailed in Annexes 6 and 7
- Annex 8 focuses on the inspection of the ductwork airtightness.
- The detailed report on the situation in non-EU countries is in Annex 9.
- Annex 10 analyses interesting outputs from several European projects.

3. Existing regulations, standards, guidelines on the inspection of stand-alone ventilation systems

3.1 Existing regulations

Regulations implementing a mandatory inspection of ventilation systems in buildings have been identified in three countries:

- In Belgium (Region of Flanders) for ventilation systems in new or renovated residential buildings; the scheme has been implemented in 2016 through recognised inspectors; they are trained, recognised and audited for surveillance by an independent quality organisation;
- In Finland, the regulation makes mandatory that the parties involved in construction of a new building operate measurement of the ventilation system airtightness (can be replaced by a check in certain circumstances), measurement of airflow rates, determination of the specific fan power, and checks of compliance with design specifications.
- In Sweden, the OVK scheme makes mandatory the initial inspection (and for some buildings the regular inspection) of ventilation systems; the scheme has been implemented in 1991; it relies on 1,400 independent inspectors;

In Ireland, an existing regulation requires commissioning of ventilation systems. A revision of this regulation is to be published, that will require an additional mandatory inspection by an independent certified person for ventilation systems in dwellings.

Other regulations requiring checking ventilation systems are:

- A regulation in Portugal that requires the measurement of ductwork airtightness in new buildings of more than 1,000 m^2. In practice, the targeted ductworks are mainly those of air conditioning systems.
- A regulation in the United Kingdom that requires the commissioning of ventilation systems.
- In France, the regulation on the building energy performance requires either a test of the ductwork airtightness, performed by a qualified tester, or a certified quality approach, if the value of ductwork airtightness used as an input data in the energy performance calculation is better than the default value of the regulation.
- Requirements in a Polish regulation requiring that ventilation system post-inspection recommendations issued by authorized inspection and supervision bodies are implemented, and that in case of a justified need, technical condition of ventilation installations and devices is controlled.

Regulations on the inspection of ventilation systems in workplaces, motivated by the protection of health of workers, have also been identified in Austria, Hungary, and Italy. These are probably only some of the countries that have regulations related to indoor air quality in workplaces, since this topic is covered by several documents from the International Labour Organisation that are used as references for national legislations.

A summary table of these existing regulations is shown in Annex 1.

The content of these regulations is detailed in Annexes 2 and 3.

3.2 Existing standards

One European standard and an associated CEN Technical Report have been developed under a Mandate given by the European Commission to the European Committee for Standardization, in relationship with the EPBD. These are:

- EN 16798-17 - Energy performance of buildings. Ventilation for buildings. Guidelines for inspection of ventilation and air conditioning systems (2017)
- CEN/TR 16798-18 - Energy performance of buildings. Ventilation for buildings. Guidelines for inspection of ventilation and air conditioning systems - Technical report - Interpretation of the requirements in EN 16798-17 (2017)

Nine other European standards have been identified that include requirements or methods for checking ventilation systems. Six of them relate to the ductwork (airtightness, cleanliness).

National standards including checks or measurements have been found in Austria and France.

Outside Europe, standards that include checks or measurements on the ventilation system have been identified in Turkey, Australia and New Zealand, USA.

A summary table of these existing standards is shown in Annex 1.

The content of these standards is detailed in Annexes 4 and 5.

3.3 Existing guidelines

A total of 47 items has been identified.

A summary table is shown in Annex 1. Despite our best efforts, this list is probably not exhaustive.

The content of these guidelines is detailed in Annexes 6 and 7 (with additional information in Annexes 8, 9 and 11 for some of them).

The following countries are covered: Austria, Belgium, Finland, France, Germany, Ireland, Netherlands, Poland, Sweden, United Kingdom, Switzerland, Turkey, and USA.

The guidelines are mainly applicable to residential ventilation systems or to ventilation systems in all types of buildings. Only a few guidelines are dedicated to non-residential ventilation systems.

They describe commissioning, hand over or inspection operations, either for stand-alone ventilation systems or for air conditioning and ventilation systems. They mainly focus on initial inspection. They usually apply to the whole ventilation system or to the ductwork alone.

They analysis shows a wide range of guideline types and their combinations:

- general text providing explanations on how to operate inspection
- checklist without explanations
- checklist with guidance and explanations
- detailed practical procedure

The inspection can rely on visual checks, limited measurements or a complete set of measurements of several parameters.

Measurements focus on air flow rates and ductwork airtightness, and measuring other quantities is not often required. Some guidelines describe, or even focus on, the measuring instruments and the way to use them.

Checking the adequacy of ventilation operation with the current ventilation needs is generally not an objective.

The categories of persons that should use the guidelines are not always mentioned, but most are intended for installers. Reporting of the inspection is not always described.

The impacts of these guidelines are generally unknown.

Several guidelines are available for free: Annex 1 provides the adequate links for download.

4. Other information on the inspection of ventilation systems

4.1 Synthesis of information available within the CA EPBD

The CA EPBD (https://epbd-ca.eu/) has been addressing inspection issues since many years during plenary meetings and, more recently, also quality issues; however only limited links were made to inspection and quality of (stand-alone) ventilation systems. In particular, one session with a link to ventilation systems was session 18 of the CA EPBD plenary meeting held in Malta on 16 February 2017, titled 'Ensuring compliance of EPC declarations: from design to as built'. The objectives of this session were to set the scene and raise awareness regarding compliance of EPC declarations and quality of works performed (challenges, compliance rates, etc.,) for new buildings, to propose incentives for better compliance frameworks and to trigger discussion and information exchange on good practices, possible challenges and opportunities. The session engaged CA participants in a discussion on quality of works and compliance frameworks for better performing buildings as examined in the context of the QUALICHeCK project.

4.2 Synthesis of information from EU projects

The following EU projects have been checked and analysed to gather relevant information for the EPBD 19a project:

- AuditAC (Field Benchmarking and Market Development for Audit Methods in Air Conditioning www.cardiff.ac.uk/archi/research/auditac)
- HARMONAC (Harmonizing Air Conditioning Inspection and Audit Procedures in the EU Tertiary Building Sector)
- iSERVcmb (Inspection of HVAC Systems through continuous monitoring and benchmarking – www.iservcmb.info)
- SuperSmart (Expertise hub for a market uptake of energy-efficient supermarkets by awareness raising, knowledge transfer and pre-preparation of an EU Ecolabel – www.supersmart-supermarket.info)
- EnVIE (Indoor Air Quality and Health Effects - https://paginas.fe.up.pt/~envie) and IAIAQ (Promoting Actions for Healthy Indoor Air)

Details can be found in Annex 9.

The AuditAC project dealt with energy auditing and improvement of air conditioning systems generally. The project lists for the auditor the potential energy savings of an air conditioning system, including its ventilation part. It also lists the various contracts for inspection and provides a training package including the description of the various ventilation systems, and that could be partly used in the context of training ventilation system inspectors.

HARMONAC project is the follow-up of AuditAC. From the measurements of the energy use of 42 air-conditioning systems (and their components), it provides an evidence-based report on the Energy Conservation Opportunities (ECOs) that can be used in the inspection. Some of the identified ECOs are common with stand-alone ventilation systems. The project has produced tools for use in the inspection process, and a teaching package to assist in the training of inspectors. The elements of an inspection are analysed in terms of time taken, ECOs and likelihood of achieving energy savings. Conclusions allow assessing the possible impacts of the inspection of air-conditioning systems.

The iSERVcmb project is based on the inspection methodology developed in HARMONAC. It describes maintenance tasks associated with air conditioning systems including the reasons for carrying them out, the typical frequency, the contents of typical maintenance, the responsibility of the further work and cost. Part of the maintenance inspection is dedicated to the air handling unit, and the approach can be useful for the inspection of stand-alone ventilation systems.

The SuperSmart project dealt with the maintenance of super-markets. It includes only a small part on the maintenance/ inspection of ventilation system (air handling unit, air ducts and grilles).

The objective of the project ENVIE was to collect scientific knowledge to elaborate policy relevant recommendations based on a better understanding of the health impacts of indoor air quality. The report includes general requirements on ventilation in Europe and calls for the inspection of ventilation systems. The impact of the inspection of ventilation systems on the risk due to bad indoor air quality is also estimated. The Disability-Adjusted Life Years (DALY) per year (and per country and policy) avoidable by ideal IAQ in Europe is calculated for the mandatory inspection of ventilation system (among other things).

Another interesting European project is the QUALICHeCK project (2014-2016 - http://qualicheck-platform.eu/). The results are described below in the chapter about other initiatives than inspection.

4.3 Synthesis of information from international projects

Within the Energy in Buildings and Community (EBC) Programme of the International Energy Agency (IEA), the research is mainly undertaken through a series of projects called 'Annexes', to which several interested countries participate.

Three finished Annexes have been identified as providing interesting information in relationship with the inspection of ventilation systems. They are summarised below.

IEA EBC Annex 34 – Computer-Aided evaluation of HVAC system performance

This IEA EBC project was running from 1997 till 2001 with participants from Canada, Finland, France, Germany, Japan, Netherlands, Sweden, Switzerland, United Kingdom, and United States of America

Studies have indicated that 20-30% of energy savings in commercial buildings is achievable by re-commissioning of the HVAC systems to rectify faulty operation. Current strategies do not explicitly optimize performance and cannot respond to the occurrence of faults which cause performance to deteriorate. The objective of this project was to work with controls manufacturers, industrial partners and building owners and operators to demonstrate the benefit of computer aided fault detection and diagnostic systems. Methods were to be incorporated either in stand-alone "PC" based systems or incorporated within a future generation of "smart" building control systems.

Research areas included:

- Construct prototype performance validation systems: these were designed to assist with final stages of the commissioning or re-commissioning of HVAC systems. Test procedures were devised to check for correct operation and the absence of particular faults in the mechanical equipment and to assess performance.
- Construct prototype performance monitoring systems: monitoring systems were designed to detect unsatisfactory performance by comparing current performance with that predicted by a reference model. Different approaches to generate reference models were investigated.
- Interface prototype systems to building control systems: interfaces were designed to connect the prototype systems to commercial control systems.
- Test and demonstrate performance validation and monitoring systems in real buildings: field trials were carried out for both new, unoccupied buildings nearing completion and buildings which had been occupied for some time. Long- term monitoring also took place to determine their effectiveness in detecting and diagnosing faults that arise during normal operation.

IEA EBC Annex 40 'Commissioning of building HVAC systems for improving energy efficiency'

This IEA EBC project was running from 2001 till 2004 with participants from Belgium, Canada, Finland, France, Germany, Hong Kong PRC, Hungary, Japan, Korea, Netherlands, Norway, Sweden, Switzerland and USA.

The primary goal of building commissioning, from an energy perspective, was to verify and optimise the performance of energy systems within a building. The objective of this annex was to develop, validate and document tools for commissioning buildings and building services that would help facilitate the achievement of this goal. These tools include guidelines on commissioning procedures and recommendations for improving commissioning processes, as well as prototype software that can be implemented in stand-alone tools and/or embedded in building energy management systems (BEMS). The work performed in the annex focussed on HVAC systems and their associated control systems, but also took into account where appropriate, interactions with other systems and with the building shell.

IEA EBC Annex 47 'Cost effective commissioning of existing and low energy buildings'

This IEA-EBC annex was running from 2005 till 2010 with participants from Belgium, Canada, Czech Republic, Finland, France, Germany, Japan, the Netherlands, Norway, Sweden, and USA

Commissioning methods and tools are required to ensure that advanced components and systems reach their technical potential and operate energy-efficiently. Likewise, commissioning methods and tools should strive to improve the energy efficiency of conventional and advanced existing buildings beyond just the design intent. The goal of the project is to enable the effective commissioning of existing and future buildings in order to improve their operating performance. The aim is to advance the state-of-the-art of building commissioning by:

Extending previously developed methods and tools to address advanced systems and low energy buildings, utilizing design data and the buildings' own systems in commissioning; Automating the commissioning process to the extent practicable; Developing methodologies and tools to improve operation of buildings in use, including identifying the best energy saving opportunities in HVAC system renovations and open reporting methods for the energy performance of buildings in support of the "EU Energy Performance of Buildings Directive"; Quantifying and improving the costs and benefits of commissioning, including the persistence of benefits and the role of automated tools in improving persistence and reducing costs without sacrificing other important commissioning considerations.

The project has been carried out by means of the following three research areas:

- Initial Commissioning of Advanced and Low Energy Buildings
- Commissioning and Optimization of Existing Buildings
- Commissioning Cost-Benefit and Persistence

4.4 Synthesis of information from national projects

The French Promevent project

In France, the Promevent project (2014-2016) resulted in an inspection protocol in order to assess the on-site quality of residential mechanical ventilation systems. The targeted buildings are new single-family houses and multi-family dwellings. The Promevent protocol is very largely accepted and is becoming the national reference for inspection of mechanical ventilation systems in dwellings. It is presented in training sessions and has been included into a MOOC. A similar research project is undergoing regarding non-residential buildings: the PromevenTertiaire project. It should propose a similar protocol for non-residential buildings. The protocol and its accompanying documents are analysed in details in Annex 6.

The Belgian optivent project

In Belgium, the optivent project (2010-2013), financed by the Flemish agency 'Agentschap Innoveren en Ondernemen' was focusing on the development of guidelines and calculation tools for residential ventilation systems.
The objectives of the project were to:

- Deliver a handbook with guidelines for the dimensioning, the installation, the commissioning and the maintenance of such systems, with recommendations adapted for dwellings which can guarantee a good price-quality relation
- Support tools for simple calculations of ductwork, measurement of pressure losses, etc.

The major deliverables are a calculation tool and a guide of practice (NIT-258), that is analysed in details in Annex 6.

The Dutch TKI-Securevent project

In the Netherlands, the ongoing TKI-Securevent project aims at describing methods to assess the air volume flow and noise of a ventilation system. It is a TKI (Top consortia for Knowledge and Innovation) project carried out under the leadership of TNO, with Topsector Energy subsidy from the Dutch Ministry of Economic Affairs. Methods and prototypes have been developed to easily, quickly and cost-efficiently assess the performance of the ventilation in dwellings.

The current instruments for measuring airflows (supply or exhaust) are relatively expensive (2000 to 3000 €). Lower cost instruments often have an issue with the accurate measurement of supply flows. The best method for measuring air flow is with an active flow hood that compensates its own resistance through a controlled ventilator: the project concluded that achieving a 500 € cost is yet not possible. An existing measuring device was redesigned so that supply flows measurements are less dependent on the flow pattern. The measuring range is 15-100 m^3/h with a measurement uncertainty of less than 15% of the measurement value below 50 m^3/h, and less than 10% up to 100 m^3/h.
In general, noise measurements for the assessment of the noise level from the ventilation system are required in living room and bedrooms. In the Netherlands, this noise measurement is based on the standard NEN 5077, which is perceived as rather complex to apply and expensive in practice, since it concerns measurements of relatively low noise levels (< 30 dB(A)) in frequency bands and at very low accompanying background levels, requiring also an experimental assessment of the reverberation time. Therefore, an alternative, simplified measurement method has been developed in BRL 8010 (2012), which assumes a reverberation time based on the size and decoration of the room and only uses overall noise levels (no frequency bands). However, this method still requires a low background noise level and relatively expensive measurement equipment. Within the TKI-SecureVent project, noise level from the ventilation system was assessed according to the method of the BRL 8010 Guidelines (see detailed analysis in Annex 7), consisting of direct measurement of the sound level in the living room and bedrooms. This method gives pretty accurate results compared to NEN 5077, while the measurements can be performed in a time period of 30 to 60 minutes for a typical Dutch dwelling.
The measurements consist of the following steps:

- Checking that the difference between the background noise level and the noise level with the ventilation system turned on is high enough (>5 dB).
- Measuring the overall noise level with the ventilation system turned on and with all windows and doors closed at 2 to 5 positions in the room (depending on the room area).
- Calculating the overall A-weighted sound level by using a room correction factor depending on the surface area and the type of materials used in the room.

Furthermore, the project is investigating whether it is possible to assess the noise level from the ventilation system by indirect, easier to apply measurements and parameters at lower costs. These indirect measurements should give a qualitative judgement of the acoustic performance of the ventilation system and consists of a combination of visual inspection of the ventilation system, noise level close to the ventilation unit, electric power consumption and pressure drop in the ventilation ducts.

5. Other initiatives than inspection

Since mandatory inspection of stand-alone ventilation systems is present in a few countries, no initiative is explicitly presented as an alternative to the inspection.

Nevertheless, initiatives can be identified whose objective is to improve the quality of design, installation and operation of stand-alone ventilation systems and that can be seen as limiting or cancelling the needs for inspection.

The European project QUALICHeCK (http://qualicheck-platform.eu/) provided the following definition of the quality of the works:

"Quality of the works: Measure of potential gap between the building works realised and the works executed in accordance with applicable regulations and specifications. The quality of the works can be considered as "good" or "compliant" if this gap does not degrade the expected performance. Note that quality of the works has no absolute meaning: it always relates to the needs (including expected performance) stated in regulations or specifications. The specifications may be set on contractual basis or defined at the level of a specific framework."[1]

The initiatives that can improve the quality of stand-alone ventilation systems include:

- Certification of product performances, and easier access to the corresponding data,
- Training of professionals,
- Procedures on how to operate design, installation, commissioning and maintenance; quality management approaches
- Qualification and certification of the competence of professionals
- Increase of occupants awareness
- Use of smart systems.

Some of these initiatives (training, qualification, and certification) are present in a figure from QUALICHeCK project[2] (Figure 1). It shows the questions that must be addressed to decide on the development of specific schemes for training, competence checks, and proper completion checks for the works by professionals.

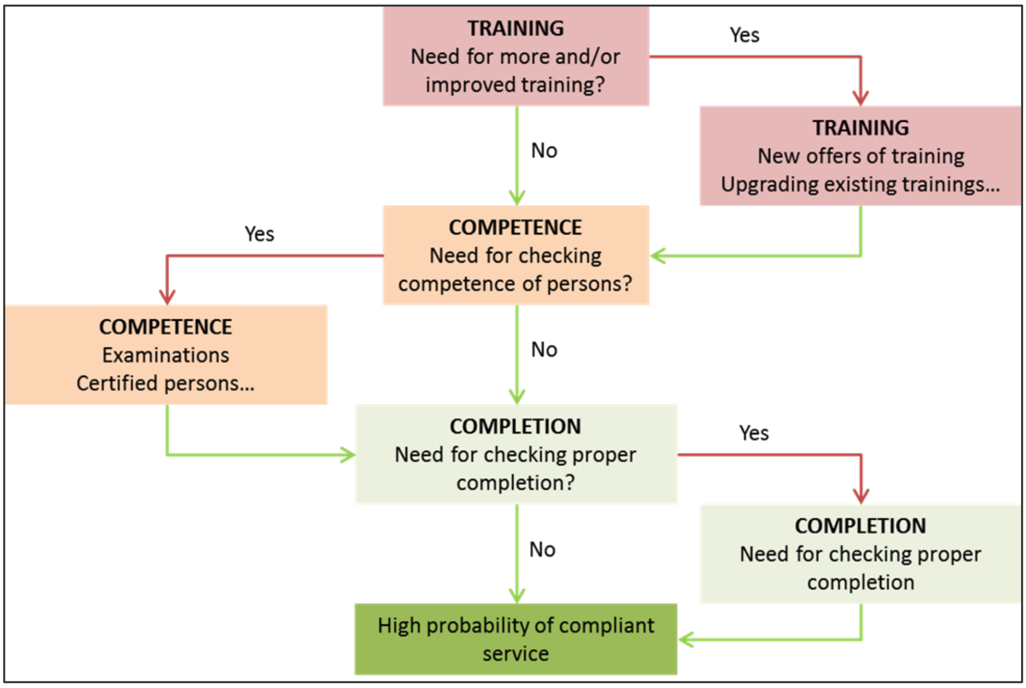


Figure 1 - Path to question relevance of developing specific schemes for training, competence checks, and proper completion checks – copied from the QUALICHeCK Booklet2[2] .

5.1 Certification of product performance and availability of data

Voluntary certifications of ventilation product performance exist at European or national levels. They allow designers to get accurate data about products.

At the European level, the Eurovent Certified Performance brand covers for example air handling units, ventilation ducts, air-to-air heat exchangers, air filters.

[1] F. R. Carrié, *Compliance and quality of works for improved energy performance of buildings - Final publishable report*, QUALICHeCK, February 2017, www.qualicheck-platform.eu

[2] F. R. Carrié, *Improving the compliance of Energy Performance Certificates and the quality of building works - Booklet*, QUALICHeCK, April 2016, www.qualicheck-platform.eu

In addition, product performance can be included into database available to the public or to professionals. Such database can be managed by product certification bodies or result from public initiatives in relationship with input data for the energy performance calculation of buildings. The QUALICHeCK project has for example documented the Belgian EPBD product database (http://www.epbd.be) that includes the characteristics of ventilation products[3] and the database implemented in the United Kingdom (http://www.ncm-pcdb.org.uk/sap/) that covers ventilation systems.

The increasing use of BIM (Building Information Modelling) is also a way to make ventilation performance data easily accessible to designers, as well as the increasing use of electronic catalogues of products.

5.2 Training of professionals

Several initiatives for the training of workers were described and implemented in the framework of the Build Up Skills European initiative (http://www.buildup.eu/en/skills .

Other initiatives exist at national level.

The survey by REHVA (Annex 12) allowed for example to identify that in Finland, the training centre of building owners association organises training for maintenance personnel (https://www.kiinko.fi/koulutus/osaamisalat-kiinkossa), covering but not focused only on ventilation

In 2016, the French ministry in charge of construction decided to invite all major actors of the ventilation field to join a working group called "Club Ventilation". The aim of this group is to identify the main pitfalls, to propose major projects and to prefigure future labels and regulations. The 45 participants include building manufacturers, building managers, craftsmen, building companies, label and certification, and ventilation manufacturer representatives but also specialists of the ventilation field including training organisations, public agencies, and engineering consultants.
In order to prevent degradation of the IAQ and the building itself, specialists agree on the need to improve the knowledge and the know-how of professionals by providing them with training resources and accompaniment tools. Two major on-going multi-partner projects aim at developing such resources for French professionals on indoor air quality and ventilation, under the initiative of the French Ministry for construction (DHUP): the development of a massive open online course (MOOC), the development of a web resource centre, including a serious game.

In Austria, ventilation systems are covered by a training programme for installers (https://www.ait.ac.at/en/research-fields/training-education-heat-pump-solarthermal-photovoltaics/weiterbildung-im-bereich-komfortlueftung/) managed by AIT (Austrian Institute of Technology.

The survey by REHVA identified training for mechanical engineers who will be involved in the production and inspection of ventilation systems in Turkey, provided by the Turkish Chamber of Mechanical Engineers (https://www.mmo.org.tr/) and a course by the University of Çukurova/Adana Meslek School titled "Ventilation systems" (see details in Annex 12).

5.3 Procedures on how to operate

Several of the identified standards and guidelines (Annex 1) do not cover inspection alone and also provide guidance for installation or maintenance. Numerous installation guidelines exist for example in Finland, France, Sweden, United Kingdom, etc.

[3] F. Durier, S. Geissler, *How to get compliant and accessible data for the energy rating calculation of a building?*, March 2016, www.qualicheck-platform.eu

The French national programme RAGE (Règles de l'Art Grenelle Environnement 2012) published several professional recommendations on ventilation systems. These are reference texts for design, dimensioning, implementation and maintenance that are recognised by insurance companies. Fulfilling their requirements helps to improve the quality of the design, installation and maintenance works. All these documents are available for free at the website of the national programme PACTE (Programme d'Action pour la qualité de la Construction et la Transition Energétique - http://www.programmepacte.fr/catalogue).

The survey by REHVA allows identifying other examples in the following countries:

- Finland, through a non-governmental organization established for qualifications and certifications of experts (FISE, http://fise.fi/en/)
- Finland: the Association for building services industry and trade (TALTEKA Association) has developed technical guidelines for installation of ventilation systems in 2017. These guidelines are also in the evaluation and revision process during 2019 (https://www.talteka.fi/).
- Finland: the Building Information Foundation RTS has also revised the guidebook for good installation practice for air conditioning and ventilation systems (Talotekniikka RYL). It is a revised version of the 2002 edition and will be published in 2019.
- Poland: a book published in 2017 concerns ventilation and air-conditioning installations in residential, public and collective buildings and describe installation works and checks at hand over: Instalacje wentylacyjne i klimatyzacyjne (https://www.ksiegarniatechniczna.com.pl/czesc-e-roboty-i-instalacje-sanitarne-zeszyt-2-instalacje-klimatyzacyjne.html).

5.4 Qualification and certification of the competence of professionals

One of the reports from the European project QUALICHeCK[1] defines qualification and certification as follows:

"*Qualification: Recognition by a third party that a person or a company has the ability, quality, or attributes to perform a particular job or task, after successful completion of a course or training or passing of an exam or audit*".

"*Certification: Procedure by which a third party gives written assurance that a product, a process, a system or a person conforms to specified requirements mentioned in the rules of the relevant certification scheme*".

Another report from QUALICHeCK allows identifying the following initiatives[4]:

- In France, several certifications of equipment installers/contractors have been implemented (QUALIBAT, QUALIFELEC, ECO Artisan, Les Pros de la Performance Energétique) under a unified label banner RGE to secure the quality of installation works of ventilation systems (among others). They generally cover quality requirements for the company and for the individual persons that operate the works. They may rely on dedicated training and requirements about the organisation and the working tools/equipment that have to be used by the company. These certifications are voluntary, but are required in order that the building owner benefits from public funding or subsidies.

[4] M. Maivel, K. Kuusk, R. Simson, J. Kurnitski, T. Kalamees, *Status on the Ground - Overview of existing surveys on energy performance related quality and compliance,* QUALICHeCK, June 2015, www.qualicheck-platform.eu

Building companies may also use a certification to improve and demonstrate the quality of their work: NF Habitat and NF Habitat-HQE for new and renovated residential buildings.

- In Sweden, in addition to the VVS AMA specifications (see Annex 7) and the OVK compulsory ventilation checks (see Annex 3), a qualification for ventilation testers is managed by KIWA for the persons that do the OVK checks on ventilation systems.

The survey by REHVA allows identifying other examples of qualification/certification of the competence of professionals in the following countries:

- Finland, through the non-governmental organization established for qualifications and certifications of experts (FISE, http://fise.fi/en/)
- Finland where Motiva (https://www.motiva.fi/motiva), a public company focusing on energy consulting and information to the public and professionals, has training and certification systems for building energy auditors, with training material and handbooks. The auditing and inspection schemes include also the inspection of ventilation systems.
- Switzerland, where a certification "Hygieneschlung" is based on the SWKI VA104-02 guidelines.
- Sweden where ventilation oriented training sessions, not only limited to inspection-related issues, are presented at: http://www.svenskventilation.se/jobb-utbildning/yrkeshogskola/
- Denmark, where the scheme "VENT-ordningen" certifies companies for the inspection of ventilation systems (https://vent.dk/in-english/)

These are only examples and providing an exhaustive review would require additional search and analysis.

5.5 Increase of occupants awareness

Occupants can play an important role in the quality of operation of stand-alone ventilation-system:

- By performing themselves some maintenance operations (for example cleaning of air exhausts terminals)
- By being able to identify operation defects, if their understanding of the role and architecture of the ventilation system is sufficient
- By avoiding inappropriate interventions on the system.

Increasing occupant awareness can rely on information from the manufacturer, the installer, the maintenance company, etc.

5.6 Use of smart systems

In 2018, the AIVC (Air Infiltration and Ventilation Centre) provided a definition of smart ventilation (https://www.aivc.org/resources/faqs/what-smart-ventilation).

This definition is reproduced below:

"*Smart ventilation is a process to continually adjust the ventilation system in time, and optionally by location, to provide the desired IAQ benefits while minimizing energy consumption, utility bills and other non-IAQ costs (such as thermal discomfort or noise).*
A smart ventilation system adjusts ventilation rates in time or by location in a building to be responsive to one or more of the following: occupancy, outdoor thermal and air

quality conditions, electricity grid needs, direct sensing of contaminants, operation of other air moving and air cleaning systems.
In addition, smart ventilation systems can provide information to building owners, occupants, and managers on operational energy consumption and indoor air quality as well as signal when systems need maintenance or repair.
Being responsive to occupancy means that a smart ventilation system can adjust ventilation depending on demand such as reducing ventilation if the building is unoccupied.
Smart ventilation can time-shift ventilation to periods when a) indoor-outdoor temperature differences are smaller (and away from peak outdoor temperatures and humidity), b) when indoor-outdoor temperatures are appropriate for ventilative cooling, or c) when outdoor air quality is acceptable.
Being responsive to electricity grid needs means providing flexibility to electricity demand (including direct signals from utilities) and integration with electric grid control strategies.
Smart ventilation systems can have sensors to detect air flow, systems pressures or fan energy use in such a way that systems failures can be detected and repaired, as well as when system components need maintenance, such as filter replacement."

The fact that a smart ventilation system can provide information to building owners, occupants, and managers, as well as a signal when the system needs maintenance or repair increases the quality of operation and can be seen as reducing to a certain extent the needs for an inspection operated by humans.

6. Conclusions

An inventory of existing regulations, standards and guidelines about the inspection of stand-alone ventilation systems has been carried out in the EU and in other regions of the world.

A total of 81 items has been found and analysed. This report provides the detailed analysis of 34 of them that have been seen as the most interesting or representative ones, according to a harmonized template.

Most of the identified items do not only cover inspection. They often provide installation, commissioning or maintenance guidelines or requirements, including an inspection part.

The identified items include:

- some national regulations, a part of them being dedicated to workplaces in the framework of the protection of workers,
- several European standards and some national standards,
- a wide range of guidelines (47 items) covering different levels of inspection, from checklists based on visual checks to measurement protocols.

Measurements, if any, are mainly focused on airflow rates, but measurements of the electrical consumption of the fans and the ductwork airtightness are also required or recommended. 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.

Standards and guidelines for the inspection of ductwork airtightness have been specifically analysed.

Finally, other initiatives than inspection, aiming at improving the quality of the installed stand-alone ventilation systems and thus reducing the needs for inspection, have been identified. They include certification of product performances and easy access to the product data, clear procedures for design, installation and commissioning of systems, training/qualification/certification of the competence of professionals, increase of occupants awareness and use of smart ventilation systems.

This inventory and analysis of existing regulations, standards and guidelines on the inspection of ventilation systems, and other relevant initiatives and projects provides useful input for the next actions of this project, i.e. the analysis of the relevance, feasibility and possible scope of measures at EU-level for the inspection of stand-alone ventilation systems, and their related impacts.

Annex 1 – Inventory of existing regulations, guidelines, standards and other related initiatives

Regulations

Regulations motivated by the performance of buildings

Country	Title	Year	Published by	Contents in relation with this study (see also Annex 2)	Detailed analysis
Belgium (Region of Flanders)	Ministerieel besluit houdende wijziging van het ministerieel besluit van 13 januari 2006 betreffende de vorm en inhoud van de startverklaring en het ministerieel besluit van 2 april 2007 betreffende de vastlegging van de vorm en de inhoud van de EPB-aangifte en het model van het energieprestatiecertificaat bij de bouw	2015	Vlaamse Overheid	Mandatory inspection of ventilation systems in new residential buildings in the Belgian Region of Flanders and recognition/control of the independent inspectors.	This regulation relies on two documents (STS-P 73-1 and NIT 258) that are analysed in Annexes 6 and 7.
Belgium (Region of Flanders)	Besluit van de Vlaamse Regering houdende wijziging van het Energiebesluit van 19 november 2010, wat betreft aanpassingen aan diverse bepalingen over de energieprestatieregelgeving	2017	Vlaamse Overheid		
Finland	Ympäristöministeriön asetus uuden rakennuksen sisäilmastosta ja ilmanvaihdosta 1009/2017 Decree of the Ministry of the Environment on the indoor climate and ventilation of new buildings	2017	Finnish Government	Applies to new buildings. Requires measurement of the ventilation system airtightness. Requires check of the completeness and cleanliness of the ventilation system, measurement of air flows at ventilation unit and at room level, and measurement of specific fan power.	Annex 3
France	Articles L111-9 and L111-9-2 of the "Code de la Construction"	2018	French Government	These articles of the Construction Code state that decrees (not yet published) must define indoor air quality requirements (IAQ) and the way for calculating and formalizing the information to comply with the requirements, especially for certain categories of products and equipment that impact IAQ. Decrees must also define how this information is made available to the public and rules on competence, independence and impartiality of the persons verifying this information.	
France	Arrêté du 26 octobre 2010 relatif aux caractéristiques thermiques et aux exigences de performance énergétique des bâtiments nouveaux et des parties nouvelles de bâtiments	2010	French Government	The value of ductwork airtightness used as an input data in the building energy performance calculation can be better than the default value of the regulation, provided that it is justified, either by a test performed by a qualified tester or by certified quality approach.	Annex 8

Ireland	Building Regulations – Technical Guidance Document F - Ventilation	2009	Environment, Heritage and Local Government	The commissioning of ventilation systems in dwellings and in other buildings than dwellings is required, with measurements of airflows for mechanical systems. A revision of this document should be published in 2019, requiring the initial inspection of ventilation systems in new and renovated buildings by an independent certified person (see Annex 12).	
Poland	Dz.U. 1994 Nr 89 poz. 414 - Ustawa z dnia 7 lipca 1994 r. Prawo budowlane - 1) Rozdział	1994, revised 2019	Polish Government	Requires that installations and devices for environmental protection (among others) are subject of a regular control.	Annex 3
Poland	Regulation of the Ministry of Interior and Administration of August 16, 1999 "on technical conditions for the use of residential buildings" (Journal of Laws No. 74 item 836) - §13.1, §22.1, §22.2, §23,	1999		This regulation requires that ventilation systems post-inspection recommendations issued by authorized inspection and supervision bodies are implemented, and that in case of a justified need, technical condition of ventilation installations and devices is controlled.	
Portugal	Despacho (extrato) n.º 15793-G/2013	2013	Diário da República	Mandatory requirements and testing for ductwork airtightness have been included in the regulation since 2006 for new buildings of more than 1,000 m^2. The testing procedure was inspired by the AMA requirements in Sweden.	Annex 8
Sweden	Regelsamling för funktionskontroll av ventilationssystem, OVK	2012	Boverket	Mandatory inspection of new ventilation systems before they are put into operation, to check compliance with the current regulation, that the ventilation system does not contain pollutants that might be spread to the building, that instructions and maintenance directions are easily available, that the ventilation system is operating as intended	Annex 3
United Kingdom	Building Regulations 2010 – Approved Document F - Ventilation	2010 + amend-ments 2013	Ministry of Housing, Communities & Local Government	The commissioning of ventilation systems in dwellings and in other buildings than dwellings is required, with measurements of airflows for mechanical systems.	

Regulations motivated by the protection of workers

The following list is probably not exhaustive: several countries follow recommendations of the International Labour Organisation, like for example the "Recommendation concerning the Protection of Workers against Occupational Hazards in the Working Environment due to Air Pollution, Noise and Vibration" (1977). Article 11 of this ILO Recommendation states that: "The employer should ensure the regular inspection and maintenance of machines and installations, with respect to the emission of harmful substances, dust, noise and vibration".
This probably results in national regulations more numerous than the ones mentioned below, that should be seen as examples.

Country	Title	Year	Published by	Contents in relation with this study (see also Annex 2)	Detailed analysis
Austria	Verordnung der Bundesministerin für Arbeit, Gesundheit und Soziales, mit der Anforderungen an Arbeitsstätten und an Gebäuden auf Baustellen festgelegt und die Bauarbeiterschutzverordnung geändert wird (Arbeitsstättenverordnung – AStV) § 13	1998	Austrian Ministry of Work, Health and Social Issues	Requirements about the inspection of ventilation systems at workplaces	
Hungary	3/2002. (II. 8.) SzCsM-EüM Joint Decree on Minimum Levels of Workplace Safety Requirements	2002	Hungarian Government	Requirements about the inspection of ventilation systems at workplaces	
Italy	DL n. 81/2008 Art.64	2008	Italian Government	Requirements about the inspection of ventilation systems at workplaces	
Canada	Occupational Health and Safety Act, Ontario Regulation 67/93, Health care and residential facilities	1993	Ministry of Labour of the Government of Ontario (Canada	Requires that mechanical ventilation systems in workplaces to which the regulation applies (hospitals, laboratories, psychiatric and mental health service facilities, long-term care homes, residences for persons with developmental or physical disabilities) be inspected by a qualified person at least every six months.	Annex 3

Standards

Country	Title	Year	Published by	Contents in relation with this study (see also Annex 4)	Detailed analysis
EU	EN 16798-17 - Energy performance of buildings. Ventilation for buildings. Guidelines for inspection of ventilation and air conditioning systems	2017	CEN	Inspection of ventilation systems.	Annex 5
EU	CEN/TR 16798-18 - Energy performance of buildings. Ventilation for buildings. Guidelines for inspection of ventilation and air conditioning systems - Technical report - Interpretation of the requirements in EN 16798-17,	2017	CEN		
EU	EN 12599 - Ventilation for buildings. Test procedures and measurement methods to hand over air conditioning and ventilation systems	2012	CEN	Handing over of ventilation systems.	Annex 5
EU	EN 14134 - Ventilation for buildings. Performance testing and installation checks of residential ventilation systems	2004	CEN	Check of residential ventilation systems.	Annex 5
EU	EN 16211 - Ventilation for buildings. Measurement of air flows on site. Methods	2015	CEN	On site air flow measurements.	Annex 5
EU	EN 15780 - Ventilation for buildings - Ductwork - Cleanliness of ventilation systems	2011	CEN	Cleanliness of ductwork	
EU	EN 12237 - Ventilation for buildings - Ductwork. Strength and leakage of circular sheet metal ducts	2003	CEN	Strength and airtightness of ductwork with circular section	Annex 8
EU	EN 1507 - Ventilation for buildings - Sheet metal air ducts with rectangular section - Requirements for strength and leakage	2006	CEN	Strength and airtightness of ductwork with rectangular section	Annex 8
EU	EN 13403 - Ventilation for buildings - Not metallic ducts - Ductwork made from insulation ductboards	2003	CEN	Strength and airtightness of ductwork made from insulation ductboards	Annex 8
EU	EN 15727 - Ventilation for buildings - Ducts and ductwork components, leakage classification and testing	2010	CEN	Airtightness of ductwork components	Annex 8
EU	EN 14239: Ductwork -Measurement of ductwork surface area	2004	CEN	Determination of ductwork surface area, needed to assess airtightness (expressed in litre per second and per square meter of ductwork surface)	Annex 8

Austria	ÖNORM H 6038 - Lüftungstechnische Anlagen - Kontrollierte mechanische Be- und Entlüftung von Wohnungen mit Wärmerückgewinnung - Planung, Ausführung, Inbetriebnahme, Betrieb und Wartung (Controlled residential ventilation including heat recovery — Planning, installation, operation and maintenance)	2014		This Standard for residential ventilation focuses mostly on planning but includes some guidelines/notes/requirements on commissioning and maintenance. It requires check for completeness according to EN 14134. It also requires that the following measurements/checks/work are documented: air flows at all terminals (possibly with pressure compensated device), power of ventilation unit, and adjustment of control parameters.	
France	NF DTU 68-3 - Installations de ventilation mécanique	2017	AFNOR/CSTB	Check of newly installed residential ventilation systems.	Annex 5
France	FD E 51-767 - Ventilation des bâtiments - Mesures d'étanchéité à l'air des réseaux	2017	AFNOR	Measurement of ductwork airtightness	Annex 8
Turkey	TS 3419 - Ventilation and Air Conditioning Installation - Requirements of projecting	2002	TSE	Measurement of air flow rates	
Australia + New Zealand	AS/NZS 3666.2:2002 - Air-handling and water systems of buildings—Microbial control - Part 2: Operation and maintenance	2002	Standards Australia/Standards New Zealand	Maintenance/checking rules for air handling systems for microbial control	Annex 9
USA	ANSI/ASHRAE Standard 62.1-2016 - Ventilation for acceptable indoor air quality	2016	ASHRAE	Check of newly-installed non-residential ventilation systems	Annex 9
USA	ANSI/ASHRAE Standard 62.2-2016 - Ventilation and acceptable indoor air quality in low-rise residential buildings	2016	ASHRAE	Measurement of air flow rates of residential ventilation systems to demonstrate compliance with specified flow rates	Annex 9
USA	ANSI RESNET/ICC 380-2016 - Standard for testing airtightness of building enclosures, airtightness of heating and cooling air distribution systems, and airflow of mechanical ventilation systems	2016	ICC	Measurement of air flow rate	Annex 5

Guidelines

Country	Title	Year	Published by	Link	Contents in relation with this study (see also Annex 6)	Detailed analysis
Austria	Checkliste – Lüftungsgerät & Abnahmeprotokoll Komfortlüftung EFH & Konformitätserklärung für Lüftungsgeräte	2016	Komfort-lüftung Information Platform	http://www.komfortlüftung.at/proficenter/einfamilienhaus/checklisten-protokolle/	Check-list, declaration of conformity for ventilation units and protocol for visual ventilation check in single-family homes.	
Belgium	STS-P 73-1 - Systemen voor basisventilatie in residentiële toepassingen / STS-P 73-1 - Systèmes pour la ventilation de base dans les applications résidentielles	2015	SPF Economie, P.M.E., Classes moyennes et Energie	https://economie.fgov.be/sites/default/files/Files/Publications/files/STS/STS-P-73-1-Systemes-pour-ventilation-de-base-applications-residentielles.pdf		Annex 7
Belgium	TV 258 - Praktische gids voor de basis ventilatiesystemen voor woon gebouwen / NIT 258 - Guide pratique des systèmes de ventilation de base des logements	2007	BBRI + IWT	https://www.wtcb.be/homepage/index.cfm?cat=publications&sub=search&id=REF00008622 https://www.cstc.be/homepage/index.cfm?cat=publications&sub=search&serie=1&ID=REF00008621		Annex 7
Belgium	Cahier des charges type 105 - Chauffage central, ventilation et conditionnement d'air	2017	Régie des Bâtiments	http://www.regiedesbatiments.be/sites/default/files/content/download/files/cct105tb_2017_fr.pdf	Describes commissioning of ventilation systems and gives some indications on the ductwork airtightness test at hand over.	
Finland	IV-kuntotutkimusohjeet	2016	SuLVI	https://sulvi.fi/materiaalipankki/iv-kuntotutkimushanke/	The HVAC Association of Finland, SuLVI, has developed and published widely used guidelines on the inspection of ventilation systems, including 17 documents for the inspection of different parts of the system or dedicated information.	Annex 7

Finland	Classification of Indoor Air Quality and Climate	2018	Finnish Association of Indoor Air Quality and Climate (http://www.sisailmayhdistys.fi/)	http://www.sisailmayhdistys.fi/Julkaisut/Sisailmastoluokitus	Guidelines for IAQ inspections and control. It includes instructions in all areas of indoor air quality and climate including air flows, cleanliness of ventilation systems, cleanliness of constructions site, and labelling of building materials regarding the pollutant emissions (including components for ventilation system, etc.).	
Finland	LVI 03-10631 Talotekniikan laadunvarmistus- ja vastaanottomenettely. Tehtävät ja dokumentointi Quality control in the handing over process	2018	The Building Information Foundation RTS sr (Rakennustieto)	https://kortistot.rakennustieto.fi/kortit/RT%2010-11301	Building Information Group is the leading provider of construction information in Finland (https://www.rakennustieto.fi/index/english.html). The Group consists of the Building Information Foundation RTS sr, which is the parent company and acts as the R&D unit for the whole group, and Building Information Ltd, which is the publishing house owned by the Foundation. This organisation has published several guidelines related to vent inspections. These guidelines are used in the inspections that the regulation makes mandatory. These guidelines include ventilation measurements, air tightness, SFP, noise, etc.	
Finland	LVI 30-10529 Ilmanvaihtojärjestelmän ominaissähköteho SFP How to measure and calculate the SFP	2013		https://kortistot.rakennustieto.fi/kortit/LVI%2030-10529		
Finland	LVI 39-10409 Ilmanvaihtojärjestelmän puhtauden tarkastus. Ilmanvaihdon parannus- ja korjausratkaisut Inspection of the cleanliness of ventilations systems	2007				Annex 7
Finland	LVI 014-10290 LVI-laitosten mittaukset How to perform measurements in ventilation systems			https://kortistot.rakennustieto.fi/kortit/LVI%20014-10290		
France	VIA-Qualité - Guide pratique à destination des constructeurs de maisons individuelles	2016	VIA-Qualité	https://www.cerema.fr/fr/actualites/qualite-ameliorer-qualite-installations-ventilation-air-0	Guidelines for house builders on a quality approach to improve indoor air quality. The quality approach includes checks and measurements.	Annex 7
France	Protocole de Diagnostic des installations de ventilation mécanique résidentielles - Promevent	2016	PROMEVENT	http://www.promevent.fr/	Guidelines for inspection of residential mechanical ventilation systems	Annex 7
France	Guide d'accompagnement du Protocole Promevent	2016	PROMEVENT		Additional explanations to the guidelines	Annex 7
France	Promevent : liste des points de vérification	2016	PROMEVENT		Checklist	Annex 7
France	État des lieux des protocoles et du matériel utilisés pour caractériser les débits de ventilation	2017	PROMEVENT		Information about measuring instruments for inspection	Annex 7

France	Fiche autocontrôle Ventilation mécanique contrôlée simple flux hygroréglable type A ou B en maison individuelle	2014	PROMOTELEC SERVICES	http://www.promotelec-services.com/les-fiches-autocontrole-ventilation.html	Checklist for mechanical demand-controlled ventilation systems in single-family houses	Annex 7
France	Fiche autocontrôle Ventilation mécanique contrôlée simple flux hygroréglable type A ou B en bâtiment collectif d'habitation	2014	PROMOTELEC SERVICES		Checklist for mechanical demand-controlled ventilation systems in multi-family buildings	Annex 7
France	Fiche autocontrôle Ventilation mécanique contrôlée double flux autoréglable en maison individuelle	2014	PROMOTELEC SERVICES		Checklist for mechanical ventilation systems in single-family houses	Annex 7
France	Diagnostic des installations de ventilation dans les bâtiments résidentiels et tertiaires - Guide pratique DIAGVENT	2005	CETIAT + PBC	http://www.cetiat.fr/fr/downloadpublic/index.cfm?docname=guide_diagvent.pdf	Guidelines for inspection of mechanical ventilation systems	Annex 7
France	DIAGVENT - Fiche de Diagnostic « Niveau 1 » du Système de Ventilation (Vérification de la complétude et mise en route)	2005	CETIAT + PBC	http://www.cetiat.fr/fr/downloadpublic/index.cfm?docname=diagvent_fiche_niv1.doc	Checklist for inspection of mechanical ventilation systems	Annex 7
France	DIAGVENT - Fiche de Diagnostic « Niveau 2 » du Système de Ventilation (Performances de l'installation)	2005	CETIAT + PBC	http://www.cetiat.fr/fr/downloadpublic/index.cfm?docname=diagvent_fiche_niv2.doc	Checklist for inspection of mechanical ventilation systems	Annex 7
France	Guide de la ventilation naturelle et hybride VNHY	2010	AVEMS	https://www.ademe.fr/guide-ventilation-naturelle-hybride-vnhyr-conception-dimensionnement-mise-oeuvre-maintenance	Guide on natural and hybrid ventilation systems, with one chapter about commissioning, maintenance and inspection	Annex 7
France	Ventilation double flux dans le résidentiel	2018	CSTB	https://boutique.cstb.fr/chauffage-ventilation-climatisation/232-ventilation-double-flux-dans-le-residentiel-9782868916877.html	Book about balanced ventilation systems in residential buildings, with one chapter about checks at handing over of the system	Annex 7
France	Ventilation Habitat collectif - Guide d'accompagnement et fiches d'autocontrôle	2013	COSTIC	https://www.costic.com/ressources-techniques-et-reglementaires/publications/ventilation-habitat-collectif-guide	Checklist with guidance for commissioning of mechanical ventilation systems in multi-family buildings	Annex 7
France	Ventilation Habitat individuel - Guide d'accompagnement et fiches d'autocontrôle	2013	COSTIC	https://www.costic.com/ressources-techniques-et-reglementaires/publications/ventilation-habitat-individuel-guide	Checklist with guidance for commissioning of mechanical ventilation systems in single-family houses	Annex 7
France	Ventilation Locaux Tertiaires - Guide d'accompagnement et fiches d'autocontrôle	2013	COSTIC	https://www.costic.com/ressources-techniques-et-reglementaires/publications/	Checklist with guidance for commissioning of mechanical ventilation systems in buildings of	Annex 7

				ventilation-locaux-tertiaires-guide	the tertiary sector	
France	Protocole de contrôle des systèmes de ventilation des bâtiments non résidentiels demandant le label : Effinergie +, Bepos-effinergie 2013, Ou un des labels BBC / BEPOS / BEPOS+ effinergie 2017	2017	Effinergie	https://www.effinergie.org/web/index.php/permeabilite-a-l-air/les-reseaux-de-ventilation	Protocol to measure ductwork airtightness and air flow rates for ventilation systems in non-residential buildings, in case one of the labels managed by Effinergie is requested	Annex 8
France	Guide des bonnes pratiques de la mesure des débits d'air sur site pour les installations de ventilation	2013	CETIAT	http://www.cetiat.fr/fr/downloadpublic/index.cfm?docname=guide_mesure_debits_air.pdf	Guidelines for the measurement of air flow rates on installed ventilation systems. Referred to by the Effinergie protocol (see ahead) for tertiary buildings.	
France	Etanchéité à l'air des réseaux de ventilation	2017	CSTB	https://boutique.cstb.fr/chauffage-ventilation-climatisation/541-etancheite-a-l-air-des-reseaux-de-ventilation-9782868916532.html	Includes a check-list for inspection of ductwork before, during and after installation works	
Germany	VDI 6022 -1: Ventilation and indoor-air quality - Hygiene requirements for ventilation and air-conditioning systems and units	2018	VDI	https://www.beuth.de/en/technical-rule/vdi-6022-blatt-1/279023701	Focuses on the hygiene of air conditioning and ventilation installations. Some parts can be used for the commissioning and inspection of systems from the point of view of hygienic aspects.	Annex 7
Germany	DIN SPEC 15240 (Entwurf) - Energetische Bewertung von Gebäuden – Lüftung von Gebäuden – Energetische Inspektion von Klimaanlagen	2018	DIN		Is referred to by the national annex of EN 16798-17. Provides additional recommendations for the inspection of air conditioning and ventilation systems.	
Ireland	Checklist and Commissioning Sheet for Domestic Ventilation Systems	2012	IVIA	http://www.atc.ie/wp-content/uploads/IVIA-Domestic-Commissioning-Certificate.pdf	Procedure for commissioning published by IVIA, the Irish Ventilation Industry Association.	
Nether-lands	BRL 8010 - Beoordelen van ventilatievoorzieningen van woningen scholen en kinderdagverblijven’	2012	KBI (Dutch Installation Sector Quality Assurance Foundation)	https://kennisbank.isso.nl/docs/brl/8010/2012	Voluntary inspection scheme for residential buildings, schools and kindergartens	Annex 7
Poland	Warunki Techniczne Wykonania i Odbioru Robót Budowlanych E2/2017 - Część E: Roboty instalacyjne sanitarne. Zeszyt 2: Instalacje	2017	Instytut Techniki Budowlanej	https://www.ksiegarniatechniczna.com.pl/czesc-e-roboty-i-instalacje-	This book concerns ventilation and air-conditioning installations in residential, public and collective	Annex 11

	wentylacyjne i klimatyzacyjne			sanitarne-zeszyt-2-instalacje-klimatyzacyjne.html	buildings. Describe installation works and checks at hand over. Includes a chapter on hand over checks.	
Sweden	AMA VVS & Kyl 09 - Allmän material- och arbetsbeskrivning för vvs- och kyltekniska arbeten	2010	Svensk Byggtjänst	https://byggtjanst.se/bokhandel/kategorier/projektering-upphandling/program-projektering-beskrivning/ama-vvs--kyl-09/	Rules for inspection of ventilation systems.	Annex 7
Sweden	AMA VVS & Kyl 16 - Allmän material- och arbetsbeskrivning för vvs- och kyltekniska arbeten	2015	Svensk Byggtjänst	https://byggtjanst.se/bokhandel/kategorier/projektering-upphandling/program-projektering-beskrivning/ama-vvs--kyl-16/	Rules for ductwork airtightness test	Annex 8
United Kingdom	BESA DW/143 - Guide to good practice ductwork air leakage testing	2013	BESA	https://www.thebesa.com/knowledge/shop/products/dw-143-guide-to-good-practice-ductwork-air-leakage-testing/		Annex 8
United Kingdom	Building standards supporting guidance domestic ventilation	2015	Scottish government	https://www.labss.org/sites/default/files/bsd_revised_guidance_02_12_2015_00490250.pdf	Commissioning procedure (visual check +- measurements) described per ventilation system type	
United Kingdom	Domestic Ventilation Compliance Guide	2011	HM Government Communities and Local Government (England and Wales)	https://www.gov.uk/government/publications/ventilation-approved-document-f	"Section 2 and 3 : provide guidance on inspection, testing and commissioning	
United Kingdom	Heating and ventilation systems - Health Technical Memorandum 03-01: Specialised ventilation for healthcare premises - Part B: Operational management and performance verification	2007	UK Dpt of Health	https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/144030/HTM_03-01_Part_B.pdf		
United Kingdom	BSRIA Guide : Domestic Ventilation Systems	2013	BSRIA	www.bsria.co.uk	Sections 5/ Measurement of airflow and 6/Testing and commissioning	
United Kingdom	GVM/14 CIBSE Guide M: Maintenance Engineering & Management	2014	CIBSE	https://www.youtube.com/watch?v=PpaGRSlWvHo	A revised version could be published in 2019	

Switzer-land	SWKI VA104-01:2019, Hygieneanforderungen an raumlufttechnische Anlagen und Geräte				Same content as VDI 6022-1 (Germany) – See ahead	
Turkey	Havalandırma Sistemleri	2005	University of Çukurova/ Adana Meslek School	http://hvacportal.org/indir/havalandirma-sistemleri_1.pdf	This course titled "Ventilation systems" includes a chapter on commissioning.	Annex 9
USA	Guideline 24-2015 - Ventilation and Indoor Air Quality in Low-Rise Residential Buildings	2015	ASHRAE	https://www.techstreet.com/standards/guideline-24-2015-ventilation-and-indoor-air-quality-in-low-rise-residential-buildings?product_id=1898710		Annex 9
USA	Proposed Guideline 42P: Enhanced indoor air quality in commercial and institutional buildings	To be published	ASHRAE			Annex 9
USA	Indoor air quality guide: Best practices for design, construction and commissioning	2010	ASHRAE			Annex 7

Annex 2 – Analysis of existing regulations

Regulations motivated by the performance of buildings

Three countries have implemented a mandatory inspection of ventilation systems: Sweden, Finland, Belgium (Region of Flanders).

In Sweden, a law makes mandatory for 1991 the initial inspection (and for some buildings the regular inspection) of ventilation systems by one of the 1,400 independent inspectors. The scheme called OVK is described in details in Annex 3.

In Finland, the Indoor Climate and Ventilation of Buildings Regulations 2017 (Ministry of the Environment, Housing and Building Department, Finland) requires mandatory testing of air tightness of ductwork, and measurement of air flow rates and specific fan power. A detailed analysis is in Annex 3.

In the Belgian Region of Flanders, a ministerial decree of 28 October 2015 and a governmental decision of 15 December 2017 have implemented a mandatory inspection of ventilation systems in new and renovated residential buildings. They refer to the document STS-P73-1 and a practical guide by BBRI, that are both analysed in details in Annex 7. They require that two distinct reports are established: a ventilation predesign report with the EPB start declaration, and a ventilation performance report for the as-built building. The quality framework relies on trained and recognized ventilation inspectors, who establish the two reports mentioned above. A surveillance of the quality framework is operated by a dedicated organization, through desktop controls and on-site audits.

In Ireland, the Building Regulations (Technical Guidance Document F – Ventilation, 2009) requires that ventilation systems are commissioned. For residential mechanical ventilation systems, visual check must be completed by airflow measurements performed with a calibrated airflow device. Actual flowrates must meet design values.
A revision of this regulation is to be published in 2019. It should be applicable on 1st November 2019 for new dwellings, with a 12 months conditional period. The revised Building Regulations – Technical Guidance Document F should include among others the following new requirements for new dwellings:

- Ventilation systems should be installed, balanced and commissioned by competent installers e.g. Quality and Qualifications Ireland accredited or Education Training Board or equivalent.
- Systems should then be validated - to ensure that they achieve the design flow rates - by an independent competent person certified by an independent third party e.g. NSAI or equivalent.

A procedure for inspection is being prepared by NSAI, based on EN 14134. The certification will be inspired from the Certified Air Tightness Certification scheme (that includes nowadays 62 certified companies).
New mechanical extract ventilation systems installed as part of a major renovation should also be designed, installed, commissioned by competent installers and validated by an independent certified person.

In the United Kingdom, the Buildings Regulations Part F requires that all mechanical ventilation systems be commissioned and that air flows are measured. High-pressure ductwork of non-domestic ventilation systems must also be tested in accordance with the guide BESA DW/143 - *Guide to good practice ductwork air leakage testing* (2013).

In France, a recent amendment (2018) to the Construction Code states that decrees (still to be published) must define indoor air quality (IAQ) requirements and the way for calculating and formalizing the information to comply with these requirements, especially for certain categories of products and equipment that impact IAQ. Decrees must also define how this information is made available to the public and rules on competence, independence and impartiality of the persons verifying this information.

In Poland, the construction law (1994, last revision April 2019) *Dz.U. 1994 Nr 89 poz. 414 - Ustawa z dnia 7 lipca 1994 r. Prawo budowlane - 1) Rozdział* requires that installations and devices for environmental protection (among others) are subject of a regular control. This regulation is analysed in Annex 3.

The Polish regulation *Rozporządzenie Ministra Spraw Wewnętrznych i Administracji z dnia 16 sierpnia 1999 r. „w sprawie warunków technicznych użytkowania budynków mieszkalnych"* on the technical conditions for the use of residential buildings requires (art.23) that ventilation systems post-inspection recommendations issued by authorized inspection and supervision bodies are implemented, and that in case of a justified need, technical condition of ventilation installations and devices is controlled.

The Polish regulation *Rozporządzenie Ministra Spraw Wewnętrznych i Administracji z dnia 7 czerwca 2010 r. „w sprawie ochrony przeciwpożarowej budynków, innych obiektów budowlanych i terenów"* requires (art. 34.2) that in facilities or their parts in which the combustion of solid, liquid or gas fuels takes place, the impurities shall be removed at least once a year from the ventilation ducts by persons with chimney qualifications, and with a higher frequency if the operational conditions require it.

In Romania, an order of the Deputy Prime Minister, Minister of Regional Development and Public Administration has approved as a Technical Regulation the "Guide on the Inspection of Climate Systems in Buildings" (GEx 009-2013: Ghid privind inspectia sistemelor de climatizare din cladiri). It relates to the inspection of air conditioning systems but it includes a paragraph 3.6. titled "Inspection of the air distribution system (air inlets, air exhausts, air ducts) in ventilation systems and air-only air conditioning systems".

Examples of regulations motivated by the protection of workers

In Austria, a regulation about workplaces (Arbeitsstättenverordnung – AStV - § 13) requires that ventilation systems in buildings with workers are checked for their correct condition at least once a year, but no later than every 15 months. After major repairs, changes or justified doubts as to the proper condition, the installations and equipment must be checked for their proper condition. Inspection shall be carried out by suitable, competent and authorized persons (e.g. authorized traders, accredited inspection bodies, civil engineers, technical offices, qualified employees) in accordance with the rules of technology. Records shall be kept of the inspections and kept in the workplace for at least three years. The regulation does not explicitly say what are the rules of technology for inspection, but the practice seems to use texts such as VDI 6220.

The Hungarian regulation *3/2002. (II. 8.) SzCsM-EüM együttes rendelet a munkahelyek munkavédelmi követelményeinek minimális szintjéről* (Joint Decree on the minimum level of workplace safety requirements) requires that employers must operate a regular maintenance and monitoring of the operation of safety devices and devices for the prevention and detection of hazards. Ventilation systems are considered as safety equipment. Their proper functioning must be checked by means of measurements in the framework of the periodic safety review specified in the relevant legislation. Ventilation systems must be kept clean on a regular basis, and any contaminated impurities must be removed without delay. After the installation of a ventilation system, it must be checked that there is sufficient quantity and quality of air. The employer is responsible for the preservation of the measuring documents certifying this.

The Italian Legislative Decree n. 81/2008 (Safety Consolidation Act) about health and safety at work requires (art. 63) that employers provide in working places a regular maintenance of the systems and devices, and that any detected defects that could jeopardize the safety and health of workers are eliminated as quickly as possible. Another requirement is that workplaces, installations and devices are subjected to regular cleaning, to ensure adequate hygienic conditions. In Annex IV (1.9.1.4), the decree states (1.9.1.4) that the systems must be periodically subjected to checks, maintenance and cleaning and sanitation for the protection of workers' health and that (1.9.1.5) any sediment or dirt that could pose an immediate danger for the health of workers due to the pollution of the breathed air must be quickly eliminated.

Outside Europe, the Government of Ontario (Canada) has implemented a regulation that requires a regular inspection by a qualified person of mechanical ventilation systems in hospitals, laboratories, psychiatric and mental health service facilities, long-term care homes, residences for persons with developmental or physical disabilities, in the framework of the protection of workers.

Annex 3 – Detailed analysis of a selection of existing regulations

- Regelsamling för funktionskontroll av ventilationssystem, OVK - Compulsory inspection of ventilation systems (Sweden)
- Finnish Decree 1009/2017 on the indoor climate and ventilation of new buildings (Finland)
- Polish requirements for the inspection of ventilation systems in residential buildings (Poland)
- Ontario Regulation 67/93 - Health care and residential facilities - Inspection of mechanical ventilation systems (Canada)

Regelsamling för funktionskontroll av ventilationssystem, OVK

Compulsory inspection of ventilation systems

<table>
<tr><td rowspan="2">Sweden</td><td rowspan="2">Legislation or Regulation ☒
Standard ☐
Guidelines ☐</td><td>Energy performance</td><td>Indoor air quality</td><td rowspan="2">Mandatory ☒
Voluntary ☐</td><td rowspan="2">Boverket</td></tr>
<tr><td>Noise level</td><td>Thermal comfort</td></tr>
</table>

Description

A Swedish law from 1991 requires compulsory inspection of ventilation systems – the OVK commissioning system – in order to control and improve the quality of ventilation installations. It applies to most types of buildings before the installations are taken into operation and then regularly depending the type of system and the type of buildings.

In the regulation for new buildings, they are few prescriptive rules, excepted for minimum outdoor air supply (0.35 l/s.m²), draught levels (max 0.15 m/s in winter), temperatures and noise levels. Instead, performance requirements are expressed: "*Good air quality shall be obtained in rooms where people stay more than temporarily, the air quality requirements shall be based on the use of the building, the air shall not include any substances that are harmful or result in bad smell. In dwelling-houses, where the ventilation airflow can be controlled locally it can be lowered (fro 0.35) to 0.10 l/s.m² when no one is present*".

Before a new installation is taken into operation, it is controlled twice:

1 – the OVK inspection controls that the installation comply with the current regulation, that the ventilation system does not contain pollutants that might be spread to the building, that instructions and maintenance directions are easily available, that the ventilation is functioning in the intended manner

2- the AMA commissioning controls that the installation comply with the contract conditions (specifications and drawings).

OVK periodic inspections must also be performed in order to control that the ventilation system is still complying with the regulation in force when it was put into use, and to give recommendations to the building's owner with measures on the ventilation system which could increase the energy savings without degrading IAQ.

Several studies have been performed since in order to evaluate how this OVK is accepted and is effective.

The AMA controls are described in another analysis sheet (see Annex 7).

Reference:
Boverket. Regelsamling för funktionskontroll av ventilationssystem, OVK, 2012, 128 pages

Release date, periodicity of revision:

2012. First published in 1991.

Types of building covered (usage, size, etc.):

Residential buildings ☒ | Non-residential buildings ☒

- Houses ☒
- Apartments ☒
- Others ☒

- Offices ☒
- Retail buildings ☒
- Educational buildings ☒
- Health buildings ☒
- Others ☒

Types of ventilation systems covered (technology, type, airflows range, etc.):
Natural ventilation, exhaust-only ventilation, balanced ventilation without or with heat recovery

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Covers the whole ventilation system.

Inspection can be operated by:

System designer ☐ Independent inspector ☒ Installer ☐ Maintenance staff ☐

Others ☐

Number of buildings/ventilation systems to which it is/has been applied:

Information not available.

All the buildings built since 1991.

Dwellings : around 700,000 (Andersson, 2013)

Number not available for others types of buildings.

Inspection contents

Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☒
- Adequacy between design and installation ☒
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates ☒
- Measurement or assessment of air pressures ☐
- Measurement or assessment of ductwork airtightness ☐
- Measurement or assessment of the electricity consumption ☐
- Measurement or assessment of indoor air quality parameters ☐
- Measurement or assessment of noise level ☐
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects ☐
- Adequacy with current ventilation needs ☐

The inspection also includes checking that instructions and maintenance instructions are easily available.

Applied to:

- Each system ☐
- Each building ☒
- A sample (explain rules) ☐

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☒
- Regular : ☒
  - Every 3 years: Day-care centres, schools etc. with all types of ventilation, Blocks of flats, office buildings etc. with balanced ventilation
  - Every 6 years: Blocks of flats, office buildings etc. with mechanical exhaust and natural ventilation
  - Only first inspection : One and two-dwellings houses with mechanical exhaust with exchanger ventilation and balanced ventilation

Inspection report:

- Certificate that the inspection has been performed ☒
- Report provided to the owner/occupant ☒
- Recommendations for improvement to owner/occupant ☒

The report should include recommendations to the owner regarding energy savings due to ventilation system, without degrading IAQ.

Specific issues

Stakeholders involved, their number and role, role of public authorities:

Two Swedish authorities are responsible for ventilation regulation at the national level: Boverket (the national board of housing, building and planning) for new installations and Socialstyrelsen (the national board of health and welfare) for existing installations. Boverket is responsible for this OVK control system and for national authorization of inspectors. Local authorities are responsible for the observance of the law locally and should report the results to Boverket.
Once recorded, the inspectors should give the inspection certificate to the owner and send a copy to local authority. The local authorities should follow-up all these inspections and ensure full history tracking. A copy of the certificate must be posted in a clearly visible place in the building by the owner, specifying the deadline for the next inspection.

Legal issues:

The building owner is responsible for ensuring that the OVK check has been carried out. He shall keep a copy of the OVK record of executed OVK inspections, notably for a future energy performance declaration.

Sanctions if the measure is not correctly implemented:

It the building owner doesn't follow the scheme or is not giving any correction required by the inspector, the local authority can order to take actions with a deadline of 6 months to implement them, and can give a financial penalty. In reality, they are rarely applied and a simple letter is often sent to building owners laggards (Baecher et al., 2017).

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Measuring instruments required, measuring uncertainty, calibration procedure:

Education or training needs:
FunkiS is the national association of the independent qualified inspectors, including 1200 members on the 1400 qualified ones in Sweden (ADEME, Baecher et al., 2017). This association insures training activities, regulation application, and proposes OVK inspection guidelines.

Qualification of persons or companies required, quality assurance system required:
Inspectors qualifications are of two types :

- Inspector N for one or two-dwelling houses, natural and mechanical exhaust in schools, blocks of flats and office buildings
- Inspector K for all types of ventilation

Inspectors must fulfil a training scheme (including regulations on IAQ), a 3-year long professional experience in the ventilation field for the N qualification, and a 5-year long one for the K qualification. The K inspectors must also certify their knowledge about radon and mitigation actions.
Agreements are given for a 5 year period. Inspectors should go through a competence test before to keep the agreement after 5 years. They are referred on the Boverket website.

Cost for managing and maintaining the inspection scheme:
Information not available.

Cost for applying the measure to a given building:

Information not available.

Advantages / Drawbacks

Advantages:

- Long term policy with OVK inspections at commissioning then regularly during the building's life
- Credibility of the inspections performed by independent qualified inspectors
- Technical support of the inspectors insured by a national association of professionals (FunkiS)

Drawbacks:

- Municipalities are both responsible for the OVK and owners of several buildings

Proven/known impact of the measure (indicators):

In 1998, a review of inspection results showed that only 34% of the 5,625 systems installed in schools, offices and multi-family houses succeed the OVK check (Engdahl, 1998).

In 2001, a survey (called STIL 2) showed that most of the schools and kindergartens succeed to the OVK check (Baecher et al., 2017)

In 2006, a national survey (called BETSI) on 1800 buildings chosen to be representative of the national building stock, showed that 60% of residential buildings, 72% of health care buildings, only 29 % of sport and cultural facilities succeed to the OVK inspection without corrective action. For schools and kindergartens, there were only 40% (Baecher et al., 2017).

In 2011, 290 local authorities have been asked to answer a survey on the implementation of housing policies related to energy, IAQ and ventilation inspections. Among the 40 of them who answered, 80% declared that they have no difficulty to deal with the OVK requirement and to follow-up the results (Gullin, 2015).

Additional information

References / Source of information / Links:

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Finnish Decree 1009/2017 on the indoor climate and ventilation of new buildings

Ympäristöministeriön asetus uuden rakennuksen sisäilmastosta ja ilmanvaihdosta

Finland	Legislation or Regulation ☒ Standard ☐ Guidelines ☐	Energy performance Noise level	Indoor air quality Thermal comfort	Mandatory ☒ Voluntary ☐	Finnish Government

Description

This decree of the Government of Finland updates the Finnish Building Code from 1st January 2018.

As the previous version of the Code (D2 Finnish Building Code Collection - Buildings indoor climate and ventilation, 1992), it requires that for new buildings, whatever the ventilation system type, the parties engaging construction operate, prior to commissioning:

- Measurement of the airtightness of the ventilation system. This measurement can be replaced by the check of the ventilation system for systems serving a single space in a building or a single dwelling unit, if their ductwork consists entirely of ducts and duct components at least of airtightness class C.
- Measurement and adjustment of airflow rates
- Determination of the system's specific fan power
- Checks that the operation of the ventilation system complies with design specifications.

The building and its ventilation system shall be clean before air flow measurement and adjustment and before system commissioning.

The person responsible for the construction shall report in the building inspection documents about compliance with design specifications of the ventilation system airtightness. Compliance will be decided taking into account the following tolerances:

- air flow at system and dwelling unit level: ± 10%,
- air flow at room level: ± 20% and at least 1 dm^3/s,
- specific fan power of ventilation system: + 10%.

References:

Ympäristöministeriön asetus uuden rakennuksen sisäilmastosta ja ilmanvaihdosta, Ministry of the Environment of Finland, 1009/2017, 2017

Updates the D2 Finnish Building Code Collection - Buildings indoor climate and ventilation, 1992 (D2 Suomen rakentamismääräyskokoelma - Rakennusten sisäilmasto ja ilmanvaihto - Määräykset ja ohjeet) that already included similar requirements on the inspection.

Release date, periodicity of revision:

2017

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☒
Houses	☐	Offices	☐
Apartments	☐	Retail buildings	☐
Others	☐	Educational buildings	☐
		Health buildings	☐
		Others	☐

Types of ventilation systems covered (technology, type, airflows range, etc.):

All types

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Covers the whole ventilation system.

Inspection can be operated by:

System designer ☒ Independent inspector ☒ Installer ☒ Maintenance staff ☐

Others ☐

Number of buildings/ventilation systems to which it is/has been applied:

All buildings built since 1992.

Inspection contents

Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☒
- Adequacy between design and installation ☒
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates ☒
- Measurement or assessment of air pressures ☐
- Measurement or assessment of ductwork airtightness ☒
- Measurement or assessment of the electricity consumption ☒
- Measurement or assessment of indoor air quality parameters ☐
- Measurement or assessment of noise level ☐
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects ☐
- Adequacy with current ventilation needs ☐

Applied to:

- Each system ☒
- Each building ☐
- A sample (explain rules) ☐

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☒
- Regular ☐

Inspection report:

- Certificate that the inspection has been performed ☒
- Report provided to the owner/occupant ☐
- Recommendations for improvement to owner/occupant ☐

Specific issues

Stakeholders involved, their number and role, role of public authorities:
Regulation published by the Ministry of Environment.

Legal issues:
Mandatory inspection and measurements for all new buildings.

Sanctions if the measure is not correctly implemented:
No information.

Measuring instruments required, measuring uncertainty, calibration procedure:
The Decree gives requirements about the permissible tolerances in respect of design values may be as follows:
1) air flow at system and dwelling unit level ± 10%;
2) air flow at room level ± 20%, with, however, the deviation always permitted to be at least 1 dm3/s;
3) specific fan power of ventilation system + 10%.

The tolerances to decide on the compliance of the measured values to the design specifications must include both measurement result deviations and the measurement uncertainty, which shall be stated in conjunction with measurement results.

The measurement method and measuring instruments shall be suitable for measuring the air flow levels to be measured.

The measuring instruments shall be calibrated, the calibration shall be currently valid, and the measurement value shall be corrected in accordance with the calibration.

Education or training needs:
No information

Qualification of persons or companies required, quality assurance system required:
No information

Cost for managing and maintaining the inspection scheme:
Information not available.

Cost for applying the measure to a given building:

Information not available.

Advantages / Drawbacks

Advantages:
- The tolerances for deciding on compliance are explicitly mentioned.
- The calibration rules for measuring instruments are required

Drawbacks:

- Complete procedure. In some other countries, it could be considered as too complex.

Proven/known impact of the measure (indicators):

No information.

Additional information

References / Source of information / Links:

https://www.finlex.fi/fi/laki/alkup/2017/20171009

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Polish requirements for the inspection of ventilation systems in residential buildings

Dz.U. 1994 Nr 89 poz. 414

Poland	Legislation or Regulation ☒ Standard ☐ Guidelines ☐	Energy performance	Indoor air quality	Mandatory ☒ Voluntary ☐	Polish Government
		Noise level	Thermal comfort		

Description

This law of 7 July 1994 (together with subsequent revisions) is the Construction Law in Poland.
Chapter 6 (articles 62 to 72) is about maintenance of buildings.
Article 62.1 requires that installations and devices for environmental protection (among others) are subject of a control by the owner or manager at least once a year (except for one-family houses), or twice a year for buildings of more than 2000 m^2 and other objects construction with a roof area exceeding 1000 m^2. It also requires that installations and devices for environmental protection are checked at least every 5 years (technical condition and suitability for use).

Reference:
Dz.U. 1994 Nr 89 poz. 414 - Ustawa z dnia 7 lipca 1994 r. Prawo budowlane - 1) Rozdział, 1994

Release date, periodicity of revision:

1994, last revision 2019

Types of building covered (usage, size, etc.):

Residential buildings	☐	Non-residential buildings	☐
Houses	☒	Offices	☐
Apartments	☒	Retail buildings	☐
Others	☐	Educational buildings	☐
		Health buildings	☐
		Others	☐

Types of ventilation systems covered (technology, type, airflows range, etc.):

Mechanical ventilation and air conditioning ducts (no mention of an airflow range)

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):
Ventilation pipes, ventilation ducts

Inspection can be operated by:

System designer ☐ Independent inspector ☐ Installer ☐ Maintenance staff ☐

Others ☐

No specification about who can operate the inspection. The regulation says that "the person making the inspection authority is obliged to notify the supervisory authority in writing without delay construction of the inspection carried out".

Number of buildings/ventilation systems to which it is/has been applied:

No information.

Inspection contents

Aspects covered:

- Completeness of the ventilation system ☐
- Cleanliness and general state of the ventilation system ☒
- Adequacy between design and installation ☒
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates ☐
- Measurement or assessment of air pressures ☐
- Measurement or assessment of ductwork airtightness ☐
- Measurement or assessment of the electricity consumption ☐
- Measurement or assessment of indoor air quality parameters ☐
- Measurement or assessment of noise level ☐
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects ☒
- Adequacy with current ventilation needs ☐

Applied to:

- Each system ☐
- Each building ☒
- A sample (explain rules) ☐

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☐
- Regular : periodically, at least every 5 years ☒

Inspection report:

- Certificate that the inspection has been performed ☒
- Report provided to the owner/occupant ☐
- Recommendations for improvement to owner/occupant ☐

Specific issues

Stakeholders involved, their number and role, role of public authorities:
Regulations developed by the government on a national level.

Legal issues:
Legal effects mentioned only in relation of the event of a change in the way the building is used.

Sanctions if the measure is not correctly implemented:
Fees intended as well following the point above (using of the building).

Measuring instruments required, measuring uncertainty, calibration procedure:
No information.

Education or training needs:

No information

Qualification of persons or companies required, quality assurance system required:

No specific details about qualifications. The text refers to "people who have building qualifications in the appropriate specialty", "persons having the qualifications required for the supervision over operation devices, installations and power and gas networks" and "people who have the qualifications of a master in the chimney industry - with regard to smoke ducts and gravity hoses combustion and ventilation"

Cost for managing and maintaining the inspection scheme:

No information

Cost for applying the measure to a given building:

No information

Advantages / Drawbacks

Advantages:

- The requirements cover the residential building sector, giving specifications on different approaches to the inspection

Drawbacks:

- The requirements do not provide indications on measurements; they are not referring to non-residential buildings

Proven/known impact of the measure (indicators):

No information.

Additional information

References / Source of information / Links:

http://prawo.sejm.gov.pl/isap.nsf/download.xsp/WDU19940890414/U/D19940414Lj.pdf

Author of the analysis: Matteo Urbani (REHVA)

Ontario Regulation 67/93
Health care and residential facilities

Inspection of mechanical ventilation systems

<table>
<tr><td rowspan="2">Canada (Ontario)</td><td rowspan="2">Legislation or Regulation ☒
Standard ☐
Guidelines ☐</td><td>Energy performance</td><td>Indoor air quality</td><td rowspan="2">Mandatory ☒
Voluntary ☐</td><td rowspan="2">Government of Ontario</td></tr>
<tr><td>Noise level</td><td>Thermal comfort</td></tr>
</table>

Description

This regulation from the Ontario State (Canada) is made under the "Occupational Health and Safety Act (OHSA)" with the aim to protect the health and safety of workers in hospitals, laboratories, psychiatric and mental health service facilities, long-term care homes, residences for persons with developmental or physical disabilities.

The regulation includes requirements that must be put into effect by employers for the health and safety of workers. They cover various topics such as personal protective equipment, lighting, hygiene facilities, electrical equipment, compressed gas cylinders, anaesthetic gases, flammable liquids, etc. One series of requirements cover ventilation.

The main requirement (art.19) is that: "*General indoor ventilation adequate to protect the health and safety of a worker shall be provided by natural or mechanical means*".

Article 20 of the regulation requires that:
- The ventilation system provides replacement air to replace air that is exhausted
- The replacement air is heated, when necessary, to maintain a suitable temperature, no less than 18°C (art. 21)
- The replacement air is free from contamination from any hazardous dust, vapour, smoke, fume, mist or gas
- The replacement air enters in such a manner so as not to cause undue drafts, and prevent blowing of settled dust into the workplace and interference with any exhaust system
- Air discharged from any exhaust system is discharged in such a manner so as to prevent the return of contaminants to any work area.

Article 19 requires that mechanical ventilation systems are serviced, have maintenance works and be repaired.

A regular inspection of mechanical ventilation systems is required (art.19):
- "*A mechanical ventilation system shall be inspected every six months to ensure it is in good condition*
- *The inspection […] shall be carried out by a person who is qualified by training and experience to make such an inspection*
- *The person carrying out the inspection shall file a report on the inspection with the employer and with the joint health and safety committee or health and safety representative, if any*".

An online guide (https://www.labour.gov.on.ca/english/hs/pubs/gl_ventilation.php) is available to help employers and persons carrying out these tasks to determine how to comply with the requirements.

Reference:

Ministry of Labour of the Government of Ontario (Canada), *Occupational Health and Safety Act, Ontario Regulation 67/93, Health care and residential facilities*, 1993 (last revision 2018), Government of Ontario, available in English and French, 20 pages

Release date, periodicity of revision:

1993.

The regulation is revised on a regular basis (13 revisions in the last 20 years), but the requirements about ventilation are present and unchanged at least since 1999.

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☒
Houses	☐	Offices	☐
Apartments	☐	Retail buildings	☐
Others	☒	Educational buildings	☐
		Health buildings	☒
		Others	☐

Applies to health care facilities, long-term care homes, residences for persons with developmental or physical disabilities, residences for mental health service.

Types of ventilation systems covered (technology, type, airflows range, etc.):

Dedicated to mechanical ventilation systems of all types, without limitation of the airflow.

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Covers the whole ventilation system.

Inspection can be operated by:

System designer ☐ Independent inspector ☒ Installer ☒ Maintenance staff ☒

Others (see below) ☒

The online guide says that the inspection may be carried out by "*a worker in maintenance or some other area of the facility who has detailed knowledge of the system, and its operation and maintenance requirements. A qualified contractor with expertise in ventilation systems who is familiar with the system may also be qualified to conduct the inspection*".

Number of buildings/ventilation systems to which it is/has been applied:

Information not available.

Inspection contents

Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☒
- Adequacy between design and installation ☐
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates ☒
- Measurement or assessment of air pressures ☒
- Measurement or assessment of ductwork airtightness ☐
- Measurement or assessment of the electricity consumption ☐
- Measurement or assessment of indoor air quality parameters ☒
- Measurement or assessment of noise level ☒
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects ☐
- Adequacy with current ventilation needs ☒

Applied to:

- Each system ☒
- Each building ☐
- A sample (explain rules) ☐

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☐
- Regular : every 6 months ☒

Inspection report:

- Certificate that the inspection has been performed ☐
- Report provided to the owner/occupant ☒
- Recommendations for improvement to owner/occupant ☐

The report should describe any deficiencies observed during the inspection.

Specific issues

Stakeholders involved, their number and role, role of public authorities:

The regulation and the online guide were developed by the Ministry of Labour of the Government of Ontario (Canada).

Legal issues:

The inspection required by the regulation is mandatory.

Sanctions if the measure is not correctly implemented:

The Occupational Health and Safety Act (OHSA) defines the fines and imprisonment terms to which are liable persons who contravenes or fails to comply with a provision of the regulation.

Measuring instruments required, measuring uncertainty, calibration procedure:

The online guide provides a check-list for the semi-annual inspection (see extracts above). This check-list includes almost no measurement but mostly visual checks of the integrity, cleanliness and proper operation of the system.

Another paragraph of the online guide lists some quantities that can be measured, explaining how they are useful to ensure that the ventilation system is operating properly and how to interpret the values: air flow rates, pressures, CO_2 concentrations.

Education or training needs:

The person carrying out the inspection must be qualified by training and experience. The online guide does not give additional information. No source has been found that provides more information. No specific training offer or qualification scheme has been identified.

Qualification of persons or companies required, quality assurance system required:

See previous point.

Cost for managing and maintaining the inspection scheme:

Information not available.

Cost for applying the measure to a given building:

Information not available.

Advantages / Drawbacks

Advantages:

- The requirements are formulated in a simple and clear way
- The online guide recommends that information about each ventilation system be recorded and be kept readily available at the workplace, including: system description, manufacturer documentation, operating procedures, maintenance program, testing and maintenance records, regular inspection reports, emergency procedures when a toxic substance has been released and could enter the ventilation system.

Drawbacks:

- The objective is limited to the protection of workers, even if an implicit result of the inspection is also the protection of patients/occupants.
- The inspection procedure is not defined into the regulation. The online guide recommends a list of items to be inspected, but the method for inspection is not explained with details.
-

Proven/known impact of the measure (indicators):

Impact unknown

Additional information

References / Source of information / Links:

Regulation:
https://www.ontario.ca/laws/docs/930067_e.doc

Online guide:
https://www.labour.gov.on.ca/english/hs/pubs/gl_ventilation.php

Author of the analysis: François Durier (CETIAT)

Annex 4 – Analysis of existing standards

European standards

The European standard EN 16798-17 - *Energy performance of buildings. Ventilation for buildings. Guidelines for inspection of ventilation and air conditioning systems* (2017) was prepared by CEN under a mandate given by the European Commission in relationship with article 15 of the EPBD on the inspection of air-conditioning systems. Since article 4 of the EPBD states that the minimum energy performance requirements "*shall take account of general indoor climate conditions, in order to avoid possible negative effects such as inadequate ventilation*", the standard also deals with the inspection of ventilation systems. It replaces the standard EN 15239:2007 "*Ventilation for buildings. Energy performance of buildings. Guidelines for inspection of ventilation systems*", that is cancelled. See detailed analysis in Annex 5.

The European standard EN 12599 - *Ventilation for buildings - Test procedures and measurement methods to hand over air conditioning and ventilation systems* (2012) describes the procedures for hand over of air conditioning and ventilation systems in residential and non-residential buildings. The revised version shall in particular include more information regarding ductwork airtightness tests. See detailed analysis in Annex 5.

EN 14134 - *Ventilation for buildings - Performance testing and installation checks of residential ventilation systems* (2019) covers the commissioning of new residential ventilation systems and their performance testing when they are in operation for a certain period of time. See detailed analysis in Annex 5.

EN 16211 - Ventilation for buildings - Measurement of air flows on site – Methods (2015) focuses on the air flow measurement methods. See detailed analysis in Annex 5.

The European standard EN 15780 - *Ventilation for buildings - Ductwork - Cleanliness of ventilation systems* (2011) applies to both new and existing ventilation and air conditioning systems. It requires a visual check of the system to assess the need for cleaning (and also the result of cleaning). It indicates that measurements are needed if the visual inspection shows uncertainty about cleanliness or need for cleaning. It recommends to set up an inspection plan (i.e. review of plans and reports, decision on what to inspect), describes evaluation methods of dust accumulation and methods of verifying deposited solid dust and micro-organisms.

Several European standards concern ductwork airtightness: EN 12237, EN 1507, EN 13403, EN 15727, EN 14239. Their content is presented and analysed in Annex 8.

National standards in EU countries

National standards have been identified in Austria and France for residential ventilation systems that include some requirements about checking of their good operation: DIN 1946-6 and NF DTU 68-3.

These standards are analysed in Annex 5.

National standards outside EU

Outside of the European Union, the Turkish standard TSE 3419 - *Ventilation and Air Conditioning Installation - Requirements of projecting* (*Havalandırma ve İklimlendirme*

Tesisleri Projelendirme Kuralları - 2002) covers the rules for the design of ventilation and air-conditioning facilities in buildings. It includes a paragraph (5) on the inspection and technical acceptance of ventilation and air conditioning systems. The measurement of supply air flow rates under steady state conditions is required for ventilation systems. General recommendations are given about where these air flow rates measurements should be done in the system. The methods for measuring air flow rates in a duct or at an air diffuser are described in details, together with information about the accuracy of measurement with different measuring devices.

In the USA, a few standards include requirements for checking of ventilation systems. The contents of ASHRAE standards 62-1 and 62-2 are described in Annex 9. One US standard (ANSI/RESNET/ICC 380-2016) is analysed in Annex 5 on the measurement of ventilation air flow rate.

In Australia and New Zealand, the standard AS/NZS 3666.2 includes checking requirements for air handling systems for microbial control.

Annex 5 – Detailed analysis of a selection of existing standards

- European standard EN 16798-17 - Energy performance of buildings - Part 17: Ventilation for buildings - Guidelines for inspection of ventilation and air conditioning systems, Module M4-11, M5-11, M6-11, M7-11
- European standard EN 12599 - Ventilation for buildings - Test procedures and measurement methods to hand over air conditioning and ventilation systems
- European standard EN 14134 - Ventilation for buildings - Performance testing and installation checks of residential ventilation systems
- European standard EN 16211 - Ventilation for buildings - Measurement of air flows on site - Methods
- French standard NF DTU 68.3 - Mechanical ventilation installations - Calculation rules, design and execution of residential mechanical ventilation systems
- ANSI/RESNET/ICC 380-2016 on testing airflow of mechanical ventilation systems (USA)

European standard EN 16798-17 on the inspection of ventilation and air-conditioning systems

<table>
<tr><td rowspan="2">Europe</td><td rowspan="2">Legislation or Regulation ☐
Standard ☒
Guidelines ☐</td><td>Energy performance</td><td>Indoor air quality</td><td rowspan="2">Mandatory ☐
Voluntary ☒</td><td rowspan="2">CEN</td></tr>
<tr><td>Noise level</td><td>Thermal comfort</td></tr>
</table>

Description

The European standard EN 16798-17 has been adopted by CEN in 2017 and had to be published as a national standard by the national standardisation bodies at the latest in December 2017.

Its full title is: Energy performance of buildings - Part 17: Ventilation for buildings - Guidelines for inspection of ventilation and air conditioning systems, Module M4-11, M5-11, M6-11, M7-11

It replaces EN 15239:2007 on the inspection of ventilation systems and EN 15240:2007 on the inspection of air-conditioning systems.

The standard EN 167988-17 applies to air-conditioning systems. Since many air-conditioning systems also provide ventilation, it covers the inspection of the air handling subsystems of an air-conditioning system. Stand-alone ventilation systems (called ventilation-only systems in the standard) are not concerned by the inspection required by the EPBD. Nevertheless, because of the energy impact of ventilation and considering the technical similarities between air conditioning air handling subsystems and stand-alone ventilation systems, this standard also covers the inspection of stand-alone ventilation systems.

The standard deals with the following points of article 15 and 16 of the EPBD (Directive 2010/31/EU):

- regular inspection of the accessible parts of air-conditioning systems of an effective rated output of more than 12 kW.
- assessment of the air-conditioning efficiency and the sizing compared to the cooling requirements of the building
- advice to users on the replacement of air-conditioning systems or on other modifications to the air-conditioning system
- inspection report handed over to the owner or tenant including recommendations for the cost-effective improvement of the energy performance of the inspected system.

In addition, since article 4 of the EPBD states that the minimum energy performance requirements "shall take account of general indoor climate conditions, in order to avoid possible negative effects such as inadequate ventilation", the standard also deals with the inspection of ventilation systems.

More information is provided in the Technical Report accompanying this standard (CEN/TR 16798-18:2016). It provides interpretation of the requirements in EN 16798-17 and is analysed in another part of this report.

The standard EN 16798-17 provides the following definition of inspection: "examination of a technical building system including at least collection of documents, on-site visual checks, and a report with recommendations". Commissioning is defined as: "process necessary to ensure the building and its associated heating, ventilation and air conditioning systems are functioning in accordance with the design parameters".

Three inspection levels are defined:
- pre-inspection and functional checks with no measurement
- functional measurements
- special measurements "to provide more detailed assessments of system performance".

The pre-inspection consist in collecting and analysing design parameters, system characteristics, and information on building and system operation and maintenance. The inspection includes a preliminary visual assessment of cleanliness of the system and its components, and accessibility of those components.

These three inspection levels are new compared to the previous standard EN 15239, which was identifying pre-inspection as being only the first phase of the inspection.

Another difference between EN 16798-17 and the former EN 15239 is the following: for mechanical ventilation systems, EN 15239 was requiring measurements of air flow rates, electrical consumption by the fans, and for centralised systems measurement of air pressures before and after the unit and the filter. In the current standard, these data can be based on the inventory of the system without measurements, or measured.

Chapter 6 of the standard describes the inspection method for ventilation-only systems. The objective of this inspection (whatever its level) is presented as being to reduce energy consumption without compromising ventilation. The minimum outputs of the inspection are air flow rates and specific fan power.

The components that must be specifically inspected are: ductwork, air handling unit or fan, filters, heat exchanger, air inlets, air outlets and air transfer devices, dampers, and controls.

The CEN Technical Report CEN/TR EN 16798-18 aims at providing information to support the correct understanding and use of the European standard EN 16798-17. It was published by national standardisation bodies in 2017.

Its full title is: Energy performance of buildings - Part 18: Ventilation for buildings - Module M4-11, M5-11, M6-11, M7-11 - Guidelines for inspection of ventilation and air conditioning systems - Technical report - Interpretation of the requirements in EN 16798-17

Non-normative information is given about:
- The parameters that should be taken into account to decide on an inspection frequency
- The way to define ventilation system categories to which can correspond different inspection procedures
- The detailed list of parameters that could be checked in the inspection of ventilation systems for each of the 3 inspection levels defined by EN 16798-17
- The list of items to consider in the collection of design and system documentation during the pre-inspection
- Advice on possible sampling rules
- Additional explanations on the inspection method described by EN 16798-17

The report also provides information on the ways by which the energy performance of a ventilation system can be improved. This can be useful when establishing recommendations for the improvement of the system in an inspection report.

References:

EN 16798-17, *Energy performance of buildings - Part 17: Ventilation for buildings - Guidelines for inspection of ventilation and air conditioning systems, Module M4-11, M5-11, M6-11, M7-11*, 2017

CEN/TR 16798-18, *Energy performance of buildings - Part 18: Ventilation for buildings - Module M4-11, M5-11, M6-11, M7-11 - Guidelines for inspection of ventilation and air conditioning systems - Technical report - Interpretation of the requirements in EN 16798-17*, 2017

Release date, periodicity of revision:

2017

The standard and the report are available for purchase from the national standardisation bodies of the EU member states.

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☒
Houses	☒	Offices	☒
Apartments	☒	Retail buildings	☒
Others	☒	Educational buildings	☒
		Health buildings	☒
		Others	☒

Applies to all building types and sizes.

Types of ventilation systems covered (technology, type, airflows range, etc.):

Covers all types of ventilation systems, without limitation of the airflow.

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Covers the whole ventilation system.

Inspection can be operated by:

System designer ☐ Independent inspector ☐ Installer ☐ Maintenance staff ☐

Others (see below) ☐

This point is not covered by the standard or by the technical report.

Number of buildings/ventilation systems to which it is/has been applied:

No information available.

Inspection contents

Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☒
- Adequacy between design and installation ☒
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates ☒
- Measurement or assessment of air pressures ☒

- Measurement or assessment of ductwork airtightness ☐
- Measurement or assessment of the electricity consumption ☒
- Measurement or assessment of indoor air quality parameters ☐
- Measurement or assessment of noise level: *see below* ☐
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects ☐
- Adequacy with current ventilation needs ☐

The standard requires that measurements, if any, are performed in accordance with EN 12599 for non-residential systems and EN 14134 for residential systems.
Causes of noise must be assessed in the cases where the ventilation system produces excessive noise or vibration.
The standard also suggests measurements of the air inlet/air exhaust areas, and for natural ventilation systems measurements of section and height of exhaust ducts.

Applied to:

- Each system ☒
- Each building ☐
- A sample (explain rules) ☒

Sampling can apply to systems and components of the same type, except for single-family house and for pre-inspections.

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☒
- Regular : periodicity is not clearly mentioned ☒

Inspection report:

- Certificate that the inspection has been performed ☐
- Report provided to the owner/occupant ☐
- Recommendations for improvement to owner/occupant ☒

Specific issues

Stakeholders involved, their number and role, role of public authorities:

The standard has been elaborated by CEN TC 156 "Ventilation for buildings" under a Mandate given to CEN by the European Commission (Mandate M480). The stakeholders involved are all those who contributed to the writing and editing of the standard.

The report has been written by CEN TC 156.

Legal issues:

Must be published as a national standard in countries whose national standardisation body is a member of CEN. Any existing national standard that conflicts with the new European Standard must be withdrawn. The use of standards is voluntary and so there is no legal obligation to apply them.

Sanctions if the measure is not correctly implemented:

Not applicable.

Measuring instruments required, measuring uncertainty, calibration procedure:

Reference is made to EN 12599 for measurements on non-residential systems and EN 14134 for measurements on residential systems.

Education or training needs:

Not in the scope of this standard.

Qualification of persons or companies required, quality assurance system required:

Not in the scope of this standard.

Cost for managing and maintaining the inspection scheme:

Not applicable.

Cost for applying the measure to a given building:

No information.

Advantages / Drawbacks

Advantages:

- Document based on a European consensus
- Covers the different aspects of Directive 2010/31/EU (inspection of air-conditioning systems) and extends them to the inspection of ventilation systems

Drawbacks:

- The standard is limited to the description of an inspection procedure. It must then be used in conjunction with other standards describing the measurement methods and the CEN Technical report (CEN/TR 16798-18) for additional explanations.
- The description of the inspection procedure remains general and could require additional practical tools to be easily applicable.

Proven/known impact of the measure (indicators):

Impact unknown

Additional information

References / Source of information / Links:

The standard as well as the report can be purchased from the national standardisation bodies of EU countries.

An article compares this standard with the previous standards EN 15239 and 15240:

F.R. Carrié, A.M. Bernard, *Guidelines for inspection of ventilation and air conditioning systems – Revision of EN 15239 and EN 15240*, REHVA Journal 01/2015, pages 38-40, https://www.rehva.eu/fileadmin/REHVA_Journal/REHVA_Journal_2015/RJ_issue_1/P.38/38-40_RJ1501_WEB.pdf

Author of the analysis: François Durier (CETIAT)

European standard EN 12599 - Ventilation for buildings - Test procedures and measurement methods to hand over air conditioning and ventilation systems

<table>
<tr><td rowspan="2">Europe</td><td rowspan="2">Legislation or Regulation ☐
Standard ☒
Guidelines ☐</td><td>Energy performance</td><td>Indoor air quality</td><td rowspan="2">Mandatory ☐
Voluntary ☒</td><td rowspan="2">CEN</td></tr>
<tr><td>Noise level</td><td>Thermal comfort</td></tr>
</table>

Description

The standard NF EN 12599 characterises the controls, test methods and measuring instruments in order to check the well capacity to use the ventilation systems for residential and non-residential buildings. It can be used before, during and after handing over.

The check list of the method follows a 5 steps-procedure:

a. Completeness checks, to ensure that the ventilation system has been installed entirely in accordance with contract,
b. Functional checks, to verifying the operation of the system,
c. Functional measurements, to check the statistical basis that the system achieves the values according to the design,
d. Special measurements, in case of doubts concerning the quality of parts of the system after application of steps a to c or especially agreed,
e. Report.

References:

EN 12599 - *Ventilation for buildings - Test procedures and measurement methods to hand over air conditioning and ventilation systems*, 2012, 95 pages.

Release date, periodicity of revision:

2012. Revised the approved standard EN 12599 of July 2000.

The standard is available for purchase from the national standardisation bodies of the EU member states.

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☒
Houses	☒	Offices	☒
Apartments	☒	Retail buildings	☒
Others	☒	Educational buildings	☒
		Health buildings	☒
		Others	☒

Applies to all building types and sizes.

Types of ventilation systems covered (technology, type, airflows range, etc.):

This standard applies to all mechanical ventilation and air conditioning systems.

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

The standard covers whole systems including ductwork, air terminal devices and units, air handling units, air distribution systems (supply, extract, exhaust), air terminal devices, fire protection devices, automatic control devices.

Inspection can be operated by:

System designer ☐ Independent inspector ☐ Installer ☐ Maintenance staff ☐

Others (see below) ☐
This point is not covered by the standard.

Number of buildings/ventilation systems to which it is/has been applied:

No information available.

Inspection contents

Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☒
- Adequacy between design and installation ☒
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates ☒
- Measurement or assessment of air pressures ☒
- Measurement or assessment of ductwork airtightness ☒
- Measurement or assessment of the electricity consumption ☒
- Measurement or assessment of indoor air quality parameters ☒
- Measurement or assessment of noise level ☒
- Measurement or assessment of thermal comfort parameters ☒
- Health and safety aspects ☒
- Adequacy with current ventilation needs ☐

Applied to:

- Each system ☒
- Each building ☒
- A sample (explain rules) ☒

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☒
- Regular : periodicity is not clearly mentioned ☒

Inspection could be done before, during the handing over, and after during other inspections or maintenance operations.

Inspection report:

- Certificate that the inspection has been performed ☐
- Report provided to the owner/occupant ☒
- Recommendations for improvement to owner/occupant ☐

Specific issues

Stakeholders involved, their number and role, role of public authorities:

The standard has been elaborated by CEN TC 156 "Ventilation for buildings", the secretariat of which being held by BSI. The stakeholders involved are all those who contributed to the writing and editing of the standard.

Legal issues:

Must be published as a national standard in countries whose national standardisation body is a member of CEN. Any existing national standard that conflicts with the new European Standard must be withdrawn. The use of standards is voluntary and so there is no legal obligation to apply them.

Sanctions if the measure is not correctly implemented:

Not applicable.

Measuring instruments required, measuring uncertainty, calibration procedure:

Table 3 describes the permissible uncertainty of each measurement: air flow rate for each room and for each system, supply air temperature, relative humidity, air velocity in occupied zone, air temperature in occupied zone, A-weighted sound pressure level in the room.
Annex D details the required devices, the measurement methods and the uncertainties and calibration requirements on the following quantities: air flow rate, ductwork leakage, indoor air velocity, air temperature, air humidity, sound pressure level, electrical power of the fan and pressure difference at the air filter.

Education or training needs:

Not specified.

Qualification of persons or companies required, quality assurance system required:

Not specified.

Cost for managing and maintaining the inspection scheme:

Not applicable.

Cost for applying the measure to a given building:

No information.

Advantages / Drawbacks

Advantages:

- This standard helps to select simple test methods or more extensive measurements.
- It has been revised notably to be used in energy inspection of air-conditioning systems according to EU Directive 2010/31/EU, and widely in EPB inspections.
- It deals with diverse measurements instruments/methods for a wide range of parameters linked to ventilation performance.
- It proposes measurement uncertainty calculation methods.

Drawbacks:

- It refers to lot of other standards or documents which give more precisions concerning the measurement protocols. Cannot be used alone.
- If this standard would be revised (it is under revision), it could be simplified referring to the recently published EN 16211:2015 focusing on in situ airflows measurement simplified methods themselves.
- It should also focus on non-residential buildings as the EN 14134:2019 already deals with residential buildings, this last one referring to EN 16211:2015 for the airflows measurement methods themselves.

Proven/known impact of the measure (indicators):

Impact unknown

Additional information

References / Source of information / Links:

The standard can be purchased from the national standardisation bodies of EU countries.

EN 12599 is linked in whole or in part with the following reference indispensable for its application:

- EN 308, Heat exchangers - Test procedures for establishing performance of air to air and flue gases heat recovery devices
- EN 1507, Ventilation for buildings - Sheet metal air ducts with rectangular section - Requirements for strength and leakage
- EN 1822-1, High efficiency particulate air filters (EPA, HEPA and ULPA) - Part 1: Classification, performance testing, marking.
- EN 12097, Ventilation for buildings - Ductwork - Requirements for ductwork components to facilitate maintenance of ductwork systems
- EN 12237, Ventilation for buildings - Ductwork - Strength and leakage of circular sheet metal ducts
- EN 12238, Ventilation for buildings - Air terminal devices - Aerodynamic testing and rating for mixed flow application
- EN 13182, Ventilation for buildings - Instrumentation requirements for air velocity measurements in ventilated spaces
- EN 13779, Ventilation for non-residential buildings - Performance requirements for ventilation and room conditioning systems
- EN 14239, Ventilation for buildings - Ductwork - Measurement of ductwork surface area
- EN 15423:2008, Ventilation for buildings - Fire precautions for air distribution systems in buildings
- EN 15726, Ventilation for buildings - Air diffusion - Measurements in the occupied zone of air conditioned/ventilated rooms to evaluate thermal and acoustic conditions
- EN 15780, Ventilation for buildings - Ductwork - Cleanliness of ventilation systems
- EN 60584-1, Thermocouples - Part 1: Reference tables (IEC 60584-1)
- EN 60584-2, Thermocouples - Part 2: Tolerances (IEC 60584-2)
- EN 60751, Industrial platinum resistance thermometers and platinum temperature sensors (IEC 60751)

- EN 61672-1, Electroacoustics - Sound level meters - Part 1: Specifications (IEC 61672-1)
- EN ISO 3740, Acoustics - Determination of sound power levels of noise sources - Guidelines for the use of basic standards (ISO 3740)
- EN ISO 3744, Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Engineering methods for an essentially free field over a reflecting plane (ISO 3744)
- EN ISO 3746, Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Survey method using an enveloping measurement surface over a reflecting plane (ISO 3746)
- EN ISO 3747, Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Engineering/survey methods for use in situ in a reverberant environment (ISO 3747)
- EN ISO 7726, Ergonomics of the thermal environment - Instruments for measuring physical quantities (ISO 7726)
- EN ISO 11201, Acoustics - Noise emitted by machinery and equipment - Determination of emission sound pressure levels at a work station and at other specified positions in an essentially free field over a reflecting plane with negligible environmental corrections (ISO 11201)
- EN ISO 12569, Thermal performance of buildings - Determination of air change in buildings - Tracer gas dilution method (ISO 12569)
- ENV 13005, Guide to the expression of uncertainty in measurement
- CR 1752, Ventilation for buildings - Design criteria for the indoor environment

Author of the analysis: Gaëlle Guyot (Cerema)

European standard EN 14134 - Ventilation for buildings - Performance testing and installation checks of residential ventilation systems

Europe	Legislation or Regulation ☐ Standard ☒ Guidelines ☐	Energy performance Noise level	Indoor air quality Thermal comfort	Mandatory ☐ Voluntary ☒	CEN

DESCRIPTION

EN 14134:2019 supersedes EN 14134:2004. This standard specifies checks and measurement methods in order to verify the fitness for purpose of installed ventilation systems in dwellings.
It can be applied both at commissioning of new systems and at performance testing of existing systems.
It provides choice between simple test methods, when sufficient, and extensive measurements, when necessary.
This method has been developed for large scale application.

Reference:

EN 14134, *Ventilation for buildings – Performance measurement and checks for residential ventilation systems*, 2019

Release date, periodicity of revision:

2019-02-27. According to CEN rules, the standard might be revised every 5 years.

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☐
Houses	☒	Offices	☐
Apartments	☒	Retail buildings	☐
Others	☐	Educational buildings	☐
		Health buildings	☐
		Others	☐

Types of ventilation systems covered (technology, type, airflows range, etc.):

This standard applies to ventilation systems (mechanical, hybrid, natural) comprising any of the following elements:

- air terminal devices (supply, extract, intake and exhaust);
- air transfer devices (externally mounted, internally mounted);
- controls;
- ducts;
- fans;
- filters;
- heat recovery;
- heating/cooling of supply air;
- recirculation air;
- cooker hood;

- cowls;
- dampers;
- sound reduction devices.

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Covers the whole ventilation system.

Inspection can be operated by:

System designer ☐ Independent inspector ☐ Installer ☐ Maintenance staff ☐

Others (see below) ☐

No information regarding this topic

Number of buildings/ventilation systems to which it is/has been applied:

This version has just been published in February 2019: no application yet.

INSPECTION CONTENTS

Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☒
- Adequacy between design and installation ☒
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates ☒
- Measurement or assessment of air pressures ☒
- Measurement or assessment of ductwork airtightness ☒
- Measurement or assessment of the electricity consumption ☒
- Measurement or assessment of indoor air quality parameters ☐
- Measurement or assessment of noise level ☒
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects ☐
- Adequacy with current ventilation needs ☐

Applied to:

- Each system ☒
- Each building ☒
- A sample (explain rules) ☒

Checks and measurements for ventilation systems of the same type (example of types are natural ventilation, unidirectional ventilation or bidirectional ventilation) within apartments belonging to the same building or within houses belonging to the same housing estate can be performed on a sample of these apartments or houses. The sample size depends on the selected sampling level and the total number of apartments or houses of the considered group. Table 2 of the standard gives the sampling error for each sampling level for a level of confidence of 95 %. Table 3 gives the sample size as a function of the total number of apartments or houses for each sampling level. For total numbers of apartments or houses that are not in Table 3, the sample size is calculated using the following formula:

$$n = \frac{N \cdot 1{,}96^2 \cdot 0{,}5^2}{(N-1) \cdot e^2 + 1{,}96^2 \cdot 0{,}5^2} \tag{1}$$

where

n is the sample size;

N is the total number of apartments or house;

e is the sampling error (decimal value).

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☒
- Regular : every 6 months ☒

This standard can be used both for commissioning new systems and for control of existing systems. It does not provide requirement regarding the periodicity.

Inspection report:

- Certificate that the inspection has been performed ☐
- Report provided to the owner/occupant ☒
- Recommendations for improvement to owner/occupant ☐

The report should include detailed information regarding each check and measurement performed during the inspection. This standard provides a list of mandatory data to be included in the report.

SPECIFIC ISSUES

Stakeholders involved, their number and role, role of public authorities:

This document (EN 14134:2019) has been prepared by Technical Committee CEN/TC 156 "Ventilation for buildings", the secretariat of which is held by BSI.

Legal issues:

Must be published at the latest by August 2019 as a national standard in countries whose national standardisation body is a member of CEN. Any existing national standard that conflicts with the new European Standard must be withdrawn. The use of standards is voluntary and so there is no legal obligation to apply them.

Sanctions if the measure is not correctly implemented:

No information.

Measuring instruments required, measuring uncertainty, calibration procedure:

Measurement of air flow rate and direction for mechanical ventilation

The measurement can be performed by different methods (e.g.: pressure compensating air flow device, vane anemometer, constant injection tracer gas, pilot static tube, velocity probe, bag method (for supply only)). Air flow measuring instruments shall respect a maximum permissible measurement error of 10 % of the measured value or 1 l/s whichever is the greater.

Measurement of air pressure

The measurement is performed with a pressure gauge connected to a static pressure probe integrated to the ATDs, or a measuring tube inserted in the ATDs. Pressure measuring instruments shall respect a maximum permissible measurement error of 2 % of the measured value or 1 Pa whichever is the greater.

Measurement of running time

Where a ventilation system or air terminal device incorporates a time switch, the running time shall be determined by reading the durations of all “On” periods from the time switch dial/display.
Where a ventilation system or air terminal device incorporates a run-on timer then the duration of the run-on time shall be determined by operating the control switch and measuring the run-on time (e.g. using a stopwatch).

Measurement of ductwork air leakage

No specification in this standard. Others standards deal with this topic (EN 1507 and EN 12237).

Measurement of sound pressure level

No specification in this standard. The measurement shall be performed according to EN ISO 16032.

Measurement of electric power

The measuring device shall be a power meter capable of measuring active (true) power, e.g. a true RMS (Root Mean Square) measuring device or a measuring device with a RMS converter. Measuring instruments shall be calibrated. Measuring instruments shall respect a maximum permissible measurement error of 3 %.

Education or training needs:

No specification.

Qualification of persons or companies required, quality assurance system required:

No specification.

Cost for managing and maintaining the inspection scheme:

No specification.

Cost for applying the measure to a given building:

No specification.

ADVANTAGES / DRAWBACKS

Advantages:

- The standard provides methodology to perform different checks and measurements. All information needed by the operator is included in this standard.
- The standard does not impose to perform all checks and all measurements: it can be used for different purposes in different situations.
- The standard proposes different level of sampling to reduce the cost of ventilation system inspection and it provides information regarding the uncertainty due to sampling on the result.
- The standard refers to EN 16211:2015 for a detailed description of the airflows measurement methods themselves.

Drawbacks:

- The standard needs national annex to address the specificities of each country.

Proven/known impact of the measure (indicators):

All national versions are not been published yet.

ADDITIONAL INFORMATION

References / Source of information / Links:

The standard can be purchased from the national standardisation bodies of EU countries as soon as they have published it.

- *Authors of the analysis: Adeline Mélois and Gaëlle Guyot (CEREMA)*

European standard EN 16211 - Ventilation for buildings - Measurement of air flows on site - Methods

Europe	Legislation or Regulation ☐ Standard ☒ Guidelines ☐	Energy performance	Indoor air quality	Mandatory ☐ Voluntary ☒	CEN
		Noise level	Thermal comfort		

Description

This standard describes simplified on site measurement methods for airflow rates on site in ducts, and at air vents and exhaust vents. It specially focus on the methods and protocols of airflows measurements to be performed within the margins of uncertainty.

This standard defines the principles and the influencing parameters, sources of error, measurements uncertainties and measurements requirements.

These simplified methods are built with the goal to facilitate the setting up of operational control for ventilations and air treatment systems.

As a variant of the method described in the ISO 3966 and the EN 12599, this simplified method measures the velocity of points in a duct to obtain the airflow.

Three categories of methods for airflows measurement are described :

ID - *(In Duct)* **methods**	**ST - Supply ATDs methods** *(ATD=Air terminal devices)*	**ET – Exhaust ATDs methods**
ID 1 Pitot static tube	**ST 1** Reference pressure	**ET 1** Reference pressure at exhaust ATD
ID 2 Anemometer	**ST 2** Tight bag	**ET2** Flow hood
ID 3 Fixed devices	**ST 3** Flow hood	
ID 4 Tracer gas		

References:

EN 16211 - *Ventilation for buildings - Measurement of air flows on site - Methods*, 2015, 47 pages.

Release date, periodicity of revision:

2015

The standard is available for purchase from the national standardisation bodies of the EU member states.

Types of building covered (usage, size, etc.):

Residential buildings ☒		Non-residential buildings	☒
Houses	☒	Offices	☒
Apartments	☒	Retail buildings	☒
Others	☒	Educational buildings	☒
		Health buildings	☒
		Others	☒

Applies to all building types and sizes.

Types of ventilation systems covered (technology, type, airflows range, etc.):

This standard covers any type of mechanical ventilation systems.

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

The standard focuses on measurements in ducts, and at supply and exhaust air terminal devices.

Inspection can be operated by:

System designer ☐ Independent inspector ☐ Installer ☐ Maintenance staff ☐

Others (see below) ☐
This point is not covered by the standard.

Number of buildings/ventilation systems to which it is/has been applied:

No information available.

Inspection contents

Aspects covered:

- Completeness of the ventilation system ☐
- Cleanliness and general state of the ventilation system ☐
- Adequacy between design and installation ☐
- Good overall operation of the installed ventilation system ☐
- Measurement or assessment of air flow rates ☒
- Measurement or assessment of air pressures ☒
- Measurement or assessment of ductwork airtightness ☐
- Measurement or assessment of the electricity consumption ☐
- Measurement or assessment of indoor air quality parameters ☐
- Measurement or assessment of noise level ☐
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects ☐
- Adequacy with current ventilation needs ☐

Applied to:

- Each system ☐
- Each building ☐
- A sample (explain rules) ☒

This standard requires a length of straight duct and a uniform velocity profile in order to achieve the measurements uncertainties specified for the simplified method.

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☒
- Regular : periodicity is not clearly mentioned ☒

Inspection report:

- Certificate that the inspection has been performed ☐
- Report provided to the owner/occupant ☐
- Recommendations for improvement to owner/occupant ☐

This is not specified by the standard.

Specific issues

Stakeholders involved, their number and role, role of public authorities:

The standard has been elaborated by CEN TC 156 "Ventilation for buildings", the secretariat of which being held by BSI. The stakeholders involved are all those who contributed to the writing and editing of the standard.

Legal issues:

Must be published as a national standard in countries whose national standardisation body is a member of CEN. Any existing national standard that conflicts with the new European Standard must be withdrawn. The use of standards is voluntary and so there is no legal obligation to apply them.

Sanctions if the measure is not correctly implemented:

Not applicable.

Measuring instruments required, measuring uncertainty, calibration procedure:

The standard details the instruments required for each described method, as pitot static tube, anemometer, tracer gas, tight bag, flow hood, etc. It describes also the requirements on resolution and uncertainty for all the measuring devices.

The calibration procedures are not explained but the standard refers at the calibration instructions from measuring devices user guides.

Education or training needs:

Not specified.

Qualification of persons or companies required, quality assurance system required:

Not specified.

Cost for managing and maintaining the inspection scheme:

Not applicable.

Cost for applying the measure to a given building:

No information.

Advantages / Drawbacks

Advantages:

- This standard provides simplified methods for air flows measurements with various measurements instruments/methods.
- It can be referred to in other standards (as does the new revision of EN 14134) or national guidelines including protocols on ventilation inspection procedures, as the reference dealing with the airflows measures themselves.

Drawbacks:

- Some methods are conditioning with ductwork minimum length restriction.

Proven/known impact of the measure (indicators):

Impact unknown

Additional information

References / Source of information / Links:

The standard as well as the report can be purchased from the national standardisation bodies of EU countries.

EN 16211 is linked in whole or in part with the following references indispensable for its application:

- EN 12792, *Ventilation for buildings — Symbols, terminology and graphical symbols*
- EN 14277, *Ventilation for buildings — Air terminal devices — Method for airflow measurement by calibrated sensors in or close to ATD/plenum boxes*

The standard EN 14134 - *Ventilation for buildings - Performance testing and installation checks of residential ventilation systems* refers to this standard EN 16211 for the in situ airflows measurements themselves.

Author of the analysis: Gaëlle Guyot (Cerema)

French standard NF DTU 68.3 - Mechanical ventilation installations

Calculation rules, design and execution of residential mechanical ventilation systems

<table>
<tr><td rowspan="2">France</td><td rowspan="2">Legislation or Regulation ☐
Standard ☒
Guidelines ☐</td><td>Energy performance</td><td>Indoor air quality</td><td rowspan="2">Mandatory ☐
Voluntary ☒</td><td rowspan="2">AFNOR</td></tr>
<tr><td>Noise level</td><td>Thermal comfort</td></tr>
</table>

DESCRIPTION

The NF DTU standards, Unified Technical Documents, cover all or part of the professional rules. Following those rules ensure good design and installation of the covered systems. As it is a French standard, its use is voluntary. However specific contract can make it mandatory, especially for public buildings. Finally this is a reference document in the case of judicial appraisals.

The NF DTU 68.3 applies to new installations of mechanical ventilation system in residential buildings. It is composed of several parts (see references), concerning general rules for design and installation (Part 1.1.1), and specific rules for ventilations systems with self-adjusting flows (Part 1.1.2), ventilation systems coupled with gas heating appliances (Part 1.1.3), and mechanical extract and supply ventilation systems (Part 1.1.4). The part 2 concerns administrative clauses of contracts.

Each technical part describes design, sizing, implementation, and commissioning.

In Part 1.1.1, chapter 7 concerns completeness check (visual inspection), functional check (On/Off verification of controllers) and functional measurements. Functional measurements are made in order to verify that the required performances of the ventilation system are fulfilled, in the framework of the design hypothesis. Measurements concern: airflows (or pressure behind air terminal devices), flow direction, and in some cases, control and time functions. The auto-control test report with all measurements and check results is a part of the technical report given to the client.

In Part 1.1.1, chapter 8 concerns hand over and put into service of the installation.

The technical report of the installation shall include also: a description of the installation and controllers settings, goal of the ventilation, instructions of use, maintenance instructions.

References:

NF DTU 68.3 - Building works - Mechanical ventilation installations
Part 1-1: Calculation rules, design and execution - Contract bill of technical model clauses

Part 1-1-1: General rules
Part 1-1- : Self adjusting controlled single flow mechanical ventilation
Part 1-1-3: Controlled gas mechanical ventilation
Part : 1-1-4: Controlled and automatically adjustable fan-assisted balanced ventilation

Part 1-2: General criteria for selection of materials
Part 2: Contract bill of special administrative model clauses

Release date, periodicity of revision:

2017.

French standardization works are submitted to automatic revision every 5 years. The revision can occur before this period with the addition of new parts describing specific systems or when technical changes are asked by users or experts.

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☐
Houses	☒	Offices	☐
Apartments	☒	Retail buildings	☐
Others	☐	Educational buildings	☐
		Health buildings	☐
		Others	☐

Applies to new mechanical ventilation system installation in residential buildings.

Types of ventilation systems covered (technology, type, airflows range, etc.):

Dedicated to new installations of ventilation systems for dwellings, with mechanical extraction and passive or mechanical supply.

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Covers the whole ventilation system.

Inspection can be operated by:

System designer ☐ Independent inspector ☐ Installer ☒ Maintenance staff ☐

Others (see below) ☒

NF DTU 68.3 – Part 1.1.1 (general rules) describes how the "*contractor*" shall do tests, checking, put into service and handing over of the installation. It recommends also using self-check reports.

NF DTU 68.3 – Part 2 describes responsibilities: the "*enterprise*" in charge of the contract shall proceed to tests, control settings, commissioning and checking of the system.

It is clearly stated that the installer is not in charge of the connexion and commissioning of components that he has not directly supplied.

Number of buildings/ventilation systems to which it is/has been applied:

Information not available.

INSPECTION CONTENTS

Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☒

- Adequacy between design and installation ☒
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates ☒
- Measurement or assessment of air pressures ☒
- Measurement or assessment of ductwork airtightness ☐
- Measurement or assessment of the electricity consumption ☐
- Measurement or assessment of indoor air quality parameters ☐
- Measurement or assessment of noise level ☐
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects ☐
- Adequacy with current ventilation needs ☒

Applied to:

- Each system ☒
- Each building ☐
- A sample (explain rules) ☐

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☒
- Regular ☐

Inspection report:

- Certificate that the inspection has been performed ☐
- Report provided to the owner/occupant ☒
- Recommendations for improvement to owner/occupant ☒

The report should describe any deficiencies observed during the inspection.

SPECIFIC ISSUES

Stakeholders involved, their number and role, role of public authorities:

The NF DTU 68.3 has been written by the French standardisation committee BNTEC P50V, which is in charge of standardisation works on the installation (design, sizing, implementation, commissioning) of ventilation systems and their maintenance. Members are professionals concerned by the installation of ventilation systems: installers, system manufacturers, designers, measurement experts, maintenance organisation, etc. Each project is submitted to a public enquiry before publication.

Legal issues:

Using NF DTU 68.3 is voluntary. It can be made mandatory by specific contracts and can be considered as a reference document in the courts.

Sanctions if the measure is not correctly implemented:

If NT DTU 68.3 is mentioned in the clauses of the contract, the customer can refuse to accept the delivery if the installation is not in accordance with it.

Measuring instruments required, measuring uncertainty, calibration procedure:

Nothing is mentioned about measurement requirements.

Education or training needs:
Not mentioned

Qualification of persons or companies required, quality assurance system required:
Not mentioned

Cost for managing and maintaining the inspection scheme:
Information not available.

Cost for applying the measure to a given building:
Information not available.

ADVANTAGES / DRAWBACKS

Advantages:

- The NF DTU 68.3 standard is considered as a reference document for ventilation system installation
- The specific technical parts which are dedicated to ventilation systems are clear and describe well each technology. Examples are given for design, sizing and installation recommendations.

Drawbacks:

- The final checks and measurements are not really well described
- The responsibility of the final functional completeness may not be really clear in the case of several installers in charge of different parts of the ventilation system (i.e. air inlets, air terminal devices, transit sections, duct connexions,…)
- It is possible that the test occurs before the end of the building construction
- The inspection procedure is not well defined into the document, and can be very light.

Proven/known impact of the measure (indicators):

Impact unknown

ADDITIONAL INFORMATION

References / Source of information / Links:

https://www.boutique.afnor.org/norme/nf-dtu-683/travaux-de-batiment-installations-de-ventilation-mecanique-partie-1-1-1-regles-generales-de-calcul-dimensionnement-et-mise-en-oe/article/812718/fa183017

- *Author of the analysis: Laure Mouradian (CETIAT)*

ANSI/RESNET/ICC 380-2016
Testing airflow of mechanical ventilation systems

<table>
<tr><td rowspan="2">USA</td><td rowspan="2">Legislation or Regulation ☐
Standard ☒
Guidelines ☐</td><td>Energy performance</td><td>Indoor air quality</td><td rowspan="2">Mandatory ☐
Voluntary ☒</td><td rowspan="2">ANSI, RESNET, ICC</td></tr>
<tr><td>Noise level</td><td>Thermal comfort</td></tr>
</table>

DESCRIPTION

This standard was developed under the auspices of the Residential Energy Services Network (RESNET), a not-for-profit, membership corporation in the USA active in the fields of building energy efficiency rating and certification systems.

The standard provides a methodology for evaluating the airtightness of building envelope, the airtightness of heating and cooling air ducts and the air flows of mechanical ventilation systems.

It can be used on a voluntary basis in building diagnostics, in quality assurance and control, for determining compliance with codes and standards, and to determine input data to energy performance calculations.

The standard applies to single-family dwellings.
The procedures for measuring the airtightness of heating and cooling air ducts and the air flows of mechanical ventilation systems are also applicable to multifamily buildings, where each dwelling has its own duct/ventilation system separate from other dwellings.

The analysis below focuses on the measurement of air flows of mechanical ventilation systems.

The air flow through the mechanical ventilation systems can be measured at air inlet, at air outlet, or in the ventilation duct between air inlet and air outlet. The equipment needed and the measurement procedure are described for each of these three options.

The standard focuses on the measurement itself. It does not include requirements or information about the way to report or to use measurements results.

References:
ANSI/RESNET/ICC 380-2016: *Standard for testing airtightness of building enclosures, airtightness of heating and cooling air distribution systems, and airflow of mechanical ventilation systems,* 23 pages

Can be visualised online at:
https://codes.iccsafe.org/content/chapter/7325/?site_type=public
Or purchased.

Release date, periodicity of revision:

2016.

An addendum has been approved in 2017 for attics and crawlspaces.

A draft for a revised version was submitted to public comments in September-October 2018. The aim is to include dwellings and sleeping units for all residential and commercial buildings. Sleeping units are rooms or spaces in which people sleep, which can also include provisions for living and eating, and either sanitation or kitchen facilities but not both.

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☐
Houses	☒	Offices	☐
Apartments	☒	Retail buildings	☐
Others	☐	Educational buildings	☐
		Health buildings	☐
		Others	☐

Applies to apartments only when each of them has its own/independent ventilation system.

Types of ventilation systems covered (technology, type, airflows range, etc.):

Mechanical ventilation systems. Covers centralised and decentralised systems.

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Covers the whole ventilation system.

Inspection can be operated by:

System designer ☐ Independent inspector ☐ Installer ☐ Maintenance staff ☐

Others (see below) ☐

The standard says that the measurement procedure is intended for use by parties evaluating the performance of residential buildings, including energy raters/auditors for which a certification scheme is managed by RESNET.

Number of buildings/ventilation systems to which it is/has been applied:

Information not available.

INSPECTION CONTENTS

Aspects covered:

- Completeness of the ventilation system ☐
- Cleanliness and general state of the ventilation system ☐
- Adequacy between design and installation ☐
- Good overall operation of the installed ventilation system ☐
- Measurement or assessment of air flow rates ☒
- Measurement or assessment of air pressures ☐
- Measurement or assessment of ductwork airtightness ☐
- Measurement or assessment of the electricity consumption ☐
- Measurement or assessment of indoor air quality parameters ☐
- Measurement or assessment of noise level ☐
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects ☐
- Adequacy with current ventilation needs ☐

Applied to:

- Each system ☒
- Each building ☐
- A sample (explain rules) ☐

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☐
- Regular ☐

No information about the periodicity of measurements.

Inspection report:

- Certificate that the inspection has been performed ☐
- Report provided to the owner/occupant ☐
- Recommendations for improvement to owner/occupant ☐

No information about reporting. The standard focuses on the measurement method.

SPECIFIC ISSUES

Stakeholders involved, their number and role, role of public authorities:

The standard is developed and maintained by RESNET. It is published as an ANSI standard and recognised by the International Code Council.

Legal issues:

Using the standard is voluntary. RESNET says that its standards are recognized by Federal government agencies, IRS for tax credit qualification, U.S. Environmental Protection Agency for ENERGY STAR labeled homes and U.S. Department of Energy for Building America and National Builders Challenge programs. No information is given about the recognition of this specific standard.

Sanctions if the measure is not correctly implemented:

Not applicable.

Measuring instruments required, measuring uncertainty, calibration procedure:

The measuring instruments are described by the standard:

- For measuring air flows at air inlet: powered flow hood, or airflow resistance device (only for ventilation systems that do not have multiple duct branches), or passive flow hood
- For measuring air flows at air outlet: powered flow hood, or bag inflation device
- For measuring air flows inside duct: airflow measurement station (measuring and averaging velocity pressure across a duct diameter), or a diagnostic tool integrated to the ventilation system.

The standard requires that measuring instruments have their calibrations checked at the manufacturer's recommended interval, and at least annually if no time is specified. Maximum measurement errors are given by the standard (for example: 5 % or 2.5 L/s for hoods, whichever is greater; or 15% of the measured flow for integrated diagnostic tool).

Education or training needs:
Not mentioned

Qualification of persons or companies required, quality assurance system required:
Not mentioned

Cost for managing and maintaining the inspection scheme:
Information not available.

Cost for applying the measure to a given building:
Information not available.

ADVANTAGES / DRAWBACKS

Advantages:
- Focused on the measurement of air flow rates, at various places in the ventilation system, and with several types of measuring instruments.

Drawbacks:
- It is not explained whether the different measuring instruments that can be used together with the specific requirements about the maximum measurement errors provide consistent results or not.

Proven/known impact of the measure (indicators):

Impact unknown

ADDITIONAL INFORMATION

References / Source of information / Links:
Version 2016 of the standard:
https://codes.iccsafe.org/content/chapter/7325/?site_type=public
Draft for revision submitted to public comments in fall 2018:
http://www.resnet.us/blog/wp-content/uploads/2018/08/DraftPDS-03.3ChangesToDraftPDS-02BSR_RESNET_ICC380_final_webcmnt.docx

- *Author of the analysis: François Durier (CETIAT)*

Annex 6 – Analysis of existing guidelines

A total of 47 guidelines items have been identified. Despite our best efforts, this list is probably not exhaustive.

14 of them have been selected for a detailed analysis (see Annex 7).

The following countries are covered: Austria, Belgium, Finland, France, Germany, Ireland, Netherlands, Poland, Sweden, United Kingdom, Switzerland, Turkey, and USA.

45% of the identified items are applicable to residential ventilation systems and 45% to ventilation systems in all types of buildings. Only a few guidelines (10%) are dedicated to non-residential ventilation systems.

Guidelines describe commissioning, hand over or inspection operations, either for stand-alone ventilation systems or for air conditioning and ventilation systems. They mainly focus on initial inspection. They usually apply to the whole ventilation system or to the ductwork alone.

Guideline contents can include:

- general text providing explanations on how to operate inspection
- checklist without explanations
- checklist with guidance and explanations
- detailed practical procedure, including the description of measurements and of the measuring instruments

Most of the identified items rely on check-lists or visual inspection. 40% include airflow measurements, while less than 20% require the measurement of electrical consumption and less than 20% the measurement of ductwork airtightness.

Some guidelines describe the measuring instruments and the way to use them. Two of them focus on this topic.

Checking the adequacy of ventilation operation with the current ventilation needs is generally not an objective.

The persons that should use the guidelines are not always mentioned, but most of the identified items are intended for installers. Reporting of the inspection is not always described.

Annex 7 – Detailed analysis of a selection of existing guidelines

- Practical Guide DIAGVENT - Diagnostic of ventilation installations in residential and tertiary buildings (France)
- PROMEVENT - Diagnostic protocol for the residential mechanical ventilation systems (France)
- ASHRAE Indoor Air Quality Guide - Best Practices for Design, Construction and Commissioning (USA)
- Inspection of natural and hybrid ventilation systems - French guidelines (France)
- Inspection of newly-installed balanced ventilation systems in residential buildings (France)
- French protocols for the initial inspection of ventilation systems by the installer (France)
- VVS Allmän Material och Arbetsbeskrivning, VVS AMA - General material and workmanship specifications on HVAC (Sweden)
- Unified Technical Specifications STS-P73-1 - Systems for the basic ventilation in residential applications (Belgium)
- Practical guidelines for residential buildings basic ventilation – Technical information note – NIT 258 (Belgium)
- The Dutch voluntary ventilation inspection (VPK) (Netherlands)
- Inspection guidelines for ventilation systems by the HVAC Association of Finland SuLVI (Finland)
- French documents for self-check by installers of the quality of installation of residential ventilation systems (France)
- VDI 6022-1 - Ventilation and indoor-air quality - Hygiene requirements for ventilation and air-conditioning systems and units (Germany)
- Inspection of the cleanliness of ventilation systems (Finland)

▪ Practical Guide DIAGVENT

Diagnostic of ventilation installations in residential and tertiary buildings

France	Legislation or Regulation ☐ Standard ☐ Guidelines ☒	Energy performance Noise level	Indoor air quality Thermal comfort	Mandatory ☐ Voluntary ☒	CETIAT PBC

Description

This practical free guide describes three procedures for the inspection of mechanical ventilation systems by professionals in residential and non-residential buildings. The three procedures correspond to three levels of details of the inspection:

- Diagvent 1: Inspection of the completeness and good overall operation of the ventilation system, without measurement
- Diagvent 2: Inspection of the performance of the ventilation system, including measurements
- Diagvent 3: Specific measurements on the ventilation system to determine causes of identified malfunctions

The two first levels Diagvent 1 and 2 rely on check lists, in addition to the explanations given by the guide.

Reference:

CETIAT and PBC, *Diagnostic des installations de ventilation dans les bâtiments résidentiels et tertiaires - Guide pratique DIAGVENT*, 2005, CETIAT, 40 pages

Release date, periodicity of revision:

2005

Available in paper format - today out of print - and through free download at www.cetiat.fr.
No revision since the first release.

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☒
Houses	☒	Offices	☒
Apartments	☒	Retail buildings	☒
Others	☐	Educational buildings	☒
		Health buildings	☒
		Others	☐

Applies to all building sizes.

Types of ventilation systems covered (technology, type, airflows range, etc.):

Dedicated to mechanical ventilation systems of all types (any size and flow rate.

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Covers the whole ventilation system (any capacity).

Cover page of the guide

Fiche de Diagnostic « Niveau 1 » du Système de Ventilation
(Vérification de la complétude et mise en route)

Trois principales actions sont à mener :
1/ Vérification de la concordance des matériels installés avec ceux préconisés au cahier des charges
2/ Vérification des branchements aérauliques et électriques
3/ Mise en route de l'installation
Pas de mesures, appui de photos souhaitable. L'intervention a lieu avant livraison des locaux aux occupants.

☒ Défauts importants à corriger rapidement ☒ Pas de défauts importants, défauts mineurs éventuels

Ouvrage/Réalisation/Complexe/Site Immeuble collectif 16 logements R+3	**Expert-Diagnostic** M,X	**Niveau Qualif.** Qualification	**Société** Société X
Adresse Ville moyenne, sud de la France	**Adresse** N°, bd, Ville		**Tél.** N°
Date de livraison prévue 2004 (neuf)	**Signature** X		**Date de la visite** Août 2004
Propriétaire/Gestionnaire Promoteur – destiné vente	**Adresse** Ville moyenne, sud de la France		**Tél.** N°
Responsable technique Aucun	**Adresse** -		**Tél.** N°
Activité bâtiment Résidentiel collectif		**Bâtiment (n°, nom)** 1	**Désignation du Système (nom)** SF-H
Type Système (N,SF,DF,DFX) SF hygro	**Débit d'Air (connu)** Hygroréglable	**Fonctionnement (sem., jour,...)** Année	**Utilisation (ponct., permanent...)** Permanent

Etape	Opération/Point à vérifier	Défaut/Problème	Note *	Autre observation	OK
	Point sur la Documentation				
	Documents disponibles			Disponibles : plans et étude thermique	OK
A	**Vérifications de l'Armoire Electrique**				
B.1	Tension d'alimentation			A priori tout est normal,	OK
B.2	Raccordement à la terre			mais le M/A du système ne peut être	
B.3	Alimentation indépendante			testé car l'immeuble n'est pas encore	
B.4	Dispositif Arrêt/Protection			alimenté en triphasé	
B	**Inspection visuelle des Réseaux**				
C.1	Nature des conduits				OK
C.2	Tracé	Réseau horizontal différent de l'étude		Attention à l'équilibrage	
C.3	Singularités			RAS	OK
C.4	Raccordements			Etanchéité soignée en combles	OK
C.5	Caissons de piquages			Présents (sauf 1, manque de place)	OK
C.6	Supports, suspentes				OK
C.7	Accessibilité	Laine minérale projetée en combles		Réseau vertical inaccessible	
	...				
C	**Inspection visuelle du(des) Caisson(s)**				
D.1	Accessibilité				OK
D.2	Type(s)			Type prévu dans l'étude	OK
D.3	Raccordements	Rejet non raccordé	2		
D.4	Tension courroie				OK
D.5	Alignement poulies				OK
D.6	Support				OK
D.7	Facilité d'ouverture				OK
D.8	Alimentation électrique				OK
	...			Manuel du caisson sur place	OK
D	**Mise en route du(des) Caisson(s)**				
E.1	Sens de rotation			(cf. B)	
E.2	Bruit, vibrations			(cf. B)	

Check-list (extract) for Diagvent1

Inspection can be operated by:

System designer ☒ Independent inspector ☒ Installer ☒ Maintenance staff ☒

Others (explain who) ☐

Number of buildings/ventilation systems to which it is/has been applied:

Information not available.

From 2005 to 2018, the number of downloads of the guide is 8329, corresponding to a mean value of about 600 downloads/year.

Inspection contents

Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☒
- Adequacy between design and installation ☒
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates ☒
- Measurement or assessment of air pressures ☒
- Measurement or assessment of ductwork airtightness ☒
- Measurement or assessment of the electricity consumption ☒
- Measurement or assessment of indoor air quality parameters ☒
- Measurement or assessment of noise level ☒
- Measurement or assessment of thermal comfort parameters ☒

- Report provided to the owner/occupant ☒
- Report including recommendations for improvement ☒

Some measurements are only mentioned by the most detailed inspection level (Diagvent3): ductwork airtightness, indoor air quality parameters (air humidity), noise level, thermal comfort parameters (air velocities, air temperature).

Applied to:

- Each system ☒
- Each building ☐
- A sample (explain rules) ☐

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☒
- Regular : periodicity not mentioned ☒

Inspection report:

- Certificate that the inspection has been performed ☐
- Report provided to the owner/occupant ☒
- Recommendations for improvement to owner/occupant ☒

Specific issues

Stakeholders involved, their number and role, role of public authorities:

The guide was developed by CETIAT, the French Technical Centre of HVAC system manufacturers, together with a consultant (PBC – Pierre Barles Consultant), at the request of ventilation system manufacturers. Four major ventilation system manufacturers contributed to validating the contents.

The budget for the developing the guide was provided by ventilation system manufacturers (through their CETIAT membership) and ADEME (the public French Environment and Energy Management Agency).

The guide was then referred to (status 2014) in:

- rules of three national certification programmes on building quality (NF Logement, NF Logement HQE, Habitat et Environnement),
- one guide from the Ministry of Ecology on the prevention of environmental health risks in buildings with children (2007)
- specifications of some construction programmes
- a subsidies programme for social residential buildings in the French region of Alsace (2013)
- a training session on ventilation system installation, proposed by CSTB (2012).

In addition, diagnosis according to the guide were proposed by several inspection companies. The actual number of inspections is unknown.

A two days training session is proposed by CETIAT and PBC for 2011. In the period 2011-2018, a total of 41 persons were trained.

Legal issues:

A detailed analysis of national and regional law and regulations would be required to identify specific legal issues.

Sanctions if the measure is not correctly implemented:

Not applicable.

Measuring instruments required, measuring uncertainty, calibration procedure:

For the level of inspection Diagvent2, measuring instruments are required for the following quantities: airflow rate and/or air velocity, air pressure, electrical power.

For the level of inspection Diagvent3, additional measuring instruments are mentioned for: noise level, air humidity, air temperature.

Photos from the guide showing examples of the measuring instruments required

Education or training needs:

No.

Qualification of persons or companies required, quality assurance system required:

No.

Cost for managing and maintaining the inspection scheme:

Implementation: 50 k€ (2003-2004).
No maintenance cost.

Cost for applying the inspection to a given building:

For the level of inspection Diagvent2, the guide provides the time estimation mentioned in the following table:

	Time required for one inspector (in person x days)			
	Preparation, studying documentation	Measurements, on-site inspection	Analysis and report	Total
Residential building with 30 apartments	0.25	0.75	0.5	1.5
Small tertiary building (1000 m²)	0.25	0.75	0.5	1.5
Medium tertiary building (between 1000 and 5000 m²)	0.5	1	0.75	2.25
Series of 4 tertiary buildings (total area between 5000 and 20000 m²)	0.75	4	1	5.75

The guide estimates that if two inspectors are present, totals (last column) become respectively: 1, 1, 1.5 and 3. It also mentions that 0.5 day should be added in case a meeting is organised to present results.

Advantages / Drawbacks

Advantages:

- Voluntary inspection, operated by various professionals, without the need for specific training or qualification
- Free guide based on check-lists
- Simple to use for persons with a certain knowledge of mechanical ventilation systems (technicians, engineers)

Drawbacks:

- Measuring appliances required for the level Diagvent2
- No control of the actual use of the guide
- No control of the way the guide is used or referred to by other initiatives
- Limited feedback from users of the guide
- No revision since 2005

Proven/known impact of the measure (indicators):

Impact unknown, except through the number of downloads of the guide (8329)

Additional information

References / Source of information / Links:

Guide:
http://www.cetiat.fr/fr/downloadpublic/index.cfm?docname=guide_diagvent.pdf

Check-lists for Diagvent1 and Diagvent2:
http://www.cetiat.fr/fr/downloadpublic/index.cfm?docname=diagvent_fiche_niv1.doc
http://www.cetiat.fr/fr/downloadpublic/index.cfm?docname=diagvent_fiche_niv2.doc

- *Author of the analysis: François Durier (CETIAT)*

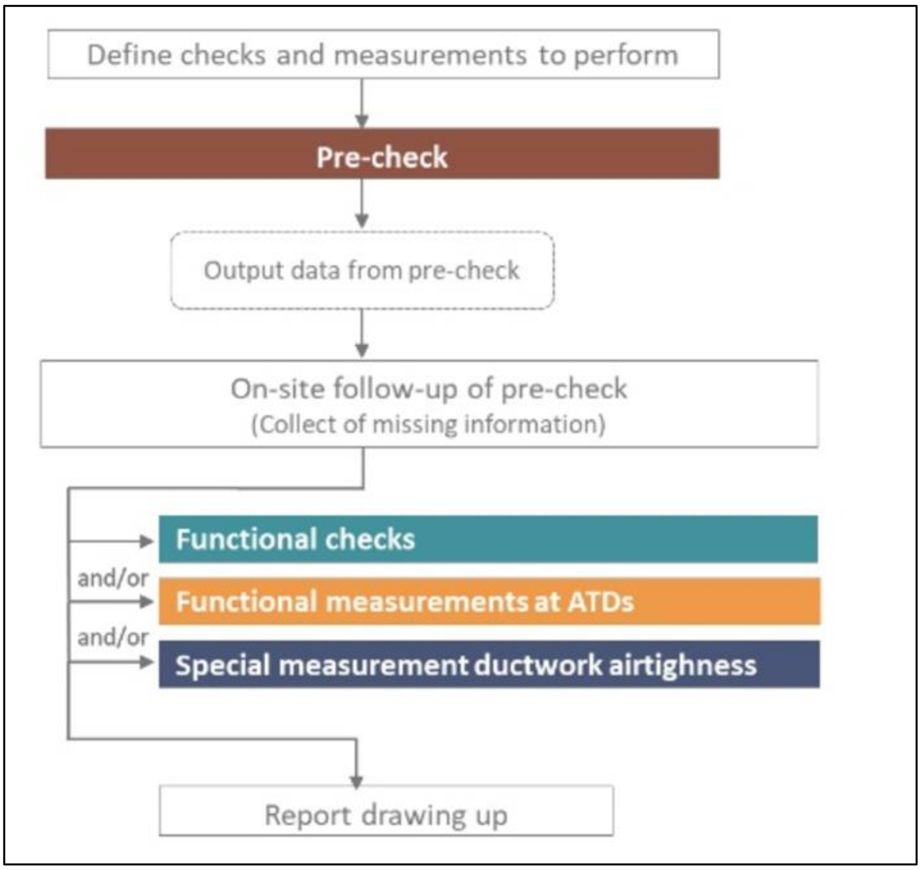
PROMEVENT

Diagnostic protocol for the residential mechanical ventilation systems

France	Legislation or Regulation ☐ Standard ☐ Guidelines ☒	Energy performance	Indoor air quality	Mandatory ☐ Voluntary ☒	PROMEVENT CEREMA
		Noise level	Thermal comfort		

Description

The Promevent protocol proposes a method to assess the on-site quality of residential mechanical ventilation systems.
The targeted buildings of this protocol are new single-family houses and multi-family dwellings.
The Promevent guidelines (December 2016) illustrate and give details explanations regarding the different steps of the Promevent protocol, in order to help the inspector on–site but also to provide support for training.
This protocol includes a documents analysis (pre-check), visual checks, airflow rate or pressure difference measurements at air terminal devices and a ductwork air leakage measurement.
The protocol applies for single humidity controlled ventilation system and balanced ventilation systems.



Organization of a ventilation system inspection according to the Promevent methodology

Reference:
CEREMA, Promevent - *Protocole de Diagnostic des installations de ventilation mécanique résidentielles*, 2016, ADEME, 46 pages

Release date, periodicity of revision:

October 2016. Revision: not planned.

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☐
Houses	☒	Offices	☐
Apartments	☒	Retail buildings	☐
Others	☐	Educational buildings	☐
		Health buildings	☐
		Others	☐

Applies to all building sizes.

Types of ventilation systems covered (technology, type, airflows range, etc.):

Humidity controlled exhaust-only ventilation systems and balanced ventilation systems.

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):
Covers the whole ventilation system: externally mounted air transfer devices, internally mounted air transfer devices, ducted air terminal devices (inside), ductwork, air handling unit including heat recovery.

Inspection can be operated by:

System designer ☒ Independent inspector ☒ Installer ☒ Maintenance staff ☒

Others (explain who) ☐

The Promevent protocol does not provide information regarding the operator of the checks and measurements. But it can be required by some labels as the Effinergie label which requires an independent and state-approved measurer.

Number of buildings/ventilation systems to which it is/has been applied:

There is no available data.

Nevertheless, several schemes require the Promevent protocol to be used:
- For each dwelling candidate to an Effinergie label, an independent and state-approved measurer has to verify the quality of the ventilation system according to the Promevent protocol,
- The Promevent protocol has to be used to assess the quality of the ventilation system in order to obtain the "bonus of constructability" with IAQ criteria (described in regulatory documents),
- The Promevent protocol has to be used to prove the respect of the IAQ criteria in the "public buildings showing exemplarity energy and environmental" approach (described in regulatory documents).

Inspection contents

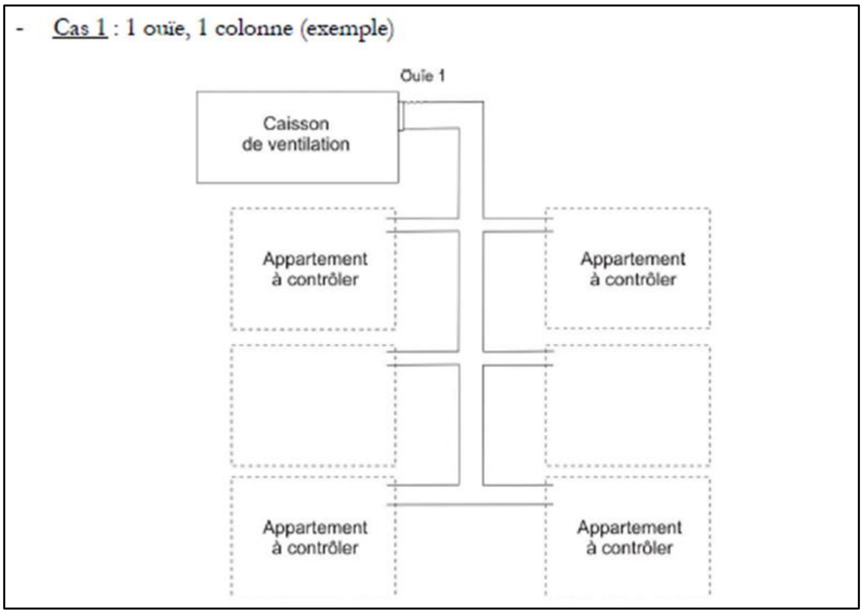
Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☒
- Adequacy between design and installation ☒
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates ☒
- Measurement or assessment of air pressures ☒
- Measurement or assessment of ductwork airtightness ☒
- Measurement or assessment of the electricity consumption ☐
- Measurement or assessment of indoor air quality parameters ☐
- Measurement or assessment of noise level ☐
- Measurement or assessment of thermal comfort parameters ☐
- Report provided to the owner/occupant ☐
- Report including recommendations for improvement ☐

Applied to:

- Each system ☒
- Each building ☒
- A sample (explain rules) ☒

The Promevent protocol defines rules for sampling in multi-family dwellings regarding the dwellings choice. In each dwelling, there is no sampling. The rules apply to one ventilation unit that serves more than 5 dwellings. In that case, it is possible to control only 4 dwellings. The rules are detailed in Annex A.

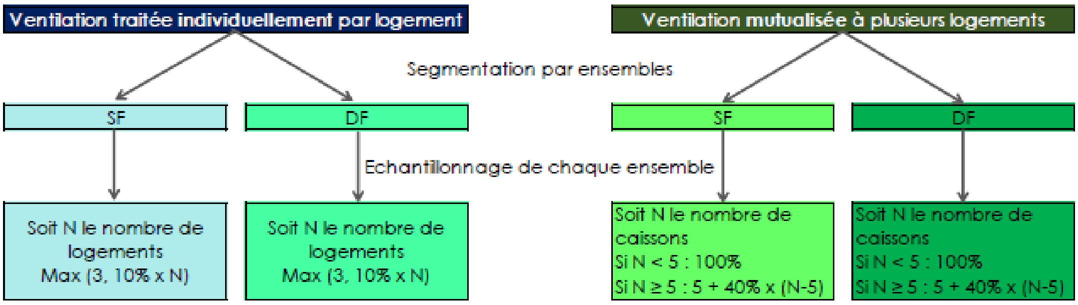


Example of sampling for a ventilation unit with one inlet for one column

The Promevent protocol does not provide information regarding buildings sampling or ventilation units sampling.

Nevertheless, a national working group dedicated to the application of the Promevent protocol has been supervised by the Ministry in charge of the construction during the last 2 years to give rules regarding buildings sampling:

- For an operation including several single-family houses or a building including several dwellings with independent ventilation systems, the size of the sample is max(10% of the number of dwellings ; 3). Dwellings included in the sample are chosen depending on their floor area.
- For an operation including several single-family houses with common ventilation systems or a building including several dwellings with common ventilation systems, a sampling can be done if there are more than 5 air handling units. In that case, it is possible to check 5 units + 40% "of the remaining" units. The units that must be controlled are chosen regarding the maximum airflow rate.



Scheme of the sampling process for an operation with several buildings

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☒
- Regular : periodicity not mentioned ☐

Inspection report:

- Certificate that the inspection has been performed ☒
- Report provided to the owner/occupant ☒
- Recommendations for improvement to owner/occupant ☐

Specific issues

Stakeholders involved, their number and role, role of public authorities:

This document is one of the deliverables of the research project "Promevent" financed by the national agency ADEME in the frame of the call "Towards sustainable buildings in 2020".

This protocol is build thanks to the partnership between: Cerema - Centre-Est (9 persons, Public expertise and coordination), CETIAT (2 persons, Laboratory of studies and test), ALLIE'AIR (4 persons, Engineering consultants), CETii (1 person, Engineering consultant), PBC (1 person, Engineering consultant), Effinergie (2 persons, labelling national organization), with the collaboration of : ICEE (1 person) and PLEIAQ (1 person).

This is a voluntary scheme which can be used by any certification, labelling or regulation body.

Legal issues:

Information not available. A detailed analysis of national and regional law and regulations would be required to identify specific legal issues.

Sanctions if the measure is not correctly implemented:

Not applicable.

Measuring instruments required, measuring uncertainty, calibration procedure:

Recommended measuring instruments for the air flows :

- uncompensated cones equipped with:
  - anemometer with reel, or
  - thermal anemometer, or
  - Pitot tube
- cones with pressure compensation

The total measurement uncertainty has to be less than 15%. The respect of this requirement has to be justified:

- By a certificate that proves that the maximal permissible error (MPE) is below 10% and the technology of the measuring device meets with the use cases defined by the Promevent guide (Figure below),
- Or by a complete uncertainty calculation.

Recommended measuring instrument for the pressure is a manometer fitted with a flexible measuring tube. The total measurement uncertainty has to be less than 10% or 5 Pa. The respect of this requirement has to be justified:

- By a certificate that proves that the maximal permissible error (MPE) is below 3% or 0.5 Pa,
- Or by a complete uncertainty calculation.

	Extraction		Soufflage		
Cône avec anémomètre thermique ponctuel	✓	✓	✗	✗	✗
Cône avec réseau d'anémomètre thermique en quadrillage	✓	✓	✓	✓	✗
Cône avec mesure de pression en croix et compensation	✓	✓	✓	✓	✓
Cône avec anémomètre à moulinet	✓	✓	✓	✓	✗
Cône avec anémomètre à moulinet déporté	✓	✓	✓	✓	✓

Measurement devices use cases defined in the Promevent guide, depending on the type of exhaust and supply air terminal devices

Education or training needs:

In order to raise awareness among ventilation professionals, the Promevent protocol has been included in the Praxibat training course. Praxibat is a national training plan regarding buildings energy efficiency. It includes 203 technical facilities in France, with 74 dedicated to ventilation. The ventilation training lasts 3 days and includes theoretical parts to understand the different types of ventilation systems, and practical parts to learn how to install a ventilation system, and how to check it.

The Promevent protocol is also be presented in a MOOC dedicated to indoor air quality and buildings ventilation.

Finally, the Promevent protocol is presented during the training included in the national testers competent scheme for ductwork airtightness measurement.

Qualification of persons or companies required, quality assurance system required:

Not specified.

Cost for managing and maintaining the inspection scheme:

Not specified.

Cost for applying the inspection to a given building:

Not specified.

Advantages / Drawbacks

Advantages:

- At the starting point, several existing protocols were used including the ones used in the regulatory compliance checks of residential ventilation systems in France (Carrié, Charrier, and Mélois 2015), in the former versions of the Effinergie labels, and developed in the quality management approaches of the "VIA Qualité" Project (Charrier et al. 2018)
  During the different steps of the Promevent project, a very large group of professionals has been consulted: from the French Ministry in charge of Construction and from the French Environment and Energy Management Agency (ADEME), but also from various associations or federations representative of industrials, builders, measurers, certification organisms, standardization organisms, training organisms, etc. Due to this consultation, the Promevent protocol is very largely accepted and it is becoming the national reference for inspection of mechanical ventilation systems in dwellings.
  It has also been used in the EN standard 14134 revision (see other analysis file).

Drawbacks:

- The Promevent protocol only applies to residential buildings and to mechanical ventilation systems. A similar research project is undergoing regarding non-residential buildings: the PromevenTertiaire project. It should propose a similar protocol for non-residential buildings. A method for evaluate the performance of natural ventilation system is tested in the VNat project.

Proven/known impact of the measure (indicators):

There is no feedback for now, but some projects of database are ongoing. We hope to have detailed feedback in the next few years.

Additional information

References / Source of information / Links:

Carrié, F. Rémi, Sandrine Charrier, and Adeline Mélois. 2015. "Regulatory Compliance Checks of Residential Ventilation in France." *Qualicheck Factsheet 6*, 7 p.

Charrier, S., G. Guyot, R. Jobert, F. R. Carrié, and C.S. Coeudevez. 2018. "Development and Test of Quality Management Approach for Ventilation and Indoor Air Quality in Single-Family Buildings." In *Smart Ventilation for Buildings*. 39th AIVC Conference, Juan les Pins, France.

CEREMA, 2016. Promevent - "Protocole de Diagnostic des installations de ventilation mécanique résidentielles", ADEME, 46 pages www.promevent.fr

Mélois, A., and L. Mouradian. 2018. "Applications of the Promevent protocol for ventilation systems inspection in French regulation and certification programs". In *Smart Ventilation for Buildings*. 39th AIVC Conference, Juan les Pins, France.

Authors of the analysis: Adeline Mélois and Gaëlle Guyot (Cerema)

ASHRAE Indoor Air Quality Guide

Best Practices for Design, Construction and Commissioning

USA	Legislation or Regulation ☐ Standard ☐ Guidelines ☒	Energy performance	Indoor air quality	Mandatory ☐ Voluntary ☒	ASHRAE
		Noise level	Thermal comfort		

Description

This free guide for architects, design engineers, contractors, commissioning agents, and professionals concerned with indoor air quality provides guidance for achieving eight critical IAQ objectives:

- Manage the Design and Construction Process to Achieve Good IAQ;
- Control Moisture in Building Assemblies;
- Limit Entry of Outdoor Contaminants;
- Control Moisture and Contaminants Related to Mechanical Systems;
- Limit Contaminants from Indoor Sources;
- Capture and Exhaust Contaminants from Building Equipment and Activities;
- Reduce Contaminant Concentrations through Ventilation, Filtration, and Air Cleaning;
- Apply More Advanced Ventilation Approaches

For each objective are proposed several strategies (with a total of 40 strategies) that are explained in details. Strategies include best practices for commissioning and design for maintainability. Examples of strategies: commission to ensure that the owner's IAQ requirements are met; facilitate effective operation and maintenance for IAQ.

The commissioning of ventilation systems is thus described in relationship with many aspects of indoor air quality.

Reference:

ASHRAE, *Indoor Air Quality Guide - Best Practices for Design, Construction and Commissioning*, 2010, ASHRAE, 696 pages

Release date, periodicity of revision:

2009

Available for free download after registration at www.ashrae.org. Print format available for purchase.
No revision since the first release.

Types of building covered (usage, size, etc.):

Residential buildings	☐	Non-residential buildings	☒
Houses	☐	Offices	☒
Apartments	☐	Retail buildings	☒
Others	☐	Educational buildings	☒
		Health buildings	☒
		Others	☐

Applies to commercial and institutional buildings.

Types of ventilation systems covered (technology, type, airflows range, etc.):

All types of ventilation systems (any capacity in commercial and institutional buildings).

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):
Covers the whole ventilation system.

Inspection can be operated by:

System designer ☒ Independent inspector ☒ Installer ☒ Maintenance staff ☒

Others (explain who) ☐

Number of buildings/ventilation systems to which it is/has been applied:

Information not available.

Inspection contents

Aspects covered:
This part of the analysis template has been adapted to this specific document, since it does not describe a specific inspection procedure but more generally the commissioning process for indoor air quality, from design to functional testing.

Aspects covered are uUnlimited, but commissioning and maintenance applications could include:

- Building pressurization control
- Outdoor air rates
- Humidity and temperature control
- Air handler controls
- Energy recover devices
- Automatic system operation

Applied to:

- Each system ☒
- Each building ☐
- A sample (explain rules) ☐

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☒
- Regular : periodicity not mentioned ☒

Inspection report:

- Certificate that the inspection has been performed ☐
- Report provided to the owner/occupant ☒
- Recommendations for improvement to owner/occupant ☒

Specific issues

Stakeholders involved, their number and role, role of public authorities:

The guide was developed by ASHRAE with several other organisations: American Institute of Architects, BOMA International, Sheet Metal and Air-Conditioning Contractors' National Association, U.S. Green Building Council, and U.S. Environmental Protection Agency. The EPA funded the development of the guide, but it is an industry developed document.

A course has been developed by ASHRAE to convey knowledge based upon the guide.

Legal issues:

Information not available. A detailed analysis of national and regional law and regulations would be required to identify specific legal issues.

Sanctions if the measure is not correctly implemented:

Not applicable.

Measuring instruments required, measuring uncertainty, calibration procedure:

Not specified.

Education or training needs:

Not specified.

Qualification of persons or companies required, quality assurance system required:

Not specified.

Cost for managing and maintaining the inspection scheme:

The guide is much broader than an inspection procedure. The development of the guide started 3 years before publication. The project committee members (19 persons) who wrote the guide met 14 times in 20 months and held numerous conference calls. 60 persons participated in 2 peer reviews, providing 1200 remarks.

Cost for applying the inspection to a given building:

Variable.

Advantages / Drawbacks

Advantages:

- Integrated approach that assures proper operation at start-up
- The focus on IAQ allows to explore all the aspects linked to this issue
- Free guide
- Very practical explanations that seem well adapted to the target audience

Drawbacks:

- Many pages
- The focus on IAQ could lead to forget other issues

Proven/known impact of the measure (indicators):

Impact unknown.

Additional information

References / Source of information / Links:

Guide:

https://www.ashrae.org/technical-resources/bookstore/indoor-air-quality-guide

- *Authors of the analysis:*
- *Max Sherman (EPB Consulting Group)*
- *François Durier (CETIAT)*

Inspection of natural and hybrid ventilation systems
French guidelines

<table>
<tr><td rowspan="2">France</td><td rowspan="2">Legislation or Regulation ☐
Standard ☐
Guidelines ☒</td><td>Energy performance</td><td>Indoor air quality</td><td rowspan="2">Mandatory ☐
Voluntary ☒</td><td rowspan="2">AVEMS</td></tr>
<tr><td>Noise level</td><td>Thermal comfort</td></tr>
</table>

Description

This procedure for the inspection of natural and hybrid ventilation systems is part of a guide mainly dedicated to the design and installation of such systems.

The guide has been developed by AVEMS, an association of French manufacturers of natural and hybrid ventilation systems, with inputs from research organisations and financial help from public authorities and energy suppliers.

One among ten chapters of the guide covers commissioning, maintenance and inspection (5 pages, including 2 pages of annexes, on a total of 75 pages).

Reference:

AVEMS, *Guide de la ventilation naturelle et hybride "VNHY"® - Conception, dimensionnement, mise en œuvre, maintenance*, 2010, AVEMS (Association professionnelle des industriels français pour la valorisation en ventilation de l'extraction mécanique-statique ou statique), in French, 76 pages

Release date, periodicity of revision:

2010

No revision since the first issue.

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☐
Houses	☐	Offices	☐
Apartments	☒	Retail buildings	☐
Others	☐	Educational buildings	☐
		Health buildings	☐
		Others	☐

The types of buildings covered is not very clearly mentioned in the guide but the regulations and the design rules of natural and hybrid ventilation systems are only described for apartment buildings. We can thus assume that the inspection part of the guide applies also to apartments buildings.

Types of ventilation systems covered (technology, type, airflows range, etc.):

Natural and hybrid ventilation systems in residential multi-storey buildings.

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Covers the whole ventilation system.

Inspection can be operated by:

System designer ☒ Independent inspector ☒ Installer ☒ Maintenance staff ☒

Others (see below) ☐

This information is not explicitly given but we assume that the inspection can be operated by several different persons.

Number of buildings/ventilation systems to which it is/has been applied:

Information not available.

Inspection contents

Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☒
- Adequacy between design and installation ☐
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates ☒
- Measurement or assessment of air pressures ☐
- Measurement or assessment of ductwork airtightness ☐
- Measurement or assessment of the electricity consumption ☐
- Measurement or assessment of indoor air quality parameters ☐
- Measurement or assessment of noise level ☐
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects ☐
- Adequacy with current ventilation needs ☐

The guide says that the inspection phases are described in standard EN 15239: 2007 "Ventilation of buildings - Energy performance of buildings - Guidelines for inspection of ventilation systems" but, given the great diversity of installation, architecture, and construction of buildings, that the verification process must be adapted as much as possible to the building.
The guide also mentions that measurements or simulations (temperature, humidity, wind speed, test hours, flow rates, pressures, detections, modulation, case of failure, security ...) may be necessary in order to validate inspection. Measurements and tests must be recorded in a report. But the guide also indicates that in case of proven good quality of the maintenance program, these checked points can be lightened.
The guide also states that measuring instantaneous airflows for natural ventilation systems is not necessary since they are too much dependent on outdoor conditions.

Applied to:

- Each system ☒
- Each building ☐
- A sample (explain rules) ☐

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☐
- Regular : periodicity is not clearly mentioned ☒

Inspection report:

- Certificate that the inspection has been performed ☐
- Report provided to the owner/occupant ☒
- Recommendations for improvement to owner/occupant ☐

Specific issues

Stakeholders involved, their number and role, role of public authorities:

The regulation and the online guide were developed by the French association of manufacturers of natural and hybrid ventilation systems AVEMS.

Legal issues:

Information not available. A detailed analysis of national and regional law and regulations would be required to identify specific legal issues.

Sanctions if the measure is not correctly implemented:

Not applicable.

Measuring instruments required, measuring uncertainty, calibration procedure:

The online guide provides a check-list for the commissioning and maintenance of the systems. For inspection, a list of points to be checked is given but it is not always very precise, especially concerning the needs to operate measurements.

Education or training needs:

No information available.

Qualification of persons or companies required, quality assurance system required:

See previous point.

Cost for managing and maintaining the inspection scheme:

The guide has been developed by several manufacturers members of AVEMS with inputs from research organisations and a financial contribution from ADEME, the French Ministry of Housing, USH (Association of social housing companies) and two energy suppliers (EDF and GDF Suez).

Cost for applying the measure to a given building:

Information not available.

Advantages / Drawbacks

Advantages:

- Very few documents exist on the inspection of natural and hybrid ventilation systems.

Drawbacks:

- The guide is mainly focused on the design and installation of natural and hybrid ventilation systems. The inspection procedure is described very shortly, and thus not very precisely. Reference is made to the European standard EN 15239: 2007 that was valid at the time the guide was published, but the guide suggests that its requirements must be adapted on a case-by-case basis.
-

Proven/known impact of the measure (indicators):

Impact unknown

Additional information

References / Source of information / Links:

Online guide:
https://www.ademe.fr/sites/default/files/assets/documents/guide-ventilation-naturelle-et-hybride-vnhy-2010.pdf

Author of the analysis: François Durier (CETIAT)

Inspection of newly-installed balanced ventilation systems in residential buildings

France	Legislation or Regulation ☐ Standard ☐ Guidelines ☒	Energy performance	Indoor air quality	Mandatory ☐ Voluntary ☒	CSTB
		Noise level	Thermal comfort		

Description

This inspection procedure is described in one chapter of a guide whose title can be translated as: "Residential balanced ventilation systems: design, implementation and maintenance in accordance with the French standard NF DTU 68.3".

The main objective of this guide is to provide recommendations for a good design and implementation of the system, but it also includes an inspection part (7 pages) that describes the contents for the reception at completion of works for the ventilation system.

The guide relies on the French standard NF DTU 68.3 Part 1.1.4 "Installations de ventilation mécanique - Partie 1-1-4 : Ventilation mécanique contrôlée autoréglable double flux - Règles de calcul, dimensionnement et mise en œuvre" published in 2017. This standard includes a description of the reception at completion of works for a newly-installed balanced ventilation system in a house or in an apartment building.

The standard requires that the following points are controlled:

- the conformity of the system to the design and sizing specifications;
- the ability of the system to operate and be maintained safely;
- the good condition of the system components, their location, their fixing and their cleanliness;
- the accessibility of the system and controls with regard to operation, cleaning and maintenance.

The guide details the contents of the standard by providing practical information such as:

- a check-list for the visual inspection of all parts and components of the system, in order to check their presence and correct installation/operation,
- a description of the measurements and measuring instruments for:
  - in apartment buildings: air pressures and air flow rates at fan level, and air flow rate or air pressure at the most and less favoured supply/exhaust:
  - houses: air pressures and air flow rates at fan level and at each room supply/exhaust.

Reference:

Anne-Marie BERNARD, Ventilation double flux dans le résidentiel – Conception, mise en œuvre et entretien, en application de la norme NF DTU 68.3, 2018, CSTB, 106 pages.

The inspection procedure is described in Chapter 7: Contrôle à réception.

Release date, periodicity of revision:

2018

Available for purchase under paper format. No revision since the first release is very recent.

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☐
Houses	☒	Offices	☐
Apartments	☒	Retail buildings	☐
Others	☐	Educational buildings	☐
		Health buildings	☐
		Others	☐

Applies to all building sizes.

Types of ventilation systems covered (technology, type, airflows range, etc.):

Dedicated to balanced mechanical ventilation systems, without limitation of the airflow.

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Covers the whole ventilation system.

Inspection can be operated by:

System designer ☒ Independent inspector ☒ Installer ☒ Maintenance staff ☐

Others (see below) ☐

Number of buildings/ventilation systems to which it is/has been applied:

The guide mentions that in order to fulfil the requirements of the standard NF DTU 68.3, each system must be controlled.

Inspection contents

Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☐
- Adequacy between design and installation ☒
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates: *see below* ☒
- Measurement or assessment of air pressures ☒
- Measurement or assessment of ductwork airtightness ☐
- Measurement or assessment of the electricity consumption ☐
- Measurement or assessment of indoor air quality parameters ☐
- Measurement or assessment of noise level ☐
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects ☐
- Adequacy with current ventilation needs ☐

Applied to:

- Each system ☒
- Each building ☐
- A sample (explain rules) ☐

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☒
- Regular ☐

Inspection report:

- Certificate that the inspection has been performed ☐
- Report provided to the owner/occupant ☒
- Recommendations for improvement to owner/occupant ☐

Specific issues

Stakeholders involved, their number and role, role of public authorities:

The guide was written by a consultant for CSTB.

Legal issues:

Information not available. A detailed analysis of national and regional law and regulations would be required to identify specific legal issues.

Sanctions if the measure is not correctly implemented:

Not applicable.

Measuring instruments required, measuring uncertainty, calibration procedure:

The measuring instruments mentioned are air flow cones and pressure probes. The guide provides information on precautions to use them and how to position them in the system.

Education or training needs:

No.

Qualification of persons or companies required, quality assurance system required:

No.

Cost for managing and maintaining the inspection scheme:

No information. The cost corresponds to part of the writing and editing of the guide.

Cost for applying the measure to a given building:

No information.

Advantages / Drawbacks

Advantages:

- Practical guide, with check lists and illustrations for measurements.

Drawbacks:

- No information about the actual use of the inspection procedure.

Proven/known impact of the measure (indicators):

Impact unknown

Additional information

References / Source of information / Links:

Guide:
http://boutique.cstb.fr/chauffage-ventilation-climatisation/232-ventilation-double-flux-dans-le-residentiel-9782868916877.html

Standard referred to by the guide:
http://boutique.cstb.fr/68-ventilation/264-nf-dtu-683-installations-de-ventilation-mecanique-3260050851626.html

Author of the analysis: François Durier (CETIAT)

French protocols for the initial inspection of ventilation systems by the installer

France	Legislation or Regulation ☐ Standard ☐ Guidelines ☒	Energy performance	Indoor air quality	Mandatory ☐ Voluntary ☒	COSTIC
		Noise level	Thermal comfort		

Description

A series of 11 check-lists has been produced by COSTIC for different centralised mechanical ventilation systems currently used in French residential and non-residential buildings. They are intended to be used by installers in a self-check process.

The 11 check-lists are grouped in three guides:

- Ventilation systems in single-family houses: the guide includes 4 check-lists covering 4 types of centralised ventilation systems (unidirectional exhaust only with and without demand-controlled ventilation based on humidity, unidirectional with exhaust coupled with the flue of a gas boiler, balanced ventilation system with heat recovery),
- Ventilation systems in apartment buildings: the guide includes 4 check-lists covering the same types of systems as for one-family houses,
- Ventilation systems in tertiary buildings: the guide includes 3 check-lists covering exhaust-only systems, demand-controlled ventilation systems and balanced ventilation systems with heat recovery.

The main objectives of these check-lists are to check compliance with:

- The applicable regulations: ventilation requirements, acoustics, energy performance and fire safety,
- Standards that are referred to in the ventilation system specifications,
- Guidelines, i.e. informative parts of the standards or current best practice.

Each check-list includes 30 to 45 points to be checked: the requirements from the regulations, standards or guidelines are listed and the compliance must be noted for each of them (yes, no, or to be corrected). Some of the requirements are described in more details in an annex to the check-list.

The check-lists for residential buildings include points that can all be checked through visual inspection without any measurement: presence and position of components, presence of controls, certification of some of the components used, compliance of components characteristics, visual inspection of the correct installation of non-rigid ductwork, correct operation of some controls.

The check-lists for non-residential buildings include points that can mainly be checked through visual inspection but some points could require measurements (for example: the fresh air flow-rate is as required by the regulation for the protection of workers). Measurement method descriptions are not part of the guide.

Each of the guides also includes a description of the different ventilation systems and information on the applicable regulations, standards and guidelines.

References:

- COSTIC, Ventilation habitat individuel – Guide d'accompagnement et fiches d'autocontrôle, 2013, COSTIC, 32 pages
- COSTIC, Ventilation habitat collectif – Guide d'accompagnement et fiches d'autocontrôle, 2013, COSTIC, 32 pages
- COSTIC, Ventilation locaux tertiaires – Guide d'accompagnement et fiches d'autocontrôle, 2013, COSTIC, 28 pages

Release date, periodicity of revision:

2013

Available for purchase under paper format. No revision since the first release.

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☒
Houses	☒	Offices	☒
Apartments	☒	Retail buildings	☒
Others	☐	Educational buildings	☒
		Health buildings	☒
		Others	☒

Applies to all building sizes.

Types of ventilation systems covered (technology, type, airflows range, etc.):

Dedicated to centralised mechanical ventilation systems, without limitation of the airflow.

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Covers the whole ventilation system.

Inspection can be operated by:

System designer ☐ Independent inspector ☐ Installer ☒ Maintenance staff ☐

Others (see below) ☐

Number of buildings/ventilation systems to which it is/has been applied:

No information available.

Inspection contents

Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☐
- Adequacy between design and installation ☒
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates: *see below* ☒
- Measurement or assessment of air pressures ☐
- Measurement or assessment of ductwork airtightness ☐
- Measurement or assessment of the electricity consumption ☐

- Measurement or assessment of indoor air quality parameters ☐
- Measurement or assessment of noise level ☐
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects: *see below* ☒
- Adequacy with current ventilation needs ☐

For non-residential buildings, the measurement of air flows in not explicitly mentioned by the guide but it is suggested since the compliance of the air flow rates to the regulation must be checked. No measurement is mentioned for residential buildings.

The health and safety aspects covered are related to fire safety and to protection of workers in non-residential buildings.

Applied to:

- Each system ☒
- Each building ☐
- A sample (explain rules) ☐

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☒
- Regular ☐

Inspection report:

- Certificate that the inspection has been performed ☐
- Report provided to the owner/occupant ☐
- Recommendations for improvement to owner/occupant ☐

The results of the inspection report are the filled-in check-lists by the installer. The guides do not mention how they are then used.

Specific issues

Stakeholders involved, their number and role, role of public authorities:

The guide was written by COSTIC with financial support from the French Ministry of Housing and the French building federation.

Legal issues:
Information not available. A detailed analysis of national and regional law and regulations would be required to identify specific legal issues.

Sanctions if the measure is not correctly implemented:

Not applicable.

Measuring instruments required, measuring uncertainty, calibration procedure:

No information in the guides.

Education or training needs:
Not mentioned.

Qualification of persons or companies required, quality assurance system required:

Not mentioned.

Cost for managing and maintaining the inspection scheme:

No information. The cost corresponds to writing and editing the guides.

Cost for applying the measure to a given building:

No information.

Advantages / Drawbacks

Advantages:

- Practical guide, with exhaustive check-lists and clear references to the requirements of the regulations, standards or guidelines
- Self-check procedure by the installer

Drawbacks:

- No information about the actual use of the inspection procedure.

Proven/known impact of the measure (indicators):

Impact unknown

Additional information

References / Source of information / Links:

Guides including the check-lists:

https://www.costic.com/ressources-techniques-et-reglementaires/publications/ventilation-habitat-individuel-guide

https://www.costic.com/ressources-techniques-et-reglementaires/publications/ventilation-habitat-collectif-guide

https://www.costic.com/ressources-techniques-et-reglementaires/publications/ventilation-locaux-tertiaires-guide

Author of the analysis: François Durier (CETIAT)

VVS Allmän Material och Arbetsbeskrivning, VVS AMA
General material and workmanship specifications on HVAC

<table>
<tr><td rowspan="2">Sweden</td><td rowspan="2">Legislation or Regulation ☐
Standard ☐
Guidelines ☒</td><td>Energy performance</td><td>Indoor air quality</td><td rowspan="2">Mandatory ☐
Voluntary ☒</td><td rowspan="2">AMA</td></tr>
<tr><td>Noise level</td><td>Thermal comfort</td></tr>
</table>

Description

In parallel to the OVK-compulsory ventilation inspection, Swedish ventilation products are usually referring to the HVAC AMA in their catalogues. AMA is a tool used since 1950 available for the building owner to specify his demands on installations in the building specification. Between 90 and 95% of all building projects in Sweden refer to AMA in the contract documents (Wahlgren, 2016).

The demands in AMA are measurable and specifies if and how the contractor should propose a guidelines for maintenance of the ventilation system.

Before a new installation is taken into operation, it is also controlled twice:

1 – the OVK inspection controls that the installation comply with the current regulation, that the ventilation system does not contain pollutants that might be spread to the building, that instructions and maintenance directions are easily available, that the ventilation is functioning in the intended manner

2- the AMA commissioning controls that the installation complies with the contract conditions (specifications and drawings).

The OVK controls are described in another analysis sheet (see Annex 3).

Reference:

AMA VVS & Kyl 09 - Allmän material- och arbetsbeskrivning för vvs- och kyltekniska arbeten, 2010, Svensk byggtjänst

Release date, periodicity of revision:

2010

First published in 1950. Updated periodically in accordance with technology development and costs.

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☒
Houses	☐	Offices	☐
Apartments	☐	Retail buildings	☐
Others	☐	Educational buildings	☐
		Health buildings	☐
		Others	☐

Types of ventilation systems covered (technology, type, airflows range, etc.):
Natural ventilation, exhaust-only ventilation, balanced ventilation without or with heat recovery.

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Whole system (all components, air handling units, ductwork).

Inspection can be operated by:

System designer ☐ Independent inspector ☐ Installer ☐ Maintenance staff ☐

Others ☐

Number of buildings/ventilation systems to which it is/has been applied:

Experience from more than 60 year old use of AMA controls, we do not have the corresponding number of buildings.

Inspection contents

Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☐
- Adequacy between design and installation ☒
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates: *see below* ☒
- Measurement or assessment of air pressures ☐
- Measurement or assessment of ductwork airtightness ☒
- Measurement or assessment of the electricity consumption ☐
- Measurement or assessment of indoor air quality parameters ☐
- Measurement or assessment of noise level ☒
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects ☐
- Adequacy with current ventilation needs ☐

Applied to:

- Each system ☒
- Each building ☒
- A sample (explain rules) ☐

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☒
- Regular: periodicity is not mentioned ☒

Inspection report:

- Certificate that the inspection has been performed ☒
- Report provided to the owner/occupant ☒
- Recommendations for improvement to owner/occupant ☐

Specific issues

Stakeholders involved, their number and role, role of public authorities:

AMA is managed by the Swedish Building Centre (called Svensk Byggtjänst AB), that aims to support, train, coordinate and inform the building sector.

AMA commissioning control is a private control in order to check that the installation comply with the contract conditions (specifications and drawings).

Calls for tenders can to a large extent be based on references to AMA.

The AMA administrative guidelines are also available in English (AMA, 2015).

Legal issues:

Information not available. A detailed analysis of national and regional law and regulations would be required to identify specific legal issues.

Sanctions if the measure is not correctly implemented:

Measuring instruments required, measuring uncertainty, calibration procedure:

Education or training needs:

Qualification of persons or companies required, quality assurance system required:

Cost for managing and maintaining the inspection scheme:

Cost for applying the measure to a given building:

Buildings stakeholders consider that there is practically no extra cost or extra time when using AMA.

Advantages / Drawbacks

Advantages:

- Securing the success both of the OVK obligatory regulatory checks and of private contracts,
- A long experience of the AMA guidelines and tools by the buildings stakeholders,
- No extra cost or extra time is considered applying AMA in general.

Drawbacks:

- There is no similar structure than AMA in other European countries, so that it is difficult to assess how it could be developed in those countries (Wahlgren, 2016),
- The revision of the AMA every 3 years, and the associated long time for consulting of experts, contribute to the fact that there is always on going revision work,
- Each AMA guideline costs around 450 €.

Proven/known impact of the measure (indicators):

Experience from more than 60 year old use of AMA has shown that it contributed to significantly increase quality level (Andersson, 2013; Wahlgren, 2016).

Additional information

References / Source of information / Links:

AMA VVS & Kyl 09, 2010 - Allmän material- och arbetsbeskrivning för vvs- och kyltekniska arbeten. Svensk byggtjänst.

AMA, 2015. AMA AF 12 - Guidance for the preparation of particular conditions for Building and Civil Engineering Works and Building Services Contracts. Svensk byggtjänst.

Andersson, J., 2013. Quality of domestic ventilation systems in Sweden : status and perspectives, in: AIVC International Workshop. Presented at the Securing the quality of ventilation systems in residential buildings: status and perspectives, Brussels, Belgium, p. 8.

Wahlgren, P., 2016. AMA - General material and workmanship specifications. Qualicheck Factsheet 9.

Author of the analysis: Gaëlle Guyot (Cerema)

Unified Technical Specifications STS-P 73-1

Systems for the basic ventilation in residential applications

Belgium	Legislation or Regulation ☐ Standard ☐ Guidelines ☒	Energy performance	Indoor air quality	Mandatory ☐ Voluntary ☒	BBRI, Published by Federal Government of Belgium
		Noise level	Thermal comfort		

Description

The STS official guidelines propose prescriptions in order to optimise and/or normalise the quality of constructions. The following STS-P 73-1 prescriptions focus on:

- the ventilation system installations in residential buildings,
- the establishment of a performance report on the expected ventilation system characteristics.

Chapter 4-"criteria of performance" provides a list of different aspects which could be set before the conception in the "Ventilation pre design", then checked once the system is installed, and lastly reported in the performance report:

- 4.1 Concept of the performance criteria
- 4.2 Ventilation pre design
- 4.3 Type of ventilations systems
- 4.4 Spaces and airflows rates
- 4.5 Mechanical airflows
- 4.6 Air transfers
- 4.7 Adjustable air supply components
- 4.8 Adjustable air exhaust components
- 4.9 Ventilation unit
- 4.10 Air filtration
- 4.11 Regulation of airflows rates and Demand-controlled ventilation
- 4.12 Electric power of the mechanical systems
- 4.13 Thermal insulation of the ventilation ducts
- 4.14 Air tightness of the ventilation ducts
- 4.15 Acoustic performance
- 4.16 Air quality
- 4.17 Floor exchanger
- 4.18 Cleanliness and maintenance of the installation
- 4.19 Information for the user

Then, these official guidelines propose five informative annexes covering:

1. The "Ventilation pre design": motivation and description,
2. The performances report: motivation and expected use,
3. Methods for determining products performances: air transfers components, adjustable air supply components, adjustable air exhaust components, and ventilation unit,
4. Methods for determining the systems performances: general principles, airflows, absorbed electric power and acoustics measurements, acoustics performance calculation,
5. Quality framework for performances assessment of ventilation installations in residential buildings.

In Flanders, a ministerial decision of 28th October 2015 requires for residential building permits after 1st January 2016 (new building or major renovation):

- A ventilation predesign at declaration of start,
- A ventilation report at EPB-registration (6 months after occupation),
- A quality framework.

A government decision taken on 15th December 2017 specifies:

- That an independent and ISO 17065 certified quality organization should supervise the process,
- The goal is to inspect 10% on site and desktop measurements or reports,
- The reliability of reporting should be controlled.

As a result in Flanders, the STS official guidelines are being used by ventilation inspectors and certified quality organizations supervising the process, which have ventilation auditors controlling the ventilation inspectors. The role of these organizations also includes training, qualification process, elaboration of rules of the framework, communication and consultation, etc.

Reference:

SPF ECONOMIE, P.M.E., CLASSES MOYENNES ET ENERGIE, STS-P 73-1 Systèmes pour la ventilation de base dans les applications résidentielles, 2015, Direction générale de la Qualité et de la Sécurité, 60 pages.

Release date, periodicity of revision:

Firstly published in July, 7th, 2015. No revision since.

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☐
Houses	☒	Offices	☐
Apartments	☒	Retail buildings	☐
Others	☒	Educational buildings	☐
		Health buildings	☐
		Others	☐

Types of ventilation systems covered (technology, type, airflows range, etc.):

Dedicated to the four reference ventilation systems (A-natural, B-exhaust only, C-supply only, D-balanced) defined in the Belgium standard NBN D 50-001 (NBN 1991).

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Covers the whole ventilation system.

Inspection can be operated by:

System designer ☒ Independent inspector ☒ Installer ☒ Maintenance staff ☒

Others ☒

As the inspection can be performed by all actors, this has been considered as important by authorities that independent auditors from a national certification organization should qualify and control inspectors.

Number of buildings/ventilation systems to which it is/has been applied:

Information not available.

Inspection contents

Aspects covered:

▪ Completeness of the ventilation system	☒
▪ Cleanliness and general state of the ventilation system	☒
▪ Adequacy between design and installation	☒
▪ Good overall operation of the installed ventilation system	☒
▪ Measurement or assessment of air flow rates: *see below*	☒
▪ Measurement or assessment of air pressures	☒
▪ Measurement or assessment of ductwork airtightness	☒
▪ Measurement or assessment of the electricity consumption	☒
▪ Measurement or assessment of indoor air quality parameters	☐
▪ Measurement or assessment of noise level	☒
▪ Measurement or assessment of thermal comfort parameters	☐
▪ Health and safety aspects	☐
▪ Adequacy with current ventilation needs	☐

Applied to:

▪ Each system	☒
▪ Each building	☒
▪ A sample (components only)	☒

Inspection periodicity:

• Once in new buildings or for new ventilation systems	☒
• Regular	☐

Inspection report:

▪ Certificate that the inspection has been performed	☒
▪ Report provided to the owner/occupant	☒
▪ Recommendations for improvement to owner/occupant	☐

Specific issues

Stakeholders involved, their number and role, role of public authorities:

The STS guidelines are validated by the Belgium General Direction of quality and safety. They are intended to be voluntary referred by public authorities and the actors in the construction sector.

The STS are normative and/or informative documents that prescriptions like federal, regional or local legislations, can build upon, as it is the case with the ministerial decision of 28th October 2015 in Flanders.

Legal issues:

Using STS-P 73-1 is voluntary. It can be made mandatory by specific contracts and can be considered as a reference document in the courts.

Sanctions if the measure is not correctly implemented:

Fines are applicable if the EPB report shows that the building does not comply with the EPB regulation. In Flanders, 90% of EPB fines are related to ventilation (De Strycker 2019).

If a ventilation auditor, working for certified quality organizations supervising the process, finds non-conformity the consequences could be: modify the report, perform extra inspections, re-measuring, until a temporary or finite exclusion from as inspector.

Measuring instruments required, measuring uncertainty, calibration procedure:

The measuring instruments required for the performance report should be able to assess all the performance criteria. They include:

- An airflow meter with a maximum of 15% incertitude method,
- A power meter,
- A sound level meter (optional, reporting acoustics is not mandatory).

In any case the measure report must describe the brand and model of the devices, including the used accessories. It should also give the date of last calibration.

Education or training needs:
Information not available

Qualification of persons or companies required, quality assurance system required:

Appendix 5.5 of the guidelines outlines how they can be used in a quality framework approach for performance inspection of ventilation installations in residential buildings.

Ventilation inspectors are recognised by the quality framework by theoretical and practical tests. Only these inspectors can report about the ventilation predesign and the ventilation performance. They could be architects, EPB-reporters, engineers, window installers, carpenters, airtightness measurers, producers, etc.

In order to ensure the reliability of the control process, the certification organizations perform notably in situ and in real-time inspections. Ventilation inspectors have to send a sms at the start of the measuring of airflows and an inspector can be on site within 15 minutes to do an inspection (De Strycker 2019).

Cost for managing and maintaining the inspection scheme:
Information not available

Cost for applying the measure to a given building:

Information not available

Advantages / Drawbacks

Advantages:

- This official guidelines including its very practical appendixes is self-supporting at the different stage of building construction,
- It helps buildings prescribers with an exhaustive list of performance criteria for ventilation, succinctly and clearly described,
- It gives requirements for measuring, including thresholds for airflows measurement errors,
- It describes the exhaustive content of the performance report, which could also be used in the long term for maintenance.

Drawbacks:

- The inspector role, posture or qualification is not defined.

Proven/known impact of the measure (indicators):

This type of scheme (official guidelines referred in regulation applied by inspectors + certification organization with auditors controlling the inspectors) has already been tested with success in the airtightness field and has consequently been extended to ventilation recently.

Additional information

References / Source of information / Links:

- SPF ECONOMIE, P.M.E., CLASSES MOYENNES ET ENERGIE, *STS-P 73-1 Systèmes pour la ventilation de base dans les applications résidentielles*, 2015, Direction générale de la Qualité et de la Sécurité, 60 pages. https://economie.fgov.be/sites/default/files/Files/Publications/files/STS/STS-P-73-1-Systemes-pour-ventilation-de-base-applications-residentielles.pdf
- De Strycker, Maarten. 2019. “Ventilation and Building Airtightness Inspection Schemes in Belgium.” presented at the Quality ventilation is the key to achieving low energy healthy buildings, SEAI energy show & AIVC Workshop, Dublin, Ireland, March 17.
- NBN. 1991. “NBN D 50-001 : Dispositif de Ventilation Dans Les Bâtiments d’habitation.”

Author of the analysis: Gaëlle Guyot (Cerema)

Practical guidelines for residential building basic ventilation

Technical information note – NIT 258

Belgium	Legislation or Regulation ☐ Standard ☐ Guidelines ☒	Energy performance	Indoor air quality	Mandatory ☐ Voluntary ☒	BBRI
		Noise level	Thermal comfort		

DESCRIPTION

These guidelines give recommendations in order to accompany step by step the different actors from the designer to the installer until the maintenance stage.

These guidelines focus on basic ventilation and do not address any other type of ventilation as peak ventilation, night free cooling, …

These guidelines address key points related to the quality of ventilation installations including:

1. General system design,
2. Natural ventilation design,
3. Transfer openings design and selection,
4. Mechanical ventilation design,
5. Mounting,
6. Commissioning and handing over,
7. Using and maintenance.

This analysis focus on the 6th section of the guidelines.

Reference:

Belgian Building Research Institute, *Guide pratique des systèmes de ventilation de base des logements*, 2016, available in French and Flemish, 92 pages

Release date, periodicity of revision:

2016. replaces the NIT 192 and 203.

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☐
Houses	☒	Offices	☐
Apartments	☒	Retail buildings	☐
Others	☐	Educational buildings	☐
		Health buildings	☐
		Others	☐

Types of ventilation systems covered (technology, type, airflows range, etc.):

Dedicated to the 4 reference ventilation systems (A=natural, B=exhaust-only, C=supply only, D=balanced) defined in the Belgium Standard NBN D 50-001 (NBN 1991).

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Covers the whole ventilation system.

Inspection can be operated by:

System designer ☒ Independent inspector ☒ Installer ☒ Maintenance staff ☒

Others (must be authorized) ☒

Number of buildings/ventilation systems to which it is/has been applied:

Information not available.

INSPECTION CONTENTS

Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☒
- Adequacy between design and installation ☒
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates ☒
- Measurement or assessment of air pressures ☐
- Measurement or assessment of ductwork airtightness ☒
- Measurement or assessment of the electricity consumption ☒
- Measurement or assessment of indoor air quality parameters ☐
- Measurement or assessment of noise level ☒
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects ☐
- Adequacy with current ventilation needs ☐
- Others (accessibility of the components for maintenance) ☒

Applied to:

- Each system ☐
- Each building ☒
- A sample (explain rules) ☐

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☒
- Regular : ☒
  The guide proposes different inspection frequencies from 1 month to 3 year-intervals depending on the type of components: 1 month for filters, 3 months for the natural openings, air intakes, exhaust devices, 1 year for heat exchangers and fans, 3 years for ducts.

Inspection report:

- Certificate that the inspection has been performed ☐
- Report provided to the owner/occupant ☒
- Recommendations for improvement to owner/occupant ☐

SPECIFIC ISSUES

Stakeholders involved, their number and role, role of public authorities:

This note has been elaborated by a national working group including a wide range of stakeholders in the ventilation field.

It specifies that following some of the recommendations allow complying with some requirements of the official guidelines STS-P-73-1. An icon is being used in the document in order to highlight the corresponding sections.

Legal issues:

NIT 258 is a technical guideline with containing recommendations. It can be made mandatory by specific contracts and can be considered as a reference document in the courts.

Sanctions if the measure is not correctly implemented:

Not addressed.

Measuring instruments required, measuring uncertainty, calibration procedure:

Not addressed.

Education or training needs:

Not addressed.

Qualification of persons or companies required, quality assurance system required:

The assessment of ventilation installation performance at the commissioning stage must be performed by an authorized person, who could be the installer himself.

Cost for managing and maintaining the inspection scheme:

Information not available.

Cost for applying the measure to a given building:

Information not available. The guide outlines that the cost of the airflows measurements can be balanced by the reward in the EPB calculation for airflows measurements (BBRI 2010).

ADVANTAGES / DRAWBACKS

Advantages:

- Those practical guidelines were elaborated involving a wide range of building ventilation stakeholders in order to deal with all the steps of the building ventilation design and installation
- This document gives a clear picture on how it is linked to the official guidelines STS-P-73-1, without redundant information on measurement procedures and reports themselves
- It outlines that ventilation inspectors must be authorized persons.

Drawbacks:

- As it does not focus on ventilation inspection, a lot of information in these guidelines is not completely relevant for the scope of our study.

Proven/known impact of the measure (indicators):

Impact unknown

ADDITIONAL INFORMATION

References / Source of information / Links:

- BBRI. 2010. "Infofiche n° 42.3 PEB Ventilation des bâtiments. Possibilités de diminution du niveau E." https://www.cstc.be/homepage/index.cfm?cat=publications&sub=infofiches&pag=42&art=3&lang=fr.
- BBRI. 2016. NIT 258 - Guide Pratique Des Systèmes de Ventilation de Base Des Logements. https://www.cstc.be/homepage/index.cfm?cat=publications&sub=search&serie=1&ID=REF00008621
- NBN. 1991. "NBN D 50-001 : Dispositif de Ventilation Dans Les Bâtiments d'habitation."

- *Author of the analysis: Gaëlle Guyot (Cerema)*

The Dutch voluntary ventilation inspection (VPK)

BRL 8010 - for residential buildings, schools and kindergartens

The Netherlands	Legislation or Regulation ☐ Standard ☐ Guidelines ☒	Energy performance	Indoor air quality	Mandatory ☐ Voluntary ☒	KBI (Dutch Installation Sector Quality Assurance Foundation)
		Noise level	Thermal comfort		

DESCRIPTION

The voluntary ventilation performance inspection (VPK) is published by the Dutch Installation Sector Quality Assurance Foundation (KBI) supported by the government and can be used in certification programs to reward ventilation quality.

This inspection aims at checking:

- if the guidelines are respected in the design,
- if the ventilation is installed in accordance with the design specifications,
- if the intended ventilation performance is achieved,
- how the system can be maintained and used by occupants.

Reference:

Sichting kwaliteitsborging installatiesector (KBI), BRL 8010 *Beoordelen van Ventilatievoorzieningen van Woningen, Scholen En Kinderdagverblijven*, 2011, Available in Dutch.

Release date, periodicity of revision:

2011. First developed in 2009.

Types of building covered (usage, size, etc.):

Residential buildings ☒
- Houses ☒
- Apartments ☒
- Others ☐

Non-residential buildings ☒
- Offices ☐
- Retail buildings ☐
- Educational buildings (schools and kindergartens) ☒
- Health buildings ☐
- Others ☐

Types of ventilation systems covered (technology, type, airflows range, etc.):

Dedicated to ventilation systems of all types.

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Covers the whole ventilation system.

Inspection can be operated by:

System designer ☐ Independent inspector ☒ Installer ☐ Maintenance staff ☐

Others (Inspectors belonging to certified companies) ☒

Number of buildings/ventilation systems to which it is/has been applied:

Despite the VPK is supported by the government, there are few demand for VPK: less than 5% of new dwellings, according to (De Jong 2014).

INSPECTION CONTENTS

Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☒
- Adequacy between design and installation ☒
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates ☒
- Measurement or assessment of air pressures ☐
- Measurement or assessment of ductwork airtightness ☐
- Measurement or assessment of the electricity consumption ☐
- Measurement or assessment of indoor air quality parameters ☒
- Measurement or assessment of noise level ☒
- Measurement or assessment of thermal comfort parameters ☒
- Health and safety aspects ☒
- Adequacy with current ventilation needs ☐
- Others (availability of maintenance information for users, reaction of CO_2-sensored components if demand-controlled ventilation) ☒

Applied to:

- Each system ☒
- Each building ☒
- A sample (50% of the dwellings for acoustic measurements) ☒

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☒
- Regular : ☐

Inspection report:

- Certificate that the inspection has been performed ☒
- Report provided to the owner/occupant ☒
- Recommendations for improvement to owner/occupant ☒

SPECIFIC ISSUES

Stakeholders involved, their number and role, role of public authorities:

BRL 8010 guidelines are managed by the Dutch Installation Sector quality assurance foundation (KBI).

The government supports this voluntary inspection scheme.

There are few demands for VPK in a large–scale. They are rather used in private contracts in order to ensure that the design agreed requirements are met (Hofman and De Schipper 2013).

Legal issues:
Information not available. A detailed analysis of national and regional law and regulations would be required to identify specific legal issues.

Sanctions if the measure is not correctly implemented:

Information not available.

Measuring instruments required, measuring uncertainty, calibration procedure:

For airflows measurements, a pressure compensating airflow meter shall be used, with a range of use from 5 to 300 dm^3/s, with an inaccuracy less than 5% of the readings values higher than 40 dm^3/s and no more than 2 dm^3/s for values up to 40 dm^3/s. The accuracy of the measurement devices is not allowed to be greater than 5% must be able to be demonstrated via a calibration report not older than one year.

The acoustics measurements must be performed using an integrating sound level meter with A-weighting according to class 2 of Dutch standards NEN-EN-1EC 61672-1 and NEN-EN-IEC 61672-2. The device must have at least an A-weight be able to measure a noise level of 25 dB(A). The deviation of the measuring instrument must not be higher than 0.5 dB and must be able to be demonstrated via a calibration report not older than one year.

A calibrated CO_2-counter must also be used in order to check that the CO_2-sensored ventilation system components react as they should do, in case of demand-controlled ventilation.

Education or training needs:
Information not available.

Qualification of persons or companies required, quality assurance system required:

Ventilation inspectors should belong to certificated companies. Companies could be certificated if they have at least one ventilation inspector in permanent employment. In 2013, there were seven certified companies (Hofman and De Schipper 2013).

Sections 6 and 7 of the BR 8010 describe in detail respectively the internal and the external quality assurance systems which shall be used.

Cost for managing and maintaining the inspection scheme:
Information not available.

Cost for applying the measure to a given building:

Information not available.

ADVANTAGES / DRAWBACKS

Advantages:

- It describes very clearly and exhaustively the different points to be visually checked or measured, with requirements on the measurement devices (type, accuracy, calibration reports),
- It includes CO_2 tests in case of demand controlled ventilation,
- In annex, there is a proposition of an extensive checklist to be completed by the ventilation inspectors during the inspection,
- Inspectors should belong to certified companies,
- Refers to ISSO 63, which consists in guidelines for installers including inspection and maintenance issues.

Drawbacks:

- The fact that this inspection is only voluntary and not obligatory is an identified reason to explain that the number of buildings where it is applied is very low.

Proven/known impact of the measure (indicators):

Impact unknown

ADDITIONAL INFORMATION

References / Source of information / Links:

ISSO. 2010. *ISSO-Publicatie 63 Beheer En Onderhoud Ventilatiesystemen in Woningen En Woongebouwen*. https://kennisbank.isso.nl/publicatie/isso-publicatie-63-beheer-en-onderhoud-ventilatiesystemen-in-woningen-en-woongebouwen/2008.

KBI. 2011. BRL 8010 "*Beoordelen van Ventilatievoorzieningen van Woningen, Scholen En Kinderdagverblijven*''."

https://www.kvinl.nl/fileadmin/user_kbi/Kritiekversies/brl_8010_kritiekversie_12-09-2011_ISSO..pdf.

De Jong, Jelmer. 2014. "Challenges for Ventilation Systems in Nearly Zero- Energy Buildings (NZEB)." presented at the 1st International QUALICHeCK conference, Brussels, Belgium.

Hofman, Marco, and Kees De Schipper. 2013. "Quality of Ventilation in Residential Buildings : Status and Perspectives in the Netherlands." In *AIVC International Workshop*, 8. Brussels, Belgium. http://www.aivc.org/resource/quality-domestic-ventilation-systems-sweden.

- *Author of the analysis: Gaëlle Guyot (Cerema)*

Inspection guidelines for ventilation systems by the HVAC Association of Finland SuLVI

Finland	Legislation or Regulation ☐ Standard ☐ Guidelines ☒	Energy performance	Indoor air quality	Mandatory ☐ Voluntary ☒	SuLVI
		Noise level	Thermal comfort		

DESCRIPTION

These technical guidelines are for the professionals who perform the inspection of ventilation systems. The guidelines were developed by the experts of the society SuLVI (https://sulvi.fi/suomen-lvi-liitto/in-english/). They include both technical requirements for inspection, technical guidelines and models for reporting the results as well as references to various additional guidelines for measurements etc.

The guidelines are available only at website of the society, guidelines include totally 17 guidelines in specific areas, some of them 2 or 3 separate guides. The areas of the guidelines are:

- Guide 1 (Ohje 1) General description of the method
- Guide 2 General evaluation of the ventilation system
- Guide 3 Model document for general evaluation of the ventilation system
- Guide 4 Guidelines for investigation of cleanliness of the ventilation system
- Guide 5 Instructions for the calculation of the energy use of the vent system
- Guide 6 Inspection of cooling systems
- Guide 7 Inspection of control system
- Guide 8 Inspections of terminal devices (diffusers, etc.)
- Guide 9 Inspection of fans
- Guide 10 Inspection of air handling units
- Guide 11 Inspection of the heat recovery systems in ventilation systems
- Guide 12 Inspection of ventilation ducts
- Guide 13 Inspection of outdoor air intakes and exhaust air grilles
- Guide 14 Inspection of filters
- Guide 15 Guidelines for measurements in the inspections
- Guide 16 Acoustic inspections and investigations
- Guide 17 Instruments for measurements in inspections

Reference:

Release date, periodicity of revision:

Released in 2016, applicable to all mechanical ventilation systems (air conditioning systems not included), no revision yet planned.

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☒
Houses	☒	Offices	☒
Apartments	☒	Retail buildings	☒
Others	☒	Educational buildings	☒
		Health buildings	☒
		Others	☒

Types of ventilation systems covered (technology, type, airflows range, etc.):

All mechanical ventilation systems, air conditioning systems not included;

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

The whole system including central units, filters, ductwork, air distribution, terminal units etc.

Inspection can be operated by:

System designer ☐ Independent inspector ☒ Installer ☐ Maintenance staff ☐

Others (must be authorized) ☐

Number of buildings/ventilation systems to which it is/has been applied:

Not recorded, system relatively new, training of the inspectors in the progress, certification system of inspectors developed.

INSPECTION CONTENTS

Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☒
- Adequacy between design and installation ☐
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates ☒
- Measurement or assessment of air pressures ☒
- Measurement or assessment of ductwork airtightness ☒
- Measurement or assessment of the electricity consumption ☒
- Measurement or assessment of indoor air quality parameters ☐
- Measurement or assessment of noise level ☒
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects ☒
- Adequacy with current ventilation needs ☐
- Others (accessibility of the components for maintenance) ☒

Indoor environment is not included as this scheme focuses only on the performance of the ventilation system itself.

Applied to:

- Each system ☒
- Each building ☒
- A sample (explain rules) ☐

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☐
- Regular : ☐

Inspection report:

- Certificate that the inspection has been performed ☒

- Report provided to the owner/occupant ☒
- Recommendations for improvement to owner/occupant ☐

SPECIFIC ISSUES

Stakeholders involved, their number and role, role of public authorities:

Voluntary scheme

Legal issues:

Information not available. A detailed analysis of national and regional law and regulations would be required to identify specific legal issues.

Sanctions if the measure is not correctly implemented:

Decree on indoor conditions in of the Ministry of Public Health can be applied to the residential buildings, limited legislation on occupational buildings.

Measuring instruments required, measuring uncertainty, calibration procedure:

Guidelines for instruments included.

Education or training needs:

Training organised, examinations for certification.

Qualification of persons or companies required, quality assurance system required:

Under development.

Cost for managing and maintaining the inspection scheme:

Information not available.

Cost for applying the measure to a given building:

Information not available.

ADVANTAGES / DRAWBACKS

Advantages:

- Voluntary scheme, guidelines are easy to update, flexible

Drawbacks:

- Not mandatory, not commonly used yet.

Proven/known impact of the measure (indicators):

Not collected.

ADDITIONAL INFORMATION

References / Source of information / Links:

https://sulvi.fi/materiaalipankki/iv-kuntotutkimushanke/

Author of the analysis: Olli Seppänen
(Past president of the organisation SuLVI)

French documents for self-check by installers of the quality of installation of residential ventilation systems

France	Legislation or Regulation ☐ Standard ☐ Guidelines ☒	Energy performance	Indoor air quality	Mandatory ☐ Voluntary ☒	PROMOTELEC SERVICES
		Noise level	Thermal comfort		

Description

Three check-lists are distributed and used by PROMOTELEC SERVICES as tools allowing to installers to control themselves the quality of their works on three types of residential ventilation systems:

- Unidirectional exhaust centralised ventilation systems in single-family houses
- Unidirectional centralised exhaust ventilation systems in apartment buildings
- Balanced ventilation systems with heat recovery in single-family houses.

PROMOTELEC SERVICES manages certification schemes for new and renovated residential buildings in France. Some of these certifications and labelling (i.e. several options of the Label Promotelec Habitat Neuf and one option of the Promotelec Services Label Performance) require the use of these self-checks documents by the installer, in one-family houses and apartment.

Each check-list includes 35 to 50 points, to be verified through visual inspection, some distance measurements (for example distance between air outlet and ceiling) and control of good operation (for example check of the correct rotation direction of the fan).

These points relate to the checking of the presence and position of components, the presence and operation of controls, visual inspection of the correct installation of ductwork, correct operation the fan, etc.

References:

- PROMOTELEC SERVICES, Fiche autocontrôle Ventilation mécanique contrôlée simple flux hygroréglable type A ou B en maison individuelle, Réf. PS 1440-1, 2014, 3 pages
- PROMOTELEC SERVICES, Fiche autocontrôle Ventilation mécanique contrôlée simple flux hygroréglable type A ou B en bâtiment collectif d'habitation, Réf. PS 1438-1, 2014, 4 pages
- PROMOTELEC SERVICES, Fiche autocontrôle Ventilation mécanique contrôlée double flux autoréglable en maison individuelle, Réf. PS 1436-1, 2014, 4 pages

Release date, periodicity of revision:

2014.

Available for free download. No revision since the first release.

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☐
Houses	☒	Offices	☐
Apartments	☒	Retail buildings	☐
Others	☐	Educational buildings	☐

Health buildings ☐
Others ☐

Applies to all building sizes.

Types of ventilation systems covered (technology, type, airflows range, etc.):

Centralised mechanical ventilation systems in single-family houses and apartment buildings, without limitation of the airflow.

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Covers the whole ventilation system.

Inspection can be operated by:

System designer ☐ Independent inspector ☐ Installer ☒ Maintenance staff ☐

Others (see below) ☐

Number of buildings/ventilation systems to which it is/has been applied:

No information available.

Inspection contents

Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☒
- Adequacy between design and installation ☐
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates ☐
- Measurement or assessment of air pressures ☐
- Measurement or assessment of ductwork airtightness ☐
- Measurement or assessment of the electricity consumption ☐
- Measurement or assessment of indoor air quality parameters ☐
- Measurement or assessment of noise level ☐
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects ☐
- Adequacy with current ventilation needs ☐

Applied to:

- Each system ☒
- Each building ☐
- A sample (explain rules) ☐

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☒
- Regular ☐

Inspection report:

- Certificate that the inspection has been performed ☐

- Report provided to the owner/occupant ☐
- Recommendations for improvement to owner/occupant ☐

The results of the inspection are the filled-in check-lists by the installer. They are part of the documentation to provide in order to get the corresponding label for the considered building.

Specific issues

Stakeholders involved, their number and role, role of public authorities:

The check-lists were written by PROMOTELEC SERVICES with contributions from the Ministry of housing and Cerema, ADEME, the installers association CAPEB, the ventilation system manufacturers association Uniclima and two ventilation system manufacturers.

Legal issues:

Information not available. A detailed analysis of national and regional law and regulations would be required to identify specific legal issues.

Sanctions if the measure is not correctly implemented:

Not applicable.

Measuring instruments required, measuring uncertainty, calibration procedure:

A meter. The check-lists do not require other measurements than lengths and distances.

Education or training needs:

Not mentioned.

Qualification of persons or companies required, quality assurance system required:

Not mentioned.

Cost for managing and maintaining the inspection scheme:

No information. The cost corresponds to writing and editing the guides.

Cost for applying the measure to a given building:

No information.

Advantages / Drawbacks

Advantages:

- Practical check-lists
- Self-check procedure by the installer

Drawbacks:

- Few information about the reason for which the indicated parameters have to be checked.

Proven/known impact of the measure (indicators):

Impact unknown

Additional information

References / Source of information / Links:

http://www.promotelec-services.com/documents/89-fiche-autocontrole-ventilation-mecanique-controlee-simple-flux-hygroreglable-type-a-ou-b-en-maison-individuelle.html

http://www.promotelec-services.com/documents/87-fiche-autocontrole-ventilation-mecanique-controlee-simple-flux-hygroreglable-type-a-ou-b-en-batiment-collectif-d-habitation.html

http://www.promotelec-services.com/documents/85-fiche-autocontrole-ventilation-mecanique-controlee-double-flux-autoreglable-en-maison-individuelle.html

Author of the analysis: François Durier (CETIAT)

VDI 6022 -1

Ventilation and indoor-air quality - Hygiene requirements for ventilation and air-conditioning systems and units

Germany	Legislation or Regulation ☐ Standard ☐ Guidelines ☒	Energy performance	Indoor air quality	Mandatory ☐ Voluntary ☒	The Associations of German Engineers
		Noise level	Thermal comfort		

DESCRIPTION

These guidelines are focused on an overall analysis on hygiene requirements, from a technical- and constructional analysis, to the maintenance of ventilation and air conditioning systems. The principal aim is of these requirements is the protection of human health. Starting from a general overview on cleanliness specifications the document mentions details about installation, commissioning and responsibilities in planning. A fundamental section is the one about hygiene checks and inspections that are developed through hazard assessment and analysis of single components. In the last part of the document are then showed measurement techniques and hygiene tests of water in ventilation systems and units.

Reference:

VDI, The Association of German Engineers, VDI 6022-1 *Raumlufttechnik, RaumluftqualitätHygieneanforderungen an raumlufttechnische Anlagen und Geräte (VDI-Lüftungsregeln)*, Verein Deutscher Ingenieure, 2018, 105 pages

Release date, periodicity of revision:

2018

Former editions: 07/2011, 01/2017

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☒
Houses	☒	Offices	☒
Apartments	☒	Retail buildings	☒
Others	☐	Educational buildings	☒
		Health buildings	☐
		Others	☐

Applies to any occupied space in buildings (occupied space= space intended or suitable for non-temporary human occupancy)

Types of ventilation systems covered (technology, type, airflows range, etc.):

All ventilation and air conditioning systems (centralized and decentralized ones).

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Whole system and all the components that can influence the quality of the supply air (outdoor air inlets, terminal units, exhaust air outlets, unit casings, air filters, air ducts…)

Inspection can be operated by:

System designer ☒ Independent inspector ☐ Installer ☒ Maintenance staff ☒

Others (see below) ☐

Number of buildings/ventilation systems to which it is/has been applied:

No information

INSPECTION CONTENTS

Aspects covered:

- Completeness of the ventilation system ☒
- Cleanliness and general state of the ventilation system ☒
- Adequacy between design and installation ☐
- Good overall operation of the installed ventilation system ☒
- Measurement or assessment of air flow rates ☐
- Measurement or assessment of air pressures ☐
- Measurement or assessment of ductwork airtightness ☐
- Measurement or assessment of the electricity consumption ☐
- Measurement or assessment of indoor air quality parameters ☒
- Measurement or assessment of noise level ☐
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects ☒
- Adequacy with current ventilation needs ☒

Applied to:

- Each system ☒
- Each building ☐
- A sample (explain rules) ☐

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☐
- Regular : (table showing the periodicity for each component) ☒

Inspection report:

- Certificate that the inspection has been performed ☒
- Report provided to the owner/occupant ☐
- Recommendations for improvement to owner/occupant ☐

The certificate is in a form of declaration where the manufacturer/planner declares the alignment with the hygiene requirements

SPECIFIC ISSUES

Stakeholders involved, their number and role, role of public authorities:

Building owners, architects, planners, system manufacturers, approving authorities, building managers, maintenance personnel, occupants.

Legal issues:

Organizational and legally binding designation of the operator shall be specified prior to commissioning.

Sanctions if the measure is not correctly implemented:

No information.

Measuring instruments required, measuring uncertainty, calibration procedure:

Hygiene tests equipment: containers for sample transport, personal protective equipment, water thermometer.

Education or training needs:

No Information.

Qualification of persons or companies required, quality assurance system required:

All parties involved in planning, manufacture, operation and maintenance shall be able at any time to provide proof of their personnel's relevant qualification. At least category A of VDI 6022 part 4 should be achieved.

Cost for managing and maintaining the inspection scheme:

No information.

Cost for applying the measure to a given building:

No information.

ADVANTAGES / DRAWBACKS

Advantages:

- Clear depiction of roles and parties involvement in different stages of commissioning, installing, maintenance and assessment of hygiene requirements

Drawbacks:

- No major drawbacks, since different part of the document can be integrated with references to relevant VDI guidelines that can be more detailed on specific topics

Proven/known impact of the measure (indicators):

Impact unknown

ADDITIONAL INFORMATION

References / Source of information / Links:

https://www.beuth.de/en/technical-rule/vdi-6022-blatt-1/279023701

Author of the analysis: Matteo Urbani (REHVA)

Inspection of the cleanliness od ventilation systems

Finnish guidelines LVI 39-10409

Finland	Legislation or Regulation ☐ Standard ☐ Guidelines ☒	Energy performance	Indoor air quality	Mandatory☐ Voluntary ☒	Rakennustieto
		Noise level	Thermal comfort		

DESCRIPTION

This guideline is one of the guidelines published by the Building Information Group, which is the leading provider of construction information in Finland (https://www.rakennustieto.fi/index/english.html). This organisation has published several guidelines related to the inspection of ventilation systems, that are used in the inspections made mandatory by the regulation. These guidelines include ventilation measurements, air tightness, SFP, noise, etc.

This specific guideline describes visual inspection of ventilation systems in order to allow the assessment of the air exchange rates and the related components, as well as the needs for remediation. Visual assessment is intended as a primary method for the cleanliness evaluation of inner surfaces. Checks are also developed mapping the microbial and mineral conditions of ventilation systems. Therefore the audit will focus on the functionality of outdoor equipment and filters selections, checking that the cleaning is fully accessible.

Reference:

LVI 39-10409 - *Ilmanvaihtojärjestelmän puhtauden tarkastus. Ilmanvaihdon parannus- ja korjausratkaisut*, Rakennustieto, 2007, 12 pages

Release date, periodicity of revision:

2007

Types of building covered (usage, size, etc.):

Residential buildings	☒	Non-residential buildings	☒
Houses	☐	Offices	☐
Apartments	☐	Retail buildings	☐
Others	☐	Educational buildings	☐
		Health buildings	☐
		Others	☐

Applies to any occupied space in buildings (occupied space= space intended or suitable for non-temporary human occupancy)

Types of ventilation systems covered (technology, type, airflows range, etc.):

Mechanical and natural ventilation systems (indicators related to the pollutant in g/m^2)

Parts of the ventilation systems covered (whole system, ductwork, fan, etc.):

Ductwork, whole system

Inspection can be operated by:

System designer ☐ Independent inspector ☐ Installer ☒ Maintenance staff ☒

Others (see below) ☐

Number of buildings/ventilation systems to which it is/has been applied:

No information

INSPECTION CONTENTS

Aspects covered:

- Completeness of the ventilation system ☐
- Cleanliness and general state of the ventilation system ☒
- Adequacy between design and installation ☐
- Good overall operation of the installed ventilation system ☐
- Measurement or assessment of air flow rates ☐
- Measurement or assessment of air pressures ☐
- Measurement or assessment of ductwork airtightness ☐
- Measurement or assessment of the electricity consumption ☐
- Measurement or assessment of indoor air quality parameters ☒
- Measurement or assessment of noise level ☐
- Measurement or assessment of thermal comfort parameters ☐
- Health and safety aspects ☒
- Adequacy with current ventilation needs ☐

Applied to:

- Each system ☒
- Each building ☐
- A sample (explain rules) ☐

Inspection periodicity:

- Once in new buildings or for new ventilation systems ☐
- Regular : periodicity not mentioned ☒

Inspection report:

- Certificate that the inspection has been performed ☒
- Report provided to the owner/occupant ☐
- Recommendations for improvement to owner/occupant ☐

SPECIFIC ISSUES

Stakeholders involved, their number and role, role of public authorities:

Installers, certified experts. Classification guidelines based on Indoor air classification "Si säilmayhdistys, 2001"

Legal issues:

Information not available. A detailed analysis of national and regional law and regulations would be required to identify specific legal issues.

Sanctions if the measure is not correctly implemented:

No information

Measuring instruments required, measuring uncertainty, calibration procedure:

Pictures of the internal ducts, mostly visual evaluations

Education or training needs:

No Information

Qualification of persons or companies required, quality assurance system required:

Qualitative checklist that grades the state of the pollutants/dust

Cost for managing and maintaining the inspection scheme:

No information

Cost for applying the measure to a given building:

No information

ADVANTAGES / DRAWBACKS

Advantages:

- No needs of particular devices for the evaluation, since the analysis is made mostly with a visual approach

Drawbacks:

- The overall document gives no specification about the qualification that inspectors need to have in order to perform the assessment

Proven/known impact of the measure (indicators):

Impact unknown

ADDITIONAL INFORMATION

References / Source of information / Links:

https://ventrix.fi/wp-content/uploads/2018/09/ILMANVAIHTOJ%C3%84RJESTELM%C3%84N-PUHTAUDEN-TARKASTUS.pdf

Author of the analysis: Matteo Urbani (REHVA)

Annex 8 – Existing regulations, standards and guidelines on the inspection of ductwork airtightness in EU countries

Valérie Leprince, PLEIAQ
April 2019

Existing regulations on the inspection of ductwork airtightness

Portugal

In Portugal, mandatory requirements for ductwork airtightness have been included in the regulation since 2006, as part of the implementation of the EPBD. Requirements for new HVAC systems include a set of mandatory tests that must be carried out during commissioning, before the building receives its permit of occupation; these requirements apply to buildings larger than 1,000 m^2. To pass the airtightness test, ductwork leakage may not exceed 1.5 l/s.m^2 under a static pressure of 400 Pa (Leprince, Kapsalaki, & Carrié, 2017).
However, a study from (Lisboa, 2018) has shown that this legal requirement is seldom complied with. An online survey has been performed on the 15 biggest contractors in the market, only 11 of them have answered:

- 64% of contractors performed, yearly, only from 1 to 10 leakage tests;
- 82% of contractors performed, on average, at most, 20 leakage tests per year;
- Only four contractors own leakage test equipment, which confirms that the remainder seven performed a small number of tests per year.

United-Kingdom

In the United Kingdom, air leakage testing is not regulatory for domestic mechanical ventilation systems, but it is mandatory and in accordance with BESA DW/143 (BESA, DW/143: Ductwork air leakage testing, 2013) for high-pressure ductwork systems of non-domestic ventilation systems. The ductwork system designer/specifier may also demand random air leakage tests of medium and low-pressure ductwork systems in his specification and choose which ductwork systems to test.
For non-domestic ventilation, the limits of air leakage for various pressure classes of ductwork systems are specified in Table 1 of BESA DW/144 (BESA, 2016)

France

In France, if a value better than the default value is used in the EP-calculation then it has to be justified (either by a test performed by a qualified tester or by certified quality approach). In France, the energy programmes Effinergie + and Effinergie BEPOS require a justified class A for ductwork airtightness (Leprince, Carrié, & Kapsalaki, 2017).
In the last 5 years in France, the awareness regarding ductwork airtightness has increased (Leprince, Carrié, & Kapsalaki, 2017). France has a qualification for ductwork testers (Qualibat 8721) with 35 qualified testers. A specific guideline for testing has been set (FD E 51-767, 2014).

Sweden

In Sweden there is a long history of ductwork requirements, the first requirements have been specified as part of building specifications since the AMA edition 1966 (Andersson, 2012). The AMA quality requirements have been raised when possible by

technology progress and when found profitable for the owner on a Life Cycle Cost basis. In 1966, Two "tightness norms" A and B, were defined. They were to be spot checked by the contractor; minimum tested duct surface area was 10 m².
In AMA version 2007, every ductwork shall meet tightness class C (even rectangular ductwork).

Norway

The building regulations only state that "Ducts and air-handling units shall be satisfactorily airtight" (Schild & Railio, 2009), there is no quantitative minimum requirements for airtightness.
However, the building owner usually specified for a class B (Schild & Railio, 2009).

Finland

The Finnish situation is similar to that in Sweden. The building regulations (Part D2 'Indoor climate and ventilation') require minimum Class B for the whole system, and gives experience-based recommendations to generally use ducts and components of Class C (minimum default) or better (Schild & Railio, 2009)..
In non-residential buildings, measurement is performed to check the compliance with the regulations.

Guidelines and standard on the inspection of ductwork airtightness

The classical method to measure ductwork airtightness is described in number of publications one could refer for example to §6.2 of the Save-duct project (chapter 6).
The ductwork under test is "isolated" from the rest of the ductwork, extremities of the tested ductwork are sealed and so are air terminal devices.
The measurement device consists in:

- A fan maintaining a constant pressure in the tested ductwork
- An airflow rate gauge, measuring the flowrate needed to maintain the constant given pressure
- A pressure gauge, checking the constancy of the pressure in the ductwork.

Usually in Europe, the test consists of a one-point measurement of the leakage flowrate at a given pressure differential. The measured flowrate, pressure and ductwork area give a leakage coefficient per square meter of ductwork area calculated as follow. This leakage coefficient is compared to airtightness class as defined in (CEN, 2003) and (CEN, 2006).

Air Tightness Class[1,2]	Air Leakage Limit, L/s per m^2 (cfm per 100 ft^2)
A	0.027 (19.2) $p_{test}^{0.65}$
B	0.009 (6.4) $p_{test}^{0.65}$
C	0.003 (2.1) $p_{test}^{0.65}$
D	0.001 (0.7) $p_{test}^{0.65}$
[1]CEN Standard EN 12237-2003 (circular ducts) [2]CEN Standard EN 1507-2006 (rectangular ducts) p_{test} =test pressure, Pa (in. of water)	

Figure 1: Definition of airtightness class in Europeans standards

European standards

In Europe, there is not just one standard describing ductwork airtightness test but a standard for each kind of ductwork. However, no standard cover all the problematic of ductwork airtightness test, therefore in countries where ductwork airtightness test are performed nationals guidelines/standards avec been developed.
Existing standards regarding ductwork airtightness test are:

- Measurement standards
  - EN 12237:2003 Ventilation for buildings - Ductwork. Strength and leakage of circular sheet metal ducts (CEN, 2003)
    - This standard describe the test protocol for circular ductwork only.
    - It includes definitions, sampling rules, testing pressure, equations to correct the flow rate and the basic contents of the test report
  - EN 1507:2006 Ventilation for buildings - Sheet metal air ducts with rectangular section Requirements for strength and leakage (CEN, 2006)
    - This standard is quite similar to the previous one but deals only with rectangular ductwork
    - It also includes the measurement of the deflexion of rectangular ductwork
  - EN 13403:2003. Ventilation for buildings. Not metallic ducts. Ductwork made from insulation ductboards.
    - This standard is specific to not metallic ducts, it includes a test procedure that can be used either on site or in laboratory
  - EN 15727:2010 Ventilation for buildings - Ducts and ductwork components, leakage classification and testing (CEN, 2010)
    - This standard classify components and provide a test method that can be performed either on-site or in laboratory
  - EN 14239: Ductwork Measurement of ductwork surface area
    - Every ductwork airtightness measurement protocol requires the measurement of the surface area of the ductwork and refer to this standard

- Inspection standard
  - EN 12599:2012: Ventilation for buildings. Test procedures and measurement methods to hand over air conditioning and ventilation systems
    - This standard provide an inspection method for non-residential building it includes reference to the measurements standards above (EN 1507 and EN 12237). This inspection standard is under revision (2019) and in its next version it shall includes more information regarding ductwork airtightness test.
    - It gives default test pressure of 200-400-1000 Pa for insufflation 200, 400, 750 for extraction ductwork. It shall be chosen the closest of the test pressure.

The multiplicity of standards can induce a confusion between the test of the airtightness of products themselves (in laboratory, actual ductwork non-implemented) and the test of the ductwork implemented of site. While, even if airtight product are needed to build airtight ductwork they are not sufficient to guaranty an airtight implemented ductwork. A bad implementation can lead to leaky ductwork whatever the product used.

National initiatives

French Standard, FD 51-767

The French standard FD 51-767 complete existing standard with information:

- To deal with various kind of ductwork (rigid, flexible, etc.) in a system
- To do sampling (according to the kind of building)
- To take into account specific devices (plenum, etc.)
- To choose the test pressure

It also imposes a calibration of the measurement device every 2 years with requirements on the accuracy.

The tested section shall be representative of all shape, size, materials used in the ductwork.
It is possible to perform the test on only part of the ductwork if at least one of those requirement is met:

- the ratio of the length of junction divided by the tested areaa is superior to 1 and the tested area is superior to 10 m2 and 10 % of the total area
- At least one whole floor to the ventilation unit and the tested areas is superior to 10 m^2 and 20% of the total ductwork area
- At least one whole column to the ventilation unit and and the tested areas is superior to 10 m^2 and 20% of the total ductwork area

If there is "N" Air Handling Unit:

- If $N \leq 5$, each shall be tested
- If $N > 5$, at least 5 + 40% x (N-5) shall be tested

In France, plenum, climate box and flexible sleeve shall be included in the measured section, if not the penalty can reach 50%.

The standard also includes correction according pressure and temperature and the description of the test report.

In addition to this standard the label Effinergie + provides technical rules that allow to estimate the ductwork area with a flat rate according to the maximum flowrate (only if the ductwork is fully tested, no sampling).

Belgian Specifications

In Belgium the "cahier des charges type 105 chauffage central ventilation et conditionnement d'air » by « régie des bâtiment », 2017 gives some guidelines to perform an airtightness test in its Article E5 part 5:

- At least 10m² and 30% of the ductwork area shall be tested
- The pressure test is defined
  - for insufflation it is:
    - 400 Pa for low pressure ductwork
    - 1000 Pa for medium pressure
    - 2000 Pa for high pressure
  - for extract ductwork it has to be 500 Pa if the airtightness requirement is class B and 750 Pa for class C and D
- Maximum uncertainties of measurement devices are also given
- Measure corrections according to the actual pressure and temperature are explained.

UK specifications (BESA, 2013)

In UK DW143 includes rules to perform the airtightness test. In UK test are mostly performed by installer. Therefore, this guide not only gives practical recommendation to perform ductwork airtightness test but also guidelines to build airtight ductwork.
In UK the part of the ductwork to be tested and the test pressure shall be agreed with the client or the system designer. The test shall be performed before insulation and installation of ATD.
Contrary to other countries, leakage testing is always performed in the UK under positive pressure even for the extract ductwork. The objective is to be able to identify the leakage paths. Only the test of high pressure ductwork is required (above 1000Pa). 100% of the high pressure ductwork shall be tested (no sampling), DW143 recommends to test at least 10% of medium pressure ductwork.

Sweden AMA VVS&KYL 16

In Sweden, rules to perform ductwork airtightness test are include in an AMA technical book entitled "General material and work description for plumbing and cooling technical work".

In Sweden, the duct system leakage has to be verified. It is normally done by the contractor as part of the contract (i.e. the cost for this first test is normally included in the contract lump sum).
The test is undertaken as a spot check where the parts to be checked are chosen by the owner's consultant.
For round duct systems 10 % and for rectangular ducts 20 % of the total duct surface has to be verified. In case the system is then found to be leakier than required, that part of the tested system shall be tightened and another equally sized part of the system shall be verified in the same manner. Should this part also be found to leak more than accepted the complete duct installation has to be leak tested and tightened until the requirements are fulfilled (Andersson, 2012). Therefore, it is expensive for contractors to install inferior duct systems, because they have to pay for both remedial work and additional tests. This motivates contractors to ensure that the work is done properly in the first place (Schild & Railio, 2009).

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Annex 9 – Existing regulations, standards, guidelines and other related initiatives in non-EU countries

Max Sherman, EPB Consulting Group
March 2019

Introduction

This annex condenses information gathered to date for non-European countries, but to summarize simply, the notion of ventilation system inspection is not something that has been adopted in any systematized way outside of Europe. Some countries have adopted pieces of what would be considered inspection as can be seen from the information below.

Information has also been searched in China and Japan, but no information could be found from contact persons in these countries.

Situation in the United States (US) including ASHRAE

A key aspect relative to this report is to note that extremely few commercial and institutional buildings have isolated ventilation systems. Such an isolated system is called a Dedicated Outdoor Air Supply (DOAS) system and is relatively rare. Local extract systems such as for toilets are normally isolated, but the systems that provide outdoor air for dilution is not. Ventilation is normally integrated into the air systems that handle heating and cooling. In some buildings natural ventilation is used.

Dwellings, on the other hand, more often have dedicated whole-dwelling ventilation systems, but may also have them integrated with the heating and cooling system. The most typical stand-alone residential ventilation system is a continuously operating extract fan—often in a wet room. Very few dwellings, however, are required to have ventilation systems.

Regulations

In the US, building regulations are generally called codes. Codes are enacted locally rather than nationally and there are approximately 4000 jurisdictions that do so. Most jurisdictions base their local code on model codes published by the International Code Council. The relevant codes include the International Building Code (IBC), the International Energy Conservation Code (IECC), the International Mechanical Code (IMC) and the International Residential Code (IRC).

The ventilation requirements in these codes are generally based on ASHRAE standards although different documents are on different revision cycles. Commissioning of low-rise dwellings is not generally required, although final inspections generally require that equipment be checked against design.

For commercial and institutional buildings that follow the IECC, there is a requirement that the HVAC system (or systems) be commissioned prior to final inspection (Section C408). A commissioning plan must be prepared by an appropriate design professional. That plan needs to include air balancing to assure that total supply air is appropriate for each supply terminal. Generally there will be an inspection to make sure that the equipment installed conforms to the design.

Some larger jurisdictions have their own code requirements, the most notable one is California who uses its own Title 24 rather than the « I-codes ». While there are a lot of differences in stringency, the requirements for ventilation are generally taken from ASHRAE.

Standards

In the North America standards are generally authoritative statements from a professional body that describe the proper way to do or build something. The American National Standards Institute (ANSI) authorizes official standards in the US either directly itself or more often by accrediting an organization to write ones in their area. ASHRAE is such an organization for writing standards and guidelines in the HVAC field. While such standards do not have the force of law, they can be relevant in court proceedings to determine the proper standard of care. They can be adopted by authorities having jurisdiction, which makes them requirements[5].

ASHRAE standards are not just used the United States, but are used in one way or another in much of the Western hemisphere and Pacific rim. ASHRAE has standards on the commissioning process generally (Standard 202) and standards on how to test and balance HVAC systems (Standard 111), but none of those are very relevant to the ventilation aspects. Ventilation of the building types in question is more directly the purview of the 62 series of standards.

Standards generally say what must be done, but not who is responsible. Regulations that adopt standards may specify that. Similarly an owner or program that requires use of a standard may specify that. Often there can be no responsible person identified.

ASHRAE Standard 62.1

ASHRAE standard 62.1 applies to commercial buildings, schools and a variety of other building types, but it does not generally cover dwellings. It should be noted that earlier versions of 62.1 applied to high-rise residential buildings and many buildings were built to that code.

Standard 62.1 has requirements for ventilation system start-up (Section 7) that require inspection of dampers, ducts, controls, and air flow rates. The standard requires that ventilation system be balanced in accordance with ASHRAE Standard 111 (or equivalent) to make sure the air flow through the ventilation system is as per design. It requires that drain pains be inspected to make sure they drain properly. It requires that air distribution systems be inspected to be free of dirt. It requires that dampers be inspected to be in proper working order. These requirements could be considered generalized inspection or commissioning requirements, but they are only required when installing a new system. (Some parts are required when there is a significant change in use of the building.)

Standard 62.1 also has a requirement for an operations and maintenance manual (Section 8) that should determine how often and in what detail regular maintenance inspections should be made. The standard requires that the system be operated (and maintained) in compliance with that manual.

[5] Annex 5 provides details about one standard developed according to this process, i.e. ANSI RESNET/ICC 380-2016 - Standard for testing airtightness of building enclosures, airtightness of heating and cooling air distribution systems, and airflow of mechanical ventilation systems.

ASHRAE Standard 62.2

ASHRAE Standard 62.2 covers most dwellings. It sets minimum requirements for whole-dwelling ventilation, local exhaust and associated equipment. It does not explicitly require any inspection or commissioning procedures. It does, however, require that ventilation air flows be measured, to demonstrate compliance with specified flow rates. The flows are to be measured according to manufacturer's directions or failing that a flow hood, flow grid or other similar air flow measuring device, but no test methods are referenced.

The standard also requires that air-moving equipment be rated by certain standards; it must meet ASHRAE Standard 51, AMCA Standard 300 and rated in accordance with HVI Standards 915, 916 and 920. Generally, equipment is labelled to show compliance with these standards and any inspection consists of checking the model of the equipment.

Guides

The term guide or guideline does not have a standardized definition. There are many kinds of guides written by private and public organizations. The standards developing organizations like ASHRAE often have such documents that are not the level of a standard, but offer authoritative guidance that goes beyond the related standard. ASHRAE has a series of guidelines on the commissioning process ASHRAE Guideline 24 includes guidance on ventilation system inspection and commissioning for dwellings.

ASHRAE is working on a similar guideline (42P) for commercial and institutional ventilation systems, but had previously created an Indoor Air Quality Design Guide[6], in the model of ASHRAE's advanced energy design guides, to address considerations related to IAQ including but not limited to ventilation. Commissioning of ventilation systems is included in this guide. The appendix contains a template describing the commissioning part of the Guide as if it were required.

There are no guides that are specific to the inspection of ventilation systems. There are many guides, including private-sector ones that include recommendations on commissioning, inspection, or maintenance for HVAC systems.

Situation in Australia

Australia's climates are relatively mild and there has been a strong tradition of, and reliance on, natural ventilation in most building typologies. Natural ventilation remains a valid response to ventilation requirements in many areas of Australia and for different building types. The use of mechanical ventilation systems, as distinct from combined heating, cooling and ventilation systems (HVAC), is not common. Because of this context, regulations regarding mechanical ventilation systems are not as well developed as in many other western countries.

There are minimal ventilation requirements for dwellings, other than mandated minimum window openings for sleeping zones and requirements for openable windows or mechanical ventilators in bathrooms and toilets. Some requirements exist for commercial buildings. Australian/New Zealand Standard 3666 "Air handling and water system of buildings" has some mild requirements for commissioning, but it is more on the aspect of microbial control than about ventilation systems themselves.

[6] Annex 7 includes a detailed analysis of the ASHRAE Indoor Air Quality Guide.

Another related standard is AUS/NZ 1668 on "The use of ventilation and air conditioning in buildings." Part 2 of that standard focusses on mechanical ventilation, but does not address system inspection. The standard is provided for advice and is not mandated.

Commissioning is encouraged by not required. There is advice provided to follow ASHRAE, CIBSE (Code A) and AIRAH (DA27 and DA28). The Australian Buildings Codes Board has recently published an IAQ Handbook, but it does not address ventilation system inspection.

Situation in Canada

The situation in Canada is quite similar to the one of the United States in many ways. Like the US codes are primarily local and not federal or provincial. Like the US models codes exist. Like the US ASHRAE is heavily relied upon for standards.

While Canada does use some of the ICC code products, it relies more on the National Building Code of Canada (and some provincial codes) as a model for jurisdictions. That model code references ASHRAE standards, particularly 62.1 for non-residential buildings.

For dwellings Canada relies more on Guideline F326, "Residential Mechanical Ventilation Systems" than on ASHRAE 62.2. As a guideline, however, F326 is not mandatory in any jurisdiction and is rarely followed in full. It does require that the ventilation system be inspected including intake and exhaust hoods (clearance, size, screening, labelling) as well as ductwork (registers, dampers, insulation, tightness and safety)[7].

Situation in Korea

While mechanical ventilation is mandated in many cases, inspection of ventilation systems is not currently. There will, however, be a regulation that will go into effect in 2020 that specifies inspection, maintenance and commissioning of overall mechanical system: The Act on the Building Mechanical System. The details of the regulation are still under discussion.

There are no requirements for small dwelling for but for new large apartments the Healthy Housing Construction Standard requires that testing and balancing be done on ventilation systems. No other inspection is required.

Situation in New Zealand

The situation in New Zealand parallels Australia in many way. AUS/NZ standards 1668 and 3666 are joint standards and are used in both countries in similar ways. Neither dwellings nor schools are required to have mechanical ventilation systems. Natural ventilation systems do not have inspection requirements.

New Zealand Building Code (NZBC) Clause G4 that regulates ventilation for compliance. There are various Acceptable Solutions offered such as natural and mechanical solutions. The code suggest, but does not require, that the verifications of

[7] In addition to this information, Annex 3 provides as an example a detailed analysis of one provincial regulation for health buildings, i.e. Ontario Regulation 67/93 - Health care and residential facilities - Inspection of mechanical ventilation systems.

the ventilation rate may use the "methods of measurement given in CIBSE Code Series A, Appendix A3.1".

There are various standards such as NZS 4303:1990 "Ventilation for acceptable indoor air quality", and AUS/NZ 1668.2:2002 "Ventilation design for indoor-air contaminant control" which gives recommendations of the flow rates for wet and dry rooms. There are no requirements.

Situation in Singapore

Singapore has no requirements for inspection of ventilation systems. It does, however, use ASHRAE standards for guidance.

REFERENCES

ASHRAE

- Standard 62.1, "Ventilation for Acceptable Indoor Air Quality"
- Standard 62.2, "Ventilation and Acceptable Indoor Air Quality in Residential Buildings"
- Standard 111, "Measurement, Testing, Adjusting and Balancing Heating, Ventilation and Air-Conditioning Systems"
- Standard 202, "Commissioning Process for Buildings and Systems"
- Guideline 11, "Field Testing of HVAC Controls Components"
- Guideline 24, "Ventilation and Indoor Air Quality in Low-Rise Residential Buildings"
- Guideline 42P, "Indoor Air Quality in Commercial and Institutional Buildings"
- Indoor Air Quality Guide: Best Practices for Design Construction and Commissioning

Australia

- Australian/New Zealand Standard 1668 "The Use of ventilation and air conditioning in buildings."
- "Prime For the future: Regulating Building Commissioning" Australian Building Code Board

Canada

- CSA/CAN F326, "Residential Mechanical Ventilation Systems (http://www.reversomatic.com/old/resources/images/CSA%20F-326.pdf)
- National Building Code of Canada

Korea

- The Act on the Building Mechanical System
- The Healthy Housing Construction Standard

New Zealand

- New Zealand Building Code
- New Zealand Standard NZS 4303 "Ventilation for Acceptable Indoor Air Quality"
- Australian/New Zealand Standard 1668 "The Use of ventilation and air conditioning in buildings."
- CIBSE Code Series A, Appendix A3.1 (UK)

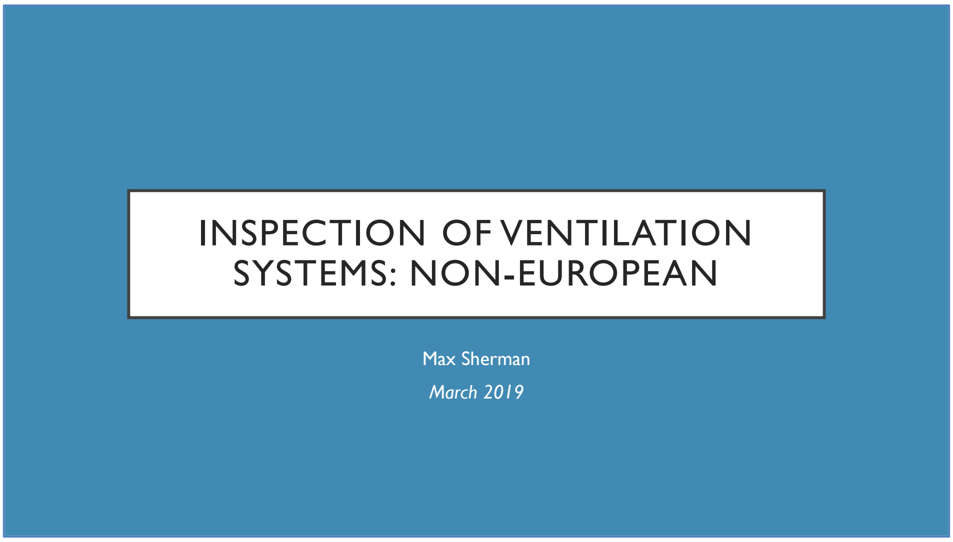
United States

- California Energy Commission Title 24 Part 6

- International Codes Council: (http://www.iccsafe.org) for International Building Code, International Energy Conservation Code, International Mechanical Code and International Residential Code.
- Air Movement and Control Association
- American National Standards Institute
- American Society of Heating Refrigeration and Air-Conditioning Engineers for standards 51, 62.1, 62.2, 111, 202; guidelines 24, 42P and Indoor Air Quality Guide.
- Home Ventilating Institute for standards 915, 916 and 920.

ANNEX: slides summarizing the study

These slides were presented during the AIVC Workshop mentioned in Annex 12.



OVERVIEW OF FINDINGS

Intention: Virtually no regulation on inspection of ventilation systems (outside of Europe).

Advice: Several countries offer suggestion, guidance, options that can be used, but are not legally required.

Approach: Penetration of stand-alone, designed ventilation systems is low.

ASHRAE COMMONALITY

ASHRAE Standards are not regulations, but represent *standard of care* and can be met: Standard 62 series deals with ventilation: Standards 202 & 111 with HVAC commissioning.

ASHRAE Guidelines and Guides offer options and advice: *ASHRAE IAQ Guide*, guidelines 24, 42p deal with ventilation.

ASHRAE is most common source of HVAC standards and guidelines outside of Europe. Some are required, but none nationally.

ASHRAE VENTILATION STANDARDS

- Commercial/institutional buildings: 62.1
- Requirements for start-up commissioning (initial inspection)
- Requirement that there be an Operations and Maintenance manual (on-going inspection
- Companion guideline 42p

- Dwellings/Residential: 62.2
- Requires air flow rates be verified
- Requires that ventilation equipment meet certain standards (e.g. HVI 915, 916, 920; AMCA 300)
- Companion guideline 24

COUNTRIES

AUSTRALIA

- Strong dependence on natural ventilation; few stand-alone ventilation systems otherwise
- Standard AUS/NZ 1668 & 3666 includes mechanical ventilation; not mandatory and does not address inspection.
- Commissioning is encouraged but not required; references to ASHRAE, CIBSE (Code A) and AIRAH (DA 27, 28)

CANADA

- Regulations are local not national. International Code Council documents used as model codes in addition to National Building Code of Canada
- Commercial-Institutional buildings usually use ASHRAE Standard 62.1
- Residential buildings use Guideline F326 on residential mechanical ventilation systems, but may allow use of ASHRAE 62.2 as well.

REPUBLIC OF KOREA

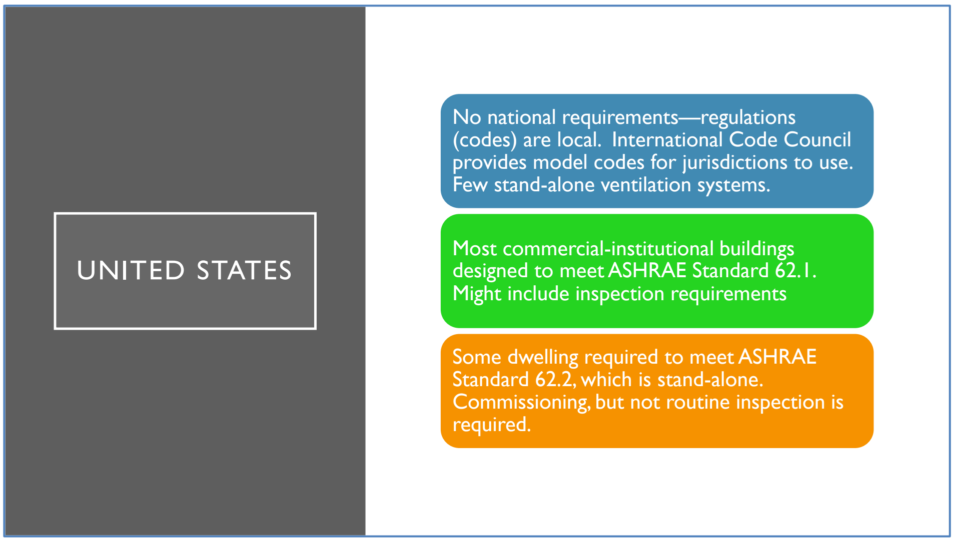
- Ventilation systems are mandated in many cases, particularly in large residential or commercial buildings, but inspection is not part of the requirement.
- No requirements for small dwellings
- In 2020 "The Act on the Building Mechanical System" will require ventilation system inspection, but the requirements are still being debated

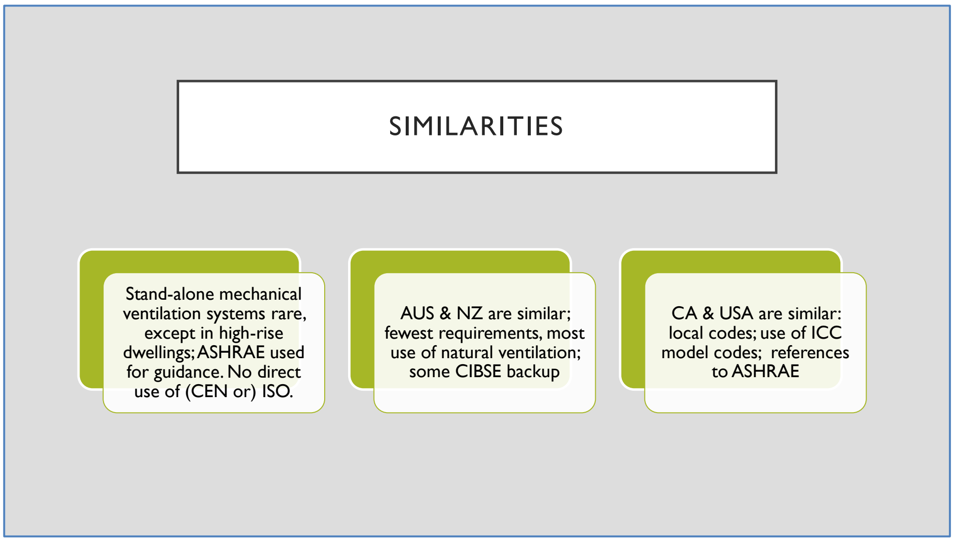
NEW ZEALAND

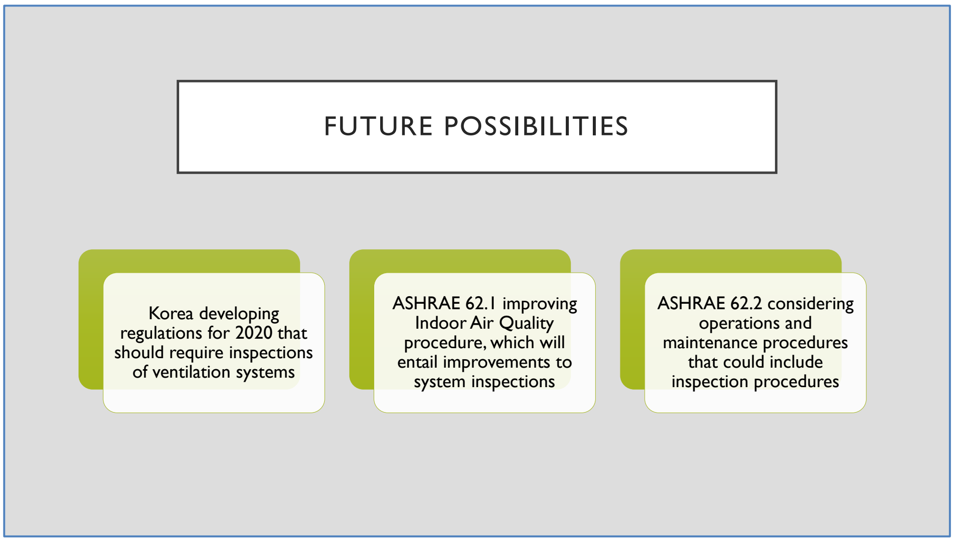
- Strong dependence on natural ventilation; few stand-alone ventilation systems. NZS 4303 provides guidance on rates.
- Standard AUS/NZ 1668 & 3666 includes mechanical ventilation; not mandatory and does not address inspection.
- New Zealand Building Code (Clause G4) regulates ventilation including several Acceptable Solutions. Suggests that CIBSE (Code A) can be used for compliance testing.

SINGAPORE

- No specific requirements for inspection or commissioning of ventilation systems
- Recommends appropriate ASHRAE Standards be used.


UNITED STATES
No national requirements—regulations (codes) are local. International Code Council provides model codes for jurisdictions to use. Few stand-alone ventilation systems.
Most commercial-institutional buildings designed to meet ASHRAE Standard 62.1. Might include inspection requirements
Some dwelling required to meet ASHRAE Standard 62.2, which is stand-alone. Commissioning, but not routine inspection is required.


SIMILARITIES
Stand-alone mechanical ventilation systems rare, except in high-rise dwellings; ASHRAE used for guidance. No direct use of (CEN or) ISO.
AUS & NZ are similar; fewest requirements, most use of natural ventilation; some CIBSE backup
CA & USA are similar: local codes; use of ICC model codes; references to ASHRAE


FUTURE POSSIBILITIES
Korea developing regulations for 2020 that should require inspections of ventilation systems
ASHRAE 62.1 improving Indoor Air Quality procedure, which will entail improvements to system inspections
ASHRAE 62.2 considering operations and maintenance procedures that could include inspection procedures

Annex 10 – Information from EU projects

Valérie Leprince, PLEIAQ
April 2019

The following EU projects have been checked and analysed to gather relevant information for the EPBD 19a study:

- HARMONAC (Harmonizing Air Conditioning Inspection and Audit Procedures in the EU Tertiary Building Sector)
- iSERVcmb (Inspection of HVAC Systems through continuous monitoring and benchmarking – www.iservcmb.info)
- SuperSmart (Expertise hub for a market uptake of energy-efficient supermarkets by awareness raising, knowledge transfer and pre-preparation of an EU Ecolabel – www.supersmart-supermarket.info)
- AuditAC (Field Benchmarking and Market Development for Audit Methods in Air Conditioning www.cardiff.ac.uk/archi/research/auditac)
- EnVIE (Indoor Air Quality and Health Effects - https://paginas.fe.up.pt/~envie) and IAIAQ (Promoting Actions for Healthy Indoor Air)

Auditac project

AuditAC stand for the project "Field Benchmarking and Market Development for Audit Methods in Air Conditioning". It aims at implementing Article 9 of the EPBD, but it has a much broader scope. It deals with energy auditing and improvement of air conditioning systems generally. The objective of the project is to provide practical support to improve the energy-efficiency A/C systems.
Auditac project stresses the need of tool for auditing, the volume 5 of the project gives a list of Energy Conservation Opportunities (ECO) for Air Conditioning Auditor. That is to say a list of potential energy saving in A/C systems, including the ventilation part. It also lists the various contracts that can be set for inspection:

- Full-coverage service contract
- Full-labour service contract
- Preventive maintenance service contract
- Inspection service contract
- End-results contracting
- Energy performance contract

The training package of the Auditac project includes the description of the various ventilation systems, and could be partly used in the context of training ventilation system inspectors. (Adnot & al., 2007)

Harmonac Project

Presentation of the project

The Harmonac project is the follow-up of the Auditac project. It has used measurement of energy use in 42 air-conditioning systems (and their components) to provide an evidence-based report on the Energy Conservation Opportunities (ECOs) available in air conditioning systems.
ECOs (defined in AUDITAC) that can be identified during an EPBD inspection process (based on the former EN 15240) have been pointed out. The project has produced

tools for use in the inspection process, and a teaching package to assist in the training of inspectors.
Therefore, the Harmonac project allows the inspection process to achieve part of the ECO's found in the Auditac project. The list of inspection items is given in Annex. (Knight & al., 2010)

Interesting ideas taken from the report

The elements of an inspection are analysed in terms of:

- Time taken
- ECOs identified
- Likelihood of achieving energy savings

Inspection Item # Short Description	Time (mins)	ECO's	Example Savings from ECO's	Teaching Package
PI6 Building mass and air tightness / leakage	9 to 30	E2.4 Correct excessive envelope air leakage E2.6 Generate possibility of night time over ventilation E3.3 Add insulation to exterior walls by filling cavities	5 to 27% or 7 to 48 kWh/m^2	PI6: Building thermal mass and ventilation

Figure 2: Typical Harmonac inspection item

Some interesting conclusions in the context of the current study are:

- At European level, the potential energy savings available in air-conditioning systems could reduce the primary energy consumption of EU non-residential buildings by 5.8%, and the EU overall primary energy use by 0.7%.
- The inspections are only likely to achieve around 37% of the possible savings in air-conditioning systems due to the cost, complexity and uncertainty of energy savings in existing systems. The rest of the potential savings will therefore simply go 'missing'.
- The time taken to complete an inspection is generally correlated with floor area.
- Difficulties to gather data for the pre-inspection may jeopardize the quality of the inspection afterward.
- A system that can automatically detect non-efficiency and propose maintenance could be rewarded in the energy performance calculation
- Observations based on real consumption data for the system inspected are the best tool to persuade the owner of the need for action.

In Harmonac, statistics have been made on large scale to estimate the total energy saving potential. Some of the identified ECOs are common with stand-alone ventilation systems. For example ECO O4.14 "Clean or replace filters regularly" occurred 57.4% of time with a measured average 24.9% energy saving potential.

iSERVcmb

The iSERVCMB project (Inspection of HVAC Systems through continuous monitoring and benchmarking) is based on the inspection methodology developed in Harmonac (Wright & Sheldon, 2012). It describes maintenance tasks associated with air conditioning systems including:

- the reasons for carrying them out,
- the typical intervals,
- the description of a typical maintenance visit
- the responsibility of the further work and cost.

Part of the maintenance inspection is dedicated to air handling units, mostly to check cleanliness and none obstruction, through:

- Inspection of air filter
- Checking of the general condition of the outdoor unit through an initial "Sight, Sound and Smell inspection"
- Checking position and condition of sensors
- Checking the condition and correction operation of fan motor and drive parties
- Checking operation of controls and safety switches
- Checking all intake and exhaust grilles
- Cleaning Air Terminal Devices
- Check the ducting

Supersmart: extract from guidebook for supermarket

This project deals with the maintenance of supermarkets. It includes only a small part on the maintenance/ inspection of ventilation system (Ciconkov & Ciconkov, 2016).

Extract from the" Eco-friendly operation and maintenance of supermarkets – Report 6":

6.1.2.3 Air handling unit - AHU

AHU unit provides ventilation and supplies fresh air to the supermarket. Airflow capacity should be tested to confirm that it meets the requirements for the conditioned space. Since lower air flow means decreased energy use, proper balance should be found not influencing indoor air quality. Air filters used in the AHU should be cleaned weekly and replaced if they are damaged since they can lead to clogging of AHU coils and supply of polluted air. Filters are helping in maintaining indoor air quality and are also protecting the other components in the AHU sections from accumulation of dirt. The easiest way of determining if the air filter is dirty is to measure the air pressure drop across the filter section. Fan motors operation and belt tensions should be tested in order to supply required air flow rates.

Air flow regulation is done by motor actuator operated dampers or by an economizer when outdoor conditions permit. These moving parts are exposed to outdoor conditions the whole year and should be inspected, cleaned, and lubricated regularly such that the components do not get stuck in one position. It is important during maintenance to get proper damper response position regarding the used set point. This will confirm that overloading of cooling/heating coil will not happen and full potential of free cooling is used.

6.1.2.4 Air ducts and grilles

Air leaks should be prevented since it leads to reducing the HVAC efficiency. Air grilles should have non obstructive air intake/outlet for proper air flow operation. It is important to have access panels in the ducting for proper maintenance to take place. The insulation of air ducts should be inspected at least once per year in order to be sure that there is no insulation damage and heat loss is prevented

ENVIE

ENVIE was an 18-month project in 2007/2008. Its objective was to collect scientific knowledge from on-going research to elaborate policy relevant recommendations based on a better understanding of the health impacts of indoor air quality (de Oliveria Fernandes & al., 2009).
Ventilation is one of the parameters having a major impact on indoor air quality. The report includes general requirements on ventilation in Europe. It promotes the inspection of ventilation system:

"Regular inspections of ventilation systems and their performance should be considered in the context of the EPBD implementation, and experiences gained from the systems used in other countries (e.g. Japan, Sweden) utilized."

New policies needed described in the ENVIE project include the inspection of ventilation systems.

Ventilation	Develop European health based ventilation guidelines to control exposure to pollutants and moisture from indoor and outdoor sources	European guidelines National building codes	CEN standards	Design guidelines to professionals
	Mandate regular inspection and maintenance for all ventilation and air conditioning systems (integrate with energy performance inspections)	Recast of EPBD related actions European guidelines National building codes	CEN standards	Guidelines or professionals
	Ban all unflued combustion heaters, equip gas stoves with exhaust hoods and fans, mandate CO detectors and regular maintenance/inspection for all combustion devices.	European directive	CEN standards Design guidelines	Design guidelines to professionals

Figure 3: Policy needed on the inspection of ventilation system according to the ENVIE project

The impact of the inspection of ventilation system on the risk due to bad indoor air quality is also estimated. The kDALYs/year (per country and policy) avoidable by ideal indoor air quality in Europe is calculated for the mandatory inspection of ventilation system (among other things).

Annex

In the Harmonac project three distinct steps are suggested as being required for a full Inspection:

- Preliminary data collection and evaluation
- Physical survey - site visit
- Analysis and reporting

Phase 1: Information Collection and Evaluation

- Establish a connection and talk briefly with the building operating personnel, owner, occupants etc. about the HVAC system, comfort, problems, etc.
- Study the plans and specifications and become familiar with the building, systems, capacities, equipment, etc.
- Examine the overall building energy consumption history AND AC system energy components consumption history if available. If not, get a complete building energy consumption history on gas, oil, and electrical use from utility companies and fuel suppliers. Compare the consumption per unit area per year with other similar buildings and determine degree of variance.
- List maintenance, cleaning, adjustment, repairs and system balancing undertaken to this point.

Phase 2: Walkthrough inspection procedure
Field Surveys

- Make an initial walkthrough inspection to become familiar with the building, systems, equipment, maintenance, operation status, etc.
- Take spot test measurements if needed.
- If the walkthrough inspection is sufficient, calculate energy savings from ECO's for the various energy improvements, estimate retrofit costs and calculate paybacks.
- Make a thorough inspection of building systems and equipment and become familiar with them. Check out operations, maintenance, malfunctions, comfort, problems etc.
- Check and record equipment specification plates and model numbers.
- Conduct in-depth interviews if needed with the HVAC system manager and some spot information could be provided by occupants in specific thermal zones (e.g. some persons who work in the north side of the building and others in the south side). Review maintenance, scheduling, performance, comfort and problems of building, equipment and systems.
- Record actual hours of operation of systems and equipment, and the hours of occupancy of the personnel.

Energy Data

- Study and analyse the history of the buildings electrical and fuel energy consumption.

Compare with building consumption indices of similar buildings.

- Determine actual existing seasonal and peak energy consumption, along with the efficiencies of specific systems and equipment based on tests and other data.
- Calculate the peak and seasonal heating and cooling loads actually required for the current conditions of the building. Compare with the design and existing capacities.

Field Tests

- Perform measurements of actual flows, temperatures, pressures, etc. in the HVAC equipment where possible.

Evaluation of Energy Improvements

- List all problems with buildings, systems and equipment.
- Generate energy improvements and develop those with most potential.
- Calculate the potential energy savings from ECO's in percentage of total consumption and in terms of kWh in a typical season. Depending on the energy contract, cost estimation should be provided.
- Estimate costs of retrofitting, payback time and return of investment.

Phase 3: Report and Analysis

1. The final report should summarise all the main findings from the Inspection and be clear as to the ECOs identified to minimise the obstacles to their implementation.

Table 35 – Average time taken by action during Pre-Inspection

Inspection Item	Short Description	Time (mins)
PI1	Location and number of AC zones	8.4
PI2	Documentation per zone	21
PI3	Images of zones/building	18
PI4	General zone data/zone	18.7
PI5	Construction details/zone	18.4
PI6	Building mass/air tightness per zone	6.5
PI7	Occupancy schedules per zone	7
PI8	Monthly schedule exceptions per zone	6.2
PI9	HVAC system description and operating setpoints per zone	24
PI10	Original design conditions per zone	7.5
PI11	Current design loads per zone	12
PI12	Power/energy information per zone	11
PI13	Source of heating supplying each zone	5.7
PI14	Heating storage and control for each zone	0
PI15	Refrigeration equipment for each zone	22.1
PI16	AHU for each zone	13.4
PI17	Cooling distribution fluid details per zone	8
PI18	Cooling terminal units details in each zone	6.2
PI19	Energy supply to the system	5
PI20	Energy supply to the building	4
PI21	Annual energy consumption of the system	13.8
PI22	Annual energy consumption of the building	12.6
	TOTAL TIME TAKEN (minutes)	**249.5**

Table 36 - – Average time taken by action for Packaged systems

Inspection Item	Short Description	Time (mins)
PP1	List of installed refrigeration plant	22
PP2	Method of control of temperature.	8
PP3	Method of control of periods of operation	4
PP4	Reports from earlier AC inspections and EPC's	0
PP5	Records of maintenance operations	0
PP6	Records of maintenance (control systems and sensors)	8
PP7	Records of sub-metered air conditioning plant (use or energy)	6.7
PP8	Design cooling load for each system	9
PP9	Description of the occupation of the cooled spaces	4.5
P1	Review available documentation from pre-inspection	12

P2	Locate the plant and compare details with pre-inspection data	5
P3	Locate supply to the A/C system and install VA logger(s)	3.5
P4	Review current inspection and maintenance regime	7
P5	Compare size with imposed cooling loads	12
P6	Compare records of use or sub-metered energy with expectations	14
P7	Locate outdoor plant	3
P8	Check for signs of refrigerant leakage.	5
P9	Check plant is capable of providing cooling	7
P10	Check external heat exchangers	7
P11	Check location of outdoor unit	4
P12	Assess zoning in relation to internal gain and orientation	4.2
P13	Check indicated weekday and time on controllers against actual	12
P14	Note the set on and off periods	7
P15	Identify zone heating and cooling temperature control sensors.	9.7
P16	Note set temperatures in relation to the activities and occupancy	5.8
P17	Provision of controls or guidance on use while windows open	0
P18	Type, age and method of capacity control of the equipment	21.6
P19	Write report	250
	TOTAL TIME TAKEN (minutes)	**452**

Table 37 - – Average time taken by action centralized systems

Inspection Item	Short Description	Time (mins)
PC1	Details of installed refrigeration plant	16
PC2	Description of system control zones, with schematic drawings.	18.8
PC3	Description of method of control of temperature.	14
PC4	Description of method of control of periods of operation.	11.8
PC5	Floor plans, and schematics of air conditioning systems.	25.3
PC6	Reports from earlier AC inspections and EPC's	6
PC7	Records of maintenance operations on refrigeration systems	1
PC8	Records of maintenance operations on air delivery systems.	1.5
PC9	Records of maintenance operations on control systems and sensors	3
PC10	Records of sub-metered AC plant use or energy consumption.	18
PC11	Commissioning results where relevant	0
PC12	An estimate of the design cooling load for each system	14
PC13	Records of issues or complaints concerning indoor comfort conditions	6
PC14	Use of BMS	15
PC15	Monitoring to continually observe performance of AC systems	14.1
C1	Locate relevant plant and compare details	60.4
C2	Locate supply the A/C system and install VA logger(s)	21
C3	Review current inspection and maintenance regime	12.3
C4	Compare system size with imposed cooling loads	18
C5	Estimate Specific Fan Power of relevant air movement systems	40.5
C6	Compare AC usage with expected hours or energy use	0
C7	Locate refrigeration plant and check operation	13
C8	Visual appearance of refrigeration plant and immediate area	4
C9	Check refrigeration plant is capable of providing cooling	6
C10	Check type, rating and operation of distribution fans and pumps	12.3
C11	Visually check condition/operation of outdoor heat rejection units	0
C12	Check for obstructions through heat rejection heat exchangers	0

C13	Check for signs of refrigerant leakage	2.7
C14	Check for the correct rotation of fans	3.9
C15	Visually check the condition and operation of indoor units	6.3
C16	Check air inlets and outlets for obstruction	3.6
C17	Check for obstructions to airflow through the heat exchangers	
C18	Check condition of intake air filters.	7
C19	Check for signs of refrigerant leakage.	3.6
C20	Check for the correct rotation of fans	1.9
C21	Review air delivery and extract routes from spaces	13
C22	Review any occupant complaints	11
C23	Assess air supply openings in relation to extract openings.	0
C24	Assess the controllability of a sample number of terminal units	2.4
C25	Check filter changing or cleaning frequency.	8
C26	Assess the current state of cleanliness or blockage of filters.	9.8
C27	Note the condition of filter differential pressure gauge.	0
C28	Assess the fit and sealing of filters and housings.	0
C29	Examine heat exchangers for damage or significant blockage	2
C30	Examine refrigeration heat exchangers for signs of leakage	5.5
C31	Note fan type and method of air speed control	4.7
C32	Check for obstructions to inlet grilles, screens and pre-filters.	3
C33	Check location of inlets for proximity to sources of heat	2.1
C34	Assess zoning in relation to internal gain and solar radiation.	3.6
C35	Note current time on controllers against the actual time	0
C36	Note the set on and off periods	8.9
C37	Identify zone heating and cooling temperature control sensors	8.5
C38	Note zone set temperatures relative to the activities and occupancy	12.1
C39	Check control basis to avoid simultaneous heating and cooling	7.7
C40	Assess the refrigeration compressor(s) and capacity control	38.4
C41	Assess control of air flow rate through air supply and exhaust ducts	36.3
C42	Assess control of ancillary system components e.g. pumps and fans	10.4
C43	Assess how reheat is achieved, particularly in the morning	0
C44	Check actual control basis of system	16
	TOTAL TIME TAKEN (minutes)	**584.4**

Annex 11 – Survey among REHVA members

A survey was sent by REHVA to its member associations on 22nd January 2019, with a deadline for answering on 13th February.

The content of the survey is shown below.

Answers were received from the following organisations:

- Czech Republic: STP (Society of Environmental Engineering)
- Estonia: EKVU (The Estonian Society of Heating and Ventilation Engineers)
- Finland: FINVAC (The Finnish Association of HVAC Societies)
- Germany: VDI-TGA (The Association of German Engineers - Society for Civil Engineering and Building Services)
- Italy: AICARR (Associazione Italiana Condizionamento dell`aria, Riscaldamento Refrigerazione)
- Hungary: MMK (Hungarian Chamber of Engineers)
- Latvia: AHGWTEL / LATVAC (Association of Heat, Gas and Water Technology Engineers of Latvia)
- Norway: NORVAC (Norwegian Society of HVAC Engineers)
- Romania: AIIR (Romanian Association for Installations Engineers)
- Slovakia: SSTP (Slovak Society for Environmental Technology)
- Slovenia: SITHOK (Slovenian Society for Heating, Refrigerating and Air-conditioning Engineers)
- Sweden: SWEDVAC (Swedish HVAC Society - Society of Energy and Environmental Technology)
- Switzerland: SWKI (Schweizerischer Verein von Gebäudetechnik Ingenieuren, Société suisse des ingénieurs en technique du bâtiment)
- Turkey: TTMD (Turkish Society of HVAC and Sanitary Engineers)

Answers allow to identify:

- The absence of regulations, national standards and guidelines in Czech Republic, Estonia, Latvia, Slovakia, Slovenia
- Regulations about the inspection of ventilation systems in Finland, Hungary, Italy, Poland, Romania and Sweden (see Annex 2), most of them related to workplaces (Hungary, Italy Poland, Romania) and the protection of workers
- European standards
- National standard in Turkey (see Annex 4)
- Guidelines in Finland and Switzerland (see Annex 6)

According to the answers received, training programmes or documents for installers exist in:

- Finland, through a non-governmental organization established for qualifications and certifications of experts (FISE, http://fise.fi/en/)
- Finland: the Association for building services industry and trade (TALTEKA Association) has developed technical guidelines for installation of ventilation

systems in 2017. These guidelines are also in the evaluation and revision process during 2019 (https://www.talteka.fi/).

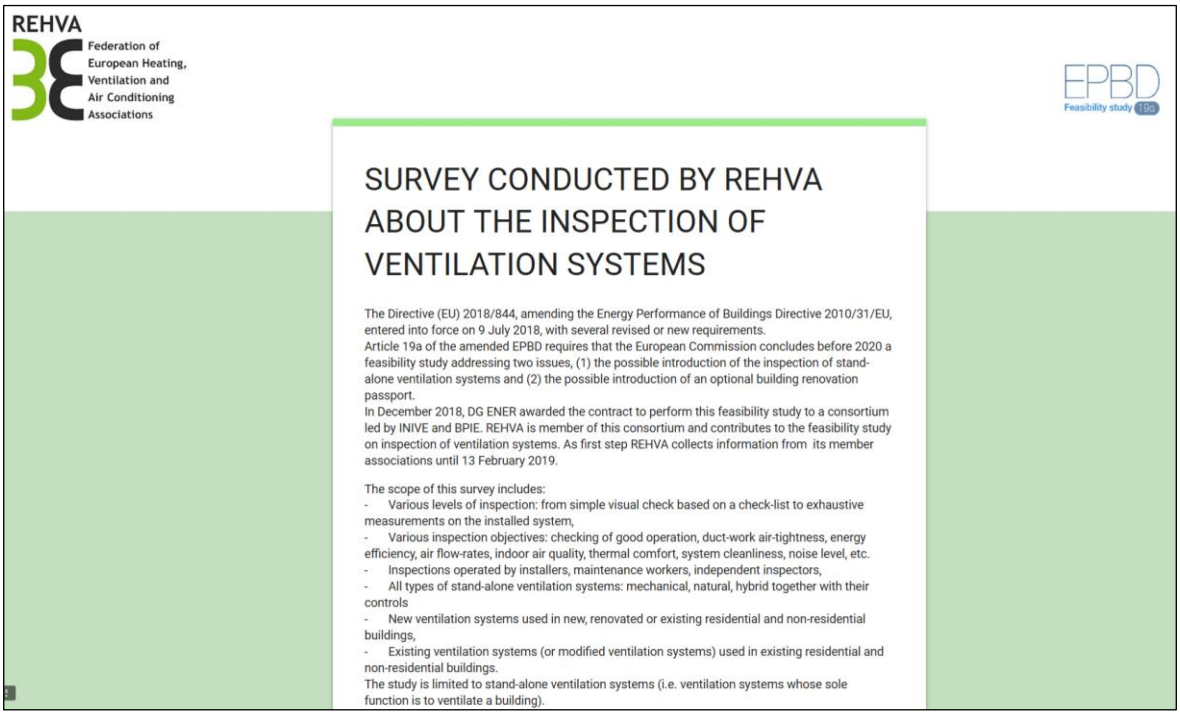
- Finland: the Building Information Foundation RTS has also revised the guidebook for good installation practice for air conditioning and ventilation systems (Talotekniikka RYL). It is a revised version of the 2002 edition and will be published in 2019.
- Poland: one document not mentioned in any regulation and applicable only to new systems is: Warunki Techniczne Wykonania i Odbioru Robót Budowlanych E2/2017 - Część E: Roboty instalacyjne sanitarne. Zeszyt 2: Instalacje wentylacyjne i klimatyzacyjne, published in 2017 by Instytut Techniki Budowlanej. This book concerns ventilation and air-conditioning installations in residential, public and collective buildings and describe installation works and checks at hand over, presented as covered by law since 31/12/2016. The chapter on hand over checks includes explanations on checking the completeness of the work carried out, functional checks, measurements, reporting (https://www.ksiegarniatechniczna.com.pl/czesc-e-roboty-i-instalacje-sanitarne-zeszyt-2-instalacje-klimatyzacyjne.html).
- Turkey: training for mechanical engineers who will be involved in the production and inspection of ventilation systems is provided by the Turkish Chamber of Mechanical Engineers (https://www.mmo.org.tr/).
- Turkey: A course published by the University of Çukurova/Adana Meslek School titled "Ventilation systems" includes a chapter on commissioning, describing operations, measurements and measuring instruments (http://hvacportal.org/indir/havalandirma-sistemleri_1.pdf)

According to the answers received, training programmes or documents for maintenance workers exist in:

- Finland: the Training centre of building owners association organises training for maintenance personnel, but not focusing only on ventilation (https://www.kiinko.fi/koulutus/osaamisalat-kiinkossa)
- Italy: a booklet from Inail (Consulenza tecnica accertamento rischi e prevenzione) and AIISA (Associazione italiana igienisti sistemi aeraulici) titled "Air conditioning systems: health and safety in inspection and reparation activities" provides guidelines for operators in order to prevent accidents and occupational diseases related to the activities of inspection and / or cleaning of air conditioning systems (https://www.inail.it/cs/internet/docs/alg-pubbl-impianti-climatizzazione.pdf)

According to the answers received, certification programmes for installation or maintenance workers or companies that cover the inspection of ventilation systems exist in:

- Finland, through a non-governmental organization established for qualifications and certifications of experts (FISE, http://fise.fi/en/)
- Switzerland, where a certification "Hygieneschlung" is based on the SWKI VA104-02 guidelines (based on the German guidelines VDI 6022).
- Sweden: ventilation oriented training sessions, not only limited to inspection-related issues, are presented at: http://www.svenskventilation.se/jobb-utbildning/yrkeshogskola/
- Denmark: the scheme "VENT-ordningen" certifies companies for the inspection of ventilation systems (https://vent.dk/in-english/)



Screen copy of the introduction to the survey

Survey contents

Part of the survey is reproduced below, limited to questions (1 to 13) about existing regulations, schemes, guidelines, standards and relevant initiatives. Other questions about the stock and market (14 to 17) are not reproduced here.

SURVEY CONDUCTED BY REHVA ABOUT THE INSPECTION OF VENTILATION SYSTEMS

The Directive (EU) 2018/844, amending the Energy Performance of Buildings Directive 2010/31/EU, entered into force on 9 July 2018, with several revised or new requirements.

Article 19a of the amended EPBD requires that the European Commission concludes before 2020 a feasibility study addressing two issues, (1) the possible introduction of the inspection of stand-alone ventilation systems and (2) the possible introduction of an optional building renovation passport.

In December 2018, DG ENER awarded the contract to perform this feasibility study to a consortium led by INIVE and BPIE. REHVA is member of this consortium and contributes to the feasibility study on inspection of ventilation systems. As first step REHVA collects information from its member associations until 13 February 2019.

The scope of this survey includes:

- Various levels of inspection: from simple visual check based on a check-list to exhaustive measurements on the installed system,

- Various inspection objectives: checking of good operation, duct-work air-tightness, energy efficiency, air flow-rates, indoor air quality, thermal comfort, system cleanliness, noise level, etc.

- Inspections operated by installers, maintenance workers, independent inspectors,
- All types of stand-alone ventilation systems: mechanical, natural, hybrid together with their controls
- New ventilation systems used in new, renovated or existing residential and non-residential buildings,
- Existing ventilation systems (or modified ventilation systems) used in existing residential and non-residential buildings.

The study is limited to stand-alone ventilation systems (i.e. ventilation systems whose sole function is to ventilate a building).

The results of this survey will be part of the data analysed by the consortium. They will be used to evaluate the impacts of the possible introduction of various types of inspection protocols, through legislative or non-legislative approaches.

You will find updates and more informed about the results of this work on the dedicated website http://epbd19a.eu and the stakeholders meetings in June and November. In addition REHVA Office will inform you about the outcomes of the survey and the completed study.

It is important for REHVA to contribute to this action, showing to the European Commission the strong support in the development of EPBD related EU policies.

PLEASE FILL IN THIS SURVEY BEFORE FEBRUARY 13th

EXISTING INSPECTION DOCUMENTS AND INITIATIVES

1 - Are there, in your country, national or regional regulations that make the inspection of ventilation systems (or parts of the ventilation system) mandatory?

YES NO

If YES, can you give the references of these regulations (in national language):

2 - In your country, are there standards or guidelines from public authorities and official standardisation bodies that describe the inspection of ventilation systems (or parts of the ventilation system)?

YES NO

If YES, Can you give the references of these standards and guidelines:

Are these standards and guidelines mentioned into regulations? If YES, can you give the references of these regulations (in national language)

3 - Is the standard EN 16798-17 "Energy performance of buildings. Ventilation for buildings. Guidelines for inspection of ventilation and air conditioning systems" being used in your country?

YES NO

If YES, can you say in which context?

4 - Was the previous version of this standard (today cancelled), i.e. EN 15239:2007 "Ventilation for buildings. Energy performance of buildings. Guidelines for inspection of ventilation systems", used in your country?

YES NO

If YES, can you say in which context?

5 - In your country, are there standards or guidelines from technical and professional bodies (published by your Association or others) that describe the inspection of ventilation systems (or parts of the ventilation system)?

YES NO

If YES, can you give the references of these standards and guidelines:

Are references to these standards and guidelines included into regulations? If YES, can you give the references of these regulations (in national language):

6 – In your country, are there training programmes or documents for installers that include training or procedure for inspecting new or existing ventilation systems (or parts of the ventilation system)?

YES NO

If YES, can you give the references of these trainings or documents (in national language):

7 – In your country, are there training programmes or documents for maintenance workers that include training or procedure for inspecting existing ventilation systems (or parts of the ventilation system)?

YES NO

If YES, can you give the references of these trainings or documents (in national language):

8 – In your country, are there certification programmes for installation or maintenance workers or companies that cover the inspection of ventilation systems (or parts of the ventilation system)?

YES NO

If YES, can you give the references of these certification programmes (in national language):

9 – Do you identify other initiatives in your country about the inspection of ventilation systems? (that are not covered by previous questions)

10 - Have there been studies in your country about the performances of installed ventilation systems? If so, can briefly describe the outcomes? Can you provide references?

11- Are there in your country concerns about the indoor air quality in buildings and/or the need to improve the performances of ventilation systems? If yes, please explain shortly the context

12 - Do you believe that more attention for inspection of ventilation systems would be useful in your country?

- For residential buildings? Please provide some arguments

- For non-residential buildings? Please provide some arguments

13 – Do you know interesting initiatives in other countries that we should investigate?

THANK YOU VERY MUCH FOR YOUR COOPERATION! Your Organization name will be published in the EPBD 19a Feasibility study report

Your Organization name will be published in the EPBD 19a Feasibility study report

Annex 12 – Outputs from the AIVC Workshop - March 2019 in Dublin

Programme of the workshop

Title: "Quality ventilation is the key to achieving low energy healthy buildings"
Date: 27-28 March, 2019
Location: RDS venue, Dublin, Ireland

Sustainable Energy Authority of Ireland (SEAI) together with the Air Infiltration and Ventilation Centre (AIVC) organised a symposium entitled " Quality ventilation is the key to achieving low energy healthy buildings " held on 27-28 March 2019 in Dublin, Ireland. Participants to the Symposium had also the possibility to visit the SEAI Energy Show 2019.

The programme of the workshop is shown below.
The presentations highlighted in red directly refer to this technical study.
The presentations highlighted in blue have been useful to this technical study.

Day 1: "Ventilation for good indoor air quality (IAQ)"
10.30am - 4.00pm

- Welcome on behalf of SEAI | John Randles, Head of Department, SEAI
- Overview of International Energy Agency activities related to energy in buildings | Paul Ruyssevelt, Vice chair of ExCo, IEA TCP EBC
- Presentation of AIVC and ventilation related activities | Peter Wouters, Manager, INIVE EEIG
- Overview of SEAI deep retrofit pilot programme and Research Development and Demonstration Fund | Phil Hemmingway, Conor Hanniffy, Brian McIntyre, SEAI
- Ventilative cooling – IEA TCP EBC annex 62 | Maria Kolokotroni, Brunel University London/IEA TCP EBC annex 62
- Health and wellbeing benefits from providing good indoor air quality | Sani Dimitroulopoulou, Public Health England
- Economics of indoor air quality (IAQ) | Max Sherman, LBNL
- Indoor Environmental Quality (IEQ) in Irish Energy Efficient dwellings | Marie Coggins, James McGrath, NUI
- New trends in ventilation systems – standardisation and specifications issues | Marc Jardinier, Convenor, CEN TC 156 WG 2
- New trends in ventilation systems and the impact on IAQ, energy performance and the installation fitter | Wouter Borsboom, TNO

Day 2: "Quality of Ventilation Systems"
9.30am - 4.00pm

- EPBD issues in relation to IAQ and ventilation and article 19a feasibility study | Peter Wouters, Manager, INIVE EEIG
- The context in France that lead to the French task force on ventilation | Gaëlle Guyot, CEREMA
- The context of the UK and recent studies into ventilation effectiveness | Ian Mawditt, Four Walls Consultants
- Inspection and other quality control activities of ventilation systems outside Europe | Max Sherman, LBNL

- The context in Ireland – changes to Irish regulations and inspection of ventilation systems | Emmanuel Bourdin, Department of Housing, Planning and Local Government
- Ventilation and building airtightness inspection schemes in Belgium | Maarten De Strycker, BCCA
- Ventilation inspection schemes in France | Adeline Mélois, French Ministry for Ecology
- Ductwork airtightness – why should we care and how to control it – a review | Valérie Leprince, Independent Scientific Consultant, PLEIAQ
- Evaluation of Low-Cost IAQ Monitors | Iain Walker, LBNL
- Overheating risk analysis for NZEB in Irish Perspective | Orla Coyle, SEAI
- Conference Summary | Peter Rickaby, Rapporteur, UKCMB/ UCL
- Electronic voting of insights | Paul Martin, SEAI
- Closing | SEAI

All the presentations at the workshop can be downloaded at: https://www.aivc.org/event/27-28-march-2019-symposium-dublin-quality-ventilation-key-achieving-low-energy-healthy

PART 2

STOCK OF VENTILATION SYSTEMS IN EU BUILDINGS AND FORESEEN EVOLUTION FOR 2030, 2040 AND 2050

Technical coordinator	Peter Wouters*, INIVE*
Authors	François Durier, *INIVE-CETIAT* Valérie Leprince, *PLEIAQ*
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Partners

Subcontractors

This study is a service contract with the European Commission's Directorate General for Energy and has received funding under contract ENER/C3/2018-447/05.

Table of Contents

Executive Summary

Article 19a of Directive 2018/844, includes the requirement for the Commission to perform, before 2020, a feasibility study to clarify the possibilities and timeline for introducing two aspects in order to improve buildings' energy performance:

- The inspection of stand-alone ventilation systems and
- An optional building renovation passport.

This technical study is contracted to a consortium formed by INIVE and BPIE who, together with a broad range of experts in the required fields, will provide technical support to the Directorate-General for Energy of the European Commission for investigating the different elements covered by the feasibility study. This technical study is coordinated by INIVE EEIG and runs from 18 December 2018 until 17 December 2019.

The first part of this technical study will 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:

- An analysis of the stock of ventilation systems in EU buildings, including their technical characteristics, the distribution systems and foreseen evolution of the stock;
- 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;
- 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.

This report covers the first objective.

It provides an assessment of the stock and sales of stand-alone ventilation systems in EU countries from the consolidation of existing data. An assessment of the evolution of this stock for 2030, 2040 and 2050 is also provided.

Insufficient information was found on natural ventilation systems to be able to assess their stock and market.

The current stock (2020) of mechanical ventilation systems is estimated to 139 million (mean value), between a minimum value of 86 million and a maximum value of 190 million, of which 93% residential and 2/3 of decentralised unidirectional residential systems.

The current annual sales are estimated to almost 8.5 million units, of which 93% residential and 60% of decentralised unidirectional units.

The evolution of stock and sales up to 2050 has also been estimated from the consolidation of the existing data, with a large uncertainty due to the low number of information sources and the inconsistency of the available data. The penetration of balanced ventilation systems should increase.

Examples of publications have been analysed that show characteristics of stand-alone ventilation systems in the existing stock. A large proportion of systems do not provide the designed or required air flow rates.

1. Introduction

1.1 Context

The publication on 19 June 2018 of the amended EPBD, Directive 2018/844 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency, represents the first major step towards the implementation of the Commission's Clean Energy for all Europeans package.

Article 19a of Directive 2018/844 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency includes the requirement for the Commission to perform, before 2020, a feasibility study to clarify the possibilities and timeline for introducing two aspects in order to improve buildings' energy performance:

- The inspection of stand-alone ventilation systems and
- An optional building renovation passport

This technical study is contracted to a consortium formed by INIVE and BPIE who, together with a broad range of experts in the required fields, will provide technical support to the Directorate-General for Energy of the European Commission for investigating the different elements covered by the feasibility study mandated under Article 19a of the amended EPBD. This technical study is coordinated by INIVE EEIG and runs from 19 December 2018 until 18 December 2019.

The first part of this technical study should assess the relevance and feasibility to introduce EU provisions (legislative and non-legislative) 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.

In this study, stand-alone ventilation systems are defined as ventilation systems whose sole function is to ventilate a building.

The study includes an overview of the stock of ventilation systems installed in Europe and related technological trends, as well as a review of mandatory and voluntary inspection schemes of ventilation systems in buildings, at EU and national levels. It will further assess the relevance, feasibility and overall impacts of introducing EU measures in relation to the inspection of stand-alone ventilation systems in buildings (e.g. development or improvement of technical standards, preparation of guidelines and identification and sharing of best practices, or extension of mandatory regular inspections to stand-alone ventilation systems under the EPBD).

1.2 Overall objectives

The objectives regarding inspection of stand-alone ventilation systems are to deliver

- An analysis of the stock of ventilation systems in EU buildings, including their technical characteristics, the distribution systems and foreseen evolution of the stock;
- 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;
- 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.

This report covers the first objective, by providing an assessment of the stock of stand-alone ventilation systems in EU buildings. From market figures, it also gives an assessment of the evolution of this stock for 2030, 2040 and 2050 and describes characteristics of ventilation systems in operation from some bibliographical references.

The report has been prepared by INIVE-CETIAT, INIVE-BBRI and PLEIAQ.

Available information about the sales of ventilation systems has been searched at national and European levels, thanks to a survey among national European associations of HVAC engineers that are members of REHVA and contacts with the two main European associations of ventilation system manufacturers, EVIA and Eurovent, who provided some data and references of data sources.

1.3 Scope

The European standard EN 12792 "Ventilation for buildings - Symbols, terminology and graphical symbols" (2003) defines ventilation as: "Designed supply and removal of air to and from a treated space".

In the AIVC Glossary (Limb, 1992), ventilation is defined as "the process of supplying or removing air, by natural or mechanical means to and from a space".

Natural ventilation is defined as "ventilation through leakage paths (infiltration) and openings (ventilation) in the building which relies on pressure differences without any fan" (EN 12792). It includes airing (ventilation by window opening), cross ventilation (resulting from wind pressures on the facades) and shaft ventilation (using a vertical or inclined duct to generate stack effect).

Mechanical ventilation is defined by AIVC (Limb, 1992) as "ventilation by means of one or more fans".

This study covers:

- Stand-alone ventilation systems, i.e. systems whose sole function is to ventilate a building; the inspection of combined heating and ventilation systems, and of combined air-conditioning and ventilation systems is covered by articles 14 and 15 of Directive 2018/844/EU
- Ventilation systems in residential and non-residential buildings, except industrial buildings
- All types of stand-alone ventilation systems: mechanical, natural, hybrid together with their controls. Airing (i.e. natural ventilation by window opening) is out of our scope since it does not rely on components dedicated to ventilation (air inlets, air outlets, etc.).

1.4 Methodology

1.4.1 Actions

The work consisted of the following 5 actions:

1. Searching and analysing information about the stock of ventilation systems in the EU
2. Searching sales data of ventilation systems in the EU
3. Analysing possible market trends
4. Assessing the evolution of the stock towards 2020 and providing extrapolations for 2030, 2040 and 2050

5. Preparing a report, together with the operational Excel file, to be included in the first interim report

1.4.2 Information sources

Searching information on the stock and sales of ventilation systems in the EU relied on:

- A survey among national European associations of HVAC engineers that are members of REHVA (see Annex 7) that provided some input
- Contacts with the two main European associations of ventilation system manufacturers, EVIA and Eurovent, which led to the identification of some information sources and data.
- The identification and analysis of various documents.

The information sources that have been used for assessing stock and sales at the EU level are:

- Reports of the Ecodesign Impact Accounting studies, conducted by VHK for the European Commission (2014-2019) with the objective to assess the impact of all eco-design and energy labelling EU-regulations
- Reports of preparatory studies to Ecodesign regulations, conducted for the European Commission on residential ventilation (2009, coordinated by ARMINES - TREN Lot 10) and air-conditioning and ventilation systems (2012, coordinated by ARMINES - ENTR Lot 6)
- Two working documents from the European Commission, introducing a possible regulation on eco-design of ventilation units (October 2012)
- A study by the German manufacturer association FGK (Fachinstitut Gebäude-Klima) on residential ventilation, published in 2010 in relationship with the Ecodesign preparatory study TREN Lot 10 (see ahead)
- Sales figures provided to us by Eurovent Market Intelligence (EMI) for residential heat recovery ventilation units (year 2017), following contacts with Eurovent
- Publications by EVIA in REHVA Journal (2001, 2017)
- Some public results of a market study by Interconnection Consulting (2016)
- Figures about the construction of new buildings from the EU Building Stock Observatory

The information sources that have been used for assessing stock and sales at country levels, sometimes common with those used for the EU level (see ahead) are:

- For all EU countries: report of the preparatory study to Ecodesign regulation on residential ventilation (2009, coordinated by ARMINES - TREN Lot10)
- For all EU countries: study by FGK on residential ventilation in relationship with the previous Ecodesign preparatory study (2010)
- For Finland, France, Germany, Greece and Italy: results of the EU Healthvent project (2012)
- For France: one report by the "Observatoire de la Qualité de l'Air Intérieur" (2009), a report by the association "air.h" (2007), annual sales statistics by the manufacturer association Uniclima (2011-2018)
- For Germany: values from a presentation by FGK in an AIVC Workshop (2013) and a study by ILK Dresden for FGK (2011)
- For Ireland: values available at the website of the journal Passive House Plus (2017)
- For the United-Kingdom: a paper by BSRIA at the AIVC Conference 2013

All the detailed references are provided in Annex 1.

Annex 2 shows the number of information sources per country and per system, which is low.
The data from individual countries are rare. They have been used to consolidate shares of data for the EU between countries.

1.4.3 Chosen approach

A first analysis of the data available on the stock showed that:

- They cover a time range from 1990 to 2050: some studies provide values for a given year, others cover passed years and some of them include assessment of future evolutions
- Many of the data are estimates, relying sometimes on rough assumptions on the stock and sales. Nevertheless, these assumptions seem reasonable and acceptable in the absence of numerous data; assumptions differ from one study to the other
- Data between different information sources are thus sometimes inconsistent (with ratios of up to 1 to 2 between some sources).

Data on sales are covering in some cases one country or one system type. No consolidated data on sales was obtained from European manufacturers associations.

In this context, our approach was to:

- Use available data on stock and sales and avoid to develop a completely new assessment, that would be based on new assumptions on stock and sales: this would just provide a supplementary report to the existing ones, with another series of different figures;
- Consolidate the available data in a single file, without discussing them, since they have been established with reasonable and acceptable assumptions;
- Use these input data to derive mean and interpolated values at the EU and country levels, and limit assumptions to those that are necessary to operate this consolidation.

2. Existing data on the EU stock and sales of ventilation systems

2.1 Data published in 2019

The most recent values on the EU-28 stock and sales of mechanical ventilation systems, and their evolution towards 2050, result from a study for the European Commission (VHK, 2019). The report includes the following data (Table 1 and Figure 1) for residential and non-residential mechanical ventilation units, as covered by the Commission Regulations (EU) No. 1253/2014 and (EU) No. 1254/2014 (eco-design of ventilation units).

These data are updated values of those from a previous report of the same study (VHK, 2016), with minor differences.

In this study, the share between residential and non-residential is based on the following elements:

- Local exhaust fans of less than 30 W are excluded because they are considered as mainly operated intermittently.
- The share between residential and non-residential is based on the electrical power of the fan, with a separation value at 125 W per fan. This is a bit different from the rules for sharing ventilation units between residential and non-residential in the

Commission Regulations (EU) No. 1253/2014 and (EU) No. 1254/2014. In these regulations, residential ventilation units are defined as having a maximum flow rate that does not exceed 250 m^3/h or between 250 and 1 000 m^3/h if the manufacturer declares its intended use as being exclusively for a residential ventilation application.

Thousands units	1990	2010	2015	2020	2025	2030	2035	2040	2045	2050
Stock of mechanical ventilation units in the EU-28 (residential and non-residential)	19,456	43,634	51,841	56,423	60,627	65,933	72,158	79,186	86,257	93,328
Sales of mechanical ventilation units in the EU-28 (residential and non-residential)	1,315	3,212	3,457	3,660	4,076	4,492	4,908	5,324	5,739	6,155

Table 1: Stock and sales of mechanical ventilation units (residential and non-residential, excluding local exhaust fans) in the EU-28 (VHK, 2019)

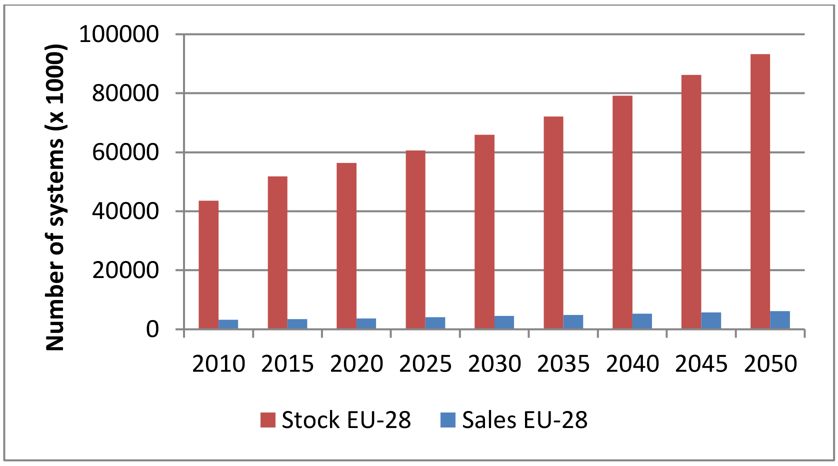


Figure 1: Stock and sales of mechanical ventilation units (residential and non-residential, excluding local exhaust fans) in the EU-28 (VHK, 2019)

Annex 3 shows detailed results from this study, especially the distribution of stock and sales for different types of mechanical ventilation units.

The 5 types of ventilation units used are defined as follows:

Residential (<125 W per fan, excluding local exhaust fans):

- Central unidirectional units: the ventilation unit either exhausts or supplies air through a ductwork serving several rooms.

- Central balanced units: the ventilation unit both exhausts and supplies air through a ductwork serving several rooms. The unit includes a heat exchanger for heat recovery between exhaust and fresh air.
- Local balanced units: the ventilation unit only ventilates the room it is installed by both supplying and exhausting air to this room. It includes heat recovery.

Non-residential ventilation units (> 125 W per fan):

- Central unidirectional units: the ventilation unit exhausts air through a ductwork serving several rooms.
- Central balanced units: the ventilation unit both exhausts and supplies air through a ductwork serving several rooms.

These different types of ventilation units are relevant and we shall also use them in this study.

2.2 Consolidation with data published in 2014 and 2016

Annex 3 explains how the data from the most recent study by VHK (VHK, 2019) can be combined with values from other documents issued from the same assessment study carried out on previous years (Kemna, 2014; European Commission, 2014; VHK, 2016), in order to get values that regularly cover the whole period 1990-2050.

After this consolidation, the values about the stock that we shall consider in this study are those given by Table 2. We shall also use sales values from Table 3.

	Residential			Non-residential	
Year	Residential central unidirectional units	Residential central balanced units	Residential local balanced units	Non-residential central unidirectional units	Non-residential central balanced units
1990	17,148	163	33	1,879	233
1995	21,331	400	70	2,800	530
2000	25,514	900	135	3,418	1,130
2005	29,697	1450	340	3,836	1,930
2010	33,878	2,140	633	4,157	2,826
2015	38,186	4,245	1,295	4,501	3,614
2020	37,438	7,492	2,439	4,726	4,329
2025	35,970	11,019	4,042	4,875	4,902
2030	35,435	14,191	5,991	4,998	5,318
2035	36,991	16,265	8,038	5,123	5,742
2040	39,653	17,999	10,113	5,247	6,174
2045	42,373	19,716	12,190	5,372	6,606
2050	45,093	21,433	14,266	5,497	7,039

Table 2: Stock of different types of residential and non-residential mechanical ventilation units in the EU-28

	Residential			Non-residential	
Year	Residential central unidirectional units	Residential central balanced units	Residential local balanced units	Non-residential central unidirectional units	Non-residential central balanced units
1990	1,042	37	7	169	61
1995	1,101	60	7	215	115
2000	2,100	80	10	260	142
2005	2,412	150	50	263	190
2010	2,336	257	85	277	257
2015	2,073	636	186	284	279
2020	1,949	816	302	291	302
2025	2,109	917	424	298	328
2030	2,269	1,018	546	306	353
2035	2,429	1,119	668	313	378
2040	2,589	1,220	790	320	404
2045	2,748	1,321	912	328	429
2050	2,908	1,422	1,035	335	455

Table 3: Sales of different types of residential and non-residential mechanical ventilation units in the EU-28

2.3 Market study 2017

Several market studies have been operated by private market consultancy firms about national, European and global markets of ventilation systems. It was foreseen that they are not purchased in the framework of this study, because each of them seems to provide only a part of the information needed and their cumulative price is too high compared to the available budget.

One of these market studies was published by Interconnection Consulting (Austria) in 2017. The press provided some information about the results (http://www.marktmeinungmensch.de/news/markt-fuer-wohnraumlueftungssysteme-wird-kraeftig-/).

The European market for residential ventilation is estimated to 2.2 million units, with an almost constant value (within a ±1.5% interval) between 2011 and 2015. The market of residential central balanced units (with heat recovery) is said to be over 210,000 units in 2016, while residential local balanced units increased their sales by 10.6%.

The total (2.2 millions) is lower than the one derived the 2019 study for year 2015 (2.9 million – see Table 3). The market for residential central balanced units (210,000) mentioned is also lower than the one in Table 3 (636,000).

2.4 Eurovent Market Intelligence Statistics 2017

Following a contact with Eurovent, sales data for residential balanced ventilation units with heat recovery for the EU-28 in 2017 were kindly provided by Eurovent Market Intelligence (EMI). They show a total of sales of 460.9 thousands units. This is lower than the two corresponding values of the 2019 study – see Table 3 for years 2015 and 2020 (respectively 636 and 816 thousands units).

2.5 Publication by EVIA 2017

In an article published in REHVA Journal (EVIA, 2017), EVIA provides a graph showing sales values for residential mechanical exhaust units (centralised and local) and bidirectional units with heat recovery (centralised and local). The data than can be derived from the graph are shown in Table 4:

Thousands units	2005	2010	2015
Residential mechanical exhaust units	1,300	1,500	1,580
Residential bidirectional units with heat recovery	100	150	250

Table 4: Sales of different types of residential ventilation units

The values for residential mechanical exhaust units are lower than the values from the 2019 study for residential central unidirectional units (between 2 and 2.5 millions).
The values for residential bidirectional units with heat recovery are higher than the values from the 2019 study for residential central and local balanced units.
The fact that the systems considered by the two studies are not exactly the same cannot explain alone the observed differences.

2.6 Publication by EVIA 2011

In an article published in the REHVA Journal (EVIA, 2011), EVIA provides a graph showing the sales evolution for single dwelling ventilation units with heat recovery, from 1985 to 2025. The sales figure for 2005 is for example about 160 thousands units. This is consistent with the sales figure of the 2019 study for residential central balanced units (150).

2.7 Ecodesign preparatory study (Lot 10) 2009

In a preparatory study (2007-2009) on residential ventilation (Rivière, 2009) linked to Directive 2005/32/EC (eco-design of energy-using products), data are provided for stock and sales.
Figure 2 shows the stock and sales data from this study. Year 2005 is the reference year, from which values up to 2025 are assessed.

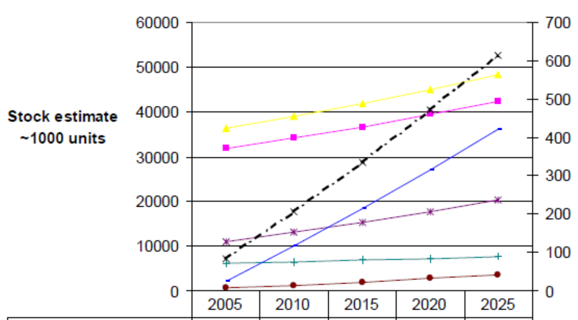
The types or systems are:

- DV= decentralised ventilation; several extraction ventilators are used in different rooms to ventilate the complete dwelling, without designed air transfer between rooms,
- DV&HR= DV with heat recovery,
- ICV= centralised ventilation systems for one-family houses (individual); we assume these are residential central unidirectional units,
- ICV&HR= ICV with heat recovery; we assume these are residential central balanced units,
- CCV= centralised ventilation systems for multi-family buildings (collective); we assume these are residential central unidirectional units,
- CCVHR= CCV with heat recovery).

The four last systems of this list correspond to those of the studies presented before.
The two first system types are new compared to the other studies.

The study also gives a repartition of stock and sales per country and per system. The available data are shown in Annex 4.

Table 2-22: Projections to 2025, stock estimate EU 25



	2005	2010	2015	2020	2025
DV (minus hoods)	31688	34105	36661	39367	42234
Hoods	36215	38978	41899	44991	48268
ICV	10992	13111	15356	17735	20260
ICV&HR	621	1299	2011	2760	3548
CCV	6161	6507	6872	7256	7661
DV&HR	84	207	336	471	613
CCV&HR	25	118	214	315	420

Figure 2-5: Projections to 2025, market estimate EU 25

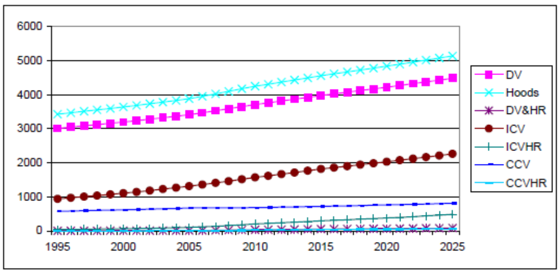


Figure 2: Stock and sales of residential ventilation units from the Ecodesign preparatory study Lot 10 (Rivière, 2009) - (Hoods are out of our scope)

2.8 Ecodesign preparatory study (Lot 6) 2012

In another preparatory study (2010-2012) linked to Directive 2009/125/EC (eco-design of energy-related products) (Rivière, 2012), data are given for residential ventilation systems in multi-family buildings and non-residential ventilation systems (Figure 3).

These data and the report show that annual unit sales of the product sales amount to 1.1 million exhaust units and 0.32 million balanced units. The installed EU-27 stock is around 19 million units.

As the share between these two types of buildings is not given, only a few data from this report can be used in the framework of our study.

Table 2-11. Ventilation equipment collective residential and non-residential estimated sales and stock 2008 [1] [2]

Ventilation collective residential and non-residential EU-27	SALES 2008										STOCK 2008			2008
	TOTAL SALES				REPLACEMENTS			NEW/1st TIME INST.			TOTAL STOCK			cap. stock
	units	cap	total*		units	total		units	total		units	total		
	# x 1000	1000 m³/h	Mm³/h	%	# x 1000	Mm³/h	%	# x 1000	Mm³/h	%	# x1000	Mm³/h	%	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)

Figure 3: Data from Ecodesign preparatory study (Lot 6) (Rivière, 2012)

2.9 Working document from the European Commission 2012

A working document from the European Commission (2012) provides a summary of the two preparatory studies previously mentioned (Lot 10 and Lot 6) (Rivière, 2009; Rivière, 2012) and of additional stakeholder consultation and additional research (in particular, a written consultation was conducted on residential ventilation units in December 2010).

Concerning residential ventilation, this document states that:

- "Residential dwellings with whole-house mechanical ventilation represent 24% of the total residential building stock. Natural ventilation (windows and infiltration), often supplemented by small intermittently operating exhaust fans in bath/kitchen/toilet, represents 76%. Around 1.5% of EU dwellings in the scope have mechanical ventilation with heat recovery".
- "[The] current annual market growth rate [is] of 5-6%."
- "In 2010, around 7.8 million residential ventilation units were sold".
- "Two-thirds of residential ventilation unit sales […] relate to small local extraction ventilation units that are mainly sold as a supplement to natural ventilation. Whole-house ventilation systems represent one-third of unit sales […], mainly in the form of central exhaust units (with natural air supply) and more-and-more central and local balanced heat recovery systems. The market for heat recovery units in Western and Northern Europe is achieving double digit growth rates. Southern and Eastern Europe are lagging behind."

The conclusions for non-residential and collective residential sectors are that:

- "In the non-residential and collective residential sector, a total of 40% of building volume is mechanically ventilated, with 19% exhaust or supply systems, 15% balanced systems without heat recovery and 7% balanced systems with heat recovery. The other 60% is using natural ventilation, including the use of small intermittently operating exhaust fans."

- "The market penetration of mechanical systems is strongest (68% of ventilated volume) in commercial buildings like retail, hotels or business offices and significantly lower (52%) in (semi-) public buildings for education, health care and public administration. Multi-family dwellings (35% penetration) mostly use exhaust units (e.g. 'rooftop' or 'boxed' ventilation units) and –for various reasons- the mechanical ventilation of warehouses, industrial and agricultural buildings is limited (17% of volume)."
- "In 2010, around 1.1 million unidirectional (mainly exhaust) and 0.32 million balanced non-residential ventilation units were sold".

The study also gives sales values between 1995 and 2005.

2.10 FGK study 2010

This study has been carried out by the German manufacturer association FGK (Fachinstitut Gebäude-Klima) on residential ventilation, in relationship with the Ecodesign preparatory study TREN Lot 10 (see ahead). The approach is similar with sometimes different assumptions. The study also covers natural ventilation systems that are not covered by others studies.

Results available are stock and sales for year 2003, per system and per country.

2.11 Comparison

Some comparisons are given in Table 5 between the data from 4 of the studies presented in the previous paragraphs: Ecodesign impact assessment (VHK, 2019+2014), Ecodesign preparatory study (Lot 10) 2009, Ecodesign preparatory study (Lot 6) 2012 and FGK study 2010:

Thousands units	Stock 2003	Stock 2005		Stock 2008
Information source	FGK (2010)	VHK Ecodesign impact assessment (VHK, 2014-2019)	Ecodesign Lot 10 (Rivière, 2009)	Ecodesign Lot 6 (Rivière, 2012)
Residential decentralised	58,265		67,965	
Residential central unidirectional	21,822	29,697	17,153	
Residential central balanced	428	1,450	646	
Residential local balanced	43	340	84	
Non-residential unidirectional		3,836		
Non-residential balanced		1,930		978

Table 5: Comparison of some data for the stock from 4 different studies

Even if these data do not cover the same year, Table 5 shows that the values are not very consistent.
This is a normal situation since each study relies on its own hypothesis. But once again, all hypothesis used in these studies seem reasonable and acceptable, and none of these studies must be seen as providing "wrong" values.

2.12 Handling of all the available existing data

As already explained, the chosen methodology for handling the available existing data was to enter them into a single file in order to consolidate all the collected information. The objective was to build an assessment of the stock and its evolution from interpolated and mean values.

Annex 5 provides some details about this process.

Our initial objective was to avoid making new assumptions on stock and sales than those used by existing studies. As the number of data and sources is low, assumptions were required in order to extend existing values to other years or to assess the share of totals at the EU-level between countries. These assumptions are explained in Annex 5.

Despite the low number of information sources for some data and the fact that they are not always consistent, this approach made it possible to get an overall picture of the stock and sales and their estimated values for the future decades. Most of the results are shown where possible with a mean value and a possible range (minimum and maximum). In some cases, no data is presented since the available data did not allow assessing a value.

3 Current stock and sales of stand-alone ventilation systems

As explained in the previous section and in Annex 5, no information has been found about the stock of natural ventilation systems except from one information source (FGK study) for year 2003. There is also no information on the sales of natural ventilation systems. Therefore, no value is given for the stock of natural ventilation systems and for its evolution. This lack of results for this specific category of system seems acceptable since natural ventilation systems are probably those for which inspection has less impact.

3.1 Current stock (year 2020)

The stock for year 2020 is shown in Table 6, in thousands of systems.

Table 6 shows wide intervals between minimum and maximum estimated values, resulting from the inconsistency between existing data.

The mean value for the total stock of mechanical stand-alone ventilation systems is found as almost 140 million units, of which 93% residential. Decentralised unidirectional residential systems represent 2/3 of the stock.

	Residential								Non-residential	
Year 2020	Decentralised unidirectional units		Central unidirectional units		Residential central balanced units		Residential local balanced units		Non-resid. central unidir. units	Non-resid. central balanced units
Mean value for different sources	**92,032**		**32,868**		**4,052**		**958**		**4,726**	**4,329**
Min and max from different sources	61,053	124,547	14,441	50,631	1,111	8,646	51	2,294		
VHK 2019 +2014			37,438		7,492		2,439		4,726	4,329

Table 6: Stock 2020

Detailed values per country are shown in Annex 6.

Decentralised unidirectional ventilation systems are mainly present in the United Kingdom, Germany, Italy and Spain: these 4 countries represent almost 60% of the stock for this type of ventilation system.

Most of the stock (almost 60%) of residential central unidirectional units is present in France, Germany, Netherlands, Spain and United-Kingdom.

The stock of residential central balanced systems in France, Germany, Netherlands, Spain and Finland represents almost 60% of the total.

Residential local balanced units are mostly present in Finland, Germany, Netherlands and Sweden. These 4 countries cover 70% of the stock.

3.2 Current sales (year 2020)

The sales estimated for year 2020 are shown in Table 7, in thousands of systems.

Intervals between minimum and maximum estimated values are as wide as for stock data.

The mean value for the total sales of mechanical stand-alone ventilation systems is found as almost 8.5 million units, of which 93% residential and 60% of decentralised unidirectional units.

	Residential								Non-residential	
Year 2020	Decentralised unidirectional units		Central unidirectional units		Residential central balanced units		Residential local balanced units		Non-resid. central unidir. units	Non-resid. central balanced units
Mean value for different sources	**5,105**		**1,948**		**647**		**196**		**291**	**302**
Min and max from different sources	4,237	5,966	928	2,768	305	870	63	343		
VHK 2019 +2014			1,949		816		302		291	302

Table 7: Sales 2020

Detailed values per country are shown in Annex 6.

4 Stock evolution assessment

Figure 4 shows the assessment of the evolution of the stock in 2030, 2040 and 2050 for the different residential and non-residential ventilation systems.

Detailed values, including figures per country for residential systems, are shown in Annex 6.

Figure 5 focuses on residential unidirectional systems, decentralised or central. The graph shows mean values and the interval between minimum and maximum values.

Figure 6 is dedicated to residential balanced systems, central and local. For these systems, the interval between minimum and maximum is relatively wider.

Figure 7 shows the evolution of the stock for non-residential systems.

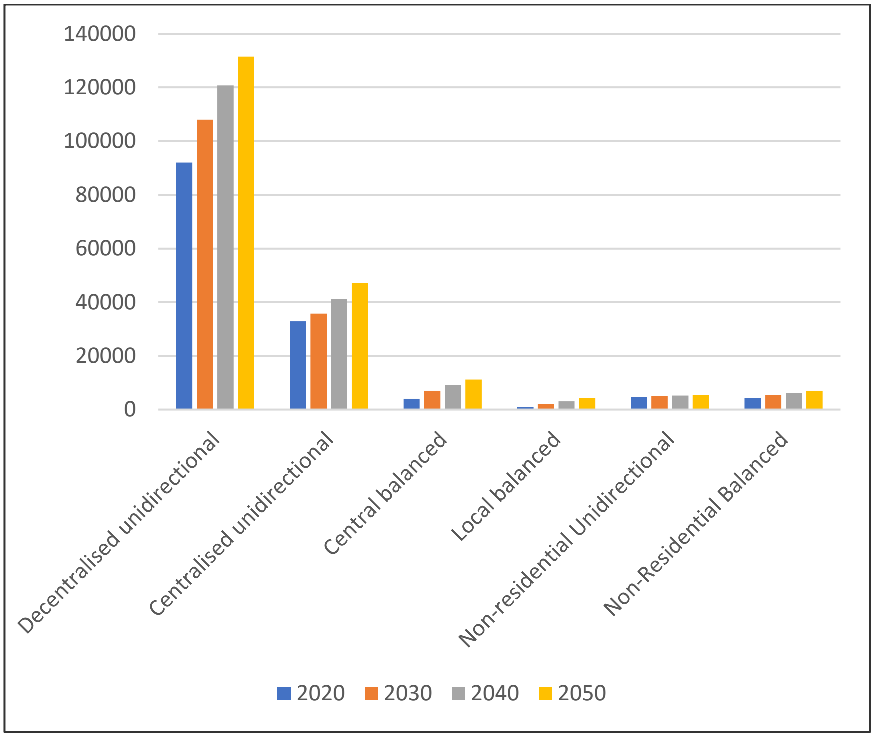


Figure 4: Evolution of the stock for mechanical ventilation systems

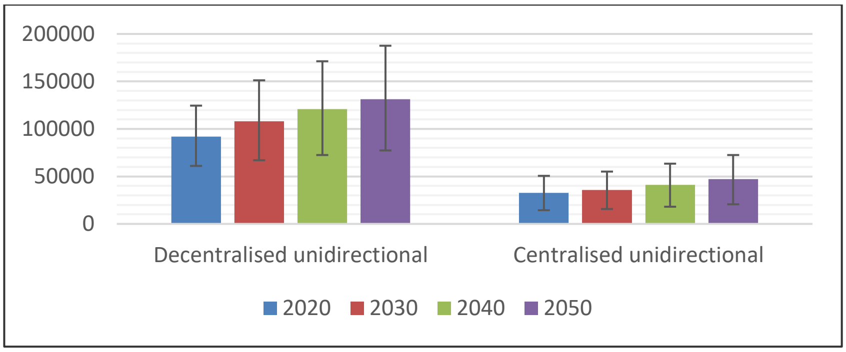


Figure 5: Evolution of the stock for residential unidirectional systems: mean values and intervals minimum-maximum

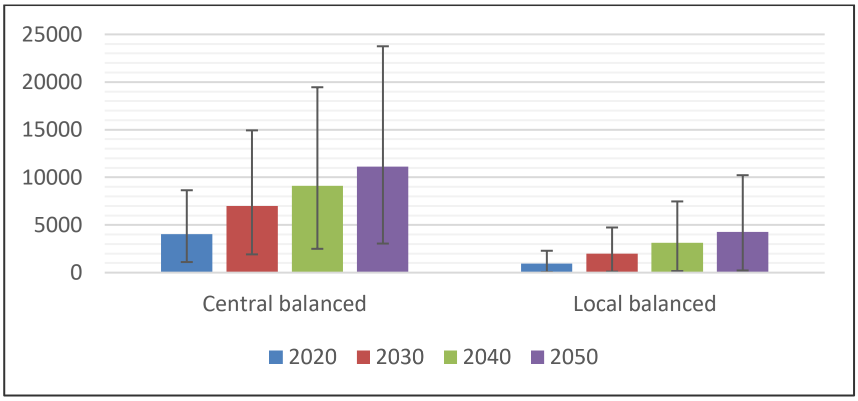


Figure 6: Evolution of the stock for residential balanced systems: mean values and intervals minimum-maximum

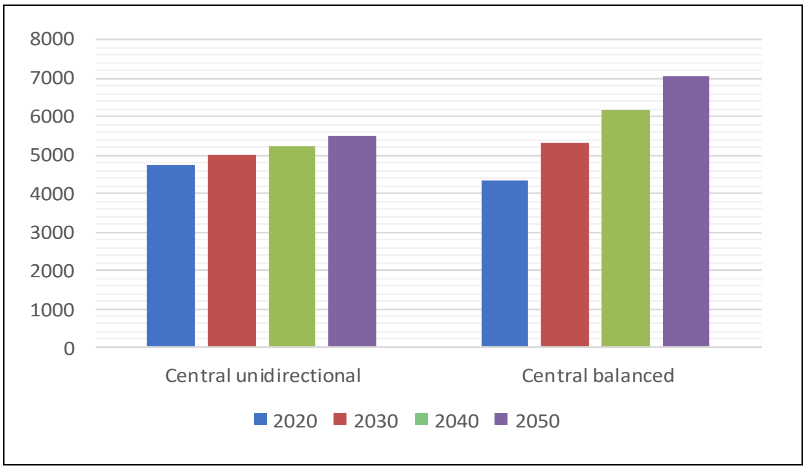


Figure 7: Evolution of the stock for non-residential systems (mean values)

5 Assessment of sales

The assessment of the evolution of sales is shown in Table 8.

	Residential				Non-residential	
Thousands units	Natural	Central unidirectional	Central balanced	Local balanced	Central unidirectional	Central balanced
2005		2,163	119	32	169	61
2010		2,295	191	55	215	115
2015		2,219	401	121	260	142
2020		1,748	647	196	263	190
2025		1,891	727	275	277	257
2030		2,034	807	354	284	279
2035		2,178	887	434	291	302
2040		2,321	968	513	298	328
2045		2,464	1,048	592	306	353
2050		2,607	1,128	672	313	378

Table 8: Evolution of sales

Figures 8 and 9 provide the corresponding graphs.

The curve for sales of residential centralised unidirectional systems (Figure 8) has a singular shape. This is due to the methodology used and to the fact that one of the study (VHK) indicates that sales for this type of system decrease from 2005 to 2020 and then increase. Another study (EVIA 2017) indicates an increase followed by stable sales. The curve in Figure 8 shows a mean value of these available data, with a discontinuity in 2020 since after this specific year only the data from one source are taken into account.

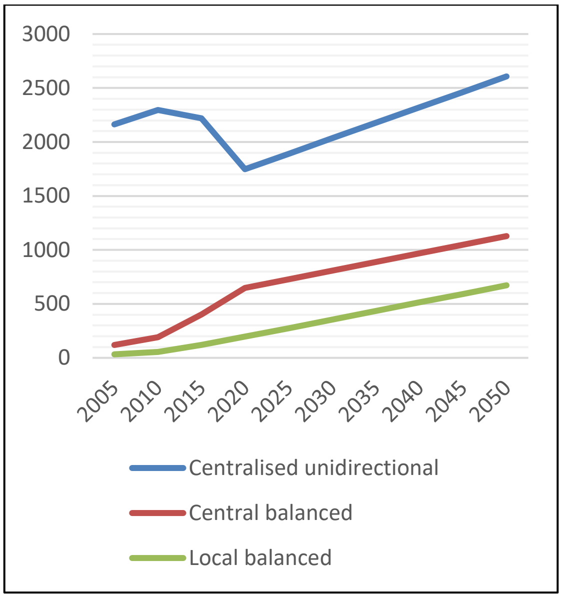


Figure 8: Sales of residential systems

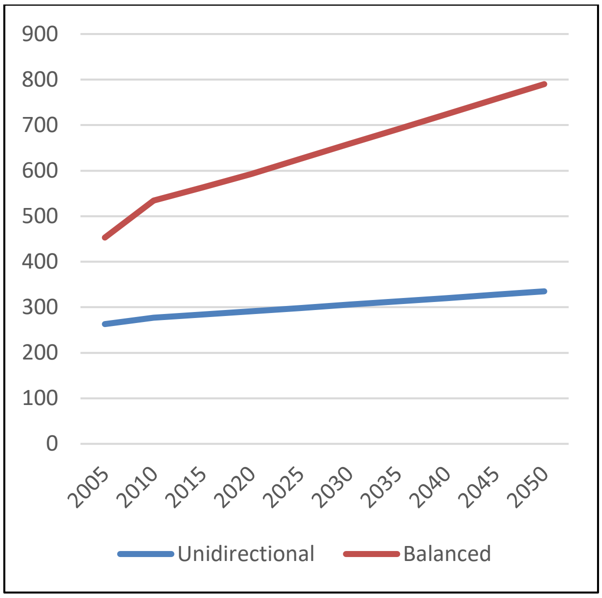


Figure 9: Sales of non-residential systems

6 Characteristics of the ventilation stock

In addition to the assessment of the stock and its evolution, it is also interesting to give some information about the characteristics of the stand-alone ventilation systems in operation.

We shall limit this section to the results of a selection of published studies, without the objective to make an exhaustive bibliographical analysis. These studies have been identified in presentations at the AIVC Workshop and in reports of the European project QUALICHeCK.

In 2016, a study commissioned by Innovate UK as part of the Building Performance Evaluation (BPE) Programme provided an overview of the performance and use of residential central balanced ventilation systems with heat recovery in the United Kingdom[1]. Results show that only 56% of the 51 investigated dwellings met the design air flow value. 52% of systems were found to be imbalanced (difference between supply and extract airflow of more than 15%) and only 44% of systems utilising flexible ducts met their design values.

A study[2] in Ireland (2010) investigated indoor air quality in five houses built according to the requirements of the 2007 Building Regulations. Three houses with natural ventilation had air changes per hour (ach) below the minimum recommended value of 0.5 (in May-June period). Only one of the two houses equipped with central balanced ventilation with heat recovery met the air change rate target value of 0.5.

[1] T. Sharpe, G. McGill (The Glasgow School of Art), R. Gupta, M. Gregg (Oxford Brookes University, I. Mawditt (fourwalls Consultants), *Characteristics and Performance of MVHR Systems: A Building Performance Evaluation Meta-Study,* 2016, 103 pages, http://www.fourwalls-uk.com/wp-content/uploads/2016/03/MVHR-Meta-Study-Report-March-2016-FINAL-PUBLISHED.pdf

[2] M. Coggins, M. Byrne, S. Kleefeld, Silke (National University of Ireland, Galway), *Pilot study to investigate indoor air quality (IAQ) in energy efficient homes in Ireland*, 2010, 44 pages, https://aran.library.nuigalway.ie/handle/10379/7240

A report[3] from the European project QUALICHeCK provides the following information:

- In 2006, the Swedish organisation Boverket was commissioned by the government to perform a large study (BETSI - Building's Energy, Technical Status and Indoor environment on the building stock with the objective to describe the technical characteristics of buildings by inspection, measurements, questionnaires, interviews, etc., about energy, indoor climate and building systems. Experts investigated approximately 1,800 buildings, statistically chosen to represent the entire building stock. The first results were presented in 2009, and more extensive results in 2010 in four reports. Among the major findings are the following: 80% of single-family houses had an air exchange lower than the required value (0.35 $l/(s.m^2)$. Of the multi-family buildings, 60% were below the requirement.
- In France, Cerema published (2013) an analysis of French regulatory compliance controls of residential ventilation systems. 1.287 dwellings have been investigated through 373 control reports performed between 2008 and 2011. Nearly all these dwellings were equipped with central unidirectional ventilation systems (humidity demand-controlled for 74% of the sample) and central balanced systems were only present in 10 single-family houses. 47% of the sample did not comply with the ventilation regulation. The non-compliance rate was 68% for single-family houses and 44% for multi-family buildings. Findings were that: ventilation installation verification is rarely planned during the construction phase; ventilation system commissioning is not systematic or is incomplete; on-site ventilation system mounting is often far from the expected quality; even if adapted industrial solutions are available, ventilation system dysfunctions are very frequently observed.
- In the UK, the Building Services Research and Information Association (BSRIA) undertook a study on 40 random properties constructed by different builders (2011), with various ventilation systems according to the 2010 Building Regulations requirements. 95% of evaluated ventilation systems failed to meet the requirements of regulation with some installations having a number of failure modes. Observed findings include: ductwork incorrectly fitted in 83% of the systems, undersized fans to meet the minimum ventilation in 25% of the systems, insufficient fans or terminal outlets for dwelling type in 15% of the systems. 3 systems showed incorrect installation data, 2 missing ductwork and 1 blocked ductwork.
- In the Netherlands, a study reported in 2012 by BBA Indoor Environment consultancy and the National Institute for Public Health and the Environment shows the performance of mechanical ventilation systems. Central unidirectional and central balanced systems were investigated in 299 homes, through visual inspections and measurements of ventilation rates per room and of noise levels. Observed findings include: in 48% of the dwellings with central balanced systems, the total air supply rate was insufficient ($< 0.7\ l/s/m^2$), while the air supply rate was insufficient compared to the Dutch Building Code in one or more rooms of 85% of dwellings; total air exhaust rates were insufficient in 55% of the dwellings with central balanced systems and in 69% of the dwellings with central unidirectional systems; the exhaust rates in one or more rooms did not comply with the standards in respectively 80% and 76% of the dwellings; noise levels

[3] M. Maivel, K. Kuusk, R. Simson, J. Kurnitski, T. Kalamees, *Status on the Ground - Overview of existing surveys on energy performance related quality and compliance,* QUALICHeCK, June 2015, www.qualicheck-platform.eu

were higher than 30 dB(A) in one or more bedrooms in 86% of homes with central balanced systems.; ductwork was not properly installed in 48% of central balanced systems and 40 % of central unidirectional systems.

These examples show that all types of installed ventilation systems meet to a large extent non-compliance and insufficient quality of operation.

7 Conclusions

The available data about the stock and sales of ventilation systems in the EU have been searched and analysed.

All these data result from several assumptions as no precise information is available, especially about the stock of stand-alone ventilation systems. Consolidated sales figures were not found.

The most recent published data result from a study by VHK for the European Commission in the framework of the impact assessment of Ecodesign regulations. It provides an assessment of the stock and sales of the different mechanical residential and non-residential ventilation systems, with estimated values up to 2050.

Other data were found in Ecodesign preparatory studies for the European Commission and in publications by manufacturer associations, research institutes and market consultant.

Consolidating these data was the chosen approach, in preference to a new study that would have relied on different assumptions and provided another series of different values.

Insufficient information was found on natural ventilation systems to be able to assess their stock and market.

Handling of the existing data led to the following estimations of the current stock and sales (2020):

- stock of stand-alone ventilation systems in the EU: 139 million (mean value), between 86 million (minimum value) and 190 million (maximum value), of which 93% residential and 2/3 of decentralised unidirectional residential systems,
- annual sales of almost 8.5 million units, of which 93% residential and 60% of decentralised unidirectional units.

The evolution of stock and sales up to 2050 has also been estimated from the consolidation of the existing data. The values show a 2050 stock of 206 million units (mean value) with annual sales in which balanced systems would represent 43% of sales of central and local balanced systems (to be compared with 34% in 2020).

Because the number of information sources is low and the available data are not consistent, these results must be seen as estimates with a large uncertainty, as the wide intervals between minimum and maximum value may suggest.

Examples of publications have been analysed that show characteristics of stand-alone ventilation systems in the existing stock. A large proportion of systems do not provide the designed or required air flow rates.

Annex 1 - References

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Annex 2 – Number of information sources

Figure 10 shows the number of information sources for the stock per country and per system.

Kind of da	Stock	Year:		Unit:	1000 of systems	Exact ye																												
				Countries																												Sums		
			Column number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	All but 3, 13, 23	All but 13	All
	Row number			A	B	BUL	CY	CZ	DK	EST	FIN	F	D	GR	H	HR	IRL	IT	LT	LIT	LUX	MT	NL	PL	P	ROM	SK	SLO	E	S	UK	EU 25	EU 27	EU 28
Systems	1	Residential Single-houses	Natural									2																			1			
	2		Decentralised									2																			1			
	3		Central unidirectional	1	1		1	1	1	1	2	3	2	2	1		1	1	1	1	1	1	1	1	1		1	1	1	1	2	1 (2005-2025)		
	4		Central balanced	1	1		1	1	1	1	2	3	2	2	1		1	1	1	1	1	1	1	1	1		1	1	1	1	2	1 (2005-2025)		
	5		Local balanced									2																						
	6	Residential Multi-family dwellings	Natural									2																						
	7		Decentralised									2																						
	8		Central unidirectionel	1	1		1	1	1	1	2	3	2	2	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1 (2005-2025)		
	9		Central balanced	1	1		1	1	1	1	2	3	2	2	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1 (2005-2025)		
	10		Local balanced									2																						
	11	Non-Residential	Natural																															
	12		Unidirectional																															1 (1990-2050)
	13		Balanced																															1 (1990-2050)
Sums	**1+6**	**Residential**	**Natural**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**		**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**		**1 (2003)**	
	2+7	**Residential**	**Decentralised**	**2**	**2**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**		**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**1 (2005-2025)**	**1 (2003)**	
	3+8	**Residential**	**Central unidirectional**	**2**	**2**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**		**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**1**	**2**	**2**	**2**	**2**	**2**	**1 (2005-2025)**	**1 (2003)**	**1 (1990-2050)**
	4+9	**Residential**	**Central balanced**	**2**	**2**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**		**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**1**	**2**	**2**	**2**	**2**	**2**	**1 (2005-2025)**	**1 (2003)**	**1 (1990-2050)**
	5+10	**Residential**	**Local balanced**	**2**	**2**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**		**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**1 (2005-2025)**	**2 (2003 + 2008)**	**1 (1990-2050)**
	7+8+12?	**Large buildings**	**Unidirectional**																														**1 (2008)**	
	9+10+13?	**Large buildings**	**Non residential balanced**																														**1 (2008)**	

Figure 10: Number of information sources for data about the stock

Figure 11 shows the number of information sources for the sales per country and per system.

	Kind of da	Market	Year:		Unit:	1000 of systems						Exact ye																						
				Countries																												Sums		
			Column number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	All but 3, 13, 23	All but 13	All
	Row number			A	B	BUL	CY	CZ	DK	EST	FIN	F	D	GR	H	HR	IRL	IT	LT	LIT	LUX	MT	NL	PL	P	ROM	SK	SLO	E	S	UK	EU 25	EU 27	EU 28
Systems	1	Residential Single-houses	Natural														1																	
	2		Decentralised									1					1																	
	3		Centralised unidirectional	1	1		1	1	1	1	1	2	1	1	1		2	1	1	1	1	1	1	1	1		1	1	1	1	1	1 (2005-2025)		
	4		Central balanced	1	1		1	1	1	1	1	2	1	1	1		2	1	1	1	1	1	1	1	1		1	1	1	1	1	1 (2005-2025)		1 (1990-2010)
	5		Local balanced														1																	
	6	Residential Multi-family dwellings	Natural																															
	7		Decentralised																															
	8		Centralised unidirectionel	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1 (2005-2025)		
	9		Central balanced	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1 (2005-2025)		
	10		Local balanced																														1 (2008)	
	11	Non-Residential	Natural																															
	12		Unidirectional																														1 (2010)	1 (1990-2050)
	13		Balanced																														1 (2010)	1 (1990-2050)
Sums	**1+6**	**Residential**	**Natural**																															
	2+7	**Residential**	**Decentralised**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**		**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1 (2005-2025)**	**2 (2003 + 2010)**	
	3+8	**Residential**	**Centralised unidirectional**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**		**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**		**1 (2003)**	**2 (1990-2050 + 2005-2015)**
	4+9	**Residential**	**Central balanced**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**1**	**1**		**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**		**1 (2003)**	**4 (2015 + 2017 + 1990-2050 + 2005-2015)**
	5+10	**Residential**	**Local balanced**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**		**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1 (2005-2025)**	**1 (2003)**	**1 (1990-2050)**
	2 to 5+6 to	**Residential**	**Mechanical**																														**1 (2010)**	
	7+8+12?	**Large buildings**	**Unidirectional**									**1**																					**1 (2008)**	
	9+10+13?	**Large buildings**	**Non residential balanced**									**1**																					**1 (2008)**	
	1 to 10	**Residential**	**all**																															**1 (2015)**
	11+12+13	**Non-residential**	**all**										**1**																					

Figure 11: Number of information sources for data about the sales

Annex 3 – Consolidation of different data published by VHK

This Annex details the values on the EU-28 stock and sales of mechanical ventilation systems, and their evolution towards 2050, resulting from the most recent study by VHK for the European Commission (VHK, 2019).

Explanations are also given on how these data can be combined with other data published by VHK, or issued from VHK studies in previous years, in order to get, with some extrapolations, values that regularly cover the whole period 1990-2050.

The latest report (VHK, 2019) includes values for stock and sales of different types of residential and non-residential mechanical ventilation systems, excluding local exhaust fans. Some values have been presented in Table 1.

Other values from this study (VHK, 2019) show the distribution of stock and sales (Tables 9 and 10) for different types of residential mechanical ventilation units (< 125 W per fan, excluding local exhaust fans):

- Central unidirectional units: the ventilation unit either exhausts or supplies air through a ductwork serving several rooms.
- Central balanced units: the ventilation unit both exhausts and supplies air through a ductwork serving several rooms. The unit includes a heat exchanger for heat recovery between exhaust and fresh air.
- Local balanced units: the ventilation unit only ventilates the room it is installed by both supplying and exhausting air to this room. It includes heat recovery.

Tables 9 and 10 show that the central unidirectional units (mostly exhaust units) represent the largest part of stock and sales for the considered types of residential units, with a decreasing percentage over the total sales (64% in 2020, 54% in 2050) and total stock (79% in 2020, 56% in 2050), in favour of the two other unit types that include heat recovery.

The different types of residential ventilation units are relevant and we shall also use them in this study.

Thousands units	1990	2010	2015	2020	2025	2030	2035	2040	2045	2050
Residential central unidir. units	17,148	33,878	38,186	37,438	35,970	35,435	36,991	39,653	42,373	45,093
Residential central balanced units	163	2,140	4,245	7,492	11,019	14,191	16,265	17,999	19,716	21,433
Residential local balanced units	33	633	1,295	2,439	4,042	5,991	8,038	10,113	12,190	14,266
Total stock	17,344	36,651	43,726	47,369	51,031	55,617	61,294	67,765	74,279	80,792

Table 9: Stock of different types of residential mechanical ventilation units in the EU-28 (VHK, 2019)

Thousands units	1990	2010	2015	2020	2025	2030	2035	2040	2045	2050
Residential central unidirectional units	1,042	2,336	2,073	1,949	2,109	2,269	2,429	2,589	2,748	2,908
Residential central balanced units	37	257	636	816	917	1,018	1,119	1,220	1,321	1,422
Residential local balanced units	7	85	186	302	424	546	668	790	912	1,035
Total sales	1,086	2,678	2,895	3,067	3,450	3,833	4,216	4,599	4,991	5,365

- *Table 10: Sales of different types of residential mechanical ventilation units in the EU-28 (VHK, 2019)*

Data are also available (VHK, 2019) for stock and sales (Tables 11 and 12) of non-residential ventilation units (> 125 W per fan):

- Central unidirectional units: the ventilation unit exhausts air through a ductwork serving several rooms.
- Central balanced units: the ventilation unit both exhausts and supplies air through a ductwork serving several rooms. While all balanced residential ventilation units feature heat recovery, the report assumes that only 37% of the non-residential balanced units in the 2010 stock is equipped with heat recovery.

The different types of non-residential ventilation units are relevant and we shall also use them in this study.

Thousands units	1990	2010	2015	2020	2025	2030	2035	2040	2045	2050
Non-residential central unidir. units	1,879	4,157	4,501	4,726	4,875	4,998	5,123	5,247	5,372	5,497
Non-residential central balanced units	233	2,826	3,614	4,329	4,902	5,318	5,742	6,174	6,606	7,039
Total stock	2,112	6,983	8,115	9,055	9,777	10,316	10,865	11,421	11,978	12,536

Table 11: Stock of different types of non-residential mechanical ventilation units in the EU-28 (VHK, 2019)

Thousands units	1990	2010	2015	2020	2025	2030	2035	2040	2045	2050
Non-residential central unidir. units	169	277	284	291	298	306	313	320	328	335
Non-residential central balanced units	61	257	279	302	328	353	378	404	429	455
Total sales	230	534	563	593	626	659	691	724	757	790

Table 12: Sales of different types of non-residential mechanical ventilation units in the EU-28 (VHK, 2019)

The explanations given below explains how these data can be combined with other data published by VHK, or issued from VHK studies in previous years, in order to get, with some extrapolations, values that regularly cover the whole period 1990-2050.

Data published in 2014

A working document from the European Commission (European Commission, 2014) is based on data provided by a contracted study (Kemna, 2014) and provides values for the stock and sales of mechanical ventilation systems in the EU. Its scope includes residential and non-residential mechanical ventilation units, excluding local exhaust fans.

The document (European Commission, 2014) provides a figure showing the actual sales data 1990-2010 and 'Business-as-Usual' projections for the period 2010-2025 (Figure 12). The values in Figure 12 are for the EU-27. They are consistent with those of Tables 1 and 3 for the EU-28 (=EU-27 + Croatia).

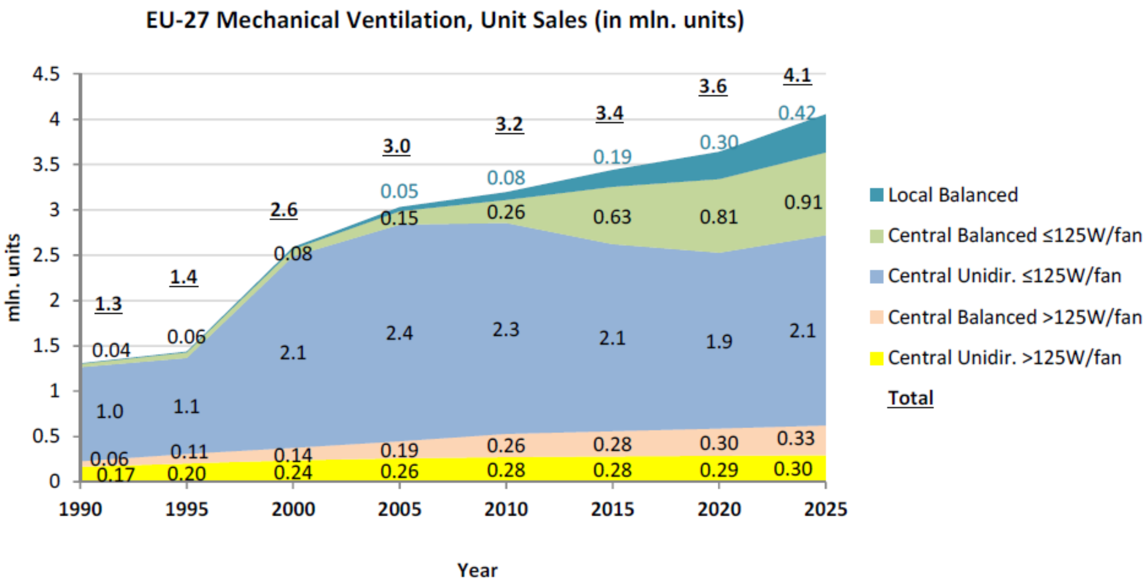

Figure 12: Sales of residential and non-residential mechanical ventilation units (excluding local exhaust fans) in the EU-27 (European Commission, 2014)

Stock values from this document (European Commission, 2014) are shown in Figure 13, copied from the original document as it appears into it, i.e. with a stretching of the picture in the horizontal direction.

The stock values for 1990 are not consistent between the report (Kemna, 2014) and the document from the EC (European Commission, 2014). We keep here the value from the report (19,360 instead of 12,100) because it is consistent with values published later (VHK, 2016). The value of the 2010 stock in Figure 13 is consistent with the values published later (VHK, 2016): 42.1 million units to be compared with 43.4. We do not consider the values of the stock of Figure 13 for years 1995, 2000 and 2005 since they are doubtful compared with other values.

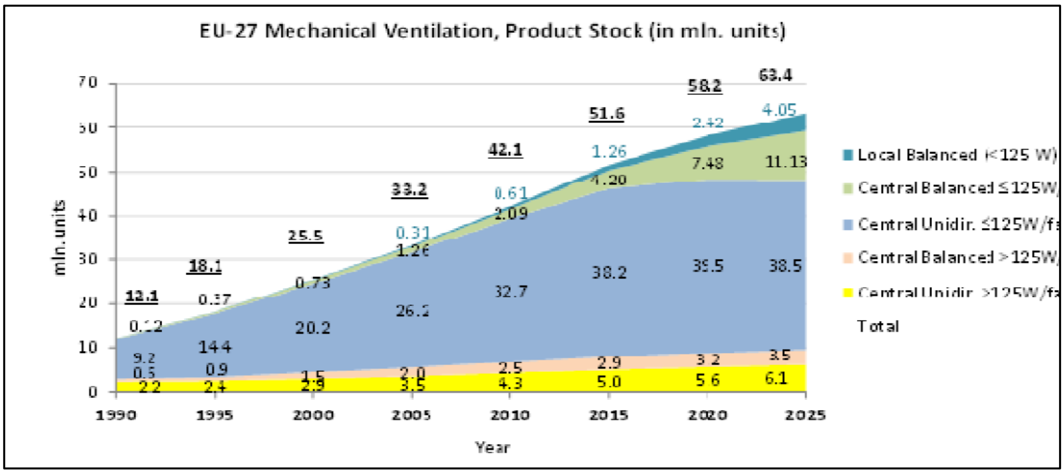

Figure 13: Stock of residential and non-residential mechanical ventilation units (excluding local exhaust fans) in the EU-27 (European Commission, 2014)

Finally, the table that can be derived from this document (European Commission, 2014), as well as from the corresponding report (Kemna, 2014) is below (Table 13):

Thousands units	1990	1995	2000	2005	2010	2015	2020	2025
Stock of residential ventilation units EU-27	17,288				36,468	43,508	47,132	50,597
Stock of non-residential ventilation units EU-27	2,102				6,948	8,075	9,009	9,728
Total of stock EU-27	19,390				43,417	51,600	56,142	60,325
Sales of residential ventilation units EU-27	1,080	1,160	2,180	2,600	2,664	2,870	3,051	3,433
Sales of non-residential ventilation units EU-27	228	330	400	450	529	560	591	623
Total of sales EU-27 (sometimes rounded)	1,309	1,400	2,600	3,000	3,196	3,440	3,642	4,055

Table 13: Stock and sales of mechanical ventilation units (excluding local exhaust fans) in the EU-27 (European Commission, 2014 and VHK, 2014)

Consolidation of 2019 stock data with data published in 2014

The combination of information from the 2019 and 2014 results leads to Table 14 about the stock, in which extrapolated values appear in red colour:

Year	Residential EU-27	Residential EU-28	Non-residential EU-27	Non-residential EU-28	Total EU-27	Total EU-28
1990	17,288	17,344	2,102	2,112	19,390	19,456
1995		21,801		3,330		25,131
2000		26,549		4,548		31,097
2005		31,487		5,766		37,253
2010	36,468	36,651	6,948	6,983	43,417	43,634
2015	43,508	43,726	8,075	8,115	51,600	51,841
2020	47,132	47,369	9,009	9,055	56,142	56,424
2025	50,597	51,031	9,728	9,777	60,325	60,808
2030		55,617		10,316		65,933
2035		61,294		10,865		72,159
2040		67,765		11,421		79,186
2045		74,279		11,978		86,707
2050		80,792		12,536		93,328

Table 14: Stock of mechanical ventilation units in the EU-27 and 28 (from Tables 1, 2 and 13)

The stock of residential ventilation units by system types can also be extrapolated from the existing data (Table 15):

Year	Residential central unidir. units EU-27	Residential central unidir. units EU-28	Residential central balanced units EU-27	Residential central balanced units EU-28	Residential local balanced units EU-27	Residential local balanced units EU-28
1990	17,063	17,148	162	163	33	33
1995		21,331		400		70
2000		25,514		900		135
2005		29,697		1450		340
2010	32,700	33,878	2,090	2,140	610	633
2015	38,200	38,186	4,200	4,245	1,260	1,295
2020	39,500	37,438	7,480	7,492	2,420	2,439
2025	38,500	35,970	11,130	11,019	4,050	4,042
2030		35,435		14,191		5,991
2035		36,991		16,265		8,038
2040		39,653		17,999		10,113
2045		42,373		19,716		12,190
2050		45,093		21,433		14,266

Table 15: Stock of different types of residential mechanical ventilation units in the EU-27 and 28 (from Tables 2 and Figure 13)

Finally, the stock of non-residential ventilation units by system types can be extrapolated from the existing data (Table 16):

Year	Non-residential central unidir. units EU-27	Non-residential central unidir. units EU-28	Non-residential central balanced units EU-27	Non-residential central balanced units EU-28
1990		1,879		233
1995		2,800		530
2000		3,418		1,130
2005		3,836		1,930
2010	4,300	4,157	2,500	2,826
2015	5,000	4,501	2,900	3,614
2020	5,600	4,726	3,200	4,329
2025	6,100	4,875	3,500	4,902
2030		4,998		5,318
2035		5,123		5,742
2040		5,247		6,174
2045		5,372		6,606
2050		5,497		7,039

Table 16: Stock of different types of non-residential mechanical ventilation units in the EU-27 and 28 (from Table 2 and Figure 13)

Consolidation of 2019 sales data with data published in 2014

The combination of information from the 2019 and 2014 results leads to the following table about sales, in which extrapolated values appear in red colour:

Year	Residential EU-27	Residential EU-28	Non-residential EU-27	Non-residential EU-28	Total EU-27	Total EU-28
1990	1,080	1,086	228	230	1,308	1,316
1995	1,160	1,168	330	330	1,490	1,498
2000	2,180	2,190	400	402	2,580	2,592
2005	2,600	2,612	450	453	3,050	3,065
2010	2,664	2,678	529	534	3,193	3,212
2015	2,870	2,895	560	563	3,430	3,458
2020	3,051	3,067	591	593	3,642	3,660
2025	3,433	3,450	623	626	4,056	4,076
2030		3,833		659		4,492
2035		4,216		691		4,907
2040		4,599		724		5,323
2045		4,991		757		5,748
2050		5,365		790		6,155

Table 17: Sales of mechanical ventilation units in the EU-27 and 28 (from Tables 1,2 and 13)

The sales of residential ventilation units by system types can also be extrapolated from the existing data (Table 18):

Year	Residential central unidir. units EU-27	Residential central unidir. units EU-28	Residential central balanced units EU-27	Residential central balanced units EU-28	Residential local balanced units EU-27	Residential local balanced units EU-28
1990	1,000	1,042	40	37		7
1995	1,100	1,101	60	60		7
2000	2,100	2,100	80	80		10
2005	2,400	2,412	150	150	50	50
2010	2,300	2,336	260	257	80	85
2015	2,100	2,073	630	636	190	186
2020	1,900	1,949	810	816	300	302
2025	2,100	2,109	910	917	420	424
2030		2,269		1,018		546
2035		2,429		1,119		668
2040		2,589		1,220		790
2045		2,748		1,321		912
2050		2,908		1,422		1,035

Table 18: Sales of different types of residential mechanical ventilation units in the EU-27 and 28 (from Table 3 and Figure 12)

The sales of non-residential ventilation units by system types can also be extrapolated with the same methodology (Table 19):

Year	Non-residential central unidir. units EU-27	Non-residential central unidir. units EU-28	Non-residential central balanced units EU-27	Non-residential central balanced units EU-28
1990	170	169	60	61
1995	200	215	110	115
2000	240	260	140	142
2005	260	263	190	190
2010	280	277	260	257
2015	280	284	280	279
2020	290	291	300	302
2025	300	298	330	328
2030		306		353
2035		313		378
2040		320		404
2045		328		429
2050		335		455

Table 19: Sales of different types of non-residential mechanical ventilation units in the EU-27 and 28 (from Table 3 and Figure 12)

Finally, the evolution of the stock for the EU-28 is summarised by the following figures for residential and non-residential systems. The increase of the total stock is shown as:

- for residential systems: +8 to 10% per 5 years between 2020 and 2050,
- for non-residential systems: +8% between 2020 and 2025 and about +5% per 5 years between 2025 and 2050.

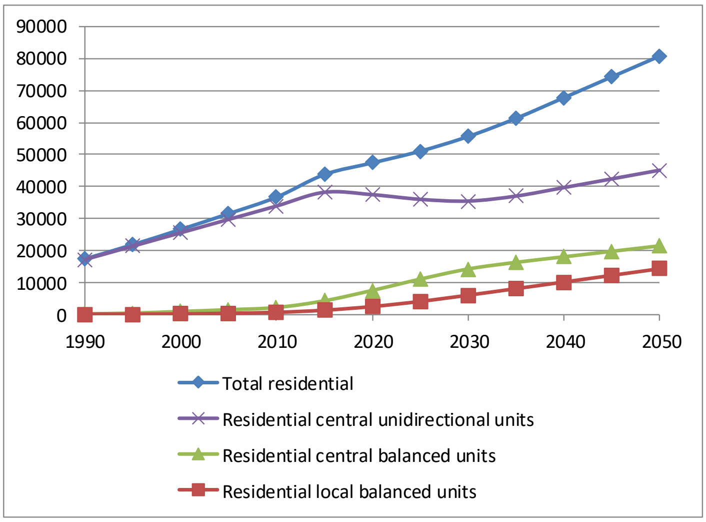

Figure 14: Stock of different types of residential mechanical ventilation units in the EU-28 (from Table 2)

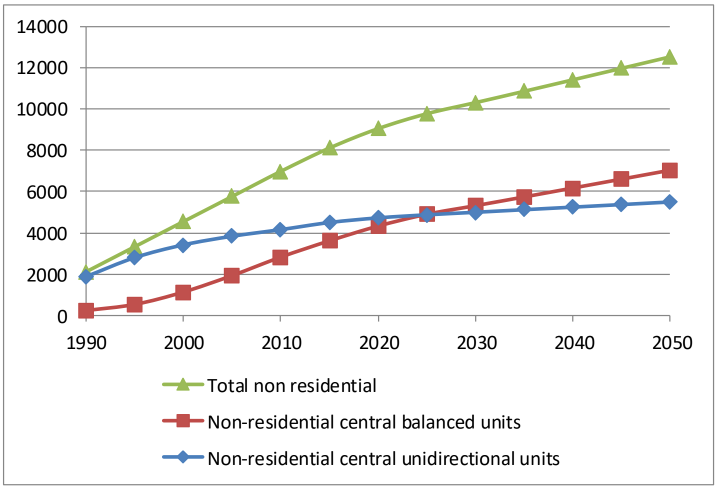

Figure 15: Stock of different types of non-residential mechanical ventilation units in the EU-28 (from Table 2)

The evolution of the sales for the EU-28 is summarised by the following figures for residential and non-residential systems. The increase of the total sales is shown as:

- for residential systems: from +12% between 2020 and 2025 to +8% between 2045 and 2050,
- for non-residential systems: around +5% per 5 years between 2020 and 2050.

Figures also show that the proportion of sales that contribute increasing the stock is assumed to be:

- about 25% for residential systems between 2020 and 2050,
- for non-residential systems: about 33% between 2020 and 2025, 24% between 2025 and 2030 and 15% between 2030 and 2050.

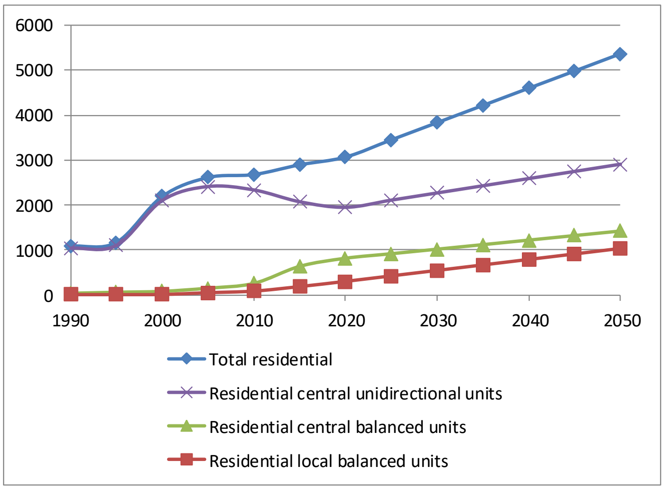

Figure 16: Sales of different types of residential mechanical ventilation units in the EU-28 (from Table 3)

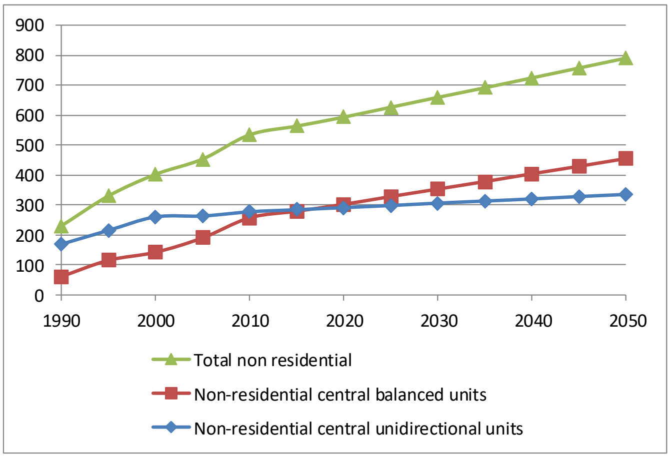

Figure 17: Sales of different types of non-residential mechanical ventilation units in the EU-28 (from Table 3)

Annex 4 – Information from the Ecodesign preparatory study (Lot 10) 2009

This Annex shows the results from the preparatory study (2007-2009) on residential ventilation (Rivière, 2009) that have been used in our study.

Figure 18 (except the two last columns of the table) gives the repartition of the stock of central ventilation systems per country in year 2005.

Table 2-18: Adjusted estimate of the stock of centralised ventilation fans in use in number of units in EU-25 in 2005

Estim.3 Stock ~1000	Nb ICV in use 1 or 2 dwelling	Nb ICV&HR in use 1 or 2 dwell.	Nb CCV in use Coll. Dwell.	Nb CCV&HR in use Coll. Dwell.	Area CCV Coll. dwell.	Area CCV&HR Coll. Dwell.
EU-25	10992	621	6161	25	2510121	11150
A	157	14	6	0	2886	0
B	1565	24	90	0	38590	0
CY	1	0	9	0	6592	0
CZ	7	0	196	0	74516	0
DK	433	95	153	4	83636	2215
EST	0	0	31	0	9353	0
FIN	272	126	217	12	83474	4460
F	3439	84	903	0	406222	0
D	1791	67	32	0	14195	0
GR	15	0	125	0	51761	0
H	9	0	107	0	40092	0
IRL	20	0	2	0	1087	0
IT	14	0	1337	0	601534	0
LT	1	0	52	0	14435	0
LIT	2	0	67	0	20334	0
LUX	60	1	4	0	2585	0
MT	0	0	5	0	2591	0
NL	2293	72	180	0	88203	0
PL	32	0	694	0	235970	0
P	31	0	71	0	29412	0
SK	35	0	858	0	240261	0
SLO	49	2	0	0	129	0
E	60	0	567	0	254957	0
S	611	135	367	10	168972	4475
UK	94	0	88	0	38332	0

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Figure 18: Stock of residential central ventilation units in 2005 in the EU-25 (Rivière, 2009) - The two last columns relate to dwellings areas and are out of our scope.

Figure 19 (except the two last columns of the table) gives the repartition of the stock of central ventilation systems per country in year 2005. The stock of the decentralised unidirectional ventilation systems (without heat recovery) is obtained by making the sum of the two first columns.

The study also provides, per system and per country, sales estimates (Figure 20) and share of sales between one-family and multi-family buildings.

Table 2-17: Adjusted estimate of the stock of distributed ventilation fans in use in number of units in EU-25 in 2005

Estim.3 Stock ~1000	Nb DV in use continuous	Nb DV in use On/off	Nb DV&HR in use Cont.	Total DV stock	Nb hoods prodcom + Est.	Nb fans prodcom + Est	Nb DV prodcom + Est
EU-25	4527	63377	**84**	**67987**	**47840**	**34223**	**82063**
A	92	1292	14	1398	383	889	1272
B	157	2191	0	2348	647	1338	1985
CY	7	97	0	104	102	49	151
CZ	65	914	0	979	802	473	1275
DK	21	296	0	317	716	310	1026
EST	9	122	0	130	102	41	143
FIN	26	361	0	387	326	465	791
F	216	3021	0	3237	4987	4969	9956
D	1063	14887	67	16018	8569	4268	12837
GR	111	1553	0	1664	761	898	1659
H	58	806	0	863	586	498	1084
IRL	99	1380	0	1479	383	1061	1444
IT	479	6700	0	7179	16076	1126	17202
LT	14	196	0	210	244	49	293
LIT	21	289	0	309	256	106	362
LUX	6	83	0	89	45	57	102
MT	4	52	0	56	16	24	40
NL	151	2118	0	2269	969	2040	3009
PL	210	2940	0	3150	590	2220	2810
P	125	1746	0	1871	859	1877	2736
SK	311	4357	0	4669	269	2162	2431
SLO	21	298	2	321	130	122	252
E	413	5785	0	6199	5451	3664	9115
S	60	835	0	895	187	465	652
UK	790	11057	0	11847	4384	5051	9435

Figure 19: Stock of residential decentralised ventilation units in 2005 in the EU-25 (Rivière, 2009) - The three last columns show production statistics and are out of our scope.

Table 2-19: Adjusted estimate of sales data

Market Estim.3 ~1000	Estimate Market DV	Of which Hoods	Of which Fans	Nb hoods from Prodcom (1/2)	Nb fans from Prodcom (T 2.3)	Estimate Market ICV	Estimate Market ICV &HR	Estimate market CCV	Estimate market CCV&HR
EU-25	7294	3883	3411	**5876**	**4194**	1316	**104**	**673**	**4**
A	160	84	76	47	109	18	2	1	0
B	240	128	112	80	164	187	4	10	0
CY	11	6	5	13	6	0	0	1	0
CZ	104	56	49	99	58	1	0	21	0
DK	32	17	15	88	38	44	16	16	1
EST	14	7	6	13	5	0	0	3	0
FIN	39	21	18	40	57	28	21	23	2
F	324	173	151	613	609	450	14	107	0
D	1701	901	800	1053	523	188	11	5	0
GR	183	98	86	94	110	3	0	14	0
H	90	48	42	72	61	1	0	11	0
IRL	180	96	84	47	130	3	0	0	0
IT	752	401	351	1975	138	2	0	139	0
LT	22	12	10	30	6	0	0	5	0
LIT	33	17	15	32	13	0	0	7	0
LUX	9	5	4	6	7	7	0	0	0
MT	6	3	3	2	3	0	0	1	0
NL	237	126	110	119	250	273	12	20	0
PL	351	187	164	73	272	5	0	77	0
P	214	114	100	106	230	5	0	8	0
SK	492	263	230	33	265	6	0	91	0
SLO	34	18	16	16	15	5	0	0	0
E	695	370	324	670	449	10	0	64	0
S	89	48	42	23	57	62	22	38	2
UK	1283	684	599	539	619	16	0	9	0

*Figure 20: Market share of residential ventilation systems (Rivière, 2009)
In the framework of this study, the following columns can be omitted: "Estimate market DV", "Of which hoods", "Nb hoods from Prodcom (1/2)", "Nb fans from Prodcom (T 2.3)". The column "Of which fans" corresponds to decentralised ventilation systems.*

Annex 5 – Methodology for the assessment of stock and sales

Entering data into a single file

All available data on stock and sales, at the EU or national level, have been gathered in a common format shown by Figure 21. One table per source and per available year has been created and filled in. This leads to 24 tables for the stock and 42 tables for the sales. Most of the tables have only a few cells that are filled in.

	Kind of data:		Year:			Unit:						Exact year:																						
				Countries																												Sums		
			Column number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	All but 13, 23	All but 13	All
	Row number			A	B	BUL	CY	CZ	DK	EST	FIN	F	D	GR	H	HR	IRL	IT	LT	LIT	LUX	MT	NL	PL	P	ROM	SK	SLO	E	S	UK	EU 25	EU 27	EU 28
Systems	1	Residential Single-houses	Natural																															
	2		Decentralised																															
	3		Centralised unidirectional																															
	4		Central balanced																															
	5		Local balanced																															
	6	Residential Multi-family dwellings	Natural																															
	7		Decentralised																															
	8		Centralised unidirectionel																															
	9		Central balanced																															
	10		Local balanced																															
	11	Non-Residential	Natural																															
	12		Unidirectional																															
	13		Balanced																															
Sums	**1+6**	**Residential**	**Natural**																															
	2+7	**Residential**	**Decentralised**																															
	3+8	**Residential**	**Centralised unidirectional**																															
	4+9	**Residential**	**Central balanced**																															
	5+10	**Residential**	**Local balanced**																															
	2 to 5+6 to 1	**Residential**	**Mechanical**																															
	7+8+12?	**Large buildings**	**Unidirectional**																															
	9+10+13?	**Large buildings**	**Non residential balanced**																															
	1 to 10	**Residential**	**all**																															
	11+12+13	**Non-residential**	**all**																															
	all but 1, 6 a	**all**	**Mechanical**																															
	all	**all**	**all**																															

Figure 21: Table used for gathering available data under a common format

The types of ventilation systems used are:

Residential					Non-residential		
Natural	Decentralised unidirectional	Central unidirectional	Central balanced	Local balanced	Natural	Central unidirectional	Central balanced

Table 20: Types of ventilation systems used for the analysis

This segmentation of ventilation systems seems logical: the stock and sales of decentralised unidirectional systems and local balanced systems in non-residential buildings is probably low and this situation is not expected to change.

All data for stock and sales have been expressed in thousands units of ventilation systems. In some cases, data were available in percentage of a building stock (for example penetration of a given ventilation system in a stock of buildings); in such cases, the available data have been converted into thousands of units of ventilation systems by using information about the building stock from the European Building Stock Observatory

Part of the data provide values per system and per country. Other data provide sums for several countries or several systems. These latter were also entered into the tables in specific corresponding cells, that correspond to sums according to lines or columns.

The general methodology is to calculate average repartition to extrapolate detailed information from sums.

Repartition per country

Both for stock and sales, the first step of the methodology was to calculate the repartition of systems per countries.

In some information sources covering the EU-25 or the EU-27, data for Bulgaria, Romania and Croatia are missing. As no specific data was found for Croatia, the assumption was made that Croatia has the same values than Slovakia (similar population and close location). One information source (FGK study) provides values for Bulgaria and Romania. The corresponding repartition of different ventilation systems in stock and sales compared to the total has been kept and applied to other

The average proportion of different ventilation systems per country has been calculated for year 2005 from the average of two studies (Ecodesign Lot 10 and FGK) for all mechanical ventilation systems. As only one source provides a repartition of residential natural ventilation systems per country (Ecodesign Lot 10), the corresponding values have been used.

For all residential ventilation systems, this proportion per country was then applied to each other "sum" data, regardless the year as there is no other proportion available than those of year 2005. When data are available for EU-25, EU-27 or only some countries, first an extrapolation to EU-28 sum is made and then all other countries are filled from the EU28 value.

The repartition per country was supposed to remain constant over years.

Repartition per system

First, year 2005 has been analysed as it was the one gathering the most data.
The repartition per system for each country was filled in according to the approach described below.
First the proportion of residential natural ventilation systems vs total stock has been calculated from the studies by FGK, OQAI and Air.h. Regarding the sales, the only available data are for single-family houses in Ireland. Therefore, it has not been possible to calculate the sales for natural ventilation at European scale.
The proportion of decentralised unidirectional ventilation systems vs all mechanical ventilation systems relies on data from the Ecodesign lot 10 and FGK studies for stock and sales. The French stock data from air.h and OQAI have also been taken into account.
The repartition of other mechanical ventilation systems was calculated with data from studies by VHK, Ecodesign lot 10 and FGK. In addition, data from air.h and OQAI has been used for the stock and data from the publication EVIA 2017 for the share of sales between balanced and unidirectional central units.
Data have been distributed between single-houses and multi-family buildings.
For the stock and sales of central systems (both unidirectional and balanced) the repartition of Ecodesign lot 10 has been used.
As, both for stock and sales, there is no data for the repartition of local balanced ventilation and as there is very few installed system, it has been assumed that the repartition is half for multi-family and half for single houses.
Regarding sales there is no data for the repartition of decentralised unidirectional system so the repartition has been assumed to be half for multi-family and half or single house.
All tables have then been filled in by using these estimated values.

The evolution of the stock and sales

The studies by VHK give evolutions of stock and sales from 1995 to 2050 for each 5 year period for unidirectional central, balanced central and local balanced for the stock and the market.
Ecodesign Lot 10 gives the evolution of stock and sales from 2005 to 2025 for each 5 years period for the same systems. For 2030, 2035, 2040, 2045 and 2050, the data to fill in the Ecodesign lot 10 table have been linearly extrapolated.
Regarding data for non-residential systems, as only the study from VHK provides usable data, only those data are summarised in the results.

Results

Finally, the calculated data provide minimum, average and maximum for year 2005, as well as evolutions of stock and sales for other years.

The detailed results and calculations are in a Microsoft Excel file that has been delivered together with the current report.

Annex 6 – Detailed values of the stock and sales 2020-2050

Figure 22 is a copy of results file showing the evolution of the stock per systems and per country towards 2050.

Figure 23 shows results for sales of residential mechanical ventilation systems per country towards 2050.

Stock in 2020

		A	B	BUL	CY	CZ	DK	EST	FIN	F	D	GR	H	HR	IRL	IT	LT	LIT	LUX	MT	NL	PL	P	ROM	SK	SLO	E	S	UK	EU28
Residential	Decentralised unidirectional	1225 2092	2016 3367	706 1218	89 150	1123 1639	357 1333	149 230	440 1038	657 9128	16971 24928	1368 2455	985 1789	550 6958	684 2264	6880 10812	240 384	355 619	71 126	48 84	2587 4019	3495 5165	1401 2757	2007 3462	550 6958	265 470	4319 9210	1016 2336	10500 19555	61053 124547
		1677	2727	953	121	1372	796	187	711	4405	21028	1929	1359	3464	1428	8928	308	478	100	66	3262	4314	2091	2712	3464	370	6769	1618	15398	92032
	Central unidirectional	219 712	1005 2226	390 449	13 53	273 609	312 788	42 84	320 658	2682 7700	2452 9177	188 1040	156 742	354 1387	30 710	130 3883	71 137	93 212	44 86	7 29	1442 3326	976 2203	137 1325	1104 1272	354 1387	66 160	843 2848	494 1315	245 6111	14441 50631
		532	1477	419	39	494	491	68	506	5874	4853	685	502	981	441	1943	112	152	58	21	2199	1680	784	1186	981	128	2141	849	3275	32868
	Central balanced	70 209	0 433	0 109	0 8	0 112	89 492	0 15	157 685	0 1478	194 698	0 152	0 112	0 211	0 90	0 270	0 25	0 31	0 17	0 4	358 686	0 404	0 180	0 308	0 211	0 28	0 449	243 720	0 509	1111 8646
		130	184	36	3	37	243	7	370	580	408	51	37	72	43	100	8	10	7	1	562	144	60	103	72	13	150	402	217	4052
	Local balanced	32 131	0 41	0 0	0 0	0 0	0 213	0 3	0 371	0 216	19 430	0 0	0 0	0 3	0 20	0 15	0 0	0 0	0 2	0 0	0 450	0 15	0 0	0 0	0 3	0 13	0 0	0 370	0 0	51 2294
		84	14	0	0	0	75	1	134	47	221	0	0	1	9	5	0	0	1	0	178	5	0	0	1	5	0	134	44	958
	Total residential mechanical	1546 3144	3020 6067	1095 1776	102 211	1396 2360	759 2826	191 331	918 2752	3339 18522	19636 35233	1556 3647	1141 2643	903 8558	714 3085	7010 14979	311 547	448 862	114 231	55 118	4387 8482	4471 7787	1538 4262	3111 5042	903 8558	331 672	5162 12507	1753 4741	10745 26175	76656 186119
		2423	4402	1408	163	1903	1605	263	1722	10905	26510	2665	1898	4517	1921	10976	429	640	166	88	6200	6143	2935	4001	4517	516	9059	3003	18933	129910
Non residential	Central unidirectional																													4726
	Central balanced																													4329

Stock in 2030

		A	B	BUL	CY	CZ	DK	EST	FIN	F	D	GR	H	HR	IRL	IT	LT	LIT	LUX	MT	NL	PL	P	ROM	SK	SLO	E	S	UK	EU28
Residential	Decentralised unidirectional	1357 2532	2213 3993	762 1474	98 179	1215 2035	383 1637	160 283	475 1289	954 11507	18483 30523	1511 2942	1062 2205	612 8399	760 2750	7544 13073	259 473	383 768	78 149	52 102	2790 4979	3796 6409	1551 3296	2172 4197	612 8399	292 564	4799 11070	1093 2876	11598 23110	67061 151214
		1975	3163	1105	141	1611	931	218	837	5564	24646	2257	1588	4037	1681	10448	360	562	116	76	3820	5080	2445	3150	4037	432	7947	1892	17846	107964
	Centralised unidirectional	239 775	1093 2422	424 489	15 57	297 663	340 858	45 91	348 716	2919 8380	2668 9987	205 1131	170 808	385 1510	32 773	142 4225	78 150	101 230	47 94	7 32	1569 3620	1063 2398	149 1442	1201 1385	385 1510	72 175	918 3100	537 1432	266 6651	15715 55101
		579	1607	456	42	537	534	74	551	6392	5282	746	546	1067	480	2115	122	165	63	23	2393	1828	853	1291	1067	140	2330	923	3564	35770
	Central balanced	120 360	0 747	0 188	0 14	0 193	154 849	0 27	272 1183	0 2551	334 1205	0 263	0 193	0 364	0 156	0 466	0 44	0 54	0 30	0 8	617 1185	0 697	0 310	0 533	0 364	0 49	0 775	420 1243	0 878	1918 14930
		224	318	63	5	64	420	12	639	1001	705	88	64	124	75	172	15	18	13	3	970	249	103	178	124	22	258	695	375	6996
	Local balanced	66 270	0 84	0 0	0 0	0 0	0 440	0 5	0 765	0 446	40 889	0 0	0 0	0 5	0 42	0 32	0 0	0 0	0 3	0 0	0 929	0 32	0 0	0 0	0 5	0 27	0 0	0 764	0 0	106 4737
		174	28	0	0	0	156	2	277	97	456	0	0	2	18	11	0	0	1	0	367	11	0	0	2	11	0	277	90	1979
	Total residential mechanical	1782 3937	3306 7247	1186 2151	112 250	1512 2892	877 3784	206 406	1095 3954	3872 22883	21526 42604	1716 4336	1232 3206	997 10278	792 3721	7686 17796	336 666	484 1052	125 277	59 141	4976 10713	4859 9535	1700 5049	3373 6114	997 10278	363 814	5717 14945	2051 6315	11864 30639	84801 225982
		2952	5115	1623	188	2213	2040	306	2304	13054	31088	3090	2199	5230	2254	12746	497	745	193	102	7550	7167	3401	4619	5230	605	10535	3787	21876	152708
Non residential	Central unidirectional																													4998
	Central balanced																													5318

Stock in 2040

		A	B	BUL	CY	CZ	DK	EST	FIN	F	D	GR	H	HR	IRL	IT	LT	LIT	LUX	MT	NL	PL	P	ROM	SK	SLO	E	S	UK	EU28
Residential	Decentralised unidirectional	1477 2862	2392 4464	814 1667	106 201	1298 2333	406 1866	171 323	506 1477	1224 13293	19860 34727	1641 3308	1132 2517	668 9481	829 3116	8148 14773	276 539	409 880	85 167	55 115	2974 5700	4070 7344	1688 3702	2322 4749	668 9481	316 634	5236 12468	1164 3282	12598 25780	72533 171248
		2215	3513	1227	158	1803	1039	243	938	6496	27556	2521	1773	4498	1885	11670	402	629	129	84	4270	5696	2729	3503	4498	481	8894	2113	19816	120778
	Centralised unidirectional	275 892	1259 2788	488 563	17 66	342 763	391 987	52 105	401 824	3360 9646	3072 11496	236 1302	195 930	443 1738	37 890	163 4864	89 172	116 265	55 108	8 36	1806 4167	1223 2760	172 1660	1383 1594	443 1738	83 201	1056 3568	618 1648	307 7655	18090 63425
		666	1850	525	48	618	615	85	634	7358	6079	858	629	1229	552	2434	141	190	73	27	2754	2104	982	1486	1229	161	2682	1063	4102	41173
	Central balanced	156 469	0 974	0 245	0 18	0 252	201 1106	0 35	354 1542	0 3324	436 1570	0 343	0 252	0 474	0 203	0 607	0 57	0 70	0 39	0 10	804 1544	0 908	0 404	0 694	0 474	0 64	0 1010	547 1620	0 1144	2499 19453
		292	414	82	6	84	547	15	833	1304	918	114	84	162	97	225	19	23	17	3	1263	325	135	231	162	29	337	905	489	9115
	Local balanced	105 425	0 132	0 0	0 0	0 0	0 694	0 8	0 1207	0 703	63 1402	0 0	0 0	0 8	0 66	0 50	0 0	0 0	0 6	0 0	0 1466	0 50	0 0	0 0	0 8	0 42	0 0	0 1204	0 0	167 7472
		274	44	0	0	0	245	3	437	153	719	0	0	3	29	17	0	0	2	0	579	17	0	0	3	18	0	436	142	3121
	Total residential mechanical	2012 4648	3651 8358	1302 2475	123 285	1640 3348	998 4653	223 471	1261 5050	4583 26966	23430 49194	1877 4953	1327 3698	1112 11701	866 4274	8311 20293	365 769	526 1215	139 319	64 162	5585 12877	5293 11061	1859 5766	3705 7037	1112 11701	398 941	6292 17046	2330 7754	12904 34580	93289 261597
		3448	5821	1833	212	2506	2446	347	2842	15310	35272	3493	2486	5891	2564	14346	562	842	220	114	8866	8141	3845	5221	5891	688	11912	4517	24549	174187
Non residential	Central unidirectional																													5247
	Central balanced																													6174

Stock in 2050

		A	B	BUL	CY	CZ	DK	EST	FIN	F	D	GR	H	HR	IRL	IT	LT	LIT	LUX	MT	NL	PL	P	ROM	SK	SLO	E	S	UK	EU28
Residential	Decentralised unidirectional	1582 3132	2550 4848	859 1825	114 219	1371 2576	427 2052	180 356	534 1631	1462 14752	21075 38159	1756 3606	1193 2772	718 10365	890 3414	8681 16160	291 594	432 971	91 181	58 126	3137 6289	4312 8107	1808 4032	2455 5200	718 10365	337 692	5621 13609	1226 3613	13480 27961	77360 187606
		2415	3805	1329	171	1963	1129	264	1022	7272	29980	2740	1927	4882	2055	12689	437	685	140	91	4644	6209	2966	3797	4882	522	9683	2296	21457	131454
	Centralised unidirectional	314 1020	1439 3188	558 643	19 75	391 873	447 1129	60 120	458 942	3842 11030	3512 13145	270 1489	223 1063	507 1987	42 1017	187 5561	102 197	133 303	62 123	10 42	2065 4764	1399 3156	197 1898	1581 1823	507 1987	94 230	1208 4080	707 1884	351 8754	20685 72524
		762	2115	600	55	707	703	98	725	8413	6952	981	719	1405	631	2784	161	217	83	31	3149	2406	1122	1699	1405	184	3066	1215	4691	47080
	Central balanced	191 573	0 1189	0 299	0 22	0 308	246 1351	0 42	433 1883	0 4059	532 1917	0 418	0 307	0 579	0 248	0 741	0 70	0 86	0 48	0 12	982 1886	0 1108	0 494	0 847	0 579	0 78	0 1233	668 1978	0 1397	3052 23751
		356	505	100	7	103	668	19	1017	1592	1121	139	102	198	119	274	23	29	20	4	1543	397	165	282	198	35	411	1105	597	11130
	Local balanced	143 582	0 181	0 0	0 0	0 0	0 950	0 11	0 1652	0 962	86 1918	0 0	0 0	0 11	0 91	0 68	0 0	0 0	0 8	0 0	0 2005	0 68	0 0	0 0	0 11	0 57	0 0	0 1648	0 0	229 10223
		375	60	0	0	0	336	4	598	210	984	0	0	4	40	23	0	0	3	0	793	23	0	0	4	24	0	597	195	4270
	Total residential mechanical	2230 5306	3990 9406	1417 2767	133 316	1763 3757	1119 5481	239 529	1425 6107	5303 30802	25205 55139	2026 5514	1417 4142	1225 12942	933 4770	8868 22530	393 861	565 1360	153 359	68 180	6184 14944	5711 12439	2005 6424	4036 7870	1225 12942	431 1057	6829 18922	2601 9124	13830 38111	101325 294104
		3908	6486	2028	234	2773	2835	384	3362	17487	39037	3861	2748	6489	2846	15770	621	931	246	126	10128	9034	4253	5779	6489	766	13161	5214	26939	193933
Non residential	Central unidirectional																													5497
	Central balanced																													7039

Figure 22: Detailed results for the evolution of the stock

Residential

Decentralised unidirectionnel was assumed to be constant																													
Decentralised unidirectiona	A	B	BUL	CY	CZ	DK	EST	FIN	F	D	GR	H	HR	IRL	IT	LT	LIT	LUX	MT	NL	PL	P	ROM	SK	SLO	E	S	UK	EU28
2020	96	139	49	6	77	43	10	40	371	1159	105	74	184	81	487	17	27	5	3	179	245	113	141	184	20	377	88	785	5105
2030	96	139	49	6	77	43	10	40	371	1159	105	74	184	81	487	17	27	5	3	179	245	113	141	184	20	377	88	785	5105
2040	96	139	49	6	77	43	10	40	371	1159	105	74	184	81	487	17	27	5	3	179	245	113	141	184	20	377	88	785	5105
2050	96	139	49	6	77	43	10	40	371	1159	105	74	184	81	487	17	27	5	3	179	245	113	141	184	20	377	88	785	5105
Central unidirectional	A	B	BUL	CY	CZ	DK	EST	FIN	F	D	GR	H	HR	IRL	IT	LT	LIT	LUX	MT	NL	PL	P	ROM	SK	SLO	E	S	UK	EU28
2005	34	118	35	2	31	37	3	39	440	240	41	27	55	27	105	6	8	5	1	194	127	57	100	55	7	150	61	156	2163
2010	36	125	37	2	33	39	4	41	467	255	44	28	58	28	112	6	9	5	1	206	135	60	106	58	7	159	65	166	2295
2015	35	121	36	2	32	38	4	40	452	246	43	27	56	27	108	6	8	5	1	199	131	58	103	56	7	154	63	160	2219
2020	28	95	28	2	25	30	3	31	356	194	33	21	44	22	85	5	7	4	1	157	103	46	81	44	6	121	49	126	1748
2025	30	103	31	2	27	32	3	34	385	210	36	23	48	23	92	5	7	4	1	170	111	50	88	48	6	131	53	137	1891
2030	32	111	33	2	29	35	3	36	414	226	39	25	52	25	99	5	8	5	1	183	120	53	94	52	7	141	57	147	2034
2035	35	119	35	2	31	37	4	39	443	242	42	27	55	27	106	6	8	5	1	196	128	57	101	55	7	151	61	157	2178
2040	37	127	38	2	33	39	4	41	473	258	44	28	59	29	113	6	9	5	1	208	137	61	108	59	7	161	65	168	2321
2045	39	135	40	2	35	42	4	44	502	273	47	30	63	30	120	6	9	6	1	221	145	65	114	63	8	171	70	178	2464
2050	41	142	42	3	38	44	4	46	531	289	50	32	66	32	127	7	10	6	2	234	153	69	121	66	8	181	74	188	2607
Central balanced	A	B	BUL	CY	CZ	DK	EST	FIN	F	D	GR	H	HR	IRL	IT	LT	LIT	LUX	MT	NL	PL	P	ROM	SK	SLO	E	S	UK	EU28
2005	6	4	1	0	0	12	0	20	11	15	0	0	0	1	2	0	0	0	0	20	1	0	0	0	0	0	18	8	119
2010	10	6	2	0	0	19	0	32	17	24	0	0	0	2	3	0	0	0	0	32	2	0	0	0	0	0	29	13	191
2015	20	12	4	0	0	40	0	68	35	50	0	0	0	4	6	0	0	0	0	68	4	0	0	0	0	0	62	27	401
2020	32	19	7	0	0	65	0	110	57	81	0	0	0	6	10	0	0	0	0	109	7	0	0	0	0	0	99	44	647
2025	36	21	8	0	0	73	0	123	64	92	0	0	0	7	12	0	0	0	0	123	7	0	0	0	0	0	112	50	727
2030	40	24	9	0	0	81	0	137	71	102	0	0	0	8	13	0	0	0	0	136	8	0	0	0	0	0	124	55	807
2035	44	26	10	0	0	89	0	150	78	112	0	0	0	9	14	0	0	0	0	149	9	0	0	0	0	0	136	61	887
2040	48	29	11	0	0	97	0	164	86	122	0	0	0	10	15	0	0	0	0	163	10	0	0	0	0	0	149	66	968
2045	52	31	11	0	0	105	0	178	93	132	0	0	0	10	17	0	0	0	0	176	11	0	0	0	0	0	161	71	1048
2050	56	33	12	0	0	113	0	191	100	142	0	0	0	11	18	0	0	0	0	190	11	0	0	0	0	0	173	77	1128
Local balanced	A	B	BUL	CY	CZ	DK	EST	FIN	F	D	GR	H	HR	IRL	IT	LT	LIT	LUX	MT	NL	PL	P	ROM	SK	SLO	E	S	UK	EU28
2005	3	0	0	0	0	0	0	1	1	15	0	0	0	0	2	0	0	0	0	2	1	0	1	0	0	1	2	3	32
2010	5	0	0	0	0	0	0	2	2	25	0	0	0	0	4	0	0	0	0	4	1	0	2	0	0	2	3	6	55
2015	12	0	0	0	0	0	0	4	4	55	0	0	0	0	9	0	0	0	0	9	2	0	3	0	0	4	6	13	121
2020	19	0	0	0	0	0	0	7	7	88	0	0	0	0	14	0	0	0	0	14	3	0	6	0	0	7	10	21	196
2025	27	0	0	0	0	0	0	10	10	124	0	0	0	0	19	0	0	0	0	19	5	0	8	0	0	10	15	29	275
2030	34	0	0	0	0	0	0	12	12	160	0	0	0	0	25	0	0	0	0	25	6	0	10	0	0	12	19	37	354
2035	42	0	0	0	0	0	0	15	15	196	0	0	0	0	31	0	0	0	0	31	8	0	12	0	0	15	23	46	434
2040	50	0	0	0	0	0	0	18	18	231	0	0	0	0	36	0	0	0	0	36	9	0	15	0	0	18	27	54	513
2045	58	0	0	0	0	0	0	21	21	267	0	0	0	0	42	0	0	0	0	42	10	0	17	0	0	21	31	63	592
2050	65	0	0	0	0	0	0	24	24	303	0	0	0	0	47	0	0	0	0	47	12	0	19	0	0	24	35	71	672

Figure 23: Detailed results for the evolution of the sales of residential mechanical systems

Annex 7 – Survey among REHVA members

A survey was sent by REHVA to its member associations on 22nd January 2019, with a deadline for answering on 13th February.

The content of the survey is shown below.

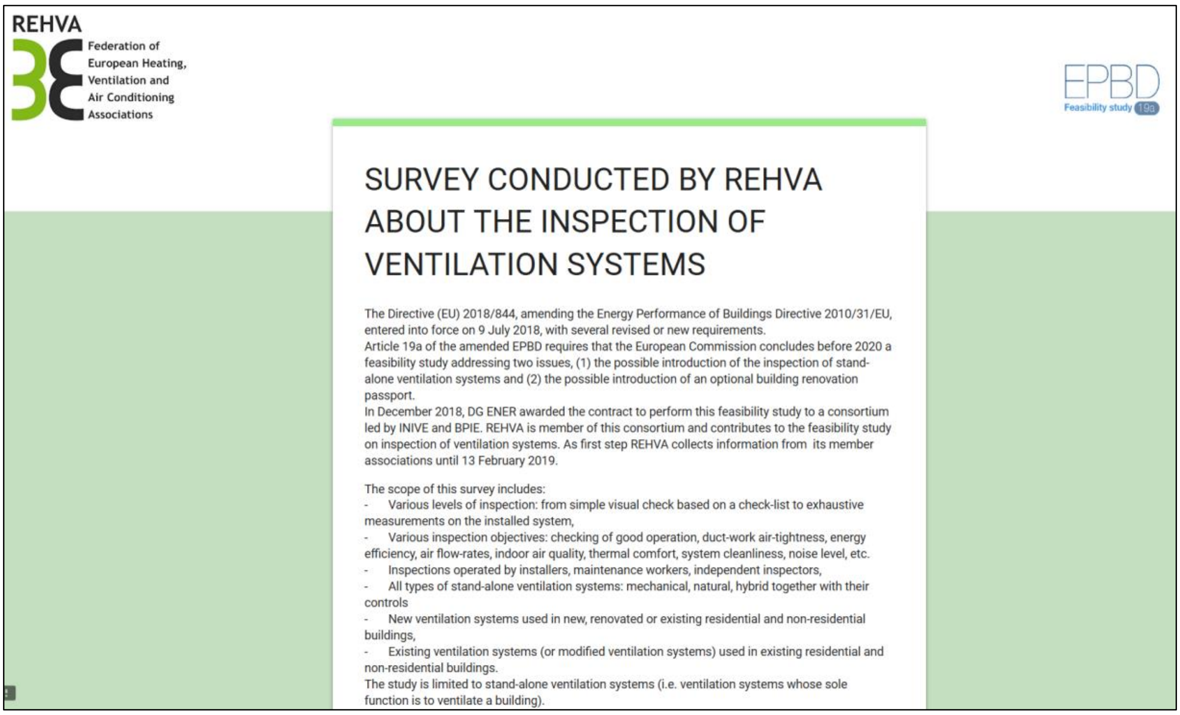
Answers were received from the following organisations:

- Czech Republic: STP (Society of Environmental Engineering)
- Estonia: EKVU (The Estonian Society of Heating and Ventilation Engineers)
- Finland: FINVAC (The Finnish Association of HVAC Societies)
- Germany: VDI-TGA (The Association of German Engineers - Society for Civil Engineering and Building Services)
- Italy: AICARR (Associazione Italiana Condizionamento dell`aria, Riscaldamento Refrigerazione)
- Hungary: MMK (Hungarian Chamber of Engineers)
- Latvia: AHGWTEL / LATVAC (Association of Heat, Gas and Water Technology Engineers of Latvia)
- Norway: NORVAC (Norwegian Society of HVAC Engineers)
- Romania: AIIR (Romanian Association for Installations Engineers)
- Slovakia: SSTP (Slovak Society for Environmental Technology)
- Slovenia: SITHOK (Slovenian Society for Heating, Refrigerating and Air-conditioning Engineers)
- Sweden: SWEDVAC (Swedish HVAC Society - Society of Energy and Environmental Technology)
- Switzerland: SWKI (Schweizerischer Verein von Gebäudetechnik Ingenieuren, Société suisse des ingénieurs en technique du bâtiment)
- Turkey: TTMD (Turkish Society of HVAC and Sanitary Engineers)

This survey focused on existing regulations, standards, guidelines and other initiatives on the inspection of stand-alone ventilation systems, but four questions (out of seventeen) were about the stock an market of ventilation systems.

Answers allow identifying that:

- Most of the respondents to the survey are not aware of information about stock and sales of ventilation systems
- There are very few information sources about the stock of ventilation systems; a reference was made to the results of the European project Healthvent (2012) that had already been identified as a potentially interesting information source; the German manufacturer organisation FGK was also mentioned and proved to be an effective source of information. Some other suggestions for information sources were collected but did not appear relevant after additional search;
- Information sources about the sales can be ventilation system manufacturers and their national associations, but the data are not always widely published or accessible.



SURVEY CONDUCTED BY REHVA ABOUT THE INSPECTION OF VENTILATION SYSTEMS

The Directive (EU) 2018/844, amending the Energy Performance of Buildings Directive 2010/31/EU, entered into force on 9 July 2018, with several revised or new requirements.
Article 19a of the amended EPBD requires that the European Commission concludes before 2020 a feasibility study addressing two issues, (1) the possible introduction of the inspection of stand-alone ventilation systems and (2) the possible introduction of an optional building renovation passport.
In December 2018, DG ENER awarded the contract to perform this feasibility study to a consortium led by INIVE and BPIE. REHVA is member of this consortium and contributes to the feasibility study on inspection of ventilation systems. As first step REHVA collects information from its member associations until 13 February 2019.

The scope of this survey includes:
- Various levels of inspection: from simple visual check based on a check-list to exhaustive measurements on the installed system,
- Various inspection objectives: checking of good operation, duct-work air-tightness, energy efficiency, air flow-rates, indoor air quality, thermal comfort, system cleanliness, noise level, etc.
- Inspections operated by installers, maintenance workers, independent inspectors,
- All types of stand-alone ventilation systems: mechanical, natural, hybrid together with their controls
- New ventilation systems used in new, renovated or existing residential and non-residential buildings,
- Existing ventilation systems (or modified ventilation systems) used in existing residential and non-residential buildings.
The study is limited to stand-alone ventilation systems (i.e. ventilation systems whose sole function is to ventilate a building).

Figure 24: Screen copy of the introduction to the survey

Survey contents

Part of the survey is reproduced below, limited to questions (14 to 17) about the stock and market of ventilation systems. Other questions about existing regulations, standards, guidelines and other initiatives (1 to 13) are not reproduced here.

SURVEY CONDUCTED BY REHVA ABOUT THE INSPECTION OF VENTILATION SYSTEMS

The Directive (EU) 2018/844, amending the Energy Performance of Buildings Directive 2010/31/EU, entered into force on 9 July 2018, with several revised or new requirements.

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- Various levels of inspection: from simple visual check based on a check-list to exhaustive measurements on the installed system,

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- Inspections operated by installers, maintenance workers, independent inspectors,

- All types of stand-alone ventilation systems: mechanical, natural, hybrid together with their controls

- New ventilation systems used in new, renovated or existing residential and non-residential buildings,

- Existing ventilation systems (or modified ventilation systems) used in existing residential and non-residential buildings.

The study is limited to stand-alone ventilation systems (i.e. ventilation systems whose sole function is to ventilate a building).

The results of this survey will be part of the data analysed by the consortium. They will be used to evaluate the impacts of the possible introduction of various types of inspection protocols, through legislative or non-legislative approaches.

You will find updates and more informed about the results of this work on the dedicated website http://epbd19a.eu and the stakeholders meetings in June and November. In addition REHVA Office will inform you about the outcomes of the survey and the completed study.

It is important for REHVA to contribute to this action, showing to the European Commission the strong support in the development of EPBD related EU policies.

PLEASE FILL IN THIS SURVEY BEFORE FEBRUARY 13th

STOCK OF VENTILATION SYSTEMS

14 – Are there existing figures about the stock of installed ventilation systems in residential buildings in your country?

YES NO

I AM NOT AWARE OF ANY

If YES, can you give the references of information sources (in national language):

15 – Are there existing figures about the stock of installed ventilation systems in non-residential buildings in your country?

YES NO

If YES, can you give the references of information sources (in national language):

ANNUAL MARKET OF VENTILATION SYSTEMS

16 – Are there existing figures about the annual sales or installation of ventilation systems (or parts of ventilation systems) for residential and non-residential buildings in your country?

YES NOT

I AM NOT AWARE OF ANY

If YES, please give us the references of information sources (in national language):

17. Are there foreseen evolutions of the context in your country (regulations, standards, various initiatives) that could change the market, or the market share between different ventilation systems?

YES NO

I AM NOT AWARE OF ANY

If YES, please give us information, or the reference of information sources (in national language):

THANK YOU VERY MUCH FOR YOUR COOPERATION! Your Organization name will be published in the EPBD 19a Feasibility study report

Your Organization name will be published in the EPBD 19a Feasibility study report

PART 3

ANALYSIS OF THE RELEVANCE, FEASIBILITY AND POSSIBLE SCOPE OF MEASURES FOR THE INSPECTION OF STAND-ALONE VENTILATION SYSTEMS

Technical coordinator	Peter Wouters, *INIVE*
Authors	François Durier, *INIVE-CETIAT* Peter Wouters, *INIVE-BBRI* Benny De Blaere, *BCCA* Maarten De Strycker, *BCCA* Gaëlle Guyot, *CEREMA* Adeline Mélois, *CEREMA* Pauline Selle-Marquis, *INIVE-CETIAT* Matteo Urbani, *REHVA*
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Partners of the service contract

Subcontractors to the service contract

This study is a service contract with the European Commission's Directorate General for Energy and has received funding under contract ENER/C3/2018-447/05.

Table of Contents

Executive Summary

Article 19a of revised Energy Performance of Buildings Directive[1], includes the requirement for the Commission to perform, before 2020, a feasibility study to clarify the possibilities and timeline for introducing two aspects in order to improve buildings' energy performance:

- The inspection of stand-alone ventilation systems and
- An optional building renovation passport.

This technical study is contracted to a consortium formed by INIVE and BPIE who, together with a broad range of experts in the required fields, will provide technical support to the Directorate-General for Energy of the European Commission for investigating the different elements covered by the feasibility study. This technical study is coordinated by INIVE EEIG and runs from 18 December 2018 until 17 December 2019.

The first part of this technical study will 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:

- An analysis of the stock of ventilation systems in EU buildings, including their technical characteristics, the distribution systems and foreseen evolution of the stock;
- 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;
- 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.

This report relates to the third objective.

It describes a broad range of options for possible approaches at EU level for the inspection of stand-alone ventilation systems in buildings, including non-legislative and legislative options, and combination of both. These options can be built by assembling modules, in order to cover the various aspects of inspection.

Modules are chosen from a total of more than 170 items. Each of these modules is described, with information about its feasibility (in particular from an economic and technical perspective) and its advantages and drawbacks.

The report also identifies other measures that can support better performance of stand-alone ventilation systems, and the options that could be chosen to introduce requirements on the inspection of stand-alone ventilation systems under the EPBD.

It finally highlights which policy options could be considered in a next part of the technical study for assessing their potential impacts.

[1] Directive 2010/31/EU as amended by Directive 2018/844

1. Introduction

1.1. Context

The publication on 19 June 2018 of the amended EPBD, Directive 2018/844 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency, represents the first major step towards the implementation of the Commission's Clean Energy for all Europeans package.

Article 19a includes the requirement for the Commission to perform, before 2020, a feasibility study to clarify the possibilities and timeline for introducing two aspects in order to improve buildings' energy performance:

- The inspection of stand-alone ventilation systems and
- An optional building renovation passport

This technical study is contracted to a consortium formed by INIVE and BPIE who, together with a broad range of experts in the required fields, will provide technical support to the Directorate-General for Energy of the European Commission for investigating the different elements covered by the feasibility study mandated under Article 19a of the amended EPBD. This technical study is coordinated by INIVE EEIG and runs from 19 December 2018 until 18 December 2019.

The first part of this technical study should assess the relevance and feasibility to introduce EU provisions (legislative and non-legislative) 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.

In this study, stand-alone ventilation systems are defined as ventilation systems whose sole function is to ventilate a building.

1.2. Overall objectives

The objectives regarding inspection of stand-alone ventilation systems are to deliver

- An analysis of the stock of ventilation systems in EU buildings, including their technical characteristics, the distribution systems and foreseen evolution of the stock;
- 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;
- 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.

Previously published reports relate to the two first objectives.

The current report relates to the third objective, by providing a description of a broad range of options for possible approaches at EU level for the inspection of stand-alone ventilation systems in buildings, including non-legislative and legislative options, and combination of both.

The aim is to list and describe modules that can be used to set-up inspection and to provide information about their feasibility, advantages and drawbacks. The aim is also to describe options different from inspections that can also support better performance of stand-alone ventilation systems and to detail the options that could concern the introduction of requirements on the inspection of stand-alone ventilation systems under the EPBD. Finally, the aim is to identify which policy options could be considered in the next part of the technical study, which will consist in assessing the potential impacts of some of the potential options.

The report has been prepared by INIVE-CETIAT with inputs from INIVE-BBRI, BCCA, CEREMA and REHVA.

1.3. Scope

This study covers:

- Stand-alone ventilation systems, i.e. systems whose sole function is to ventilate a building; the inspection of combined heating and ventilation systems, and of combined air-conditioning and ventilation systems is covered by articles 14 and 15 of Directive 2018/844/EU
- Ventilation systems in residential and non-residential buildings, except industrial buildings
- Newly-installed ventilation systems in new, renovated or existing buildings, and ventilation systems already installed and in operation in existing buildings
- All types of stand-alone ventilation systems: mechanical, natural, hybrid together with their controls. Airing (i.e. natural ventilation by window opening) is out of our scope since it does not rely on components dedicated to ventilation (air inlets, air outlets, etc.)
- Initial or regular inspection(s) with various levels of inspection: from simple visual check based on a check-list to exhaustive measurements on the installed system
- Various inspection objectives: checking of good operation, ductwork airtightness, energy efficiency, air flow-rates, indoor air quality, thermal comfort, system cleanliness, noise level, etc.
- Inspections operated by installers, maintenance workers, independent inspectors or others
- Other measures than inspection that can support better performance of ventilation systems and be considered as alternatives to inspection or combined with it.

1.4. Methodology

The methodology relied on:

- the identification of possible measures through analysis and brainstorming meetings between participants in the study, taking into account the results of the review of existing regulations, standards, guidelines and other initiatives operated in a previous part of the study and the stakeholders' views from the first stakeholders meeting (June 2019);
- the detailed description of the identified measures; it was chosen to describe them as assemblies of modules taken from a list of more than 170 items;
- the analysis of the advantages and drawbacks, including an analysis of the legal issues and compliance framework.

2. Defining possible approaches for inspection

2.1. General

Defining a possible approach for the inspection of stand-alone ventilation systems requires building the technical contents of the inspection: What must be checked and how? Does inspection require measurements? How are inspection results reported?

Organisational aspects must also be defined: Is inspection mandatory or voluntary? When does it take place? By who is it operated? Is training, certification, qualification or surveillance of inspectors required? What are the sanctions if the rules are not followed?

Then, legal and economic aspects should be examined, as well as the stakeholders to be involved.

Finally, additional aspects should be studied: market and societal acceptance, resulting barriers and risks.

2.2. How to define inspection?

The four types of aspects mentioned in the previous section can be translated into a series of detailed questions, listed in Tables 1 to 4.

Tables 1 and 2 deal with technical and organisational aspects. These should be defined first.

Tables 3 and 4 (legal and economic aspects, list of stakeholders, and other aspects) depend on the technical and organisational aspects, and should be examined at a second stage.

The overall list of questions emphasises the fact that defining an inspection protocol alone is not sufficient. Measures allowing to check/ensure the compliance of inspections with the foreseen technical and organisational aspects should also be decided.

Those measures were defined by the European project QUALICHeCK (2014-2016 - http://qualicheck-platform.eu/) as a "compliance framework", i.e. a "structured set of processes for maintaining accordance with established regulations, specifications or legislation[2]". The development of an effective compliance framework should be based on 6 key questions[3]:

1. What is the scope of the framework?
2. At which level and on which basis should it be prescribed?
3. On which type of requirement should it be based, and which type of control should it foresee?
4. What are the procedures to comply with?
5. What are the procedures for identifying and handling non-compliance?
6. How will it be implemented in practice?

These recommendations were used as a background to build the list of questions in Tables 1 to 4.

[2] F. R. Carrié, *Compliance and quality of works for improved energy performance of buildings - Final publishable report*, QUALICHeCK, February 2017, www.qualicheck-platform.eu

[3] F. R. Carrié, *Improving the compliance of Energy Performance Certificates and the quality of building works - Booklet*, QUALICHeCK, April 2016, www.qualicheck-platform.eu

TECHNICAL ASPECTS	
Aim of inspection	Which performance to be inspected?
	How to decide on the performance to be inspected?
Targets of inspection	Who should benefit from inspection?
	What types of buildings should be covered?
	What types of ventilation systems should be inspected?
	Which climatic zones should be concerned?
	In which period of the year can inspection take place?
Rules for inspection	What are the technical aspects covered by inspection?
	Which parts of the ventilation system need to be inspected?
	Is it sufficient to inspect only a sample of the ventilation systems?
In-situ measurements	What are the measured quantities?
	What are the measuring instruments?
	What is the measuring uncertainty?
	What is the calibration frequency of measuring instruments?
	What is the calibration procedure?
Reporting about inspection	What is the content of the inspection report?
	Who receives the report?
	Who keeps the report?
	What are the compliance criteria?
	What is the acceptable deviation for deciding on compliance?

Table 1 - Questions to define the technical aspects of an inspection

ORGANISATIONAL ASPECTS	
Periodicity of inspection	Does inspection occur once or is it regular?
	When does inspection occur?
Inspectors	By whom is inspection operated?
	Is there a need for quality assurance?
	Is there a need for training of inspectors?
	Is there a need for qualification of inspectors?
	Is there a need for certification of inspectors?
	Is there a need for surveillance of inspectors?
Non-compliance	What happens if inspection results show compliance or non-compliance of the ventilation system?
	What are the sanctions if inspection is not performed according to the rules?
Status	Is the inspection voluntary or mandatory?

Table 2 - Questions to define the organisational aspects of an inspection

LEGAL AND ECONOMIC ASPECTS, STAKEHOLDERS INVOLVED	
Conformity to legislation	Is the inspection framework in conformity with the legislations?
Economy	What is the cost of the inspection?
	Who is going to pay?
	What are the benefits?
Stakeholders	Who are the stakeholders involved in the implementation of the inspection framework?
	Who are the stakeholders involved in the operation of the framework?
	What is the role of public authorities?
	How is surveillance organised?

Table 3 - Questions to identify the legal and economic aspects of an inspection and the stakeholders involved

OTHER ASPECTS	
Other aspects	Does the inspection framework create a market differentiation?
	Will the inspection framework receive societal support?
	Does the inspection framework create barriers to innovation?
	Does the inspection framework generate any risk?

Table 4 - Questions covering other aspects of an inspection than those in Tables 1, 2 and 3

When all these questions have been answered, the consistency of the whole set of answers must be cross-checked. For example, looking at the measuring uncertainty is not relevant if it has been chosen not to include measurements in the technical aspects covered by inspection.

2.3. What could be measures other than inspection?

Measures other than inspection can also support better performance of stand-alone ventilation systems. They are listed in Table 5 and are also documented in this report.

They could be considered as alternatives to inspection, or be combined with inspection, allowing it to be lighter or more cost-efficient.

OTHER MEASURES	
Awareness	Increasing awareness on ventilation among users and owners
	Increasing awareness on ventilation among professionals
	Increasing awareness on ventilation among policy makers
Products	Easier access to ventilation product data
	Certification of ventilation product performances
Education	Education of professionals on ventilation
Training	Training of professionals on ventilation
Quality assurance	Quality assurance scheme for design, installation, commissioning and maintenance of ventilation systems
Qualification	Qualification of professionals concerned by ventilation
Certification	Certification of the competence of professionals about ventilation
Requirements for indoor environment	Regulations with requirements on the indoor environment (IAQ, noise, etc.), including measurements
Smart systems	Stimulating the use of smart ventilation systems

Table 5 - Measures other than inspection that can support better performance of ventilation systems

3. Description of the various options for inspection

3.1. Technical and organisational aspects

For each of the questions that have to be answered in order to build an inspection framework (see Tables 1 and 2 – technical and organisational aspects), several possible answers have been identified.

Each possible answer to a given question constitutes a module that can be assembled with other modules in order to set-up an inspection framework that covers the various aspects.

The modules related to the technical aspects of inspection are shown in Table 6.

Table 7 shows the modules related to the organisational aspects of inspection.

In Annex 1, a detailed description of each of these modules (= possible answers to the questions of Tables 1 and 2) is given, together with their advantages and drawbacks and comments about their feasibility.

Assembling these modules allows a broad range of options for possible inspection of stand-alone ventilation systems, including non-legislative and legislative options, and a combination of both.

TECHNICAL ASPECTS													
ASPECT	QUESTION	MODULES											
		a	b	C	d	e	f	g	h	i	*j*	*k*	*l*
AIM *AIM*	1- Which performance to be inspected?	Energy performance	Air flow rates, air change	Indoor air quality	Hygiene of the ventilation system	Noise	Thermal comfort (draughts, temperature gradient)	Overall well-being of occupants	Overall well-being of neighbour-hood	Protection of building against humidity			
	2- How to decide on the performance to be inspected?	Mandatory list of performance to inspect	List of inspected performance to be decided										
TARGETS *TAR*	1- Who should benefit from inspection?	Occupants	Workers	Children	Elderly people	Persons with low revenues	Owners	Employers	Ventilation system manufac-turers				
	2- What types of buildings should be covered?	All residential	Single-family house	Multi-apartment buildings	All non-residential	Offices	Retail buildings	Educational buildings	Health care facilities	Hotels and restaurants	Sport facilities		
	3- What types of ventilation systems should be inspected?	Natural	Hybrid	Mechanical decentralised unidirectional	Mechanical decentralised balanced without heat recovery	Mechanical decentralised balanced with heat recovery	Mechanical centralised unidirectional	Mechanical centralised balanced without heat recovery	Mechanical centralised balanced with heat recovery	Demand-controlled ventilation system			
	4- Which climatic zones should be concerned?	All climatic zones	Colder	Warmer									
	5- In which period of the year can inspection take place?	All year	Warm season	Cold season	Mid-season								
RULES *RUL*	1- What are the technical aspects covered by inspection?	Pre-check	Complete-ness	Adequacy between design and installation	Cleanliness and hygiene	General state	Good overall operation	Good operation of controls	Occupants satisfaction	Energy con-sumption	Measure-ments	Adequacy with current ventilation needs	Quality of maintenance
	2- Which parts of the ventilation system need to be inspected?	Whole system	Ductwork	Ventilation unit	Air inlets	Air outlets	Air transfers	Filters	Sensors	Controls			
	3- Is it sufficient to inspect only a sample of ventilation systems?	Inspection of each system	Inspection of a sample of the systems	Inspection of a sample of the buildings									

Table 6 – Modules for the technical aspects of inspection (1/3) – See Annex 1 for a detailed description of each module

TECHNICAL ASPECTS													
ASPECT	QUESTION	MODULES											
		a	b	c	d	e	f	g	h	i	*j*	*k*	*l*
IN SITU MEASUREMENT *MEA*	1-What are the measured quantities?	Air flow rates at fan level	Air flow rates at room level	Air pressures at fan level	Air pressures at room level	Ductwork airtightness	Electrical power input	Performance of heat recovery	Indoor air quality parameters	Noise level in rooms	Noise level outdoors	Thermal comfort parameters	Air cross-sections areas
	2- What are the measuring instruments?	Air flow meter	Anemometer	Manometer	Wattmeter	Thermometer	Pollutant concentration analyser	Noise analyser	Hygrometer	Dimensional measurement tools	Pressurisation measurement device		
	3- What is the measuring uncertainty?	No uncertainty specified	Fixed uncertainty	Uncertainty of the measurement method	Uncertainty of the measuring instrument								
	4- What is the calibration frequency of measuring instruments?	None	Once	Regular									
	5- What is the calibration procedure?	By the manufacturer of the measuring instrument	By an independent laboratory	By an independent accredited laboratory	By an ISO 9001 certified organisation	By the inspector	Calibration range						

Table 6 – Modules for the technical aspects of inspection (2/3) – See Annex 1 for a detailed description of each module

TECHNICAL ASPECTS												
ASPECT	QUESTION	MODULES										
		a	b	c	d	e	f	g	h	i	j	k
REPORTING ABOUT INSPECTION *REP*	1- What is the content of the inspection report?	Certificate	Certificate with parameters checked	Certificate with results	Certificate with target values and results	Certificate with target values, results and advice	Certificate stating compliance					
	2- Who receives the report?	Owner	Occupant	Public authority	Architect	Installer	Person in charge of the calculation of the building's energy performance	Employees	Employer			
	3- Who keeps the report?	Owner	Installer	Occupant	System designer	Independent inspector	Public authority	Certification organisation	Architect	Person in charge of the energy performance of building calculation	Digital monitoring system of the building	Building Infor-mation Model (BIM)
	4- What are the compliance criteria?	Comparison with usual practice	Comparison with values fixed by regulation, standard, guidelines	Comparison with design values	Comparison with builder's require-ments	Comparison with current ventilation needs	None					
	5- What is the acceptable deviation for deciding on compliance?	None	Lower performance accepted within a certain tolerance	Higher performance required to make sure that the actual value will fulfil the requirement (safety margin)								

Table 6 – Modules for the technical aspects of inspection (3/3) – See Annex 1 for a detailed description of each module

ORGANISATIONAL ASPECTS										
ASPECT	QUESTION	MODULES								
		a	b	c	d	e	f	g	h	i
PERIODICITY OF INSPECTION *PER*	1- Does inspection occur once or is it regular?	Once	Regular							
	2- When does inspection occur?	At regular time intervals	With renewal of the Energy Performance Certificate	When building is rented or sold out	After installation of a new system	When parts of the system are changed or repaired	When the owner or occupant requests it	When controls indicate that inspection is necessary	At building's commissioning	After building's major renovation
INSPECTORS *INS*	1- By whom is inspection operated?	System designer	Independent inspector / Third party service provider	Installer	Maintenance staff	Owner	Occupant	Architect	Building airtightness tester	Person in charge of the energy performance of building calculation
	2- Is there a need for quality assurance?	Quality assurance	No quality assurance							
	3- Is there a need for training of inspectors?	Theoretical training	Practical training	No training						
	4- Is there a need for qualification of inspectors?	Qualification	No qualification							
	5- Is there a need for certification of inspectors?	Certification	No certification							
	6- Is there a need for surveillance of inspectors?	None	Information to be provided by inspectors	Audit of inspectors						
NON-COMPLIANCE *NC*	1- What happens if inspection results show compliance or non-compliance of the ventilation system?	Obligation to make the system compliant	Sanctions	Rewarding	Nothing specific					
	2- What are the sanctions if inspection is not performed according to the rules?	No sanction	Sanctions							
STATUS *STA*	1- Is the inspection voluntary or mandatory?	Mandatory	Voluntary							

Table 7 – Modules for the organisational aspects of inspection – See Annex 1 for a detailed description of each module

3.2. Legal aspects

Both the technical and the organisational aspects of a ventilation inspection framework can be concerned by different legislations.

An inspection framework must of course be in conformity with the EU legislation (primary EU legislation (EU treaties), secondary EU legislation), and national, regional and local legislations.

This conformity must be checked once the technical and organisational aspects are defined – or during their definition (see previous sections).

Main legal issues are:

- The ventilation products must comply with the regulations, as for example the eco-design requirements for ventilation units that are put on the market (Regulations 1433/4014 and 1434/4014); although these regulations are not making reference to inspection, some of their aspects may have an influence on the inspection of stand-alone ventilation systems, in which the checked parameters could be those referred to by the eco-design requirements.
- An inspection framework must not create obstacles to the free movement of goods, and no obstacle for EU service providers to establish themselves freely or provide services in any EU Member State.
- It must not lead to anti-competitive agreement or effect, and must rely on mutual recognition of qualifications of persons in the EU Member States.
- Personal data, if any, must be managed according to the General Data Protection Regulation.
- National public procurement and/or concession laws must be followed for the selection of a private party that would be asked to supply services linked to inspection to the public authorities.

These aspects are described in Table 8, together with the references of the modules used to build an inspection scheme for which the corresponding legal issue can be relevant.

In addition, Annex 2 provides details about the legislation that can intervene in the development of inspection frameworks for stand-alone ventilation systems. There are many different ways to implement an inspection framework. An example is given in Annex 2 showing how the organisation of the inspection framework can be delegated to a private party and which legal considerations should be taken into account. Annex 2 concludes with some specific aspects of an inspection framework (the role of accreditation, the role of laboratory results, access to buildings and coupling with other building certificates) and an FAQ reformulating the content of the annex.

Reference	Legal issue	Description	Modules for which this legal issue can be relevant	Comments
CON-1	No obstacle to the free movement of goods	According to the principle of free movement of goods, EU Member States are forbidden to take public measures that constitute an obstacle to this free movement. This results from Article 34 of the Treaty on the Functioning of the European Union.	TAR-3 RUL-2 MEA-2 MEA-5	Applicable whenever requirements are set about ventilation products and measuring instruments.
CON-2	Not impeding the free provision of services and the right of establishment	According to the principle of free provision of services and the right of establishment, EU Member States are forbidden to take public measures that constitute an obstacle to this free movement. This results from Articles 26, 49-55 and 56-62 of the Treaty on the Functioning of the European Union.	RUL-1j MEA-5 INS-1 INS-2a; INS-3a; INS-3b; INS-4a; INS-5a; INS-6c NC-1b; NC-1C; NC-1d; NC-2b STA-1a	Applicable whenever requirements are set about a person or company active in parts of the inspection scheme: calibration of measuring instruments, training, qualification, certification
CON-3	No anti-competitive agreement or effect	When organising and applying an inspection framework, private companies must always comply with the prohibition of anti-competitive agreements. This results from Article 101 of the Treaty on the Functioning of the European Union.	INS-1; INS-2a; INS-3a; INS-3b; INS-4a; INS-5a; INS-6c STA-1a	Applicable whenever private parties are active in the inspection scheme.
CON-4	Mutual recognition of qualifications of persons from the EU Member States	Qualifications of persons must be mutually recognised between the EU Member States. This results from Directive 2005/36/EC on the recognition of professional qualifications.	RUL-1j INS-1; INS-2a; INS-3a; INS-3b; INS-4a; INS-5a; INS-6c STA-1a	Applicable whenever a qualification requirement is set about a person active in the inspection scheme.
CON-5	Personal data must be managed according to the General Data Protection Regulation	An inspection scheme can require the creation of databases containing information, which might be personal data. The storage and processing of these data, information about these databases, data retention period, accessibility of data, precautions to protect these data, etc. must be in accordance with applicable laws and regulations, and especially the Regulation (EU) 2016/679 (General Data Protection Regulation).	TAR-2a; TAR-2b; TAR-2c REP-1 REP-2 REP-3 INS-6b; INS-6c	
CON-6	National public procurement and/or concession laws for the selection of a private party that is asked to supply services to the public authorities	When a private party is asked to supply services to the authorities, the public procurement and/or concession legislation apply to the selection of that party, with various conditions applying to the selection of the successful candidate. General principles such as equal treatment, competition, conflicts of interest and prior involvement apply.	INS-1; INS-2a; INS-3a; INS-3b; INS-4a; INS-5a; INS-6c STA-1a	

Table 8 – Legal aspects to which an inspection framework must conform

3.3. Economic aspects and stakeholders involved

Once the technical and organisational aspects of an inspection framework are defined – or during their definition (see previous sections) – the questions mentioned below (and also in Table 3) must be answered in order to draw the full picture of the inspection framework.

What is the cost of the inspection?

The cost reflects the direct and indirect costs of the inspection. Direct costs include inspector's labour and transportation, the use of measuring instruments, consumable materials, etc. Indirect costs can include training or certification of inspectors, calibration of measuring instruments, management of inspections, contribution to the costs of development and operation of the inspection framework, insurance, taxes, etc.

The cost of the inspection should be estimated for different cases, allowing adaptation of the technical and organisational aspects to the acceptable value while keeping a low cost/performance ratio.

Who is going to pay? What are the benefits?

It is necessary to identify who is going to pay for the inspection. Is it the owner or the user? Is the cost of the initial inspection of a new system paid together with the installation costs? Is the cost of a regular inspection paid together with the maintenance costs? Are there subsidies or incentives available?

Deciding on who is going to pay can rely on the identification of the expected benefits of the inspection: Will the energy bill decrease? Will the indoor environment be improved? Will only the user or owner benefit from the inspection, or are there societal benefits that justify public funding? Ideally, the benefits should be monetised, which is not always evident, leading to the use of a mix of qualitative and quantitative factors.

Who are the stakeholders involved in the implementation/in the operation of the inspection framework? What is the role of public authorities?

Identifying and mapping the stakeholders involved in the implementation and in the operation of the inspection framework is essential. It allows to check that all aspects can be managed and to clearly describe who will be responsible for the various tasks. It is also important during the preparation phase of the inspection framework in order to create societal support.

This allows in particular assessing the weight of the role of public authorities. It can range from zero or insignificant for inspection frameworks implemented and operated from a private initiative, to very important if the inspection framework is completely implemented and managed by a public authority.

How is surveillance organised?

It is important to define how the surveillance of the good operation of the inspection framework will be organised.

The surveillance of inspectors is already covered by two questions in Tables 2 and 7 (INS-6, NC-2). It must be decided how to operate the surveillance that the overall system is performing well and that the stakeholders in charge of the operation of the framework operate an efficient and fair work.

3.4. Other aspects

Does the inspection framework create a market differentiation?

In case of a voluntary inspection framework, it is interesting to identify whether inspection provides competitive advantages, for example by facilitating sales or rentals, or providing a clear advantage in terms of energy savings or improved indoor air quality. Differentiation makes inspection more desirable to the target market and creates motivations for prescribing/asking for inspection, contributing to its wide implementation.

In the ramp-up phase of a new mandatory inspection framework, it is also interesting to check if such differentiation exists between systems already inspected and those that are not yet inspected. This can facilitate the acceptability and societal support to the framework.

Will the inspection framework receive societal support?

As for each policy implementation, it is good to think about the societal support that the inspection framework could get in a specific market and context. Negative or passive support makes the implementation of the inspection framework more difficult and increases the implementation costs. Positive support makes that inspection will be perceived as useful and leading to benefits, increasing its acceptability and reducing the implementation and surveillance costs. In case of a strong opposition from key stakeholders, it might not be evident to reach the expected impact.

Does the inspection framework create barriers to innovation?

Caution must be taken so that the inspection framework does not create barriers to innovation. For example, a framework which is making inspection for innovative ventilation systems more complicated/more expensive could restrict the relevant market and prevent from benefiting from innovation.

Does the inspection framework generate any risk?

One aspect that needs particular attention is to ensure that the defined inspection framework does not create any collateral risks as, e.g., damages to the inspected system, safety or health issues, etc.

4. Description of measures other than inspection

As previously mentioned (see Table 5), measures other than inspection can also support better performance of stand-alone ventilation systems. They are described in Table 9 together with their advantages and drawbacks.

Reference	Measure	Description	Advantages / Drawbacks
ALT-1a	Increasing awareness on ventilation among users and owners	Users and owners can play an important role in the quality of operation of stand-alone ventilation-system, by performing themselves some maintenance operations (for example cleaning of air exhausts terminals); by being able to identify operation defects, if their understanding of the role and architecture of the ventilation system is sufficient; by avoiding inappropriate interventions on the system. Increasing users/owners awareness can rely on information from the manufacturer, the installer, the maintenance company, etc. and contribute to maintain the performance of ventilation systems.	*Advantages:* Interested occupants can have very positive actions to maintain the performance of systems, with an effort to inform them that is low. *Drawbacks:* The equilibrium has to be found between too much information/request to the user or owner and too limited information that would make the measure inefficient. Moreover, it might require technical competence which is not available by most users.
ALT-1b	Increasing awareness on ventilation among professionals	Communication towards professionals through different means can contribute to improve their knowledge/know how, and thus improve the quality and performance of ventilation systems. It can consist in promoting best practice, installation and maintenance guidelines, self-check procedures, etc.	*Advantages:* Lighter than education or training. *Drawbacks:* Should probably be combined with other measures to be fully efficient.
ALT-1-c	Increasing awareness on ventilation among policy makers	It is important that policy makers are informed about the important role of building ventilation and the current status of the operation/defects of installed ventilation systems. If this information is not available, campaigns should be organised to collect feedback from the ground, by auditing ventilation systems and looking at the way they operate.	*Advantages:* Policy makers require true and fair information about the current situation, in order to define which measures could be taken and what is the starting point. *Drawbacks:* Requires some means to collect a sufficient amount of information and draw some conclusions.
ALT-2a	Easier access to ventilation product data	The designer of a ventilation system must choose the appropriate components. This relies on the available product data that describe the characteristics of the components of the ventilation system (for example air flow rates, pressures, noise attenuation, etc.). The installer and the maintenance staff must also easily identify the characteristics of the installed products in order to check that they are consistent with the design values. An easier access to ventilation product data thus facilitates the works of the designer, installer and maintenance personnel. This easy access can rely on: clear documentation from product manufacturers, product characteristics database (possibly embedded into design software and BIM). The European product database for energy labelling will also be a useful information source for residential ventilation units. Legal issue: the measure must be compliant with the absence of obstacles to the free movement of goods (CON-1).	*Advantages:* Easier access to product data contributes to increase the quality of installed ventilation systems, thus reducing the needs for inspection. *Drawbacks:* Easier access to product data is in itself not enough to secure the quality of installed ventilation systems. It should probably be combined with other measures.
ALT-2b	Certification of ventilation product performances	Certification of the performances of ventilation products provides the assurance that the published performance is the right one according to the assessment /measurement method mentioned in the certification rules (usually a testing standard). Legal issue: the measure must be compliant with the absence of obstacles to the free movement of goods (CON-1).	*Advantages:* Certification provides confidence about the announced performance. The products are correctly chosen and this contributes to increase the quality of installed ventilation systems. *Drawbacks:* Cost.

Table 9 – Description of measures other than inspection (1/3)

ALT-3	Education of professionals on ventilation	Education of future professionals, covering topics such as the need for ventilation and indoor air quality, the description of different ventilation systems, the way to design them, the way to ensure good installation and maintenance, contributes to improve the quality and performance of ventilation systems that will be installed by these persons in their design, installation and maintenance works. Legal issue: the measure must be compliant with the free provision of services and the right of establishment (CON-2) and the mutual recognition of qualifications of persons (CON-4).	*Advantages:* Allows benefiting of existing structure of education of professionals. *Drawbacks:* Requires developing education programmes and facilities for practical training. Education is only an initial step and should be completed by other actions, such as training or qualification once the professional has gained some experience.
ALT-4	Training of professionals on ventilation	Training of professionals can allow them to get or improve their knowledge/know-how about the role, design, installation and maintenance of ventilation systems. It helps them to improve their usual practice, correcting possible defects and thus contributes to improve the quality and performance of ventilation systems. Legal issue: the measure must be compliant with the free provision of services and the right of establishment (CON-2) and the mutual recognition of qualifications of persons (CON-4).	*Advantages:* Allows increasing skills of professionals who will directly use the gained knowledge/know-how. *Drawbacks:* Impact limited to the trained persons, whose number remains probably low if it relies on a voluntary basis. *Drawbacks:* Communication alone can have a low impact. Requires the relevant messages, format and media.
ALT-5	Quality assurance for design, installation, commissioning and maintenance of ventilation systems	Quality assurance is a set of measures and activities to prevent defects in the design, installation, commissioning and maintenance of stand-alone ventilation systems. It can include for example internal procedures, monitoring of the works, self-checks or checks by a third-person, measurements and the feedback loop to improve these tools.	Advantages: Involvement of the concerned persons. Drawbacks: Quality assurance is nowadays not frequent in the construction sector.
ALT-6	Qualification of professionals concerned by ventilation	Qualification can be defined as "the recognition by a third party that a person or a company has the ability, quality, or attributes to perform a particular job or task, after successful completion of a course or training or passing of an exam or audit" (source: QUALICHeCK project). Qualification of professionals concerned by ventilation (designers, installers, and maintenance staff) can recognise not only their competence but also the ownership and correct use of the tools they are using (software for design, tools for installation and maintenance, measuring instruments for commissioning and maintenance, etc. Legal issue: the measure must be compliant with the free provision of services and the right of establishment (CON-2) and the mutual recognition of qualifications of persons (CON-4).	*Advantages:* Gives confidence to the clients. Probably contributes to increase or maintain the quality and performance of ventilation systems. *Drawbacks:* Cost.
ALT-7	Certification of the competence of professionals about ventilation	Certification can be defined as "the procedure by which a third party gives written assurance that a product, a process, a system, a person conforms to specified requirements mentioned in the rules of the relevant certification scheme" (source: QUALICHeCK project). Certification of professionals concerned by ventilation (designers, installers, and maintenance staff) or certification of the quality assurance system under which they operate allows getting assurance that ventilation systems will be designed, installed or maintained according to the defined rules.	*Advantages:* Gives confidence to the clients. Probably contributes to increase or maintain the quality and performance of ventilation systems. *Drawbacks:* Cost.

Table 9 – Description of measures other than inspection (2/3)

ALT-8	Regulations with requirements on the indoor environment (IAQ, noise, etc.), including measurements	Regulations that include requirements on the indoor environment (IAQ, noise, etc.), and the obligation to verify that these requirements are fulfilled by measuring indoor environment parameters, can contribute to detect that the ventilation system operates with a level of performance that is not as expected. The existence of such regulations makes probably designers, installers, maintenance staff, owners, employers, occupants aware about the need for a good ventilation system, and thus contributes to indirectly improve the quality and performance of ventilation systems.	*Advantages:* The verification of indoor environment parameters is a simple indirect way to identify that the performance of ventilation systems is not as expected.
			Drawbacks: Indoor environment parameters are not only influenced by the ventilation system. Non-compliant values can also result from the building envelope, building materials, indoor activities, occupant behaviour, outdoor pollution, etc. On the other hand, compliant indoor air quality can also for example result from an overventilation. It is therefore not absolutely sure that the defects of the ventilation system can all be identified.
ALT-9	Stimulating the use of smart ventilation systems	In its definition of smart ventilation, AIVC mentions that "smart ventilation systems can provide information to building owners, occupants, and managers on operational energy consumption and indoor air quality as well as signal when systems need maintenance or repair" and that they "can have sensors to detect air flow, systems pressures or fan energy use in such a way that systems failures can be detected and repaired, as well as when system components need maintenance, such as filter replacement". Stimulating the development and use of smart ventilation systems is thus a way to improve the performance and quality of installed ventilation systems.	*Advantages:* Makes the system able to inform and alert about their performance.
			Drawbacks: Increased complexity and cost of systems

Table 9 – Description of measures other than inspection (3/3)

5. Introduction of requirements on stand-alone ventilation systems under the EPBD

There are different possibilities to introduce requirements on the inspection of stand-alone ventilation systems. These possibilities are summarised in Figure 1 and described below:

- no requirement (❶);
- requirements for Member States to implement frameworks for the voluntary inspection of stand-alone ventilation systems (❷);
- requirements for Member States to implement regular inspections of stand-alone ventilation systems (❸);
- requirements for Member States (❹) to implement measures other than ❷ or ❸, for example awareness raising on ventilation, certification of installers, training of maintenance teams, etc. (see Table 9), with the objective to support better performance of stand-alone ventilation systems.

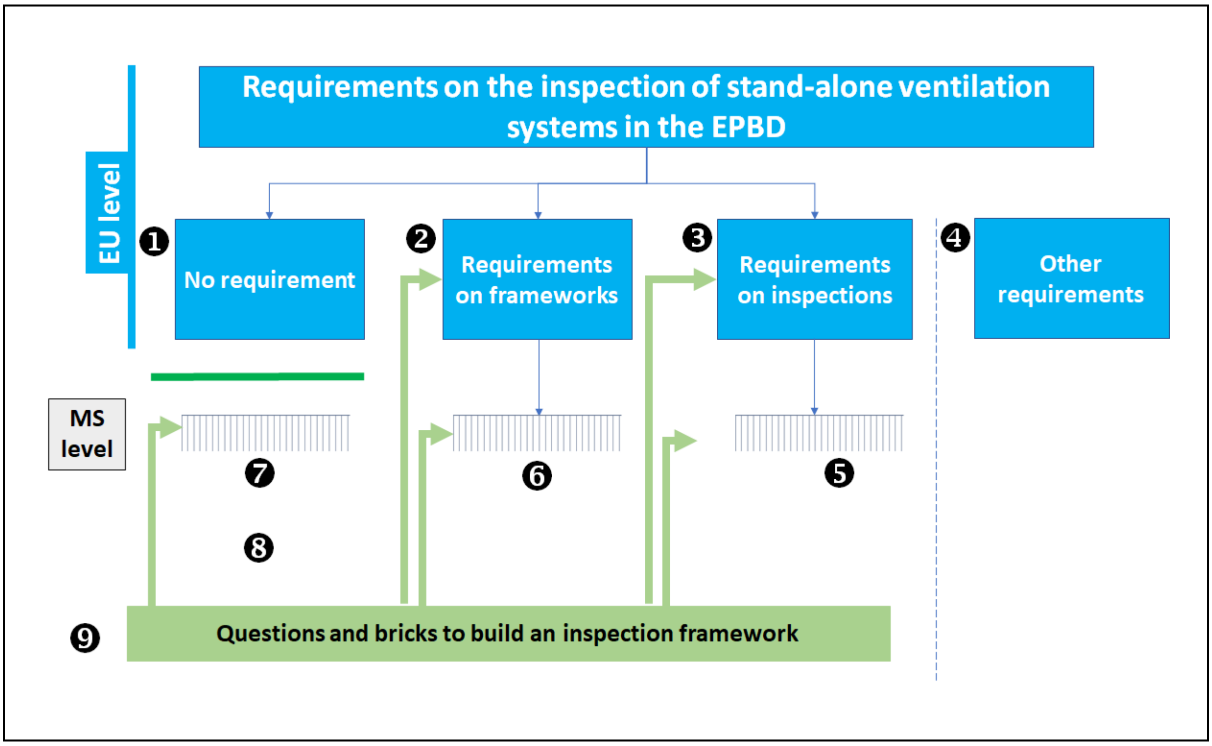

Figure 1– Possibilities to introduce requirements on the inspection of stand-alone ventilation systems

In the cases ❷ and ❸, it is possible that the directive just includes a requirement without any technical or organisational specification, leaving Members States the freedom to decide about all the aspects of the transposition at national level. It is also possible that the directive imposes some criteria. In such case, the present report with its approach of questions and modules (❾) can be used as a guidance document for developing such specifications, by choosing which of the aspects are included into the requirements of the EPBD, and which are left to a decision at Member States' level.

In the cases ❷ and ❸, it is up to the Member States to transpose requirements (❺ and ❻). In line with the subsidiarity principle, there should be room for interpretation and adaptation to the local context. Also in this case, the Member States can use this report with its approach of questions and modules as a guidance document for developing such specifications.

In the case ❶ (which is the situation today), Member States might still decide to set up inspection schemes for stand-alone ventilation systems (❼). Also in this case, the present report can be a valuable guidance document (❾).

Finally, the present report can also be a valuable guidance document for voluntary inspection frameworks independent of the EPBD context (❽), implemented by Member States or resulting from private initiatives.

One question is to identify the way by which various parameters would influence the impact of the introduction of regular inspection of stand-alone ventilation systems in the EPBD. Those parameters of the inspection framework include for example types of ventilation systems, types of buildings, thresholds on the capacity of ventilation systems, technical contents of inspections, etc.

Ventilation system national stocks and markets widely differ among them. The types of buildings equipped with stand-alone ventilation systems, the types of ventilation systems used, their nominal flow rate, their controls vary from one country to another, because of specificities of markets, regulations, habits, etc. Ventilation systems do not represent a homogeneous series of products designed, installed and used in the same way in all EU countries. Markets and stocks are very often specific to a given country. Even if it is clearly established that most of the ventilation systems in EU countries do not operate ideally, the status of their actual operation probably also depends on the country.

For the reasons mentioned above (different national stocks and markets with different typologies of ventilation systems, different status regarding the good operation of systems), it seems not evident to identify the way by which various parameters would influence the impact of the introduction of regular inspection of stand-alone ventilation systems in the EPBD.

From a qualitative point of view, the impact of having requirements linked to a threshold on capacity would depend on the country. Higher capacity ventilation systems use more energy than small systems but their maintenance is in certain countries probably more frequent and with a higher quality level, which means that the inspection of small systems could have a higher impact. However, there are probably high capacity ventilation systems that do not operate efficiently.

The impact of having requirements of inspection for certain types of systems/buildings is also not evident to assess. For example, the performance of natural ventilation systems probably has a better chance to remain stable over time than that of mechanical ventilation systems; therefore, natural ventilation systems could perhaps be inspected only once. Balanced ventilation systems with heat recovery are the most efficient if their operation is correct but their installation and maintenance is more complicated, making them good candidates for inspection; however, their number is low in the current stock, which reduces the overall impact of their inspection. Inspection of newly installed systems is easier to organise than inspection of ventilation systems already installed since a while, but the proportion of newly-installed systems in the stock is low.

Various influence parameters will be explored in the further assessment of the potential impact of policy options (see next section), providing some answers.

6. Selection of options for further assessment of their potential impacts

The next part of the technical study will be an assessment of the potential impacts of selected policy options. The policy options that will be analysed are described below. For most options, a detailed description of the reference scenario for the impact assessment is given, whereby variations of this reference scenario can be assessed in the next part of the study.

Option 1: Better knowledge about the status on the ground in combination with awareness raising of stakeholders

This option includes the following actions, managed or encouraged by public authorities:

- Collection of data about the national stocks and markets per type of building and type of ventilation system
- Surveys on actual performances of installed systems, focusing on air flow rates, energy efficiency (electrical consumption or power input), acoustics, hygiene of the system
- Information of stakeholders about the results of the two previous points
- Consultation on possible actions to improve performance (air flow rates, energy efficiency, acoustics, hygiene).

This option is in particular important for countries which at present have little information available about the status on the ground in their country. It is very difficult to find societal support for inspection schemes if there is no clear evidence of the need for such inspection schemes.

Option 2: Professionals skills increase through training programmes

This option consists in implementing training of installers, in order to increase the quality of their works and thus improve the performance of newly-installed stand-alone ventilation systems.

Training should have the objective that installation companies increase their skills for the design of ventilation systems, the choice of components, the installation works and the commissioning including measurements of air flow rates, electrical power input and hygiene of the system.

There are various schemes possible, e.g. creating training offer with no obligations, obligations to follow training programmes, obligation to successfully pass a training programme, etc.

The reference scenario for the next part of the study will be a mandatory training of installation companies leading to their certification.

Option 3: Visual inspection of stand-alone ventilation systems

This option includes a visual inspection of newly installed ventilation systems in buildings after their installation.

The objective of the inspection, based on a checklist, is to assess the completeness, general state, cleanliness and good overall operation of the system, without measurements.

The reference scenario for the next part of the study will focus on initial visual inspection that can be operated by every professional who has been qualified. The qualification of companies relies on the successful completion of a theoretical and practical training by a certain number of employees. Audits of inspections are made by the qualification body. Sanctions are defined and implemented if inspectors do not perform inspections according to the rules.

A report provided to the owner and to a public authority identifies which parameters have been verified. ,

<u>Option 4</u>: Inspection of stand-alone ventilation systems with measurements

The reference scenario for the next part of the study will be the mandatory initial inspection of new ventilation systems in residential buildings after their installation.

Inspection can be operated by every professional who has been qualified. The qualification of companies relies on the successful completion of a theoretical and practical training by a certain number of employees. Audits of inspections and of the measuring instruments are made by the qualification body. Sanctions are defined and implemented if inspectors do not perform inspections according to the rules.

Inspections include:

- the visual inspection of the hygiene of the ductwork, ventilation unit and filter(s);
- the measurement of air flow rates at room level;
- the measurement of air cross-section areas of air transfers between rooms;
- the measurement of fan(s) electrical power input.

The measuring instruments are calibrated by an accredited laboratory on a regular basis.

A report provided to the owner and to a public authority includes the inspection results compared to target values fixed by a regulation, a standard or guidelines. Nothing specific is required by the inspection rules if the target values or the hygiene level are not met; defining and implementing corrective actions relies on further interaction between the owner, the installer, the designer that are outside of the inspection itself.

<u>Option 5</u>: Inspection of stand-alone ventilation systems with measurements and the obligation to make the system compliant

The reference scenario for the next part of the study will be the mandatory initial inspection of new ventilation systems in residential buildings after their installation. It uses the same approach as option 4.

The additional requirement is that the ventilation system is made compliant within a certain delay if the inspection shows that target values are not met or the hygiene of the system is not good. Inspection must be repeated after corrective actions to check that the compliance is achieved.

Option 6: Measurement of indoor air quality parameters

The reference scenario for the next part of the study will cover mandatory requirements about the maximum values of an indoor air quality indicator in all buildings with employees (except industrial buildings), i.e. in most of the non-residential buildings (offices, retail buildings, educational buildings, health care facilities, hotels, restaurants, sport facilities, etc.).

The measurement of this indoor air quality parameter can be asked by employees and/or employer and the obligation is that it is made by an independent certified inspector.

Measurements of indoor pollutant concentrations use analysers that are regularly calibrated through reference gases.

A report with the measured indoor air quality parameter and the maximum value fixed by regulation is provided to the employees and employer.

Possible corrective actions relies on further initiative of the employer and are outside of the option itself.

The 6 options above can be considered as presenting an increasing complexity and could be implemented on a progressive time schedule, as shown by the table below.

Option	Aim	Timeline
1: Status on the ground + Awareness raising of stakeholders	Awareness	Could be implemented first
2: Professionals skills increase through training	Skills	Could be implemented as a result of option 1, or as a result of options 3, 4 or 5
3: Initial visual inspection	Perception of the system	Could be implemented as a result of option 1. Requires training - see option 2.
4: Initial inspection with measurements	Observed performance of the system	Could be implemented as an evolution of option 3.
5: Inspection with the obligation to make the system compliant	Effective performance of the system	Could be implemented as an evolution of option 4.
6: Measurement of indoor climate parameters and energy consumption	Good indoor climate at room level and/or energy efficiency of ventilation system	Could be implemented as an alternative to option 5.

Table 10 – Summary of aim and possible timeline of the 6 proposed options

Each of these options could first be implemented on a voluntary basis (in order to gain experience) and later be made mandatory.

Choosing between these options as well as the timeline to implement them depend on the current operational status of the stock of ventilation systems. The choice may thus be different per country/region.

7. Conclusions

The works whose results are presented in this report allowed to:

- Define the list of questions that must be answered for building up an inspection framework for stand-alone ventilation systems
- Identify possible answers to the questions on the technical and organisational aspects of the inspection framework, and describe these answers in detail together with their advantages and drawbacks
- List and provide detailed information about measures other than inspection that can also support better performance of stand-alone ventilation systems
- Point out legal issues that must be taken into account when deciding about the contents of an inspection framework or other measures
- Comment different possibilities to introduce requirements on the inspection of stand-alone ventilation systems under the EPBD
- Clarify that the influence of various parameters on the impact of regular inspection in the EPBD is not evident to assess, since it deeply depends on national or regional situations (different stocks and markets, different typologies of ventilation systems, different status regarding the good operation of systems)
- Make a proposal about the selection of options for a further assessment of their potential impacts in the next part of the study.

The approach to build up an inspection framework from a list of questions and a selection between possible answers (modules) could be useful to public or private parties when they decide about the objectives, contents, organisation and status of the inspection of stand-alone ventilation systems.

Annex 1 – Detailed description of the modules for the technical and organisational aspects of an inspection

AIM OF INSPECTION (AIM)

Which performance to be inspected? (AIM-1)

Reference	Modules's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
AIM-1a	Energy performance	Inspection aim can be to check energy performance of the ventilation system since ventilation highly impacts building energy performance, due to the introduction of outside air into the building and to the fan(s) electrical consumption: excessive ventilation airflows increase heating and/or cooling needs and induce higher electrical consumption of the fans. Checking ventilation performance regarding its impacts on energy is crucial in low-energy buildings.	*Advantages:* Building energy-performance calculations often use ventilation design values as input data. Checking actual energy performance of the ventilation system is relevant because it highly influences the achievement of the building energy performance requirements. *Drawbacks:* Checking only energy performance could lead not to detect insufficient airflows driving to health and condensation risks in buildings.	Most of the existing inspection guidelines, standards and regulations target energy performance".
AIM-1b	Air flow rates, air change	Inspection aim can be to check air flow or air change rates. These are often required by regulations, labels, and/or technical or contractual documents. Checking air flow rates consists in airflow measurements (or pressure measurements from which airflow is derived) at fan or at various places in the ventilation system, at different ventilation stages (low, high).	*Advantages:* The advantage is to target on air renewal, which is the primary objective of ventilation. *Drawbacks:* Inspecting airflow rates corresponds to a technical approach that may not increase the awareness of non-technical stakeholders (building's owner, occupants). Focusing on airflow rates can lead to forget fan energy consumption. Airflows or air change rates can be not easy to measure with natural ventilation systems.	

AIM-1c	Indoor air quality	Inspection aim can be to check indoor air quality (IAQ), regarding ventilation's ability to dilute and evacuate indoor pollutants while limiting transfer of outdoor pollutants to indoors. Insufficient ventilation airflows can involve unhealthy indoor air.	*Advantages:* It could drive to improve IAQ and awareness about the links between ventilation and IAQ. *Drawbacks:* Checking only IAQ could lead not to detect excessive airflows driving to high energy consumptions. IAQ is not only linked to ventilation, but also to indoor and outdoor pollutant sources.	Few existing inspection guidelines, standards and regulations directly target indoor air quality.
AIM-1d	Hygiene of the ventilation system	Inspection aim can be to check hygiene of the ventilation system, i.e. its ability maintaining health and preventing disease. It is usually assumed than ventilation provides fresh and clean air but an unhygienic ventilation system can provide unhealthy air to the occupants.	*Advantages:* Secure the supply of healthy ventilation airflows, and encourage for ventilation maintenance.	
AIM-1e	Noise	Noise can increase in case of incorrect installation or operation of the system. It can impact overall well-being of occupants and neighbourhood, propagating through the ductwork and through the air. Noise sources include fan and electrical motor, air flows, inappropriate connection of the components to the ductwork, etc. Noise can as well reveal other dysfunctions, such as too high flow rates or dirty components.	*Advantages:* Identify if noise is disturbing for occupants. Identify other defects (that imply noise increase). *Drawbacks:* Acoustics is a specific skill rarely mastered by persons inspecting a building from an energy or IAQ point of view.	Identification of noise sources can be difficult.
AIM-1f	Thermal comfort (draughts, temperature gradient)	Thermal comfort is the well-feeling of occupants in the building that can be disturbed by cold/warm air draughts, high stratification (temperature difference between feet and head), and uncomfortable temperature set point (too high or too cold). Thermal discomfort linked to ventilation systems may result from inappropriate air diffusion in the occupation zone (wrong direction on the flow, high velocities, temperature…). This can result in increasing energy consumption (the set point temperature being increased by occupants to regain comfort) or decreasing IAQ (occupants can seal trickle ventilators due to air draughts).	*Advantages:* Identify comfort issues for occupants and possibly energy over-consumption and IAQ issues. *Drawbacks:* Thermal comfort is a subjective perception.	Thermal discomfort can be difficult to identify because it relies on subjective feelings from occupants, that can vary according to their age, sex, occupation, clothing, etc.

AIM-1g	Overall well-being of occupants	Overall well-being of occupants represents their general comfort covering thermal, olfactory, acoustic and visual comfort. Its assessment usually relies on questionnaires for occupants about their perception of noise, odours, indoor air quality, thermal comfort, health symptoms, etc.	*Advantages:* Focus on human beings and not only on technical objects. Protocols used to measure perceived IAQ are available and can be used. *Drawbacks:* Overall well-being is a subjective perception. Humans cannot detect all problems (as for example the presence of all air pollutants)	
AIM-1h	Overall well-being of neighbourhood	Overall well-being of neighbourhood represents the general comfort covering thermal, olfactory, acoustic and visual comfort of the neighbours of the building where the ventilation system operates. For example the ventilation system can propagate noise disturbing the neighbourhood, or the polluted/odorous exhaust air can be received by neighbourhood.	*Advantages:* Identify if the ventilation system is disturbing for neighbourhood can allow identifying that it does not operate correctly. *Drawbacks:* Overall well-being is a subjective perception.	
AIM-1i	Protection of building against humidity	Inspection aim can be to check that the ventilation system protects the building against humidity (mould growth risk). Insufficient ventilation air flows can involve building damages. This issue is especially crucial during construction phase with airtight building's envelopes (drying of screeds), in very humid climates, in low insulated buildings, in buildings with humidity sensitive materials.	*Drawbacks:* Checking only this point could lead not to identify energy issues linked to excessive airflows driving to high energy consumptions.	

How to decide on the performance to be inspected? (AIM-2)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
AIM-2a	Mandatory list of performance to inspect	In this approach, the set of elements to be inspected is fixed.	*Advantages:* Clear for the market, uniform procedure and report on performance of the inspected ventilation systems. Price of inspection can be lesser concern. Inspection can focus on highest risks. *Drawbacks:* Needs an authority, an organisation, a protocol that imposes the inspection contents ; less flexible implementation and adaptation	Note: a voluntary list of performance to inspect can be additional to a mandatory list.
AIM-2b	List of inspected performance to be decided	In this approach, the list of performance to inspect is left up to the market (builder, owner, architect, etc.) or to the expertise of the inspector, depending on the specific system inspected.	*Advantages:* Allows to adapt inspection contents to the specificities of the inspected system. Can make inspection more widely accepted. *Drawbacks:* Can rely on arbitrary/subjective choices not focusing on the most important aspects.	

TARGETS OF INSPECTION (TAR)

Who should benefit from inspection? (TAR-1)

Those who benefit from an inspection may be direct beneficiaries (all building occupants, or specific types of occupants: workers, children, elderly people, persons with low revenues) or indirect beneficiaries (building owners, employers, ventilation system manufacturers).

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
TAR-1a	Occupants	Inspection of stand-alone ventilation systems can target all types of building occupants. Occupants can be permanent (residential buildings), semi-permanent (schools) or changing (health care, commercial, hotel), and several types of occupants are often combined (for example employees and public). The link between the occupants and the building's owner strongly influences the ability of action of the occupants on the ventilation system and occupants awareness about ventilation.	*Advantages:* Occupants are concerned by IAQ and energy impacts (if they pay their energy consumption) and should be aware. In order that they fully benefit from inspection, it could be interesting that they are able to identify operation defects, and avoid inappropriate interventions on the system *Drawbacks:* Changing occupants will probably not identify the direct benefits of inspection. Performance indicators are not shared at the moment.	
TAR-1b	Workers	Inspection of stand-alone ventilation systems can target workers who should generally be protected by their employers, thanks to regulations, and who can gain in productivity with adequate ventilation.	*Advantages:* Workers have only limited effect on the design and commissioning of the system, as they most often appear only after commissioning. Workers seldom have a direct link with the building owner, in most cases the relation goes via the employer.	Specific working areas as industrial facilities, chemical and laboratory facilities, hospitals, etc. should be specifically treated, taking into account that they probably use few stand-alone ventilation systems).

TAR-1c	Children	Inspection of stand-alone ventilation systems can target children. It has been shown in the literature than because of their growth and intense metabolism children are vulnerable to the air they respire. Lung aggression due to polluted air during the first months and years of the life can mortgage and reduce lung capacity for the whole life. Moreover, children are the most exposed to the indoor pollutants, since they breathe in more than twice an adult (Ref: Déoux, 2010). As a result, they should be targeted in priority.	*Advantages:* Decrease vulnerability of this population. Increase children awareness about ventilation and the quality of the air they respire; this should contribute to a good awareness for the entire families and also the next generations.	As they spend most of their time in nurseries, schools and homes, it drives to target specifically those types of buildings.
TAR-1d	Elderly people	Inspection of stand-alone ventilation systems can target elderly people because they are part of the most vulnerable populations from a health point of view. It could also allow to increase the use of ventilative cooling in order to limit the energy consumption of air-conditioning systems.	*Advantages:* Decrease vulnerability of this population and energy consumption.	As they spend most of their time in retirement residences, specialized institutions and homes, it drives to target specifically those types of buildings.
TAR-1e	Persons with low revenues	Inspection of stand-alone ventilation systems can target persons with low revenues as they could be considered as vulnerable to the energy cost due to ventilation and thus limit ventilation rates. Moreover, these persons could be the most exposed ones to dangerous pollutants sources due to the use of additional heating appliances in under-ventilated rooms.	*Advantages:* Decrease vulnerability of this population.	
TAR-1f	Owners	Building owners can benefit from the inspection of stand-alone ventilation systems. Their links with the occupants are of types: owner/tenant, employer/employee, public or private owner/public and employees with (commercial buildings) or without direct link (school). Time budget analysis shows that we spend in Europe generally 2/3 of the time in our houses, so that residential building's owners could be considered as a priority target.	*Advantages:* Building's owners have the responsibility to provide healthy buildings to the occupants and are concerned about building's damages. *Drawbacks:* For owners of private buildings, energy performance is rarely an issue of interest, except at the design stage if the inspection scheme targets the commissioning stage.	

TAR-1g	Employers	Employers can benefit from the inspection of stand-alone ventilation systems since their responsibility is to provide healthy working places and good working conditions to their employees.	*Advantages:* Employers should be interested in the good operation of ventilation systems in buildings where the activity of their employees takes place: indoor environment is known as a factor of productivity. *Drawbacks:* Precaution must be taken not to duplicate or be in contradiction with existing legal requirements about the protection of workers.	
TAR-1f	Ventilation system manufacturers	Ventilation systems manufacturers can indirectly benefit from the inspection of the stand-alone ventilation systems if they can access to inspection results, it can provide them feedback from different types of systems and technologies, from a big number of installations, allowing statistical analysis of defects, and ideas on how to improve the products and facilitate their good installation, maintenance and operation.	*Advantages:* Building's owners have the responsibility to provide healthy buildings to the occupants and are concerned about building's damages. *Drawbacks:* Access to inspection results by ventilation system manufacturers should probably be limited to anonymous information concerning the ownership and precise location of the inspected systems, Results should not make it possible to identify specific weaknesses of a given product manufactured by a competitor, which could jeopardize fair competition.	

What types of buildings should be covered? (TAR-2)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
TAR-2a	All residential	Residential buildings are used primarily as a dwelling for one or more households. Residential buildings include single-family houses (detached houses, semi-detached houses, terraces houses) and multi-family houses (or apartment blocks) which include apartment/flats *(ref. REHVA Terminology table)*. Inspection of stand-alone ventilation systems could apply to all types of residential buildings. Generic inspection requirements for all residential buildings would need by design to cover all types of ventilation systems while including at least common overall aspects (e.g. indoor environmental quality - notably indoor air quality and noise levels + energy use) and include additional aspects defined at national level based for example on construction/renovation year. More focused on living conditions and health and less on productivity.	*Advantages:* Easy to identify the targeted buildings. Reaches the masses and raise awareness. Occupants (owner/tenant) and building operator could be involved e.g. online tool. Create trigger points for e.g. better maintenance practices, ventilation system improvements. *Drawbacks:* Could require a high number of inspectors and market surveillance. Large number of single-family buildings can lead to huge travel costs and difficulty to get into private property	The relevant EPB standards could serve as basis and would need adjustment to existing national level standards, guidelines and practices.
TAR-2b	Single-family house	Single family houses are dwelling units that include e.g. detached houses, semi-detached houses and terraces houses *(ref. REHVA terminology table)*. Their counterparts are multi-family residential dwellings. Similar to TAR-2a, generic inspection requirements would need by design to cover all types of ventilation systems, although a less complex task due to low complexity of ventilation systems. The split could be done for example on construction/renovation year. More focused on living conditions and health and less on productivity. The frequency of inspection is also affected by occupant awareness of efficiency, maintenance or indoor comfort aspects.	*Advantages:* Easy to identify the targeted buildings. Reaches the masses and raise awareness. Occupants (owner/tenant) could be involved e.g. online tool. Create trigger points for e.g. better maintenance practices, ventilation system improvements. *Drawbacks:* Could require a high number of inspectors and market surveillance.	

TAR-2c	Multi-apartment buildings	Multi apartment buildings are dwelling units agglomerated within one building (apartment blocks) and they include apartments/flats *(ref. REHVA terminology table)*. Their counterparts are multi-family residential dwellings. Multi-apartment buildings can have central ventilation systems or distributed ones. It is more likely to find central ventilation systems in mid- and high-rise buildings. Similar to TAR-2a, generic inspection requirements would need by design to cover all types of ventilation systems, however there would be a clear cut between dwelling level ventilation systems and building level ventilation system (including contracted building operator). More focused on living conditions and health and less on productivity.	*Advantages:* Easy to identify the targeted buildings. Reaches the masses and raise awareness. Occupants (owner/tenant) and building operator could be involved e.g. online tool. Create trigger points for e.g. better maintenance practices, ventilation system improvements. Highest energy use reduction for residential buildings, because more mechanical ventilation systems than TAR-2b. *Drawbacks:* Could require a high number of inspectors and market surveillance.	
TAR-2d	All non-residential	A non-residential building is a building which is mainly used or intended for non-residential purposes. If at least half of the overall useful floor area is used for residential purposes, the building can be classified as a residential building *(ref. EUROSTAT Glossary https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Building)*. Ventilation in non-residential buildings impacts a large number of occupants in terms of productivity, health and well-being. Non-residential buildings are more likely to have more complex mechanical ventilation systems combined with control and energy management systems. Generic inspection requirements for all non-residential buildings would need by design to cover all types of ventilation systems, although easier to treat at building level and would have higher focus on mechanical ventilation systems. Focused on productivity, health and occupants well-being.	*Advantages:* Easy to identify the targeted buildings. Building operator could be involved e.g. online tool. Create trigger points for e.g. better maintenance practices, ventilation system improvements and health and well-being related benefits for owners/tenants. Highest energy use reduction for non-residential, because all mechanical ventilation systems in non-residential buildings would be covered. *Drawbacks:* Could require a high number of inspectors and market surveillance. Comprehensive inspection could be expensive and time consuming. In professionally maintained and operated buildings, additional value might not be seen.	The relevant EPB standards could serve as basis and would need adjustment to existing national level standards, guidelines and practices.

TAR-2e	Offices	The purpose of offices buildings is to provide to employees an indoor area where to perform daily activities for a company/organization/institution/private employer. Specific inspection requirements for office buildings would treat in a tailored manner the typical installed ventilation systems according to the ventilation needs of the different functionality spaces. Inspection is more focused on productivity and health aspects, as employers are responsible to provide a healthy work environment.	*Advantages:* High energy use reduction due to high number of mechanical ventilation systems. Increased productivity. *Drawbacks:* Maybe more difficult to identify than TAR-2d due to multi-functional buildings (different ventilation systems for different parts)	
TAR-2f	Retail buildings	Retail buildings include shops, supermarkets, shopping centres, etc. There are also mixed retail and commercial/residential buildings. Specific inspection requirements for retail buildings would treat in a tailored manner the typical installed ventilation systems considering the IAQ requirements linked to the possibly higher number of indoor pollutant types and volumes that are likely present in retail buildings. The inspection requirements could be split for example based on construction/renovation year. More focused on productivity and health and less on living conditions.	*Advantages:* High energy use reduction due to high number of mechanical ventilation systems. Increased customer satisfaction/retention. *Drawbacks:* Maybe more difficult to identify than TAR-2d due to multi-functional buildings (different ventilation systems for different parts)	
TAR-2g	Educational buildings	Specific inspection requirements for educational buildings would treat in a tailored manner the typical installed ventilation systems. The split could be done for example on construction/renovation year. Focused on health and good living and learning conditions.	*Advantages:* These buildings are used by a vulnerable occupant group whose health and learning performance can be increased with good ventilation. Easy to perform invasive inspection during vacations.	Cost of the inspection in public sector buildings can be difficult to cover. In schools and day care centres, the inspection need is arguable the highest. These buildings can be used as a test bed for inspection system testing and development. If successful, then can be extended to other building types

TAR-2h	Health care facilities	Health facilities provides healthcare in indoor spaces for patients and staff involved directly in the facility activities (e.g. hospitals, private clinics, specialised care centres, nursery homes, psychiatric care centres, and medical laboratories). Health care facilities typically contain highly specific spaces with higher ventilation need and specific requirements in terms of IAQ. Specific inspection requirements for health care facilities would treat in a tailored manner the typical installed ventilation systems according to the ventilation needs of specialized spaces to meet the strict hygiene and cleanliness requirements and to decrease infection risks. At the same time, energy efficiency of the systems is very relevant due to the high energy need of such facilities. Inspection should focus on hygiene, health, wellbeing and efficiency at the same time. Inspection requirements could be split based on construction/renovation year, considering that majority of hospitals are old and inefficient buildings.	*Advantages:* Building operator could be involved e.g. online tool. High energy use reduction due to high number of mechanical ventilation systems. Increased health, hygiene, reduced healing time. High social impact due to healthcare costs. Addresses the specific conditions of a vulnerable occupant group. *Drawbacks:* Comprehensive inspection is expensive and time consuming. In professionally maintained and operated buildings, additional value might not be seen.	
TAR-2i	Hotels and restaurants	The design of hotels and restaurants should guarantee a high level of comfort for customers and good working conditions for employees. Hotels are characterized by different functionalities of spaces with different ventilation needs (professional kitchens, hotel rooms, meeting rooms, laundry, etc.). Specific inspection requirements for hotel and restaurant would treat in a tailored manner the typical installed ventilation systems. The split could be done for example on construction/renovation year. More focused on wellbeing and health and less on productivity.	*Advantages:* Building operator could be involved e.g. online tool. High energy use reduction due to high number of mechanical ventilation systems. Increased customer satisfaction/retention. *Drawbacks:* Comprehensive inspection is expensive and time consuming. In professionally maintained and operated buildings, additional value might not be seen. Maybe more difficult to identify than TAR-2d due to multi-functional buildings (different ventilation systems for different parts)	. Possible crossings with other safety and hygiene related mandatory inspections can decrease cost.

TAR-2j	Sport facilities	Sport facilities provide indoor services in spaces used to practice recreational/physical activities (e.g. swimming pools, gyms, indoor arenas, and indoor stadium). The indoor spaces used for sport facilities can also include additional services dedicated to the presence of the audience. Recreational facilities for indoor sports can either include multipurpose activities or specific ones. Specific inspection requirements for sport facilities would treat in a tailored manner the typical installed ventilation systems according to the functionalities considering specific pollutants, high air humidity levels and odours beside energy efficiency. Inspection requirements can be split based on construction/renovation year. Equally focused on health, wellbeing and productivity.	*Advantages:* Building operator could be involved e.g. online tool. High energy use reduction due to high number of mechanical ventilation systems. Improved living conditions/physical performance. Easy to perform also invasive inspection during off periods.	

What types of ventilation systems should be inspected? (TAR-3)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
TAR-3a	Natural	Natural ventilation is defined as "ventilation through leakage paths (infiltration) and openings (ventilation) in the building which relies on pressure differences without any fan" (EN 12792). It includes airing (ventilation by window opening), cross ventilation (resulting from wind pressures on the facades) and shaft ventilation (using a vertical or inclined duct to generate stack effect). Airing (i.e. natural ventilation by manual window opening by occupants) is not considered here since it does not rely on a ventilation system.	*Advantages:* Inspection could be seen as easier to operate than for mechanical ventilation systems. *Drawbacks:* Inspection of natural ventilation systems could have a limited impact since these systems only use 'static components' with a low performance drift.	Inspecting natural ventilation systems must take into account the fact that ventilation air flow rates vary according to the climatic conditions.
TAR-3b	Hybrid	Hybrid ventilation systems supply air either naturally or thanks to mechanical components. They make it possible to control the air flows if natural ventilation alone does not provide the required values because of insufficient difference of pressure or temperature between indoor and outdoor spaces. Sensors and controls usually drive the operation of mechanical ventilation.	*Advantages:* Such systems rely on a control strategy to decide on the operation of the mechanical part of the system that could be considered as requiring inspection. *Drawbacks:* The stock and market of such systems is relatively low, making the overall impact of inspection probably small.	Hybrid ventilation systems operating in natural mode may have the same problems as natural ventilation systems. When operating in mechanical mode, the performance drift can be similar to the one of other mechanical ventilation systems.

TAR-3c	Mechanical decentralised unidirectional	These systems use one or several extraction ventilators placed in different rooms and used to ventilate the complete dwelling, without designed air transfer between rooms, Unidirectional refers to a ventilation unit producing an air flow in one direction only, where the mechanically produced air flow is balanced by natural air supply or exhaust. The word 'decentralised' is sometimes replaced by 'local'.	*Advantages:* Inspection can focus on the ventilators (fans + small portion of duct).	The number of such systems in the stock is estimated to about 92 million units.
TAR-3d	Mechanical decentralised balanced without heat recovery	These systems include a ventilation unit that only ventilates the room where it is installed by both supplying and exhausting air to this room (two fans). There is no heat exchanger between exhaust and fresh air.	*Advantages:* The inspection can focus on the unit itself since ductwork is absent or reduced.	
TAR-3e	Mechanical decentralised balanced with heat recovery	These systems are similar to those described in TAR-3d except that the ventilation unit includes a heat exchanger between exhaust and fresh air that allows heat recovery.		

TAR-3f	Mechanical centralised unidirectional	These systems include a ventilation unit that either exhausts or supplies air (one fan) through a ductwork serving several rooms.		The number of such systems in the stock is estimated to about 38 million units.
TAR-3g	Mechanical centralised balanced without heat recovery	Mechanical centralised balanced systems include a ventilation unit that both exhausts and supplies air (two fans) through a ductwork serving several rooms. The unit includes <u>no</u> heat exchanger for heat recovery between exhaust and fresh air.		
TAR-3h	Mechanical centralised balanced with heat recovery	These systems are similar to those described in TAR-3g except that the ventilation unit includes a heat exchanger between exhaust and fresh air that allows heat recovery.	*Advantages:* *Drawbacks:*	The number of such systems in the stock is estimated to about 8 million units. Inspection of these systems can be justified by the fact that their performance can be sensitive to installation errors, whose potential number is higher.
TAR-3i	Demand-controlled ventilation system	In demand control ventilation systems, a control parameter is measured and the value is used to regulate automatically the flow rates. The control parameter usually reflects the current demand for ventilation. It can detect the presence or number of occupants, or rely on a parameter that indicates ventilation needs (CO2 or humidity concentration in the air for example). Demand-controlled ventilation systems are a variant of all the mechanical ventilation systems previously described.	*Advantages:* *Drawbacks:* These systems are the most sophisticated ones, making their inspection time consuming and complex.	Inspection of these systems can be justified by the fact that their performance can be sensitive to installation errors, whose potential number is higher.

Which climatic zones should be concerned? (TAR-4)

This question is to decide whether inspection should be restricted to ventilation systems installed in specific climatic zones or not.

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
TAR-4a	All climatic zones	It can be considered that all stand-alone ventilation system must be inspected in the same way whatever the climate of the place where they are installed.	*Advantages:* Simplest approach. If inspection is mandatory, ensures equality before the law.	
TAR-4b	Colder	Colder climatic zone in Europe is for example defined in one of the MEErP 2011-Methodology reports*. The city taken in reference is Helsinki with an outside temperature range for the heating period of [-22°C;+15°C]. It can be chosen to inspect ventilation systems in zones where the climate is colder. This choice can be based on criteria such as: in cold season, overflows can lead to an increased energy consumption since fresh air is very cold; it is important that the ventilation system operates correctly since opening windows is not possible or difficult; heat recovery is often used in such climates and it is important to check its correct efficiency; low temperatures of fresh air can lead to thermal discomfort.	*Advantage:* Can allow to focus on zones where the impact of some operation defects is higher. *Drawback:* There can exist ventilation systems in other climatic zones that are not energy efficient and that do not provide a good indoor environment.	
TAR-4c	Warmer	Warmer climatic zone in Europe is for example defined in one of the MEErP 2011-Methodology reports *. The city taken in reference is Athens. It can be chosen to inspect systems in zones where the climate is warmer. This choice can be based on criteria such as: in warm season, the stack effect for natural ventilation systems can provide insufficient fresh airflow rate; for balanced ventilation systems, incorrect controls such as a defect in the by-pass of the heat exchanger can lead to an increase of indoor temperature.	*Advantage:* Can allow to focus on zones where the impact of some operation defects is higher. *Drawback:* There can exist ventilation systems in other climatic zones that are not energy efficient and that do not provide a good indoor environment.	

* https://ec.europa.eu/docsroom/documents/26526

In which period of the year can inspection take place? (TAR-5)

This question is to decide whether inspection should take place at any time or be restricted to certain seasons because of climatic issues.

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
TAR-5a	All year	Choice can be made not to restrict inspection to a specific period of the year.	*Advantages:* Simplest approach. No restriction perceived, permitting more flexibility in the organisation of inspections. *Drawbacks:* Performances of some ventilation systems can be better or better evaluated in a specific season than the others.	
TAR-5b	Warm season	Inspection of ventilation system during the warm season can be useful to check the compatibility with cooling system. For example, in case of a high air flow rate, the energy consumption for cooling or discomfort can increase. In case of natural ventilation, inspection in warm season can be useful to check that the fresh air flowrate is sufficient even with a reduced stack effect.	*Advantage:* Can allow to focus on climatic conditions in which the impact of some operation defects is higher. *Drawbacks: Makes the organisation of inspections not evident (seasonal activity).*	Seems difficult to organise.
TAR-5c	Cold season	Inspection of ventilation system during the cold season can be useful to check the compatibility with heating system. For example, in case of a high air flow rate, the energy consumption for heating or discomfort because of draughts can increase.	*Advantage:* Can allow to focus on climatic conditions in which the impact of some operation defects is higher. Drawbacks: Makes the organisation of inspections not evident (seasonal activity).	Seems difficult to organise.
TAR-5d	Mid-season	Inspection of ventilation system during the mid-season can permit to focus only on the ventilation system and not be disturbed by the heating or cooling system of the building. For stack natural ventilation systems, it allows having average operation conditions, between cold season where air flow rates can be very high and warm season when they are at their minimum.	*Advantage:* Can allow to have an inspection when climatic conditions do not enhance or limit the impact of some operation defects. *Drawbacks:* Makes the organisation of inspections not evident (seasonal activity).	Seems difficult to organise.

RULES FOR INSPECTION (RUL)

What are the technical aspects covered by inspection? (RUL-1)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
RUL-1a'	Pre-check	The aim of the pre-check (or pre-inspection) is to access to all relevant documentation relating to the ventilation system and to analyse it, regarding the design parameters, systems characteristics and settings, operation, maintenance and use.	*Advantages:* Low cost. Crucial before going on-site. It can allow saving time on-site, because the inspector knows more precisely what to look for and can ask for necessary information before going on-site to be able to perform the inspection.	The steps of the pre-check are detailed in EN 16798-17 and EN14134 with a table (EN 14134) describing for each component (air terminal devices, air transfer devices, ductworks, heat recovery, filters, etc.) the information to collect during the pre-check step.
RUL-1b	Completeness	This type of inspection consists in checking the completeness of the system, i.e. to verify that all components are present at the right place and that their assembly seems correct. Checking completeness relies on visual inspection, and ideally on a comparison between available documents describing the system and the actual installation. Checking completeness also includes verification of the electrical connections and on the ductwork circuits: this can be checked for example by dismounting air inlets/outlets to check that they have been correctly connected to a duct.	*Advantages:* This type of inspection can take place on the system out of operation. This type of inspection is low cost compared to an inspection with measurements. *Drawbacks:* If this inspection is made on a system out of operation, the correct direction of rotation of the fan and the detection of abnormal noise, vibrations or significant air leakage cannot take place. It can happen that parts of the system are not easily accessible to visual check: in such a case, the inspection report should mention which parts of the system have not been inspected.	Included in the "Functional checks" of EN 14134 and "method 1" of EN 16798-17 These standards recommend that a pre-check takes place before this type of inspection.

RUL-1c	Adequacy between design and installation	This type of inspection consists in checking how the installed system complies with design specifications. It includes checking the completeness of the system compared to the design parameters but also other visual inspections (adequacy between designed the installed components and the designed ones, location of the ducts throughout the buildings in order to check assumptions done on pressure drop, mortise size for trickle ventilators, doors undercut size, ..).	*Advantages:* This type of inspection can secure energy and IAQ performance at building commissioning compared to the design one. It allows/requires increasing building's professional awareness to reach a common target. It makes designers (architect, engineer) concerned by inspection results. *Drawbacks:* It doesn't secure the durability of the performances, depending of the use and maintenance of the system. It doesn't secure the cleanliness of the supplied air.	Included in the "Functional checks" of EN 14134 and "method 1" of EN 16798-17 These standards recommend that a pre-check takes place before this type of inspection.
RUL-1d	Cleanliness and hygiene	This type of inspection consists in a visual check of the cleanliness of ventilation components, including trickle ventilators or suppliers (in the rooms and on the envelope), exhaust devices, filters and ductwork. It secures that fresh air is not more polluted than outside, and that the air flow cross sections are maintained to insure designed supply and exhaust airflows. It can/should be performed during construction phase, during first commissioning, and regularly after.	*Advantages:* Very low-cost. Very effective and easy to correct. Increasing occupant and building owner awareness about the need of cleaning and maintenance. *Drawbacks:* Ductwork is not always accessible to be visual checked, except before installation.	Included in the "Functional checks" of EN 14134 and "method 1" of EN 16798-17. Also included in most of the existing guidelines, standards or regulations in countries such as Finland, Belgium, Finland, France, Germany, Sweden, Poland, Canada.
RUL-1e	General state	This type of inspection consists in checking that the ventilation system seems in good conditions and is safe to operate and to maintain. It is based on visual checks.	*Advantages:* This type of inspection can take place on a system out of operation. This type of inspection is very low cost and useful to detect major dysfunctions. *Drawbacks:* Does not ensure that the ventilation system will operate well once it will be turned on.	Included in the "Functional checks" of EN 14134 and "method 1" of EN 16798-17

RUL-1f	Good overall operation	This type of inspection consists in checking that the ventilation system seems in good operation. It is based on a visual check with the system in operation. It consists in checking that all the components of the system are operating well: responding to the turn-on operations, including high-speed operation, opening of the exhaust devices, well-functioning of by-pass function, etc.	*Advantages:* This type of inspection is low cost and useful to detect major dysfunctions, going a step further that the "General state" inspection *Drawbacks:* Does not ensure that the ventilation system will provide correct air flow rates.	Included in the "Functional checks" of EN 14134 and "method 1" of EN 16798-17
RUL-1g	Good operation of controls	This type of inspection is particularly worthwhile for smart ventilation systems (including demand-controlled ventilation) but also for all controls including sensors. The check should verify that all controls are readily accessible, that the sensors and actuators are well functioning: for example, good operation for on-off devices (such as occupancy based components) or reaction to the pollutants for IAQ sensors (such as humidity or CO2).	*Advantages:* This type of inspection is low cost and can avoid major dysfunctions on smart ventilation systems. *Drawbacks:* Does not ensure the ventilation system performance. Checking that the controls react to high humidity and CO2 is not so easy.	Included in the "Functional checks" of EN 14134 and "method 1" of EN 16798-17
RUL-1h	Occupants satisfaction	This type of inspection is based on occupants feedbacks on how the ventilation system fulfil their own requirements related to comfort, energy use, operability, acoustics, air velocities, etc. It is based on occupants' questionnaires.	*Advantages:* This approach is based on global performance and doesn't focus only on energy, acoustic or IAQ. It focuses on occupants who are often the main target of ventilation (see "TAR" section) *Drawbacks:* This approach is time-consuming. It can be widely variable depending on the occupants in a same building, but also depending on the type of building, the period in the year, etc.	
RUL-1i	Energy consumption	This type of inspection is based on the analysis of energy consumption of the ventilation system (electricity used over a given period of time, in kWh), provided that this data is available.	*Advantages:* Low-cost inspection if the data is available. Can avoid major dysfunctions such as under or over ventilation. *Drawbacks:* Requires that the ventilation system is equipped with a dedicated electrical meter, which can be the case for big systems. Most of the ventilation dysfunctions could not be detected precisely.	

RUL-1j	Measurements	Depending on their aim (AIM section), inspections based on measurements could target different parameters such as airflow rates, air pressures, ductwork airtightness, electrical consumption, noise, etc. (See MEA section). It should require the use of precise and calibrated devices, by trained or certificated professionals, according to standardized protocols.	*Advantages:* One of the best ways to secure the ventilation performances and to make the construction actors aware of their responsibilities. It can be done at different stages: first use, regularly to secure the durability of the performances and the maintenance issues. *Drawbacks:* High cost, especially if several measuring instruments are used.	
RUL-1k	Adequacy with current ventilation needs	This type of inspection is based on the analysis of the comparison between the actual ventilation characteristics and the current needs in the occupied buildings. Current ventilation needs can be defined by regulations or standards and depend not only of the building characteristics (area, volume, etc.) but also on its occupation (number of occupants, activities of occupants, etc.).	*Drawbacks:* The current ventilation needs are not always clearly defined. The links with the design stage and the designer responsibilities are not evident.	
RUL-1l	Quality of maintenance	This type of inspection consists in checking that the maintenance of the system has been correctly operated. In the absence of maintenance procedures, this can rely on the inspection of "cleanliness and hygiene", "General state" and "Good overall operation" of the system (see above). Where maintenance procedures are available, the inspection can consist in checking that they cover all required aspects and that they are followed (for example by looking at maintenance reports).	*Advantages:* Very important to secure the performance of the ventilation system not only at commissioning, but during the whole building's life.	

Which parts of the ventilation system need to be inspected? (RUL-2)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
RUL-2a	Whole system	Whole system includes the ventilation unit and all the components permitting the air distribution and the air extraction of the building (terminals, ductworks, controls...)	*Advantages:* Global vision of the entire ventilation system operation *Drawbacks:* Time consuming	
RUL-2b	Ductwork	The ductwork connects all components of the ventilation system between them, allowing ducted air flows. Checking the air tightness of the ductwork allows to verify that there is no overconsumption of the fan or insufficient air flows due to air leakage (holes in the ducts, disconnection or leaky connection between components) or to duct blockage.	*Advantage:* Rather simple test. *Drawbacks:* Checking air tightness alone does not cover pressure drop over ductwork, which might affect the airflow rates.	
RUL-2c	Ventilation unit	The ventilation unit is composed of: an electrical motor, a fan, a box with inlets and outlets, possibly air filters and a heat exchanger (for balanced ventilation units). It is usually intended to be connected to ducts. The ventilation unit exhausts polluted indoor air and/or provides fresh air from outside. The ventilation unit can meet problems such as: bad mechanical transmission between motor and fan, inadequate airflow rate delivered, blocked filter, bad direction of fan rotation, vibration transmissions from the unit to the building due to the support, bad efficiency of the air heat exchanger (non-insulated unit and unit placed in a non climate-controlled room), absence or bad control of the bypass of the air heat exchanger (important for fresh cooling during warm season).	*Advantages:* Rather simple inspection, since ventilation unit is in most cases accessible.	

RUL-2d	Air inlets	Air inlets provide fresh air to the building. Problems usually identified: absence or wrong selection of air inlet dimensions, wrong position (for e.g. too close to an air outlet), wrong airflow rate (dirty or broken), not well connected, creating discomfort (fresh air draught, noise).		
RUL-2e	Air outlets	Air outlets extract polluted indoor air from the building. Problems usually identified: absence or wrong selection of air outlet dimensions, wrong position, wrong air flow rate (dirty or broken), not well connected, creating discomfort (air draughts, noise).		
RUL-2f	Air transfers	Air transfers are passages or grilles that allow airflow to go from one room to another inside the same building. Example of verification: presence of air transfer devices, right air-cross section area, etc.	*Advantages:* Simple inspection. *Drawbacks:* Might be numerous in a ventilation system.	
RUL-2g	Filters	Filters can take place at various locations in the ventilation system, either to improve air quality or to protect ventilation system components (for example heat exchangers) against fouling. Inspection of filters allows to detect filter clogging.		
RUL-2h	Sensors	Sensors that are present in the ventilation system can be inspected to check their operation and their ability to detect the intended quantity or threshold.	*Drawbacks:* It can be difficult in practice to emulate a sensor in a controlled way in order to check its correct operation.	
RUL-2i	Controls	Controls can adjust air flow rates in response to the signals received from various types of sensors. Problems usually identified: defects of sensors, connection problems, wrong position of the sensor (for example: next to an air inlet which makes the measured parameter not representative of the air in the room), inappropriate control mode, etc.		

Is it sufficient to inspect only a sample of the ventilation systems? (RUL-3)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
RUL-3a	Inspection of each system	It can be decided that the inspection targets each ventilation system, i.e. the whole system of each building.	*Advantages:* Systematic coverage of all systems. *Drawbacks:* Higher cost.	
RUL-3b	Inspection of a sample of the systems	It can be decided that inspection is performed on a sample of the systems. Sampling rules must be clearly defined. For example, when several apartments belonging to the same building have the same or similar ventilation systems, it can be decided that inspection is performed on a sample of these apartments.	*Advantages:* Lower cost. *Drawbacks:* Sampling rules cannot be defined in all circumstances. There is a risk that the checked ventilation systems are not representative of all systems.	A sampling method is proposed in EN 14134* and the French Promevent protocol. EN 12237** proposes also a sampling method for ductwork airtightness test.
RUL-3c	Inspection of a sample of the buildings	It can be decided that inspection is performed on a sample of the buildings. Sampling rules must be clearly defined. For example, when several buildings belonging to the same estate have similar ventilation systems, it can be decided that inspection is performed on a sample of these buildings.	*Advantages:* Lower cost. *Drawbacks:* There is a risk that the checked buildings have ventilation systems that are not representative of all systems.	A sampling method is proposed in EN 14134* and the French Promevent protocol. It should be combined with a quality management approach applied by the designer, to make sure that the sample checked is representative. It could also be combined with a secure procedure in the checked buildings selection.

* EN 14134: Ventilation for buildings. Performance measurement and checks for residential ventilation systems
** EN 12237: Ductwork. Strength and leakage of circular sheet metal ducts

IN-SITU MEASUREMENTS (MEA)

Note: This part is applicable only if it has been chosen to include measurements in the inspection (see RUL-1j).

What are the measured quantities? (MEA-1)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
MEA-1a	Air flow rates at fan level	Airflow rate at fan level means the airflow supplied or exhausted by the fan (the total airflow). It is usually expressed in m^3/h. It can be measured by a flow meter (MEA-2a) or thanks to several anemometers (MEA-2b) in the duct at fan level by using an anemometer and then, calculating the overall air flow rate. It can also be read on the control panel of the ventilation unit if the unit has an integrated flow metering system.	*Advantages:* One measure, time gains. *Drawbacks:* Does not show the distribution of the air flow between the different rooms.	
MEA-1b	Air flow rates at room level	Airflow rate at room level means airflow supplied in the room or exhausted from the room. It is usually expressed in m^3/h. It can be measured by using flow meters (MEA-2a).	*Advantages:* It allows the verification of local airflow rates.	EN 14134 proposes that airflows measurement is one of the two functional measurements.
MEA-1c	Air pressures at fan level	Air pressure at fan level is the pressure of the air upstream or downstream of the fan. It is usually expressed in Pascal. It can be measured by a manometer (MEA-2c) and can also be read on the control panel of the ventilation unit if the unit has an integrated manometer. The pressure can be used to assess the airflow rate at fan level thanks to the fan-characteristic curve.		
MEA-1d	Air pressures at room level	Air pressures at room level are the pressures in the duct upstream or downstream of the air inlet/outlet. Air pressure at room level is usually expressed in Pascal. It can be measured by a manometer (MEA-2c) and be used to assess the airflow rate delivered in the room by the inlet or exhausted from the room through the outlet.		

MEA-1e	Ductwork airtightness	Low ductwork airtightness is due to air leaks in the duct and/or in connections between ductwork components. It is expressed in m^3/h per square meter of duct surface related to a certain pressure difference between inside and outside of ductwork, or in class (A to D, EN 12237 and EN 1507). It can be measured by plugging all extremities of the ductwork and creating a given overpressure inside it in order to measure the airflow rate of the leakages (MEA-2j).		EN 14134 proposes that ductwork airtightness test is considered as a special measurement. EN 12237 and EN 1507 describes the method to perform ductwork airtightness measurement.
MEA-1f	Electrical power input	Electrical power input is the electrical power required by the ventilation unit (fan motor and internal controls) and additional controls (sensors, motor variable speed drives, etc.), or the electrical power required by standby mode. It is usually expressed in KW. It can be measured by a wattmeter (MEA-2d) or it can be read directly on the control panel of the ventilation unit if the unit has an integrated wattmeter.		EN 14134 proposes that it is considered as a special measurement.
MEA-1g	Performance of heat recovery	In balanced ventilation systems (bidirectional systems) with heat recovery, heat is recovered from one air flow to the other thanks to a heat exchanger located inside the ventilation unit. In order to check the heat recovery efficiency, checks can be made on the cleanliness of the heat exchanger, the thermal insulation of the unit and ducts, the temperature differences between inlet and outlet of the unit, etc. Controls that allow air to by-pass the heat exchanger when required can also be checked.		

MEA-1h	Indoor air quality parameters	Indoor air quality parameters are temperature, humidity, CO2 level and pollutant concentrations (particles, gaseous pollutants). They are directly related to the well-being and health of occupants. Different sensors and analysers exist to measure the levels of these parameters (MEA-2f).		
MEA-1i	Noise level in rooms	Noise level in rooms can directly impact comfort of the occupant when it is too high. The level is measured with a noise analyser (MEA-2g) and usually expressed in dB or dB(A).		EN 14134 proposes that it is considered as a special measurement.
MEA-1j	Noise level outdoors	Noise level outdoors can directly impact comfort of the neighbourhood when it is too high. The level is measured with a noise analyser (MEA-2g). Example: if the ventilation unit is located on the roof of the building, the fan and the motor can create noise to another building.		
MEA-1k	Thermal comfort parameters	Thermal comfort parameters are air temperature and temperature differences, air velocity and turbulence, air humidity. ISO 7730 describes these parameters. Measurements require defining a space grid on which temperature, humidity and air velocities are measured. Measuring instruments include temperature probes, hygrometer, anemometer…	*Drawbacks:* Suck measurement can be complicated and time consuming (expensive and breakable measuring instruments, big number of measurements, heavy exploitation of results (cartography))	
MEA-1l	Air cross-sections areas	Air cross-sections are spaces required to allow air transfer. They ensure the correct airflow rate and avoid the under-ventilation in some of the rooms Air cross section areas (in m^2) can be measured by using a dimensional measurement tool (MEA-2i).		

What are the measuring instruments? (MEA-2)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
MEA-2a	Flow meter	A flow meter should be used to perform measurement of airflows at room level, i.e. at air terminal devices (supply and exhaust). Different flow meters could be used: pressure compensating flow hood (flow hood with an auxiliary fan), flow hood with no pressure drop compensation, based on different integrated anemometers: punctual thermal anemometer, hot-wire grills, etc.	*Drawbacks:* Impossible to use "hand" airflow meters if the air inlet/outlet is not surrounded by a plane surface, if it is too large or if flow is very turbulent.	See EN 16211 for detailed information.
MEA-2b	Anemometer	An anemometer should be used to perform airflow measurement in ducts at fan level. It consists in measuring the air velocity and calculating the airflow. It can also be used to measure thermal comfort parameters (air velocity in the room). There are hot-wire or mechanical anemometers.		See EN 16211 for detailed information.
MEA-2c	Manometer	A manometer, usually a pitot static tube, can be used to measure pressure differences at room or fan levels.		See EN 16211 for detailed information.
MEA-2d	Wattmeter	A wattmeter should be used to measure electrical consumption. The electrical input power of a fan drive including any motor control equipment and controls shall be measured using a power meter capable of measuring active (true) power, e.g. a true RMS (Root Mean Square) measuring device or a measuring device with a RMS converter (source : EN 14134).		
MEA-2e	Thermometer	Thermometer is a resistance thermometer or thermo-couples and should be used to measure heat exchanger performance, IAQ and thermal comfort parameters, but also in order to calculate correction factors on airflows, by instance.		

MEA-2f	Pollutant concentration analyser	Pollutant concentration analyser should be used to measure IAQ parameters as CO2, aldehydes, VOC, particle matters, ozone, radon, carbon monoxide, etc. A large scale of technologies exists depending on the measured pollutants.		
MEA-2g	Noise analyser	A noise analyser is an instrument which can measure an instant acoustic pressure (in Pascal) that is transformed in an acoustic level (in decibel, dB).		
MEA-2h	Hygrometer	This measuring instrument provides indication about the amount of humidity in the air. It is usually expressed in %, showing the relative humidity, i.e. the ratio of the partial pressure of water vapour in the air to the equilibrium vapour pressure of water at a given temperature.		
MEA-2i	Dimensional measurement tools	Such measurement tools should be used to measure air cross-section areas or other dimensions in the ventilation system, as the door undercuts, or other distances and area (the floor's area if the airflows are a function of the floor area, distances between an exhaust device and the wall edge).		
MEA-2j	Pressurisation measurement device	This device is used to performed ductwork airtightness measurement: it provides airflow in order to maintain a fixed pressure difference between inside the ductwork and outside, and measures this airflow rate. This airflow rate is converted into a leakage factor.	*Advantages:* The only way to quantify ductwork air leakage, and to secure that ductwork are not too leaky, with impacts on energy consumptions and IAQ (if targeted airflows cannot be obtained) *Drawbacks:* Cost.	

What is the measuring uncertainty? (MEA-3)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
MEA-3a	No uncertainty	In measurements on a ventilation system during an inspection, it can be chosen to ignore the uncertainty of the measurements.	*Advantages:* Lower cost. The result is directly available. If the regulation/label doesn't propose rules in order to take into account the measurement uncertainty, it is difficult to use it. *Drawbacks:* There is a risk to use non-accurate devices and non-reliable protocol. The cost of the measurement could be counterbalanced by the fact that we don't trust the result, which could be far from the real value.	
MEA-3b	Fixed uncertainty	It is possible to evaluate a priori the total maximal uncertainty of the measurements, including both the uncertainty of the measurement methods and of the measuring instruments, and to use it as a fixed value of uncertainty.	*Advantages:* The total maximal uncertainty is given by the measurement protocol which does not require for the inspector to have specific knowledge regarding uncertainty calculation. *Drawbacks:* This is an evaluated maximal uncertainty: the real uncertainty could be very lower in good conditions, but also higher is some specific cases not always taken into account by the protocol.	
MEA-3c	Uncertainty of the measurement method	In a ventilation inspection, it is possible to calculate the uncertainty of the measurements methods. For the airflows for instance, the measurement method uncertainty results from deviations from the calibration method to the on-site method. It includes deviations from the calibration curve for series-produced measurement devices, dampers or terminals with in-built measurement outlets. The method uncertainty is normal distributed (source : EN 16211)	*Drawbacks:* It is complicated to assess the uncertainty of the method on-site by the inspectors: there are too many variables for on-site measurements and the theory of the uncertainty calculation is not mastered by inspectors.	EN 14134 which is an on-site measurement standard, does not propose any method for this point.
MEA-3d	Uncertainty of the measuring instrument	Uncertainty due to the measuring instrument has an important impact on total uncertainty of the measurement. It is based on the 3 following points: measured values shall be within the measuring interval of the equipment; measuring instruments shall be calibrated; measuring instruments shall respect a Maximum Permissible Error (MPE) of x % or y unit, whichever is the greater.	*Advantages:* Simple application at large scale *Drawbacks:* This uncertainty takes into account only a part of the total uncertainty.	EN 14134 proposes the following values for the MPE of the measurement of airflow rates, pressure differences and electric power: respectively 10 or 1 l/s, 2% or 1 Pa, 3%.

What is the calibration frequency of measuring instruments? (MEA-4)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
MEA-4a	None	The inspection cannot require any calibration frequency for measurement devices.	*Advantages:* Low-cost *Drawbacks:* The measuring device uncertainty will be high. The cost of the measurement could be counter-balanced by the fact that we don't trust the result.	
MEA-4b	Once	The inspection can require measurement devices calibration once, for instance before the first use.	*Advantages:* Lower cost *Drawbacks:* If the measurement takes place too long after the last calibration (depending of the type of measuring device, usually 1 year) , the conclusion of the calibration are not valid anymore and the measurement device uncertainty will be unknown. The cost of the measurement could be counter-balanced by the fact that we don't trust the result.	Any calibration must be combined with specifications on the MPE (see MEA-3d), as the calibration does not warranty the accuracy but only characterize the error.
MEA-4c	Regular	The inspection can require regular measurement devices calibration, with a fixed frequency for calibration.	*Advantages:* We secure the confidence we have in the measurement result, calculating a lower measurement uncertainty. *Drawbacks:* Not easy to know what is the good compromise between the cost of the calibration and the risk of high deviations, because we need more feedbacks for every type of devices.	Any calibration must be combined with specifications on the MPE (see MEA-3d), as the calibration does not warranty the accuracy but only characterize the error.

What is the calibration procedure? (MEA-5)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
MEA-5a	By the manufacturer of the measuring instrument	The calibration is performed by the manufacturer of the measuring instrument.		
			Drawbacks: It should be checked that the organisation of the calibration allows to consider it as being performed by an independent third party.	
MEA-5b	By an independent laboratory	The calibration is performed by an independent laboratory.	*Advantages:* Impartiality of the results.	
			Drawbacks: No warranty about the quality of the calibration.	
MEA-5c	By an independent accredited laboratory	The calibration is performed by an independent accredited laboratory.	*Advantages:* Impartiality of the results and warranty about the quality of the calibration.	
			Drawbacks: Probably higher cost.	
MEA-5d	By an ISO 9001 certified organisation	The calibration is performed by an organisation that is certified according to ISO 9001.	*Advantages:* The ISO 9001 certification will secure the reproducibility of the calibration.	
			Drawbacks: Probably high cost. An ISO 9001 certification does not necessarily cover all the technical aspects of calibration.	
MEA-5e	By the inspector	The calibration is performed by the inspector.	*Advantages:* For some measuring instruments, this can be possible and/or necessary (for example calibration of a pollutant concentration analyser by using a reference gas cylinder) It can reduce the frequency of the calibration by a third party.	
			Drawbacks: Require other competence and tools for inspectors than the usual ones.	
MEA-5f	Calibration range	Each calibration procedure should precise a calibration range compatible with the using range. If not, the measurement uncertainty will increase.		

REPORTING ABOUT INSPECTION (REP)

What is the content of the inspection report? (REP-1)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
REP-1a	Certificate	The inspection report can be a certificate that an inspection has occurred.	*Advantages:* Simple, low cost. Any certificate should push to care more in the ventilation design, installation, and maintenance. *Drawbacks:* Very low efficiency. Such a certificate provides no information about the status of the ventilation system and what has been inspected. There is no possible action to improve its performance.	
REP-1b	Certificate with parameters checked	The inspection report can be a certificate that an inspection has occurred, including the list of all checked parameters.	*Drawbacks:* Provides very few information on the status of the ventilation system and the way to improve its performance.	
REP-1c	Certificate with results	The inspection report can be a certificate that an inspection has occurred, including the obtained results for all the checked parameters.	*Drawbacks:* It can be difficult to know if the performance is at the right level and to improve the installation if necessary.	
REP-1d	Certificate with target values and results	The inspection report can be a certificate that an inspection has occurred, including the obtained results for all the checked parameters, and the target values.	*Advantages:* It is easy to conclude on the ventilation system performance, and if improvement is needed. *Drawbacks:* There can be a high number of target values. They can be difficult to determine.	
REP-1e	Certificate with target values, results and advice	The inspection report can be a certificate that an inspection has occurred, including the obtained results for all the checked parameters, the target values, and advice to improve the performance.	*Advantages:* Very efficient. The installation can be improved in order to perform as intended. *Drawbacks:* Higher cost. The inspector should have competence not only for the inspection but also in advice for improvement. It might engage the responsibility of the inspector regarding the proposed modifications and might require a specific insurance coverage (and its cost).	
REP-1f	Certificate stating compliance	The inspection report can be a certificate, stating that the ventilation system is compliant with the applicable regulations, standards, guidelines or specifications.	*Drawbacks:* Low efficiency. With such a certificate, it is not possible to know how to improve the system.	

Who receives the report? (REP-2)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
REP-2a	Owner	It can be decided that the report of the inspection must be given to the owner of the building in which the inspected ventilation system is in operation. The owner is the person directly concerned by this report in terms of maintenance or modifications needs if the ventilation system is not compliant.	*Advantages:* It informs and gives a sense of responsibility to the owner. *Drawbacks:* The owner is not a professional. In this case, the owner can make the choice to not apply the inspector's recommendations. There won't be any verification if the inspection is not regular.	
REP-2b	Occupant	It can be decided that the report of the inspection must be given to the occupant of the building in which the inspected ventilation system is in operation. The occupant is the person directly concerned by this report in terms of his well-being (sufficient air change rates for indoor air quality).	*Advantages:* It raises awareness and gives a sense of responsibility to the occupant about ventilation importance. *Drawbacks:* The occupant can decide to not apply the inspector's recommendations, without any verification if the inspection is not regular.	
REP-2c	Public authority	It can be decided that the report of the inspection must be provided to a public authority which can be informed about the defects and assure/compel the good application of inspector's recommendations if the ventilation system needs maintenance or modifications.	*Advantages:* In that case, public authority can have an overview of the status of ventilation systems operation and defects. *Drawbacks:* Requires administrative works to manage a great quantity of information and data.	
REP-2d	Architect	It can be decided that the report of the inspection must be given to the architect of the building.	*Advantages:* The architect is a professional, who can inform the person in charge to apply inspector's recommendations if there are any. *Drawbacks:* The architect is probably not directly concerned.	
REP-2e	Installer	It can be decided that the report of the inspection must be given to the installer of the ventilation system. It can help if modifications of the system are required or if the installer also operates maintenance.	*Advantages:* The installer is a professional, who can inform the person in charge to apply inspector's recommendations if there are any.	
REP-2f	Person in charge of the calculation of the building's	It can be decided that the report of the inspection must be given to the person who was in charge of the building energy performance calculation (at design stage)	*Advantages:* This professional can inform the person in charge to apply inspector's recommendations if there are any. *Drawbacks:* The person who calculated the energy performance of the building is probably not directly concerned.	

	energy performance			
REP-2g	Employees	For buildings in which people are working, it can be decided that the report of the inspection must be given to the employees.	*Advantages:* Inform occupants about the situation. *Drawbacks:* Employees must have the skills to understand technical aspects of the report and should not be alarmed unnecessarily by misinterpreting some results.	
REP-2h	Employer	For buildings in which people are working, it can be decided that the report of the inspection must be given to their employer.	*Advantages:* Employers should be interested in the good performance of ventilation systems: indoor environment is known as a factor of productivity.	

Who keeps the report? (REP-3)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
REP-3a	Owner	It can be decided that the report of the inspection is kept by the owner of the building in which the inspected ventilation system is in operation.	*Advantage:* The report can be handed over when the building is sold.	
REP-3b	Installer	It can be decided that the report of the inspection is kept by the installer of the ventilation system.		
			Drawbacks: Risk of loss along time.	
REP-3c	Occupant	It can be decided that the report of the inspection is kept by the occupant of the building in which the inspected ventilation system is in operation.		
			Drawbacks: Risk of loss when occupants are changing.	
REP-3d	System designer	It can be decided that the report of the inspection is kept by the designer of the ventilation system.	*Advantages:* Good traceability. It can be interesting for the system designer to keep this document for performance retrofits of his system in the building.	
			Drawbacks: Risk of loss along time.	
REP-3e	Independent inspector	It can be decided that the report of the inspection is kept by the independent inspector who operated the inspection of the ventilation system.	*Advantage:* Logical option.	
			Drawbacks: Risk of loss along time.	
REP-3f	Public authority	It can be decided that the report of the inspection is kept by a public authority.	*Advantages:* Public authority can have an overview of the ventilation performances. It is interesting for them if they operate statistical analysis.	
REP-3g	Certification organisation	It can be decided that the report of the inspection is kept by an organisation that certify the inspectors or that certify building performances	*Advantages:* Storage assured.	
REP-3h	Architect	It can be decided that the report of the inspection is kept by the architect of the building in which the inspected ventilation system is in operation.		

REP-3i	Person in charge of the energy performance of building calculation	It can be decided that the report of the inspection is kept by the person in charge of the energy performance calculation of the building in which the inspected ventilation system is in operation.	 *Drawbacks:* Risk of loss along time.	
REP-3j	Digital monitoring system of the building	It can be decided that the report of the inspection is stored into the digital monitoring system of the building in which the inspected ventilation system is in operation, if this system allows to store electronic documents.	*Advantages:* Good traceability and storage assured.	
REP-3k	Building Information Model (BIM)	It can be decided that the report of the inspection is kept into the Building Information Model of the building in which the inspected ventilation system is in operation.	*Advantages:* Good traceability and storage assured.	

What are the compliance criteria? (REP-4)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
REP-4a	Comparison with usual practice	Inspection results can be compared to usual practice to decide about compliance. Usual practice will depend of the country or of the inspector's criteria / methods.	*Advantages:* It can facilitate the decision on compliance. *Drawbacks:* It can be difficult to find "usual practice". Inspectors can be unable to define usual practice.	
REP-4b	Comparison with values fixed by regulation, standard, guidelines	Compliance of the ventilation system can be decided by comparing inspection results with requirements or values fixed by regulations, standards, and guidelines.	*Advantages:* Decision on compliance is taken on a solid basis and does not depend on the inspector. *Drawbacks:* The inspector needs to be well informed and maybe trained.	
REP-4c	Comparison with design values	Compliance of the ventilation system can be decided by comparing inspection results with design values if they are available. It allows to check that the actual ventilation performance is the one that was planned in the design phase of the ventilation system.	*Advantages:* Easy way for deciding on compliance if the design values are available. *Drawbacks:* The ventilation needs can change throughout the life of the building and the design values can differ to the values linked to the current ventilation needs.	
REP-4d	Comparison with builder's requirements	Compliance of the ventilation system can be decided by comparing inspection results with builder's requirements if they are available.	Drawbacks: Requires that builder's requirements are available to the inspector, which does not seem evident.	
REP-4e	Comparison with current ventilation needs	In order to decide on the compliance of the inspected system, it can be chosen to operate a comparison between the ventilation actually provided by the system (in terms of air flow rates or air change rates) and the current ventilation needs of the building. Current ventilation needs can be defined by regulations or standards and depend not only of the building characteristics (area, volume, etc.) but also on its occupation (number of occupants, activities of occupants, etc.).	*Advantages:* This comparison is the best approach to make sure that the actual operation of the ventilation system is adapted to the needs of contaminants removal and air renewal. *Drawbacks:* It can be difficult for inspectors to assess the current ventilation needs, especially where data are missing about building characteristics and its occupation. This also requires some skills beyond the ventilation system that inspectors may not have.	
REP-4f	None	The choice is made that the inspection does not conclude on compliance.		

What is the acceptable deviation for deciding on compliance? (REP-5)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
REP-5a	None	No deviation of the inspection results from the compliance criteria is accepted. For example, if the requirement is that the air flow is bigger than 50 m^3/h, the compliance is achieved when the measured value is bigger than this threshold.	*Drawbacks:* Uncertainties of measurement can impact the compliance.	
REP-5b	Lower performance accepted within a certain tolerance	A deviation of the inspection results from the compliance criteria is allowed: performance can be lower than the compliance value within a certain tolerance, in order to take in account measuring uncertainties without taking the risk to declare as non-compliant a system that is actually compliant.	*Advantages:* The product supplier, designer, installer or maintenance staff have no risk that their product or work is wrongly considered as non-compliant because of the measuring uncertainties. *Drawbacks:* Definition of the tolerance can depend of the methods of measurement.	See EN 14599 "Ventilation for buildings. Test procedures and measurement methods to hand over air conditioning and ventilation systems", Table 3.
REP-5c	Higher performance required to make sure that the actual value will fulfil the requirement (safety margin)	In this approach, performance resulting from inspection must be higher than the compliance value plus a certain tolerance. It means that the results of the inspection must be over the performances required in order to make sure of the ventilation system compliance without taking the risk to declare as compliant a system that is actually not.	*Advantages:* Performances respected even if there is an uncertainty of measurement thanks to the safety margin. The owner or occupant has no risk that the system is wrongly considered as compliant. *Drawbacks:* Level of compliance can be high for the market. Risk of over-ventilation (higher energy consumption).	

PERIODICITY OF INSPECTION (PER)

Does inspection occur once or is it regular? (PER-1)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
PER-1a	Once	Inspection occurs only once. This inspection can take place just after commissioning of a new system, or at any moment on a system already in use for a while.	*Advantages:* Simple approach.	
			Drawbacks: Does not allow identifying performance drifts along time.	
PER-1b	Regular	Regular inspection occurs at uniform time intervals. The frequency of the inspection can depend on the type and size of the system, as well as the type of its controls. Deciding on the inspection frequency must rely on an analysis of the risk of the system performance drift. It must also take into account the costs of the inspection and its estimated impacts (for example energy cost savings).The inspection frequency can also be adapted (reduced or increased) according to a statistical analysis of the results of a big number of passed regular inspections.	*Advantages:* Allows detecting performance drift of the ventilation system, on a regular basis.	
			Drawbacks: High frequency regular inspections can lead to significant costs.	

When does inspection occur? (PER-2)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
PER-2a	At regular time intervals	It can be chosen to have inspection at regular time intervals, for example each year or every two years. The time interval can be decided from a cost/benefit analysis and adapted from an analysis of inspections, depending on the number of defects and performance drifts that are identified.	*Advantages:* Easy definition and organisation.	
PER-2b	With renewal of the Energy Performance Certificate	It can be chosen to have inspection at the same time when the Energy Performance Certificate of the building must be renewed. The duration of the validity of an Energy Performance Certificate depends on the national transposition of the EPBD.	*Advantages:* This leads to a regular inspection if the duration of the validity of the EPC is not too long. Inspection of ventilation system can be operated by the same person as the one who provides the EPC. *Drawbacks:* It can happen that the frequency of renewal of the EPC is not consistent with the periodicity required for ventilation systems. Precaution must be taken because the skills required for inspection are not the same as the skills for establishing an EPC.	
PER-2c	When building is rented or sold out	It can be chosen to have inspection when the building is rented or sold out. Such inspection can be very rare in case of buildings occupied or owned for a very long time by the same persons.	*Advantages:* Provides assurance to the new occupant that the ventilation system operates correctly. *Drawbacks:* No regular frequency, it can be stringent for owners.	
PER-2d	After installation of a new system	It can be chosen to have inspection after installation of a new stand-alone ventilation system, either in a new building or in an existing building.	*Advantages:* Allows to check the quality of the installation.	
PER-2e	When parts of the system are changed or repaired	It can be chosen to have inspection when parts of the system are changed or repaired.	*Drawbacks:* The information that parts of the system are changed or repaired can be difficult to get if the inspector is someone else than the installer who changed or repaired.	

PER-2f	When the owner or occupant requests it	It can be chosen to have inspection when the owner or occupant requests it. Requests can be made in case of the well-being of occupants is not good.	*Advantage:* Inspection corresponds to an identified need by occupants or owners. *Drawbacks:* Most of the time, occupants don't realize if there is problem in the ventilation system.	
PER-2g	When controls indicate that inspection is necessary	It can be chosen to have inspection when the controls of the system indicate that it is necessary. It can be the case for example when a pressure sensor detects that a filter is too dirty and needs to be changed. It can also result for example from an inspection frequency registered in the controls.	*Advantage:* Automated management of the frequency of inspections *Drawbacks:* Probably requires a human request for inspection, unless sensors and controls are designed to communicate the information to the inspector.	
PER-2h	At building's commissioning	It can be chosen to have inspection at building commissioning, when construction of the new building is finished, at the building's delivery.	*Advantages:* Initial state of ventilation system of the building. *Drawbacks:* It occurs only once. Some problems can be detected only during the occupancy. Ventilation needs may change during lifetime of the building (for example office buildings).	
PER-2i	After building's major renovation	It can be chosen to have inspection after building's major renovation. Renovation may not take in account the ventilation system such as modification of the geometry of the living space without any verification of the airflow rate or the position of air inlet/outlet, replacing windows that increases the building airtightness, etc.	*Advantages:* In case of a new ventilation system in the renovation, the inspection will verify the correct installation. *Drawbacks:* It occurs only once. Some problems can be detected only during the occupancy	

INSPECTORS (INS)

By whom is inspection operated? (INS-1)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
INS-1a	System designer	The system designer can be the person in charge of the inspection.	*Advantages:* It could increase the awareness of the system designer about the achievement of the target.	
			Drawbacks: The system designer is not an independent third party, so there is a risk that failures due to the system design are hidden.	
INS-1b	Independent inspector / Third party service provider	An independent inspector can be the person in charge of the inspection.	*Advantages:* Independency from the parties directly involved in the design, installation, maintenance, use and ownership of the ventilation system. It probably encourages these parties working together in order to achieve the target.	
			Drawbacks: High cost. Training and competence needed.	
INS-1c	Installer	The installer can be the person in charge of the inspection.	*Advantages:* It could increase the awareness of the installer about the achievement of the target, and encourage him/her to perform intermediate testing. Probably cheaper as installer is already on-site and should have the measuring instruments.	
			Drawbacks: The installer is not independent third party so there is a risk that failures due to the installation are hidden.	
INS-1d	Maintenance staff	The maintenance staff can be in charge of the inspection.	*Advantages:* In the case of frequent inspections, it allows combining inspections with maintenance checks and decreasing the cost.	
			Drawbacks: Depending on the content of the inspection, it will require competences that the maintenance staff could not have (measurement).	
INS-1e	Owner	The owner can be the person in charge of the inspection.		
			Drawbacks: The owner can hide dysfunctions to avoid the cost of remediation measures. Depending on the content of the inspection, it would require competences that the owner would often not have (ventilation components, measurement, etc.)	

INS-1f	Occupant	The occupant can be in charge of the inspection.	*Advantages:* Increases the occupant awareness about the ventilation system operation and maintenance.	
			Drawbacks: Feedbacks from in situ campaigns show that occupants are rarely aware about the ventilation system and that they don't even clean the components. So there is a risk that occupants are not interested in or are not able to perform the inspection. Depending on the content of the inspection, it would require competences that the occupant would probably not have (ventilation components, measurement, etc.).	
INS-1g	Architect	The architect can be in charge of the inspection.	*Advantages:* Due to his responsibility, it would insure that the architect is involved in the different crucial steps of the ventilation installation in order to achieve the target. Depending on the content of the inspection, it would require competences that the architect may not have (ventilation components, measurement, etc.).	
			Drawbacks: The architect is not an independent third party so there is a risk that failures due to the building's design are hidden.	
INS-1h	Building airtightness tester	The building airtightness tester can be in charge of the inspection.	*Advantages:* The cost of the inspection could be lowered if it is combined with the building airtightness test. Both require similar skills, especially if the inspection includes a ductwork airtightness test. Can be an independent third party.	
INS-1i	Person in charge of the energy performance of building calculation	The person in charge of the energy performance calculation of the building can be the one in charge of the inspection.	*Advantages:* This person would know what are the input data for the energy performance calculation, reflecting what is supposed to be installed in the building, and what are the associated measurable variables.	
			Drawbacks: Required skills for the energy performance calculation of the building and the inspection of the ventilation system are different.	

Is there a need for quality assurance? (INS-2)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
INS-2a	Quality assurance	Quality assurance is a set of measures and activities to prevent defects in the inspection of stand-alone ventilation systems. It can include for example internal procedures for inspection, monitoring of the works, self-checks or checks by a third-person, and the feedback loop to improve these measures.	*Advantages:* Involvement of the inspector in checking that the works operated complies with the rules. Increases the reliability of inspectors, inspection and inspection reports.	
INS-2b	No quality assurance	It can be chosen to have no quality assurance for the inspection works.		
			Drawbacks: No procedure to prevent defects in the inspection (rules not followed). It could be compensated by surveillance (INS-6) or/and by training, qualification or certification of inspectors.	

Is there a need for training of inspectors? (INS-3)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
INS-3a	Theoretical training	A theoretical training can include: - an overview of the elements of the ventilation system to be inspected and how the performance of the ventilation system can be determined and measured - operational aspects of the inspection scheme and of reporting - background about the physics of ventilation - additional background on technical aspects of ventilation Depending on the scope of the training and the inspection scheme, a training can take one to several days.	*Advantages:* Direct way to spread information about ventilation and the inspection scheme. If there is one or several harmonised training programme, allows to disseminate uniform and updated information to inspectors, and to control possible interpretations of the rules. *Drawbacks:* Direct and indirect cost. For persons well familiar with ventilation the added value of a mandatory training can be modest. Course material should be developed, trainers should be trained? Capacity for training should be available: trainers, training room, regionally distributed.	
INS-3b	Practical training	A practical training can include: - measuring techniques for airflow and other parameters - identification of components of a ventilation system - safety aspects, e.g. measuring electric power (if necessary for the inspection scheme) - techniques to operate/adjust the ventilation system for inspection if applicable.	*Advantages:* Direct way to spread information about ventilation and the inspection scheme. . If there is one or several harmonised training programme, allows to disseminate a uniform and updated information to inspectors and to control possible interpretations of the rules. *Drawbacks:* Direct and indirect cost. For persons well familiar with ventilation the added value of a mandatory training can be modest. Course material should be developed, trainers should be trained. Capacity for training should be available: trainers, practical training installations, regionally distributed	

INS-3c	No training	There is no training of inspectors.	*Advantages:* No costs for training. Faster implementation of the inspection scheme: no time needed for development of training programme and organisation of training.	Even if no training is required, rules, standards and guidelines should be made available. If no training is required, qualification or certification of inspectors (INS-4, INS-5) could make training asked by candidate inspectors. Voluntary trainings could also be developed by private training institutes if the market requires for it.

Is there a need for the qualification of inspectors? (INS-4)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
INS-4a	Qualification	Qualification can be defined as "the recognition by a third party that a person or a company has the ability, quality, or attributes to perform a particular job or task, after successful completion of a course or training or passing of an exam or audit" (source: QUALICHeCK project). Qualification of inspectors can recognise not only their competence but also the ownership and correct use of the measuring instruments required.	*Advantages:* Gives confidence to those who benefit from the inspection. Probably increases or maintain the quality level of inspections. *Drawbacks:* Cost.	
INS-4b	No qualification	No qualification of inspectors means that the persons or companies performing inspection are not recognised by a third-party about their ability, quality, and attributes.	*Advantages:* Easy approach (nothing to implement) *Drawbacks:* The control of the ability of inspectors must either use another approach or is not made.	

Is there a need for the certification of inspectors? (INS-5)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
INS-5a	Certification	Certification can be defined as "the procedure by which a third party gives written assurance that a product, a process, a system, a person conforms to specified requirements mentioned in the rules of the relevant certification scheme" (source: QUALICHeCK project). Certification of inspectors or certification of the quality assurance system under which they operate allows getting assurance that inspection will be operated according to the defined rules.	*Advantages:* Gives confidence to those who benefit from the inspection. Probably increases or maintain the quality level of inspections. *Drawbacks:* Cost. Need for certification scheme and competent third party.	
INS-5b	No certification	No certification of inspectors means that the persons performing inspection or the process they use are not covered by the assurance given by a third-party that they conform to the defined rules.	*Advantages:* Easy approach (nothing to implement) *Drawbacks:* The assurance that the rules are followed must either result from another approach or is not present.	

Is there a surveillance of inspectors? (INS-6)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
INS-6a	None	No surveillance of the inspections	*Advantages:* Less costs. *Drawbacks:* Difficult to guarantee the reliability of reporting.	
INS-6b	Information to be provided by inspectors	The information to be provided by the inspectors to a surveillance body can include: identity of the inspector, company name of the inspector, registration number, date and time of the inspection, the inspection report, measurement tools (and calibration data) used, pictures of the installation, proof of inspection.		
INS-6c	Audit of inspectors	An audit of an inspector means that the inspector is audited by the surveillance body while performing an inspection on-site. During the audit the whole inspection process can be checked (all elements from INS-6b and all rules set by the inspection scheme). An auditing protocol is necessary. Audits can be announced in advance or unannounced to the inspectors. In the case of unannounced inspections, a specific system should be set up to know the on-going inspections and be able to audit them.	*Advantages:* Drive for reliable reporting. Direct information about ventilation systems from auditors *Drawbacks:* Cost. Time distribution of audits should be in line with time distribution of inspections. Geographical distribution of audits must be ensured: if no audits are done in a certain region, this may introduce reliability issues in the scheme.	Care should be taken when the audit of the inspection is not done at the same time or just after the inspection: airflows and ductwork airtightness might alter in time. This will be a direct source of discussion; tolerance on the findings shall have to be higher in this case. Fixed components of the ventilation system (e.g. the unit, vents, silencers, etc.) are normally not altered on short term. Feedback is available from the Belgian experience (Region of Flanders).

NON-COMPLIANCE (NC)

What happens if inspection results show compliance or non-compliance of the ventilation system? (NC-1)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
NC-1a	Obligation to make the system compliant	If inspection results show non-compliance of the ventilation system, it can be chosen to have the obligation that the system is made compliant. It must be decided who is the stakeholder that must take care that the system is made compliant (is it the owner? is it the installer for newly-installed ventilation systems? etc.). It must also be decided how the fact that the system has been made compliant will be checked, and who will pay for this additional inspection. Rules should probably also define a time-delay in which the system must be made compliant and sanctions if this is not done within this delay.	*Advantages:* This obligation makes the risks clear for all parties involved in the design, inspection and maintenance of ventilation systems. They can create a drive for a good quality of the works. They show the concern of the authority on good ventilation. *Drawbacks:* Need for inspection results that have no weaknesses and cannot be discussed.	The decision that the system is non-compliant could be subject to discussions and disputes.
NC-1b	Sanctions	A sanction is a reaction on results of the inspection if they show non-compliance of the ventilation system. It can be set up for inspections performed by independent third parties. Sanctions should be proportional, relevant and create a drive for correct design, installation and maintenance of ventilation systems.	*Advantages:* Sanctions make the risks clear for all parties involved in the design, inspection and maintenance of ventilation systems. They can create a drive for a good quality of the works. They show the concern of the authority on good ventilation. *Drawbacks:* Need for an impartial organisation that registers non-compliant inspection results, sets the sanctions and follows the effective implementation of the sanctions. Cost of the system for follow-up of inspection results and sanctions.	The set of possible sanctions should be clearly and well in advance communicated to the concerned stakeholders. Depending on the gravity of the sanction, it will be necessary to inform the sanctioned party clearly and underpin the sanction well.

NC-1c	Rewarding	In this case, a successful inspection showing compliance of the ventilation system earns a reward.	*Advantages:* Positive approach, which rewards the work well done.	
			Drawbacks: The type and nature of the reward must be well adapted so that it creates a drive for a good quality of design, installation and maintenance works, and awareness of owners/users of the importance of good ventilation.	
NC-1d	Nothing specific	In this case, non-compliance (and compliance) of the ventilation system has no direct consequence except that the report of the inspection mentions it (REP-1f) or allow to understand it.	*Advantages:* Simpler approach.	
			Drawbacks: Without sanctions there is only little chance that non-compliance found during inspections will lead to an improvement of the design, installation and maintenance of ventilation systems.	

What are the sanctions if inspection is not performed according to the defined rules? (NC-2)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
NC-2a	No sanctions	An inspection scheme without sanctions couples no direct consequences to complaints or findings during audits for inspectors.	*Advantages:* An inspection scheme without sanctions is much simpler. *Drawbacks:* Without sanctions there is only little chance that complaints or findings during audits will lead to an improvement of the inspections.	
NC-2b	Sanctions	A sanction in the inspection scheme is a reaction on findings during audits of inspections or on a complaint. Sanctions should be proportional, relevant and create a drive for correct and reliable inspections. This includes correcting the non-compliance found, or relieving the cause of the complaint, but also focuses on avoiding similar non-compliance in the future.	*Advantages:* - Sanctions make the risks clear for all parties involved in the inspection scheme (supposed that highest risks have most severe sanctions). - sanctions can create a drive for correct and reliable reporting and are thus an essential tool in creating a level-playing field between the inspectors. - Sanctions show the concern of the authority on good ventilation. *Drawbacks:* - Need for an impartial organisation that registers inspections, sets the sanctions and follows the effective implementation of the sanctions. - Cost of the system for follow-up of audits and sanctions.	The set of possible sanctions should be clearly and well in advance communicated to inspectors to keep the support for the inspection scheme. Depending on the gravity of the sanction, it will be necessary to inform the inspector clearly and underpin the sanction well.

STATUS OF THE INSPECTION (STA)

Is the inspection voluntary or mandatory? (STA-1)

Reference	Module's name	Description	Advantages / Drawbacks of the presence of this module in the inspection	Comments on the feasibility
STA-1a	Mandatory	When an inspection scheme is mandatory, it is imposed by a public authority for a well-defined scope of stand-alone ventilation systems: e.g. residential systems, residential systems in all dwellings, in all dwellings built after a certain date, all systems installed after a certain date, etc.	*Advantages:* Clear for the market: uniform report on performance of ventilation systems. Price can be lesser concern. Can focus on highest risks. Can cover risks systematically for certain parties in the building process (e.g. supervision role of the architect). *Drawbacks:* Need for societal support, price can be part of this discussion. Finding societal support might be time consuming. Less flexible implementation and adaptation. All legal aspects can intervene in a mandatory inspection framework.	The inspection scheme should be very clear.
STA-1b	Voluntary	In a voluntary approach, the implementation and operation of the inspection framework results from the initiative of a private party that proposes inspection to interested clients. This also covers inspections asked on a voluntary basis by various stakeholders (e.g. the builder, the occupant, a social housing company, the manufacturer of the ventilation unit, an insurance company, etc.) outside of an organised overall framework. In a defined framework, voluntary inspection in a defined framework can for example be applicable as one criterion to get subsidies or incentives.	*Advantages:* Less concern about reaction of the market. Can be more flexible in time but also for types of buildings covered. *Drawbacks:* Risk of no interest from the market, so no effect at all. Can become price-driven. Bad systems may stay out of sight Probably slow evolution to higher quality Can be selective on criteria and highest risks may be overseen	

Annex 2 – Considerations regarding legal boundary conditions for the implementation of inspection schemes

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Introduction

This document provides an overview of legal provisions that may have an impact on the implementation of an inspection framework. The document is written in the context of the EPBD 19a feasibility study on the inspection of stand-alone ventilation systems but its application is broader than the inspection of such stand-alone ventilation systems.

A number of questions are raised which must be asked and answered before an inspection framework is legally imposed. Some questions are fundamental and must be answered by the authorities imposing the framework; others can be answered by other parties. But there should be an *inspection scheme* that defines the rules.

To avoid confusion about the word *inspection*, it is defined in this Annex as establishing characteristics of a ventilation system (e.g. by measuring, documentation, visual checks, etc.) and reporting these characteristics in a declaration by a qualified person. The declaration is traceable and can be used for evaluation of the ventilation system.

The implementation of an inspection framework comprises technical aspects (*what should be inspected, how it should be checked, how should it be measured and how should it be reported*) and organizational aspects (*who can do inspections and under which conditions*).

It is impossible to describe all the possibilities in this document: different models for inspection frameworks are possible. This ranges from self-declaration by the installer of the ventilation system over independent inspection by an accredited institution to inspection by the public authority (civil servants) itself.

We note that besides European legislation, account must also be taken of national and regional legislation in force in the Member State that is considering imposing an inspection framework. As this is country-specific, no concrete information can be given in this general document.

So most topics are described in general terms and limited to legal aspects of such a framework.

Major legal boundary conditions

In general, legislation that intervenes in the implementation of an inspection framework on stand-alone ventilation systems can refer to:

- accepted services (requirements on people, companies, methods, etc.) and products (measurement tools, fans, heat recovery units, ducting, vents, etc.)
- mandatory services (requirements on people, companies, methods, etc.) and products (measurement tools, fans, heat recovery units, ducting, vents, etc.)

Both the technical and organizational aspects of a ventilation inspection framework can be referred to in different legislations on different levels: primary EU legislation (EU treaties), secondary EU legislation, national and regional and local legislation.

An overview of the relevant legislation that can intervene in the development of inspection frameworks for stand-alone ventilation systems is given below.

Primary EU legislation

Primary EU legislation comprises the EU treaties. The EU treaties have been adopted and ratified democratically by all EU member states and they are binding upon them.

The EU treaties set out among others the EU objectives, the EU competences, the powers of and rules for EU institutions, how decisions are made and the relationship between the EU and the EU Member States.

The EU competences are limited to what is expressly stated in the EU treaties. If a policy area is not cited, the EU institutions lack the competence to propose and adopt legislation in that area.

An overview of the different treaties can be found at: https://europa.eu/european-union/law/treaties_en.

The Treaty on the Functioning of the European Union (TFEU)

The TFEU (https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:14016ME/TXT&from=EN) contains several provisions that may impact the creation and implementation of an inspection framework for ventilation systems.

Article 34 TFEU (free movement of goods)

The imposition of an inspection framework or a reference to a voluntary system in EU Member State legislation or regulations is subject to the general principle of free movement of goods within the EU.

According to this principle, EU Member States are forbidden to take public measures that constitute an obstacle to this free movement. For example, a statutory requirement to use a given voluntary system, so that the voluntary system becomes mandatory, will be an obstacle to the free movement of goods.

Before EU harmonisation legislation has been adopted, a barrier may be justified if (i) it is necessary to achieve a legitimate aim (those stated in article 36 TFEU, e.g. the protection of the safety or health and life of humans) and (ii) it does not go beyond what is necessary to achieve that aim. The Court of Justice of the EU has not accepted the application of these exceptions in the case of restricting the free movement of construction products by mandatorily requiring a national voluntary system on construction products.

Also, there will be no obstacle to the free movement of goods if the EU Member States provide for the possibility of accepting equivalent voluntary schemes from other EU Member States, and the equivalence assessment is carried out on the basis of a useful and clear procedure (principle of mutual recognition).

After EU harmonisation legislation has been adopted, obstacles to the free movement of goods will have to be in accordance with the rules laid down in the harmonisation legislation.

Articles 46, 49-33 and 36-64 TFEU (free provision of services and right of establishment)

By analogy with the free movement of goods, EU Member States must also refrain from impeding the free provision of services and the right of establishment. This is provided for in the abovementioned articles of the Treaty. See also: http://www.europarl.europa.eu/factsheets/nl/sheet/40/vrijheid-van-vestiging-en-vrij-verrichten-van-diensten

Article 101 TFEU (prohibition of anticompetitive agreements)

When organising and applying an inspection framework, private companies must always comply with the prohibition of anti-competitive agreements, as set out in article 101 TFEU.

Article 101 TFEU, as explained in more detail by the European Commission in among others the Guidelines on horizontal cooperation agreements, provide guidance for the competition assessment as it may be applicable to the creation and implementation of an inspection framework for ventilation systems.

Practically speaking, if private actors set up an inspection framework, at least the following principles must be taken into account:

- There must be no anti-competitive object (e.g. deliberate discrimination or exclusion of products from certain manufacturers, market sharing or price fixing.
- Any anti-competitive effects must be proportionate to the objective pursued. Such proportionality can be achieved by allowing all interested parties to participate in the development of type specifications, by making the development process transparent, by making the technical regulations voluntary and by allowing access to the standard on fair, reasonable and non-discriminatory terms (FRAND access). If there is only limited participation, the potentially negative effects can be eliminated or at least reduced by ensuring that stakeholders are informed and consulted on the ongoing work.

Secondary EU legislation

The TFEU is implemented by means of secondary EU legislation, i.e. regulations, directives, decisions, etc.

Construction Products Regulation - Regulation (EU) No 303/4011

Public authorities must respect the specific rules applicable to the free movement of construction products, and in particular the CE marking. CE marking ensures that the actual performance of the product corresponds to the certified performance.

According to the Construction Products Regulation, voluntary schemes may only cover essential characteristics of construction products which are not covered by a harmonised standard. Practically speaking, this means that the potential scope of voluntary systems that cover essential characteristics of construction products is limited to characteristics that are not covered by a harmonised standard (or European Technical Assessment).

Services Directive - Directive 4006/143/EC

The aim of the Services Directive is to ensure that EU service providers can establish themselves freely in any EU Member State or provide services in those Member States on a temporary basis.

If an EU Member State includes a reference to a voluntary system in its laws or regulations, this may make it more difficult, or even impossible, for service providers from other EU Member States to offer their services. If so, such a reference constitutes an obstacle to the free movement of services. That being said, provided certain conditions are met, laws or regulations can be envisaged that would make it possible for such service providers to submit equivalent national certification or accreditation.

Directive on the recognition of professional qualifications – Directive 4003/36/EC

This directive may apply to persons active in the inspection of ventilation systems. In this case, it must be taken into account that the qualifications of persons must be mutually recognised between the EU Member States (see: https://ec.europa.eu/growth/single-market/services/free-movement-professionals/qualifications-recognition_en).

General Data Protection Regulation (GDPR) - Regulation (EU) 4016/679
The implementation of inspection frameworks must take account of applicable privacy and data protection legislation.

Generally speaking, an inspection framework will require the creation of databases containing information:

1. Personal data of inspectors
2. Personal data of persons being inspected
3. Details of the ventilation system subject to inspection. It is very likely that personal data will also be processed here, e.g. address, personal data of the owner of the system.

The storage and processing of these data, information about these databases, data retention period, accessibility of data, precautions to protect these data, etc. must be in accordance with applicable laws and regulations.

Eco-design requirements for ventilation units - Regulations 1433/4014 and 1434/4014
Although these regulations are not making reference to inspections on the installed ventilation units, some aspects may have an influence on the inspection of stand-alone ventilation systems.

More information can be found on:

https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/energy-efficient-products/ventilation-units_en

Renewable energy directive – Directive 4018/4001
Although the renewable energy directive is not referring to ventilation systems, it might be a source of inspiration for inspection frameworks on ventilation systems, especially annex 4, which describes the certification requirements for installers. More information can be found on:

https://ec.europa.eu/energy/intelligent/projects/en/projects/qualicert

https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:34018L4001&from=EN

EPBD directive – Directive 4010/31 amended by Directive 4018/844
This study is made within the framework of this directive.

National and regional laws and regulations, including public procurement

Because national and regional law and regulations may intervene in the development of an inspection framework, an analysis of such laws and regulations, as they may apply to the inspection framework in the Member State concerned will be required.

For example, legislation about ventilation and indoor air quality may exist in different domains. Also, there may be requirements on ventilation systems in EPB-regulation and regulations with threshold values for air quality in the workplace and in homes. These may be defined in another way, e.g. some requirements may be defined in minimum air flows per space or per person in the room, or maximum ppm of a certain substance in the air in the room. Clearly, such regulations may impact the technical requirements for the ventilation systems.

Ventilation systems will generally contain a ventilation unit, which is an electric device. Specific rules for working on electric devices may apply in labour law, and these may have an impact on the qualification of inspectors in the inspection framework.

As discussed below, authorities may decide to delegate the creation and/or implementation of an inspection framework to private parties.

When a private party is asked to supply services to the authorities, the public procurement and/or concession legislation applies to the selection of that party, with various conditions applying to the selection of the successful candidate.

Further to the implementation of the applicable EU rules, in Belgium, for example, the following applies (Table 1).

Criteria	Open procedure	Restricted procedure	Competition procedure with negotiation	Competitive dialogue	Innovation partnership	Negotiation with publication	Negotiation without publication
Always applicable?	Yes	Yes	No	No	No	No	No
Requires notice?	Yes	Yes	Yes	Yes	Yes	Yes	No
Preselection?	No	Yes	Yes	Yes	Yes	No	No
Deadline for participation	NA	30d.	30d.	30d.	30d.	NA	NA
Deadline for quotation	33d.	30d.	30d.	"appropriate period"	"appropriate period"	44d.	NA
Award criteria	Free choice	Free choice	Free choice	Price/quality	Price/quality	Free choice	Free choice
Minimum number of candidates	NA	3	3	3	3	NA	NA
Maximum thresholds (EUR)	NA	NA	144000-449000	NA	NA	144000-449000	144000

Table 1: Schematic overview of award procedures in Belgium

In the framework of these procedures, a number of general principles apply:

- Equal treatment. This means, among other things, that the public authorities must give adequate publicity to the award and award of a concession, so that interested companies can participate in the procedure on an equal footing.
- Competition. Neither the granting authority nor the prospective concessionaires may infringe competition law in the context of the procurement procedure. The Member State may not issue a concession with the aim of artificially restricting competition between

potential concessionaires. This means that the government may not draw up the selection criteria and technical specifications with the (underlying) aim of unduly favouring or penalising certain entrepreneurs or works, supplies or services. On the other hand, potential licensees are not allowed to enter into agreements that could distort the normal conditions of competition (e.g. agreements with other potential licensees on the bids or requests to be submitted).

- Conflicts of interest. The placing and execution of concessions must be free of conflicts of interest. A conflict of interests is any situation in which an official involved in the placement or implementation, directly or indirectly, has financial, economic or other personal interests which could compromise his impartiality and independence.
- Prior involvement. The prospective concessionaire who has informed or advised the tenderer, or who has otherwise been involved in the preparation of the concession or its award procedure, may be excluded from the procedure if adequate means to ensure compliance with the principle of equal treatment are not available. The appropriate means are in place: (i) the communication to the other candidates of relevant information exchanged in the context of or as a result of the candidate's involvement in the preparation of the procedure, and (ii) the setting of appropriate time limits for the receipt of tenders. The tenderer may exclude the prospective concessionaire only if the problem cannot be remedied by less far-reaching measures; the exclusion must be regarded as a last resort sanction.
-

Organisation of inspection frameworks

An inspection framework for ventilation systems consists of several parts, to which different rules apply. The following parts can be distinguished:

- Technical requirements for the ventilation system itself,
- Requirements for the inspection on this system,
- Requirements for the auditing of inspectors and inspections,
- Requirements for treatment of findings during the audit, in particular the handling of non-conformities found during audits and inspections,
- Requirements on communication of the results of the inspection framework.

- Technical requirements for the ventilation system. Strictly speaking, these are not covered by the inspection framework, but they are necessary to assess compliance, to establish what needs to be checked and worked out. For example, it is not necessary to specify the minimum flow rates to be achieved in the inspection framework, but the fact that there are minimum flow rates to be achieved does mean that the inspection framework must stipulate that the flow rates must be measured, so that it can subsequently (possibly outside the inspection framework) be assessed whether the flow rates meet the minimum requirements.
- Requirements for the inspection. This comprises requirements for the execution of the inspection, e.g. inspection checklists, requirements for flow measurement, the tools that must be used, the interpretation of measurement, duration of the inspection.
- Requirements for the auditing of inspections. For certain models of inspection schemes, there are also operational requirements for auditing the inspectors, e.g. the auditing rate, the distribution of audits (e.g. over different types of systems, over installers, geographical distribution, etc.), the type of audit: desktop (e.g. design, completeness of report) or on-site audit, the purpose of the inspection: correct reporting or correct functioning systems, etc.
- Requirements for the handling of non-conformities found during audits and inspections. This includes rules for enforcement, namely corrective actions on the dossier (correct

report, correct functioning ventilation system), corrective actions for the process of inspection (fees, higher inspection rate, correction of the non-conformity, avoiding that incorrect inspection reports are published) and determining the cause of non-conformity (which is important for imposing the corrective action and fee).

- Requirements on communication. This includes communication to the authorities, to the stakeholders about the results of inspections and audits, enforcement, effectiveness of the inspection framework.

  These requirements are organised on different levels. A distinction must be made between:

  - the authorities, who are formulating the requirements on the inspection framework in a general way,
  - the scheme owner, who is defining the rules of the scheme. In principle, there should be only one scheme owner for an inspection framework,
  - the organizer of the scheme, who is putting the rules of the scheme into actions: certifying inspectors, organizing enforcement, controlling the operators, etc.
  - the operator, who is managing the audits of the inspections, in principle under mandate of an organiser,
  - the inspector, who is doing the inspections.

  The authorities can delegate actions at different levels, so that many different models can be imagined depending on the goal of the inspection framework (e.g. energy saving, guarding indoor air quality, guarding indoor environment quality), the level of control and effort that can be justified by the authorities.

  Depending on the model chosen, it may be not necessary to have all levels present. For example, if a model is chosen in which the inspections are done by accredited inspection bodies, an operator doing audits on the inspections may be less relevant. On the other hand, in a model in which the installer of the ventilation system is doing the inspection (a self-declaration model), audits on this installer will be necessary and the operator will have a prominent role and will very likely be an independent party.

Below we elaborate three options for organising the inspection framework. In so doing, we assume that:

- the rules of the inspection framework have been clearly set (the scheme owner is known and the scheme is developed); and
- the inspections are performed by private parties which must be motivated by the organiser to make reliable reports of the inspection framework.

Inspection framework organised by the public authority itself

The first option is that the organisation of the framework is not delegated. In this case, the public authority organises the inspections itself on the basis of the rules of the inspection framework. Inspections could be carried out by civil servants or private parties.

All the requirements set out above must be adopted and complied with by the public authority, requiring a serious human resources and time effort on its part.

Whilst the rules will be very clear in this case and little interpretation will be possible, it will not be easy to revise them, as this will require legislative or regulatory action.

The treatment of non-conformities found during audits and the consecutive enforcement will have to be very strictly defined and executed.

Links with other databases that are also managed by the public authority should be possible in a smooth way, because all databases are managed by the same party that must comply with all legal requirements.

Inspection framework organised by a designated private party

A private company (the organizer) receives an extensive unique assignment from the public authority to create and implement the inspection framework. The organiser is solely responsible for the qualification and audit of the inspectors. In addition to the organiser, other private companies may be active at the downstream level of the inspections.

A public authority may, in accordance with EU and national law, award a unique contract to a private company for the provision of services on the basis of a concession or a public contract. A third option is to award a contract via an authorisation scheme. In this chapter, only the public contract and the concession are mentioned, the authorising scheme is discussed in the following section, in which is discussed how the inspection framework can be organized by several private parties.

The fundamental difference between a public contract and a concession is that, in the case of a public contract, the operating risk does not pass to the organiser of the inspection framework. The consideration does not consist of the right to exploit the services but of payment of the price indicated in the tender.

An overview of the main differences between a concession and a public contract is given in Table 2.

The public authority has the free choice of awarding the organisation of the inspection framework either through one or the other option. The public authority may decide to award individual contracts, e.g. qualification of inspectors, execution of audits, writing of the scheme. In all cases, candidates must submit an offer that meets the requirements imposed by the public authority on the organisation of the inspection framework. The selection of a credible party can take place on other criteria than cost alone (most economical offer) and include quality criteria (best price/quality offer).

	Concession	Public contract
Operating risk	Concessionaire	Contracting authority
Consideration	Operation of service (possibly + payment of the price	Payment of the price
Duration	Limited in time (in principle max. 3 years)	Limited in time (in principle max. 4 years)
Choice of procedure	The contracting authority is free to organize the procurement procedure, provided that transparency, equality and fair competition are respected	The contract is awarded on the basis of the price, the costs and/or the best price/quality ratio
Award criteria	Free choice of tenderer, provided that it is objective, non-discriminatory and transparent	Most economically advantageous offer based on price, costs and/or the best price/quality ration
Public services	Specific rules: changeability, continuity, equality of use, language laws	No specific rules
Other	Analogue rules regarding fair competition, conflicts of interest, previous involvement, grounds for exclusion, legal protection, subcontracting, concession/contract modification, ex-officio measures, unilateral termination	

Table 2: Concession versus public service contracts

The public authority can determine what this party has to develop for the scheme and therefore has a great deal of control over the rules of the inspection framework, without having to lay down all the details in legislation. Depending on how strict the conditions that are drawn up for the organiser are, the implementation and adjustment can be done in a flexible way.

The designated party shall enforce the inspection framework on a case-by-case basis in accordance with the overall framework laid down by the public authority, based on its expertise. The public authority has a great deal of control over this.

Inspection framework organised by different private parties

The public authority may also choose to have the organisation of the inspection framework carried out by different parties. This third option is likely to be based on an authorisation scheme, so that any company that is eligible for an authorisation can obtain it from the public authority. The authorisation scheme allows a public authority to organise an inspection framework based on the competition between the authorised organisers

An authorisation scheme must be based on objective criteria which are proportionate to their objective and applied in a non-discriminatory manner. This means that they must be made public in advance, transparent and accessible.

In this case, the conditions met by the organisers must be clearly defined and sufficiently detailed to ensure a level playing field at the level of the organisers of inspection frameworks. For the elements for which no rules have been drawn up, differences may arise between the various parties, which may have an impact on the realisation of the objectives of the inspection framework.

Public authorities must, where appropriate, put in place internal regulations and processes to ensure that these private companies carry out their tasks properly. The public authority therefore has a strong supervisory role if various private parties organise the inspection framework.

The fact that there are different operators may mean that there are different databases, which could make the exchange of data a problem.

It is also possible to admit several organisers via a concession.

Summarising table

	Public authority	Designated public contract	Designated concession	Authorization scheme
Charge for public authority	Very high[4]	Depending on the level of detail	Depending on the level of detail	Substantial[5]
Supervision on private party	NA	Necessary, can be low	Necessary, can be high	High
Control of public authority on outcome of framework	Complete[6]	Very high	High	Can be challenging[7]
Legislations/regulations	Necessary	Not necessary[8]	Not necessary	Might be necessary[9]
Flexibility in implementation	Limited[10]	Might be	Might be	Very limited[11]
Challenges for appropriate level playing field	NA	No – only 1 party	No – only 1 party	Major[12]
Cost optimisation	NA	Stimulation	Stimulation	Competition
Enforcement	Strict	Strict if defined	Strict if defined	Difficult
Possibility to link to EPC	Yes	Yes, if defined in offer	Yes, if defined in offer	Yes, if defined in conditions

Table 3: Comparison of various schemes

4 The public authority has to take care of all aspects, including legislation and regulations, operational procedures, personal, enforcement, financing, …
5 It is very important that the public authority defines a clear level playing field in order to guarantee equivalence between the various parties. The public authority is also in charge of assessing compliance by the various parties.
6 The public authority is in control of all aspects of the inspection.
7 A full definition of the requirements to be met by the various parties is challenging. Also the follow up might require substantial efforts.
8 There is no need for specific legislation.
9 The requirements to be met by the various parties probably have to be part of specific legislation.
10 In general, administrations have to follow the legal rules very strict with limited margin for interpretation.
11 It is important that the different players have to respect the same rules.
12 It is not evident to define from the start all relevant aspects to be met by the various parties. In case further refinements in the requirements are needed, it may require a long legal process.

Specific aspects

What can be the role of accreditation?

Accreditation can play a role in 3 different ways:

- Option 1: Bodies accredited to carry out inspections in accordance with EN ISO/IEC 17040[13] may be appointed;
- Option 4: Bodies carrying out inspections may be supervised by a body accredited to certify services in accordance with EN ISO/IEC 17063[14];
- Option 3: Inspectors may be certified by a body accredited to certify persons in accordance with EN ISO/IEC 17044[15].

Option 1: If the organisations that carry out inspections must be accredited as an inspection body, a number of concerns that public authorities may have when carrying out inspections on ventilation systems are covered by the accreditation. This requirement does not conflict with EU legislation, as the accreditation rules are clear and transparent and institutions can be accredited in any EU Member State. The scheme to be followed may be country-specific. In practice, it does not appear to be easy to impose this requirement, as the inspections are usually carried out by small organisations that are not eligible for accreditation because of the scope of the accreditation procedure.

Option 4: A second option is to require the organiser of the inspection framework to have an accreditation in accordance with EN ISO/IEC 17063. The organisation of an inspection framework is not in itself accredited, as there are no specific standards in this area. The organisations that carry out the inspections are then certified for the services they provide, i.e. an inspection of the ventilation system. That in itself may be accredited as a certification of a service. However, due consideration must be given to the confidentiality that exists between the certified (i.e. the inspector) and the certifying body (the organiser of the inspection framework), because the standard imposes certain conditions on the exchange of information with third parties (including the public authority).

Option 3: A third alternative is that it also be required that the persons carrying out inspections are certified by a body accredited for the certification of persons. Again, there should not normally be a problem with the free movement of qualified persons, provided that the certification scheme to be followed is public and transparent and that the public authority also accepts equivalent certificates from foreign accredited bodies.

What can be the role of laboratory results?

Some components of ventilation systems do not require on-site measurements, on the one hand, because the data can be measured by laboratories (e.g. the flow rate of a fixed length ventilation grille) and, on the other hand, because it is impossible to determine the performance of the component on site (e.g. the efficiency of a heat exchanger).

In such cases, it may be sufficient to establish on-site that the component is present and correctly positioned (and connected). However, a clear identification is required (e.g. brand,

[13] EN ISO/IEC 17020 – Conformity Assessment – Requirements for the operation of various bodies performing inspection
[14] EN ISO/IEC 17065 – Conformity Assessment – Requirements for bodies certifying products, processes and services
[15] EN ISO/IEC 17024 – Conformity Assessment – General requirements for bodies operating certification of persons

type, article number and length) and the performance must be traceable on the basis of the findings.

Access to company premises and private homes

Company premises and private homes can only be entered if permission for such entry is granted. This can and must be arranged contractually.

Coupling with energy performance certificates or building passport

When personal data are exchanged because the database of the EPC or the building passport is not managed by the party that carries out the inspections and/or audits, the exchange is subject to compliance with the privacy legislation.

FAQ

Can a public authority outsource the organisation of the inspection framework to a private company?

Yes. It may choose to outsource all aspects (establishment of the scheme, organisation of the framework, organisation of the audits, organisation of the qualification of inspectors, etc.) or one aspect to one or more private parties.

Can the development of e.g. the scheme of the inspection framework be granted on an exclusive basis to single party?

Yes, provided the applicable public procurement or concession legislation is complied with, see section "Inspection framework organised by a designated private party".

Is it necessary to have different private parties involved on a certain level in the framework, e.g. for carrying out inspections?

No. However, the public authority must ensure that the various eligible candidates are informed that there is a request to set up an inspection framework and that they are treated equally when submitting a tender. It is up to the public authorities to choose the tenderer submitting the best/most economically advantageous tender.

Can all levels of the inspection framework be assigned to one and the same private party?

Yes, this is possible as long as the applicable regulations are followed. It is not necessary to split up between the different levels. The development and organisation of an inspection framework can be tendered as a whole. The boundary conditions should be clearly communicated to interested parties.

Can different private parties perform the same tasks within the inspection framework?

Yes, that is possible. This is likely to be possible for very specific tasks (e.g. setting up qualifications for inspectors, carrying out audits according to a specific checklist), but the organiser will have to ensure that the rules are clear and that these parties have a supervisory role.

Should the public authority always select the cheapest provider for a particular task in the inspection framework?

No, that is not necessary. Other elements may also be taken into account, but this must be communicated clearly and transparently to the candidates for the task when the tender is published. In a public tender, the cost price will always be an important argument.

Could the authorities refer to existing voluntary schemes in order to introduce a mandatory inspection framework?

Yes, that is possible, but under strict conditions, which vary depending on the context and on whether there is harmonisation legislation.

Before harmonisation, the principle of mutual recognition requires that the EU Member States must provide for the possibility to use equivalent voluntary market initiatives from other Member States. A reference to a national voluntary scheme will therefore be possible only if the public authority provides a useful and clear procedure on the basis of which voluntary systems from other EU Member States can be accepted (this does not constitute an obstacle to free movement).

After harmonisation, any exception to the free movement of goods, the provision of services or the right of establishment must comply with EU secondary legislation, including the Construction Product Regulation or the Services Directive.

In the context of public procurement, a public authority is entitled to refer to a national voluntary system to prove compliance with the technical specifications set by the public authority, provided that any candidate can use equivalent systems.

When referring to voluntary labels, owned by private actors, care should be taken with property rights, in particular copyrights on published documents.

PART 4

SELECTION OF POLICY OPTIONS FOR INSPECTIONS OF STAND-ALONE VENTILATION SYSTEMS AND ANALYSIS OF RELATED POTENTIAL IMPACTS

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Executive Summary

A technical study has been contracted by the Directorate-General for Energy of the European Commission to a consortium formed by INIVE and BPIE, whose aim is to provide technical support on the possibilities and timeline for introducing:

- the inspection of stand-alone ventilation systems in buildings and
- an optional building renovation passport.

This work is linked to the requirement of Article 19a of Directive 2018/844 that the Commission must carry out a feasibility study on these two topics before 2020.

Concerning the inspection of stand-alone ventilation systems, the technical study should assess the relevance and feasibility to introduce EU provisions, e.g., the development or improvement of technical standards, guidelines and practices, or the possible extension of the mandatory regular inspection requirements of the EPBD to ventilation systems.

The objectives are to deliver:

- an analysis of the stock of ventilation systems in EU buildings and its foreseen evolution;
- a review of existing regulations, schemes, guidelines and standards on the inspection of ventilation systems, and other relevant initiatives and projects;
- an investigation of the relevance and feasibility of further promotion of inspections of stand-alone ventilation systems and an exploration of the possible approaches.

This report addresses the third objective. Six options have been defined and are described in detail. They cover both legislative and non-legislative measures, and include three options concerning mandatory inspection, one option concerning voluntary measurement of indoor air parameters, and two options that include other measures than inspection (awareness raising of stakeholders and training of installers).

The objectives and the methodology for the analysis of the potential impacts of these 6 options are described. Results of the impact analysis calculations are presented and analysed.

All options show, to a greater or lesser extent, a positive contribution to the improvement of the indoor air quality (IAQ), while at the same time increasing the energy consumption for ventilation. This is due to the assumption that, based on several publications analysed in a separate report[1], actual building ventilation is on average too low for achieving good indoor air quality and that all of the options should contribute to an increase in air flow rates. Nevertheless, the choice for implementing these options should also take into account the cost of poor IAQ on health, impact on productivity, and other factors.

It is not evident to rank the various options in terms of priority; they could be implemented consecutively, by looking at societal support in case of a mandatory implementation.

The direct impact of stakeholder awareness raising might be limited but is essential for achieving the societal support for implementing other options. Moreover, awareness raising campaigns can contribute to the decision to implement IAQ or ventilation requirements in countries which do not have such requirements.

Inspection schemes can be implemented with various sub-options. An interesting alternative to inspection can consist in defining indoor air quality requirements. Inspection and/or IAQ requirements might be a strong driver for the development of innovative systems.

[1] *Feasibility Study EPBD19a - Stock of ventilation systems in EU buildings and foreseen evolution for 2030, 2040 and 2050 – June 2019*

1. Introduction

1.1 Context

The publication, on 19 June 2018, of Directive 2018/844 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency, represents the first major step towards the implementation of the Commission's Clean Energy for all Europeans package.

Article 19a includes the requirement for the Commission to perform, before 2020, a feasibility study to clarify the possibilities and timeline for introducing two aspects in order to improve buildings' energy performance:

- the inspection of stand-alone ventilation systems and
- an optional building renovation passport.

This technical study is contracted to a consortium formed by INIVE and BPIE who, together with a broad range of experts in the required fields, provide technical support to the Directorate-General for Energy of the European Commission for investigating the different elements covered by the feasibility study mandated under Article 19a of the amended EPBD. This technical study is coordinated by INIVE EEIG and runs from 19 December 2018 until 18 December 2019.

The first part of the technical study assessed the relevance and feasibility to introduce EU provisions (legislative and non-legislative) 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.

In this study, stand-alone ventilation systems are defined as ventilation systems whose sole function is to ventilate a building.

1.2 Overall objectives

The objectives regarding inspection of stand-alone ventilation systems were to deliver:

- an analysis of the stock of ventilation systems in EU buildings, including their technical characteristics, the distribution systems and foreseen evolution of the stock; a report previously published provides this analysis[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; a report previously published provides this review[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.

The third objective has been partly covered by a previous report[4] that provides a description of a broad range of options for possible approaches at EU level for the inspection of stand-alone ventilation systems in buildings, including non-legislative and legislative options, and combinations of both.

The current report, prepared by INIVE-CETIAT, INIVE-BBRI and the University of Ghent, also relates to the third objective.

[2] *Feasibility Study EPBD19a - Stock of ventilation systems in EU buildings and foreseen evolution for 2030, 2040 and 2050 – June 2019*

[3] *Feasibility Study EPBD19a – Existing regulations, standards and guidelines on the inspection of ventilation systems, and other relevant initiatives and projects – June 2019*

[4] *Feasibility Study EPBD19a - Analysis of the relevance, feasibility and possible scope of measures for the inspection of stand-alone ventilation systems - September 2019*

It provides:

- a detailed description of the most feasible and relevant approaches to the inspection of stand-alone systems at EU-level;
- an analysis of their potential impacts towards 2030, 2040 and 2050.

1.3 Methodology

Preparing this report relied on the following tasks:

- the identification, in concertation with the European Commission, of six policy options to be further analysed, taking into account the description of a broad range of possible approaches from a previous report1 and the stakeholders' views from the first stakeholders' meeting (June 2019);
- the detailed description of the selected policy options and some of their variants, especially the description of the technical and organisational aspects, the legal and economic aspects, the stakeholders involved and their role, etc.;
- the analysis of their advantages and drawbacks, including suggestions of a possible timeline for implementing them;
- the setting-up of a model to evaluate the impacts of the policy options considered, for different ventilation systems and their stock, and taking into account their different defects and the ability of the policy options to correct these defects;
- the implementation of this model into a calculation tool;
- a series of calculations to analyse the impacts of the policy options considered towards 2050.

The policy options whose potential impacts were to be analysed have been briefly described in a separate report[4] and are:

Option 1: Better knowledge about the status on the ground in combination with awareness raising of stakeholders

Collection of data on stocks, markets and actual performances of installed systems. Information to stakeholders and consultation on possible actions to improve performance.

Option 2: Professionals' skills increase through training programmes

Implementation of a mandatory training of installers leading to the certification of installation companies.

Option 3: Visual inspection of stand-alone ventilation systems

Mandatory initial visual inspection of new ventilation systems in buildings after their installation, performed by qualified companies.

Option 4: Inspection of stand-alone ventilation systems with measurements

Mandatory initial inspection of new ventilation systems in residential buildings after their installation, performed by qualified companies, including measurements of air flow rates at room level and fan(s) electrical power input.

Option 5: Inspection of stand-alone ventilation systems with measurements and the obligation to make the system compliant

The same as option 4 with the obligation to make the ventilation system compliant within a certain timeframe if the inspection shows non-compliance. Inspection must be repeated after corrective actions to check compliance.

Option 6: Indoor air quality requirements

Mandatory maximum values of an indoor air quality indicator in buildings with employees. Measurement of indoor air quality parameters by an independent certified inspector can be asked by employees and/or employer, and a report is provided to the employees and employer. Corrective actions rely on further initiative of the employer.

Note: in the current report, the definition and field of application of option 6 is revised in order to cover residential buildings, thereby allowing comparison with the other options (see section 2.6).

2. Detailed description of the six options

Data related to the stock and sales of ventilation systems from a previous part of the study[2] showed that 93% of stand-alone ventilation systems are installed in residential buildings. Based on this, the options described here below, the analysis of their impact and the calculation approach focus on residential buildings.

Consistent with the finding during a previous part of the study[3] that existing regulations and guidelines mainly relate to initial inspection, it has also been chosen to estimate the impact of the different options for new stand-alone ventilation systems installed in new or renovated buildings.

However, the various options could also be applied to existing ventilation systems, i.e., systems already installed for a while (see section 5.10).

With some adaptations, the options could also be applied to non-residential buildings, especially in the case of small buildings, even if other instruments exist to ensure that these systems operate correctly, such as energy service companies, commissioning and maintenance contracts, building automation and control systems, etc. For large non-residential buildings, the definition of the options should probably be adapted.

Systems in non-residential buildings were not chosen for the impact analysis because there are few available data on the distribution of their stock between different types, and also because the impact of the different options would depend to a very large extent on the type of building, the size of the system, the way it is operated and controlled, etc. These limitations do not allow a quantification of the impacts of the selected options for systems in non-residential buildings in the framework of this study.

2.1 Awareness raising (option 1)

2.1.1 Description of the reference case for impact analysis

This option includes the following actions, managed or encouraged by public authorities:

- collection of data about the national stocks and markets per type of building and type of ventilation system[5];
- surveys on actual performances of installed systems, focusing on air flow rates, energy efficiency (electrical consumption or power input), acoustics and hygiene of the system;
- information to stakeholders about the findings of the two previous points;
- consultation on possible actions to improve performance (air flow rates, energy efficiency, acoustics, hygiene).

2.1.2 Motivation for considering this option

Users and owners can play an important role in the quality of operation of stand-alone ventilation-systems, e.g.: by performing themselves some maintenance operations (for example cleaning of air exhausts terminals); by being able to identify operation defects, if their understanding of the role and architecture of the ventilation system is

[5] *For the types of ventilation systems, the list in Annex 2, section 3.1.2 can be used.*

sufficient; and by avoiding inappropriate interventions on the system. Increasing users/owners awareness can contribute to maintaining the performance of ventilation systems.

Communication towards professionals can contribute to improving their knowledge/know how, and thus improving the quality and performance of ventilation systems. In addition to disseminating findings on the stock, market and actual performances of the installed systems, communication can also promote best practice, installation and maintenance guidelines, self-check procedures, etc.

It is important that policy makers are informed about the important role of building ventilation and the current status of the operation/defects of installed ventilation systems.

This option is in particular important for countries which at present have little information available about the status on the ground

It is very difficult to find societal support for inspection schemes as described in options 3 to 6 if there is no clear evidence of the need for such schemes.

The potential impact of this option strongly depends on the reference situation in a given country:

- In a country with ventilation requirements for specific or all types of buildings, new and/or existing buildings, and/or buildings which undergo a major renovation:
    - awareness raising can highlight various aspects, e.g.:
        - although required, there might be a substantial share of buildings without a ventilation system;
        - for buildings with a ventilation system:
            - the actual airflow performances might be substantially different from the required performances;
            - there might be problems in terms of operation and maintenance;
            - there might be problems in other areas, e.g. acoustics.
- In a country without ventilation requirements:
    - awareness raising activities can provide a good picture of the indoor climate performances, the presence of ventilation systems, and others.

Potential impact:

- Awareness campaigns can motivate the whole chain of stakeholders (building owners, architects and designers, engineers, manufacturers, installers, building users) to pay more attention to the presence of ventilation systems which perform correctly.
- Awareness campaigns can result in stakeholders' request for governmental actions, e.g., to impose the installation of ventilation systems, to impose inspection of ventilation systems or similar measures, and/or to increase the type and level of requirements, e.g., on acoustical performances, or assessment of performances during the system's lifetime, etc.

2.1.3 Legal, economic and other aspects

There are no major legal issues in implementing this option. It must not lead to anti-competitive effect and personal data must be managed according to the General Data Protection Regulation.

The cost of the option can vary significantly depending on the effort and ways to collect data and operate surveys. The budget for communication can also vary significantly.

Such an option should probably be financed by public authorities or through research projects, but professional organisations could also contribute to the effort in kind or cash.

Monetising the benefits of such an option is very difficult. Its impact on the quality of the installed ventilation systems leads indirectly to an improved indoor air quality, with individual and societal benefits.

The stakeholders involved in the implementation of the framework are:

- the public authorities and/or organisations in charge of research, to decide, manage and coordinate the actions and disseminate the findings;
- professional organisations (system manufacturers, building contractors, installers, maintenance companies, etc.) or contractors, contributing to the collection of data and surveys
- stakeholders involved in the dissemination of the information;
- building owners and occupants participating to the survey.

This option would probably receive societal support. It does not directly stimulate nor create barriers to innovation.

There are no identified significant risks linked to this option.

2.2 Training (option 2)

2.2.1 Description of the reference case for impact analysis

This option consists of implementing a mandatory theoretical and practical training of installers, in order to increase the quality of their works and thus improve the performance of newly-installed stand-alone ventilation systems. This option also includes a mandatory certification[6] of installation companies based on training a certain number or share of their employees.

Training should have the objective that installation companies increase their skills on the design of ventilation systems and on the choice of components, the installation works and the commissioning, including measurements of air flow rates, electrical power input and hygiene of the systems. Training should be part of a process by which installation companies receive a certification by a third party for their ability to perform installation works.

2.2.2 Motivation for considering this option

Training improves installers' knowledge and know-how about the role, design, installation, commissioning and maintenance of ventilation systems. It helps them to improve their usual practice, correcting possible defects and thus contributes to improving the quality and performance of ventilation systems.

In certain countries, it is common practice that owners themselves install a ventilation system; obliging the use of a trained installer might reduce the societal support for such option in these countries. This concern does not exist with options 3 to 5, as the assessment is based on the performances obtained on site.

2.2.3 Legal, economic and other aspects

Training must be implemented by considering some legal issues: it must not create obstacles for EU service providers to establish themselves freely or provide services in any EU Member State. It must rely on mutual recognition of qualifications of persons in the EU Member States.

[6] *Certification is the procedure by which a third party gives a written assurance that a product, a process, a system, or a person conforms to specified requirements mentioned in the rules of the relevant certification scheme.*

The cost for implementing the option can vary according to the contents of the training. It also depends on the decision to use an already existing training framework or to fully develop a new one. The implementation phase requires the financial support of public authorities.

The cost for the training itself corresponds to a theoretical and practical training of some days (from 2 to 4), paid by the installation companies that want to get certified.

Monetising the benefits of such an option is not easy. Its impact on indoor air quality certainly provides a certain benefit to occupants, and more generally to the society. There might be an energy saving due to a better sizing, installation and operation of systems thanks to training, but this is not always the case. For example, if training leads to an increase in the systems' size compared to the usual practice without training, the energy consumption may increase (along with an improvement of the indoor air quality).

The stakeholders directly involved in such an option are:

- the installation companies and their employees;
- the training body(ies) with their trainers;
- the body(ies) that manage(s) and deliver(s) certificates to installation companies.

The stakeholders involved in the implementation and management of the framework are:

- the public authorities to implement the regulation which makes training mandatory;
- the body responsible for deciding on the contents of the training;
- the body performing training and qualification of trainers;
- the body that decides on the certification rules for installation companies.

Some of these actions can be combined under the responsibility of one stakeholder.

The minimum role for public authorities is to implement the regulation requiring mandatory training and to decide on the bodies that are mandated for the different aspects of the option (deciding on the contents of the training, training of trainers, qualification of training bodies and certification of installation companies).

Such an option can create a market differentiation between buildings with systems installed by certified installers and other buildings.

It is not evident that such an option would receive societal support: in some countries, installers already have to get several qualifications/certifications for the installation of different products, and they could consider this option a constraining measure. On the other hand, a mandatory training of installation companies would reassure customers.

This option does not seem to create barriers to innovation, except if the training does not consider all systems. It is therefore crucial that the training programmes are regularly updated to take into account innovative systems.

Defining this option according to thresholds (for example on the capacity of the system or on the ventilated floor area) does not seem necessary since residential systems represent a homogeneous group in terms of technologies, operating conditions and stakeholders.

There are no identified significant risks linked to this option.

2.3 Visual inspection (option 3)

2.3.1 Description of the reference case for impact analysis

Option 3 is a mandatory initial visual inspection of each new stand-alone mechanical ventilation system in a residential building, whatever the type and location of this building and the type of mechanical ventilation system.

Occupants should benefit from this inspection, whose aim is to focus on energy performance, air flow rates/air change and hygiene of the ventilation systems.

The inspection relies on a pre-established checklist of the points that must be visually inspected, covering completeness, cleanliness and hygiene of the components, the ductwork, the ventilation unit and filter(s), general state and good overall operation of the whole ventilation system.

Inspection can be performed, whatever the season, in an unoccupied or occupied building. Even if no measurement is performed, it must be possible to operate the system during inspection in order to check for example the right direction of air flows at air inlets / air outlets and the right direction of rotation of the fan.

Results of visual checks (usually binary answers such as yes/no) are listed in a report, based on the checklist used. This report is provided to the building owner and to a local, regional or national public authority. Both the building owner and the public authority keep the report for a certain period of time.

The inspection can be carried out by several types of operators, not only by independent inspectors/third party service providers, but also by system designers, installers, architects, building airtightness testers, persons in charge of the calculation of the building energy performance and property owners, provided that each of the operators has successfully completed a theoretical and practical training and got a qualification, i.e., the recognition by a third party of the ability to perform the visual inspection.

A surveillance of inspectors is organised through audits and sanctions are foreseen and implemented if inspection is not performed according to the rules.

The rules do not include specific action in case of non-compliance; defining and implementing corrective actions relies on further interaction between the owner and the installer or designer, and falls outside the scope of the inspection itself.

2.3.2 Motivation for considering this option

This option is likely to motivate all professionals involved, e.g., installers, manufacturers, designers, architects, to deliver compliant systems with good performance.

The option relies on a rather simple inspection approach, requiring only visual checks and avoiding the use of measuring instruments. This does not fully guarantee that air flow rates and indoor air quality are achieved, but contributes to improving the current situation, by limiting big installation mistakes that can currently be observed in many countries.

This option could be implemented as a result of option 1.

2.3.3 Legal, economic and other aspects

Such an option must be in conformity with the EU legislation and national, regional and local legislations:

- It must not create obstacles to the free movement of goods, and no obstacle for EU service providers to establish themselves freely or provide services in any EU Member State. It must not lead to anti-competitive agreement or effect, and must rely on mutual recognition of qualifications of persons in the EU Member States.

- Personal data must be managed according to the General Data Protection Regulation.
- National public procurement and/or concession laws must be followed for the selection of a private party that would be asked to supply services to the public authorities, like the qualification or audits of inspectors, the management of inspection reports, etc.

More details about these legal issues can be found in a previous report[7].

There is no estimation available on the time required for such an inspection. One hour in total (including the inspection and the preparation of the report but excluding time for travel) could be considered as a possible target for a single-family house.

Such an inspection is finally paid by the building owner. It can be invoiced directly to him, or be ordered by another stakeholder, the cost then being passed on to the building owner.

Although the impact of this option on indoor air quality clearly provides a certain benefit to occupants, and more generally to the society, monetising the said benefits is not simple.

The stakeholders directly involved in such an inspection are:

- the building owner or its representative;
- the operator of the inspection.

The stakeholders involved in the implementation of the framework are:

- the public authorities to implement the regulation which makes inspection mandatory;
- the body responsible for establishing the check-list (public authority, professional organisation, standardisation body, etc.) and probably also a template for the report; the recently published/updated standards EN 14134[8] and EN 16798-17[9] can be helpful to establish the check-list and the template;
- the body responsible for deciding on the contents of the training of inspectors;
- the body that decides on the qualification rules for inspection companies;
- the body that decides on the organisation of the audits of inspectors;
- the body that decides on the sanctioning rules for the inspectors.

The stakeholders involved in the management of the framework are:

- the local, regional or national public authority that will receive and keep the reports;
- the body(ies) that propose(s) theoretical and practical training to inspection operators;
- the body(ies) that manage(s) and deliver(s) qualification to inspection companies;
- the body(ies) that perform(s) audits of the inspectors;

[7] *Feasibility Study EPBD19a - Analysis of the relevance, feasibility and possible scope of measures for the inspection of stand-alone ventilation systems – September 2019 - See Annex 2 of this report: "Considerations regarding legal boundary conditions for the implementation of inspection schemes"*

[8] *EN 14134 (2019): Ventilation for buildings - Performance measurement and checks for residential ventilation systems*

[9] *EN 16798-17 (2017): Energy performance of buildings. Ventilation for buildings. Guidelines for inspection of ventilation and air conditioning systems (Module M4-11, M5-11, M6-11, M7- 11)*

- the body that decides on individual sanctions for inspectors that did not perform inspection according to the rules.

Some of the actions can be combined under the responsibility of one stakeholder.

The minimum role for public authorities is to implement the mandatory inspection, to receive and keep the reports, to decide on the bodies that are mandated for the different aspects of the implementation and management of the framework, and to follow up the overall operation of the framework.

Such an inspection creates a market differentiation between buildings with newly installed ventilation systems and other buildings.

It is not evident that such an inspection would receive societal support: this probably depends, on the one hand, on the awareness of building owners and occupants, and on the cost for owners, on the other. It also depends on the acceptance by installers for being controlled, especially in the case this inspection is provided by a third-party.

This option does not seem to create barriers to innovation, except if the checklist used does not allow inspecting all systems. It is therefore crucial that the inspection rules are regularly updated to take into account innovative systems.

Defining this option according to thresholds (for example on the capacity of the system or on the ventilated floor area) was considered as not appropriate: the skills, procedures and tools to operate visual inspection are the same for all types and sizes of systems in residential buildings, as well as for all involved stakeholders.

There are no identified significant risks linked to this option.

2.4 Inspection with measurements (option 4)

2.4.1 Description of the reference case for impact analysis

Option 4 is a mandatory inspection of each newly-installed stand-alone mechanical ventilation system in a residential building, including measurements.

Occupants should benefit from this inspection, whose aim is to focus on energy performance, air flow rates/air change and hygiene of the ventilation systems.

The inspection includes the visual inspection of the hygiene of the ductwork, ventilation unit and filter(s)[10], the measurement of air flow rates at room level (or pressures in case of demand-controlled ventilation), the measurement of air cross-section areas of air transfers between rooms and the measurement of fan(s) electrical power input.

The measuring instruments required are air flow meter (or manometer) and wattmeter, with a measuring uncertainty below a given threshold. They must be regularly calibrated by an accredited laboratory on a regular basis.

Inspection can be performed, whatever the season, in an unoccupied or occupied building. It must be possible to operate the system during inspection.

A report includes the inspection results compared to target values fixed by a regulation, a standard or guidelines. This report is provided to the building owner and to a local, regional or national public authority. Both the building owner and the public authority keep the report for a certain period of time.

The inspection can be carried out by several types of operators: independent inspectors/third party service providers, system designers, installers, architects, building airtightness testers, persons in charge of the calculation of the building energy performance and property owners, provided that they have successfully

[10] *This visual inspection is therefore lighter than the visual inspection of option 3.*

completed a theoretical and practical training and received the relevant qualification, i.e., the recognition by a third party on their ability to perform the inspection.

A surveillance of inspector is organised through audits, and sanctions are foreseen and implemented if inspection is not performed according to the rules.

The rules do not include specific actions in case the target values or the hygiene level are not met; defining and implementing corrective actions relies on further interaction between the owner and the installer or designer, and falls outside the scope of the inspection itself.

2.4.2 Motivation for considering this option

This option is likely to motivate all professionals involved, e.g., installers, manufacturers, designers and architects, to deliver compliant systems with good performance.

Because it requires measurements, this option secures compliance of air flow rates.

This option could be implemented as a result of option 1, or as an evolution of option 3.

2.4.3 Legal, economic and other aspects

The legal and economic aspects are the same as in option 3 (see paragraph 2.3.3).

The time required for such an inspection is mentioned in one of the existing guidelines[11]: it is estimated to range between 1.5 and 2 person days for an apartment building of 30 dwellings with a centralised unidirectional ventilation system, whereby the measurements are performed on a sample of the dwellings (at least the closest and the farthest from the ventilation unit)[12].

The stakeholders directly involved in such an inspection are the same as in option 3.

The stakeholders involved in the implementation of the framework are the same as in option 3. The body responsible for establishing the checklist must also define the measurement protocol. The qualification rules must take into account the ownership and the calibration of measuring instruments. The recently published/updated standards EN 14134[8] and EN 16798-17[9] can be helpful to establish the checklist, the measurement protocol, the measurement devices uncertainty requirements and a template for the report.

The stakeholders involved in the management of the framework are the same as in option 3. Two additional stakeholders are the producers of measuring instruments and the body(ies) that perform(s) the calibration of the measuring instruments.

The role of public authorities is the same as in option 3, as are the resulting market differentiation and the possible barriers to innovation.

As for option 3, it is not evident that such an inspection would receive societal support, especially taking into account its higher direct and indirect costs (see section 5.2.3 about the costs of an inspection scheme).

As for option 3, defining this option according to thresholds (capacity of the system, ventilated floor area, etc.) does not seem necessary, even if the measuring instruments used must be adapted to the size of the inspected system: the skills,

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[11] *CETIAT, PBC (France) - Diagnostic des installations de ventilation dans les bâtiments résidentiels et tertiaires - Guide pratique DIAGVENT – 2005*

[12] *The French document "Livre blanc de la ventilation – Acte 1" (www.batiment-ventilation.fr/a-propos/livre-blanc) gives the following values in € (excluding taxes, including travelling expenses) for France: 150 to 300 € for a single family house, 450 € for 3 semi-detached houses, 750 to 1500 € for a multi-family building of less than 30 apartments, 750 to 5000 € for a multi-family building of more than 30 apartments.*

procedures and stakeholders are similar whatever the size of the considered ventilation systems.

There are no identified significant risks linked to this option.

2.5 Inspection with measurements and compliance (option 5)

2.5.1 Description of the reference case for impact analysis

Option 5 is exactly the same as option 4 (see paragraph 2.4) with the additional requirement that the ventilation system is made compliant within a certain timeframe if the inspection shows non-compliance. Inspection must be repeated after corrective actions to check compliance.

This means that the report not only includes results of visual checks and measurements, but also a certificate stating compliance.

Sanctions should also be foreseen if the ventilation system is not made compliant within the given timeframe.

2.5.2 Motivation for considering this option

This option creates a very strong motivation for all professionals involved, e.g., installers, manufacturers, designers and architects, to deliver compliant systems with good performance. It also creates a motivation for owners to order a compliant system.

Because it requires measurements and compliance to target values, this option fully secures compliance of air flow rates.

This option could be implemented as a result of option 1, or as an evolution of option 4.

2.5.3 Legal, economic and other aspects

The legal and other aspects are the same as in option 4 (see paragraph 2.4.3). The recently published standard EN 16798-17[9] would also here be helpful to establish the advice for improvements.

The cost is increased in case of non-compliance since inspection must be repeated after corrective actions.

2.6 Indoor air quality requirements (option 6)

2.6.1 Description of the reference case for impact analysis

The reference scenario for option 6 covers a case with mandatory requirements about the maximum value of an indoor air quality criterion in residential buildings equipped with a newly-installed ventilation system. This criterion is, e.g., the maximum CO_2 concentration in bedrooms and living rooms.

The measurement of this indoor air quality parameter can be performed by occupants or requested by occupants to the owner, sometime after the installation of the ventilation system.

Measurements can be done for example with low cost analysers placed in the dwelling for some days. Such analysers usually have an internal self-calibration procedure, based on an assumption on what should be the level of the minimum measured value. Their measurement uncertainty can be high: therefore, measured concentrations higher than the threshold value should be allowed within a certain tolerance which should be mentioned in the mandatory requirements.

Possible corrective actions rely on further initiative of the occupant or owner, and fall outside the scope of the option itself. Nevertheless, the impact analysis assumes that this option has a market impact and that the performances will be improved, especially regarding indoor air quality.

2.6.2 Motivation for considering this option

As already mentioned, this option was initially considered for buildings with employees, where the measurement of indoor air quality parameters ccould be done either by employees or by an independent certified inspector, and a report is provided to the employees and employer. Corrective actions could then rely on further initiative of the employer or the building owner.

In this report, it was chosen to adapt this option to residential buildings, in order to be able to compare its possible impacts with those of the other options.

Even if this option could be considered as more adapted to non-residential buildings, the motivation to consider it for residential buildings is that it can be worth to focus on the consequences of the operation of the ventilation system, i.e., the indoor air quality. This consists in looking at the results (indoor air quality) from the point of view of the occupants, and not at the means used to get these results (ventilation system).

This makes this option rather simple in its implementation and management. In order to have a robust compliance and enforcement framework, it is important that the boundary conditions for the performance assessment are clearly specified (e.g., occupancy, weather conditions, allowed deviation for deciding on compliance, etc.).

The practical applicability of this option has substantially increased due to the availability of cheap sensors, IoT and data in the cloud. There are already systems on the market which continuously monitor the indoor air quality, and which regulate the ventilation systems as function of these measurements. Moreover, such systems can inform the occupants or the installer in case of problems or maintenance issues. It is expected that, on the longer term, such systems become the reference. For such systems, one could consider the development of an inspection scheme which would be fully based on data collected in the cloud in combination with random checks concerning the reliability of collected data.

2.6.3 Legal, economic and other aspects

Such an option must be in conformity with the EU legislation and national, regional and local legislations, and especially personal data must be managed according to the General Data Protection Regulation.

The cost of one CO_2 sensor or a sensor to detect volatile organic compounds ranges between 100 and 200 € and the price is expected to decrease if the market becomes bigger.

Monetising the benefits of such an option is not simple. Knowledge about the indoor air quality level can lead to its improvement, providing a benefit to occupants, and more generally to the society.

The stakeholders directly involved in such an inspection are the occupant, the building owner or its representative, and the manufacturer and provider of sensors.

The stakeholder involved in the implementation of the framework is a public authority for preparing and publishing the regulation on maximum indoor air quality criteria.

Such an option does not seem to create a market differentiation.

The societal support would probably be neutral. It is not evident that a lot of occupants would decide or ask for a measurement. It is also not evident that corrective actions would be implemented.

This option does not seem to create barriers to innovation.

Defining thresholds on the systems to be considered does not seem appropriate since the checked characteristic (indoor air quality) is independent from the size of the system.

The main risk is that this option is not much used and that conflicts occur about the results and the need and contents of the corrective actions.

3. Objectives and methodology of impact analysis

3.1 Objectives

The objectives of the impact analysis are:

- to set-up a model to assess the impacts of the 6 policy options considered, for different ventilation systems and their stock, and taking into account their different defects and the ability of the policy option to correct these defects;
- to implement this model into an Excel tool and to perform with this tool calculations to analyse the impacts of the 6 policy options on different parameters towards 2050: electrical and primary energy use, carbon emissions, indoor air quality (IAQ).

As already mentioned, the data about the stock and sales of ventilation systems from a previous report[13] show that 93% of stand-alone ventilation systems are installed in residential buildings. The chosen options, the impact analysis and the calculation approach therefore focus on residential buildings. It is also assumed in the calculation that the different options for inspection of stand-alone ventilation systems only have an impact on new systems installed in new or renovated buildings: this is consistent with the options described in the previous chapter.

3.2 Methodology

The methodology for the impact analysis is described in detail in Annex 2. It consists of the following steps, which are performed for 5 European climate regions, and for the EU-28:

1. Calculation of the performances of dwellings with 10 different types of ventilation systems (see Annex 2, section 3.1.2), considering the impact of the 6 policy options on various parameters influencing the energy use and IAQ, such as the quality of design and installation, the control of systems, the specific fan power, etc. The calculations of ventilation related energy indicators and carbon emissions are based on the ecodesign SEC-calculation method (Directive 2009/125/EC). Energy performances (fan energy use, ventilation related heating energy use, ventilation related primary energy use) are expressed as a specific value per m² of floor area, and quantify the average performance of dwellings with a specific type of ventilation system. The IAQ-indicator is based on the assessment of a generic pollutant dose taking account of the effective flow rates and exposure times of the different types of ventilation systems. In case of poor IAQ, the exposure indicator has a value larger than 1; in case of improved IAQ it has a value smaller than 1.
2. Estimation of the distribution of different types of ventilation systems in the existing dwelling stock, and of the evolution of the market share of ventilation systems in future new and retrofitted dwellings towards 2050. The estimation is based on the analysis of the stock of ventilation systems in EU buildings[13] and on the building stock evolution derived from 'the Agreed Amendments pathway' used in the technical study commissioned and supervised by the European Commission towards the development of a smart readiness indicator

[13] *Feasibility Study EPBD19a - Stock of ventilation systems in EU buildings and foreseen evolution for 2030, 2040 and 2050 – June 2019*

for buildings[14]. The impact of the 6 policy options on the evolution of the market share of ventilation systems is also considered, by assuming that more new ventilation systems are installed in comparison with a baseline option with no actions.

3. Extrapolation of the specific performance indicators calculated in step 1 to the total building stock by combining the specific performance indicators with the building stock data and the data about the market share of ventilation systems, estimated in step 2. As a result, the impact of the 6 policy options may be compared for the following global indicators, assuming that each policy option is introduced in 2020 and has an immediate effect:
    a. the electrical, heating and primary energy use, as a result of the ventilation of the dwelling stock;
        i. electrical energy use relates to the fan energy use in mechanical ventilation systems;
        ii. heating energy use relates to the ventilation and infiltration heat losses for which building heating systems need to compensate;
        iii. primary energy use is the sum of primary electrical and heating energy used for ventilation. It only includes the primary energy use by fan operation and by ventilation and infiltration of air.
    b. the carbon emissions resulting from the ventilation of the dwelling stock;
    c. the average exposure to pollutants over the dwelling stock.

Given the uncertainties and the many parameters involved in the ventilation system performance calculation, in the estimated evolution of the ventilation stock and in the estimated distribution of ventilation system types over the dwelling stock, the outcome of the analysis should be treated with care.

Given the high number of hypothesis made for the impact analysis, the graphs in Chapters 3, 4 and Annex 2 should not be used to compare different ventilation systems, but only to estimate the possible differences between the impacts of the various options analysed.

3.3 Assumptions for an option with no action

The impact of the 6 options is compared to a baseline scenario with no specific policy actions at a European level (also referred to as 'no policy option'). This scenario considers the fact that in a vast majority of European countries the quality of installed ventilation systems is very poor[13]. The main factors taken into account in the calculation of the performances of different ventilation systems are the following:

- A large proportion of systems (20%-55% depending on system type) have flow rates which are significantly lower than the required values.
- In a large proportion of systems (50%-75% depending on system type), users operate the systems at lower flow rates than the nominal values, e.g. because of noise or draft problems.
- A large proportion of mechanical ventilation systems (25%-70% depending on system type) have a higher specific fan power than the default values defined in ventilation standards (500-750 W/(m³/s) per fan).
- A large proportion (50%) of balanced mechanical systems with heat recovery have imbalanced supply and extract air flows or malfunctioning devices, decreasing the heat recovery performance.

[14] *VITO et al. - Support for setting up a Smart Readiness Indicator for buildings and related impact assessment – August 2018*

The figures indicated above are derived from published studies (QALICHeCK[15], AIVC[16] [17]) and applied in the impact analysis discussed in the next paragraph.

Figure 1 shows the estimated distribution of different types of ventilation systems in the existing dwelling stock, and of their evolution towards 2050. Annex 2 includes the definition of the different types of ventilation systems. Figure 2 shows the evolution of the market share of newly installed ventilation systems in future new and retrofitted dwellings, which may be impacted by the 6 policy options. The estimates show a gradual evolution of the market share of ventilation systems towards more mechanical and smart systems. They assume that there are no future changes in ventilation regulation. In many European countries it is not mandatory to install ventilation systems in new or retrofitted dwellings (e.g. Germany, Greece, etc.), or ventilation regulations are not enforced. This results in approximately 50% of new and retrofitted dwellings not being equipped with new ventilation systems, as is also the case today.

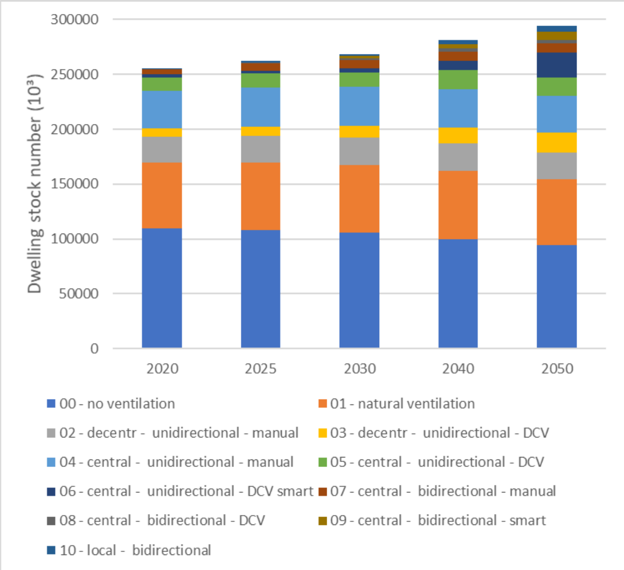


Figure 1: EU evolution of total number of dwellings with a specific ventilation system (see Annex 2 – section 3.1.2 for a description of the different types of ventilation systems)

[15] *Overview of existing surveys on energy performance related quality and compliance – Report from the European project QUALICHeCK, June 2015, Lund (Sweden) - http://qualicheck-platform.eu/*

[16] *Securing the quality of ventilation systems in residential buildings – Presentations at an AIVC Workshop, March 2013, Brussels (Belgium) – www.aivc.org*

[17] *Quality ventilation is the key to achieving low energy healthy buildings – Presentations at an AIVC Workshop, March 2019, Dublin (Ireland) – www.aivc.org*

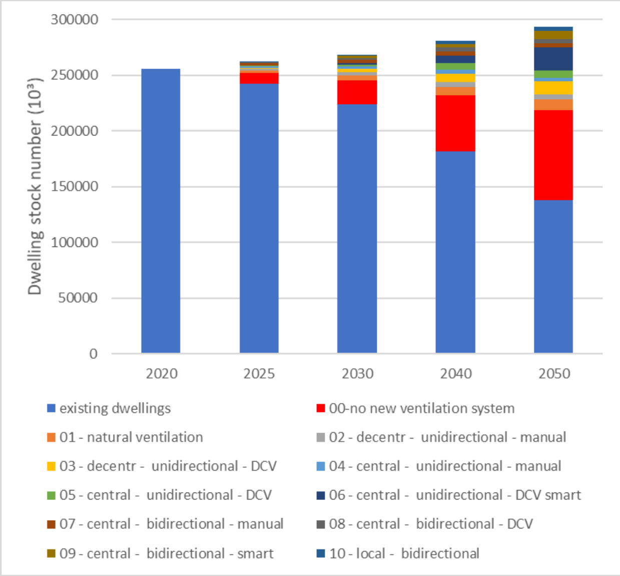


Figure 2: EU evolution of total number of new and retrofitted dwellings with a specific ventilation system (see Annex 2 – section 3.1.2 for a description of the different types of ventilation systems)

Figure 3 shows the evolution of the ventilation related primary energy use of the European dwelling stock, and the evolution of the average exposure to pollutants over the dwelling stock. As a result of the growth of the dwelling stock and of the expected increase of ventilation systems on the market, the primary energy use as a result of the ventilation of the dwelling stock (fan energy, ventilation and infiltration heat loss) will increase by 18% in between 2020 and 2050, while the average exposure to pollutants will decrease by 10%. For comparison: the EU dwelling stock floor area is estimated to increase by 15% between 2020 and 2050. As Figure 3 shows, the total primary energy use is dominated by the primary heating energy use related to ventilation and infiltration, while the primary fan energy use represents a small fraction (3% in 2020, 6% in 2050) of total primary energy use. A larger share of the total primary energy use is the result of infiltration due to air leakages (57% in 2020, 53% in 2050).

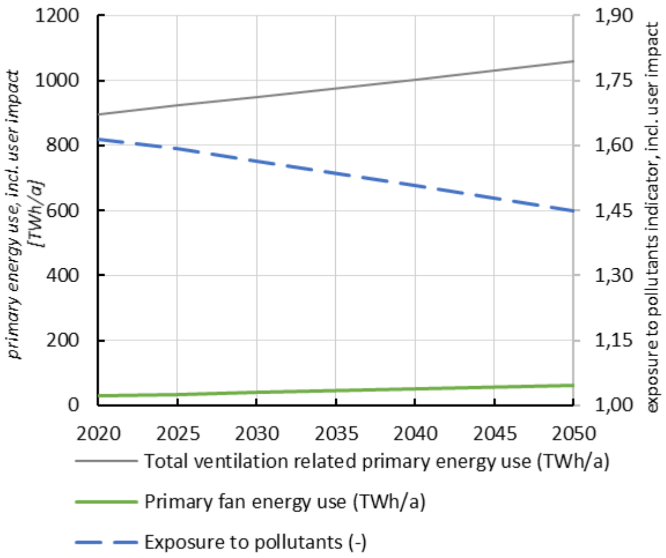


Figure 3: Evolution of the total ventilation related primary energy use, primary fan energy use (primary axis) and the average exposure to pollutants (secondary axis) over the European dwelling stock in case no policy actions are taken.

4. Impact analysis findings for the 6 options

4.1 Awareness raising (option 1)

4.1.1 Reference

Based on literature findings, it is assumed that the impact of awareness raising on the performances is limited compared to the baseline scenario. Experiences for instance in France showed that, despite the implementation of ventilation compliance checks by state controllers on samples of the yearly production of new buildings and raising awareness about the poor status of residential ventilation systems on the ground, there is little or no effect on the high non-compliance rate observed for many years[18]. However, awareness campaigns can result in stakeholders' request for governmental action, e.g., imposing inspection of ventilation systems based on visual observations or measurements. Awareness campaigns can also motivate various stakeholders to give more attention to the installation of ventilation systems and to the correct performance of these systems, for instance when awareness campaigns show the relation between ventilation and health. Moreover, in countries with no ventilation or IAQ requirements, awareness raising campaigns can highlight the need for appropriate ventilation systems and therefore be a driver for appropriate legislation regarding ventilation and/or IAQ requirements. Once such regulation exists, options 2 to 6 can be considered.

4.1.2 Variants

The variants of the reference option as described in 2.1.1 correspond to different levels of efforts:

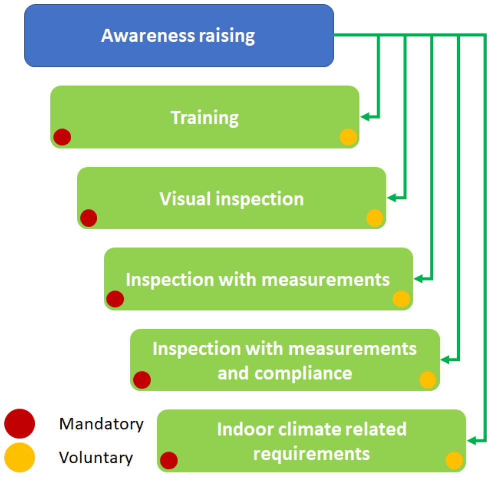
- Surveys on actual performances of installed systems: the surveys on indoor air quality performances and/or actual performances of installed systems can vary widely in sample size and in the aspects covered in the data collection, e.g.:
  - whether or not there are ventilation systems;
  - indoor air climate related parameters (indoor air quality, acoustics, …);
  - physical measurements on the ventilation systems (e.g., air flow rates, energy related performances, acoustics, cleanliness of the system, …);
  - perception of the users;
  - comparison of the performances of different samples (e.g., with/without inspection, with/without a ventilation system, new systems versus older systems, etc.).
- Information to stakeholders can cover a very wide range of potentially interested stakeholders. The general public, as users of the buildings, is a very important group. Politicians as well as all professionals active in the sector are also an important target.
- Consultation on possible actions to improve performance can also have different scopes and the required effort can vary widely.

[18] *François Rémi Carrié (ICEE), Sandrine Charrier, Adeline Bailly (Cerema) - Regulatory compliance checks of residential ventilation systems in France – QUALICHeCK Factsheet #06 – Nov. 2015*

A potential impact of awareness raising can be an interest to improve the performances of stand-alone ventilation systems and to impose requirements on ventilation systems and/or to implement options 2 to 6.

Such implementation can be a voluntary measure (●) or a measure made mandatory by the public authorities (●). In terms of impact analysis of option 1, this indirect effect can be important when assessing the cost benefit relation.

In practice, it is in many circumstances essential to have sufficient awareness raising before there will be societal support for imposing ventilation requirements and/or options 2 to 6.



4.2 Training (option 2)

4.2.1 Reference

It is not evident to assume that more competence will automatically result in better installations or in more installations of ventilation systems in new and retrofitted dwellings. If the price competition is very high and/or if the clients are not in a good position to easily refuse non-compliant installations, the impact of training may be limited.

Still, in the impact analysis it is assumed that training has a positive influence on the quality of design and installation, resulting in 0-10% more systems (depending on system type) achieving required flow rates, 5-10% less systems operated at significantly lower flow rates than nominal values because of comfort problems experienced by users, 10% more systems achieving specific fan power default values, and 10% less imbalanced systems, in comparison with the option with no actions.

Furthermore, this scenario assumes that the increase in awareness and expertise among professionals results in 5% more new systems installed in new and retrofitted dwellings.

As a consequence, this policy option results, for the total EU dwelling stock (Figure 4) in a limited increase of the ventilation related energy use (+1% by 2050), and in a reduction of the average exposure to pollutants in the dwelling stock (-2% by 2050). The influence of this policy option on increased flow rates has a larger overall impact on energy use in comparison to its influence on reduced fan energy and improved heat recovery.

Although the impact at the level of the dwelling stock is limited because the policy option is assumed to impact only newly installed systems, the impact of this policy option at dwelling level is larger and depends on the type of ventilation system. For dwellings equipped with central bidirectional systems for example, the estimated reduction of exposure to pollutants is 11-15% at the expense of an increase of primary energy use per m^2 of floor area of 0-3% (mean system performance), depending on the type of control.

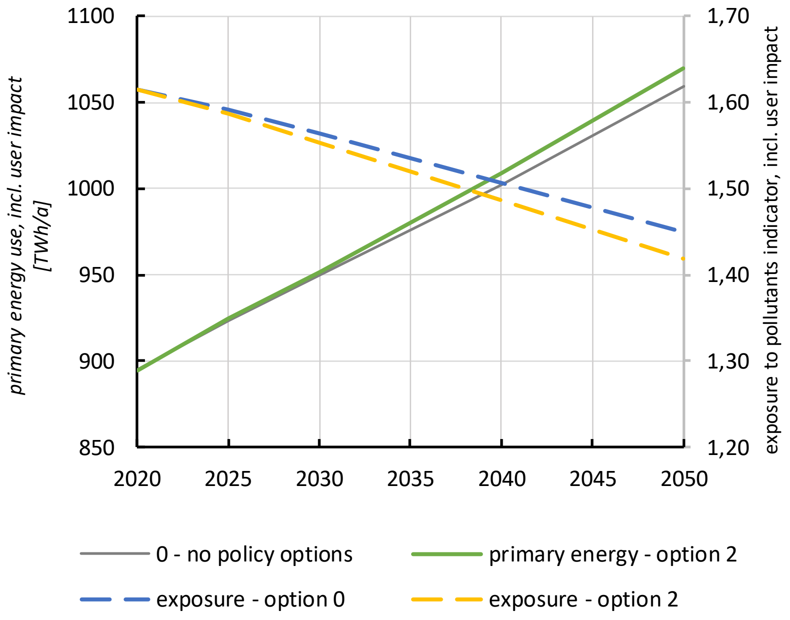


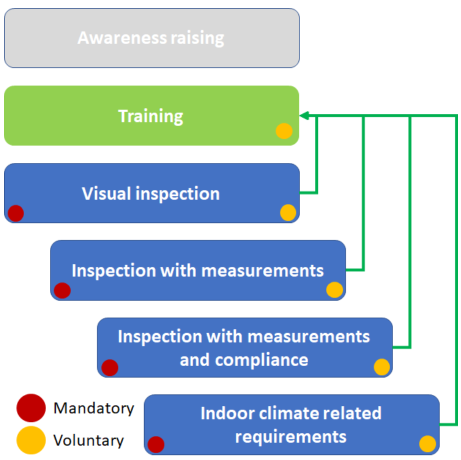
Figure 4: Impact of policy option 2 on the evolution of ventilation related primary energy use and exposure to pollutants for the EU-dwelling stock, in comparison to option 0 without actions.

4.2.2 Variants

Possible variants of the reference option as described in paragraph 2.2.1 could be:

- to implement a training offer with no obligation of training and certification;
- to implement a mandatory training but no mandatory certification;
- to include more or less aspects in the training and certification. An important aspect is the acoustical performance. Acoustics is clearly a very critical aspect of ventilation systems and requires specific competence.

A specific challenge in the case of mandatory training and/or certification, is to define the contents of the training and related assessment. There is a wide range in complexity of ventilation systems to cover (individual dwelling ventilation systems vs. collective ventilation systems in apartment buildings, various types and technologies of ventilation systems, etc.). In order to have societal support for such mandatory training/certification and the required added value, it might be necessary to foresee various types of training/certification.



The initiative for mandatory training (and certification) can be an explicit decision by government or prescribers.

However, it is also possible that a strong interest in voluntary training is created due to the existence of inspection schemes (option 3 to 5) or indoor climate related requirements (option 6).

If the practitioners experience difficulties in meeting the requirements, there might be a strong interest to voluntary follow training courses in order to work more efficiently with the resulting cost savings.

Such situation has a number of advantages in terms of societal acceptance as there is no obligation to follow training and/or to be certified.

Another variant of the reference option could be that mandatory training is extended to professionals other than installers, i.e., designers and maintenance staff.

4.3 Visual inspection (option 3)

4.3.1 Reference

Initial visual inspection of newly installed ventilation systems allows to assess completeness and good overall operation of the systems, by checking the presence and functioning of all relevant components. As a consequence, the effect of visual performance on system performance is system type dependent. For systems where the achieved flow rates and operation are largely related to the presence of different components, such as in natural ventilation systems, the impact of visual inspection is probably larger than for mechanical ventilation systems, where correct performance is less likely to be assessed without measurements. However, also with mechanical systems, visual inspection may contribute to a better performance by checking the presence and location of different components, the presence of silencers when prescribed, draught risk related to the position of supply vents, the presence and functioning of heat recovery systems, etc.

Based on these considerations, in the impact analysis it is assumed that initial visual inspection has a positive influence on the quality of design and installation, resulting in 5-20% more systems achieving required flow rates (depending on system type), 10% less systems operated at significantly lower flow rates than nominal values because of comfort problems experienced by users, and 15% less systems with imbalanced or malfunctioning heat recovery system, in comparison with the option with no actions.

Also, in construction and renovation projects that are subject to ventilation requirements, visual inspection allows for the detection of systems' effective and complete installation. In countries with mandatory ventilation regulations, this option may therefore help to comply with regulations. As a consequence, the impact analysis assumes that 10% more new systems are installed in new and retrofitted dwellings in comparison with the option with no actions.

Based on the above, this policy option results, for the total EU dwelling stock, in a similar increase of the ventilation related energy use (+1% by 2050), and reduction of the average exposure to pollutants in the dwelling stock (-2% by 2050), as estimated for the previous policy option (training). The impact on pollutant exposure is largely (67%) related to the assumed 10%-increase of newly installed ventilation systems due to the introduction of initial visual inspection.

The impact of this policy option at dwelling level is larger than at the level of the dwelling stock. For example, for dwellings equipped with central bidirectional systems with manual control or Demand Control Ventilation (DCV), the estimated reduction of exposure to pollutants is 11-13% at the expense of an increase of primary energy use per m² of floor area of 3-4% (mean system performance).

4.3.2 Variants

Possible variants of the reference option as described in paragraph 2.3.1 could be (to be considered alone or in combination):

- to implement not only an initial inspection of newly installed ventilation system, but to require also a <u>regular inspection</u> at a given time frequency; this would allow to check that the general state of the ventilation system remains good; it could be combined with regular maintenance;
- to make an initial visual inspection mandatory not only for newly installed systems, but <u>also for all systems already in operation for a while</u>, to be performed before a given deadline; this would probably contribute to improving the whole stock;
- to include into the technical aspects covered by the inspection the check of the <u>adequacy between design and installation</u>. This is for example suggested by the

European standards EN 14134[19] and EN 16798-17[20], as well as by the French protocol Promevent[21], and requires a pre-check phase to collect the relevant information;

- to focus inspection on some specific systems for which risks of installation defects are higher;
- to choose that inspection is performed by independent inspectors only; in the reference option, visual inspection can be performed by several types of operators (designers, architects, property owners, installers, etc.) provided that they are trained and qualified; this variant is to be considered only if there are serious doubts linked to the fact that other operators could be in conflict of interest;
- to decide that training or qualification is not required; this would be possible if inspectors are considered as having initial skills and knowledge which allow them to perform inspection without dedicated training or recognition by a third party or their ability to perform the inspection;
- to decide that surveillance of inspectors through audits is not required; this would be possible if there is confidence in the fact that inspectors will follow the rules even without audits and predefined sanctions;
- to combine this option with options other than the ones described before concerning the involvement of public authorities, depending on the national, regional or local context.

In terms of actions in case of non-compliance, there are various possibilities, e.g.:

- no specific action but rely on communication of the results of visual inspection to interested third parties, e.g., in the EPC, building renovation passport, etc.;
- compliance requirement: obligation to make the ventilation system compliant in relation to the non-compliances identified by the visual inspection;
- mandatory training of installers, which can be effective if the major reason for non-compliance is a lack of competence among the installers.

The effective implementation of option 3 cannot guarantee that a ventilation system works correctly. There can, e.g., be low or high air flow rates, acoustical problems, leaky ductwork, poor energy performances, etc. that visual inspection does not allow to detect. An awareness raising campaign (option 1) on a sample of installations which have been found compliant in visual inspection can give insights of the actual performances: in case it shows good performances, this might increase the societal support for option 3; in case the monitoring campaign identifies various (serious) non-compliance issues, this might give societal support for considering options 4 or 5.

4.4 Inspection with measurements (option 4)

4.4.1 Reference

Initial inspection of newly installed ventilation systems with measurements allows better assessment of ventilation system performances compared to the previous option (visual inspection of completeness and good overall operation). Visual inspection and measurements of flow rates at room level and of electrical fan-power, which are then reported to owners and public authorities and compared to target values, is expected to result in more corrective actions to achieve prescribed flow

[19] *EN 14134 (2019): Ventilation for buildings - Performance measurement and checks for residential ventilation systems*

[20] *EN 16798-17 (2017): Energy performance of buildings. Ventilation for buildings. Guidelines for inspection of ventilation and air conditioning systems (Module M4-11, M5-11, M6-11, M7-11)*

[21] *http://www.promevent.fr/publications.php*

rates, supply and extract flow balancing and energy efficiency, than is the case with the previous policy options.

Based on these considerations, in the impact analysis it is assumed that initial inspection with measurements has a positive influence on the quality of design and installation. This is expected to result in 10-35% more systems achieving required minimum flow rates (depending on system type), 10% less systems operated at significantly lower than nominal flow rates (because of comfort problems experienced by users), 15-20% more systems achieving specific fan power default values (depending on system type), and 25% less imbalanced systems or systems with malfunctioning heat recovery, compared to the option with no actions.

Also, in construction and renovation projects that are subject to ventilation requirements, this policy option (which also includes visual inspection) allows to detect whether systems are effectively in place and complete. As a consequence, similar as in option 3, in the impact analysis it is assumed that 10% more new systems will be installed in new and retrofitted dwellings in comparison to the option with no actions.

As a consequence, this policy option results, for the total EU dwelling stock, in a similar increase of the ventilation related energy use (+1% by 2050) as the previous two policy options (training, visual inspection), but with a larger reduction of the average exposure to pollutants in the dwelling stock (-3.5% by 2050). Nearly half of the impact on pollutant exposure and 10% of the impact on primary energy use is related to the assumed 10% increase of newly installed ventilation systems.

The observed reduction of average exposure to pollutants follows from the assumed increase of achieved flow rates, both as a result of better commissioning and better operation. At the same time, despite the increased flow rates, the primary energy use does not increase to a larger extent compared to previous policy options because also the energy efficiency of systems is assumed to improve in this policy option (on average lower specific fan power, higher thermal efficiency of heat recovery).

The impact of this policy option at dwelling level (mean system performance) is larger than at the level of the dwelling stock (since not all dwellings will be inspected). For dwellings equipped with central bidirectional systems with manual or DCV control, the estimated reduction of exposure to pollutants is 24-26%, at the expense of a minor increase in primary energy use of 1% (mean system performance). For dwellings equipped with other systems, the estimated reduction of exposure to pollutants is on average lower.

4.4.2 Variants

Possible variants of this reference option, as described in paragraph 2.4.1, are the same as for option 3 (see paragraph 4.3.2), with the following additional variants:

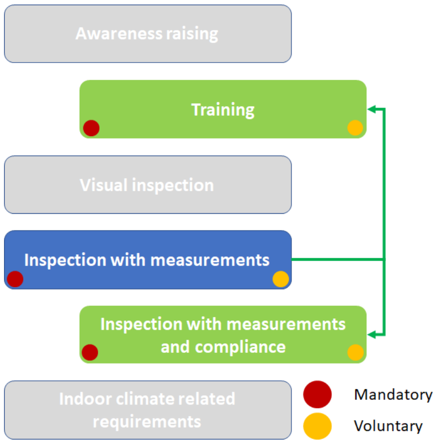
- <u>measurement of acoustical performances;</u> this can include measurements of the acoustical performances of the mechanical ventilation system as well as measurements of the ability of the ventilation system to avoid the transmission of noise from outside and between adjacent rooms or apartments;
- <u>measurement of thermal comfort related performances;</u>
- <u>measurement of ductwork airtightness</u> which could be the main cause of insufficient airflows and/or overconsumption of fans; this measure could improve both energy and IAQ performance;
- <u>to reduce the requirements on measurement equipment</u> (e.g., decide that measuring instruments do not require calibration on a regular basis or decide that the calibration of measuring instruments can be performed by laboratories that are not accredited).

In terms of actions in case of non-compliance, there are various possibilities, e.g.:

- no specific action, but rely on communication of the results of the measured performances to interested third parties, e.g.:
  - use of measured performances as input in EPC calculations (air flow rates, fan power, etc.);
  - integrating the results in a building renovation passport;
- compliance: obligation to make the ventilation system compliant;
- mandatory training.

The first case (no action but rely on communication) can in certain cases be a pragmatic option, e.g., if the results of the measurements have to be used as input data in an EPC calculation. Moreover, there is a large probability that clients who receive a report which shows non-compliance of the ventilation system will not be willing to pay for the installation.

In the context of the impact analysis, it is also possible that the findings from inspections with measurements will motivate to consider option 2 (mandatory training) or to impose option 5 (inspection with measurements and compliance). This could, e.g., be the case with professional investors who require that the work is done with inspection at the end of the works and proof of compliance.



4.5 Inspection with measurements and compliance (option 5)

4.5.1 Reference

In this option, it is required that new ventilation systems are made compliant if the inspection results based on the previous option show that target values are not met. As a consequence, it is expected that all possible corrective actions will be taken to achieve prescribed flow rates, supply and extract flow balancing and energy efficient fans. However, since comfort measurements (noise and draught problems) are not required in the inspections, it is expected that not all defects that result in comfort problems may be solved, apart from the defects observed in visual inspection.

Based on these considerations, in the impact analysis it is assumed that inspection with measurements and the obligation to make the system compliant has a positive influence on the quality of design and installation. This is expected to result in 20-55% more systems achieving required minimum flow rates (depending on system type), 10-15% less systems operated at significantly lower than nominal flow rates (because of comfort problems experienced by users), 15-20% more systems achieving specific fan power default values (depending on system type), and 25% less imbalanced systems or systems with malfunctioning heat recovery, compared to the option with no actions. Compared to the previous option, all systems are assumed to achieve the minimum required flow rates, with improved energy efficiency (fan power, heat recovery).

Also, in construction and renovation projects that are subject to ventilation requirements, it may be expected that ventilation systems are effectively in place and are complete in this option. As a consequence, in the impact analysis it is assumed (Figure 5) that 20% more new systems will be installed in new and retrofitted dwellings in comparison with the option with no actions, which assumes that ventilation regulations are not everywhere enforced. Further, it is assumed that 75% of the additionally installed systems will be systems with smart features, as defined in Annex 2, because in these systems it is easier for installers to demonstrate compliance. The assumed figure of 20% might be quantified in a more precise way based on information about which European countries have requirements in place for the installation of ventilation systems in both new and retrofitted dwellings, and on the extent to which these requirements are enforced. However, this information is not systematically available. The role of inspection also depends on the procedure that is already in place to enforce these regulations. For instance, in Belgium, it is the task of energy auditors to report about the presence and performance of ventilation systems in new and retrofitted dwellings based on as-built information, with penalties in case of non-compliance to ventilation requirements. In this situation, complementary inspection procedures will probably not contribute to an increased installation of systems.

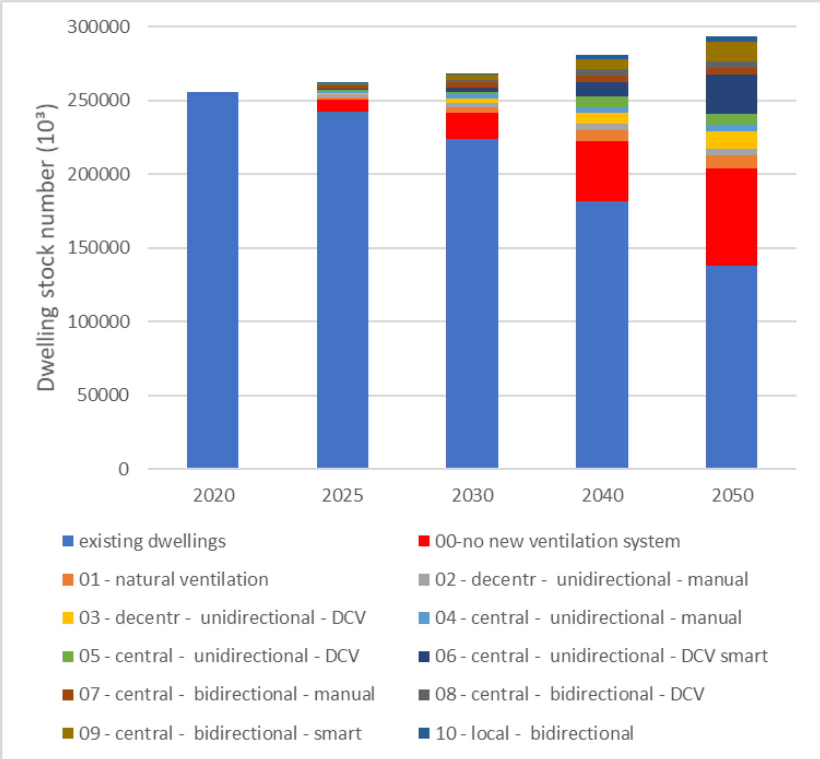


Figure 5: EU evolution of the total number of new and retrofitted dwellings with a specific ventilation system, and an assumed increase of 20% in newly installed systems compared to the option with no actions (Figure 2)

Based on the above assumptions, this policy option results, for the total EU dwelling stock, in an increase of the ventilation related primary energy use (+2% by 2050), and a reduction of the average exposure to pollutants (-6% by 2050), compared to the option with no actions. Half of the impact on pollutant exposure and 12% of the impact on primary energy use is related to the assumed 20% increase of newly installed ventilation systems.

At dwelling level, this policy option has the highest impact on dwellings equipped with a central bidirectional system with manual or DCV control, with an estimated reduction of exposure to pollutants of 32-35% without increasing primary energy use (mean system performance) compared to the option with no actions.

4.5.2 Variants

Possible variants of this reference option, as described in paragraph 2.5.1, are the same as for option 4 (see paragraph 4.4.2).

4.6 Indoor air quality requirements (option 6)

4.6.1 Reference

In this option (only measurement of indoor air quality, no other aspects are checked), it is expected that actions will be taken to achieve the minimum flow rates, contributing to meeting maximum target values for an indoor air quality parameter, while less corrective actions will be taken to solve other defects, such as unbalanced flow rates, high fan power, noise and draught issues, compared to the previous policy options. Since the measurement of indoor air quality requirements is based on the initiative of the occupant or owner, and it is not mandatory to take corrective actions, it is expected that not all dwellings will achieve the targets. At the same time, users, being more aware of the achieved IAQ, might be inclined to operate systems at higher flow rate.

Based on these considerations, in the impact analysis it is assumed that measurement of indoor air quality parameters results in 10-30% more systems achieving required minimum flow rates (depending on system type), 10% less systems operated at significantly lower than nominal flow rates , and 15-20% more oversized systems (50% higher than required minimum rates), in comparison to the option with no actions. Estimates of fan power and heat recovery performance are the same as in the option with no actions.

Also, in construction and renovation projects that are subject to ventilation requirements, this policy option may convince more builders and owners to invest in the installation of a ventilation system. As a consequence, in the impact analysis it is assumed that 10% more new systems will be installed in new and retrofitted dwellings, in comparison to the option with no actions.

Based on the above assumptions, this policy option results, for the total EU dwelling stock, in an increase of the ventilation related primary energy use (+3% by 2050), and a reduction of the average exposure to pollutants in the dwelling stock (-4% by 2050), compared to the option with no actions (Figures 8-9). About 40% of the impact on pollutant exposure and 10% of the impact on primary energy use is related to the assumed 10% increase of newly installed ventilation systems. Even when ignoring the assumed increase of newly installed systems, this option results in a smaller reduction to pollutant exposure and a larger increase in energy use, compared to the previous option 5. This is the result of the fact that, in option 6, it is assumed that not all systems have to meet minimum required flow rates, and that energy efficiency of systems is not improved.

At dwelling level, this policy option has the highest impact on dwellings equipped with a central bidirectional system with manual or DCV control, with an estimated reduction of exposure to pollutants of 28-30% at the expense of 26-27% increase in primary energy use (mean system performance) compared with the option with no actions.

4.6.2 Variants

Possible variants of this reference option. as described in paragraph 2.6.1. could be:

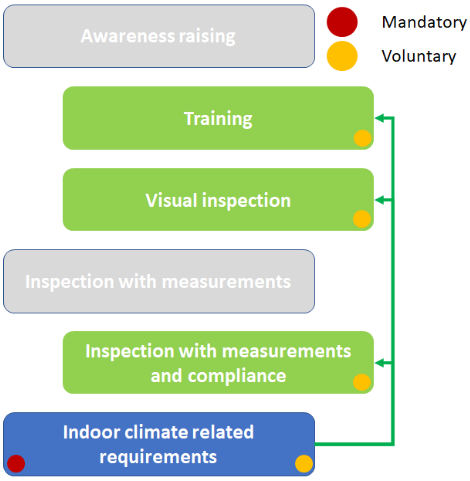
- to make the measurements of indoor air quality in the occupied building mandatory a few times after the (new) ventilation system has been installed;
- to make measurements mandatory by a certified third party, with a report;
- to make corrective actions mandatory if the measured values show non-compliance;

- to require a permanent monitoring of indoor air quality parameters with automatic warning system;
- to include other indoor climate parameters, e.g., acoustical performances.

Compliance with the requirements of option 6 can in principle be achieved without the availability of ventilation systems. A very leaky building, the opening of windows or doors, can indeed allow meeting the IAQ requirements.

However, it is in practice in most climates not feasible to meet the IAQ requirements in most circumstances. Therefore, for architects, contractors, buildings owners, etc., to be able to guarantee that the IAQ requirements will be met, there is a need for an appropriate (natural or mechanical) ventilation system.

As practice shows that it is not so evident to achieve compliant ventilation systems, option 6 might indirectly be a major driver for interest in option 2 (training) or options 4 and 5 (measurements with inspection). However, it will not be necessary to have mandatory requirements, as the involved stakeholders will be interested in such schemes in order to guarantee to meet the requirements of option 6.



4.7 Conclusions for the 6 reference options

Figures 6-7 give an overview of the impact of the 6 policy options on the ventilation related primary energy use and on the average exposure to pollutants in the total EU dwelling stock. The impact on carbon emissions is in line with the impact on primary energy.

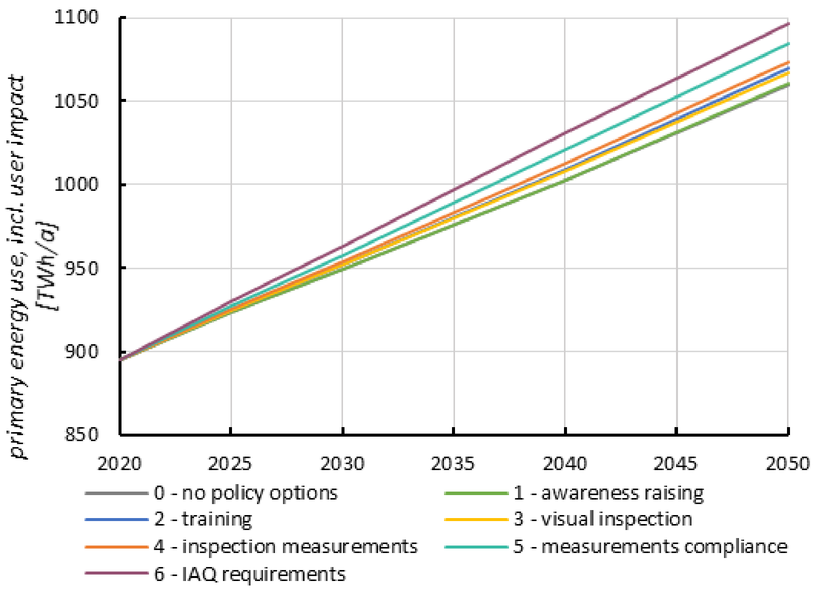


Figure 6: Evolution of the ventilation related primary energy use of the EU dwelling stock.

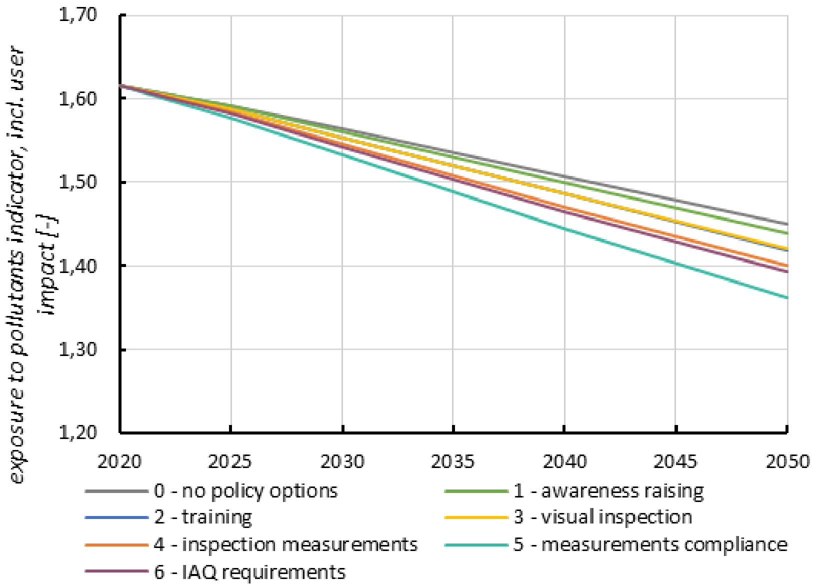


Figure 7: Evolution of the average exposure to pollutants over the EU dwelling stock.

The impact analysis indicates as an overall trend that the various options result in a better indoor air quality but also in a higher energy consumption. This is the consequence of the fact that in a vast majority of European countries the current quality of installed ventilation systems is shown to be poor, and delivered air flow rates are often insufficient. Therefore, air flow rates in the dwelling stock on average increase due to the implementation of one of the policy options.

This can be due, for example, to the following situations:

- Without an efficient control, it is not possible to ensure that all buildings required by regulations to have ventilation systems do indeed have them installed. Options 1 to 6 can reduce the number of buildings without a ventilation system, and result on average in a higher ventilation rate.
- Building occupants might not use the system or use it at a lower capacity due to issues of noise, draught, the intention to save energy, etc. Options 1 to 6 should directly or indirectly result in more correct ventilation systems and, if attention is paid to the previously mentioned issues, in a more effective use of such ventilation systems.
- The design and installation of ventilation systems is not always correctly done, which may result in air flow rates different from the intended values. The expectation is that, in most cases, this will result in lower air flow rates than the expected values. Options 1 to 6 might result in better designed and executed ventilation systems and therefore higher ventilation rates.

However, these conclusions are based on the aggregated results over the EU dwelling stock. A reduction of the energy consumption in combination with a good indoor air quality is also possible. This would be the case for buildings that in the reference situation would have an over-dimensioned ventilation system. In such a case, options 1 to 6 would directly or indirectly contribute to a better control of the air flow rates (i.e., lowering air flow rates to minimum requirements) and to reduced ventilation heat loss and fan energy use.

When considering the aggregated results over the EU dwelling stock, the policy options seem to have a marginal impact. However, this is the consequence of the chosen scope of the impact analysis, focusing on newly installed ventilation systems in new and renovated dwellings. As discussed in section 3.3, dwellings equipped with new ventilation systems represent a small share of the total dwelling stock. When analysing the impact of the policy options over the EU dwelling stock with newly installed ventilation systems only, the impact of the options is more pronounced, as Figures 6' and 7' show.

Figure 6' shows the ventilation related primary energy use aggregated over all EU dwellings with newly installed ventilation systems, and divided by the total floor area of those dwellings with new systems. This 'specific primary energy use' is a measure for the energy efficiency related to ventilation. Figure 7' shows the average exposure to pollutants for the same group of dwellings. The policy options result in important reductions of the average exposure to pollutants, up to 22% (2025) and 17% (2050) in case of option 5. The ventilation related specific primary energy use increases up to 26% for the same option. Because of the shift to systems with DCV and smart controls, the specific primary energy use and the exposure to pollutants is reduced towards 2050 for all options.

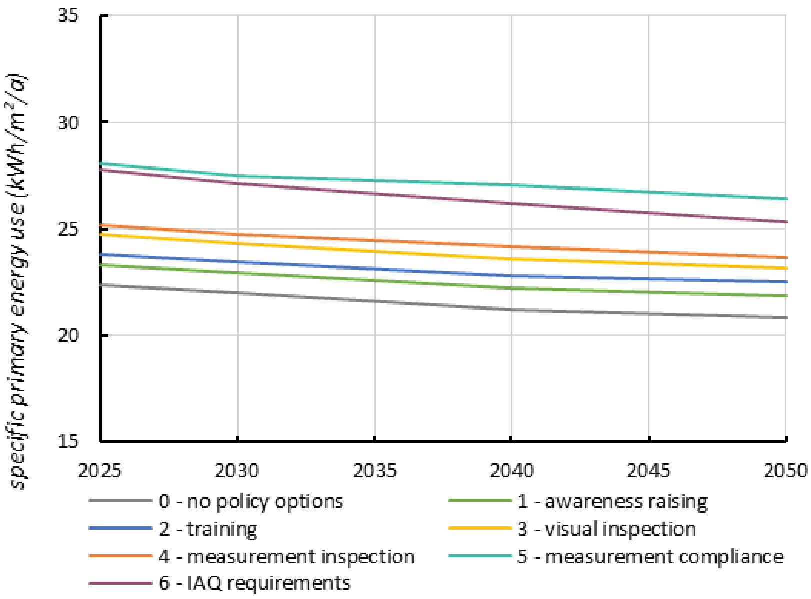


Figure 6': Evolution of the ventilation related specific primary energy (kWh/m²/a) of the EU stock of new and renovated dwellings equipped with newly installed ventilation systems.

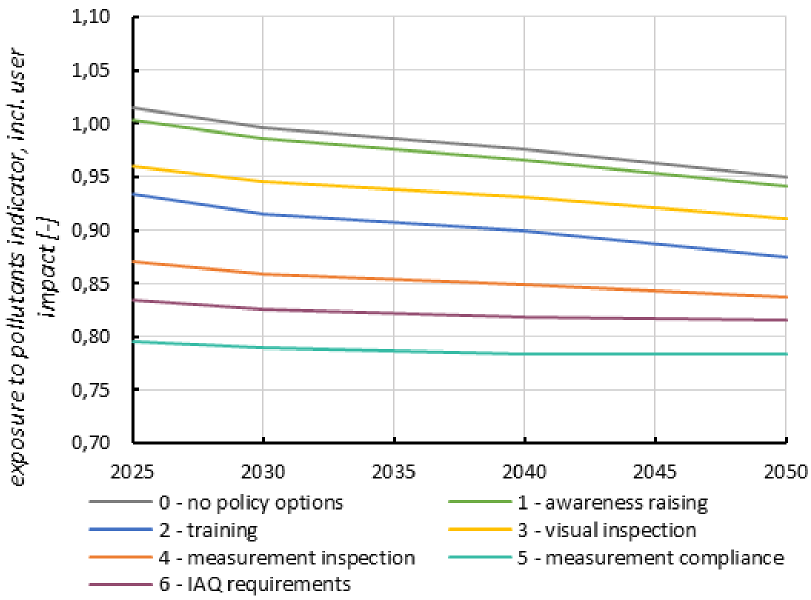


Figure 7': Evolution of the average exposure to pollutants over the EU stock of new and renovated dwellings equipped with newly installed ventilation systems.

The impacts of the policy options are also system type dependent, as illustrated in Figures 8 and 9. Here, the impact of the policy option 5 on the mean performance of dwellings is compared to the case of no policy actions, for different types of ventilation systems. As the figures show, in half of the 10 studied systems – natural ventilation, bidirectional systems (with heat recovery)-, inspection contributes to an improved IAQ with limited or no increase of primary energy use. The figures were developed to demonstrate the system dependent impact of inspection on the mean performance of different types of ventilation systems, not to compare the performance of systems against each other. Given the uncertainties and the many parameters involved in the calculations, these results should be interpreted with care.

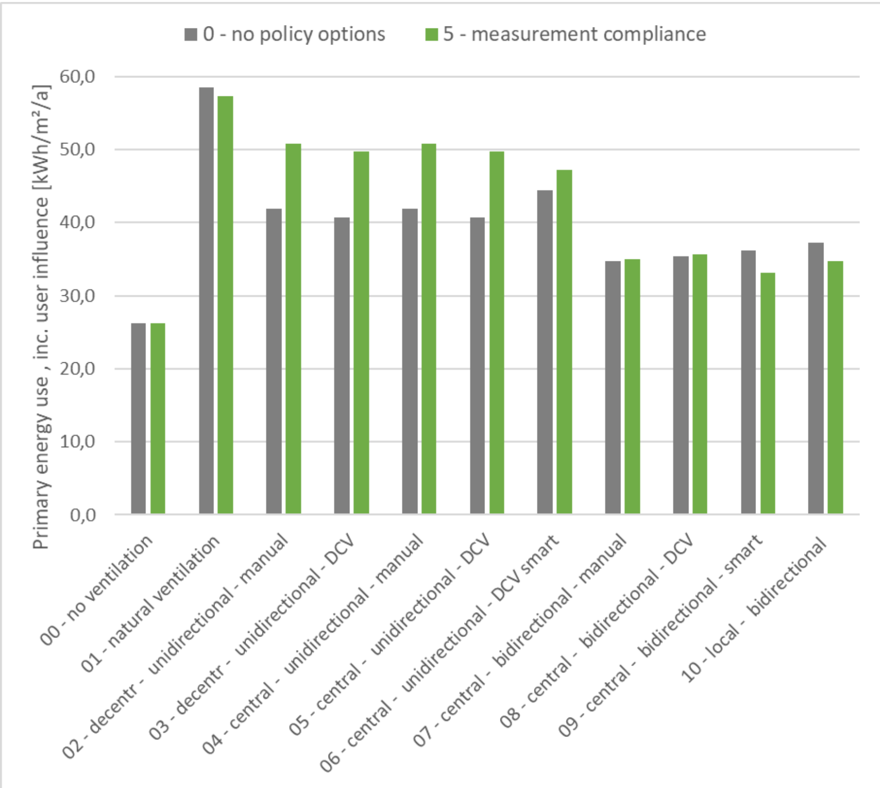


Figure 8: Average ventilation related primary energy use in dwellings equipped with different types of ventilation systems in case of no policy actions and policy option 5.

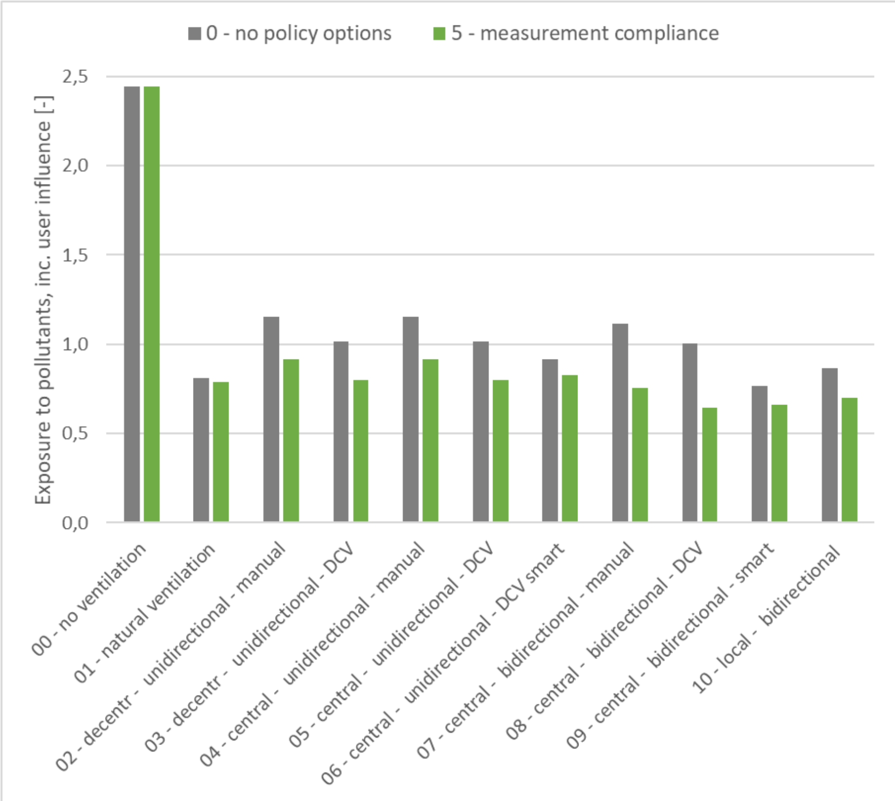


Figure 9: Exposure to pollutants in dwellings equipped with different types of ventilation systems in case of no policy actions and policy option 5.

5. Other considerations related to the impact analysis

5.1. Importance to quantify multiple benefits of options 1 to 6

As indicated in section 4.7, it is expected that options 1 to 6 will in practice contribute to a better indoor air quality. The implementation of these options has cost implications, e.g.:

- the cost for setting up each option (methodology, legal context, etc.);
- the cost for implementing these options (training, inspections, etc.);
- the increase in energy costs;
- the cost of the ventilation system (components and installation) which could be higher due to the increased attention for quality.

In the context of a qualitative cost-benefit analysis, it is important to identify the benefits qualitatively but also quantitatively.

Improving the indoor air quality can give various benefits, such as less health-related problems and increased productivity.

It is estimated that Europeans spend more than 90% of their time inside buildings and that between one in three and one in six European citizens live in an unhealthy building, depending on the country[22].

The WHO estimation is that 4.3 million deaths can be annually attributed to indoor air pollution[23], of which 99,000 in Europe. It includes more than 50% of pneumonia deaths among children under five. In France, indoor air pollution has been estimated

[22] *Healthy Homes Barometer. Buildings and Their Impact on the Health of Europeans – Ecofys, Fraunhofer IBP, Copenhagen Economics, Velux, 2017*

[23] *www.who.int/features/qa/indoor-air-pollution/en/*

to be responsible for nearly 20,000 deaths and for a global cost (health, production loses, public action) of 19.5 billion € every year[24].

In case of new or renovated buildings, in order to reach the target of nearly zero energy buildings, there typically is an improvement of the building airtightness resulting in less air infiltration. In such buildings, the attention for appropriate ventilation is therefore even more important than in non-renovated buildings.

5.2. Cost aspects related to options 3 to 6

5.2.1. Costs of an effective control and enforcement framework

In order to be effective, options 3 to 6 require the organisation of a control system and, in case of non-compliance, to set up enforcement actions. This requires various investment and staffing costs, which will depend on various elements, e.g.:

- the type of control: visual inspection, inspection with measurements, etc.;
- the frequency of control;
- the intensity of control;
- the frequency of non-compliance and the number of enforcement actions;
- development and maintenance of an IT environment;
- consultation process, legal advice, etc.

5.2.2. Estimation of the total cost

The total cost of implementing options 1 to 6 consists of the following elements:

Cost	Description
↗	The cost for setting up the option
↗	The cost for implementation in practice
↗	The extra costs for delivering a compliant ventilation installation
↗↘	The change in energy consumption due to the implementation of the option, as indicated in chapter 4. It is expected that, in most cases, the energy cost will increase due to higher air flow rates, but it might also decrease in other cases
↘	The cost reduction due to an improved indoor air quality and its impact on health
↘	The savings due to increased productivity

5.3. Options 3 to 6 as means against unfair competition

Options 3 to 6 (with compliance checks and effective enforcement) create a level playing field for all actors involved in the project. If well implemented, this can substantially contribute to a reduction of unfair competition.

5.4. Importance of clear and manageable specifications (options 3-6)

In order to guarantee that the inspections as described in option 3 and in particular to options 4 to 6 can effectively assess non-compliance issues, it is important that the specifications are clear with little margin for interpretation.

This might perhaps look evident and easy (e.g., a standard which requires 30 m^3/h in a bathroom or a maximum of 1000 ppm CO_2), but there are in practice many challenges, e.g.:

[24] *Kopp, P., Boulanger, G., Pernelet-Joly, V., Bayeux, T., Vergriette, B., Mandin, C., Kirchner, S., Pomade, A., 2014. Etude exploratoire du coût socio-économique des polluants de l'air intérieur. CSTB - OQAI – ANSES.* www.anses.fr/fr/system/files/AUT-Ra-CoutAirInterieurSHS2014.pdf

- How to assess on site air flow rate requirements in case of demand-controlled ventilation systems (with variable airflows, sometimes low and difficult to measure precisely)?
- How to define the conditions for measuring air flow rates?
- How to describe the specifications for acoustical measurements in such a way that it is affordable and applicable in practice? This is in particular challenging when maximum sound levels are low (e.g., 27…30 dB in bedrooms).
- Which tolerances between measured values and requirements are acceptable?
- Under which boundary conditions must IAQ requirements be achieved (e.g., nominal capacity of rooms, etc.)?

5.5. Impact analysis for non-residential and existing buildings?

The impact analysis presented in chapter 4 is focused on new residential buildings.

The calculation tool can be used for non-residential buildings as well as for existing buildings. What has to be changed are the input data, i.e.:

- characterisation of the building stock;
- market share of different types of ventilation systems as function of time;
- performances of these ventilation systems as function of the 6 options.

In order to have an overall impact assessment, it is very important to have a good estimation of the market of ventilation systems. In practice, very few reliable data are available for non-residential buildings and for existing residential buildings, as already explained in the introductory text of Chapter 2.

5.6. Considerations about good IAQ during the whole building lifetime

Achieving good air quality is not only needed when the building comes into use, but should also be guaranteed during its whole operation. It is not evident to assume that a ventilation system which works well at the moment of delivery will guarantee good IAQ during its lifetime.

Two main reasons for poor performances are:

- modifications in the performances of the ventilation system itself (due to actions by users, ageing of the system, poor maintenance, etc.);
- poor operation of the ventilation system (due to problems as noise or draught, concerns of energy conservation, etc.).

All 6 options can have a relevant contribution to performances over the lifetime of the installations, e.g.:

- Option 1 can raise the awareness on the systems' performance over its lifetime and motivate decision makers to set up actions on performance checking during the operation of the system.
- Option 2 can focus on specific training aspects with respect to maintenance, regular inspection, etc.
- Options 3 to 5 can be applied on existing installations with a certain interval.
- Option 6 can in principle be continuously used and covers both the intrinsic characteristics of the installation and the use of the building and installation.

5.7. Impact of evolutions of legislation on IAQ and ventilation

The present impact analysis explicitly assumes that the ventilation requirements in the EU countries are not changed between now and 2050, and that options 3 to 6 are only applied in countries with ventilation requirements. This assumption was necessary to avoid that different types of measures would be combined in the impact assessment without the possibility to separate each impact. As there are in 2020 still many countries without a specific ventilation or IAQ regulation, this assumption clearly has an important influence on the calculated impacts of the options 3 to 6.

Given the increased attention for health issues in many countries, it seems logical to expect that the overall tendency will be to have more requirements in terms of indoor air quality and/or ventilation.

As indicated in §5.4, it is very important to have clear specifications for allowing an efficient assessment of compliance/non-compliance in options 3 to 6, but also in option 2 in order to provide the appropriate training.

Therefore, if new regulations or revised regulations would be considered at the level of Member States, it is highly recommended that such regulations contain clear specifications which allow robust compliance checks. At the same time, it is important that such new regulations also pay attention to allowing innovative solutions (see §5.8).

5.8. Options 4 to 6 as drivers for innovation

Options 4 to 6 (with compliance checks and effective enforcement) can stimulate the development and market uptake of innovative systems.

The resulting types of innovation can cover a wide range of aspects, e.g.:

- development/optimisation of self-regulating air terminal devices (air supply and exhaust);
- development of highly efficient heat exchangers;
- development/optimisation of easy to install airtight air distribution systems;
- development/optimisation of ventilation components and systems with improved acoustical performances;
- development/optimisation of ventilation systems which are easy to install and maintain;
- development/optimisation of low-pressure air distribution systems;
- development/optimisation of smart IAQ sensors and control;
- development/optimisation of systems based on monitoring and control from the cloud;
- development/optimisation of systems with automatic fault detection.

Indirectly, options 4 to 6 can also stimulate other developments, e.g.:

- development and market uptake of smart design tools which guarantee the installers that the required specifications will be met;
- development/optimisation of tools in a Building Information Modelling (BIM) environment.

Therefore, the implementation of options 4 to 6 can be seen as a major driver for innovation and reduce the need for governmental support for industrial innovations.

5.9 Change in options over time

It is possible that, for a given country, the selection of one of 6 options (with all related choices) is in 2020 a very reasonable choice but that, in 2030 or later, it becomes less evident to continue with this choice.

Reasons can be for example:

- The market and stakeholders might in 2020 not be ready for a certain approach, whereas in 2030 societal support has changed.
- New technological developments (e.g., smart ventilation systems, data in the cloud, etc.) can result in other options which give a better value for money outcome.

5.10. Differences between newly installed and older systems

Options 3 to 6 can be considered for newly installed ventilation installations as well as for older installations.

Stand-alone ventilation systems installed for a while can be submitted to:

- an initial inspection whose content may be identical to that of options 3 to 6; the state of the systems before inspection can vary over a wide range of operating and performance conditions, depending on their type, age, obsolescence of components, maintenance status, etc.; the impact of an inspection is therefore difficult to estimate given the wide variety of situations encountered;
- a regular inspection relying on procedures similar to the ones of options 3 to 6; according to the frequency of these regular inspections and to the maintenance plan of the systems, the impact of an inspection can vary a lot.

In terms of liability for non-compliance, the boundary conditions can be very different:

- for newly installed installations:
  - It should in principle be clear who has been involved in the design, execution and commissioning of the installation.
  - It should in principle be possible to identify who is responsible for non-compliance and who has to take care of making the system compliant.
- for older installations:
  - In most cases, the installer will no longer be liable for non-compliance issues; compliance related actions probably have to be covered by the building owner.

These differences might have a major impact on the level of societal support for compliance and enforcement with potentially a big difference in support for newly installed installations versus older existing installations.

5.11 Impact of smart monitoring and control

In its definition of smart ventilation, the Air Infiltration and Ventilation Centre (AIVC) mentions that "smart ventilation systems can provide information to building owners, occupants, and managers on operational energy consumption and indoor air quality as well as signal when systems need maintenance or repair" and that they "can have sensors to detect air flow, systems pressures or fan energy use in such a way that systems failures can be detected and repaired, as well as when system components need maintenance, such as filter replacement". Stimulating the development and use of such smart ventilation systems is thus a way to improve the performance and quality of installed ventilation systems that might reduce the need for inspection in order to achieve the desired quality.

5.11.1 Impact of smart monitoring

By providing information about indoor contaminant concentrations, ventilation rates and fan energy use to building owners, users and managers, certain defects in the installation and operation of the system may be detected and repaired. Users may also become better aware of achieved performances and adjust user settings to obtain sufficient indoor air quality.

5.11.2 Impact of smart control

Since smart ventilation can continuously adjust the ventilation system in order to meet the desired indoor air quality and minimise energy consumption, the achieved performance may be less dependent on quality of commissioning, and less influenced by user actions, provided that the system is installed correctly, e.g., all sensors connected, or components in correct location.

In order to make sure that smart systems are able to achieve the desired indoor air quality, they need to have features for self-calibration and automated commissioning, assisting installers in achieving design targets. More advanced systems on the market today already have these features, and market evolution will probably continue in this direction. Today, residential bidirectional ventilation units frequently also have systems for automatic volume flow balancing. However, there are still large differences relating to maintenance of the balance[25]. Smart systems may have an improved accuracy of the flow balancing contributing to more optimal heat recovery in these systems.

Furthermore, smart ventilation can adjust ventilation depending on demand in response to detected occupancy or to the direct sensing of indoor contaminants. As a result, the heating or cooling energy use related to air renewal, as well as electrical energy of fans is on average reduced.

In the impact analysis, these features are considered by assuming that, in case of the policy option with no actions:

- 80% of smart mechanical ventilation systems with DCV controls and smart features are able to achieve minimum required flow rates, compared to 45%-60% for manually controlled systems.
- All systems have medium to high demand control features.
- In a large proportion of smart systems users do not feel the need to adjust system operation; as a result, indoor air quality is not affected by user interaction, e.g., to solve noise or draft problems.
- There are no balanced mechanical systems with heat recovery having imbalanced supply and extract air flows that decrease the heat recovery performance.

As a result of these smart features, the impact of the 6 policy options on smart system performance is smaller than with other systems, both in terms of energy performance (Figure 10) and indoor air quality (Figure 11). In fact, as the figures show, smart mechanical systems may achieve better indoor air quality in the option without actions than manually controlled mechanical systems in case of the most optimal policy option. The improved indoor air quality in smart systems is accompanied by an increased primary energy use, but the increase is smaller or equal to the increase in primary energy use resulting from the introduction of policy options in other systems. This indicates that the promotion of smart monitoring and control systems in stand-alone ventilation systems might complement the promotion of one (or more) of the investigated policy options.

In case data are collected in the cloud, options 3 to 6 could be replaced by procedures whereby performance monitoring is done from distance. Possible inspection protocols should then focus on the performances of the smart control strategies and on the reliability of the data collection in the cloud.

[25] *Bräunlich K. 2014. Automatic volume flow balancing in ventilation units, REHVA-Journal 04/2014*

6. Conclusions

This report describes the findings regarding the feasibility study on the inspection of stand-alone ventilation systems.

Six different options have been analysed in detail with estimations of the impact of the various options on the ventilation market development and on the performances of individual ventilation systems.

1. The findings of the impact analysis, as reported in chapter 4, give as an overall trend that the various considered options contribute, to a smaller or larger extent, to a better indoor air quality, whereby at the same time increasing the ventilation related energy consumption. These findings are directly related to the assumption that, on average, actual dwelling ventilation is too low for achieving good IAQ and that all of the options should contribute to an increase in air flow rates. However, it can be that, for specific situations, the original air flow rates are too high whereby the various options can result in a reduction of the energy consumption while maintaining a good IAQ.
2. It is crucial in the cost-benefit analysis to pay attention to the cost of poor IAQ on health, impact on productivity, and other factors due to a poor IAQ.
3. It is not evident to rank the various options in terms of priority. As highlighted in chapter 4, a succession among them is possible.
4. In general, the existence of sufficient awareness among citizens and decision makers is crucial to have societal support for the mandatory implementation of options 2 to 6. Moreover, awareness campaigns can also be a driver for appropriate ventilation or IAQ requirements in countries which do not yet have such type of requirements.
5. If the choice is made to implement an inspection of ventilation systems, there is a broad range of inspection schemes (options 4, 5 and 6), with a broad range of sub-options within each of them. Also, many choices exist with respect to the organisation of compliance and enforcement.
6. A valid alternative for inspection of ventilation systems can be imposing requirements on indoor air quality. This might in practice lead to the voluntary inspection of ventilation systems with the advantage of having effect during the whole lifetime of occupation.
7. Imposing inspection and/or IAQ requirements might be a strong driver for the development of innovative ventilation systems. In general, it should be a point of attention to assess the potential impact of the various options on innovation.

Annex 1 – Modules used to define options 3 to 6

In a previous report[26], the aspects that must be covered when defining an inspection framework have been identified through a list of questions.

For each of the questions related to the technical and organisational aspects of an inspection, several possible answers have been identified. Each possible answer constitutes a module to be assembled with other modules in order to set-up an inspection framework that covers the various aspects.

The objective of this Annex is to explain which of these modules were used to define the options 3, 4, 5 and to 6.

Tables 1 and 2 give the questions related to the technical and organisational aspects of an inspection.

Tables 3 and 4 show which modules have been selected to define the detailed contents of options 3 to 6:

- Option 3: visual inspection
- Option 4: inspection with masurements
- Option 5: inspection with measurements and the obligation to make the system compliant
- Option 6: indoor air quality requirements

A detailed description of each module can be found in Annex 1 of the previously published report[2].

[26] *Feasibility Study EPBD19a - Analysis of the relevance, feasibility and possible scope of measures for the inspection of stand-alone ventilation systems - Final report - September 2019*

TECHNICAL ASPECTS	
Aim of inspection	Which performance to be inspected?
	How to decide on the performance to be inspected?
Targets of inspection	Who should benefit from inspection?
	What types of buildings should be covered?
	What types of ventilation systems should be inspected?
	Which climatic zones should be concerned?
	In which period of the year can inspection take place?
Rules for inspection	What are the technical aspects covered by inspection?
	Which parts of the ventilation system need to be inspected?
	Is it sufficient to inspect only a sample of the ventilation systems?
In-situ measurements	What are the measured quantities?
	What are the measuring instruments?
	What is the measuring uncertainty?
	What is the calibration frequency of measuring instruments?
	What is the calibration procedure?
Reporting about inspection	What is the content of the inspection report?
	Who receives the report?
	Who keeps the report?
	What are the compliance criteria?
	What is the acceptable deviation for deciding on compliance?

Table 1 - Questions to define the technical aspects of an inspection

ORGANISATIONAL ASPECTS	
Periodicity of inspection	Does inspection occur once or is it regular?
	When does inspection occur?
Inspectors	By whom is inspection operated?
	Is there a need for quality assurance?
	Is there a need for training of inspectors?
	Is there a need for qualification of inspectors?
	Is there a need for certification of inspectors?
	Is there a need for surveillance of inspectors?
Non-compliance	What happens if inspection results show compliance or non-compliance of the ventilation system?
	What are the sanctions if inspection is not performed according to the rules?
Status	Is the inspection voluntary or mandatory?

Table 2 - Questions to define the organisational aspects of an inspection

TECHNICAL ASPECTS													
ASPECT	QUESTION	MODULES											
		a	b	C	d	e	f	g	h	i	*j*	*k*	*l*
AIM	1- Which performance to be inspected?	3 4 5 Energy performance	Air flow rates, air change	6 Indoor air quality	3 4 5 Hygiene of the ventilation system	Noise	Thermal comfort (draughts, temperature gradient)	Overall well-being of occupants	Overall well-being of neighbour-hood	Protection of building against humidity			
AIM	2- How to decide on the performance to be inspected?	3 4 5 Mandatory list of performance to inspect	6 List of inspected performance to be decided										
TARGETS	1- Who should benefit from inspection?	Occupants	Workers	Children	Elderly people	Persons with low revenues	Owners	Employers	Ventilation system manufac-turers				
	2- What types of buildings should be covered?	3 4 5 6 All residential	Single-family house	Multi-apartment buildings	All non-residential	Offices	Retail buildings	Educational buildings	Health care facilities	Hotels and restaurants	Sport facilities		
TAR	3- What types of ventilation systems should be inspected?	Natural	Hybrid	3 4 5 Mechanical decentralised unidirectional	Mechanical decentralised balanced without heat recovery	Mechanical decentralised balanced with heat recovery	Mechanical centralised unidirectional	Mechanical centralised balanced without heat recovery	Mechanical centralised balanced with heat recovery	Demand-controlled ventilation system			
	4- Which climatic zones should be concerned?	All climatic zones	Colder	Warmer									
	5- In which period of the year can inspection take place?	3 4 5 6 All year	Warm season	Cold season	Mid-season								
RULES	1- What are the technical aspects covered by inspection?	Pre-check	3 4 5 Complete-ness	Adequacy between design and installation	3 4 5 Cleanliness and hygiene	General state	Good overall operation	Good operation of controls	Occupants satisfaction	4 5 Energy con-sumption	4 5 6 Measure-ments	Adequacy with current ventilation needs	Quality of maintenance
RUL	2- Which parts of the ventilation system need to be inspected?	3 Whole system	4 5 Ductwork	Ventilation unit	Air inlets	Air outlets	Air transfers	Filters	Sensors	Controls			
	3- Is it sufficient to inspect only a sample of ventilation systems?	3 4 5 Inspection of each system	Inspection of a sample of the systems	Inspection of a sample of the buildings									

Table 3 – Modules for the technical aspects of options 3 to 6 (1/3) – Figures in red refer to option numbers

TECHNICAL ASPECTS													
ASPECT	QUESTION	MODULES											
		a	b	c	d	e	f	g	h	i	*j*	*k*	*l*
IN SITU MEASUREMENT *MEA*	1-What are the measured quantities?	Air flow rates at fan level	4 5 Air flow rates at room level	Air pressures at fan level	Air pressures at room level	Ductwork airtightness	4 5 Electrical power input	Performance of heat recovery	6 Indoor air quality parameters	Noise level in rooms	Noise level outdoors	Thermal comfort parameters	4 5 Air cross-sections areas
	2- What are the measuring instruments?	4 5 Air flow meter	Anemometer	Manometer	4 5 Wattmeter	Thermometer	6 Pollutant concentration analyser	Noise analyser	Hygrometer	4 5 Dimensional measurement tools	Pressurisation measurement device		
	3- What is the measuring uncertainty?	No uncertainty specified	Fixed uncertainty	Uncertainty of the measurement method	4 5 6 Uncertainty of the measuring instrument								
	4- What is the calibration frequency of measuring instruments?	None	Once	4 5 6 Regular									
	5- What is the calibration procedure?	6 By the manufacturer of the measuring instrument	By an independent laboratory	4 5 By an independent accredited laboratory	By an ISO 9001 certified organisation	By the inspector	Calibration range						

Table 3 – Modules for the technical aspects of options 3 to 6 (2/3) – Figures in red refer to option numbers

TECHNICAL ASPECTS												
ASPECT	QUESTION	MODULES										
		a	b	c	d	e	f	g	h	i	*j*	*k*
REPORTING ABOUT INSPECTION *REP*	1- What is the content of the inspection report?	Certificate	3 Certificate with parameters checked	Certificate with results	4 Certificate with target values and results	Certificate with target values, results and advice	5 Certificate stating compliance					
	2- Who receives the report?	3 4 5 Owner	6 Occupant	3 4 5 Public authority	Architect	Installer	Person in charge of the calculation of the building's energy performance	Employees	Employer			
	3- Who keeps the report?	3 4 5 Owner	Installer	Occupant	System designer	Independent inspector	3 4 5 Public authority	Certification organisation	Architect	Person in charge of the energy performance of building calculation	Digital monitoring system of the building	Building Infor-mation Model (BIM)
	4- What are the compliance criteria?	3 Comparison with usual practice	4 5 6 Comparison with values fixed by regulation, standard, guidelines	Comparison with design values	Comparison with builder's require-ments	Comparison with current ventilation needs	None					
	5- What is the acceptable deviation for deciding on compliance?	3 4 5 None	6 Lower performance accepted within a certain tolerance	Higher performance required to make sure that the actual value will fulfil the requirement (safety margin)								

Table 3 – Modules for the technical aspects of options 3 to 6 (3/3) – Figures in red refer to option numbers

ORGANISATIONAL ASPECTS										
ASPECT	QUESTION	MODULES								
		a	b	c	d	e	f	g	h	i
PERIODICITY OF INSPECTION *PER*	1- Does inspection occur once or is it regular?	3 4 5 6 Once	Regular							
	2- When does inspection occur?	At regular time intervals	With renewal of the Energy Performance Certificate	When building is rented or sold out	3 4 5 After installation of a new system	When parts of the system are changed or repaired	6 When the owner or occupant requests it	When controls indicate that inspection is necessary	At building's commissioning	After building's major renovation
INSPECTORS *INS*	1- By whom is inspection operated?	3 4 5 System designer	3 4 5 (6) Independent inspector / Third party service provider	3 4 5 Installer	Maintenance staff	(3 4 5) Owner	Occupant	3 4 5 Architect	Building airtightness tester	Person in charge of the energy performance of building calculation
	2- Is there a need for quality assurance?	Quality assurance	3 4 5 6 No quality assurance							
	3- Is there a need for training of inspectors?	Theoretical training	3 4 5 Practical training	No training						
	4- Is there a need for qualification of inspectors?	4 5 Qualification	3 No qualification							
	5- Is there a need for certification of inspectors?	3 Certification	4 5 No certification							
	6- Is there a need for surveillance of inspectors?	None	Information to be provided by inspectors	3 4 5 Audit of inspectors						
NON-COMPLIANCE *NC*	1- What happens if inspection results show compliance or non-compliance of the ventilation system?	5 Obligation to make the system compliant	Sanctions	Rewarding	3 4 6 Nothing specific					
	2- What are the sanctions if inspection is not performed according to the rules?	No sanction	3 4 5 Sanctions							
STATUS *STA*	1- Is the inspection voluntary or mandatory?	3 4 5 Mandatory	6 Voluntary							

Table 4 – Modules for the organisational aspects of options 3 to 6 – Figures in red refer to option numbers

Annex 2 – Details of the impact analysis methodology

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Contents

1. Introduction

This annex describes the calculation methodology for the market impact analysis of different options related to the inspection of stand-alone ventilation systems and other quality related measures. The methodology has been implemented in an excel-based calculation tool that is delivered in addition to this report.

2. Features of the tool for inspection of ventilation systems

The calculation tool has the following features:

- To allow a regional analysis

- To consider a wide range of ventilation systems, whereby the market share of these systems can vary over time and vary by country
- To consider a whole range of measures with an impact on the quality of stand-alone ventilation systems, whereby inspection schemes are the major point of attention but also other measures (awareness raising, training, certification of installer, etc.)
- To have some common data with the tool developed for the renovation passport and for the study on the smart readiness indicator
- To allow considering regional differences, e.g. in terms of building airtightness, etc.

Since the data about the stock and sales of ventilation systems from a previous report[27] showed that 93% of stand-alone ventilation systems are residential, the focus in the calculation tool is on residential buildings, as well as the options that are analysed. At the same time the tool assumes that the different options for inspection of stand-alone ventilation systems primarily have an impact on new systems installed in new or renovated buildings. In principle, other calculations are possible for existing installations or for non-residential buildings, based on a similar methodology.

3. Input parameters

3.1 Building stock description

3.1.1 Building stock division

In this study, the potential impact of introducing inspection schemes for stand-alone ventilation systems is determined at two different scales:

- On the one hand, the entire European building stock is considered to assess the impact on a large scale.
- On the other hand, the European building stock is divided into five different climate regions to define the impact on a small scale assuming that countries within the same climate region will show similar results.

Analogous to the technical study commissioned and supervised by the European Commission towards the development of a smart readiness indicator for buildings[28], the division of the European building stock into climate regions is based on typical climate conditions and building stock characteristics. The corresponding countries of each climate region are summarised in Table 1.

[27] *Feasibility Study EPBD19a - Stock of ventilation systems in EU buildings and foreseen evolution for 2030, 2040 and 2050 – June 2019*

[28] *VITO et al. - Support for setting up a Smart Readiness Indicator for buildings and related impact assessment – August 2018*

N	**- Northern**	**N**
- FIN	- Finland	N- FIN
- S	- Sweden	N- S
- DK	- Denmark	N- DK
W	**- Western**	**W**
- GB	- United Kingdom	W - GB
- IRL	- Ireland	W - IRL
- D	- Germany	W - D
- A	- Austria	W - A
- F	- France	W - F
- B	- Belgium	W - B
- L	- Luxembourg	W - L
- NL	- The Netherlands	W - NL
S	**- Southern**	**S**
- P	- Portugal	S - P
- E	- Spain	S - E
- CY	- Cyprus	S - CY
- M	- Malta	S - M
- I	- Italy	S - I
- GR	- Greece	S - GR
NE	**- North-Eastern**	**NE**
- EST	- Estonia	NE - EST
- LV	- Latvia	NE - LV
- LT	- Lithuania	NE - LT
- PL	- Poland	NE - PL
- SK	- Slovakia	NE - SK
- CZ	- Czech Republic	NE - CZ
SE	**- South-Eastern**	**SE**
- SLO	- Slovenia	SE - SLO
- HR	- Croatia	SE - HR
- H	- Hungary	SE - H
- BG	- Bulgaria	SE - BG
- RO	- Romania	SE - RO

Table 1: Corresponding countries of each climate zone.

3.1.2 Building stock data

Building stock data are obtained through the EU Building Stock Observatory of the European Commission. The Observatory includes inter alia an EU Building database[29] summarising different characteristics of the European building stock per year.

Moreover, the source is used to collect residential European and country-specific data about the total number of dwellings and their floor area. Data is available up to and including 2014. Since the data of 2014 are calculation-based values, the year 2013 is used as a base point to determine the building stock evolution. Furthermore, no distinction is made between the different residential building types (e.g., single-family, and small and large multi-family houses) within this impact analysis.

3.1.3 Building stock evolution

The assumptions concerning the building stock evolution are derived from 'the Agreed Amendments pathway' used in the technical study on a Smart Readiness Indicator[14]. By averaging the proposed set of building stock scenario parameters per climate region, the evolution rates are as follows (Table 2):

[29] https://ec.europa.eu/energy/en/eu-buildings-database

N	**new building**	< 2026 2026 - 2050	1,04% 1,08%
	demolition	< 2026 2026 - 2050	0,10% 0,10%
	retrofit	< 2026 2026 - 2050	0,89% 1,43%
W	**new building**	< 2026 2026 - 2050	0,63% 0,56%
	demolition	< 2026 2026 - 2050	0,10% 0,10%
	retrofit	< 2026 2026 - 2050	0,89% 1,43%
S	**new building**	< 2026 2026 - 2050	0,63% 0,53%
	demolition	< 2026 2026 - 2050	0,10% 0,10%
	retrofit	< 2026 2026 - 2050	0,89% 1,43%
NE	**new building**	< 2026 2026 - 2050	0,82% 0,48%
	demolition	< 2026 2026 - 2050	0,10% 0,10%
	retrofit	< 2026 2026 - 2050	0,89% 1,43%
SE	**new building**	< 2026 2026 - 2050	0,36% 0,32%
	demolition	< 2026 2026 - 2050	0,10% 0,10%
	retrofit	< 2026 2026 - 2050	0,89% 1,43%

Table 2: Building stock scenario rates per climate region.

By combining the above-mentioned evolution rates with the building stock data obtained from the EU Building Stock Observatory, the development regarding the number of dwelling and their floor area can be derived for different timeframes. The method provides a building stock status for Europe and for the five predefined climate regions in 2020, 2025, 2030, 2040 and 2050. The results are presented in Figure 1 and Figure 2.

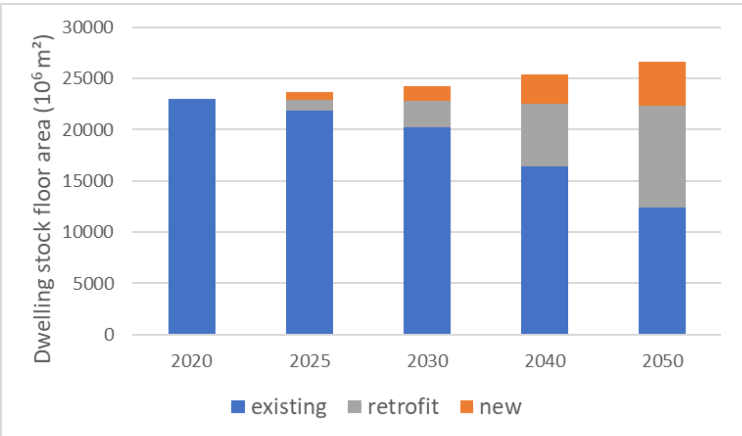


Figure 1: EU Residential stock evolution total floor area.

Figure 2: EU Residential stock evolution total number of dwellings.

3.2 Ventilation systems

3.2.1 Type of ventilation systems

A very important element in the impact analysis study is the type of ventilation systems under consideration, because the impact of quality related measures can vary widely as function of the type of ventilation systems.

A few illustrations:

- Natural ventilation systems are essentially based on the availability of devices for allowing air supply, transfer and exhaust. An inspection will be primarily focused on the presence of the appropriate devices and their product performances (air transfer, acoustics, etc.).
- Ventilation systems with manually controlled mechanical supply and/or exhaust are typically characterised in terms of appropriate air flow rate, ductwork airtightness, control settings, fan power, etc.
- In case of mechanical ventilation systems with demand control the control characteristics are very important and the checking of the nominal air flow rate may be less critical.
- In case of mechanical ventilation systems with smart control the possible impact of inspection schemes is potentially very different.

The calculation tool foresees the possibility of having 10 types of ventilation systems. The main categories are based on the analysis of the stock of ventilation systems in EU Buildings[13], with subcategories based on the types of controls. Terminology used is from Directive 2009/125/EC (ecodesign requirements for ventilation units). All 10 types are considered in the impact analysis.

0. **No ventilation**: there are still many buildings without a ventilation system. This is the case for existing buildings, but also for new buildings, in countries where it is not mandatory to install ventilation systems, or even sometimes when there are regulations in place, but which are not respected.
1. **Natural supply and exhaust – manual**: fully natural ventilation, which may include air supply grills and extraction grills connected to chimneys. Opening and closing of devices can be possible or not possible, depending on country regulations. In case possible, it is by manual control.
2. **Decentralised unidirectional systems – manual**: systems consisting of free air supply ventilators, and one or more mechanical exhaust fans in dedicated

rooms. Manual opening or closing of ventilators can be possible or not possible, depending on country regulations. Exhaust fans may be manually switched on or off.

3. **Decentralised unidirectional systems – DCV**: Identical to system 2, but exhaust fans are demand-controlled by built-in sensors.
4. **Central unidirectional systems – manual:** ventilation systems with natural supply ventilators and a single central mechanical exhaust fan. Manual opening or closing of ventilators can be possible or not possible, depending on country regulations. The user may manually switch the fan to different speeds. This category may also include systems with mechanical supply in combination with natural exhaust chimneys, but this is less common.
5. **Central unidirectional systems – DCV**: Identical to system 4, but with demand control for supply and/or exhaust, based on the information of sensors positioned in ducts or in rooms.
6. **Central unidirectional systems – DCV – smart**: Identical to system 5, but in addition including smart features, e.g., self-calibrating of the system, fault detection, information on maintenance needs, feedback to the user, etc.

   The cases 'DCV' and 'Smart' are separately considered as they may have a substantial influence on the potential impact of policy options.

7. **Central bidirectional system – manual:** ventilation system with a central mechanical supply fan and a central mechanical exhaust fan. Usually, the ventilation unit is equipped with a heat recovery system. The user may manually switch the fans to different speeds.
8. **Central bidirectional system – DCV**: Identical to system 7, but with demand control for supply and exhaust, based on the positioning of sensors in ducts or rooms.
9. **Central bidirectional system – smart:** Identical to system 7, but in addition including smart features, e.g., self-calibrating of the system, fault detection, information on maintenance needs, feedback to the user, etc.
10. **Local bidirectional system:** systems consisting of decentralised bidirectional ventilation units, often with heat recovery system, located in dedicated rooms. Local systems may be easier applicable in renovation.

3.2.2 Market share of ventilation systems

It is clear that the type of ventilation system may differ from country to country and that the market share of each system can vary over time.

The calculation tool allows to define for each climate region the market share of each system and this for 2020, 2025, 2030, 2040 and 2050.

As the impact of the various policy options may (substantially) differ for the various types of ventilation systems, the estimation of market distribution as function of time is important.

The evolution of the market share of ventilation systems, Figure 3, is based on the analysis of the stock of ventilation systems in EU buildings from the consolidation of existing data in a previous report[7]. The share of the subcategories (manual, DCV, smart) is estimated starting from the share of main categories. The market share is further refined by comparing the stock of ventilation systems to the dwelling stock evolution. This way, the number of dwellings equipped with a specific type of ventilation system may be estimated. Since the total increase of new and retrofitted houses according to the 'agreed amendments pathway' is larger than the total increase of ventilation units estimated in Figure 3, the difference between both gives an indication of the number of new and retrofitted houses without ventilation system, for instance because the installation of a ventilation system in construction or renovation projects is not mandatory in every country.

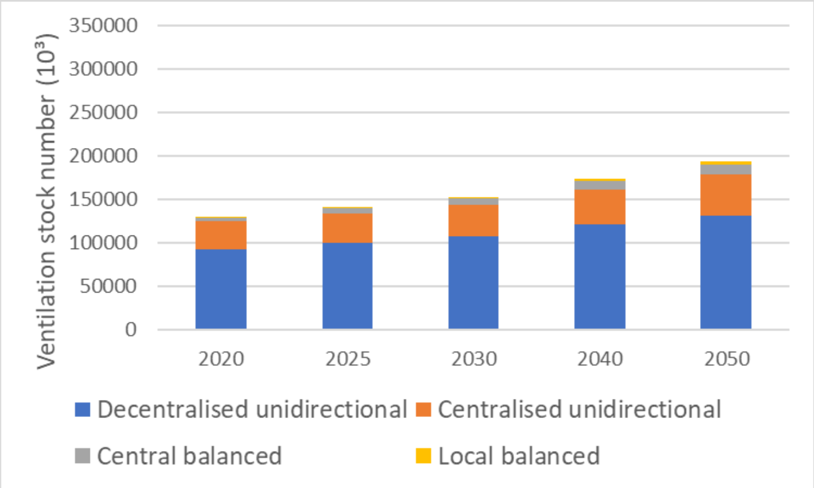


Figure 3: EU evolution of the total number of ventilation units (from the report mentioned in footnote [13]).

There are many uncertainties in the conversion of the ventilation stock to the dwelling stock:

- How to deal with the number of decentralised units, since often several extraction fans are used in different rooms to ventilate the complete dwelling (e.g., one exhaust fan in the bathroom, one in the kitchen, etc.)?
- How to deal with the number of centralised ventilation systems, knowing that in multi-family buildings a single ventilation unit may serve several dwellings?
- How to estimate the market share and future evolution of natural ventilation systems, for which data are lacking?
- How to estimate the market share and future evolution of DCV and smart systems, for which data are lacking?
- How to deal with differences in assumptions concerning the ventilation stock evolution (business as usual) and the dwelling stock evolution (increased renovation rate after 2026)? Without a correction for these differences the number of renovated dwellings without a new ventilation unit may be unrealistically large.
- How to deal with the future introduction or evolution of ventilation regulations in EU Member States? Today, not all European countries have mandatory requirements for the installation of ventilation systems in new or renovated buildings. It is likely that, between now and 2050, more countries will impose ventilation requirements for new or renovated dwellings and that there even might be IAQ or ventilation requirements for existing dwellings.

In relation to these uncertainties, the following assumptions are made for the purposes of the calculation :

- On average three decentralised units are installed per dwelling.
- On average one central unit serves 1.5 dwellings (considering the fact that the ventilation stock data[13] show that 20% of all central units are installed in multifamily buildings).
- The market share of natural ventilation systems is based on information from FGK[30] (2010).
- The share and future evolution of natural, DCV and smart systems are based on country reports, assuming a future shift towards DCV and smart systems, as documented in the tool.
- The increased renovation rate in the dwelling stock evolution after 2026 is taken into account by assuming that the ventilation stock evolution increases with the same rate as the dwelling stock evolution, in comparison to the ventilation stock evolution[13]. The increase is depending on the climate region but is in the order of 30%.
- There is no change in ventilation regulations between now and 2050. This means that there is little to no increase in ventilation systems in countries which today have no ventilation requirements for new and renovated dwellings. Existing dwellings which have no ventilation systems today and which are not renovated between now and 2050, will remain without system.

Figure 4 shows the result of the combination of all these data.

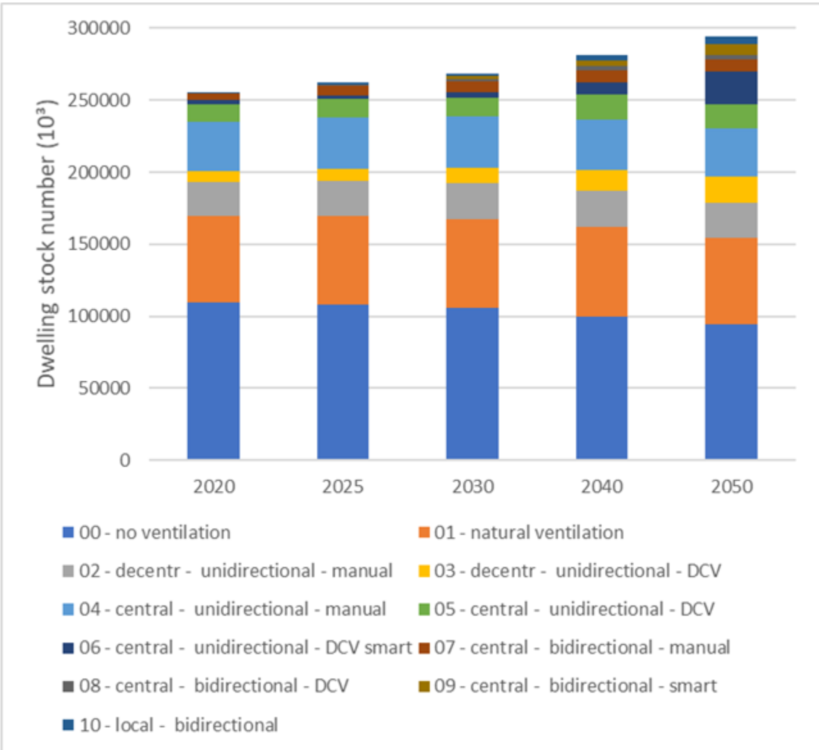


Figure 4: EU evolution of the total number of dwellings with a specific ventilation system.

[30] *FGK, Supplements to Preparatory Study on Residential Ventilation Lot 10 (i.e. mechanical ventilation units with fans < 125 W) – Final draft, 2010*

The figures included in the tool for 2020 relate to the market share of ventilation systems in the existing dwelling stock in 2020, see Table 4. The colours qualitatively indicate the market share (red = close to 0%, dark green = about 60% market share).

		reference situation in 2020											
climate zone	year	00 - no ventilation	01 - natural ventilation	02 - decentr - unidirectional - manual	03 - decentr - unidirectional - DCV	04 - central - unidirectional - manual	05 - central - unidirectional - DCV	06 - central - unidirectional - DCV smart	07 - central - bidirectional - manual	08 - central - bidirectional - DCV	09 - central - bidirectional - smart	10 - local - bidirectional	CHECK
EU	2020	43,0%	23,5%	9,0%	3,0%	13,5%	4,8%	1,0%	1,8%	0,0%	0,0%	0,4%	100%
N	2020	32,3%	24,6%	6,7%	2,2%	16,7%	6,0%	1,2%	10,1%	0,0%	0,0%	0,1%	100%
W	2020	35,0%	27,1%	10,0%	3,3%	15,7%	5,6%	1,1%	2,0%	0,0%	0,0%	0,2%	100%
S	2020	60,6%	18,4%	6,8%	2,3%	8,0%	2,9%	0,6%	0,6%	0,0%	0,0%	0,0%	100%
NE	2020	40,7%	23,0%	10,3%	3,4%	14,9%	5,3%	1,1%	1,3%	0,0%	0,0%	0,0%	100%
SE	2020	40,6%	20,4%	10,7%	3,6%	16,3%	5,8%	1,2%	1,4%	0,0%	0,0%	0,0%	100%

Table 3: Example of the share of existing dwellings with a specific ventilation type in 2020 for different climate regions based on the analysis of the stock of ventilation units and the dwelling stock.

The figures included for 2025 and later relate to the market share of systems in new and retrofitted dwellings constructed between 2020 and the year indicated in the table, as defined in the residential building stock model described in 3.1. The difference between the number of new and retrofitted dwellings, and the estimated number of dwellings with newly installed ventilation system, relates to new and retrofitted dwellings where no (new) ventilation system is installed. This number may relate to countries where it is not mandatory to install ventilation systems in new or renovated dwellings (e.g., in Germany, Greece, etc.), to projects with requirements to install ventilation but where compliance is not checked or enforced, or to renovation projects where building services are not renovated (e.g., façade renovation). The fact that the relative share of new and retrofitted dwellings without new ventilation system increases is caused by the differences in assumption concerning ventilation stock evolution and dwelling stock evolution, as explained before (despite the corrections taken into account).

		0 - no policy options											
climate zone	year	00 - no new ventilation system	01 - natural ventilation	02 - decentr - unidirectional - manual	03 - decentr - unidirectional - DCV	04 - central - unidirectional - manual	05 - central - unidirectional - DCV	06 - central - unidirectional - DCV smart	07 - central - bidirectional - manual	08 - central - bidirectional - DCV	09 - central - bidirectional - smart	10 - local - bidirectional	CHECK
EU	2025	48,2%	10,0%	8,1%	5,4%	6,6%	3,3%	1,1%	8,8%	4,4%	1,5%	2,6%	100%
EU	2030	48,8%	8,9%	6,8%	6,8%	5,6%	2,8%	2,8%	7,5%	3,7%	3,7%	2,6%	100%
EU	2040	51,0%	7,2%	4,5%	7,3%	3,7%	6,4%	6,4%	3,8%	3,6%	3,6%	2,7%	100%
EU	2050	52,0%	5,9%	2,8%	7,6%	2,3%	4,1%	13,2%	2,4%	2,3%	4,8%	2,7%	100%

Table 4: Example of the reference EU market trends for 2025, 2030, 2040 and-2050 based on the analysis of the stock of ventilation systems and the dwelling stock evolution in EU buildings.

3.3 Selected policy options for the inspection of stand-alone ventilation systems

The goal of this technical study is to analyse the potential impacts of the selected policy options. The considered policy options are described more in detail in chapter 2 of the main part of this report, and are included in the calculation tool.

0. The reference option refers to a business as usual scenario, where none of the other six policy options are prescribed at a European level
1. Better knowledge about the status on the ground in combination with awareness raising of stakeholders
2. Professionals skills increase through training programmes
3. Visual inspection of stand-alone ventilation systems
4. Inspection of stand-alone ventilation systems with measurements
5. Inspection of stand-alone ventilation systems with measurements and the obligation to make the system compliant
6. Measurement of indoor air quality parameters

As the various policy options may have an influence on the market share of ventilation systems, the tool allows to define different market share evolutions for the options of inspection schemes considered. The policy options will mainly have an impact on the use of ventilation systems in projects with requirements to install ventilation but where compliance is not checked or enforced in the scenario without policy options, for example:

- With increased awareness raising, more builders might decide to install ventilation when renovating their house, even in countries where it is not mandatory. Also, more builders might decide to install balanced ventilation systems instead of natural or unidirectional systems.
- With visual inspection or inspection with measurements, builders who do not install a system even though it is mandatory, might be forced to do so.

- With inspection with measurements, the shift towards smart systems might be faster, because in these systems it is easier for installers to perform the required measurements.

Information about the enforcement of requirements to install ventilation systems, and about the impact of policy options on compliance is scarce. Therefore, the tool allows to define default values quantifying the increase of new ventilation systems in new and retrofitted dwellings as a result of a policy option, in comparison with a scenario without policy options.

Impact policy options on ventilation market	
0 - no policy options	0%
1 - national field data	5%
2 - training	5%
3 - visual inspection	10%
4 - measurement inspection	10%
5 - measurement compliance	20%
6 - measurement indoor air	10%

Table 5: Increase of new ventilation systems in new and retrofitted dwellings as a result of a policy option, in comparison with a scenario without policy options.

In the tool, it is assumed that the additionally installed ventilation systems as a result of a policy option are either central unidirectional or central bidirectional systems (50/50), with a share between manual, DCV or smart proportional to the share in the scenario without policy options. In policy option 5, it is assumed that 75% of the additionally installed systems are smart systems.

3.4 Impact of policy options on ventilation performances

Each type of policy option might have a different impact on the performance of the ventilation system (in terms of indoor air quality, acoustics, fan energy, air flow rate, etc.). The impact was estimated for each approach and for each type of ventilation system, based on a few performance data, which are then used for estimating the effect of the policy options on the energy use and indoor air quality in the total building stock.

The performance parameters included in the tool are three flow rate adjustment factors, and two energy performance factors, described in the following sections:

3.4.1 Quality factor of design and installation

The quality factor expresses to what extent the air flow rate delivered by the installed system meets the required nominal air flow rate, prescribed in standards or legislation. The factor is expressed as a percentage of the required nominal air flow rate, and has an impact on both the energy use and the indoor air quality. The distribution is then estimated for the whole market of the specific type of ventilation system. As concluded in a previous report[13], a large proportion of systems on the market do not provide the required air flow rates.

Example:

	Description	% of nominal flow	Policy option X	Policy option Y
Quality factor of design and installation	High	150%	10%	30%
	Nominal	100%	50%	60%
	Low	66%	20%	10%
	Very low	33%	20%	0%

Table 6: Example of the possible impact of two policy options on the nominal air flow rate for a given type of ventilation system.

In the example:

- In the case of policy option X, there is a substantial number of installations with a nominal air flow rate below the requirements and a small percentage which is over ventilated.
- In the case of policy option Y, there are less under-dimensioned ventilation systems and an increase in over-dimensioned ventilation systems.

3.4.2 Control factor of ventilation system

Depending on the type of controls installed or integrated in the ventilation system, the air flow rates may vary as a function of the needs based on user interaction or sensor information. There are various types of controls, ranging from no control at all (all the time at maximum speed), manual control, central or local demand control using information from sensors of humidity, CO_2, etc. The control factor expresses the ratio between the mean air flow rate achieved by the system (considering control actions) and the maximum air flow rate that can be delivered by the installed system. It is assumed that it has an impact on the energy use, but not on the indoor air quality, since it is assumed that the air flow rates are reduced by the controls only at times of reduced ventilation needs.

Example:

	Description	% of nominal flow	Policy option X	Policy option Y
Control of ventilation system	No	100%	50%	30%
	Medium	85%	50%	60%
	High	60%	0%	10%

Table 7: Example of the possible impact of two policy options on the control of the ventilation system for a given type of ventilation system.

In the example:

- In the case of policy option X, 50% of the installations of a certain type of ventilation system have no control, and 50% have medium control possibilities.
- In the case of policy option Y, there are less ventilation systems without control, and an increase in ventilation systems with medium to high control possibilities.

The figures 60%, 85%, 100% are based on performance figures of systems on the market (see Figure 5), and on the range of control factors defined in the ecodesign SEC calculation.

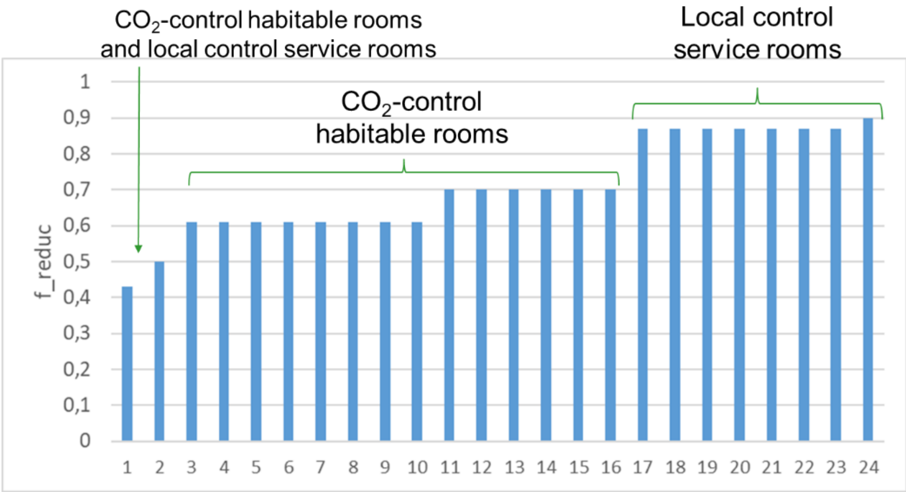


Figure 5: Control factors for 24 different demand-controlled ventilation systems available on the Belgian market (epbd.be).

3.4.3 User impact on the air flow rate

Users can have a major impact on the operation of a ventilation system, e.g.:

- When they experience comfort problems, such as noise or draught, or are concerned about a very high energy bill, they might switch the system off or in lower position. Field studies show that mechanical ventilation systems on the market are often not operated at the nominal flow rates due to noise problems (Figure 6).
- When they are not aware of the benefit of reducing the ventilation in case of lower occupancy and/or absence, there is unnecessary energy consumption.

The user impact factor expresses the ratio between the mean air flow rate achieved by the system (considering inappropriate user actions) and the maximum air flow rate that can be delivered by the installed system. It has an impact on the energy use and on the indoor air quality, since it is assumed that the air flow rates may be reduced by the user also at times of increased ventilation needs.

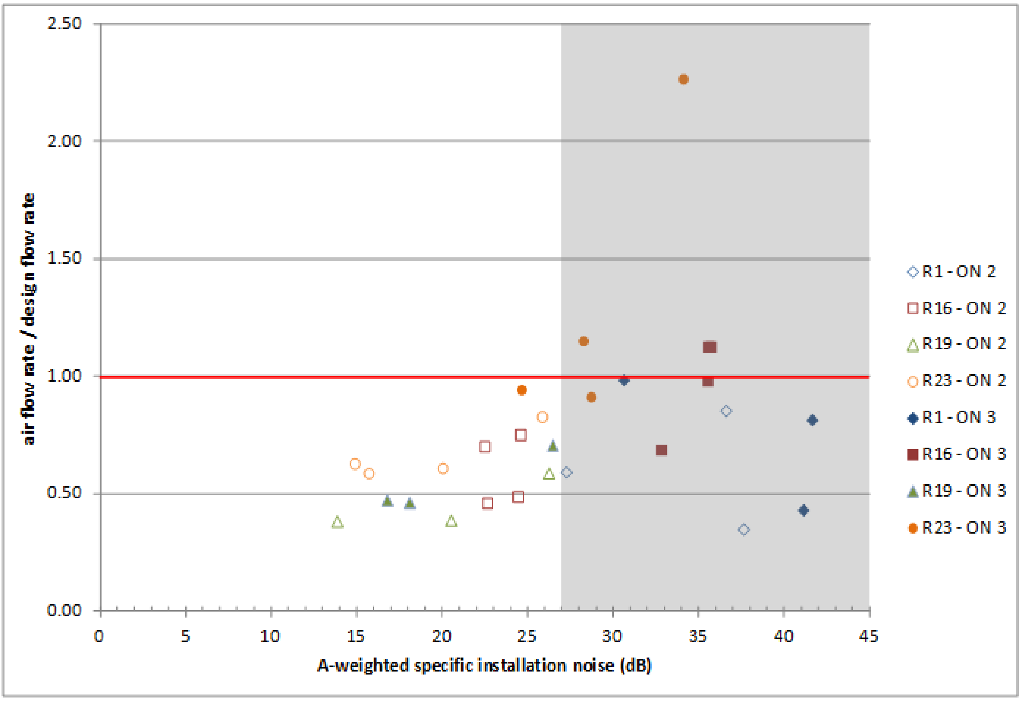


Figure 6: Measured noise in bedrooms as a function of the flow rate control of the mechanical ventilation system, showing that when systems deliver the design flow rate, the risk for noise nuisance increases (L > 27dBA) (INIVE, 2013).

Example:

	Description	% of time system in use	Policy option X	Policy option Y
User impact on air flow rates	Low	100%	25%	50%
	Medium	70%	25%	35%
	High	40%	50%	15%

Table 8: Example of the possible impact of two policy options on the user impact for a given type of ventilation system.

In the example:

- Three classes of user impact are considered:
    - low: the users have, on average, only a negligible impact on the air flow rates due to issues as acoustics, draught, perception of very high energy consumption;
    - medium: the users reduce, on average, the air flow rates by 30% due to issues as acoustics, draught, perception of very high energy consumption;
    - high: the users reduce, on average, the air flow rates by 60% due to issues as acoustics, draught, perception of very high energy consumption.
- In policy option Y, the impact of the user is smaller than in policy option X.

3.4.4 Electrical efficiency

The electrical efficiency is characterising the electrical fan consumption. The SFP-value (Specific Fan Power) is used to characterise the system performances, with classes defined in EN 13779.

A whole range of factors influence the SFP, e.g., fan characteristics, aeraulic characteristics of ductwork and system components such as heat recovery, air terminal devices, filters, dampers, ductwork airtightness, etc. As a consequence, the SFP also depends on the type of system, as Figure 7 illustrates.

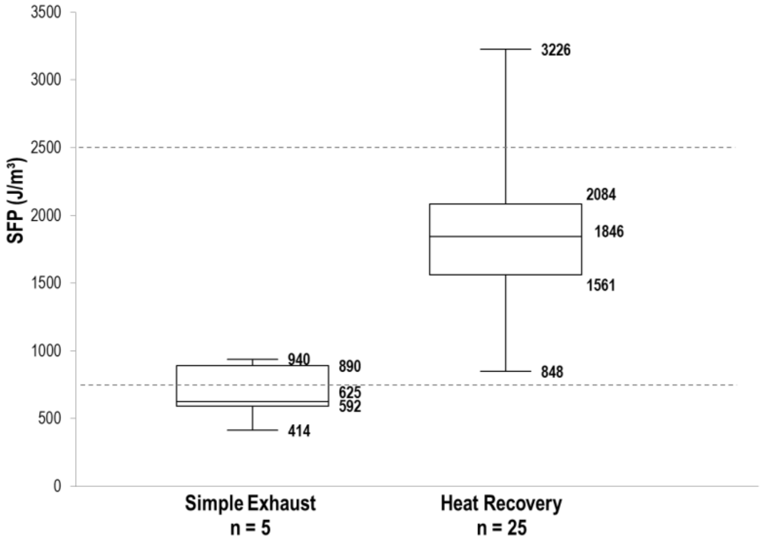


Figure 7: Measured SFP in unidirectional and bi-directional mechanical residential ventilation systems (Caillou, 2011).

Example:

	Description	Specific Fan Power (W per m³/h)	Policy option X	Policy option Y
Electrical efficiency	No fan	0.00	0%	0%
	Very high	0.14	0%	5%
	High	0.21	10%	10%
	Medium	0.35	20%	50%
	Low	0.56	50%	35%
	Very low	1.00	20%	0%

Table 9: Example of the possible impact of two policy options on the electrical efficiency for a given type of ventilation system.

In the example:

- Policy option Y clearly results in better SFP values than policy option X.
- In case of a natural ventilation system, or no ventilation system, no fan power is taken into account in the calculation (100% no fan).

3.4.5 Thermal efficiency of heat recovery

The thermal efficiency characterises the level of heat recovered with respect to the energy needed to heat the outdoor air to the desired indoor temperature. This is typically done by a heat exchanger in combination with mechanical supply and exhaust. The achieved thermal efficiency depends on the heat exchanger technology, but also on quality aspects such as the balancing of supply and exhaust flow rates, leakage of the air handling unit, thermal insulation of ductwork in unheated spaces, etc. As an example, Figure 8 shows the variation of the equivalent heat recovery thermal efficiency as a function of the balancing of supply and exhaust flows.

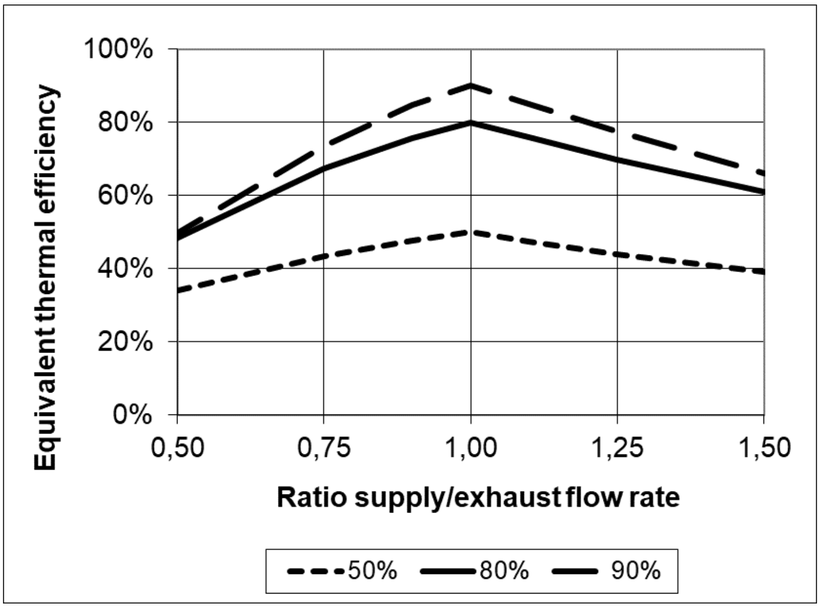


Figure 8: Equivalent thermal efficiency of heat recovery as a function of the ratio between supply and exhaust flow rate (1.0: perfectly balanced) and the value of the nominal thermal efficiency in bi-directional mechanical ventilation systems.

Example:

	Description	% of nominal flow	Policy option X	Policy option Y
Thermal efficiency	Very high	90%	5%	10%
	High	75%	40%	60%
	Medium	60%	30%	30%
	Low	40%	20%	0%
	Nihil	0%	5%	0%

Table 10: Example of the possible impact of two policy options on the thermal efficiency of the ventilation system for a given type of ventilation system.

In the example:

- Policy option Y clearly results in a better thermal efficiency than policy option X, for instance because supply and exhaust flows are better balanced.
- In case of a natural ventilation system or a mechanical exhaust ventilation system, 100% is linked to ‘Nihil’.

4. Calculation of direct indicators

4.1 General – basis analysis

In this study, we analyse the direct impact of introducing policy options in three main outputs:

- The impact on the energy use (final and primary)
- The impact on the CO_2-emissions
- The impact on the indoor climate, in particular on the indoor air quality and on the health of occupants, using an indicator that expresses the exposure of occupants to pollutants

These indicators are first calculated for each selected ventilation system and policy option, as a specific value per m² floor area. In a second step the indicators are extrapolated to the total building stock by combining the initially calculated figures with the building stock data and the data about the market share of ventilation systems (see §9).

The indicators are calculated twice: once without considering the user impact factor, and a second time including the impact of user interaction.

4.2 Energy consumption

The final and primary energy consumption consists of two parts:

- Fan energy
  - The estimated average fan power can easily be transformed into energy consumption.
- Heating energy use
  - The estimated ventilation rates are combined with climate data and a simplified energy model to estimate the heating demand and the energy consumption.

The calculation method is inspired by the eco-design SEC calculation (specific energy consumption).

For the primary fan energy use (Wh/(m²year)):

$$P_{f,p} = t_a.pef.q_{net}.f_{qual}.f_{ctr}^{x}.f_{use}.SFP$$

with t_a the annual operating hours (8760 h/year), pef the primary energy factor for electrical power generation and distribution (2.5), q_{net} the net ventilation rate demand per heated floor area (m³/(m².h)), f_{qual} the mean quality factor of design and installation, f_{ctr} the mean ventilation control factor, x an exponent depending on motor and drive characteristics, f_{use} the mean user impact factor, and SFP the specific fan power (W/(m³/h)).

For the final and primary heating energy use (Wh/(m²year)):

$$Q_{h,p} = t_h.\Delta T_h.\eta_h^{-1}.c_{air}.\left(q_{net}.f_{qual}.f_{ctr}.f_{use}.(1-\eta_t) + n_{50}.H.0.04\right)$$

with t_h the heating season hours (h), ΔT_h the average difference between indoor and outdoor temperature over a heating season considering solar and internal heat gains (K), η_h the average space heating efficiency, c_{air} the specific heat capacity of air

(J/(kgK)), η_t the average thermal efficiency of a heat recovery system, n_{50} the average air leakage rate at a pressure difference of 50Pa (h^{-1}), H the average floor height (m), 0.04 a scaling factor to scale the air leakage rate at 50Pa to pressure differences under normal climatic conditions.

The product $t_h.\Delta T_h$ is climate zone dependent, and may be derived from degree-day data.

As the equations show, two additional calculation parameters are introduced to complement the performance factors defined in 7.4:

1. **Net ventilation rate demand**

   The net ventilation rate demand gives the total design flow rate of fresh air per heated floor area of the dwelling. Its value may differ from country to country and from system to system depending on prescribed flow rates in local standards and regulations. In the tool only the differences between systems are considered:

q_net	no ventilation	0	[m³/h.m²]
	natural	1,3	[m³/h.m²]
	unidirectional	1,3	[m³/h.m²]
	bidirectional	2	[m³/h.m²]

2. **Building airtightness**

   Building airtightness is taken into account, because the analysis also considers buildings without ventilation system, where the indoor air quality and the related heat loss depends on the air leakage rate through the building envelope. The calculation of the air leakage rate is based on the n_{50}-value of the building envelope, which may vary to a large extent over the building stock, and which is typically smaller in new and energy efficient construction:

$$q_{inf} = n_{50}.H.0.04 \text{ (m}^3\text{/(h.m}^2\text{))}$$

   The tool allows to define the variation of the air leakage rate for a specific ventilation system. The table below shows an example of the input for existing buildings without ventilation system, and new buildings with mechanical ventilation system.

high infiltration rate	n50	13,00	15%	10%
moderate infiltration rate		9,00	40%	10%
medium infiltration rate		5,00	30%	30%
resonable infiltration rate		3,00	15%	50%
low infiltration rate		1,00	0%	0%
		CHECK	100%	100%
Average infiltration rate		[m³/h.m²]	0,81	0,56

4.3 Exposure indicator

The estimated ventilation rates have to be converted into an indoor air quality indicator. Since indoor air quality and health relate to the exposure dose to pollutants, the indicator is based on the assessment of the generic pollutant dose to which occupants are exposed, taking the different flow rate adjustment factors into account:

$$Dose \sim \frac{t}{q}$$

with t the duration of exposure (h) and q the effective flow rate during the exposure time (m³/(h.m²)).

For a specific combination j of flow rate adjustment factors, the available flow rate of a specific ventilation system is equal to:

$$q_j = q_{net} \cdot f_{qual} \cdot f_{use} \cdot f_{clim} + q_{inf}$$

The exposure dose related to this specific combination of flow rate adjustment factors may be estimated based on the distribution of each factor, and its probability of occurrence p, assuming the different factors are independent:

$$Dose_j \sim \frac{p_{qual} \cdot p_{use} \cdot p_{clim}}{q_j}$$

When taking all possible combination of flow rate adjustment factors into account, and adding the doses related to all these combinations, the total exposure dose may be calculated by summing up the doses of each combination:

$$Dose_{total} \sim \sum \frac{\prod_j p_i}{q_j}$$

Finally, the IAQ-indicator or exposure indicator is defined as the ratio between the total pollutant dose and the exposure dose of a system continuously delivering the net ventilation rate demand with reference value 1.3 m³/(h.m²). In case of poor IAQ, the exposure indicator has a value larger than 1, in case of improved IAQ it has a value smaller than 1. Since the influence of air infiltration through leakages is taken into account, the value of the exposure indicator may be smaller than 1 also in systems which deliver a smaller flow rate than the net ventilation rate demand.

$$exposure\ indicator = \frac{Dose_{total}}{1/q_{net}}$$

As the equations show, one additional calculation parameter is introduced to complement the performance factors defined in 7.4:

1. **Climate influence factor**

   This factor takes account of the fact that, depending on the type of system, flow rates are not constant over time. For instant, in natural ventilation systems, flow rates fluctuate as a function of climatic conditions. Even when the system components are correctly designed and installed, flow rates may be reduced at times with low wind speeds and warm weather. On the other hand, flow rates might be excessive at times with the opposite weather conditions. This is expressed by a climate factor defined as the ratio between the effective flow rate and the installed flow rate. The table shows an example of the input for a natural ventilation system with important climate influence, and for a unidirectional mechanical ventilation system with limited climate influence.

higher ventilation rate	System in operation	150%	33%	10%
no influence		100%	33%	80%
lower ventilation rate		50%	33%	10%

5. Calculation of global indicators

The global impact of initiating policy options is evaluated for the following indicators, assuming that each policy option is introduced in 2020 and has an immediate effect:

- The **energy consumption** (electrical, heating and primary energy), as a result of the ventilation of the dwelling stock
- The **CO_2-emissions** based on the primary energy use, as a result of the ventilation of the dwelling stock
- The **indoor air indicator** indicating the average exposure to pollutants over the dwelling stock

These global indicators are calculated based on the results of the direct indicators clarified in the preceding paragraph. As these values are expressed in m² floor area, the next step is to extend the results to the whole dwelling stock concerning:

- on the one hand, the different climate regions
- on the other hand, Europe.

The calculation merges the direct indicator with data on the evolution of the building stock and on the share of the ventilation systems.

The basic approach to evolve from direct indicators to global indicators is identical for the energy consumption, the CO_2-emissions and the pollutant indicator. The calculation method consists of two components. The first component is related to the share of existing ventilation systems, for which the performances are not affected by the policy options. The second component applies to the share of newly-installed systems in new and retrofitted dwellings, for which the performance depends on the policy options. The sum of both components gives the result for the global indicator.

5.1 Existing ventilation systems

As mentioned before, it is assumed that the ventilation systems already existing in 2020 are not influenced by policy options. So, a different approach to calculate the before mentioned indicators is adopted compared to newly installed systems. The subsequent parameters are multiplied in the first part of the calculation method:

- The results of the direct indicators per ventilation system considering no policy options (A)
- The share of ventilation systems for the existing building stock in 2020 per ventilation system (B)
- The existing building stock floor area according to the considered year (C)
- The share of new and retrofitted dwellings with no newly installed ventilation system according to the considered year (D)
- The sum of the new and retrofitted building stock floor area according to the considered year (E)

Taking into account the code mentioned with the above described parameters, the first component is determined by means of the following formula:

$$Global\ indicator_1 = \left(C_j + D_j \cdot E_j\right) \cdot \sum_{i=00}^{11} \left(A_{i,k} \cdot B_{i,2020,k}\right)$$

with:

- i = 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 10 (ventilation systems)
- j = 2020, 2025, 2030, 2040, 2050 (considered years)
- k = 0 (no policy options)

5.2 Newly installed ventilation systems

Whereas the performance of the existing ventilation systems is not affected by the policy options regarding different inspection schemes, the performances of newly installed ventilations systems in new and retrofitted houses will be influenced. The following parameters are applied in the second part of the calculation method:

- The results of the direct indicators per ventilation system according to the considered policy option (A)
- The share of newly installed ventilation systems in new and retrofitted dwellings at the considered year per ventilation system (B)
- The sum of the new and retrofitted building stock floor area according to the considered year (E)

Taking into account the code mentioned with the above described parameters, the second component can be calculated with the subsequent formula:

$$Global\ indicator_2 = E_j \cdot \sum_{i=01}^{10} (A_{i,k} \cdot B_{i,j,k})$$

with:

- i = 01, 02, 03, 04, 05, 06, 07, 08, 09, 10 (ventilation systems)
- j = 2025, 2030, 2040, 2050 (considered years)
- k = 1, 2, 3, 4, 5, 6 (policy options)

5.3 Example

To better understand how the calculation method actually works, an example is elaborated in this section. The global impact indicator for 2030 is calculated considering policy option 1 (national field data):

$$Global\ indicator = (C_{2030} + D_{2030} \cdot E_{2030}) \cdot \sum_{i=00}^{11} \left(A_{i,0} \cdot B_{i,2020,0}\right) + E_{2030} \cdot \sum_{i=01}^{10} (A_{i,1} \cdot B_{i,2030,1})$$

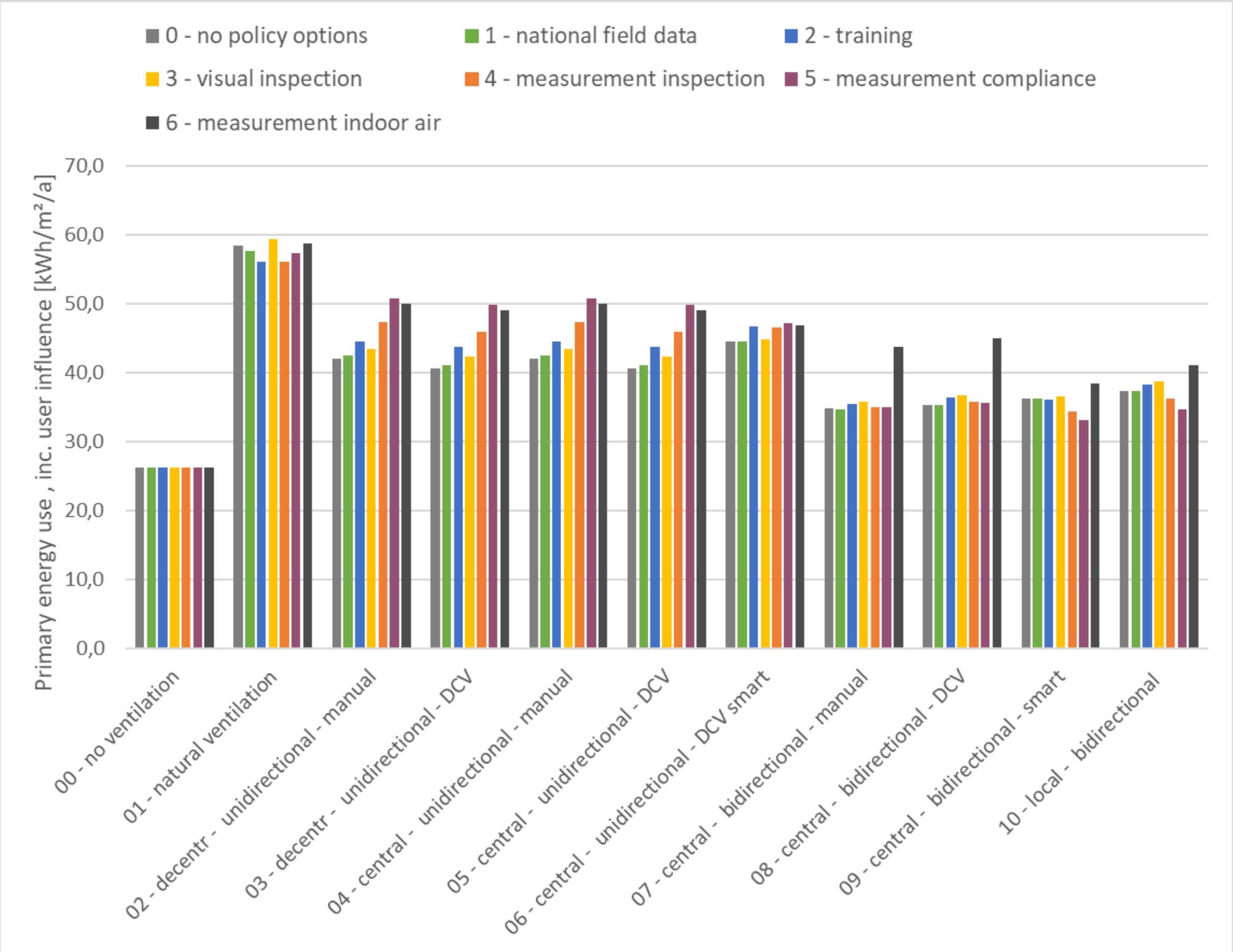
Annex 3 – Details of the impact analysis results

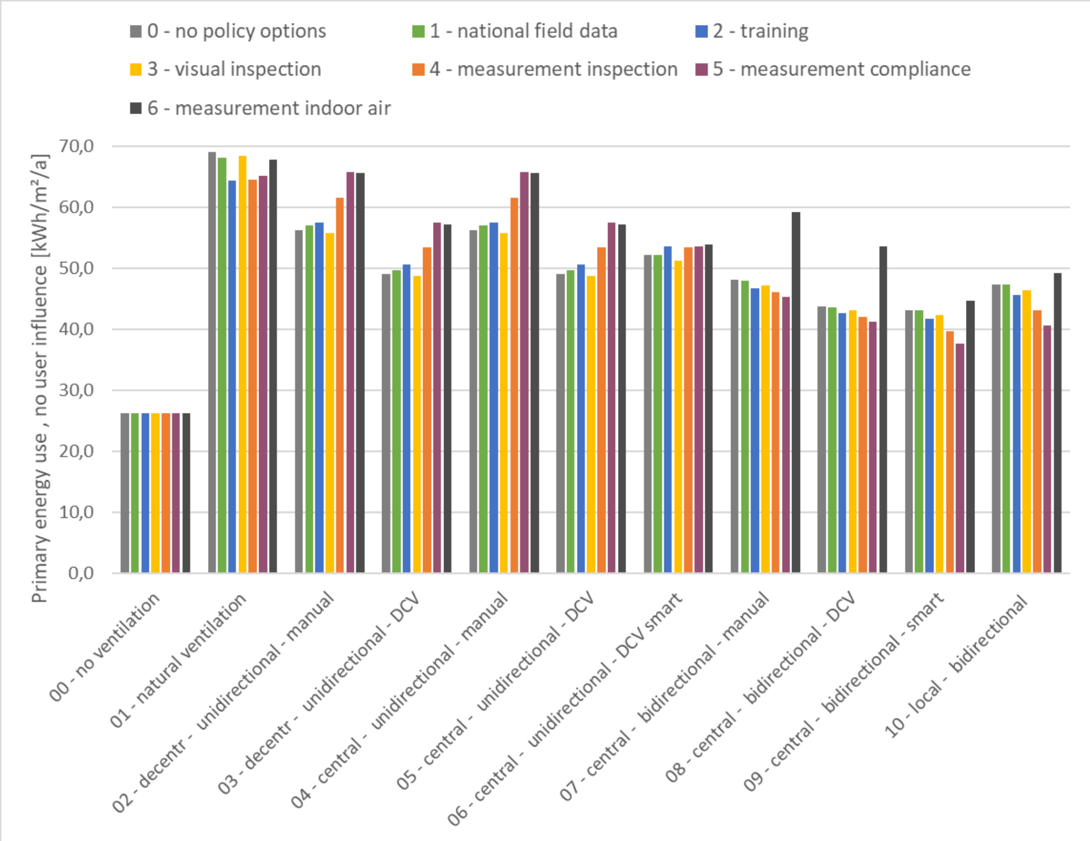
Detailed results of performances of dwellings equiped with different types of ventilation systems

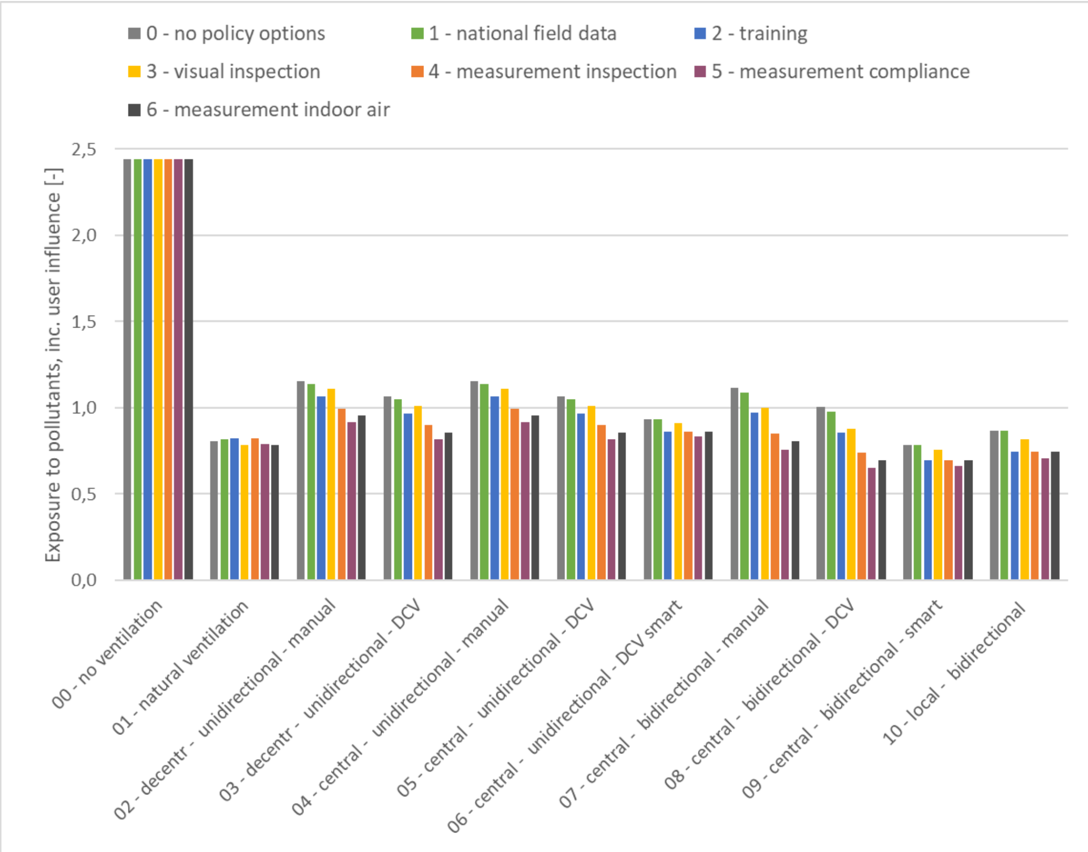
The following performances are calculated in the tool (both with and without considering user impact):

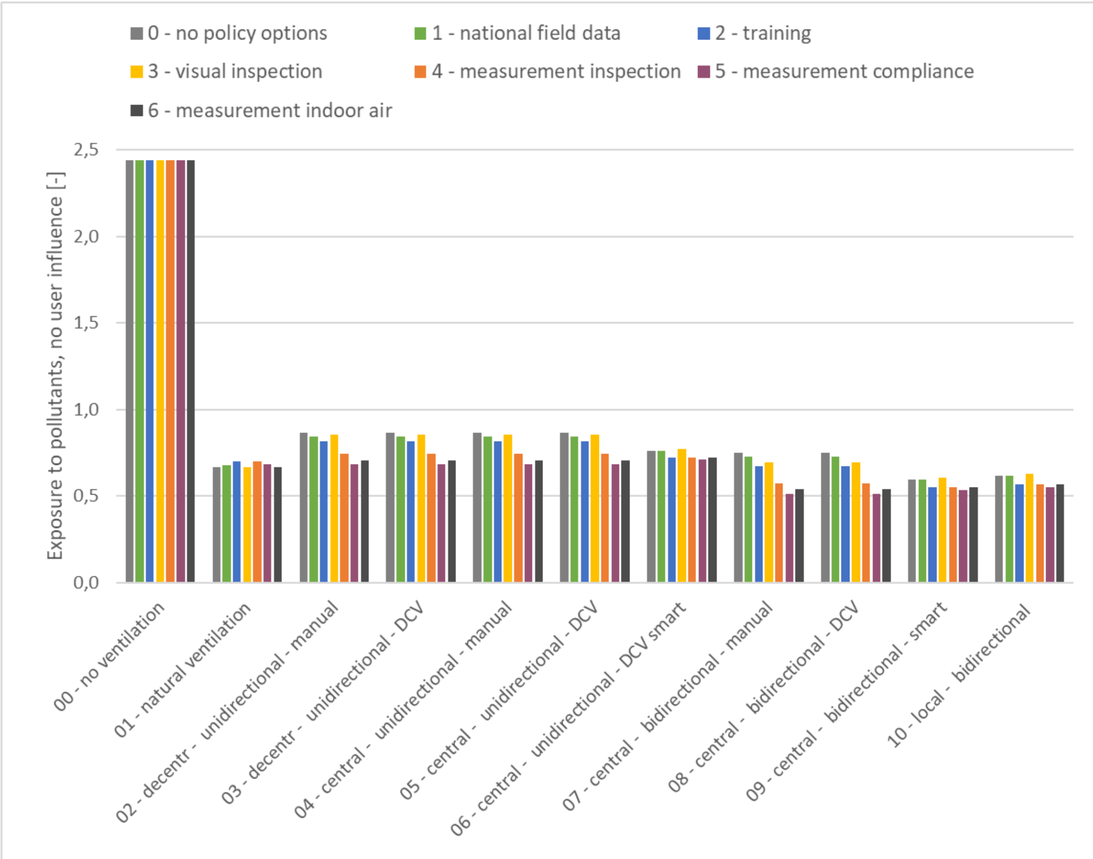
- Primary fan energy use (kWh/m²/a)
- Primary heating energy use as a result of dwelling ventilation (kWh/m²/a)
- Total primary energy use as a result of dwelling ventilation (kWh/m²/a)
- Exposure to pollutants indicator (-)
- Carbon emissions as a result of dwelling ventilation (ton/m²/a)

As an illustration, the following figures show the predicted performances for total primary energy use and exposure to pollutants (both with and without considering user impact), for the six policy options.




0 - no policy options
1 - national field data
2 - training
3 - visual inspection
4 - measurement inspection
5 - measurement compliance
6 - measurement indoor air
Primary energy use , no user influence [kWh/m²/a]
70,0
60,0
50,0
40,0
30,0
20,0
10,0
0,0
00 - no ventilation
01 - natural ventilation
02 - decentr - unidirectional - manual
03 - decentr - unidirectional - DCV
04 - central - unidirectional - manual
05 - central - unidirectional - DCV
06 - central - unidirectional - DCV smart
07 - central - bidirectional - manual
08 - central - bidirectional - DCV
09 - central - bidirectional - smart
10 - local - bidirectional

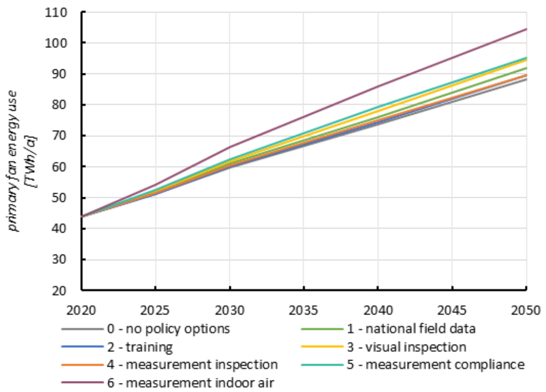

0 - no policy options
1 - national field data
2 - training
3 - visual inspection
4 - measurement inspection
5 - measurement compliance
6 - measurement indoor air
Exposure to pollutants, inc. user influence [-]
2,5
2,0
1,5
1,0
0,5
0,0
00 - no ventilation
01 - natural ventilation
02 - decentr - unidirectional - manual
03 - decentr - unidirectional - DCV
04 - central - unidirectional - manual
05 - central - unidirectional - DCV
06 - central - unidirectional - DCV smart
07 - central - bidirectional - manual
08 - central - bidirectional - DCV
09 - central - bidirectional - smart
10 - local - bidirectional

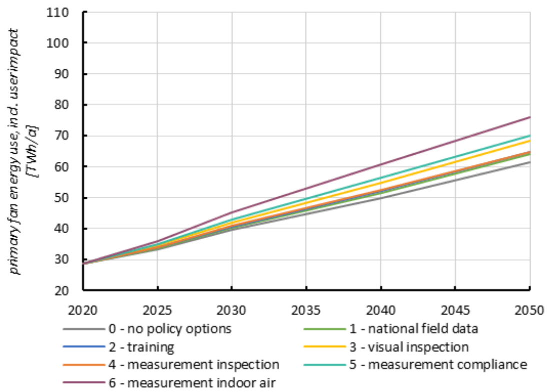


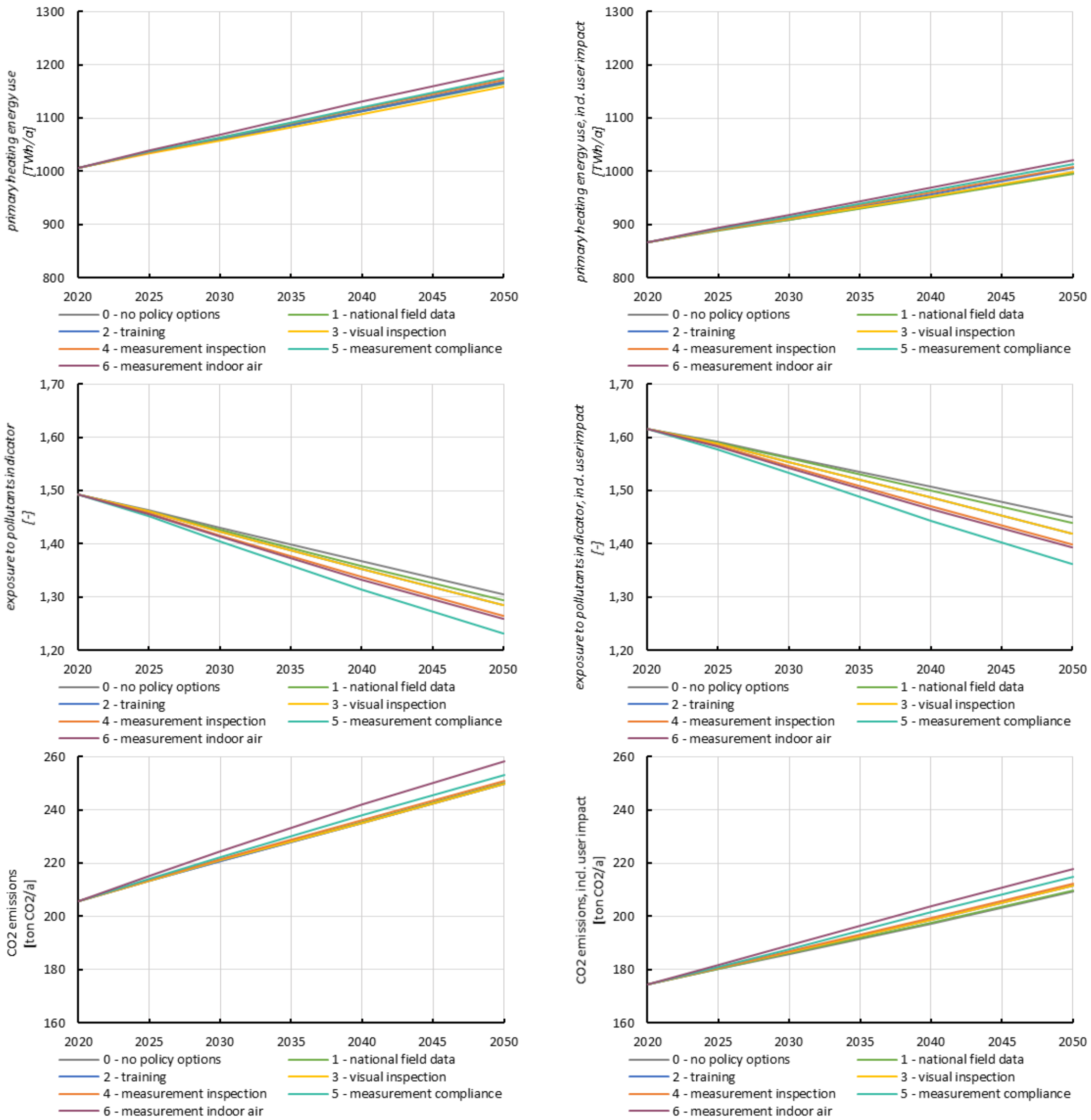
Detailed results of global dwelling stock indicators for EU28

The following graphs show the calculated global dwelling stock indicators for EU28 (both with and without considering user impact):

- Primary fan energy use (TWh/a)
- Primary heating energy use as a result of dwelling ventilation (TWh/a)
- Average exposure to pollutants indicator (-)
- Carbon emissions as a result of dwelling ventilation (ton/a)





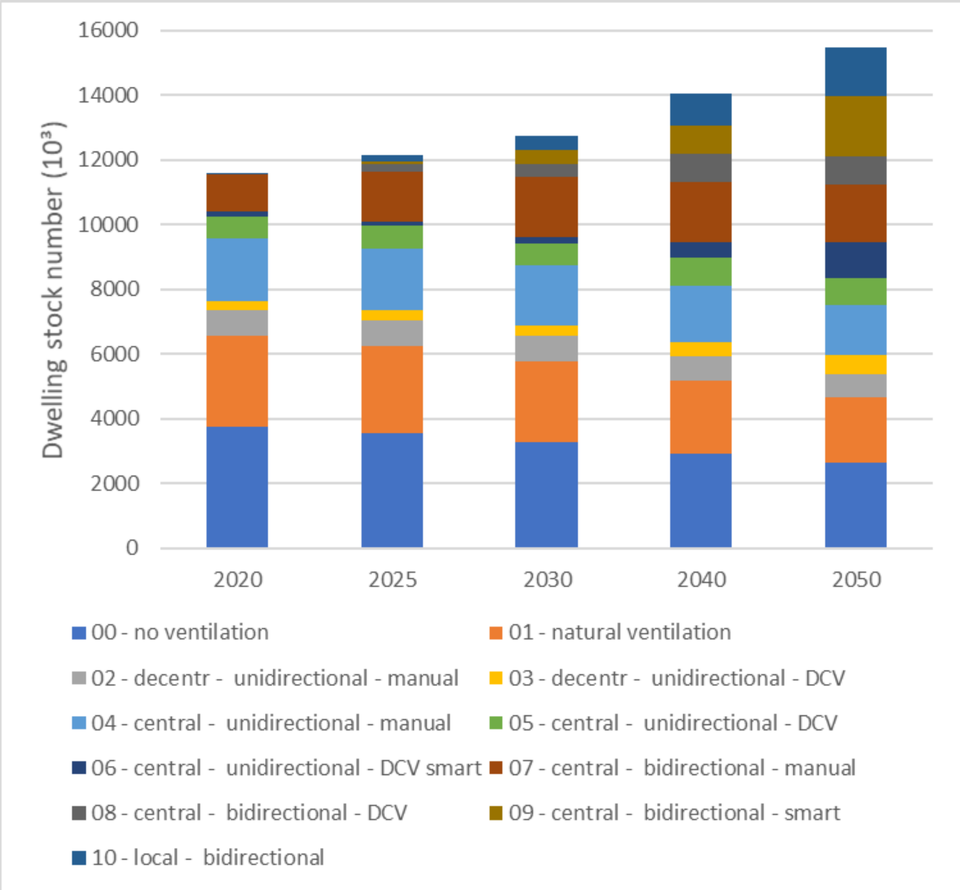


Global dwelling stock indicators for EU28.

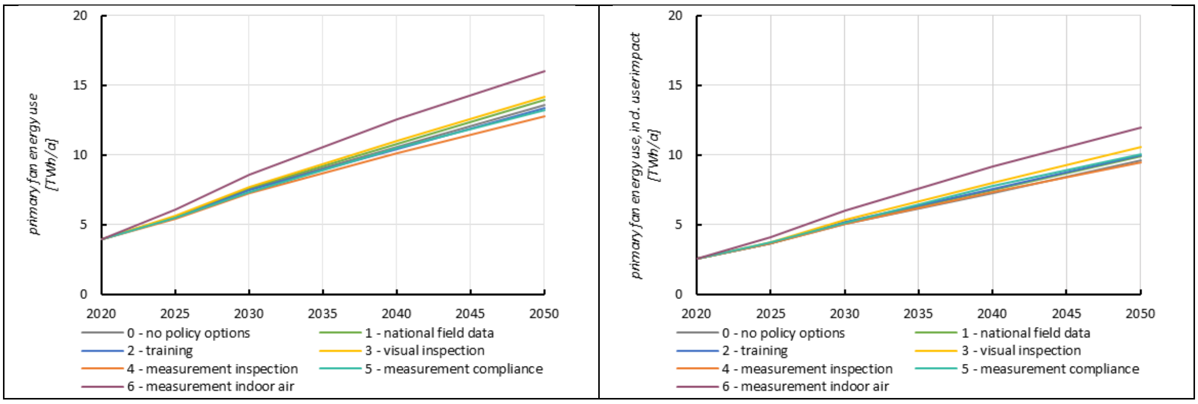
Detailed results of global dwelling stock indicators for North climate region

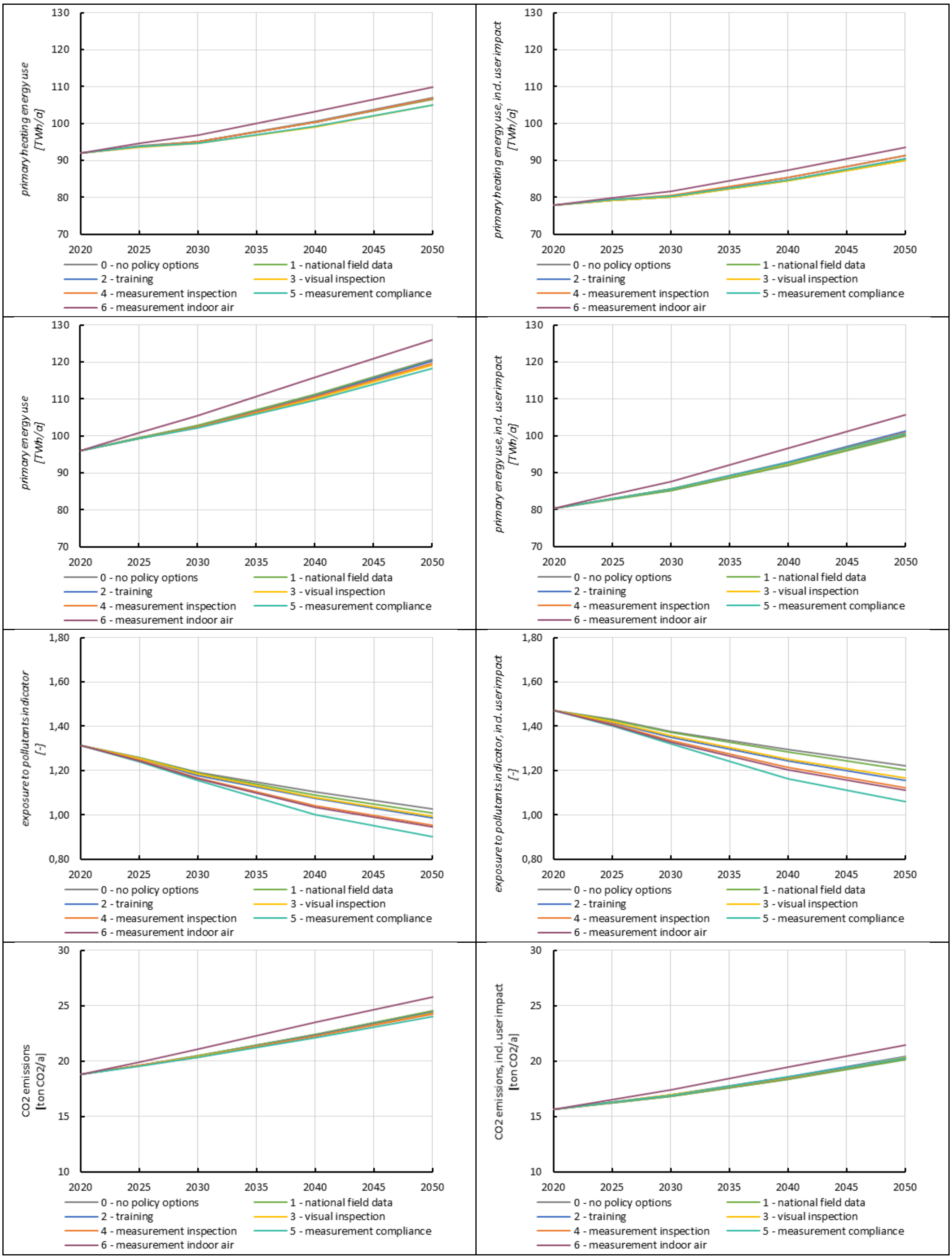
The tool allows to analyse the impact of the six policy options for five climate zones. The results of the North climate region are displayed in this section, as an example of the impact on a region with a significantly different distribution and evolution of ventilation systems compared to other climate regions and the EU28 as a whole. As the figure of this evolution shows, the share of mechanical ventilation systems is allready large in the existing dwelling stock, and will continue to expand in the future.

The impact of the policy options on the global dwelling stock indicators is calculated based on the same assumptions for system performances and ventilation stock evolution as applied in the EU dwelling stock impact analysis. As a result of the larger share of mechanical ventilation systems in the North region, the relative impact of policy options on indoor air quality is significantly larger with a smaller increase in primary energy use, compared to the results for EU28. For instance, the policy option of measurements with compliance results in an increase of the ventilation related primary energy use of +0.5% by 2050 (+2.4% for EU28), and on a reduction of the average exposure to pollutants in the dwelling stock of -15% by 2050 (-6% for EU28), compared to the option with no actions.



Evolution of total number of dwellings with a specific ventilation system in North climate region (option with no policy actions).





Global dwelling stock indicators for North climate region.

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