Technical assistance for ensuring optimal performance of technical building systems under the new Energy Performance of Buildings Directive (EU) 2018/844

Final report with technical guidelines for establishing and enforcing technical building system requirements and system performance assessment and documentation under Article 8

Written by: Paul Van Tichelen, Jad Al Koussa (VITO), Paul Waide (Waide Strategic Efficiency), Markus Offermann (Guidehouse)
December – 2021

Main author and study team contact: Paul Van Tichelen(paul.vantichelen@vito.be)

Study team and co-authors: Paul Van Tichelen(VITO), Paul Waide (Waide Strategic Efficiency Europe), Markus Offermann (Guidehouse), Jad Al Koussa (VITO)

Contract reference: ENER/C4/2019-468/04

Submitted by:

In collaboration with:

EUROPEAN COMMISSION

Directorate-General for Energy
Directorate B — Just Transition, Consumers, Energy Efficiency and Innovation
Unit B.3 — Buildings and Products

Contact: Georgios Takoudis

E-mail: georgios.takoudis@ec.europa.eu

European Commission
B-1049 Brussels

Technical assistance for ensuring optimal performance of technical building systems under the Energy Performance of Buildings Directive

Final report with technical guidelines for establishing and enforcing technical building system requirements and system performance assessment and documentation under Article 8

Written by: Paul Van Tichelen, Jad Al Koussa (VITO), Paul Waide (Waide Strategic Efficiency), Markus Offermann (Guidehouse)

Directorate-General for Energy

2023

EN

Manuscript completed in December 2021

Revised edition

LEGAL NOTICE

Print	ISBN 978-92-68-03153-7	doi:10.2833/096363	MJ-04-23-433-EN-C
PDF	ISBN 978-92-68-03123-0	doi:10.2833/036335	MJ-04-23-433-EN-N
EPUB	ISBN 978-92-68-03154-4	doi:10.2833/862733	MJ-04-23-433-EN-E
HTML	ISBN 978-92-68-03152-0	doi:10.2833/619420	MJ-04-23-433-EN-Q

Luxembourg: Publications Office of the European Union, 2023

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

AC	air-conditioning
AHU	air-handling unit
API	application programming interfaces
AUDITAC	IEE Project name
BAC	building automation control
BACS	building automation and control system
BAPV	building attached photovoltaics
BAT	best available technology
BBSR	German Federal Institute for Reseach on Building, Uraban Affairs and Spatial Development
BC	base case
BEG	Bundesförderung für Effiziente Gebäude
BEM	building energy management
BEMS	building energy management system
BESS	battery energy storage systems
BIM,	Building Information Modelling
BIPV	building integrated photovoltaics
BMWi	Federal Ministry for Economic Affairs and Energy
CA	Concerted Action (of the EPBD)
CAV	constant air volume
CB	chilled beams
CE	"Conformité Européenne" (European conformity marking)
CEN	French: Comité Européen de Normalisation; English: European Committee for Standardization
CENELEC	French: Comité Européen de Normalisation Électrotechnique; English: European Committee for Electrotechnical Standardization
COP	coefficient of performance

CTI	Italian Thermotechnical Committee
DC	direct current
DCV	demand-controlled ventilation
DE	Deutschland; Germany
DG	Directorate-General
DHW	domestic hot water
DIN	German standards organisation
DR	demand response
DX	direct expansion
EBPD	Energy Performance of Buildings Directive
EC	European Commission
ECO	energy conservation opportunity
ED	Ecodesign Directive
EEA	European Economic Area
EED	Energy Efficiency Directive
EEI	energy efficiency index
EEOS	Energy Efficiency Obligation Scheme
EER	energy efficiency ratio
ELR	Energy Labelling Regulation
EMS	energy monitoring system
EN	European norm
ENER	Directorate-General for Energy
EPATEE	Evaluation Into Practice to Achieve Targets for Energy Efficiency
EPB	Energy performance of Buildings (Directive)
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
EPREL	European Product Database for Energy Labelling
ESCO	energy services company
EU	European Union
EU27	27 Member countries of the EU

EU28	the former 28 Member countries of the EU
eu.bac	European Building Automation Controls Association
EUR	Euro (currency)
FCU	fan coil unit
FM	facility manager
FP	flue pipe
GEG	German Energy Saving Ordinance for Buildings
GHG	greenhouse gas [appears once in table]
H2020	Horizon 2020
HARMONAC	HARMONAC IEE project
HBES	home and building electronic systems
HIU	heat interface
HP	heat pump
HR	heat recovery
HRS	heat recovery system
HVAC	heating, ventilation and air-conditioning
HVAC&R	heating, ventilation, air-conditioning and refrigeration
IAQ	indoor air quality
ICT	Information and communications technology
IEA	International Energy Agency
IEC	International Electrotechnical Committee
IEE	Intelligent Energy Europe
INTAS	INTAS H2020 project
iSERV	iSERV IEE project
ISO	International Organization for Standardization
IT	information technology
KEYTV	thermostatic radiator valves
KPI	key performance indicator
LED	light emitting diode
LENI	lighting numerical indicator

LPHE	liquid-to-liquid plate heat exchangers
lx	Lux
MFH	Multi-family housing
MID	Only appears once
MISE	Ministry of Economic Development
MS	Member State
MSA	market surveillance authority
MURE	MURE II database
NF	Norm Francais
NGO	non-governmental organisation
NZEB	nearly zero-energy building
O&M	operation & maintenance
OJ	Official Journal (of the EU)
PDI	lighting power density
PICS	Protocol Implementation Conformance Statement
PI	Performance indicator
POA	plane-of-array
PR	performance ratio
PSFP	average specific fan power
PV	Photovoltaic
PVGIS	Photovoltaic Geographical Information System
QR	QR code
RAC	Room air conditioner
RE	renewable energy
RES	renewable energy systems/sources
RT	rooftop
SEDBUK	seasonal efficiency of a domestic boiler in the UK
SEER	seasonal energy efficiency ratio
SFP	specific fan power
SK	solar keymark

SME	small or medium enterprise
SRI	Smart Readiness Indicator
STC	standard test conditions
TBS	technical building systems
TC	technical committee
TES	thermal energy systems
TIM	installation and maintenance technician
TR	as in CEN/TR
TS	technical specification
TW	Terawatt
TWh	terawatt hours
US	United States
VAV	variable air volume
VOC	volatile organic compound
VRF	variable refrigerant flow

INTRODUCTION AND OVERVIEW OF PROJECT TASKS

Introduction/background

Energy performance of buildings is key to achieving the EU's Climate & Energy 2020 objectives and long-term targets. The Energy Performance of Buildings Directive[1] (EPBD) sets minimum requirements for the energy performance of new and retrofitted buildings, requires certification of building energy performance and declaration via energy performance certificates, and requires inspection of building heating and air conditioning systems. In 2018[2] the EPBD was amended to address the following aims:

- accelerate the cost-effective renovation of existing buildings, with the vision of a decarbonised building stock by 2050
- mobilise investments in building renovation
- support electromobility infrastructure deployment in building car parks
- introduce new provisions to enhance smart technologies and technical building systems, including automation.

In consequence, new provisions to enhance technical building systems were introduced.

Background: technical building systems under the EPBD

Technical building systems are defined in the EPBD as 'technical equipment for space heating, space cooling, ventilation, domestic hot water, built-in lighting, building automation and control, on-site electricity generation, or a combination thereof, including those systems using energy from renewable sources of a building or building unit' (Article 2(3) of the EPBD).

Article 2 of the EPBD also provides additional definitions for 'building automation and control system'(BACS) (Article 2(3a)); 'air-conditioning system' (Article 2(15)); and 'heating system' (Article 2(15a)).

The performance of technical building systems has a significant impact on overall building energy performance, therefore, one of the aims of the EPBD is to ensure that technical building system performance is optimised. In particular:

- Article 8(1) requires Member States to set system requirements on overall energy performance, proper installation, appropriate dimensioning, adjustment and control of technical building systems
- Article 8(9) require Member States to ensure that when a technical building system is installed, replaced or upgraded, the overall energy performance of the altered part or (where relevant) of the complete altered system is assessed

[1] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings, OJ L 153 of 18.6.2010, p. 13. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:EN:PDF

[2] 6 Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency, https://eur-lex.europa.eu/eli/dir/2018/844/oj

- Article 14 and 15 requires Member States to establish regular inspections of heating systems, air-conditioning systems, and combined ventilation and heating/air conditioning systems above an effective rated output of 70 kW.

It is clear that the performance of these technical building systems have a major impact on overall building energy efficiency and can be equally important as the energy efficiency measures set at the component level (which are regulated via the Ecodesign Directive and Energy Labelling Regulation). Therefore, they merit being the recipients of sufficient policy attention and related regulatory requirements to ensure that the systems - when being installed, retrofitted, operated and maintained - are as efficient as is technically and economically justified within the broader context of EU energy policy.

Despite the establishment of such system requirements, it has become clear that the understanding, interpretation and enforcement of these requirements would benefit from greater standardisation and that there is a need for further clarification by means of technical guidelines to help Member States put these provisions into practice and increase the their impact in the EU building stock.

Project activities and report structure

This project addresses these objectives via the conduct of five specific tasks listed below:

Task 1: Review of technical building system requirements (definition and enforcement) and other relevant measures and initiatives, identification of good practices

Task 2: Identification and assessment of possible technical building system requirements

Task 3: Possible approaches for enforcement of technical building system requirements and assessment and documentation of system performance

Task 4: Technical guidelines for establishing and enforcing technical building system requirements, and for system performance assessment and documentation

Task 5: Technical guidelines for an effective understanding of BACS capabilities under the EPBD

The Task 1 to 3 reports served as inputs to this Task 4 report and are included in the second interim report and are summarised in the presentation delivered at the stakeholder meeting.

The final Task 5 report which concerns EPBD Articles 14 & 15, is published as a separate report.

Note, the tasks, their contents and structure are all in accordance with the Terms of Reference specified in the call for tender for this project, and with the contract signed between the Consortium and the Commission Services.

This document is the final Task 4 report which addresses guidelines for establishing and enforcing technical building system requirements in line with the EPBD's Article 8.

A short companion report is also available that summarises the guidance in two-page length vignettes, each addressing a specific TBS.

TASK 4. TECHNICAL GUIDELINES FOR ESTABLISHING AND ENFORCING TECHNICAL BUILDING SYSTEM REQUIREMENTS, AND FOR SYSTEM PERFORMANCE ASSESSMENT AND DOCUMENTATION

4.1 Objectives and approach

The objectives of this task are to provide guidance to EU Member State regulators on the EPBD Article 8(1) and 8(9) provisions, the obligations they have to implement them and to provide guidance on how they could be implemented within Member States jurisdictions.

4.2 Structure of the guidance

This guidance begins with a short resume of what the Article 8(1) and Article 8(9) provisions are and why they are needed. It then discusses the process that Member States would need to follow in setting requirements that respect the Article 8(1) and (9) provisions, before considering how they can be enforced, and performance assessment and documentation from a generic perspective. Thereafter the guidance treats each TBS (space heating & domestic hot water; space cooling; ventilation; building, automation and control systems (BACS); fixed lighting systems; and renewable energy systems) in turn, wherein for each TBS the text sets out guidance sets on:

- the Commission's existing guidance with regard to the interpretation of the specification of measures addressing: Overall energy performance; Appropriate dimensioning; Proper installation; Adjustment; and Appropriate control
- a summary of the study team's assessment of the shortlist of most promising energy saving measures and the related regulatory pathways
- examples of good practice.

4.3 General guidance

This section sets out generic (i.e. non-TBS specific) guidance to assist Member States with the implementation of EPBS Article 8(1) and 8(9) provisions. TBS-specific guidance is presented in the sections which follow this one.

4.3.1 The Article 8(1) provisions and why they're needed

To respect the requirements of the EPBD Member States are obliged to implement measures that fulfil any binding provisions in the Directive. In the case of Article 8(1) Member States are required to set technical building system requirements when they are installed in existing buildings on:

- overall energy performance
- proper installation
- appropriate dimensioning
- adjustment, and
- control of technical building systems

In addition, the 3rd paragraph of Article 8(1) of Directive (EU) 2018/844 introduces new requirements related to the installation of self-regulating devices and building automation and control systems in buildings that meet specific conditions. More precisely, under the third subparagraph of Article 8(1) of the EPBD, Member States must require the installation of self-regulating devices in all new buildings and in existing buildings when heat generators are replaced, where technically and economically feasible.

The precise Article 8(1) text is:

"1. Member States shall, for the purpose of optimising the energy use of technical building systems, set system requirements in respect of the overall energy performance, the proper installation, and the appropriate dimensioning, adjustment and control of the technical building systems which are installed in existing buildings. Member States may also apply these system requirements to new buildings.

System requirements shall be set for new, replacement and upgrading of technical building systems and shall be applied in so far as they are technically, economically and functionally feasible.

Member States shall require new buildings, where technically and economically feasible, to be equipped with self-regulating devices for the separate regulation of the temperature in each room or, where justified, in a designated heated zone of the building unit. In existing buildings, the installation of such self-regulating devices shall be required when heat generators are replaced, where technically and economically feasible."

What does Article 8(1) do that whole building performance requirements do not?

As the EPBD requires Member States to set minimum energy performance requirements for new buildings or the parts of buildings subject to major renovations, the need to also set requirements for technical building systems might be questioned.

However, the whole building energy performance requirements are applied when a building is newly constructed or a major renovation is made (and then just to the renovated part) – they do not apply to existing, un-renovated buildings nor to buildings where some part of the TBS is modified. It is important to appreciate that not only all building energy use is consumed by technical building systems, but the replacement and modification of TBS's happens at a far greater frequency than major renovations or new construction. Thus, complementing whole building energy performance requirements with the Article 8(1) requirements will lead to much faster and deeper energy savings in the building stock.

EPBD standards exist that can be used to establish the impact of all pertinent factors affecting whole building performance including the building fabric and the energy performance of the TBS installed in the building.

In theory TBS performance is taken into account for Energy Performance Certificates (EPCs) but most Member States use these purely to provide information and not as mandatory triggers that oblige improvements. In addition, EPCs usually have a lower issuance frequency than the intervention trigger points of the Article 8(1) provisions and may apply (sometimes very) simplified assessment methods that could risk missing much of the TBS energy savings potential.

What does Article 8(1) do that Ecodesign and energy labelling do not?

The Ecodesign Directive[3] (ED) and the Energy Labelling Regulation[4] (ELR) apply to manufactured products that are placed on the market. While it is theoretically possible to use these regulatory frameworks to set requirements on products when put into service there has been little willingness to do so, in part because different market surveillance auhorities and processes are usually involved. Rather the market surveillance process for products put into service is suited to that used for other EPBD requirements.

The scope of the Ecodesign and Energy Labelling product regulation tends to stop at the packaged product level, but does not extend to include the other aspects of the technical building system that it connects to. E.g. for space heating the ELR/ED requirements include the boiler and controls sold as part of the boiler but not:

- the heat distribution system including balancing
- the heat emitters
- zonal and room controls, programmers, occupancy detection, weather compensation, optimal stop/start etc.

Nor does it address the system sizing, installation/commissioning & operation.

All of these can have a major impact on the energy efficiency of the technical building system as a whole.

Under ED/ELR the product energy performance is determined under standard test conditions (STC) which necessarily make many assumptions about how a product is used – e.g. its duty cycle and part-load operation. However, these will mostly not correspond to the conditions that the same product is actually used in any given installation – this is important because the product is likely not to be optimised for any given installed application.

In practice, there can be many product-types that can fulfil a given function (say space heating) but the ED process may be reluctant to set efficiency criteria that prohibit some types because they could be the only viable choice in certain site-specific applications[5].

This constraint does not apply when site-specific factors can be taken into account (which they can when setting requirements under the Article 8(1) provisions).

In theory, requirements set under the EPBD Article 8 have more freedom to link the energy performance requirement to the type of application (for which ED cannot so readily distinguish) and thus to fine-tune requirements based on the characteristics of the site-specific application. This can help avoid inefficient product selection choices in specific applications that ED allows in the market so that they can be used in other applications.

Thus, while ED and ELR requirements are very helpful for ensuring minimum energy performance and declared energy performance of components used in TBS they are not

[3] Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (Text with EEA relevance)

[4] REGULATION (EU) 2017/1369 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 4 July 2017 setting a framework for energy labelling and repealing Directive 2010/30/EU (Text with EEA relevance)

[5] For example, a requirement to use TRVs which are EN15232 class B or A compatible i.e. are programmable from a central management system, might be appropriate in many site-specific applications (e.g. high occupancy rooms) but not in all, so the Ecodesign process could be reluctant to prohibit the sale of TRVs without this functionality en masse, whereas building regulation specifications could specify application-specific criteria linked to the type of building and sub-space when such functionality is required. Site specificity allows differentiation by function of the space – corridors, cellars, high occupancy rooms etc.

appropriate to access many of the additional energy savings that can be addressed by Article 8(1) provisions. As such they provide a common regulatory baseline, but the setting of additional Article 8(1) provisions is essential (and obligatory) to access the *system level* and *site-specific* savings potentials.

Figure 1 summarises how Article 8 (and 14/15) provisions are complementary but distinct from both whole building energy performance requirements and product policy requirements.

Building energy policies

Type of regulation	Applicability
EPBD building performance regulations for new buildings or major renovations	To the whole building or to the renovated area
EPBD Article 8/14/15 requirements for new and existing technical building systems	To each technical building system as an ensemble
Ecodesign and labelling requirements for new or replacement TBS components	To each component of a technical building system

Figure 1: How Article 8(1) requirements are additional to whole building and Ecodesign/labelling performance requirements

How important is the systems aspect of TBS in energy terms?

All energy used in buildings is used by TBS and thus the Article 8(1) provisions are an essential element to achieve the broader EU and Member State energy saving and climate change objectives.

The savings potentials which are accessible from Article 8(1) measures are huge. On average the meta-analysis of savings potentials studies reported in Task 2 estimates that Article 8(1) provisions could achieve savings equal to ~ 9% of total EU energy consumption which is of a similar scale to:

- all other EPBD measures that could realistically be delivered by 2040 (NZEB's, new build requirements, major renovations and EPCs)
- the combined impact of currently adopted Ecodesign and ELR measures.

However, the challenges in effectively stimulating these savings are significant and should not be underestimated – they will not happen without robust policy design and effective implementation.

When are the provisions triggered?

Under the terms of the EPBD, Member States are required to set these system requirements for all "the technical building systems which are installed in existing buildings", i.e. it is mandatory and is irrespective of the size or nature of the building.

These provisions are triggered whenever a technical building system is:

- installed,
- replaced or,
- upgraded.

and "in so far as they are technically, economically and functionally feasible".

The mandatory requirements apply to existing buildings, but Member States may decide to apply these requirements also to new buildings.

Case study from the Netherlands[6]:

The system requirements apply:

- if a new technical building system is installed
- if in existing systems the generator or the ventilation unit (for example the central heating boiler, central air conditioner, hot water appliance or ventilation unit) or a third of the delivery bodies or built-in fittings is installed, replaced or improved.

Interpretation of technical, economic and functional feasibility

As mentioned above the requirements must be set and be mandatory in so far as they are" technically, economically and functionally feasible".

The European Commission Commission's guidance[7] states that the notion of 'feasibility' is relevant for:

(a) the application of system requirements under Article 8(1) of the EPBD, which states that system requirements must be applied 'in so far as these are technically, economically and functionally feasible'; and

(b) the installation of self-regulating devices (Article 8(1)) of the EPBD and BACS (Article 14(4) and 15(4) of the EPBD), as related requirements apply only 'where technically and economically feasible'.

Note that it is for Member States to detail in which specific cases meeting the requirements is not feasible from a technical, economic and/or functional perspective. Member States should ensure that these cases are clearly identified, framed and justified.

The interpretation of technical, economic and functional feasibility should not be left to the sole judgement of interested parties (e.g. owners or system installers). The conditions under which feasibility is evaluated should be defined at Member State level or, where regional conditions affect only part of a Member State's territory, at regional level. However, in the latter case, regional conditions should be defined in national transposition measures. In all cases, these conditions should be documented (e.g. as part of technical guidelines) and should apply uniformly on the national, or, where applicable, regional,

[6] Source: https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/wetten-en-regels/nieuwbouw/epbd-iii/systeemeisen-technische-bouwsystemen

[7] COMMISSION RECOMMENDATION (EU) 2019/1019 of 7 June 2019 on building modernisation, OJEU L165/70

territory. Finally, the non-application of system requirements should be assessed using clear procedures established and supervised by public authorities.

These procedures may differentiate between different types of buildings, in particular to address specific types for which technical, economic or functional feasibility is an issue.

One example is historical or listed buildings, which can have specific constraints that make it more difficult to apply some of the requirements. In this context, note that compliance with these requirements would not, in principle, alter the character or appearance of historical or listed buildings.

To avoid any doubt, also note that the requirements are also applicable to all categories of buildings for which the Directive allows Member States to introduce derogations in the application of minimum energy performance requirements (Article 4(2) of the EPBD).

Nevertheless, the specificities of certain buildings can be taken into account when evaluating the technical, economic and/or functional feasibility of meeting the requirements. In exceptional cases, where the evidence points to the conclusion that compliance with the requirements is technically, economically or functionally impossible for a specific building, the requirements can be disregarded. Such a conclusion can only be reached on a case-by-case basis, and Member States should not introduce systematic exemptions for any category of buildings.

Technical, economic and functional feasibility case study from Flanders, Belgium

In Flanders[8] is it possible to be exempted from specific TBS requirements based on, technical, economic or functional feasibility not being attained and thereby avoid the obligation to apply system requirements. To do this an individual application has to be submitted to the managing authority, VEKA.

Note, while Flanders allows project-specific submissions for exemptions on why it may not be technically & economically feasible to implement a measure these are assessed by the administration (with an open-ended approach) and the administrative hurdle is a deterrent to routine exploitation i.e. it is not a regulatory loophole and this pathway is only likely to be used in more plausible cases.

4.3.2 Process of setting Article 8 TBS provisions

This section considers the process regulators can take to set Article 8(1) requirements.

Addressing overall energy performance of the TBS

There are different approaches that can be followed in setting such overall technical building system energy performance requirements. One approach is that followed in the Netherlands where limit values for technical system energy performance are set for each system type (see Table 1 below). In this approach the Member State authorities make a horizontal determination of the minimum performance level that TBS's should attain per TBS and impose these horizontally across the relevant parts of the building stock. In practice, making requirements in these terms necessitates that viable calculation methods have been established which TBS installers can apply to determine and demonstrate the conformity of their installations. In the Netherlands case the energy performance requirements that apply to technical building systems are expressed in terms of the ratio of the calculated primary energy to the final demand for each TBS. As a result, not only the efficiency of a technical building system is valued, but also the use of renewable

[8] Bijlage XII: Eisen voor technische installaties, Belgian OFFICIAL GAZETTE and monitor 28.10.2020 – and monitor 78086 to 78130.

energy, which creates a supplementary stimulus for RES-based solutions. A digital calculation tool has been developed to support installer conformity assessment for this purpose.

Table 1: Overall system energy performance requirements in the Netherlands[9]

	Limit value energy performance		Installation of new system	Installation, replacement or improvement of generator or ventilation unit	Replacement 1/3 of delivery bodies or built-in fittings
	Residential applications	Other applications			
Heating systems	1.31	1.31	√	√	√
Cooling systems	1.33	1.33	√	√	√
Ventilation systems		3.8			
Warm tap-water systems	3.45	3.45	√	√	
Built-in lighting systems		75kWh prim/ m2	√		√

A slightly alternative approach is to set system efficiency requirements based on the rated performance of the principal technical building system components and then apply correction factors for the inclusion of different aspects affecting overall system performance as is done in Flanders[10]. While there are default values for the correction factors which regulators have determined based on their understanding of the typical impact of a particular technical characteristic TBS project implementors can request that these be amended if they can make a compelling case for why they should be. Such practice creates an incentive for the use of more thorough assessment and documentation techniques.

Addressing appropriate dimensioning of the TBS

Article 8(1) requires Member States to set appropriate TBS dimensioning requirements because oversized systems will often operate far from the optimal efficiency level and create unnecessary energy wastage. In practice, this requires obligations to be imposed on system designers and installers to conduct an adequate dimensioning assessment according to specified procedures and to document the outcome. The dimensioning assessment needs to determine the realistic (not overly inflated) maximum load based on the actual characteristics of the building, its occupants and how it's to be used and climate. It also needs to determine the efficiency of the system in delivering that load so it can be sized accordingly.

For thermal systems (space heating and cooling) the sizing requirements should be based on specified design temperatures. For example, Spain requires space heating systems to

[9] Handreiking, Energieprestatie installaties in gebouwen Uitwerking van de EPBDIII in de praktijk, Rijkdeinst voor Ondernemend Nederland, December 2020

[10] Bijlage XII: Eisen voor technische installaties, Belgian OFFICIAL GAZETTE and monitor 28.10.2020 – and monitor 78086 to 78130.

be sized to deliver a 21°C indoor temperature and space cooling systems to be sized to deliver a 25°C indoor temperature and requires the outdoor temperature to be based on the 99% most extreme thermal conditions[11].

Addressing proper installation of the TBS

The quality of installation often has a significant impact on the delivered performance of a TBS thus Article 8(1) requires Member States to set proper system installation requirements to minimise the risk of poor installation outcomes.

For example, Flanders, Belgium,[12] applies installation correction factors to the overall system performance requirements for ventilation for:

- the airtightness of the air group e.g. of the Air Handling Unit
- the airtightness of the ducts
- the insulation of the ducts.

These correction factors penalise poor adjustment practice and reward good practice, thereby creating an incentive to implement higher quality system adjustment practices.

Addressing adjustment of the TBS

Many/most TBS's require proper adjustment to perform at or near to their optimal operational levels thus Article 8(1) requires Member States to set adjustment requirements.

For example, Flanders[13] applies correction factors to the overall system performance requirements for space heating for adjustment for:

- the control of boiler temperature
- the regulation of normal regimen
- self-regulating equipment
- hydraulic balancing.

These correction factors penalise poor adjustment practice and reward good practice, thereby creating an incentive to implement higher quality system adjustment practices.

Addressing control of the TBS

Research has illustrated how the quality of system control has a very large impact on the energy consumption and quality of service provision of TBSs. Accordingly, Article 8(1) requires Member States to set TBS control requirements. The system boundary at which the control provisions apply can have a large bearing on the energy saving impact as can the sophistication of the control requirements.

Many of the largest energy savings opportunities for system operation identified in Task 2 concern control and to a large degree these options are applicable at a system boundary

---

[11] Source: Section IT 1.2.4.1.1. *General criteria* in REGULATION OF THERMAL INSTALLATIONS IN BUILDINGS: CONSOLIDATED VERSION + MODIFICATIONS, MARCH 2021, SECRETARY OF STATE FOR ENERGY, DIRECTORATE-GENERAL FOR ENERGY POLICY AND MINES

[12] Bijlage XII: Eisen voor technische installaties, Belgian OFFICIAL GAZETTE and monitor 28.10.2020 – and monitor 78086 to 78130.

[13] Bijlage XII: Eisen voor technische installaties, Belgian OFFICIAL GAZETTE and monitor 28.10.2020 – and monitor 78086 to 78130.

level that is not captured by control provisions in product policy instruments such as Ecodesign for TBS components and energy labelling for space and water heating.

4.3.3 Performance assessment and documentation: Article 8(9) provisions

Article 8(9) of the EPBD stipulates that:

"Member States shall ensure that, when a technical building system is installed, replaced or upgraded, the overall energy performance of the altered part, and where relevant, of the complete altered system, is assessed. The results shall be documented and passed on to the building owner, so that they remain available and can be used for the verification of compliance with the minimum requirements laid down pursuant to paragraph 1 of this Article and the issue of energy performance certificates. Without prejudice to Article 12, Member States shall decide whether to require the issuing of a new energy performance certificate."

The European Commission's guidance[14] states:

"Article 8(9) of the EPBD requires that the results of the assessment of the system (or of an altered part of it) performance are documented and passed on to the building owner. Member States are free to determine the form and content of this documentation, which can vary depending on the type of intervention considered. However, in this context, Member States should ensure that the documentation covers the scope of the assessment performed and can be useful for the verification of compliance with the minimum requirements on energy performance laid down pursuant to Article 8(1) of the EPBD and for energy performance certification (see next paragraph). Member States are also free to determine how the documentation is to be passed on to the building owner.

The obligations in Article 8(9) of the EPBD on documenting system (or altered part) performance aim to ensure that up-to-date information on technical building system performance is made available to building owners. Such information can be used, for instance, for energy performance certification or to verify compliance with minimum energy performance requirements (e.g. when a building undergoes a major renovation). It is up to Member States to decide whether a new energy performance certificate (EPC) will have to be issued as a result of the energy performance assessment of the technical building system (or an altered part of it)."

Thus, it is up to the Member States to define in their national legislation the cases where it is relevant to assess the performance of the whole system, as opposed to those where only the assessment of the performance of the altered part is required.

- a new system is installed
- a whole system is replaced
- a part, or parts, of a system undergo a major upgrade that can significantly affect the overall performance of the system.

Assessment and documentation case study for Flanders, Belgium[15]

In Flanders each time a TBS is installed it has to be checked by an EPB-reporter, who has been accredited by the government. The EPB-reporter uses software made available by

[14] COMMISSION RECOMMENDATION (EU) 2019/1019 of 7 June 2019 on building modernisation, OJEU L165/70

[15] Bijlage XII: Eisen voor technische installaties, Belgian OFFICIAL GAZETTE and monitor 28.10.2020 – and monitor 78086 to 78130.

the government to do this check and generates an EPB declaration which is kept in a database.

Assessment and documentation case study for the Netherlands[16]

In the Netherlands obligated parties have to demonstrate compliance with energy performance requirements by performing a calculation and providing a certificate.

The energy performance is calculated using the same methods as the NZEB requirements, based on the national standard NTA8800 (NTA), taking into account only the energy performance of the system in question. For common situations, a calculation tool is available[17], with which a simplified calculation can be performed; complex situations require a complete NTA calculation in an NTA calculation tool. Complex situations include large utility systems with integrated systems (e.g. both radiator heating and heating via an air treatment cabinet) and situations where unusual techniques are used as main heating (e.g. IR panels).

The installer is obliged to document the energy performance of the new system and hand it over to the building owner. However, the building owner does not need to keep this information. When the documentation is available, it can be checked whether energy performance requirements are met.

Without documentation, a checklist can be used to check whether the system meets the energy performance requirements in a number of common situations. Where an installation complies with the control points in the checklist, and falls within the situations for which the checklist has been drawn up, it may be assumed that the energy performance requirements are met. If this is not the case, or the installation does not fit within the scope of the checklist, a calculation must be done with the calculation tool or in complex cases an NTA calculation.

4.3.4 Enforcement of Article 8 TBS provisions

Achieving compliance with system requirements necessitates the establishment of an effective process of enforcement which is thus critical in being able to ensure that any regulatory requirements translate into concrete beneficial impacts.

Enforcement case study for Flanders, Belgium[18]

In Flanders the enforcement process for the Article 8(1) provisions is in line with other EPB enforcement processes as follows:

- check of compliance to the procedures (pre-calculation and as-built report)
- check of the (system) requirements (for the building owner)
- check of correct reporting by the EPB-reporter.

In the event of non-compliance fines are set out in the annex to the Energy decree[19].

Note, the approach taken in Flanders is an intriguing one from the perspective of aiming to strike a good balance between setting of requirements and economic feasibility. This is

[16] Handreiking, Energieprestatie installaties in gebouwen Uitwerking van de EPBDIII in de praktijk, Rijkdeinst voor Ondernemend Nederland, December 2020

[17] on https://bit.ly/37XKKwN

[18] Bijlage XII: Eisen voor technische installaties, Belgian OFFICIAL GAZETTE and monitor 28.10.2020 – and monitor 78086 to 78130.

[19] https://codex.vlaanderen.be/Zoeken/Document.aspx?DID=1018092&param=inhoud

because the extent to which proof of compliance needs to be demonstrated is contingent on the building's overall EPC rating, such that new or altered TBS installations made in buildings with poor EPC ratings are more proactively enforced than those made in buildings with good EPC ratings, which reflects that the Article 8(1) measures are likely to be appreciably more cost effective in buildings with a poor overall energy performance.

Enforcement case study for the Netherlands[20]

The text below sets out details of how enforcement is managed in the Netherlands.

"Conformity assessment and enforcement procedures vary with the type of buildings. For new buildings, developers have to demonstrate compliance through their building permit application; for work in existing buildings, local governments verify compliance.

The approach to enforcement is based on the following principles:

- Maintaining the energy performance of installations is as close as possible to existing enforcement processes:
    - Requirements in new construction situations are maintained as much as possible through the existing process for building applications. Each new construction project makes a building application which is assessed individually, and in this it can be properly checked for specific points for the energy performance of installations
    - Other requirements (in existing construction) are maintained as much as possible through existing processes for environmental requirements. It is up to the enforcer to approach building owners and managers; there is no obligation to report to supervisors (other than in the case of new construction).
- When maintaining requirements in existing construction, target groups are prioritised, taking into account:
    - Buildings of companies and institutions already under regular supervision: there, control of the energy performance of installations can be added to regular supervision
    - Buildings of companies and institutions subject to authorisation: more data are available about this target group and it is possible to quickly estimated which requirements apply
    - Other buildings, for which it must first be estimated, on the basis of key figures, which requirements are likely (but not certain) to apply.
- Prioritisation shall make the best possible use of existing data, including:
    - Use information from the obligation to provide energy savings to determine which installations of what size are present in buildings
    - Data from the SCIOS register to determine whether buildings have heating systems have already been carried out; (c) assess, on the basis of key figures (m2, building type, sector), which other buildings really have an installation to be inspected, should have a BACS and/or have a charging point installed.

[20] Handreiking, Energieprestatie installaties in gebouwen Uitwerking van de EPBDIII in de praktijk, Rijkdeinst voor Ondernemend Nederland, December 2020

- Enforcement in steps:
    - a) Writing to priority target groups, with follow-up
    - b) Inclusion of inspections, BACS and energy performance requirements in a protocol for company visits (in which various environmental aspects are checked)
    - c) Write to other target groups.

For each sub-area, this approach is completed as follows

Requirements for the energy performance and documentation of that energy performance

Compliance with the requirements of technical construction systems is initially promoted through communication, in particular to professional parties in the installation sector. For this purpose, they cooperate with their interest groups and installers are informed about the current requirements. In order to support installers, a checklist is developed that allows simple systems (such as these normally found in homes and small buildings) to determine whether a technical building system complies. This checklist can of course also be used for enforcement control.

In new construction, enforcement is primarily carried out through the assessment of building decree requirements for the environmental permit. This is an existing, streamlined process with which every municipality has experience.

For existing construction, the starting point for technical building systems (installations) is that it is initially maintained in response to complaints. Based on complaints from residents and users of buildings, municipalities can specifically check whether the requirements of the Building Decree have been met. A municipal inspector can also use the tool "Calculation tool Energy Performance Installations" to calculate the energy performance of an installation. It is distributed via RVO.nl[21].

System requirements for adequate sizing, installation, adjustment and installation adjustment (technical building systems)

For system requirements, the starting point is that complaints are initially maintained, both for new construction and existing construction. Based on complaints from residents and users of buildings, municipalities can specifically check whether the requirements of the Building Decree have been met.

The sector is working on quality systems for installations (technical construction systems), in particular, for installations in small and medium-sized buildings. The government supports this effort and offers help in developing energy performance and system requirements in practically applicable guidelines for installers and consultants. Such a system can also be used for enforcement, whereby enforcers can, on the one hand, monitor the application of a quality system by installers (process control, checking the application of a quality system by installers working in a sector or region) and, on the other hand, make use of the control points from a quality system in order to be able to carry out a technical check on work carried out (technical control, for situations where work has been carried out without a quality system). At the time of writing the approach was under development and is contingent on clarity regarding the design of the quality system for the installation sector.

[21] https://bit.ly/37XKKwN

Mandatory installation of thermostatic heating control in all rooms

Maintenance of the mandatory installation of thermostatic heating controls follows the approach of (a) requirements for the energy performance and documentation of that energy performance.

Mandatory installation of a Building Automation and Control System (BACS)

In new construction, this part is also primarily maintained through the assessment of Building Decree requirements for the environmental permit. For existing construction, the approach consists of two steps and: (1) determining whether a building is covered by the BACS obligation; (2) assess whether a BACS is present meets the requirements. The BACS obligation applies from 2026 to buildings with heating or air conditioning systems larger than 290kW. One-off enforcement is required for existing construction; after that, inspection of new construction ensures that the entire stock remains provided with a BACS.

Determining the size of the installation follows the same approach as for the inspection staff, and is further elaborated in the data structure chapter. Determining whether a BACS meets the required requirements can be done on the basis of the criteria (in Appendix 4: Checklist technical requirements BACS. of the regulation)"

For TBS's checklists of what is and is not allowed are often applied. An example for space cooling is shown in Table 2.

Table 2: Article 8(1) compliance checklist for space cooling in the Netherlands[22]

3. Air conditioning system parts	
3.1 Control of delivery unit (cold panel, fan coil unit, indoor unit air conditioning)	
Not allowed	*Allowed*
• No automatic temperature control • Central automatic temperature control	• Individual temperature control per room • Individual temperature control per room with communication to central system • Individual temperature control per room with communication and presence detection
3.2 Regulation of the delivery unit for thermally activated building structures	
Not allowed	*Not allowed*
• No automatic temperature control	• Central automatic temperature control • Advanced central temperature control • Advanced central temperature control with non-continuous use and/or room temperature feedback
3.3 Control of water temperature in the distribution network (supply or discharge)	
Not allowed	*Allowed*
• No automatic temperature control	• Outdoor temperature compensation scheme • Demand-driven scheme
3.4 Regulation of distribution pumps	
Not allowed	*Allowed*
• No automatic control	• On-off scheme • Multi-phase / multi-step control • Variable speed control (internal or external)
3.5 On-off control of cooling system	
Not allowed	*Allowed*
• No automatic control	• Automatic control with timer

[22] Handreiking, Energieprestatie installaties in gebouwen Uitwerking van de EPBDIII in de praktijk, Rijkdeinst voor Ondernemend Nederland, December 2020

	• Automatic control with start-stop optimization • Automatic demand-driven control
3.6 Interlock between heating and cooling	
Not allowed	*Allowed*
• No interlock	• Partial interlock • Full interlock
3.7 Regulation of cold generators	
Not allowed	*Allowed*
• Fixed temperature setting	• Variable temperature setting based on outdoor temperature • Demand-driven variable temperature setting
3.8 Order of cold generators	
Not allowed	*Allowed*
• Prioritisation based only on operating hours	• Prioritisation based on tax (cold demand) • Dynamic prioritisation based on efficiency and characteristics of the devices • Demand-driven prioritization (based on multiple parameters)
3.9 Control of heat and cold storage	
Not allowed	*Allowed*
• Continuous operation	• Time-controlled heat storage • Demand-driven heat storage

4.4 Space heating and domestic hot water

When setting Article 8(1) requirements it is helpful to consider the Commission's guidance[23] on the possible interpretation of system requirements for space heating as shown in Table 3. Study team proposals for added or modified text are in italic.

Table 3: Commission Article 8(1) guidance for space heating (amended text is in italic)

Type of requirement	Possible interpretation for space heating (1)	Useful references (2)
Overall energy performance	In this context, overall performance refers to the performance of the whole process of energy transformation in heat generators, heat distribution across the building, heat emission in individual rooms or spaces of the building and, where applicable, heat storage. In particular, it is not limited to performance of heat generators and can include requirements that affect other parts of the system (e.g. insulation of distribution piping network).	EN 15316 standard series, e.g. EN 15316-1, EN 15316-2, EN 15316-3 (3), EN 15316-4-1 (4), EN 15316-4-2 (5), EN 15316-4-5 (6), EN 15316-4-8 (7), EN 15316-5 (8) EN 15316-4-8 (9) EN 15316-5 (10)

[23] COMMISSION RECOMMENDATION (EU) 2019/1019 of 7 June 2019 on building modernisation, OJEU L165/70

Appropriate dimensioning	For heating systems, 'appropriate dimensioning' would refer to the determination of heating needs, taking into account relevant parameters (in particular intended usage of the building and its spaces) and to the translation of these requirements into design specifications for heating systems. *Note, additional requirements for heat pumps and self-consumption are included in the RES section.*	EN 12831-1 (11), EN 12831–3 (12), Module M8–2, M8–3EN 12828 (13) EN 14337 (14), EN 1264-3:2009 (15)
Proper installation	Proper installation refers to the need to ensure the system will be able to operate in accordance with design specifications. Ensuring proper installation can rely e.g. on national technical guidelines, products manufacturer documentation, certification of installers.	EN 14336 (16), EN 1264-4 (17), EN 14337 (14)
Adjustment	Adjustment refers here to the test and fine tuning of the system under real-life conditions (18), in particular to check and possibly adjust system functions that can have an important impact on performance (e.g. control capabilities – see below).	EN 15378-1 (19), EN 14336, (16) EN 15378–3 (20)
Appropriate control	Concerns control capabilities that heating systems can include in order to optimize performance, e.g. automatic adaptation of heat output of emitters in individual rooms or spaces, adaptation of system temperature based on outside temperature ('weather compensation') or time schedules, dynamic and static hydronic balancing, system operation monitoring, adjustment of water / air flow depending on needs, etc.	EN 15500-1 (21), EN 15316-2 (4), EN 15232 (22), space heater energy labelling regulations (23)

(1) Most of the information given in this table also applies to systems for domestic hot water.

(2) The references focus on EU standards. In addition to these, Member States are invited to consult available resources at national level, e.g. in Belgium the 'Spécifications techniques (STS)' on thermal solar systems: https://economie.fgov. be/sites/default/files/Files/Publications/files/STS/STS-72-3-systemes-solaires-thermiques.pdf

(3) EN 15316-1:2017 'Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 1: General and Energy performance expression, Module M3-1, M3-4, M3-9, M8-1, M8-4'.

(4) EN 15316-2:2017 'Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 2: Space emission systems (heating and cooling), Module M3-5, M4-5'.

(5) EN 15316-3:2017 'Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 3: Space distribution systems (DHW, heating and cooling), Module M3-6, M4-6, M8-6'.

(6) EN 15316-4-1:2017 'Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-1: Space heating and DHW generation systems, combustion systems (boilers, biomass), Module M3-8-1, M8-8-1'.

(7) EN 15316-4-2:2017 'Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-2: Space heating generation systems, heat pump systems, Module M3-8-2, M8-8-2'.

(8) EN 15316-4-5:2017 'Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-5: District heating and cooling, Module M3-8-5, M4-8-5, M8-8-5, M11-8-5'.

(9) EN 15316-4-8:2017 'Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-8: Space heating generation systems, air heating and overhead radiant heating systems, including stoves (local), Module M3-8-8'.

(10) EN 15316-5:2017 'Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 5: Space heating and DHW storage systems (not cooling), Module M3-7, M8-7'.

(11) EN 12831-1:2017 'Energy performance of buildings — Method for calculation of the design heat load — Part 1: Space heating load, Module M3-3'.

(12) EN 12831-3 'Energy performance of buildings — Method for calculation of the design heat load — Part 3: Domestic hot water systems heat load and characterisation of needs, Module M8-2, M8-3'.

(13) EN 12828:2012+A1:2014 'Heating systems in buildings — Design for water-based heating systems'.

(14) EN 14337:2005 'Heating Systems in buildings — Design and installation of direct electrical room heating systems'.

(15) EN 1264-3:2009 'Water based surface embedded heating and cooling systems — Part 3: Dimensioning'.

(16) EN 14336:2004 'Heating systems in buildings — Installation and commissioning of water-based heating systems'.

(17) EN 1264-4:2009 'Water based surface embedded heating and cooling systems — Part 4: Installation'.

(18) Member States may consider ensuring a degree of alignment between the methods followed for adjusting heating systems for the purpose of compliance with Article 8(1) on heating system requirements and the methods followed to assess performance of heating systems under typical or average operating conditions, where relevant, under Article 14-15.

(19) EN 15378-1:2017 'Energy performance of buildings — Heating systems and DHW in buildings — Part 1: Inspection of boilers, heating systems and DHW, Module M3-11, M8-11'.

(20) EN 15378-3 'Energy performance of buildings –Heating and DHW systems in buildings — Part 3: Measured energy performance, Module M3-10 and M8-10'.

(21) EN 15500-1:2017 'Energy Performance of Buildings — Control for heating, ventilating and air conditioning applications — Part 1: Electronic individual zone control equipment — Modules M3-5, M4-5, M5-5'.

(22) EN 15232 'Energy performance of buildings — Impact of Building Automation, Controls and Building Management'.

(23) Commission Delegated Regulation (EU) No 811/2013 of 18 February 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of space heaters, combination heaters, packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device (OJ L 239, 6.9.2013, p. 1).

4.4.1 Space heating and domestic hot water – shortlist of measures

Table 4 provides a non-comprehensive shortlist of measures to be considered when devising Article 8(1) and Article 8(9) space heating requirements as informed by the analysis reported in Task 2. In particular, it provides a matrix of the key space heating parameters that shows: how they affect system performance and its dimensioning; how they are affected by installation and adjustment; the potential source of assessment inputs to determine the parameter values; the magnitude of the impact they have on energy savings as a function of system size; their links with other EU regulations; and their links to the most promising set of energy saving measures identified in Task 2.

Table 4: Matrix of space heating parameters versus Article 8(1) & 8(9) measures and promising energy saving requirements

	Affects		Is affected by		Assessment							Link to other EU regulation			Link to identified requirements in Task 2											
					Inputs from:					Impact	Impact															
Key Parameters	Overall energy performance	Dimensioning	Installation	Adjustment	Product data	EPC data	Design calcs	visual check and Declaration	Measurement	Impact small systems	Impact large systems	Ecodesign limit values	Ecodesign product data	Installer energy label	VH1: Monitoring and Parameter Adaptation	VH2: Night time set back (residential)	VH3: overall performance (large buidlings)	VH4: replace old boilers in SFH	VH5: individual emittor control (TRVs)	VH6: hydronic balancing and heat zoning	VH7: Night time set back (large buildings, office)	VH8: Heat pumps (SHP monitoring)	VH9: Insulation on pipes(small system)	VH10: interlock between heating/cooling(emission)	VH11: weather compensation to adapt supply	VH12: insulation on pipes (large system)
Monitoring																										
each respective service	✓	✓	✓						✓					✓	✓		✓					✓		✓		
other- outdoor temperature	✓	✓	✓						✓					✓	✓		✓					✓		✓		
other - occupancy indicator for non-residential note, can be combination of: presence detectors + lift power use + representative plug loads power use (min.max) + calender/clock	✓	✓	✓						✓					✓	✓		✓					✓		✓		
Control functions																										
room or zone heating or cooling emission control	✓	✓	✓	✓	✓	✓		✓	✓	L	H			✓	✓		✓		✓					✓		
control of the temperature of the heating and cooling distribution network, typically water in a hydronic network	✓	✓	✓	✓		✓		✓	✓	M	M			✓	✓	✓	✓			✓	✓				✓	
control of distribution pumps (circulator pump) in heat or cold distribution networks	✓		✓	✓		✓		✓	✓	L	M			✓	✓		✓			✓						
interlock control between heating and cooling emission and/or distribution systems	✓		✓	✓				✓	✓	L	H			✓	✓		✓							✓		
hydronic efficiency(balancing) EN15316-2 (includes automatic balancing)	✓	✓	✓	✓		✓		✓	✓	L	M			✓	✓		✓			✓						

	Affects		Is affected by		Assessment							Link to other EU regulation			Link to identified requirements in Task 2											
					Inputs from:					Impact	Impact															
Key Parameters	Overall energy performance	Dimensioning	Installation	Adjustment	Product data	EPC data	Design calcs	visual check and Declaration	Measurement	Impact small systems	Impact large systems	Ecodesign limit values	Ecodesign product data	Installer energy label	VH1: Monitoring and Parameter Adaptation	VH2: Night time set back (residential)	VH3: overall performance (large buidlings)	VH4: replace old boilers in SFH	VH5: individual emittor control (TRVs)	VH6: hydronic balancing and heat zoning	VH7: Night time set back (large buildings, office)	VH8: Heat pumps (SHP monitoring)	VH9: Insulation on pipes(small system)	VH10: interlock between heating/cooling(emission)	VH11: weather compensation to adapt supply	VH12: insulation on pipes (large system)
Generation																										
Final heating demand	✓					✓			✓	H	H				✓		✓									
Maximum heating load as required per EPC calculation (Φsu)		✓				✓	✓		✓	H	M				✓		✓									
rated power of the heater (Φheater)		✓						✓																		
Oversizing factor heat generator calculated (=Φheater/Φsu)		✓				✓	✓			H	M															
heating seasonal efficiency (ErP) for gas boiler								✓		H	L	✓	✓					✓				✓				
Seasonal Coefficient of Performance for heating (ErP) with AW HP								✓		H	L	✓	✓									✓				
average conversion efficiency for gas boiler		✓				✓	✓		✓	H	M				✓		✓									
Seasonal performance factor for heating with HP		✓				✓	✓		✓	L	H				✓		✓	✓								
Distribution																										
design exit temperature (max.)		✓		✓		✓		✓	A	M	H				✓		✓			✓						
design return temperature (max.)		✓		✓		✓		✓	A	M	H				✓		✓			✓						
heat loss coefficient per m pipe			✓			✓		✓		L	H												✓			✓
k errors between heat and cold distribution networks (fan coils, valves)			✓					✓		L	H															
calculated design flow rate for the rated thermal peak power		✓				✓	✓			L	H															
the electrical auxiliary energy for heating, pumps	✓			✓		✓			✓	L	H				✓		✓			✓						
calculated maximum hydronic power		✓					✓			L	H				✓		✓			✓						
max. flow rate		✓		✓			✓		✓	L	H				✓		✓			✓						

	Affects		Is affected by		Assessment							Link to other EU regulation			Link to identified requirements in Task 2											
					Inputs from:					Impac	Impac															
Key Parameters	**Overall energy performance**	**Dimensioning**	**Installation**	**Adjustment**	**Product data**	**EPC data**	**Design calcs**	**visual check and Declaration**	**Measurement**	**Impact small systems**	**Impact large systems**	**Ecodesign limit values**	**Ecodesign product data**	**Installer energy label**	VH1: Monitoring and Parameter Adaptation	VH2: Night time set back (residential)	VH3: overall performance (large buildings)	VH4: replace old boilers in SFH	VH5: individual emittor control (TRVs)	VH6: hydronic balancing and heat zoning	VH7: Night time set back (large buildings, office)	VH8: Heat pumps (SHP monitoring)	VH9: Insulation on pipes(small system)	VH10: interlock between heating/cooling(emission)	VH11: weather compensation to adapt supply	VH12: insulation on pipes (large system)
Emission																										
the heating energy needs of the building (calc. from balance)		✓				✓	✓			H	H															
needed heat emission capacity (total) at the design exit and return temperature the heat generator for 20 °C interior temperature		✓				✓																				
return termperature from an emittor (radiator)				✓					✓						✓		✓			✓						
pressure drop kv value of radiator itself		✓						✓			H															
pressure drop kv value of radiator itself (preset kv valve)		✓	✓	✓			✓				H									✓						

Key: L = low, M = Medium, H = High

This table groups the measures (via the rows whose topic is explained on the left-hand column) into those concerning monitoring, control, generation, distribution and emission of space heating systems. In addition, rows addressing heat storage, heat recovery and the integration of demand response (DR) and renewable energy systems (RES) are mentioned for completeness and as a reminder to regulators to consider provisions for these aspects too. A tick mark indicates that there is a significant linkage between the horizontal parameter and the vertical parameter.

The first two vertical columns show how the horizontal parameters affect the overall system performance and the dimensioning calculations.

The next two vertical columns show how the installation and adjustment, respectively, affect the horizontal parameter.

The first five "Assessment" vertical columns indicate the options to receive assessment inputs e.g. from any of product data, EPC data, design calculations, visual checks or declarations of conformity, or direct measurement.

The following two vertical columns indicate the impact that the horizontal parameter has on small TBS and large TBS respectively, where H = a high impact, M = a medium impact, and L = a low impact and A = affected. Note, often small TBS will be used in single family housing or sometimes small non-residential buildings while larger TBS will be used in other non-residential buildings or in multi-family buildings.

The final set of vertical columns show the linkages between the horizontal parameters and the recommended TBS energy saving measures identified in Task 2.

Over the European building stock as a whole the study team estimates (from Task 2) that the most promising energy saving measures are those cited below (the corresponding codes VH1 to VH12 shown in Table 4 are also indicated).

System performance requirements could be set:

- to require the installation of a heat recovery system (or an exhaust air heat pump in case of space constraints) for larger systems (>70kW) to be made mandatory whenever a major system component is installed or replaced (V4) (This could also be part of the ventilation requirements)
- to require overall space heating system energy performance limits to be met, e.g. in line with the 2030 reduction target for buildings (VH3)
- to oblige the replacement of old combustion (non-condensing) boilers (25–30 years old) – privately owned and used single-family houses can be excluded as well as boilers with proven fulfilment of actual minimum Ecodesign requirement (VH4)
- to require installation of insulation on pipes (at a 100% of the pipe diameter in thermal effect terms) – for accessible pipes outside the heated zone for all systems (VH9 and VH12).

Sizing dimensioning & installation requirements could be set:

- per those parameters indicated in the table above
- to ensure proper installation according to standards.

- Over-dimensioning of gas boilers can result in part load operation and cycling which might reduce efficiency and increase hazardous emissions. It can be recommended to use metered data, if available, e.g. via a digital gas meter.

Adjustment requirements could be set:

- to require that in any building a night set-back control panel is installed in an easily accessible location– adjusted settings (e.g. 11pm to 6am, 2 K temperature reduction) in residential buildings if system and user allows (VH2) (note: this might only apply to certain types of buildings, it might not be possible in low energy buildings with slow acting heat emitters such as underfloor heating).
- to require night set-back – adjusted settings (e.g. for offices use 5pm to 6am, 2 K temperature reduction) in non-residential buildings, if system and user allows to (VH7)
- to stimulate hydronic balancing (VH6) and heat zoning.

Control requirements could be set:

- to require that appropriate heat emission control is installed per zone/room – for example thermostatic radiator valves (VH6)
- to require or incentivise larger systems >70kW to install a building energy monitoring system (BEMS), to be triggered whenever a major system component is installed or replaced, that allows comparison of actual performance with expected performance and parameters to be adapted when needed (VH1)
- to require heat pumps in new buildings to be equipped with a monitoring system to visualise actual seasonal performance in relation to the calculated value of the energy performance certificate (VH8)
- avoid simultaneous heating and cooling, by implementing a central controller or ensuring separate controllers do not overlap in systems >70kW (VH10)
- use of weather compensation to adapt supply temperature (VH11).

4.4.2 Space heating and sanitary hot water: examples of good practice

***Space heating and DHW case study for Flanders, Belgium*[24]**

Flanders requires the efficiency of space heating systems to be greater than a minimum threshold. The efficiency of the entire heating system must meet a specific requirement, depending on the type of heating system and any applicable European Regulation. Specifically:

Eq. 1 $\eta_{sys} \geq \eta_{sys,min,EU} \cdot 0{,}9$

Eq. 2 $\eta_{sys} \geq \eta_{sys,min}$

[24] Bijlage XII: Eisen voor technische installaties, Belgian OFFICIAL GAZETTE and monitor 28.10.2020 – and monitor 78086 to 78130.

Eq. 3 $f_{sys} \geq f_{sys,min}$

Where:

η_{sys} is the system efficiency of the entire heating system, as determined according to Equation [4]

$\eta_{sys,min,EU}$ is the imposed minimum system efficiency for heating systems that fall under the scope of European Regulation (EU) n°811/2013, n°813/2013, n°206/2012 and n°2016/2281 fall, determined according to the type of heating system according to Table 5 below.

$\eta_{sys,min}$ is the imposed minimum system efficiency for heating systems that do not fall under the scope of European Regulation (EU) n°811/2013, n°813/2013, n°206/2012 and n°2016/2281, determined according to the type of heating system according to Table 5 below.

f_{sys} is the system factor, determined according to equation [4] below.

$f_{sys,min}$ is the imposed minimum system factor, determined according to the type of heating system according to Table 5.

Table 5: Overall system energy performance limits for space heating in Flanders

	$H_{sys,min,EU}$ (-)	$\eta_{sys,min}$ (-)	$f_{sys,min}$ (-)
Gaseous and liquid fuel condensing boiler	0,94	0,84	-
Non-condensing boiler on gaseous and liquid fuel	0,94	0,84	-
Electric ground/water heat pump	3,32	3,30	-
Electric water/water heat pump	3,32	3,30	-
Electric air/water heat pump	3,20	2,80	-
Electric air-to-air heat pump with a rated thermal output greater than 12 kW(1)	3,40	2,90	-
Electric air-to-air heat pump with a rated thermal output not exceeding 12 kW(1)	3,80	2,90	-
System of external heat supply	-	-	0,90
System of external heat supply	-	-	0,90

(1) This includes split units, even if they only serve one room

Specific requirements are set for electrical resistance heating systems and also the insulation of circulation pipes and combination loops.

To calculate the system efficiency the efficiency of the entire heating system is determined as follows for the example of gaseous and liquid fuel condensing boilers only (other cases are addressed in the regulation):

Eq. 4 $\eta_{sys} = [\eta_{app} + f_{NCV/GCV} \cdot 0{,}003 \cdot (\theta_{30\%} - \theta_{ave,boiler})] \cdot f_{dim} \cdot f_{install} \cdot f_{adj} \cdot f_{control}$

where:

η_{app} is the appliance efficiency, determined in accordance with the method in the section *Determination of the device efficiency* below.

$f_{NCV/GCV}$ is a multiplication factor equal to the ratio of the lowest to the highest calorific value of the fuel used

$\theta_{30\%}$ is the boiler inlet temperature at which the appliance efficiency η_{app} is determined, in °C. The value in the absence is 30°C

$\theta_{ave,boiler}$ is the seasonal average boiler water temperature to be used, in °C

f_{dim} is the system dimensioning correction factor

$f_{install}$ is the system installation correction factor

f_{adj} is the system adjustment correction factor

$f_{control}$ is the system control correction factor.

Determination of the device efficiency

For non-condensing and condensing boilers on gaseous and liquid fuel that meet the relevant conditions, the appliance efficiency η_{app} is equal to the part-load efficiency $\eta_{\_part,GCV}$ (relative to the upper calorific value) at 30% of the nominal heat output, determined as the useful efficiency η1 according to European Regulation (EU) n°813/2013. If the partial load efficiency $\eta_{\_part,GCV}$ (in relation to the calorific value) is not known, it is calculated according to the methods in equations [5] to [7].

For non-condensing and condensing boilers on gaseous and liquid fuel, the appliance efficiency η_{app} is equal to the part-load efficiency $\eta_{\_part,GCV}$ (relative to the calorific value) at 30% of the nominal heat output. Exception: For air heaters for which the efficiency at 30% load cannot be measured, the value at 100% load may be used. If the partial load efficiency $\eta_{\_part,GCV}$ (in relation to the calorific value) is not known, it is calculated according to the methods in equations [5] to [7].

For electric ground/water, water/water, air/water and air/air heat pumps, the appliance efficiency η_{app} is equal to the generation efficiency $\eta_{\_gen,heat}$ determined according to the method described in the regulation.

For standard boilers (constant temperature) if:

Eq. 5 $\eta_{part,GCV} = f_{NCV/GCV} \cdot (0{,}80 + 0{,}03 \cdot \log P_{nom})$

For low temperature boilers (including condensing gas oil boilers) as:

Eq. 6 $\eta_{part,GCV} = f_{NCV/GCV} \cdot (0{,}875 + 0{,}015 \cdot \log P_{nom})$

For gas-fired condensing boilers such as:

Eq. 7 $\eta_{part,GCV} = f_{NCV/GCV} \cdot (0{,}97 + 0{,}01 \cdot \log P_{nom})$

If "P" _"nom" is not known:

Eq. 8 $\eta_{part,GCV}$ = 0,73

in which:

P_{nom} is the rated useful thermal power of the boiler, in kW;

$f_{\_NCV/GCV}$ a multiplication factor equal to the ratio of the lower to the upper calorific value of the fuel used

Determination of the dimension correction factor

In the case of the dimension correction factor, f_{dim}, a bonus is offered when the system dimensioning calculation has been conducted and a note provided as testimony.

Determination of the installation correction factor

In the case of system installation $f_{install}$ is determined from:

$$f_{install} = f_{loc} \cdot f_{insul,duct} \cdot f_{insul,exch}$$

Where:

f_{loc} is a correction factor for the location of the heat generator or the heat exchanger that forms the boundary with the system of external heat supply

$f_{insul.duct}$ is a correction factor for the pipe insulation

$f_{insul.exch}$ is a correction factor for the insulation of the heat exchanger that forms the boundary with the system of external heat supply.

Determination of the adjustment correction factor

In the case of system adjustment f_{adj} is determined from:

$$f_{adj} = f_{reg,burn} \cdot f_{reg,norm} \cdot f_{reg,self} \cdot f_{hyd}$$

Where:

$f_{reg,burn}$ is a correction factor for the control of the boiler temperature

$f_{reg,norm}$ is a correction factor for the regulation of normal regime

$f_{reg,self}$ is a correction factor for self-regulating equipment

f_{hyd} is a correction factor for hydraulic balancing.

Determination of the control correction factor

In the case of system control $f_{control}$ is determined from:

$$f_{control} = f_{mon}$$

Where f_{mon} provides a bonus when energy consumption monitoring is used the magnitude of which is distinguished depending on whether:

- the total nominal thermal power of the heat production installation is less than or equal to 70 kW

- the total nominal thermal power of the heat production installation is greater than 70 kW and less than or equal to 290 kW.

Noting that EPBD Article 14(4) makes the inclusion of such monitoring mandatory for systems with a heating capacity of > 290 kW.

The specifics of the correction factor values and other parameters cited above are provided in the regulation.

Domestic Hot Water control case study for Spain[25]

II. _1.2.4.3.4. Control of centralized domestic hot water preparation facilities

1 minimum equipment for the control of centralized installations for the preparation of sanitary hot air shall be as follows:

a) Control of the accumulation temperature;

b) Control of the water temperature of the pipe network at the hydraulically farthest point of the accumulator;

c) Control to carry out the heat shock treatment;

d) Differential type of operation control in the forced circulation of the primary, and, where appropriate, secondary, of the solar thermal energy installations. In addition to the differential control, control systems operated by solar radiation may be used, or other similar systems that do not reduce the possibilities of using solar energy.

e) Security control for users.

4.5 Ventilation

When setting Article 8 requirements for ventilation it is important to consider the Commission's guidance, as shown in Table 6.

[25] Source: Section IT 1.2.4.1.1. *General criteria* in REGULATION OF THERMAL INSTALLATIONS IN BUILDINGS: CONSOLIDATED VERSION + MODIFICATIONS, MARCH 2021, SECRETARY OF STATE FOR ENERGY, DIRECTORATE-GENERAL FOR ENERGY POLICY AND MINES

Table 6: Commission Article 8(1) guidance for ventilation

Type of requirement	Possible interpretation for ventilation	Useful references (1)
Overall energy performance	The energy performance of the ventilation system as a whole, taking into account e.g. fans energy efficiency, the characteristics of the ventilation duct network, heat recovery, etc.	EN 16798–3 (2), EN 16798–5–1, (3) EN 16798–5–2 (4)
Appropriate dimensioning	Dimensioning refers to the optimal sizing of the ventilation system with regard to the ventilation needs of the building and its spaces.	EN 16798-7 (5), CEN/TR 14788 (6), CR 1752 (7)
Proper installation	Proper installation refers to the need to ensure the system will be able to operate in accordance with design specifications. Ensuring proper installation can rely e.g. on national technical guidelines, products manufacturer documentation, certification of installers.	N/A
Adjustment	Adjustment refers here to the test and finetuning of the system under real-life conditions (8), in particular to check and possibly adjust system functions that can have an important impact on performance (e.g. control capabilities – see below).	EN 12599 (9), EN 16798-17 (10), EN 14134 (11)
Appropriate control	Concerns control capabilities that ventilation systems can include in order to optimize performance, e.g. airflow modulation.	EN 15232 (12), EN 15500-1 (13)

(1) The references focus on EU standards. In addition to these, Member States are invited to consult available resources at national level, e.g. in France, the NF DTU 68.3 'Installations de ventilation mécanique' standard.

(2) EN 16798-3 'Energy performance of buildings — Ventilation for buildings — Part 3: For non-residential buildings — Performance requirements for ventilation and room-conditioning systems (Modules M5-1, M5-4)'.

(3) EN 16798-5-1 'Energy performance of buildings — Ventilation for buildings — Part 5-1: Calculation methods for energy requirements of ventilation and air conditioning systems (Modules M5-6, M5-8, M6-5, M6-8, M7-5, M7-8) — Method 1: Distribution and generation'.

(4) EN 16798-5-2 | Energy performance of buildings — Ventilation for buildings — Part 5-2: Calculation methods for energy requirements of ventilation systems (Modules M5-6, M5-8, M6-5, M6-8, M7-5, M7-8) — Method 2: Distribution and generation.

(5) EN 16798-7 | Energy performance of buildings — Ventilation for buildings — Part 7: Calculation methods for the determination of air flow rates in buildings including infiltration (Module M5-5).

(6) CEN/TR 14788:2006 'Ventilation for buildings — Design and dimensioning of residential ventilation systems'.

(7) CR 1752:1998 'Ventilation for buildings — Design criteria for the indoor environment'.

(8) Member States may consider ensuring a degree of alignment between the methods followed for adjusting heating systems for the purpose of compliance with the provisions of Article 8(1) ventilation system requirements and the methods followed to assess performance of combined heating/air-conditioning and ventilation systems under typical or average operating conditions, where relevant, under Article 14-15.

(9) EN 12599:2012 'Ventilation for buildings — Test procedures and measurement methods to hand over air conditioning and ventilation systems'.

(10) EN 16798-17 'Energy performance of buildings — Ventilation for buildings — Part 17: Guidelines for inspection of ventilation and air conditioning systems (Module M4-11, M5-11, M6-11, M7-11)'

(11) EN 14134:2004 Ventilation for buildings — Performance testing and installation checks of residential ventilation systems.

(12) EN 15232 'Energy performance of buildings — Impact of Building Automation, Controls and Building Management'.

(13) EN 15500-1:2017 'Energy Performance of Buildings — Control for heating, ventilating and air conditioning applications — Part 1: Electronic individual zone control equipment — Modules M3-5, M4-5, M5-5'.

4.5.1 Ventilation – shortlist of measures

Table 7 provides a non-comprehensive shortlist of measures to be considered (informed by the analysis reported in Task 2). In particular, it provides a matrix of the key ventilation parameters that shows: how they affect system performance and its dimensioning; how they are affected by installation and adjustment; the potential source of assessment inputs to determine the parameter values; the magnitude of the impact they have on energy savings as a function of system size; their links with other EU regulations; and their links to the most promising set of energy saving measures identified in Task 2.

Table 7: Matrix of ventilation parameters, Article 8(1) & 8(9) measures and promising energy saving requirements (A means applicable)

	Affects		Is affected by		Assessment – Inputs from:					Impact small systems	Impact large systems	Link to other EU regulation			Link to identified requirements in Task 2								
Key Parameters	Overall energy performance	Dimensioning	Installation	Adjustment	Product data	EPC data	Design calcs	visual check or Declaration of Conformance	Measurement			Ecodesign limit values	Ecodesign product data	Installer energy label	V1a and V1b: Limitation on PSFP of all fans	V2: Volume reduction to actual demand by p	V3a,b,c: Installation of air-volume controls	V4: Installation of a heat recovery system (or	V5: Improvement of filter exchange	V6: Monitoring and Parameter Adaptation	V7: overall performance (large buidlings)	Vx: Air tightness of ducts (small system)	Vx: Air tightness of ducts (large system)
Monitoring	✓	✓	✓						✓											✓	✓		
Control functions																							
demand adapted air flow rates (on zone- and/or central-level)	✓		✓	✓			✓		✓	M	H					✓	✓			✓	✓		
supply air temperatures	✓	✓	✓	✓			✓		✓	M	M									✓	✓		
humidty (humidification and /or dehumidfication)	✓	✓	✓	✓			✓		✓	L	M									✓	✓		
control of secondary air system	✓	✓	✓	✓			✓		✓	M	M									✓	✓		
control of heat recovery system (e.g. bypass, pumps, defrosters)	✓		✓	✓	✓		✓		✓	M	M									✓	✓		
interlock control to other other domains, expecially for combined heating and cooling systems	✓		✓	✓				✓	✓	L	M									✓	✓		
Filter maintainance information	✓			✓				✓	✓	L	L								✓		✓		
Generation																							
Fan efficiency (PSFP; dependant of efficiencies of impeller, motor, belt drive and controls)	✓	✓	✓	✓			✓		✓	M	M	✓	✓	✓	✓					✓	✓		
Design air flow rates (fan sizing)	✓	✓				✓	✓			H	H										✓		
Efficiency and quality of heat recovery system (temperature ratio,additional pressure drop (additional fan electricity), possible pumps and defrosters, existance of a bypass)	✓		✓		✓			✓	✓	H	H	✓	✓	✓	✓			✓		✓	✓		
type of (de-)humidification	✓				✓					L	L										✓		

	Affects		Is affected by		Assessment							Link to other EU regulation			Link to identified requirements in Task 2								
					Inputs from:					Impact small systems	Impact large systems												
Key Parameters	Overall energy performance	Dimensioning	Installation	Adjustment	Product data	EPC data	Design calcs	visual check or Declaration of Conformance	Measurement			Ecodesign limit values	Ecodesign product data	Installer energy label	V1a and V1b: Limitation on PSFP of all fans	V2: Volume reduction to actual demand by p	V3a,b,c: Installation of air-volume controls	V4: Installation of a heat recovery system (or	V5: Improvement of filter exchange	V6: Monitoring and Parameter Adaptation	V7: overall performance (large buildings)	Vx: Air tightness of ducts (small system)	Vx: Air tightness of ducts (large system)
Distribution																							
sizing of duct system	✓	✓					✓	✓		M	H				✓						✓		
sizing and quality of heat exchangers	✓	✓			✓			✓	✓	L	L				✓						✓		
sizing and quality of filters	✓	✓			✓			✓	✓	L	M				✓				✓		✓		
sizing and of flaps and throttles	✓	✓		✓				✓		L	L				✓						✓		
heat loss (insulation) of duct system	✓	✓	✓		✓	✓	✓	✓		L	L										✓		
air tightness of duct system	✓	✓	✓					✓		L	M										✓	✓	✓
the electrical auxiliary energy for heating, pumps	✓			✓		✓			✓	L	L										✓		
Emission																							
suitable and suitably sized air in- and outlets	✓	✓	✓		✓		✓	✓		M	M				✓						✓		
correct adjusted air-in- and outlets	✓			✓			✓		✓	M	M				✓						✓		

Key: L = low, M = Medium, H = High

This table groups the measures (via the rows whose topic is explained on the left-hand column) into those concerning monitoring, control, generation, distribution and emission of space heating systems. In addition, rows addressing heat storage, heat recovery and the integration of demand response (DR) and renewable energy systems (RES) are mentioned for completeness and as a reminder to regulators to consider provisions for these aspects too. A tick mark indicates that there is a significant linkage between the horizontal parameter and the vertical parameter.

The first two vertical columns show how the horizontal parameters affect the overall system performance and the dimensioning calculations.

The next two vertical columns show how the installation and adjustment, respectively, affect the horizontal parameter.

The first five “Assessment” vertical columns indicate the options to receive assessment inputs e.g. from any of product data, EPC data, design calculations, visual checks or declarations of conformity, or direct measurement.

The following two vertical columns indicate the impact that the horizontal parameter has on small TBS and large TBS respectively, where H = a high impact, M = a medium impact, and L = a low impact. Note, often small TBS will be used in single family housing or sometimes small non-residential buildings while larger TBS will be used in other non-residential buildings or in multi-family buildings.

The final set of vertical columns show the linkages between the horizontal parameters and the recommended TBS energy saving measures identified in Task 2.

Over the European building stock as a whole the study team estimate (from Task 2) that the most promising energy saving measures are those cited below.

System performance requirements could be set:

- to require the PSFP of fans to achieve minimum permissible performance levels; furthermore, for larger systems specific it would be reasonable to set minimum PSFP limits applicable to existing systems (V1a and V1b)
- to require the installation of a heat recovery system (or an exhaust air heat pump in case of space constraints) for larger systems to be made mandatory whenever a major system component is installed or replaced (V4)
- to oblige systems using filters above a certain air flow rate to satisfy minimum filter exchange performance levels through specification of minimum filter classes (V5)
- to require overall ventilation system energy performance limits to be met requirements, e.g. in line with the 2030 reduction target for buildings (V7).

Sizing dimensioning & installation requirements could be set:

- per the dimensioning of the parameters indicated in the table above
- to ensure proper installation according to standards
- to ensure that airflow volumes are better matched to the actual demand – adjustment could be required for all larger existing systems independently of intervention trigger points and design sizing obliged for all systems when replaced or a major component/set of components are being replaced (V2).

Control requirements could be set:

- that require all larger systems to have airflow volume controls independently of intervention trigger points, and potentially to be verified through periodic system inspections (V3a, V3b, V3c)
- that require or incentivise larger systems to install a monitoring system, triggered whenever a major system component is installed or replaced, that allows comparison of actual performance with expected performance (V6).

4.5.2 Ventilation: examples of good practice

Case study of Flanders,Belgium[26]

Flanders requires the efficiency of ventilation systems to be greater than a minimum threshold. It distinguishes between the following system configuration cases:

- Central ventilation system with mechanical supply and natural exhaust
- Central ventilation system with natural supply and mechanical exhaust
- Central ventilation system with mechanical supply and mechanical exhaust

each of which has a minimum system efficiency factor f_{sys} set.

Satisfaction of these requirements is determined by inputting the system values into the following equation:

$$f_{sys} = f_{dim} \cdot f_{install} \cdot f_{adj} \cdot f_{control}$$

where:

f_{dim} is the system dimensioning correction factor

$f_{install}$ is the system installation correction factor

f_{adj} is the system adjustment correction factor

$f_{control}$ is the system control correction factor

In the case of central ventilation systems with mechanical supply and mechanical discharge f_{dim} is set to zero if there is no heat recovery system in place which means such systems could not comply with the requirements.

In the case of system installation $f_{install}$ is determined from:

$$f_{install} = f_{at,AHU} \cdot f_{at,duct} \cdot f_{insul,duct}$$

Where:

$f_{at.AHU}$ is the correction factor for the air tightness of the air handling unit

$f_{at.duct}$ is the correction factor for the air tightness of the ducting

$f_{insul.duct}$ is the correction factor for the quality of insulation of the ducting

In the case of system adjustment f_{adj} is determined from:

[26] Bijlage XII: Eisen voor technische installaties, Belgian OFFICIAL GAZETTE and monitor 28.10.2020 – and monitor 78086 to 78130.

$$f_{adj} = f_{ae} \cdot f_{reg,vent}$$

Where:

f_{ae} is the correction factor for the aeraulic adjustment.

$f_{reg.vent}$ is the correction factor for the a correction factor for the speed control of the fans.

The f_{ae} value depends on whether there is a report available on the aeraulic adjustment or not and thus incentivises the assessment of the aeraulic performance.

The $f_{reg.vent}$ value incentivises the use of fan speed controls such that the fans are equipped with a speed control that regulates the ventilation flow rate as a function of the ventilation demand. The speed control can be done on the basis of at least one measured parameter. This parameter can be, for example (not exhaustive):

- CO2 content in the room;

- CO2 content in the extraction air;

- Humidity in the room;

- Humidity in the extraction air;

- Presence detection;

- Press via VAV or CAV systems.

In the case of system control $f_{control}$ is determined from:

$$f_{control} = f_{mon}$$

Where f_{mon} is unity for all systems with a total discharge flow rate is less than 10,000 m³/h but for other systems there is a bonus when energy consumption monitoring is used.

In addition to the above the regulations set out minimum performance requirements for the insulation of the air ducts.

4.6 Space cooling

When setting Article 8 requirements for space cooling it is important to consider the Commission's guidance[27] on the possible interpretation of system requirements for space cooling as shown in Table 8.

Table 8: Commission Article 8(1) guidance for space cooling

Type of requirement	**Possible interpretation for space cooling (1)**	**Useful references**
Overall energy performance	In this context, overall performance refers to the performance of the whole process of energy transformation in cooling generators, cooling distribution across the building, cooling emission in individual rooms or spaces of the building and, where applicable, cool storage. In particular, it is not limited to performance of cooling generators can include requirements that affect other parts of the system (e.g. insulation of distribution piping network).	EN 16798 standard series on cooling systems, e.g. EN 16798–9 (2), EN 16798–13 (3), EN 16798–15 (4)

[27] COMMISSION RECOMMENDATION (EU) 2019/1019 of 7 June 2019 on building modernisation, OJEU L165/70

Appropriate dimensioning	Dimensioning refers to the optimal sizing of the cooling system with regard to the cooling needs of the building and its spaces.	EN 1264-3:2009 (5)
Proper installation	Proper installation refers to the need to ensure the system will be able to operate in accordance with design specifications. Ensuring proper installation can rely e.g. on national technical guidelines, products manufacturer documentation, certification of installers.	EN 1264-4 (6)
Adjustment	Adjustment refers here to the test and fine-tuning of the system under real-life conditions (6), in particular to check and possibly adjust system functions that can have an important impact on performance (e.g. control capabilities – see below).	EN 16798–17 (7)
Appropriate control	Concerns control capabilities that systems for space cooling can include in order to optimize performance, e.g. automatic adaptation of cooling output of emitters in individual rooms or spaces.	EN 15500-1 (9), EN 15316-2 (10), EN 15232 (11)

(1) In line with Article 2(3) and 8(1) of the EPBD, this table focuses on active cooling in buildings. While not covered here, it is worth bearing in mind that passive cooling — e.g. shading — is also effective.

(2) EN 16798-9 'Energy performance of buildings — Ventilation for buildings — Part 9: Calculation methods for energy requirements of cooling systems (Modules M4-1, M4-4, M4-9) — General'.

(3) EN 16798-13 'Energy performance of buildings — Ventilation for buildings — Part 13: Calculation of cooling systems (Module M4-8) — Generation'.

(4) EN 16798-15 'Energy performance of buildings — Ventilation for buildings — Part 15: Calculation of cooling systems (Module M4-7) — Storage'.

(5) EN 1264-3:2009 'Water based surface embedded heating and cooling systems — Part 3: Dimensioning'.
(6) EN 1264-4:2009 'Water based surface embedded heating and cooling systems — Part 4: Installation'.

(7) Member States may consider ensuring a degree of alignment between: (a) the methods followed for adjusting space cooling systems in order to comply with the provisions of Article 8(1) on requirements for space cooling systems; and (b) the methods followed to assess performance of air-conditioning systems under typical or average operating conditions, where relevant, under Article 14-15.

(8) EN 16798-17 'Energy performance of buildings — Ventilation for buildings — Part 17: Guidelines for inspection of ventilation and air conditioning systems (Module M4-11, M5-11, M6-11, M7-11)'.

(9) EN 15500-1:2017 'Energy Performance of Buildings — Control for heating, ventilating and air conditioning applications — Part 1: Electronic individual zone control equipment — Modules M3-5, M4-5, M5-5'.

(10) EN 15316-2:2017 'Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 2: Space emission systems (heating and cooling), Module M3-5, M4-5'.

(11) EN 15232 'Energy performance of buildings — Impact of Building Automation, Controls and Building Management'.

4.6.1 Space cooling – shortlist of measures

Table 9 provides a non-comprehensive shortlist of measures to be considered (informed by the analysis reported in Task 2). In particular, it provides a matrix of the key space cooling parameters that shows: how they affect system performance and its dimensioning; how they are affected by installation and adjustment; the potential source of assessment inputs to determine the parameter values; the magnitude of the impact they have on energy savings as a function of system size; their links with other EU regulations; and their links to the most promising set of energy saving measures identified in Task 2.

Table 9: Matrix of space cooling parameters, Article 8(1) & 8(9) measures and promising energy saving requirements

	Affects		Is affected by		Assessment: Inputs from:					Impact small systems	Impact large systems	Link to other EU regulation			Link to identified requirements in Task 2											
Key Parameters	Overall energy performance	Dimensioning	Installation	Adjustment	Product data	EPC data	Design calcs	visual check or Declaration of Conformance	Measurement			Ecodesign limit values	Ecodesign product data	Installer energy label	C3+C7+C9: switch off systems when not needed	C8: modify controls to sequence heating+cooling	C26: overall requirement to annual savings of 4% for small buildings	C26: overall requirement to annual savings of 4% - large buildings	C11: install BEMS	C12: improve central chiller/ refrigeration control	C18+C15: exchange old and inefficient pumps and compressors	C6: sequence heating and cooling	Monitoring & and Parameter Adaptation	VH5: individual emitter control (TRVs)	VH10: interlock between heating and cooling (emission)	VH12: insulation on pipes (large system)
Monitoring	✓	✓	✓						✓					✓				✓	✓				✓		✓	
Control functions														✓												
room or zone heating or cooling emission control	✓	✓	✓	✓	✓	✓		✓	✓	L	H			✓			✓	✓	✓			✓	✓	✓	✓	
control of the temperature of the heating and cooling distribution network, typically water in a hydronic network	✓	✓	✓	✓		✓		✓	✓	M	M			✓		✓	✓	✓	✓	✓		✓	✓			
control of distribution pumps (circulator pump) in heat or cold distribution networks	✓		✓	✓		✓		✓	✓	L	M			✓	✓		✓	✓	✓	✓		✓				
interlock control between heating and cooling emission and/or distribution systems	✓		✓	✓				✓	✓	L	H			✓		✓		✓		✓		✓			✓	
hydronic efficiency (balancing) EN15316-2 (includes automatic balancing)	✓	✓	✓	✓		✓		✓	✓	L	M			✓				✓								

	Affects	Is affected by			Assessment — Inputs from:							Link to other EU regulation			Link to identified requirements in Task 2											
Key Parameters	Overall energy performance	Dimensioning	Installation	Adjustment	Product data	EPC data	Design calcs	visual check or Declaration of Conformance	Measurement	Impact small systems	Impact large systems	Ecodesign limit values	Ecodesign product data	Installer energy label	C3+C7+C9: switch off unneeded systems	C8: controls to sequence heating+ cooling	C26: overall annual savings of 4% small buildings	C26: overall annual savings of 4% large buildings	C11: install BEMS	C12: improve central chiller/ refrigeration control	C18+C15: exchange old and inefficient pumps and compressors	C6: sequence heating and cooling	Monitoring & and Parameter Adaptation	VH5: individual emitter control (TRVs)	VH10: interlock between heating and cooling	VH12: insulation on pipes (large system)
Generation																										
Final cooling demand	✓					✓			✓	H	H						✓	✓					✓			
maximum cooling load as required per EPC calculation (Φsu)		✓				✓	✓		✓	H	M						✓	✓					✓			
rated power of the cool generator (Φcool)		✓						✓																		
Oversizing factor coolth generator calculated (=Φcool/Φsu)		✓				✓	✓			H	M												✓			
Seasonal performance factor for cooling		✓				✓	✓		✓	L	H						✓	✓			✓					
Distribution																							✓			
design exit temperature (max.)		✓		✓		✓		✓	✓	M	H						✓	✓					✓			
design return temperature (max.)		✓		✓		✓		✓	✓	M	H						✓	✓					✓			
heat loss coefficient per m pipe			✓			✓		✓		L	H															✓
Interlock errors between heat and cold distribution networks (fan coils, valves)			✓					✓		L	H															
calculated design flow rate for the rated thermal peak power		✓				✓	✓			L	H															

	Affects		Is affected by		Assessment: Inputs from:					Impact small systems	Impact large systems	Link to other EU regulation			Link to identified requirements in Task 2											
Key Parameters	Overall energy performance	Dimensioning	Installation	Adjustment	Product data	EPC data	Design calcs	visual check or Declaration of Conformance	Measurement			Ecodesign limit values	Ecodesign product data	Installer energy label	C3+C7+C9: switch off unneeded systems	C8: controls to sequence heating+ cooling	C26: overall annual savings of 4% small buildings	C26: overall annual savings of 4% large buildings	C11: install BEMS	C12: improve central chiller/ refrigeration control	C18+C15: exchange old and inefficient pumps and compressors	C6: sequence heating and cooling	Monitoring & and Parameter Adaptation	VH5: individual emitter control (TRVs)	VH10: interlock between heating and cooling	VH12: insulation on pipes (large system)
the electrical auxiliary energy for cooling, pumps	✓			✓		✓			✓	L	H				✓		✓	✓			✓		✓			
calculated maximum hydronic power		✓					✓		✓	L	H						✓	✓								
max. flow rate		✓		✓			✓		✓	L	H						✓	✓								
Emission																										
the cooling energy needs of the building (calc. from balance)		✓				✓	✓			H	H															
needed cooling emission capacity (total) at the design exit and return temperature the cold generator for 26°C interior temperature		✓				✓																				
return temperature from an emitter				✓					✓								✓	✓								
pressure drop kv value of radiator itself		✓						✓			H															
pressure drop kv value of radiator itself (preset kv valve)		✓	✓	✓			✓				H															

Key: L = low, M = Medium, H = High

This table groups the measures (via the rows whose topic is explained on the left-hand column) into those concerning monitoring, control, generation, distribution and emission of space heating systems. In addition, rows addressing heat storage, heat recovery and the integration of demand response (DR) and renewable energy systems (RES) are mentioned for completeness and as a reminder to regulators to consider provisions for these aspects too. A tick mark indicates that there is a significant linkage between the horizontal parameter and the vertical parameter.

The first two vertical columns show how the horizontal parameters affect the overall system performance and the dimensioning calculations.

The next two vertical columns show how the installation and adjustment, respectively, affect the horizontal parameter.

The first five "Assessment" vertical columns indicate the options to receive assessment inputs e.g. from any of product data, EPC data, design calculations, visual checks or declarations of conformity, or direct measurement.

The following two vertical columns indicate the impact that the horizontal parameter has on small TBS and large TBS respectively, where H = a high impact, M = a medium impact, and L = a low impact. Note, often small TBS will be used in single family housing or sometimes small non-residential buildings while larger TBS will be used in other non-residential buildings or in multi-family buildings.

The final set of vertical columns show the linkages between the horizontal parameters and the recommended TBS energy saving measures identified in Task 2.

Over the European building stock as a whole the study team estimate (from Task 2) that the most promising energy saving measures are those cited below.

System performance requirements could be set:

- to require overall space cooling system energy performance limits to be met, e.g. in line with the 2030 reduction target for buildings (C26)
- when applicable, to require the installation of a heat recovery system (or an exhaust air heat pump in case of space constraints) for larger systems (>70kW) to be made mandatory whenever a major system component is installed or replaced (per Ventilation V4)
- when applicable to require installation of insulation on pipes (at a 100% of the pipe diameter in thermal effect terms) – for accessible pipes outside the cooled zone for all systems (per Space heating VH9 and VH12).

Sizing dimensioning and installation requirements could be set:

- per those parameters indicated in the table above
- reduce motor size (fan power) when oversized for all non-packaged systems (C4)
- to ensure proper installation according to standards (CH11).

Adjustment requirements could be set:

- to require the regular cleaning or replacement of filters (C2)
- reduce power consumption of auxiliary equipment (C16).

Control requirements could be set:

- to oblige circulation pumps to be switched off when not required for all non-packaged systems (C3)
- to avoid simultaneous heating and cooling: by implementing a central controller or making sure that separate controllers do not overlap for all cooling systems of >70kW with heating (CH9)
- shut off auxiliaries when not required for all non-packaged systems (C5)
- shut chiller plant off when not required for systems using chillers (C7)
- sequence heating and cooling for all non-packaged systems with space heating (C6 & C9)
- shut off AC equipment when not needed (C9)
- to require or incentivise larger systems >70kW to install a monitoring system, to be triggered whenever a major system component is installed or replaced, that allows comparison of actual performance with expected performance and parameters to be adapted when needed (CH7)
- to require or incentivise the installation of BACS for systems >70kW (C11)

4.6.2 Space cooling: examples of good practice

Case study from Spain[28]

The text below relays the Spanish requirements for space cooling systems, as translated from the original Spanish text. The IT section notation used is copied verbatim from this regulation and reprised here to enable easy cross referencing. In addition, the relationship between these measures and the recommended measures in the previous section are cross referenced in bold text. The text is extensive and mostly reprised here but in some cases IT sections are skipped, which can be inferred by their numerical sequencing.

IT 1.2.4.1.3.1. Minimum energy efficiency requirements for cold generators. **(Measure C26 – overall system performance)**

1. The minimum requirements shall be those laid down in accordance with paragraph 1 of IT 1 .2.4.1.1 General criteria.

The individual EER and COP coefficients of each equipment will be indicated when the demand varies from the maximum to the lower limit of partial load, under the planned design conditions, as well as that of the plant with the chosen operating strategy. In addition, the information appearing on the product sheet, which is required by the energy labelling regulations applicable to each type of cold generator, must be indicated.

2. The temperature of the refrigerated water at the exit of the plants must be kept constant when the demand varies, except for exceptions that will be justified.

[28] Source: Section IT 1.2.4.1.1. *General criteria* in REGULATION OF THERMAL INSTALLATIONS IN BUILDINGS: CONSOLIDATED VERSION + MODIFICATIONS, MARCH 2021, SECRETARY OF STATE FOR ENERGY, DIRECTORATE-GENERAL FOR ENERGY POLICY AND MINES

3. The temperature jump shall be an increasing function of the power of the generator(s), up to the limit laid down by the manufacturer, in order to save pumping power, except for exceptions which shall be justified.

IT 1.2.4.1.3.2. Staging of power in cold generation plants. **(Measure C14 – split the load amongst various chillers)**

1. Cold generating plants must be designed with a number of steps such that the variation in the demand of the system is covered with an efficiency close to the maximum offered by the chosen generators.

2. The partial supply of the cooling power should preferably be obtained continuously and for installations with a rated useful power exceeding 70 kW, with at least 4 stages of the plant, the maximum being 25 %. For installations with lower powers, the part load of the power supplied must be obtained at least in stages. These requirements exclude generation plants with geothermal machines, except those with a rated useful power exceeding 70 kW, which must have at least 2 power steps.

3. For installations with rated useful power exceeding 70 kW, if the lower limit of demand could be less than the lower limit of part supply of a machine, a system designed to meet that demand during its duration over the course of a day should be installed. The same system will be used to limit the tip of the maximum daily demand.

4. Reversible refrigeration equipment when operating under a heat pump regime is also subject to this requirement.

IT 1.2.4.1.3.3. Air-cooled refrigeration machinery **(Dimensioning)**

1. The condensers of the air-cooled refrigeration machinery shall be sized for a dry outside temperature equal to that of the most demanding percentile level plus 3 °C.

2. Air-cooled refrigeration machinery shall be fitted with a system for monitoring the condensation pressure, except where it is certain that it will never operate at outside temperatures below the minimum limit indicated by the manufacturer.

3. When the machines are reversible, the minimum design temperature shall be the wet temperature of the most demanding percentile level minus 2 °C.

IT 1.2.4.1.3.4. Water-cooled refrigeration machinery or evaporative condenser **(Dimensioning)**

1. The cooling towers and evaporative condensers will be sized to the value of the wet temperature that corresponds to the most demanding percentile level plus 1 °C.

2. The approach differential and the temperature jump of the water will be selected to optimize the sizing of the equipment, considering the impact of such parameters on the energy consumption of the system.

3. By decreasing the wet bulb temperature and/or the thermal load, the thermal level of the condensation water will be reduced to the minimum value recommended by the manufacturer of the refrigeration equipment, varying the rotation speed of the fans, by steps or with continuity, or the number of them in operation.

4. The water in the condensation circuit shall be adequately protected against frost.

5. Cooling towers and evaporative condensers will be selected with energy-efficient fans, preferably induced draught. **(overall system performance)**

6. It is recommended to design a hydraulic decoupling between the refrigeration equipment of the condensing water and the condensers of the refrigeration machines.

7. The cooling towers and evaporative condensers will comply with the current hygienic-sanitary legislation for the prevention and control of Legionnaires' disease. Additionally, and provided that it does not contradict the legislation in force in the matter, they will comply with the provisions of the section 6.5.1 of the UNE 100030 standard, as regards the distance to air intakes and windows.

With regards to the distribution system minimum energy performance requirements are specified for **(Measure C26 – overall system performance)**:

- IT 1.2.4.2. Networks of pipes and ducts.
- IT 1.2.4.2.3. Tightness of duct networks
- T 1.2.4.2.4. Pressure drops in components

Additionally,

IT 1.2.4.2.5. Energy efficiency of fluid transport equipment **(Measure C26 – overall system performance)**

Minimum performance limits are specified for pumps and circulators, motor fans and fans specific fan power efficiency levels.

2. The selection of the propulsion equipment for the carrier fluids shall be carried out in such a way that their performance is maximum under the calculated operating conditions.

3. For variable flow systems, the above requirement must be met in the average operating condition over a period of time.

4. The specific power of the pumping systems, called SFP and defined as the power absorbed by the engine divided by the flow of fluid transported, measured in W/(m3/s), shall be justified for each circuit.

Requirements are also set for:

IT 1.2.4.2.6. Energy efficiency of electric motors. **(Measure C26 – overall system performance)**

2. Hydraulic balancing of pipe circuits will be achieved during the design phase using balancing valves, if necessary **(Measure CH4 –hydraulic balancing)**

1.2.4.2.8 Ventilation units.

IT.1.2.4.2.9 Thermal emitters **(dimensioning)**

Thermal emitters shall be sized for heating inlet temperatures below 60 °C and cooling input temperatures above 7 °C.

Section IT 1.2.4.3. on Control includes the following provisions:

IT 1.2.4.3 .1. Control of air conditioning installations

1. All thermal installations shall be equipped with the necessary automatic control systems so that the planned design conditions can be maintained in the premises, adjusting energy consumption to variations in the thermal load. Thus, in newly built buildings, where technically and economically feasible, they shall be equipped with self-

regulation provisions which regulate separately the ambient temperature in each interior space or, in justified cases, in a heating or cooling area selected from the building as a whole.

In existing buildings, the installation of such devices will be required in the case where heat generators are replaced, and only for the self-regulation of heating installations, when technically and economically feasible.

In the case of installations equipped with several heat generators, if these serve the same space and any of them are replaced, the obligation will apply to these spaces. If the generators are independent and do not service the same space, the requirement shall apply only to the spaces serviced by the replaced heat generators.

Devices installed as a result of the application of these provisions must:

a) Allow the automatic adaptation of the calorific power according to the interior temperature (and optional additional parameters);

b) To permit the regulation of heat power in each interior space (or area), in accordance with the heating parameters of the interior space (or area) in question.

Solutions that allow temperature to be regulated automatically, but not at the indoor (or area) scale, for example, automatic regulation at housing scale, would not meet the requirements.

2. The use of all-nothing controls is limited to the following applications:

a) Safety limits of temperature and pressure.

b) Regulation of fan speed of terminal units.

c) Control of the thermal emission of generators of individual installations.

d) Control of the temperature of rooms served by unit apparatus of a useful power of 70 kW or less.

e) Control of the operation of the ventilation of engine rooms

3. Automatic rearmament of safety devices shall be permitted only where expressly stated in these Technical Instructions.

4. Systems consisting of different subsystems must have the necessary devices to take each of these out of service depending on the occupancy regime, without affecting the rest of the installations.

5. The automatic control valves shall be selected in such a way that, at the maximum project flow rate and with the valve open, the pressure loss that will occur in the valve is between 0,6 and 1,3 times the loss of the controlled element. In variable flow installations with total thermal generating power exceeding 70 kW, it will be necessary to stabilize the differential pressure on the control valve to ensure an adequate temperature

6. The variation of the water temperature in fa score of the external conditions, or to adapt the generation to the environmental conditions, will be made in the secondary circuits of the heat generators of standard type and in the same generator in the case of generators of low temperature and of condensation, up to the limit fixed by the manufacturer.

7. The temperature of the refrigerated fluid at the outlet of an instantaneous production refrigeration plant shall remain constant, whatever the demand and regardless of the external conditions, except in situations which must be justified.

8. The control of the operating sequence of the heat or cold generators will be done according to these criteria:

a) When the efficiency of the generator decreases as demand decreases, the generators will work in sequence.

By reducing the demand, the power delivered by each generator will be modulated (with continuity or by steps) until the minimum allowed value is reached and stopping a machine; then the other generators will act in the same way.

Increasing demand will act in reverse.

b) When the efficiency of the generator increases as demand decreases, the generators will remain running in parallel.

As demand decreases, the power delivered by the generators (continuously or by step) will be modulated until maximum efficiency is reached; then the power of one generator will be modulated until it reaches its stop and the other generators will be acted in the same way.

Increasing demand will act in reverse.

9. For the control of the condensing temperature of the refrigeration machine, the criteria referred to in paragraphs 1.2.4.1.3 for air-cooled machines and for water-cooled machines shall be followed.

10. The other 5 m3/s fans shall be incorporated with an indirect device for the measurement and control of air flow.

11. Thermostatic valves must comply with the UNE EN 215 standard

IT 1.2.4.3.2. Control of thermo-hygrometric conditions

1. The air conditioning systems, centralized or individual, will be designed to control the interior environment from the thermo-hygrometric point of view.

2. In accordance with the ability of the air conditioning system to control the temperature and relative humidity of the premises, the systems for monitoring thermohygrometric conditions shall be classified according to a set of specified requirements.

1.2.4.3.5 Automation and control systems of facilities.

1. Where technically and economically feasible, non-residential buildings with rated power useful for heating, cooling, combined heating and ventilation installations, or for combined cooling and ventilation installations of more than 290 kW shall be equipped with building automation and control systems.

Such building automation and control systems shall be capable of:

a) Monitor, record, analyse and allow the adaptation of energy consumption continuously

b) Carry out a comparative assessment of the energy performance of the building, detect the loss of efficiency of its technical installations and inform the person responsible for the installation or technical management of the building about the possibilities for improving energy efficiency

c) Allow communication with connected technical installations and other equipment that are inside the building, as well as ensure interoperability with technical facilities of the building of different types of patented technologies, devices and manufacturers.

For the purposes of this requirement, automation and control that have an impact on the energy efficiency of the building, such as those contained in standard UNE-EN 15232-1, will be considered.

2. Residential buildings may be equipped with the following:

a) Continuous electronic monitoring functionality that measures the efficiency of the facilities and informs the owners or managers of the property when it decreases significantly and when the installation needs to be repaired, and

b) Effective control functionalities to optimize production, distribution, storage and energy consumption.

3. The automation and control systems to be installed in the cases referred to in paragraphs 1 and 2 shall be adapted to the size or capacity of the installation, taking into account the needs and characteristics of the building under the intended conditions of use, determining the optimum control capacities according to the type of building, the intended use and the possible energy sources.

Once the automation and control system has been installed, it will be necessary to carry out verification actions that the system is operating according to its specifications and adjustment actions, where appropriate, in the installation under conditions of actual use.

Automation and control systems shall be configured to operate the installations according to operating regimes which allow the conditions of welfare and hygiene laid down in Article 11 with the minimum energy consumption. This will take into account the periods of inactivity of the building, the use of the spaces, the operating regimes at the point of maximum performance of the equipment and the maximum use of renewable energies and waste available. The indications and instructions for the correct operation of the automation and control system must be included in the "Manual of Use and Maintenance".

Requirements are also set for:

IT 1.2.4.3.3. Indoor air quality control in air conditioning installations.

IT 1.2.4.5. Energy recovery

IT 1.2.4.5.1 Free outdoor air cooling, **(Measure C1)**

1. All-air air conditioning subsystems with a rated useful power greater than 70 kW under cooling, shall have a free outdoor air-cooling subsystem.

2. In all-air air conditioning systems, the design of the floodgate sections is valid following sections 6.6 and 6.7 of the UNE-EN 13053 and UNE-EN 1751 standard:

a) Maximum frontal speed in the intake and air ejection gates: 6 m/s.

b) Temperature efficiency in the mixing section: greater than 75 percent.

3. In mixed water-air air conditioning systems, free cooling will be obtained by water from cooling towers, preferably closed circuit, or, in case of use of air-water refrigeration machines, by the use of batteries hydraulically placed in series with the evaporator.

4. In these cases, the need to reduce the freezing temperature of the water through the use of glycol solutions in water will be evaluated.

5. In any case and in accordance with the provisions of article 14, paragraph 2, of this royal decree, failure to comply with any of the aspects established in this technical instruction may be justified by the difficulty of achieving it.

IT 1.2.4.5.2. Heat recovery from extraction air

1. In the air conditioning systems of the building in which the flow of air expelled to the outside, by mechanical means, is greater than 0.28 m 3/s, in accordance with the provisions of the ecological design regulation for the ventilation units, the energy of the expelled air will be recovered.

2. Bidirectional ventilation units, or ventilation components of air treatment units in all-air systems, shall comply with the requirements laid down in the European Ecodesign regulations applicable to them.

In the project or technical report, for those cases in which the equipment has energy labelling, its class will be indicated. In addition, the information appearing on the product sheet required by the implementing energy labelling regulation shall be indicated.

3. In heated pools, the thermal energy contained in the expelled air must be recovered, with a minimum efficiency and maximum pressure losses equal to those indicated in Table 2.4.5.1 for more than 6,000 annual operating hours, depending on the flow rate

4. As an alternative to the use of outdoor air, the maintenance of the relative humidity of the environment can be achieved by means of a heat pump, sized specifically for this function, which cools, dehumidifies and reheats the same air from the environment in a closed cycle

5. As an alternative to the use of outdoor air, the maintenance of the relative humidity of the environment can be achieved by means of a heat pump, sized specifically for this function, which cools, dehumidifies and reheats the same air from the environment in a closed cycle.

IT 1.2.4.5.3. Stratification

In high-rise premises the thermal stratification of indoor air should be studied and encouraged during periods of thermal cooling demand and combated during periods of thermal heating demand

IT 1.2.4.5.4. Zoning

1. The zoning of an air conditioning system will be adopted in order to obtain a high well-being and energy saving.

2. Each system will be divided into subsystems, taking into account the compartmentalization of the interior spaces, orientation, as well as their use, occupation and operating hours.

IT 1.2.4.6. Use of renewable and waste energy

IT 1.2.4.6.1. Contribution of renewable or waste heat to the thermal production of the building

1. In new buildings or buildings undergoing renovation, with forecast of thermal demand, a part of the thermal energy needs derived from this demand will be covered by the incorporation of systems for the use of renewable energy, residual or from renewable cogeneration processes.

2. These systems shall be designed to achieve at least the minimum renewable contribution for domestic hot water and indoor pool heating established in section HE4 of the Technical Building Code, and the limit values for non-renewable primary energy consumption in accordance with section HE0 of the Technical Building Code. In the selection and design of the solution, the criteria of energy balance and economic profitability will be taken into consideration.

3. The coefficients of passage of the production of CO2 and primary energy shall be applied in accordance with the provisions of section 2 of IT1 .2.2.

4. In the event of using heat pumps to meet the demands of air conditioning, domestic hot water production or pool heating, in order to be able to consider part of their energy contribution as renewable energy, they must reach an average seasonal performance value (SPF) higher than that indicated in the Commission Decision of 1 March 2013 laying down guidelines for the calculation by the Member States of the renewable energy from heat pumps of different technologies, in accordance with Article 5 of the Directive 2009/28/CE of the European Parliament and of the Council of 23 of April of 2009 relative to the promotion of the use of energy from renewable sources and by which modify and derogate the Directives 2001/77/CE and 2003/30/CE. This seasonal average yield value (SPF) may be amended by delegated acts of the Commission as set out in Article 7 of Directive 2018/2001 of 11 December 2018, including a methodology for calculating the amount of renewable energy used in cooling, district cooling and for amending Annex VII to that Directive.

5. The average seasonal yields referred to in the previous point shall, wherever possible, be determined by the standard corresponding to the type of machine and the profile of use and applied to the climatic zone where the installation is located.

IT 1.2.4.6. 3. Air conditioning of open spaces

The air conditioning of open spaces can only be carried out through the use of renewable or residual energies. Conventional energy may not be used for the generation of heat and cold for the climate of these spaces.

IT 1.2.4.7. Limitation of conventional energy use

IT 1.2.4.7.1. Limitation of conventional energy use for centralised heating production

The use of direct electrical energy by 'Joule effect' for the production of heating in centralised installations shall be permitted only in:

a) Heat pump installations, when the ratio between the electrical power in support resistors and the electrical power in compressor motor terminals is equal to or less than 1,2.

b) Premises served by installations which, using renewable energy sources or residual energy, use electricity as an auxiliary source of support, provided that the degree of coverage of annual energy needs by the renewable energy source or waste energy is greater than two thirds:

…

(e) premises served with heat generation installations by means of thermal accumulation systems, provided that the accumulation capacity is sufficient to capture and retain during the hours of electricity supply type 'valley', defined for the regulated electricity tariff, the total daily thermal demand foreseen in the project, the number of hours per day of coverage of said demand by the accumulation system must be justified in its memory without the need to attach its heat generator to the grid of electricity supply.

IT 1.2.4.7.3. Simultaneous action of fluids with opposite temperature

l. The maintenance of the thermo-hygrometric conditions of a thermal zone is not permitted by:

a) successive cooling and heating processes; or

b) the simultaneous action of two fluids with temperature of opposite effects;

2. It is exempted from the above prohibition, provided that the solution adopted is justified, in the following cases, where:

a) is made by a free energy source or is recovered from the condenser of a refrigeration equipment;

b) is imperative for the maintenance of relative humidity within the required margins;

(e) it is necessary to maintain the rooms equipped with positive pressure with respect to the adjacent premises;

d) it is necessary to simultaneously the air flow inlets of antagonistic temperatures to maintain the minimum flow of ventilation air;

e) the air mixture takes place in two different areas of the same environment.

4.7 Built-in lighting

Lighting systems were already part of the technical building systems before the 2018 amendment of the EPBD but were not covered by the provisions on system requirements. However, following the amendment, system requirements have to be established for 'built-in' lighting systems. The update of the wording is only a clarification of the scope. The new EBPD wording of the scope emphasises that it covers only lighting equipment that is installed in order to implement lighting specifications defined at design time, and to fulfil related requirements. Table 10 contains the Commission's Guidance[29] on the possible interpretation of system requirements for built-in lighting.

Table 10: Commission Article 8(1) guidance for built-in lighting (amended text is in italic)

Type of requirement	Possible interpretation for built-in lighting	Useful references
Overall energy performance	Minimum requirements on the performance of the built-in lighting system as a whole, taking into account relevant parameters. The LENI (lighting energy numeric indicator) as defined in EN 15193-1:2017 standard can, for example, be a way to express requirements on the performance of lighting systems. *In addition, it is possible to set limits on the lighting power density PDI [W/100 lx/m] and require the consideration of a new lighting design when the threshold is exceeded.*	EN 15193-1:2017 (1), CEN/TR 15193-2:2017 (2)
Appropriate dimensioning	For lighting systems, 'appropriate dimensioning' refers to:	EN 12464-1 (3),

[29] COMMISSION RECOMMENDATION (EU) 2019/1019 of 7 June 2019 on building modernisation, OJEU L165/70

	(i) determining illumination level requirements, taking into account relevant parameters (in particular intended usage of the building and its spaces); and (ii) translating those requirements into design specifications for lighting systems. In addition, *for non-residential lighting that should comply with EN 12464 provide a lighting design file as proof of compliance.*	CEN/TS 17165 (4)
Proper installation	Installation of electric equipment, including lighting, in accordance with applicable regulations at national level. *In addition, for non residential illumination that should comply with EN 12464, it can be required to:* • *check the maximum power (W/m²) at commissioning and check against the design file -and keep a record* • *measure the minimum power of all lights in stand by – and keep a record)* • *control maximum illumination (Emax,m) in key task areas and glare where appropriate, compare to the design file - and keep a record* • *control the floor and wall reflection (take a picture with a grey chart), compare to the design file and report if substantially lower reflections are measured.*	*EN 12464-1 (3)*
Adjustment	Adjustment may refer here to: (i) checking that capabilities of lighting systems comply with design specifications, particularly in terms of controls and; (ii) performing any relevant fine-tuning. *In addition, for non residential illumination that should comply with EN 12464, it can be required to check and fine tune illumination set points per task area.*	Same as below
Appropriate control	In this context, 'control' refers to the ability of the lighting system to control the lighting level, taking into account parameters from the environment (e.g. daylight) and from the building (e.g. occupation). *In addition for non residential illumination that should comply with EN 12464, it could be required to monitor LENI and hourly energy consumption profiles):*	CEN/TR 15193-2 (5), CIE 222:2017 (6) *EN 12464-1 (3)*

(1) EN 15193-1:2017 'Energy performance of buildings — Energy requirements for lighting — Part 1: Specifications'.

(2) CEN/TR 15193-2 'Energy performance of buildings — Energy requirements for lighting — Part 2: Explanation and justification of EN 15193-1, Module M9'.

(3) EN12464-1:2011 'EN12464-1:2011 Light and lighting — Lighting of workplaces Part 1: Indoor work places'.

(4) CEN/TS 17165 'Light and Lighting — Lighting System Design Process'.

(5) CEN/TR 15193-2:2017 'Energy performance of buildings — Energy requirements for lighting — Part 2: Explanation and justification of EN 15193-1, Module M9'.

(6) CIE 222:2017 'Decision Scheme for Lighting Controls in Non-Residential Buildings'.

4.7.2 Built-in lighting – shortlist of measures

Over the European building stock as a whole the study team estimate (from Task 2) that the most promising energy saving measures are those cited below.

System performance requirements could be set:

Member States could consider setting the following system performance requirements:

For non-residential lighting in indoor workplaces in large buildings where EN 12464 (>500 m²) applies, the following data should be calculated at design stage or monitored:

- The reference LENI [kWh/m²/h] design value should be available (EN15193) and from monitoring after installation
- The reference PDI [W/100 lx/m²] design value should be available [EN15193] or can be measured for existing installations
- The measured maximum luminaire power Pl [W/m²]
- The measured parasitic power of the lighting circuit with all lights switched off Ppc [W/m²].

For other lighting applications the following data could be required:

- the measured maximum luminaire power Pl [W/m²]
- the measured parasitic power of the lighting circuit with all lights switched off Ppc [W/m²].

In large non-residential buildings an audit and justification for not considering a relighting and redesign could be requested when the benchmark values in Table 11 are exceeded for two consecutive years.

Table 11: (repeat of Table 38): Recommended performance benchmarks to trigger a relighting and redesign of a lighting system.

Application	LENI max [kWh/m²/y]	PDI max [W/100lx/m²]	Pl max [W/m²]	Ppc max [W/m²]
Office, education	15	2	10	0.25
Circulation area, corridor	10	2.5	6	0.5
Retail				0.5
Industry workplaces				0.25
Warehouse				0.25
Horeca				0.5
Other				0.5

Note: The data in this table might be outdated because LED lighting products are constantly improving in efficacy.

Similar benchmark data can be found here:

- older LENI and Pl max data (2008) from the Energieplus[30] website with general building renovation advise (BE, W)
- newer data from Lot 37[31] but which might be too ambitious

[30] https://energieplus-lesite.be/reglementations/eclairage9/performance-energetique-des-batiments-exigences-energetiques-pour-l-eclairage-norme-nbn-en-15193-2008/

[31] https://ecodesign-lightingsystems.eu/

- older data from the Swiss Standard 380/4(2006)[32] or the updated standard SIA 387/4(2017)[33] can also be considered.

Dimensioning requirements

Dimensioning requirements could be set for new or replacement lighting systems:

For non-residential lighting in indoor workplaces in large buildings where EN 12464 (>500 m²) applies, the following data needs to be provided at the design stage:

- printout (pdf) of the calculated LENI, PDI, Pl, Ppc values including EN 12464 minimum values (e.g. as can be generated by DIALUX, RELUX, OXYTECH, etc. software)
- floor plan (pdf) with indication of luminaires, sensors for BACS and major task areas (EN 12464)
- inform the building owner that wall reflection coefficients can have significant impact on the illumination values. Issue a warning for high lighting power demand when the coefficient of reflection is below: 70% for walls, <85% for ceilings and 50% for floors.
- averaged value (LENI, PDI, Pl, Ppc) per submeter area whereby at least one submeter per 200 m² must be assumed. Electrical wiring diagram (1-wire) to show how the luminaires are connected to the LENI submeters
- luminaire data sheets.

For other lighting applications the following data could be required:

- the total calculated luminaire power Pl [W/m²]
- the total calculated parasitic power of the lighting circuit with all lights switched off Ppc [W/m²].

Adjustment requirements

Adjustment requirements could be set:

For non-residential lighting in indoor workplaces within large buildings where EN 12464 (>500 m²) applies, the following data would be needed:

- a declaration of honour from the installer that all luminaires and sensors are installed according to the plans (see dimensioning requirements in the previous subsection)
- a checklist for BACS lighting functions that includes a declaration of honour that all presence detectors and daylight detectors are fine-tuned and checked
- measurement of illumination with a lux meter [lx] that the minimum target illumination values are exceeded with at least 1 measurement per 15 m² of floor area, report with results
- check the floor and wall coefficient of reflection [%] with a luminance and illuminance meter is in-line with assumptions. Check for impact of furniture. If the

[32] https://www.energie-zentralschweiz.ch/fileadmin/user_upload/Downloads/Vollzugshilfen/11_VoHi_EN12_ElektEnergieSIA380_4_Beleuchtung.pdf

[33] https://www.minergie.ch/de/news/news-de/neue-sia-norm-387-4/

interior is much darker than assumed in the design file, issue a warning to the building owner. At least 10 surfaces should be checked per 100 m².

- measurement of the maximum luminaire power (Pl [W/m²] and verify against the design value. If these deviate by more than 5% the design file needs to be updated
- measurement of the maximum luminaire power (Pl [W/m²] and verify against the design value. If these deviate by more than 5% the design file needs to be updated.

For other lighting applications the following data could be required:

- a checklist for BACS lighting functions that includes a declaration of honour that all presence detectors and daylight detectors are fine-tuned and checked
- measurement of the maximum luminaire power (Pl [W/m²] and verify against the design value. If these deviate by more than 5% the design file needs to be updated
- measurement of the maximum luminaire power (Pl [W/m²] and verify against the design value. If these deviate by more than 5% the design file needs to be updated.

Control and adjustment requirements

Control and adjustment requirements could be set:

In addition to the previous requirements for control systems at the time of installation or renovation the following could be required for control systems:

- A requirement that lighting installations in common circulation areas in existing buildings should have a presence detector that controls lighting for useful floor areas of at least 50 m² and in staircases at least one per every three floor levels
- A requirement for non-residential buildings to have a central lighting management system and/or an automatic controller:
  - that allows for unoccupied periods:
    - dimming to the minimum required levels if technically justified

or

- switching off lighting.
  - for high occupancy rooms with available daylight, to have:
    - daylight dependent dimming
    - a controller loop every 25 m².

Metering and monitoring requirements for continuous commissioning and adjustment

Although this was not found in the examples cited in Task 1, it is additionally proposed to require for large buildings (>1000 m²) that there should be an energy monitoring system (EMS) or BACS function in place for lighting that measures:

- LENI [kWh/m²/month]
- quarterly power data (Pl) at least per area of (>200 m²) and hereby:

- detect the minimum consumption is the self-consumption (Ppc = Pl_min)
- to verify daylighting control functioning, a yearly check if the maximum power (Pl_max_june) measured during June at 17 h(check all days of a month and keep the quarterly maximum value) >0.8 that of December (Pl_max_17h_dec)
- calculate seasonal (winter–spring–summer–autumn) aggregated statistics per day of week (Mon-Fri, Sat, Sun) computer equivalent operating hours equal to LENI/Pl [h]
- monitor the occupancy with at least one alternative parameter (e.g. lift operation, occupancy detectors, ICT up-time, etc.) and display data next to equivalent operating hours obtained from LENI/Pl
- to verify yearly occupancy control functions when anomalies are detected in the equivalent operating hours by considering the data collected.

If the measured LENI and PDI are not within the limits of the overall system energy performance requirements for two consecutive years than a relighting and redesign should be considered (i.e. new luminaires, controls and lighting design).

4.8 Building automation and control systems

The 2018 amendment to the EPBD made it explicitly clear that BACS are a TBS in their own right and that the Article 8(1) and 8(9) requirements apply to them as much as they do to the other TBS.

When setting Article 8(1) requirements it is helpful to consider the Commission's guidance[34] on the possible interpretation of system requirements for BACS as shown in Table 12.

Table 12: Commission Article 8(1) guidance for BACS

Type of requirement	Possible interpretation for BACS	Useful references (1)
Overall energy performance	Minimum requirements on control capabilities that have an impact on building energy performance. These requirements can concern the scope of control (i.e. which systems are controlled), the depth (or granularity) of control, or both. In defining these requirements, references can be made to available standards, for instance to BACS energy classes as defined in EN 15232 standard. Requirements can vary depending on the type of buildings (e.g. residential vs non-residential) and on some characteristics of buildings (e.g. surface area).	EN 15232 (2) EN 16947- 1:2017 (3) and TR 16947-2 (4)
Appropriate dimensioning	Dimensioning would refer here not to the system size (as it would for some other systems), but more to the way the design of a BACS can be tailored to a specific building.	ISO 16484-1:2010 (5)

[34] COMMISSION RECOMMENDATION (EU) 2019/1019 of 7 June 2019 on building modernisation, OJEU L165/70

	The aim of dimensioning is to reach the best compromise between costs and capabilities in consideration of the specific needs of the considered building. Requirements on dimensioning will list the relevant aspects that should be taken into account when designing a BACS for a specific building (e.g. expected or measured energy consumption, building usage, technical building systems installed in the building, operation and maintenance requirements, etc.) in order to reach this optimal compromise. In the scope of these requirements, it can be useful to refer to relevant standards or guidelines.	
Proper installation	Requirements on the 'proper installation' is a generic reference to the need to ensure that the system (here, the BACS) is installed in a way that will ensure safe and optimal operation. Usually this is linked to requirements on the qualification of the installer (e.g. certified installer) and to specific technical guidelines.	EN 16946- 1:2017 (6) and TR 16946-(7)
Adjustment	Adjustment' refers to post-installation test of the system in order to check that the system operates properly, and to fine-tuning when the system operates under real conditions. Such actions would generally require human intervention, but BACS give the opportunity to also consider ongoing commissioning approaches, where this process is partially automated (8).	EN 16946- 1:2017 (6)and TR 16946-2 (7); ISO 50003 (9)
Appropriate control	This category mostly applies to technical building systems that are controlled (e.g. heating systems) than to BACS, whose main purpose is to control other systems. However, 'appropriate control' can refer here to the functions that a BACS can offer in order to support or facilitate human control (e.g. display of consumption data or any other interaction with building operator and building occupants)	EN 15232 (2), EN 16947-1:2017 (3) and TR 16947-2 (4)

(1) The references given all relate to standards. In addition to these, Member States can consider drawing on the practices of some industry-led schemes, whether European, e.g. the eu.bac certification scheme (https://www.eubac.org/systemaudits/index.htm) or national, e.g. in Germany the VDMA 24186-4 'Program of services for the maintenance of technical systems and equipment in buildings — Part 4: Measurement and control equipment and building automation and control systems'.

(2) EN 15232 'Energy performance of buildings — Impact of Building Automation, Controls and Building Management'.

(3) EN 16947-1:2017 'Energy Performance of Buildings — Building Management System — Part 1'.

(4) TR 16947-2 'Building Management System — Part 2: Accompanying prEN 16947-1:2015'.

(5) ISO 16484-1:2010 Preview 'Building automation and control systems (BACS) — Part 1: Project specification and implementation'.

(6) EN 16946-1:2017 'Energy Performance of Buildings. Inspection of Automation, Controls and Technical Building Management'.

(7) TR 16946-2 'Inspection of Building Automation, Controls and Technical Building Management — Part 2: Accompanying TR to EN 16946-1'.

(8) This comment also applies to some extent to all technical building systems that are monitored and controlled by BACS.

(9) ISO 50003:2014 'Energy management systems — Requirements for bodies providing audit and certification of energy management systems'.

Self-regulating devices

Paragraph 3 of Article 8(1) stipulates that "Member States shall require new buildings, where technically and economically feasible, to be equipped with self-regulating devices for the separate regulation of the temperature in each room or, where justified, in a designated heated zone of the building unit. In existing buildings, the installation of such self-regulating devices shall be required when heat generators are replaced, where technically and economically feasible."

As such a device must allow for the separate regulation of the temperature in each room (or, where justified, in a designated zone) of the building unit the devices installed as a result of the implementation of these provisions should therefore:

- allow for the automatic adaptation of heating output depending on the indoor temperature (and optionally additional parameters)
- allow for the regulation of heating output in each room (or zone), in accordance with the heating settings of the considered room (or zone).

This means, in particular, that:

- any solution based on the manual regulation of heating output would not fulfil the requirements, even if the adjustment can be performed at room (or zone) level
- any solution that allows for the automatic regulation of temperature but not at room (or zone) level, e.g. automatic regulation at dwelling-level, would not fulfil the requirements.

It is important to note that, regardless of the number or types of system(s) installed, what matters is that the systems make it possible for users to adjust temperature settings and ensure that these settings are respected. Examples of self-regulating devices are shown in Table 13.

Table 13: Examples of self-regulating devices

Device	Type of system	Regulation capability
Thermostatic radiator valve	Hydronic heating system and radiators	Regulation of hot water flow in emitters according to temperature setting
Room thermostat	Hydronic heating system and surface heating (e.g. floor heating)	Regulation of hot water flow in the surface heating thanks to the room's mixing valve
Fan coil unit thermostat	Hydronic heating/cooling system	Control of hot/cool water- and air-flow based on temperature setting
Individual thermostat	Standalone heaters or air-conditioners	Control of heat output depending on temperature setting

Note, the Commission's guidance document makes it clear that not only heating systems but also air-conditioning systems and systems for space cooling should meet the requirements related to self-regulating devices, although when heat generators are replaced in existing buildings, the requirement to install self-regulating devices should apply only to heating systems.

In particular, the reference to 'heated zone' in the text should not be interpreted as implicitly restricting the requirements to only to the heating systems but all components that regulate the temperature (e.g. also cooling). Based on the findings of the study and discussions with stakeholders, ''heated zone can be interpreted as:

- A room in a building in the case of buildings with poor air-tightness
- A ventilation zone in the case of buildings with demonstrated air-tightness levels , high level of thermal insulation and having mechanical ventilation.

4.8.1 BACS – shortlist of measures

As explained in the discussion of scope in Task 2 BACS are a horizontal topic that overarches all previously discussed TBS service domains. This means that the specification of BACS requirements under Article 8(1) could be addressed indirectly by the specification of measures that require control and monitoring capabilities for each of the other TBS (space heating, domestic hot water, space cooling, ventilation, lighting and RES). However, it is equally possible, appropriate and complementary to specify BACS functionality at the whole building level via the BACS energy performance classes defined in the standard EN 15232. These options are now considered in turn.

BACS energy performance requirements specified at the other TBS level

The TBS control measures that could be required under Article 8(1) provisions include requiring the[35]:

- Capability of the heat or cool generator system, or ventilation air handling unit, to vary the heating/cooling power or fresh air output upon signals from the control system / demand signals from the emission spaces – so called "modulation" of the output
- Capability of the HVAC system to vary energy distribution according to actual demand (e.g. capability of the pumps, compressors and fans to adjust water/refrigerant/air flows and temperatures to actual needs)
- Capability of the control system to automatically modulate and adapt the output of heat or cool emitters – e.g. radiators or a fan coil unit – to match actual and desired room temperature in individual rooms of the building – so called individual room temperature control based on various parameters such as room temperature / occupancy
- Capability of the control system to adapt space heating and cooling energy output to outdoor temperatures – so called weather compensation
- Capability of the control system to automatically adjust humidity level – so called humidification or de-humidification. The control set point for cooling can be increased with lower relative humidity and thus provide savings. Also, an overly narrow dead band for minimum and maximum relative humidity can result in excessive energy consumption for humidification or de-humidification. Humidity control is usually a subsystem of the cooling TBS and air-conditioning.
- Capability of the control system to manage automated solar protection to ensure the correct level of HVAC / avoid unnecessary cooling and glare protection depending on natural solar gains or overheating depending on seasons
- Capability of the control system to manage artificial lighting level depending on natural light through automated solar protection
- Capability of the control system to coordinate systems that are integrated in order to facilitate energy efficiency and smooth operation (e.g. scheduler and setpoint manager for rooms covering all installed services (e.g. heating, cooling, ventilation, light and sun protection))

[35] This list is reprised from Guidelines for the transposition of the new Energy Performance Buildings Directive (EU) 2018/844 in Member States, European Building Automation Controls Association subject to review and modest adaptation by the study team

- Capability of the control system to avoid simultaneous heating and cooling at the same time in the same room / space through any installed system (e.g. ventilation and heating)
- Capability of the HVAC / hydronic system to ensure smooth distribution of energy across the building in water-based heating, air conditioning and cooling systems – so called dynamic hydronic balancing
- Capability of the control system to support monitoring operation and changes in the system – in particular setpoints and schedules of room systems and equipment. Usually Energy Performance Certificates (EPC) are computed and benchmarked with standard predefined user-profiles and comfort settings per type of application, but in actual operation these values can differ and a key function of a BACS central management system is to adapt for this.

In addition, provisions to implement the previously mentioned Article 8(1) paragraph 3 measures on self-regulating devices also need to be adopted.

It is recommended that Member States should draw up a matrix of such control functionality requirements and ensure that appropriate Article 8(1) measures are in place to stimulate technically and economically feasible adoption of such measures for each affected TBS.

Whole building BACS energy performance class requirements

The EN 15232 standard defines BACS energy performance classes that range from D (less efficient) to A (more efficient) and are an expression of the degree of sophistication that the BACS functionality provides.

In order to quantify the impact of BACS functions EN 15232 defines BACS efficiency factors (fBAC) which also provide a simplified method to estimate energy savings from adoption of higher BACS functionality classes. Under this approach the BACS reference case for all building types is set to be class C which has a BACS efficiency factor of 1. Hence, under this relativistic energy performance expression:

Total energy demand BACS planned class = fBAC x total energy demand BACS Class C.

The annex of the standard provides a set of reference values as a function of the BACS energy performance functionality class that can be applied to the components of the energy balance. This is comprised of a set of three "BACS factors" for heating (fBAC, H), for cooling (fBAC, C) and for auxiliary electricity including ventilation (fBAC, el). Underlying these BACS factors is the whole set of EN 15232 functions and their minimum functional performance capabilities necessary to attain a specific BACS energy performance class. The three BAC factors can be considered as the key factors to quantify the energy impact associated with the operation of BACS of a given functionality. The annex of the standard, but also the Ecodesign Preparatory Study for BACS, shows how these can be computed or verified.

The three BAC factors can be considered as the key factors to quantify the energy impact associated with the operation of BACS of a given functionality. The annex of the standard, but also the Ecodesign Preparatory Study for BACS, shows how these can be computed or verified.

It is recommended that Member States consider setting minimum whole-building BACS energy performance class requirements that may be differentiated by the type, energy intensity and/or energy performance of the building in order to ensure their cost-effectiveness. Similarly, the trigger point wherein these have to be met could be set such that from a certain time no existing high energy intensity building can have a BACS class lower than a stipulated minimum level when replacing/renewing all or a significant part of the HVAC system unless it is demonstrated in accordance with an accepted methodology that it is not technically, economically or functionally feasible to do so.

Additional potential BACS requirements

Potential requirements for installing or putting into service of BACS are discussed in the recent Ecodesign Study for BACS[36]. Hereby, if adopted from the proposed study[36], it could be required under Article 8 that any replacement of a TBS subsystem (e.g. heater) should be done with equipment which is compatible with class B and is interoperable. For further details please consult the study.

BACS are an important means to deliver proper adjustment and control of heating, cooling, ventilation and lighting systems and can play an important role in continuous commissioning. More detailed BACS requirements to be applied to any existing heating and cooling (>290 kW) are also proposed under Article 14/15 (4) in Task 5. They can also be applied to smaller systems under Article 8 when part of the heating or cooling system is repaired (>70 kW) or when the building undergoes a major renovation. Typically, one could require the following:

- Minimum EN15232 class C for existing systems when an important part of the TBS is repaired or changed
- Minimum use of EN15232 class B compliant and interoperable equipment (see also Ecodesign proposal of the BACS study) for any repair or upgrade of the TBS to avoid a lock-in into a lower performing BACS and to support a later class B upgrade.

Minimum class B for non-residential buildings (>1000 m²) that undergo a major renovation.

4.8.2 BACS: examples of good practice

Flanders[37] rewards the use of BACS by applying system energy performance correction factors that reward more sophisticated TBS control solutions and penalise less sophisticated one; thereby creating an incentive to achieve system performance requirements via the use of BACS. This approach is a good example of how control functionality stimulus can be applied at the "other TBS" level to stimulate the adoption of technically and economically feasible BACS.

In Italy, a newly adopted requirement[38] is that new buildings or buildings undergoing major renovation have to be equipped with intelligent metering systems (according to EED implementation decree) and satisfy a minimum level of automation for building control, regulation, and management (UNI EN 15232 Class B) in the case of non-residential buildings (according to the EPBD implementing decree). It applies to all buildings and there is no HVAC capacity or floor area size threshold. Compliance and enforcement for BACS in Italy should be assessed based on a declaration of honour (DOH) from an auditor and by providing the necessary documentation or checklist that functions

[36] https://ec.europa.eu/energy/studies_main/preparatory-studies/ecodesign-preparatory-study-building-automation-and-control-systems_en

[37] Bijlage XII: Eisen voor technische installaties, Belgian OFFICIAL GAZETTE and monitor 28.10.2020 – and monitor 78086 to 78130.

[38] https://www.epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Italy-2018.pdf

are implemented according to EN 15232. Hence, from this it can be concluded that at least for the large (>1000 m²) non-residential buildings that undergo major renovations a class B compliance can be set as minimum.

The Netherlands[39] requires all larger buildings (>290kW) to attain a minimum class C BACS functionality under the EN15232 classification system. This is an example of the adoption of whole building BACS energy performance requirements.

4.9 Renewable energy systems

4.9.1 On-site electricity generation

Taking into account the ongoing photovoltaic system Ecodesign and Energy labelling[40] and the findings of the previous tasks it is proposed to amend and complement Table 9 on 'Possible interpretation of system requirements for on-site electricity generation' from the Commission's guidance[41] as explained hereafter. The study team have proposed some amendments to this shown in italics in Table 14.

The most important finding of this review is related to dimensioning of on-site electricity generation. It was found that there are various definitions of ''on-site production of photovoltaic energy' and the various local authorities involved in EPCs (EPBD) and metering and billing need to cooperate to support the proper understanding and dimensioning of photovoltaic systems. For electricity metering and billing the important parameter in self-consumption schemes is the 'maximum time frame for credit compensation'[42]. This parameter refers to schemes that allow credits for all electricity injected during a certain period of time in which compensation is permitted, meaning that the injected energy can be subtracted later on from grid consumption. This period can be real-time (20ms), 15 minutes, 1 hour, 1 day, 1 month or 1 year. For example, in 2020 in Denmark 1 hour is used, in Finland (real-time), France (1/2 hour), Belgium Wallonia (Annual for small systems), Belgium Flanders (20 ms), etc. Also, for Energy Performance Certificates (EPCs) the EN EPBD standard allows various methods for accounting PV to supply HVAC which range from annual, monthly or hourly time credits for self-consumption. Often the methods used for an EPC of a building and the metering do not align which is confusing for building owners and does not allow for an economic assessment. Therefore, it is recommended to require clear dimensioning information related to this, see proposals added in the table below.

Outside the scope of Article 8 but to support self-consumption with HVAC of PV it is recommended that the 'maximum time frame for credit compensation'[42]. in energy metering and billing schemes which is under control of the local authorities is ½ hour or more (e.g. as done in F, DK, BE(W), ..). When using ½ hour or more this will align well the new set of EPBD standards has been updated with an hourly method for HVAC final energy demand computations[43]. In this case it means that proper dimensioning for on-site consumption can be done using those standards. Else, real-time solar yield (20 ms)

[39] Handreiking, Energieprestatie installaties in gebouwen Uitwerking van de EPBDIII in de praktijk, Rijkdeinst voor Ondernemend Nederland, December 2020

[40] https://susproc.jrc.ec.europa.eu/product-bureau/product-groups/462/home

[41] COMMISSION RECOMMENDATION (EU) 2019/1019 of 7 June 2019 on building modernisation, OJEU L165/70

[42] https://iea-pvps.org/wp-content/uploads/2020/01/IEA-PVPS_-_Self-Consumption_Policies_-_2016_-_2.pdf

[43] https://epb.center/news/news_events/fourth-webinar-epb-standards-hourly-vs-monthly-met/

can be very erratic under cloudy conditions which can be problematic for HVAC systems because speed modulations under variable cloud conditions could shorten the lifetime and also decrease the coefficient of performance. In this case consumers should be warned for this. In the case of real time metering a battery energy storage system (BESS) but the proper metrics and data was not yet available to establish.

Table 14: Commission Article 8(1) guidance for onsite electricity generation (amended text is in italic)

Type of requirement	Possible interpretations for on-site electricity generation systems	References (1)	*Verification*
'overall energy performance'	Minimum requirements on the performance of the system (as installed) in terms of electricity generation under typical operating conditions. In defining these requirements, Member States are encouraged to consider applicable standards, in particular from the list of EPB standards (see third column), and applicable Ecodesign and Energy Labelling regulations (2) that are under elaboration In additions, for countries or regions with real time energy metering and billing requirements, consumers should be warned that this might be incompatible with HVAC self-consumption and that a battery energy storage system (BESS) might be needed.	EN 15316-4-6 (3) EN 61724 (4) and IEC 61853-2:2016 (5) for photovoltaic systems, EN 15316-4-4 standard (6) for building-integrated cogeneration system, EN 15316-4-10 (7) and IEC 61400-12-1 (8) for wind power generation systems *See: ongoing Ecodesign and Energy labelling study*[40].	*See ongoing study*[40] *(calculation file)*
'appropriate dimensioning	Dimensioning can first relate to the generation capacity of the system considered. One aim can be to ensure that this capacity is adequate with regard to considered needs (e.g. the design of heat load for cogeneration space heaters). Dimensioning can also relate to the physical dimensions of systems' components, taking into account the constraints that apply to the specific building (9) (e.g. position, orientation, slope of photovoltaic panels, maximum power point tracking configuration, cable size, etc.). *Additional parameters to be provided:* *Calculated annual exported electricity from PV and Self-consumption based on the local electricity metering scheme taking 'maximum time frame for credit compensation'*[42]. *Inform the building owner on the impact of maximum time frame for credit compensation* *Calculated annual electricity from PV that can be taken into account for an EPC (notes: this depends on the local EPC calculation code).*	~~Calculation of design heat load: EN 12831-1 (10) ISO 15927-5:2004 (11)~~ *EN ISO 52000-1, 52003-1, 52010-1, 52016-1, and 52018-1* *See ongoing study40*	per month a hourly yield calculation file (*See study40*) For per month average hourly HVAC EPC calculated data or measured data for existing buildings
proper installation'	Requirements on 'proper installation' is a generic reference to the need to ensure that the system is installed in a way that will ensure safe and optimal operation. Usually this is linked to requirements on the qualification of the installer (e.g. certified installer) and to specific technical guidelines. For photovoltaic systems, standards applying to building-integrated photovoltaics (BIPV) can be relevant in this context *Within the warranty period (2yrs) include a post-installation test of the system to check that it operates properly*	For BIPV systems, EN 50583-2 For PV systems, IEC/EN 62446	*Check documentation (EN 62446)*
appropriate adjustment'	~~'Adjustment' refers to: (i) a post-installation test of the system to check that it operates properly; and (ii) fine-tuning when the system is operating under real conditions~~.	~~For PV systems, IEC/EN 62446~~	Not relevant

'appropriate control'	In this context, 'control' refers to the ability of the system to control its own operation, taking into account parameters from the environment and from the building. This is most relevant for micro CHP systems, due to their simultaneous production of thermal and electrical energy.	~~N/A~~ *See ongoing study40 with regard to smart readiness requirements for photovoltaic inverters*	Check inverter data sheet

(1) The references focus on EU standards. In addition to these, Member States are invited to consult available resources at national level, e.g. in Belgium the 'Spécifications techniques (STS)' on photovoltaic systems: https://economie.fgov. be/sites/default/files/Files/Publications/files/STS/STS-72-1-systemes-photovoltaiques.pdf

(2) To date, the most relevant regulation for on-site electricity generation is the one on heaters and water heaters, which covers cogeneration space heaters, see 'Commission Regulation (EU) No 813/2013 of 2 August 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for space heaters and combination heaters'. In addition, the Ecodesign working plan 2016-2019 (COM(2016) 773 final) mentions that solar panels and inverters will be subject to preparatory studies, which means such systems could be covered by Ecodesign and/or energy labelling regulations in the future. See http://susproc.jrc.ec.europa.eu/solar_ photovoltaics/projectplan.html for more details.

(3) EN 15316-4-6 'Heating systems in buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-6: Heat generation systems, photovoltaic systems'.

(4) IEC/EN 61724: Photovoltaic system performance monitoring — Guidelines for measurement, data exchange and analysis.

(5) IEC 61853-2:2016 'Photovoltaic (PV) module performance testing and energy rating — Part 2: Spectral responsivity, incidence angle and module operating temperature measurements'.

(6) EN 15316-4-4 'Heating systems in buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-4: Heat generation systems, building-integrated cogeneration systems'.

(7) EN 15316-4-10 'Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-10: Wind power generation systems'.

(8) IEC 61400-12-1 Ed. 2.0 b:2017 'Wind energy generation systems — Part 12-1: Power performance measurements of electricity producing wind turbines'.

(9) The aim is to ensure that the system will have optimal performance over its lifetime. Suboptimal dimensioning could lead to poor performance, which is detrimental to the building owner.

(10) EN 12831-1 'Energy performance of buildings — Method for calculation of the design heat load'.

(11) ISO 15927-5:2004 'Hygrothermal performance of buildings — Calculation and presentation of climatic data — Part 5: Data for design heat load for space heating'.

(12) EN 50583-2:2016 'Photovoltaics in buildings. BIPV systems'.

(13) Photovoltaic systems — Minimum requirements for system documentation, commissioning tests and inspection'.

4.9.2 Other renewable systems for DHW or heating

The current COMMISSION RECOMMENDATION (EU) 2019/1019 has no section related to other renewable systems for Domestic Hot Water (DHW) or heating under Article 8, which can be justified because thermal renewable energy is already well covered by EN standards Article 2 and 9 of the EPBD and Article 15 of the EED. Nonetheless, some jurisdictions have applied Article 8 to phase out the use of fossil fuel for DHW or heating, with example as follows:

- In 1999, Barcelona's City Council passed the Solar Thermal Ordinance[44] that requires all new buildings, renovated buildings, and buildings changing their use

[44] http://ccap.org/assets/CCAP-Booklet_Spain.pdf

(e.g. a villa turned into a hotel), both private and public, to supply at least 60 percent of DHW with solar energy. Depending on the local climate this can also be considered in other regions.

- Banning the installation of fossil fuel heating in some types of buildings and district is a possible radical implementing measure. For example, the Netherlands wants reduce gas as heating source and therefore does not allows to install gas boilers in some types of buildings and districts[45]. This is a radical measure which could be considered for new or deeply renovated buildings. It could also be considered in selected districts, for example when a district heating network with renewable energy is available. In principle it could also be required for large SFH when it can be assumed that there is sufficient space available to install a heat pump. The effective enforcement can easily be done by cutting off the gas supply.

[45] https://www.rijksoverheid.nl/onderwerpen/duurzame-energie/vraag-en-antwoord/hoe-lang-kan-ik-nog-koken-op-gas

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct information centres. You can find the address of the centre nearest you at: https://europa.eu/european-union/contact_en

On the phone or by email

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

– by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),

– at the following standard number: +32 22999696, or

– by email via: https://europa.eu/european-union/contact_en

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website at: https://europa.eu/european-union/index_en

EU publications

You can download or order free and priced EU publications from: https://op.europa.eu/en/publications. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see https://europa.eu/european-union/contact_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1952 in all the official language versions, go to EUR-Lex at: http://eur-lex.europa.eu

Open data from the EU

The EU Open Data Portal (http://data.europa.eu/euodp/en) provides access to datasets from the EU. Data can be downloaded and reused for free, for both commercial and non-commercial purposes

Publications Office
of the European Union