Report Tasks 1-3

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

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EXECUTIVE SUMMARY

This interim report presents the mid-way findings of the project on *Technical assistance for ensuring optimal performance of technical building systems under the Energy Performance of Buildings Directive*.

In line with the provisions specified in the EPBD technical building systems comprise space heating systems, domestic hot water (DHW) systems, space cooling systems, ventilation systems, building automation and control systems (BACS), lighting systems and renewable energy systems (RES). These report addresses each of these.

The methodological approach followed in the conduct of the assignment is set out below for each of the tasks in turn. Figure ES-1 provides a schematic summary of the six principal tasks and the relationships between them. Tasks 1 and 2 review technical building system (TBS) requirements (including their enforcement) and identify potential requirements. This provides inputs for the identification of approaches to enforce potential requirements and conduct assessment and documentation of system performance in Task 3, followed by the derivation of guidelines with regard to the establishment and enforcement of TBS energy performance requirements in Task 4 (to be done for the final report). Task 5 entails the derivation of technical guidelines for the effective understanding of BACS capabilities under the EPBD (of which only the first part is conducted in this interim report). Finally, Task 6 entails the derivation and application of a dissemination road map to communicate the findings from the other tasks to Member States and relevant actors as well as stakeholder consultation (this activity is not reported in this report).

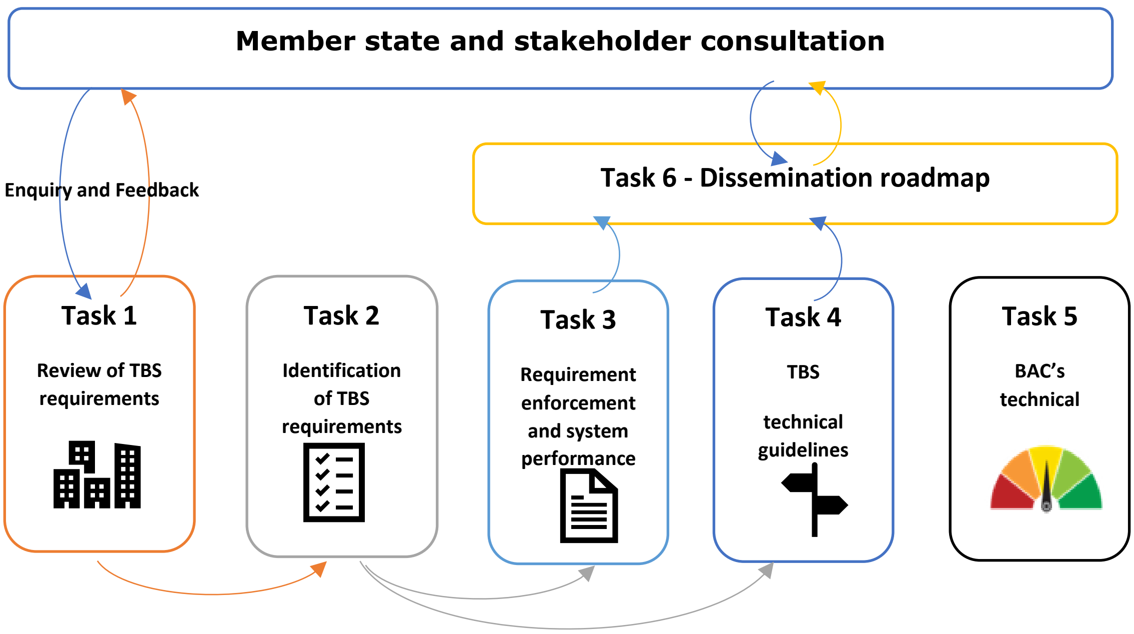

Figure ES-1: Schematic summary of the six tasks and the relationship between them.

As indicated in Figure ES-1, the first task forms the basis for the other tasks as they are built upon its results. Readers of this interim report should be aware that the review findings presented here are incomplete due to the ongoing conduct of an enquiry of Member State activities with regards to technical building systems that will inform these findings. Thus, the results presented in this interim report are necessarily incomplete and provisional.

With these caveats in mind the following tentative findings can be reported:

- while all Member States have transposed Ecodesign and Energy labelling requirements applicable to elements within technical building systems only some Member States have gone beyond these and adopted overall technical building system (TBS) energy performance requirements
- when such requirements have been adopted they apply to new installations of TBSs in either new or existing buildings or both
- such requirements appear to be most common for HVAC TBS, especially heating and ventilation systems
- they appear to be least common for RES, BAC and lighting systems
- some Member States have adopted energy performance requirements for parts of a TBS, e.g. insulation of pipework, but have not necessarily set overall system performance requirements
- for TBS installed in new buildings or major renovations by far the most common approach is to require their overall performance to be assessed as part of the whole building energy performance using the same software tools used to determine EPC ratings; however, it is rarer to complement this with specific overall TBS energy performance requirements
- many Member States have been, or still are, in the process of transposing the latest 2018 EPBD requirements into national regulations and thus the actual situation could alter as this transposition process is complete and the findings are reported to the study team.

Nonetheless, several good practices have been identified and these are reported in Task 1.

The analysis presented in sections 1.6 and 2.2 illustrates that there are very significant remaining energy savings potentials from more efficient overall TBS energy performance solutions. For each TBS a long list of energy saving measures are identified and then assessed using a multi-criteria framework that applies quantitative estimates of energy savings (both in terms of percentage energy savings per measure adopted, the capacity weighted share of TBS systems the measure is applicable to, and the estimated potential saving for the EU TBS stock as a whole were it to be adopted by all TBS it is applicable to) and a set of ranked qualitative assessment scores for (i) cost effectiveness, (ii) level of implementation effort required for existing buildings other than major renovation, (iii) enforceability, and (iv) benefit of intelligent metering/monitoring in cases where this could be relevant). These findings are reported in full in an evaluation spreadsheet as a compendium to this report. The TBS energy savings options and then ranked in order of their overall ranking, which is intended to capture the magnitude of savings they could achieve and the viability/attractiveness of setting requirements to stimulate these savings.

After this screening process to identify the most compelling energy saving measures, a set of policy recommendations are proposed in section 2.2, setting out options for regulatory requirements that Member States would adopt to capture these savings. These mostly fall into the following broad types:

- requirements addressing the overall energy performance on new TBS installations in both existing and new/renovated buildings
- requirements addressing the control and controllability of TBS in both existing and new installations
- requirements addressing the metering and performance monitoring of existing TBS.

In addition requirements are also proposed with regard to the dimensioning of some TBS.

In each case the scope of applicability of the requirements is set out with regard to:

- the type and sub-types of TBS the requirements could apply to
- the type of installation trigger points (in terms of building stage and related TBS installation stages) the requirements could apply to.

The Task 3 work set out in section 4 presents analysis on pathways by which these requirements could be enforced and on the associated conformity assessment and technical documentation.

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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
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

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 directive was amended with the aim:

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

and 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' (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) of the EPBD 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) of the EPBD requires 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 of the EPBD 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 with regard to energy efficiency measures 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 being more standardised and is in need of further clarification by means of technical guidelines to help Member States put these provisions into practice and to increase the impact of these measures in the EU building stock.

Aims and objectives of the project

The objectives of this project are to develop and disseminate technical guidelines for the further establishment and enforcement of technical building system requirements and to support the effective assessment and documentation of overall system performance.

In order to achieve these objectives and to establish a reference, the current regulations on technical building system requirements applied in the different EU Member States and their enforcement is investigated. All technical building systems and aspects referred to in Article 8(1) of the EPBD are covered.

Project activities and report structure

Satisfaction of these objectives is achieved by the conduct of the six 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

Task 6: Dissemination, including stakeholder consultation.

This 2nd Interim report is structured in the same manner, i.e. in Task sequence, noting that Task 4 and Task 5b will only be completed for the draft final report and are therefore empty. Equally, Task 6 follows a separate reporting process so is not included in this 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.

TASK 1. REVIEW OF TECHNICAL BUILDING SYSTEM REQUIREMENTS (DEFINITION AND ENFORCEMENT) AND OTHER RELEVANT MEASURES AND INITIATIVES, AND IDENTIFICATION OF GOOD PRACTICES

1.1 Objectives

The objective of Task 1 is to review and screen technical building systems requirements applied within the EU and also related initiatives and measures that are pertinent to these (e.g. Ecodesign regulations that apply to specific components within technical building systems, inspection and maintenance schemes, etc.). As such, this task aims at reviewing a broad scope of information, while taking into account:

- completeness of the targeted sources of information
- complementarity of the references, including policy initiatives such as Energy Performance certificates (EPC), building renovation passports; but potentially also other market initiatives such as voluntary labelling schemes for buildings or specific product segments
- usability of the identified requirements
- their degree of connection with system performance.

1.2 Task approach and proposed methodology

The methodological activities undertaken under Task 1 are:

- Activity 1. A review of technical building system requirements
- Activity 2. A review of other initiatives and measures relevant for the establishment and enforcement of technical building system requirements
- Activity 3. The identification of good practices
- Activity 4. The estimation on potential impacts.

The findings of these activities are presented in sequence in the subsequent sections.

1.3 Activity 1: Review of technical building system requirements defined in the context of the EPBD

This targeted state-of-the-art review involves the conduct of a thorough review covering all aspects that relate to technical building system energy performance requirements. Specifically, it involves reviewing Member State (and/or regional) building code specifications on technical building system energy performance requirements and the approaches followed to enforce them.

The review covers all the technical building systems defined in the EPBD (Article 2(3)) and all areas of requirements referred to in Article 8(1) of the EPBD[3] and addresses both the requirements themselves and the approaches followed to enforce them.

[3] Article 8(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 methodology utilised to conduct the review combines desk research with direct survey of Member State officials responsible for the adoption and implementation of EPBD requirements within their jurisdictions. With approval from the Commission Services a detailed enquiry was developed regarding the provisions Member States have put into place or are considering with regard to Articles 8, 14 and 15 of the EPBD. This enquiry was distributed to Member States at the end of February 2021 but its results will not arrive and be processed until after this interim report has been drafted. Therefore the findings presented below rely entirely on desk research and will need to be updated to incorporate the enquiry findings in subsequent versions of the report.

Two primary sources of information are used for the current desk research:

- The reports, and especially the country reports, included within the Concerted Action EPBD[4]
- in some cases, additional information was accessed for specific Member States (e.g. Belgium, France, Germany, Netherlands) by consulting information available on government websites.

As the overall project results will depend to a considerable extent on the quality and completeness of the review work it is hoped all Member States will be able to complete the surveys and share their responses with the study team.

The findings are presented by TBS in order of space heating and DHW, space cooling, ventilation, BACS, lighting and RES. For each of the HVAC TBS, the current EPBD provisions are first relayed and then a table of normative requirements adopted by Member States is presented. A more bespoke approach is applied for the other TBS.

1.3.1 Space heating and DHW

EPBD requirements

The EPBD requirements identified in the review that are applicable to space heating and domestic hot water (DHW) systems in existing buildings are presented in Table 1.

Normative requirements

The Member State normative requirements identified in the review that are applicable to space heating and domestic hot water (DHW) systems in existing buildings are presented in Table 2.

1.3.2 Space cooling

EPBD requirements

The EPBD requirements that are applicable to space cooling systems in existing buildings are presented in Table 3.

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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."

[4] https://epbd-ca.eu/

Table 1: EPBD requirements for space heating and DHW.

Art. no.	Scope of application	Requirements	Sub-requirements	Req. no.	Notes
8	• TBSs installed in **existing buildings** – no differentiation between type of use of building or size of installation • Optional: application in **new buildings**	System requirements in respect of:	Overall energy performance	1	(Minimum) requirements to ultimately improve system energy performance are referenced and need to cover all following 5 aspects:
			Proper installation	2	Performance of system as a whole (not to be confused with performance at product or component level and performance of whole building)
			Appropriate dimensioning	3	How system should be installed for proper operation, e.g. installation by trained and/or certified installer
			Appropriate adjustment	4	Appropriateness of system size (here: heating & DHW) or capacity given needs and characteristics of building under expected usage conditions, e.g. in line with EU standards
			Appropriate control	5	Testing and fine-tuning actions on system, once installed, under real usage conditions, e.g. sequence of tests performed after installation to check system operates in accordance with specifications, inc. part-load conditions
			Documentation and regulation	6	Desired or required control capabilities of systems. NB: new requirements are introduced on installation of self-regulating devices and BACS in buildings
	• **New building**, where technically and economically feasible • **In existing buildings, when heat generators are replaced**, where technically and economically feasible	Installation of self-regulating devices for separate regulation of temperature in each room or, where justified, in a designated heated zone of the building unit	–	7	

	• When a TBS is installed, replaced or upgraded	Assessment of overall energy performance of altered part and, where relevant, of complete altered system	Results to be documented and passed on to building owner	8	
14	• **Existing buildings,** heating/cooling systems or systems with combined space heating/cooling and ventilation with effective rated output >**70 kW** **• Exempt: TBSs covered explicitly by an agreed energy performance criterion or a contractual arrangement specifying an agreed level of energy efficiency improvement (e.g. energy performance contracting), or operated by a utility or network operator and thus subject to performance monitoring measures on system side provided that overall impact of such an approach is equivalent to that resulting from paragraph 1.EN 19.6.2018 Official Journal of the European Union L 156/85**	Establish regular inspections of accessible parts of heating/cooling systems or for systems with combined space heating/cooling and ventilation	Heat generator, control system and circulation pump(s) used for heating buildings	9	
			Assessment of efficiency and sizing of heat generator c.f. heating requirements of building. (Not needed if no changes to heating/ heating & ventilation system following earlier inspection)	10	
			Consider capabilities of heating system or of system for combined space heating and ventilation to optimise its performance under typical or average operating conditions	11	
	• **Non-residential buildings** with an effective rated output for heating/cooling systems or systems for combined space heating/space cooling and ventilation of **>290 kW**	Building equipment with BACS that are capable of	Continuously monitoring, logging, analysing and allowing for adjusting energy use	12	
			Benchmarking building energy efficiency	13	
			Detecting losses in efficiency of TBSs	14	
			Informing person responsible for facilities or technical building management about opportunities for energy efficiency improvement	15	
			Allowing communication with connected TBSs and other appliances inside building	16	
			Communicating with TBSs across different types of proprietary technologies, devices and manufacturers	17	
	• Optional: residential buildings	Residential buildings are equipped with:	Functionality of continuous electronic monitoring that measures system efficiency and informs building owners or managers when it has fallen significantly and when system servicing is necessary; and	18	

			Effective control functionalities to ensure optimum generation, distribution, storage and use of energy	19	

Abbreviations: BACS = building automation control system; c.f. = compare with; DHW = domestic hot water; inc. = including; Req. = requirement; TBS = technical building system.

Table 2: Space heating system and DHW energy performance requirements specified by Member States.

Addressing Article 8 and 14 requirements	Requirement specification	Application scope	Trigger point	Country	Source
Overall energy performance	Gross seasonal efficiency: 91%	Natural gas, single boiler system ≤2 MW output (new buildings)	**New buildings**	UK Scotland	https://epbd-ca.eu/wp-content/uploads/2019/05/CA-EPBD-IV-UK-Scotland-2018.pdf
Overall energy performance	Heating Heat generator COP 2.5 at rating conditions in EN 14511	Heat pump – electrically driven (not air to air): space heating	**New and existing buildings**	UK Scotland	https://epbd-ca.eu/wp-content/uploads/2019/05/CA-EPBD-IV-UK-Scotland-2018.pdf
Overall energy performance	r Seasonal Efficiency of Domestic Boilers in the UK (SEDBUK 2009): 88%	Gas-fired wet central heating: condensing boiler	**New and existing buildings**	**UK England**	https://epbd-ca.eu/wp-content/uploads/2019/05/CA-EPBD-IV-UK-England-2018.pdf
Overall energy performance	Seasonal efficiency (SEDBUK 2009): 88%	Oil-fired wet central heating: condensing regular boiler	**New and existing buildings**	**UK England**	https://epbd-ca.eu/wp-content/uploads/2019/05/CA-EPBD-IV-UK-England-2018.pdf
Overall energy performance	Minimum thickness of thermal insulation for different pipes diameters (Lambda = 0.35 W/m.K)	Requirements on thermal insulation of pipes and components in heating, hot water and cooling systems	**Existing buildings**	**Poland**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Poland-2018.pdf
Overall energy performance	Ratio between efficiencies of building's main heating system and main heat distribution system must be ≥0.8. Ratio is quotient of annual efficiencies of heating system and heat distribution system	When related equipment and systems are renewed	When technical systems of any type of existing buildings are renovated, modernize or replaced	**Finland**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Finland-2018.pdf
Monitoring	Has been mandatory to install individual meters for cold and warm water. Not mandatory to use readings as a basis for billing	When installing system in new buildings	Buildings	**Finland**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Finland-2018.pdf
Inspection requirements	Annual maintenance visits for boilers of 4–400 kW, inspection every 2 years for boilers >400 kW and inspections every 5 years for AC	Boilers starting at 4 kW and AC systems with reversible heat pump >12 kW	Periodic inspections	**France**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-France-2018.pdf
Overall energy performance	Minimum energy performance requirements	Heating production installations	New or existing buildings when a TBS is renovated or for major renovations	**Portugal**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Portugal-2018.pdf

Energy consumption monitoring	Energy consumption monitoring of HVAC systems equipment	Electric power >25 kW. Boilers with thermal power >100 kW	Non-residential buildings	**Portugal**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Portugal-2018.pdf
Proper installation	Have an installation and maintenance technician (TIM) that guarantees proper system installation and maintenance	Buildings with thermal power >25 kW must	Existing buildings	**Portugal**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Portugal-2018.pdf
Appropriate control	Controls that adjust temperature of heating medium based on time and outside temperature, and which shut down circulating pumps accordingly	Water-based central heating systems	Existing buildings, no specific trigger	**Germany**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Germany-2018.pdf
Appropriate control	Room-temperature controls; exemptions for small rooms with floor heating, old floor heating and non-residential buildings, where rooms of similar type and use may share controls	Water-based central heating systems	Existing buildings, no specific trigger	**Germany**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Germany-2018.pdf
Appropriate control	Automatic control	Circulation pumps in water-based heating systems with >25 kW heat output m	Existing buildings, in case of relevant change in system	**Germany**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Germany-2018.pdf
Appropriate control	Automatic control	Circulation pumps in DHW systems must have time control	Existing buildings, in case of relevant change in system	**Germany**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Germany-2018.pdf
Overall energy performance	Minimum TBS efficiency	Heat generation	New or major renovation buildings (requirements vary slightly depending on degree of renovation)	**Italy**	https://epbd-ca.eu/wp-content/uploads/2019/06/CA-EPBD-IV-Italy-2018.pdf
Inspection requirements	Designers of new heating systems and energy distributors obliged to provide documentation of both new heating systems and grid-connected clients to region; this facilitates control of compulsory maintenance of systems by the users. Regions also responsible for selection and qualification of inspectors and for organisation of annual campaigns for compliance control of inspection reports	Heating systems	Not clear how often	**Italy**	https://epbd-ca.eu/wp-content/uploads/2019/06/CA-EPBD-IV-Italy-2018.pdf
Overall energy performance	A number of requirements for TBSs (see Table 5 in the link provided)	Heating systems	New, replaced or upgraded systems in existing building	**Belgium – Flemish region**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Belgium-Flemish-Region-2018.pdf
Inspection requirements	Requirements for periodic inspections of different types of boilers. Check Table 7 in the link provided	Heating systems	Periodic	**Belgium – Flemish region**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Belgium-Flemish-Region-2018.pdf

Overall energy performance	Insulation requirements	Insulation of hot water pipes	Existing buildings	**Belgium – Walloon region**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Belgium-Walloon-Region-2018.pdf
Overall energy performance	Installation of solar water heaters for DHW in new residential buildings	DHW system	New buildings	**Cyprus**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Cyprus-2018.pdf
Overall energy performance	Maximum heat losses requirements from DHW storage vessels	DHW systems	New buildings	**Malta**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Malta-2018.pdf
Overall energy performance	Minimum insulation of pipes and components for DHW systems	Insulation of DHW pipes	New buildings	**Poland**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Poland-2018.pdf
Overall energy performance	Owner of a building with central DHW generation obliged to ensure and maintain hydronic balancing of DHW distribution system in building	Central DHW systems	Existing large buildings	**Slovak Republic**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Slovak-Republic-2018.pdf
Overall energy performance	Minimum thickness of thermal insulation of hot water distribution pipes	DHW systems	Existing buildings	**Slovak Republic**	https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Slovak-Republic-2018.pdf

Abbreviations: AC = air-conditioning; BACS = building automation control system; COP = co-efficient of performance; DHW = domestic hot water; HVAC = heating, ventilation and air-conditioning; TBS = technical building system.

1.3.3 Space cooling

EPBD requirements

The EPBD requirements that are applicable to space cooling systems in existing buildings are presented in Table 3.

Table 3: EPBD requirements for space cooling systems.

Art. no.	Scope of application	Requirements	Sub-requirements	Req. no.	Notes
8.1	• TBSs in **existing buildings** - no differentiation between type of use of building or size of installation • Optional: application in **new buildings**	System requirements in respect of:			(Minimum) requirements to ultimately improve system energy performance are referenced, and need to cover all following 5 sub-requirements
			Overall energy performance	1	System performance as a whole (not to be confused with performance at product or component level and performance of whole building)
			Proper installation	2	How system should be installed in building in order to operate properly, e.g. installation by trained and/or certified installer
			Appropriate dimensioning	3	Appropriateness of system size or capacity given needs and characteristics of building under expected usage conditions, e.g. in line with EU standards
			Appropriate adjustment	4	Testing and fine-tuning actions on system once installed, under real usage conditions, e.g. sequence of tests to be performed after installation to check that system operates in accordance with its specifications, inc. part-load conditions

			Appropriate control	5	Desired or required control capabilities of systems. NB: new requirements are introduced on installation of self-regulating devices and BACs in buildings
8.9	When a TBS is installed, replaced or upgraded	Assessment of overall energy performance of altered part, and where relevant, of complete altered system	Results shall be documented and passed on to building owner	6	
15	• **Existing buildings,** cooling systems or for systems with combined space heating/cooling and ventilation with an effective rated output **>70 kW** **• Exempt: TBSs which are explicitly covered by an agreed energy performance criterion or a contractual arrangement specifying an agreed level of energy efficiency improvement, such as energy performance contracting, or that are operated by a utility or network operator and therefore subject to performance monitoring measures on system side provided that the overall impact of such an approach is equivalent to that resulting from paragraph 1. EN 19.6.2018 Official Journal of the European Union L 156/85**	Establish regular inspections of accessible parts of cooling systems or for systems with combined space heating/cooling and ventilation	Cold generator, control system and circulation pump(s) used for heating buildings	9	
			Assessment of efficiency and sizing of cold generator compared with cooling requirements of building. (Not needed if no changes made to the cooling/ cooling+ventilation system following an earlier inspection)	10	
			Consider capabilities of cooling system or of system for combined space cooling and ventilation to optimise its performance under typical or average operating conditions	11	
	• **Non- residential buildings** with an effective rated output for cooling systems or systems for combined space heating/space cooling and ventilation >**290 kW**	Equipment of building with building automation and control systems that are capable of:	Continuously monitoring, logging, analysing and allowing for adjusting energy use	12	
			Benchmarking building energy efficiency	13	
			Detecting losses in efficiency of TBSs	14	
			Informing person responsible for facilities or technical building management about opportunities for energy efficiency improvement	15	
			Allowing communication with connected TBSs and other appliances inside building	16	
			Communicating with TBSs across different types of proprietary technologies, devices and manufacturers	17	

	• Optional: residential buildings	Residential buildings are equipped with:	Functionality of continuous electronic monitoring that measures system efficiency and informs building owners or managers when it has fallen significantly and when system servicing is necessary; and	18	
			Effective control functionalities to ensure optimum generation, distribution, storage and use of energy.	19	

Abbreviations: BACS = building automation control system; Req. = requirement; TBS = technical building system.

Normative requirements

The Member State normative requirements identified in the review that are applicable to space cooling systems in existing buildings are presented in Table 4.

1.3.4 Ventilation

EPBD requirements

The EPBD requirements applicable to ventilation systems in existing buildings are presented in Table 5.

Normative requirements

The Member State normative requirements identified in the review that are applicable to ventilation systems are presented in Table 6. The requirements are grouped according to the different Article 8 requirements.

Table 4: Cooling system energy performance requirements specified by Member State.

<table>
<tr><th>Article 8 requirement</th><th>Requirement specification</th><th>Addressed for</th><th>Trigger point</th><th>Country</th><th>Source</th></tr>
<tr><td>Overall energy performance – Ecodesign 206/2012</td><td>
<table>
<tr><th></th><th>SEER</th><th>COP</th></tr>
<tr><td>If GWP of refrig</td><td>4.6</td><td>3.8</td></tr>
<tr><td>If GWP of refrig</td><td>4.14</td><td>3.42</td></tr>
<tr><td>If GWP of refrig</td><td>4.3</td><td>3.8</td></tr>
<tr><td>If GWP of refrig</td><td>3.87</td><td>3.42</td></tr>
</table>
<table>
<tr><th></th><th>SEER</th><th>COP</th></tr>
<tr><td>If GWP of refrigerator</td><td>4.6</td><td>3.8</td></tr>
<tr><td>If GWP of refrigerator</td><td>4.14</td><td>3.42</td></tr>
<tr><td>If GWP of refrigerator</td><td>4.3</td><td>3.8</td></tr>
<tr><td>If GWP of refrigerator</td><td>3.87</td><td>3.42</td></tr>
</table>
</td><td>AC ≤12 kW</td><td>New or replacement AC units</td><td>All (since 2014)</td><td>Ecodesign 206/2012 and CA reports</td></tr>
<tr><td>Overall energy performance – Ecodesign 2016/2281</td><td>
<table>
<tr><th colspan="2">minimum seasonal space cooling energy efficiency of cooling products, expressed in % [ηs,c]</th></tr>
<tr><td>Air-to-water ch</td><td>161</td></tr>
<tr><td>Air-to-water ch</td><td>179</td></tr>
<tr><td>Water/brine to</td><td>200</td></tr>
<tr><td>Water/brine to</td><td>252</td></tr>
<tr><td>Water/brine to</td><td>272</td></tr>
<tr><td>Air-to-water ch</td><td>154</td></tr>
<tr><td>Air-to-air air co</td><td>189</td></tr>
<tr><td>Rooftop air cor</td><td>138</td></tr>
<tr><td>Air-to-air air co</td><td>167</td></tr>
</table>
</td><td>Chillers, rooftops, Air-to-air ACs driven by an electric motor, except rooftop ACs, air-to-air ACs driven by an internal combustion engine</td><td>New or replacement units</td><td>All (from 1/1/2021)</td><td>Ecodesign 2016/2281 and CA country reports</td></tr>
<tr><td>Overall energy performance – space cooling demand</td><td>2 kWh/m²/year (from 1/1/2017). National plan (March 2014) also defines minimum requirements for residential and non-residential buildings undergoing major renovations valid from 1 Jan 2021, but limits are not in CA document</td><td>All cooling systems</td><td>Not mentioned in document</td><td>Austria</td><td>CA country report</td></tr>
</table>

Not mentioned in document	Energy Efficiency Act states that the following energy efficiency improvement measures shall be assessed as regards their technical and economic appropriateness: district or block heating and cooling, including those that are based entirely or partially on energy from RES, heat pumps. Energy performance must conform to minimum regulatory requirements defined in Ordinance No. 7 of 2004 on energy efficiency in buildings, as amended in 2015, after deep or major renovations that lead to a change in energy performance of building	*Not mentioned in document*	These assessments are applicable for improvement measures that are recommended upon each change of use, deep renovation or major renovation of a building (or part of a building) in use	Bulgaria	CA country report
Not mentioned in document	For TBSs, new comprehensive requirements issued in 2016 cover almost all conventional TBSs installed in buildings. Requirements described in two documents, one for residential and another for non-residential buildings, and cover not just whole system, but also individual parts. Requirements are also supplemented by recommendations of best practices	*Not mentioned in document*		Cyprus	CA country report
Appropriate dimensioning, control, and metering – design, sizing, control and metering requirements	Heating and cooling systems must be sized, designed, controlled and operated as specified in Danish Standard DS 469 "Varme – og køleanlæg I bygninger" ("Heating and cooling systems in buildings"), which has different functional requirements for commissioning of heating and cooling systems as well as additional requirements for use, operation and maintenance. All TBSs must be insulated as required by DS 452 "Termisk isolering af tekniske installationer" ("Thermal insulation of technical installations"). Heat pumps/ cooling plants must have individual energy meters if annual consumption >3000 kWh	*Not mentioned in document*	*Installation or replacement*	Denmark	CA country report
AC efficiency	SEER >5.1 W/W	*AC or air-to-air heat pump for cooling up to 12 kW*	*Installation or replacement*	Estonia	CA country report
Metering requirements	Mandatory installation of individual meters for cold and warm water. Not mandatory to use readings as basis for billing	*Not mentioned in document*	*Renovated buildings*	Finland	CA country report
AC efficiency	Regulation by Building Component sets minimum efficiency: for AC units <12 kW; energy efficiency rating should be ≥3.0. For other AC systems efficiency should be 2.6–3.0 W/W	*Not mentioned in document*	*Not mentioned in document*	France	CA country report
Appropriate control	AC systems >12 kW output and due to influence humidity must have controls with separate set-points for humidification and dehumidification	AC systems >12 kW output	*All*	Germany	CA country report

System performance - Heat recovery	SFP value may not exceed class SFP 4 (EN 13779: 2007); air-flow must be controlled automatically according to thermal and sensible load if hourly flow >9 m^3/m^2; exemptions exist; systems must be equipped with heat recovery units of class H3 (EN 13053: 2007) or better	AC systems >12 kW output and ventilation systems >4000 m^3/h supply air	First-time installation and major changes *"The following requirements must be met in case of relevant changes to the system"*	Germany	CA country report
Appropriate control	Regulations include requirements on TBS elements (e.g. balancing, control, pumps, airtightness of ventilation ducts)	*Not mentioned in document*	*Not mentioned in document*	Hungary	CA country report
Appropriate design, sizing, controls, maintenance and efficiency	General wording on "L4 For existing buildings other than dwellings, the requirements of L1 shall be met by:— (b) providing energy efficient space heating and cooling systems, heating and cooling equipment, …, with effective controls; (c) ensuring that the building is appropriately designed to limit need for cooling and, where air-conditioning or mechanical ventilation is installed, that installed systems are energy efficient, appropriately sized and adequately controlled; (e) limiting the heat gains by chilled water and refrigerant vessels, and by pipes and ducts that serve air-conditioning systems; (g) providing to the building owner sufficient information about the fixed building services, controls and their maintenance requirements when replaced so that the building can be operated in such a manner as to use no more fuel and energy than is reasonable"	*Not mentioned in document (but non-residential applications)*	*Not mentioned in document*	Ireland	CA country report
Appropriate control and documentation	Presidential Decree 74/2013 on heating/cooling systems lays down obligations and criteria applicable to public and private buildings, applying to most building uses and inc. ambient temperature limits for cooling (weighted average air temperature measured in each cooled space must not be <26°C – 2°C tolerance in all buildings). Ministry of Economic Development (MISE) set up template for heating or cooling system log book and another for energy efficiency report, and asked Italian Thermotechnical Committee (CTI) to publicise examples for the most common types of systems to facilitate and standardise completion of log books and energy efficiency reports		*Not mentioned in document*	Italy	CA country report
Overall performance – system efficiency	Chiller with electrically driven compressor = 2.5 W/W. Indirect power absorption chiller – 0.60 x ηgn (**) where (**) The efficiency of the system installed in real building is assumed. Direct-fired absorption chillers = 0.6. AC systems H=0.83, C = 0.83 where thermal energy use (***) ηu. (***) Including emission, control and distribution	*Chillers*	*Not mentioned in document*	Italy	CA country report
Overall performance – efficiency	Eurovent Label B (e.g. chiller COP ≥3.0; EER ≥2.9)	*Chillers and other AC equipment*	*Existing buildings*	Portugal	CA country report

Metering	Mandatory metering	*AC >25kW*	*All*	Portugal	CA country report
Overall performance – efficiency	EER ≥3.0	*Chillers*	*Existing buildings*	England, Northern Ireland, Wales	CA country report
Overall performance – efficiency	EER ≥ 2.5	*Comfort cooling: water-cooled ACs working in cooling mode*	*Existing buildings*	Scotland	CA country report
Overall performance – efficiency	EER ≥ 4.7	*Comfort cooling, vapour compression cycle chillers, water cooled >750 kW*	*Existing buildings*	Scotland	CA country report

Abbreviations: AC = air-conditioning/air-conditioners; CA = Concerted Action; COP = co-efficient of performance; EER = energy efficiency ratio; SFP = specific fan power; RES = renewable energy system; TBS = technical building system.

Table 5: EPBD requirements for ventilation.

Art. no.	Scope of application	Requirements	Sub-requirements	Req. no.	Notes
8.1	• TBSs installed in **existing buildings** – No differentiation between type of use of building or size of installation • Optional: application in **new buildings**	System requirements in respect of:			(Minimum) requirements to ultimately improve system energy performance are referenced and need to cover all 5 following aspects:
			Overall energy performance	1	System performance as a whole (not to be confused with performance at product or component level and performance of whole building)
			Proper installation	2	How system should be installed in building in order to operate properly, e.g. installation by trained and/or certified installer
			Appropriate dimensioning	3	Appropriateness of system size or capacity given needs and characteristics of building under expected usage conditions, e.g. in line with EU standards
			Appropriate adjustment	4	Testing and fine-tuning actions on system once installed, under real usage conditions, e.g. sequence of tests to be performed after installation to check that system operates in accordance with its specifications, inc. part-load conditions
			Appropriate control	5	Desired or required system control capabilities. NB: new requirements are introduced on installation of self-regulating devices and BACs in buildings
8.9	When a TBS is installed, replaced or upgraded	Assessment of overall energy performance of the altered part and, where relevant, complete altered system	Results shall be documented and passed on to building owner	6	
14/15	Combined heating/cooling and ventilation systems	See heating and space cooling section	See heating and space cooling section	See heating and space cooling section	See heating and space cooling section

Abbreviations: BACS = building automation control system; Req. = requirement; TBS = technical building system.

Table 6: Ventilation system energy performance requirements specified by Member State.*

Article 8 requirement	Requirement specification	Application scope	Trigger point	Country	Source
Overall energy performance	Max. P_{SFP}: # Type and application of fan — Specific Fan Power SFP [kW/(m³/s)] 1 Supply fan: a) air-conditioning system or supply and exhaust ventilation with heat recovery — 1.60 b) supply and exhaust ventilation without heat recovery and supply ventilation — 1.25 2 Exhaust fan: a) air-conditioning system or supply and exhaust ventilation with heat recovery — 1.00 b) supply and exhaust ventilation without heat recovery and supply ventilation — 1.00 c) exhaust system — 0.80	*Not mentioned in document*	New buildings and renovation of existing buildings	Poland	CA country report
Overall energy performance	Max. P_{SFP} – supply and exhaust system: 2.0 kW/(m³/s) – exhaust air system: 1.0 kW/(m³/s) – AC system: 2.5 kW/(m³/s)	Dependent on system type *→ Further specifications not mentioned*	Renovation, modernisation or replacement of ventilation systems	Finland	CA country report
Overall energy performance	Weighted average P_{SFP} for all fans at design conditions may not exceed class SFP 4 (DIN EN 16798-3: 2017-11) (P_{SFP} ≤2.0 kW/(m³/s))	>4000 m³/h and AC systems >12 kW	First-time installation or major changes	Germany	German Energy Saving Ordinance for Buildings (GEG[5])
Overall energy performance	Maximum P_{SFP}: 1.5 W/(l.s) Remark: most likely meant as maximum P_{SFP} per fan system (supply or exhaust)	Air-distribution systems, central balanced mechanical ventilation with heating only	New and existing buildings	UK Scotland	CA country report
Overall energy performance	Max. P_{SFP}: 1.5 W/(l.s) Reference is unclear	Mechanical ventilation: continuous supply and extract with heat recovery	New and existing buildings	UK England	CA country report

[5] https://www.bgbl.de/xaver/bgbl/start.xav?startbk=Bundesanzeiger_BGBl&start=//*[@attr_id=%27bgbl120s1728.pdf%27]#__bgbl__%2F%2F*%5B%40attr_id%3D%27bgbl120s1728.pdf%27%5D__1608102586031

<table>
<tr>
<td>Overall energy performance</td>
<td>Residential:
<table>
<tr><td>Eurovent Label D
Efficiency ≥ 57%
Velocity ≤ 2.2 m/s
Δp ≥ 170 Pa</td><td>EN 13053</td></tr>
</table>
Non-residential:
<table>
<tr><td>Minimum IE2 or IE3 class
Minimum SFP 4 or 5 (W/m3/s)</td><td>IEC60034-30
EN 13779</td></tr>
</table>
</td>
<td>Dependent on building type</td>
<td>New buildings and renovations of residential building</td>
<td>Portugal</td>
<td>CA country report</td>
</tr>
<tr>
<td>Overall energy performance</td>
<td>P_{SFP} of AHU may not exceed 2.5 kW/(m³/s)</td>
<td>Not mentioned in document</td>
<td>Not mentioned in document</td>
<td>Estonia</td>
<td>CA country report</td>
</tr>
<tr>
<td>Overall energy performance</td>
<td>Ventilation unit consumption:– ≤0.25 Wh/m³ for residential: ≤0.3 Wh/m³ for non-residential
for units with nominal power not covered by Ecodesign Directive 2009/125/EC</td>
<td>Dependent on building type</td>
<td>Not mentioned in document</td>
<td>France</td>
<td>French Energy Saving Ordinance for Existing Buildings [6]</td>
</tr>
<tr>
<td>Overall energy performance</td>
<td>Ecodesign Regulation 1253/2014: SEC ≤ – 20 kWh/(m² · a)
(Considers SPI, η, control and typology (ducted or not))</td>
<td>Residential ventilation systems (<1000 m³/h)</td>
<td>First-time installation or replacement</td>
<td>Various countries</td>
<td>CA country report</td>
</tr>
<tr>
<td>Overall energy performance</td>
<td>Labelling Regulation No. 1254/2014:
<table>
<tr><th>SEC class</th><th>SEC in kWh/a.m²</th></tr>
<tr><td>A+ (most efficient)</td><td>SEC < – 42</td></tr>
<tr><td>A</td><td>– 42 ≤ SEC < – 34</td></tr>
<tr><td>B</td><td>– 34 ≤ SEC < – 26</td></tr>
<tr><td>C</td><td>– 26 ≤ SEC < – 23</td></tr>
<tr><td>D</td><td>– 23 ≤ SEC < – 20</td></tr>
<tr><td>E</td><td>– 20 ≤ SEC < – 10</td></tr>
<tr><td>F</td><td>– 10 ≤ SEC < 0</td></tr>
<tr><td>G (least efficient)</td><td>0 ≤ SEC</td></tr>
</table>
</td>
<td>Residential ventilation systems (<1000 m³/h)</td>
<td>First-time installation or replacement</td>
<td></td>
<td>CA country report</td>
</tr>
<tr>
<td>Overall energy performance</td>
<td>Ecodesign Regulation 1253/2014: min. thermal efficiency η_{t_nrv}: 73%
Thermal by-pass facility
Min. fan efficiency for single duct system (ηvu): 6.2% * ln(P) + 42.0%, for P ≤30 kW / 63.1%, for P >30 kW

Other systems SFP_{int_limit}: 1 100 + E[7] – 300 * q_{nom}/2 – F[8], for q_{nom} <2 m³/s / 800 + E – F, for q_{nom} ≥ 2 m³/s</td>
<td>Non-residential ventilation systems >250 m³/h</td>
<td>First-time installation or replacement</td>
<td>Various countries</td>
<td>Ecodesign Regulation 1253/2014 to which various CA country reports refer</td>
</tr>
</table>

[6] https://www.legifrance.gouv.fr/loda/id/LEGIARTI000034310764/2018-01-01/

[7] E: Efficiency bonus for ventilation systems with a higher thermal efficiency: E = (η_{t_nrvu} – 0,68) * 3 000

[8] F: Filter correction: F = 150 if the medium filter is missing; F = 190 if the fine filter is missing; F = 340 if both the medium and the fine filters are missing.

	With exceptions for run-around HRS				
Overall energy performance	Dry heat recovery efficiency: 70%	Heat recovery: balanced mechanical ventilation systems	New and existing buildings	UK England	CA country report
Overall energy performance	Performance efficiency of heat recovery must be ≥70% run-around HRS least 50%	Not mentioned in document	Not mentioned in document	Estonia	CA country report
Overall energy performance	Heat recovery units of class H3 (EN 13053: 2007) or better η_e ≥55%	>4000 m^3/h and AC systems ≥12 kW	First-time installation or major changes	Germany	CA country report
Overall energy performance	Dry heat recovery efficiency: 50%	Air-distribution systems, plate heat exchanger	New and existing buildings	UK Scotland	CA country report
Overall energy performance	Min. annual efficiency of heat recovery must be ≥45%	*Not mentioned in document*	Renovation, modernisation or replacement of ventilation systems	Finland	CA country report
Overall energy performance	Min. efficiency of heat recovery → *Specifications not mentioned in document*	Ventilation systems with mechanical supply and extraction	New, replaced or upgraded systems in existing buildings	Belgium	CA country report
Overall energy performance	Ventilation heat recovery unit Insulation of air ducts → *Specifications not mentioned in document*	Existing residential and non-residential buildings	Installation, replacement or upgrading	Belgium	CA country report
Overall energy performance Proper installation Appropriate dimensioning	Ventilation systems must be designed, installed, fully commissioned and handed over as stated in national regulation DS 447 and insulated as required by DS 452 → *Specifications not mentioned in document*	*Not mentioned in document*	*Not mentioned in document*	Denmark	CA country report
Proper installation	When new building services are installed in buildings, owner must provide Building Regulation Office with certificate issued by warranted engineer, declaring compliance with applicable minimum energy performance requirements as set in Technical Document F (Part 2)	Not mentioned in document	Installation of new building services	Malta	CA country report
Proper installation	Commissioning of fixed TBSs required by Building Regulations. Typically, guides recommend following manufacturer instructions and include information such as qualifications/accreditation required for commissioning experts	Not mentioned in document	Domestic and Non-domestic Building Services	UK England	CA country report

Proper installation	Soft landings, voluntary approach to address performance gap between design intentions and operational outcomes	*Not mentioned in document*	Non-residential	UK England	CA country report
Appropriate dimensioning	Check dimensioning → *Specifications not mentioned in document*	*Not mentioned in document*	During periodic inspections	Luxemburg	CA country report
Appropriate control	Controls with separate set-points for humidification and dehumidification	AC systems with >12 kW with influence humidity	No trigger point	Germany	German Energy Saving Ordinance for Buildings
Appropriate control	Automatically controlled air-flow according to thermal and sensible load	>4000 m^3/h and >9 m^3/m^2a; and AC systems >12 kW; exemptions exist	First-time installation or major changes	Germany	German Energy Saving Ordinance for Buildings
Appropriate control	Independent systems ensure ventilation of premises that clearly relate to different occupations or uses	Non-residential buildings	First-time installation or replacement	France	French Energy Saving Ordinance for Existing Buildings
Appropriate control	Ventilation systems must have demand-based control system that is either occupancy-dependent or time-controlled	Non-residential buildings	New ventilation systems	France	French Energy Saving Ordinance for Existing Buildings
Appropriate control	Devices for manually changing air-flow rates of a room must be timed	Non-residential buildings	New ventilation systems	France	French Energy Saving Ordinance for Existing Buildings
Unspecific	National Building Technical Regulation STR 2.09.02:2005 → *Specifications not mentioned in document*	*Not mentioned in document*	When designing and building ventilation systems	Lithuania	CA country report
unspecific	National regulations: RGD 2007 and RGD 2010 → *Specifications not mentioned in document*	*Not mentioned in document*	*Not mentioned in document*	Luxemburg	CA country report
Unspecific	National regulations: Technical Document F, Part 2 → *Specifications not mentioned in document*	Fixed building systems that are being designed and/or installed in both new and existing buildings	*Not mentioned in document*	Malta	CA country report
Unspecific	National regulation: GEx 011 – 2015 (ventilation & AC installations) Calculation: SR 6648-1&2:2014 (ventilation & AC installations) → *Specifications not mentioned in document*	*Not mentioned in document*	New buildings	Romania	CA country report

Unspecific	National Law no. 372/2005 (2016 recast) National technical regulations (C 107-2005, Mc 001-2006, I5-2010, I7 -2011, I9-2015 and I13-2015) → *Specifications not mentioned in document*	*Not mentioned in document*	Major renovations	Romania	CA country report
Unspecific	National regulation: PURES 2010 regulations (rev. 2018) → *Specifications not mentioned in document*	*not mentioned in document*	New and existing buildings	Slovenia	CA country report

Key: * Red text denotes where unit requirements but not system requirements have been set; orange text denotes where requirements are not adequately specified.

Abbreviations: AC = air-conditioning; CA = Concerted Action; HRS = heat-recovery system; SFP = specific fan power; TBS = technical building system.

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1.3.5 BACS

EPBD requirements

Before 2018 BACS were not a specific service mentioned in the EPBD itself. The impact from BACS is linked directly to HVAC, lighting and RES. Therefore, the specific requirements within the EPBD are sometimes also those discussed in the other respective sections. This means that several functions of BACS are taken into account with the service (heating, cooling, ventilation, lighting).

According to EN ISO 16484-2, BACS refers to "building automation and control systems comprising all products and engineering services for automatic controls (including interlocks), monitoring, optimisation, for operation, human intervention and management to achieve energy–efficient, economical and safe operation of building services. Controls herein also refer to processing of data and information".

EN 15232 is the key EPBD standard that describes the BACS functions. EN 15232 also refers to separate standards that are used to derive the energy performance impact of each building system sub-element, e.g.:

- heating, EN 15316-1 and EN 15316-4
- domestic hot water, EN 15316-3
- cooling, EN 15243
- ventilation, EN 15241
- lighting, EN 15193
- technical building management, EN 16947.

These standards also often describe more detailed control functions. Note, that some gaps have been identified in the EN 15232 standard which are discussed in the dedicated Ecodesign Preparatory Study on BACS[9].

It is important to be aware that the treatment of BACS is a horizontal issue that overlaps will all other TBS services discussed in this document.

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

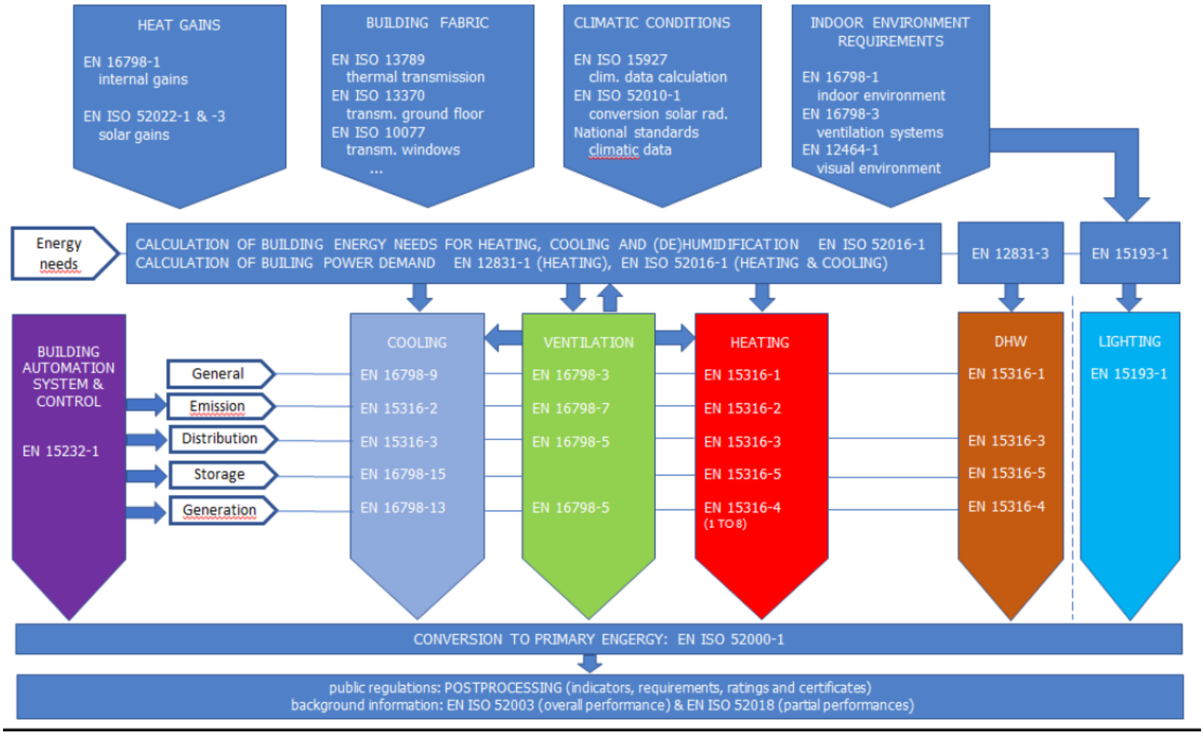

Figure 1: The relationship between BACS (EN 15232-1) and cooling, ventilation, heating, DHW and lighting (source: EPB Center).

An overview of the most relevant EN 15232 BACS functions is presented in Table 7. From this it is apparent that this standard interacts with all other TBS discussed in this document.

Table 7: BACS functions defined in EN 15232.

BACS function optimized Task 4/5/6	EN15232 function #
Heating and/or Cooling Control	**1 & 3**
Emission control	1.1 & 3.1
Control of distribution network hot or chilled water temperature (supply or return)	1.3 & 3.3
Control of distribution pumps in networks	1.4 & 3.4
Intermittent control of emission and/or distribution	1.5 & 3.5
Generator control	1.6 & 1.7
Sequencing of different generators	1.8 & 3.8
Interlock between heating and cooling control of emission and/or distribution	3.6
Domestic hot water supply control	**2**
Control of DHW storage charging using hot water generation	2.2
Control of DHW storage charging with solar collector and supplementary heat generation	2.3
Control of DHW circulation pump	2.4
Ventilation and air-conditioning control	4
Supply air flow control at the room level	4.1
Room air temp. control (all-air systems)	4.2
Room air temp. control (Combined air-water systems)	4.3
Air flow or pressure control at the air handler level	4.5
Free mechanical cooling	4.8
Supply air temperature control	4.9
Humidity control	4.1
Blind control	6
Blind control	6.1
Technical home and building management	7
Setpoint management	7.1
Runtime management	7.2
Detecting faults of technical building systems and providing support to the diagnosis of these faults	7.3
Reporting information regarding energy consumption, indoor conditions	7.4
Hydronic efficiency EN15316-2** automatic balancing of hydronic circuit to optimize heat distribution	
Lighting	
Occupancy control	
light level	

Abbreviations: BACS = building automation control systems.

Normative requirements

The term BACS has only been added to the latest edition of the EPBD. Prior to that BACS were sometimes classified as a kind of innovative building technology. Nonetheless, from a review of the CA EPBD database[10] the study team are aware of the following and noted that:

> For Finland, it was reported that regulations usually do not take into account energy efficiency improvements which are due to building automation. Current standard practice is to install class B level, but there is no specific requirement for a high-level building automation system. Automation features meeting, at the very least, class C level could be required in the future. 'Experiences reported in Finland were that it is time consuming to provide evidence showing that a particular system is more efficient than the default energy demand and that BACS will not remain well-tuned and energy-efficient unless they are properly commissioned and maintained.'
>
> Additional experiences from Germany show that user satisfaction is achieved when users can noticeably influence the system and when controls and displays are easy to understand. User dissatisfaction occurs when the information given to users is insufficient in quantity or clarity, when automation is not reliable (especially if there is no manual override), or when regular user intervention is required.
>
> Building automation systems are incorporated into the national EPBD calculation by use of a detailed method in Estonia (classes A, B and C), Italy and Norway (for lighting only). Rough estimates are used instead of a detailed calculation in Estonia (class D), Poland, Greece, Belgium, Croatia (using CEN standards), France, Italy and Germany (classes A and B in non-residential buildings). These systems are not included at all in the national methods of Slovakia, Germany (in the simpler calculation method that can be used for residential buildings), Portugal, Austria and The Netherlands (except for non-residential lighting). An external calculation tool is used in Sweden (for classes A to C).
>
> A newly adopted requirement in Italy[11] 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.
>
> In the Netherlands[12] non-residential buildings with NACE activity codes for healthcare, office, education, sport, recreation, hotels, restaurants and retail with a gas consumption above 50000 kWh are obligated to take energy saving measures. One such measure is that they need to install an Energy Management System (EMS)[13]. The required functionality of this EMS is partly related to EN 15232; in particular, the monitoring capability of the energy management system which is function 7.4 of EN 15232. For all existing buildings self-regulation temperature

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[10] https://epbd-ca.eu/wp-content/uploads/2018/04/04-CCT1_Factsheet-Innovative_technologies.pdf

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

[12] https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/energie-besparen/informatieplicht-energiebesparing/energiebesparingsplicht

[13] https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/wetten-en-regels/nieuwbouw/energieregistratie-en-bewakingssysteem-ebs

controllers[14] need to be installed per living area or zone when the gas heater or heat generator is replaced according to Art. 6.55a of the construction decree from 2012, taking effect since 10/3/2020.

In France, in October 2019 the Tertiary Decree (Décret tertiaire[15]); also called the Tertiary Renovation Decree, was approved. Under the terms of Article 175 all buildings that have 1000 m² or more of floor area that are used for tertiary purposes must declare their energy consumption on a yearly basis and ensure they reduce it. Companies should collect the energy data of their buildings and submit the yearly consumption data to the digital platform OPERAT, operated by ADEME. In practice, this new decree facilitates companies being able to review their entire energy management system.

In Ireland, under the latest update of 7 December 2020[16] of the Technical Guidance Document L - Conservation of Fuel and Energy – Dwellings, minimum or backstop regulatory requirements are set for the space heating and hot water supply system controls in existing buildings (section 1.4.3). Specifically, it is required that the mainstream control features that are provided with space heating and hot water products should be effectively installed. Hence it is a kind of backstop policy and installation requirement.

The study team are aware that this policy field is rapidly changing due to the ongoing implementation of EPBD Art. 8 requirements in Member States. Considering this, and in order to check for the latest state of play, a new enquiry has been launched. The key questions for EPBD implementation related to BACS from this enquiry are included in Table 8 and an overview of replies received to date per MS in Table 9.

Table 8: EPBD requirements for BACS.

General questions on the application of standard EN 15232 on the energy performance of Building Automation and Control Systems (BACS) in EPCs for existing buildings:	
Are building automation and controls systems incorporated into the national EPBD calculation methodology using a detailed method based on EN standards? (Yes/No) *Note: for further information see: https://epbd-ca.eu/wp-content/uploads/2018/04/04-CCT1_Factsheet-*	Yes
Are building automation and controls systems incorporated into the national EPBD calculation methodology? (Yes/No)	Yes
If Yes, is this done by use of rough estimates and/or simplifications compared to the detailed methodology in EN 15232?	Simplifications were made relative to the detailed methodology in EN 15232

Abbreviation: BACS = building automation control systems.

[14] Artikel 6:55a van het Bouwbesluit 2012: https://rijksoverheid.bouwbesluit.com/Inhoud/docs/wet/bb2012_nvt/artikelsgewijs/hfd6/afd6-13/art6-55a

[15] https://www.legifrance.gouv.fr/loda/id/JORFTEXT000038812251/

[16] gov.ie - Technical Guidance Document L - Conservation of Fuel and Energy – Dwellings (www.gov.ie)

Table 9: BACS energy performance requirements specified by Member State.

General questions on the application of standard EN 15232 on the energy performance of Building Automation and Control Systems (BACS) in EPCs for existing buildings:	AT	BE-BR	BE-FL	BE-WA	BG	CZ	CY	DE	DK	EE	EL	ES	FI	FR	HR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SK	SI
Are building automation and controls systems incorporated into the national EPBD calculation methodology using a detailed method based on EN standards? (Yes/No) *Note: for further information see: https://epbd-ca.eu/wp-content/uploads/2018/04/04-CCT1_Factsheet-*	?	Y	Y	Y	?		?	?	?	?	?	?	?	?	?	?		?	?		?	?	?	?	?		?	?	
Are building automation and controls systems incorporated into the national EPBD calculation methodology? (Yes/No)	?	Y	Y	Y	?		?	?	?	?	?	?	?	?	?	?		?	?		?	?	?	?	?		?	?	
If Yes, is this done by use of rough estimates and/or simplifications compared to the detailed methodology in EN 15232?																													

Abbreviation: BACS = building automation control systems.

Review of compliance/enforcement methods

To the study team's knowledge compliance and enforcement for BACS in Italy should be assessed based on a declaration of honour from an auditor and by providing the necessary documentation or checklist that functions are implemented according to EN 15232. The European industry association for BACS, eu.bac, has recently published a template[17] for this.

1.3.6 Lighting

EPBD requirements

The key energy efficiency standard addressing lighting in the EPBD is EN 15193 and the key metric for lighting system energy performance within this standard is the Lighting Numerical Indicator (LENI), which is included in the overarching energy balance (EN ISO 52000-1). The secondary metric sometimes used is the lighting power density (PDI) [W/l(x.m²)] which is a metric for installation efficacy.

For non-residential functional lighting the key standard is EN 12464 and the key metric to specify lighting requirements is average maintained illuminance of the area (Eavg) [lx], the standard also contains other lighting quality parameters.

To the study team's knowledge these standards are applied horizontally for non-residential lighting in Europe and therefore no further investigation has been done on this topic for the present study. In amenity lighting, and therefore also residential lighting, these standards are not applied for the reasons mentioned in the Ecodesign Study on lighting systems. At best there are some requirements for functional areas in residential buildings, such as corridors, staircases or public parking in multi-family houses in line with EN 15193.

For existing non-residential buildings incentives and relighting schemes are common practice and are often based on benchmarked lighting power density (PDI) [W/l(x.m²)] levels in combination with daylight and occupancy control installation requirements. Support for such relighting schemes via subsidies are often one of the set of measures that are stimulated through the Energy Efficiency Directive.

According to EN 15193, metered LENI data can be used for existing buildings; EN 15193 also enables this to be calculated with detailed lighting design parameters, (see Figure 2) as documented in the Ecodesign Lot 37 lighting system preparatory study[18]. More

[17] https://www.eubac.org/cms/upload/downloads/BACS_COMPLIANCE_VERIFICATION_CHECKLIST_Draft.pdf

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

information on these standards can be found in this study. It also provides a more in-depth overview of the various secondary parameters that contribute to achieving a lower LENI value as shown in Figure 2. In a full lighting design, which is commonly done for the design of the lighting installation of new and existing buildings, all these sub-parameters must be considered.

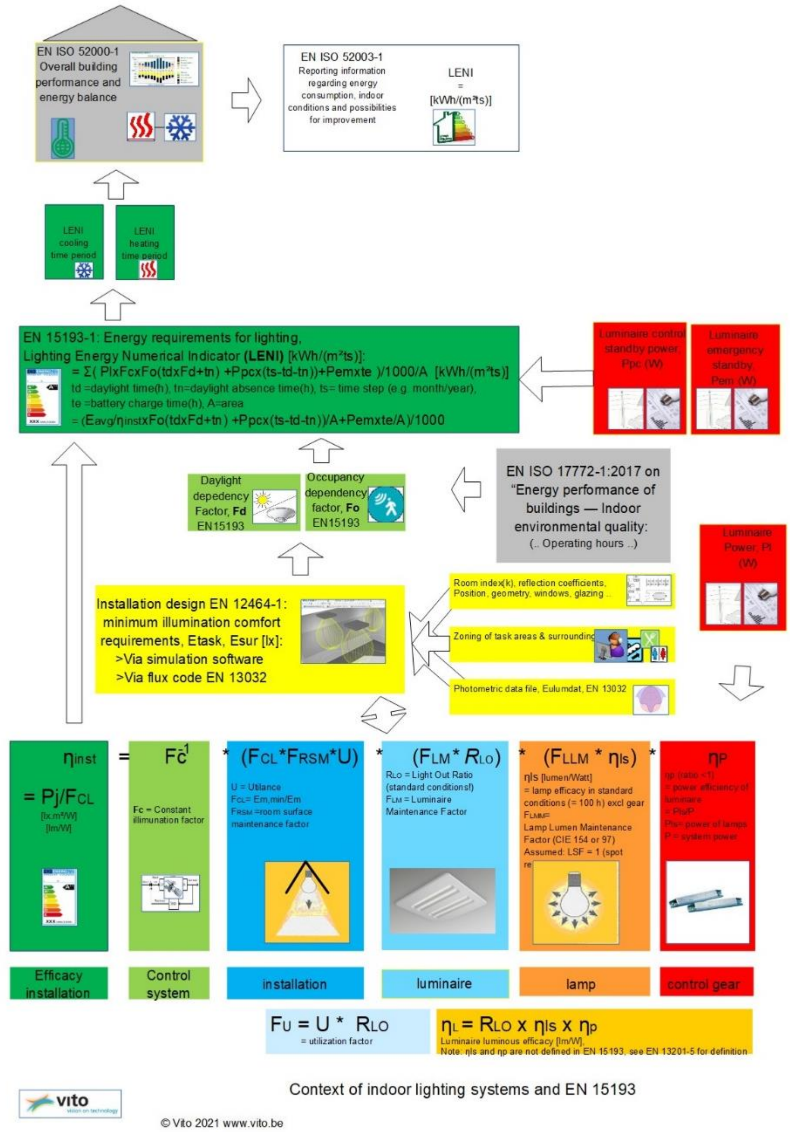

Figure 2: Full context of indoor lighting within EPBD according to EN 15193.

Normative requirements

Most MS take lighting into account in the overall calculation of the Energy Performance Certificate of non-residential buildings and therefore this is reflected in the calculated or measured primary energy per m² per year (kWh/m²/y). LENI is also reported separately in the building EPC. For existing buildings LENI can be easily measured according to EN 15193 by installing a submeter for electricity.

Only a few Member States to the study team's knowledge require specific LENI, PI or PDI thresholds for lighting to be met in their regulations. Two examples found from screening the CA EPBD database[19] and the study team's desk research are shown below.

France

According to the Decree[20] of 3/5/2007 that entered into force in 2018:

- Art. 42 requires that lighting installations in common circulation areas in existing buildings need a presence detector per 100 m² useful floor area and in staircases at least one per three floor levels.
- Art. 43 requires that non-residential buildings need a central lighting management system and/or an automatic controller:
    - that allows for unoccupied periods:
        - dimming to the minimum required levels if technical justified

        or

        - switch-off lighting
    - for rooms with high occupancy that have daylight available, also:
        - should have daylight-dependent dimming
        - have a controller loop per 25 m².

This complements the Tertiary Decree (Décret tertiaire[21]) that requires large (>1000 m²) existing non-residential buildings to save 40% of their baseline (determined from as early as 2010) energy consumption by 2030. In practice, lighting renovations can be used to help achieve these objectives.

Spain

The Spanish building code[22] sets specific requirements for interior lighting installations in large non-residential buildings. Specifically, these are:

- limit values for lighting power density or installation efficacy ($VEEI_{inst}$ [W/100 lx] or $1/\eta_{inst}$) while also requiring that lighting quality requirements are respected (EN 12464-1), for example below 3 W per 100 lx installed in an office area.
- limiting the value of installed power per unit floor area to 5 W/m² in apartment buildings and other non-residential buildings to 10 W/m² for applications that require ≤600 lx (EN 12464) and 25 W/m² if required >600 lx.
- Minimum requirements for lighting control systems similar to those applied in France.

[19] https://epbd-ca.eu/database-of-outputs

[20] https://www.legifrance.gouv.fr/loda/id/LEGIARTI000034310764/2018-01-01/

[21] https://www.legifrance.gouv.fr/loda/id/JORFTEXT000038812251/

[22] https://www.codigotecnico.org/pdf/Documentos/HE/DccHE.pdf

Review of compliance/enforcement methods

For new building and deep renovations that require a new lighting design:

- enforcement can be done based on providing the documentation and a declaration of honour that lighting designs followed the EN 15193 approach (see Figure 2), to satisfy the minimum lighting quality requirements according to EN 12464. The main outcome is the computed LENI[kWh/m²/y] and Pl[W/m²], calculation is usually done with lighting design software (DIALux (free), RELUX (free), LITESTAR 4D, etc.). This software does the calculations according to EN 15193 and includes the required manufacturer product data within their databases (photometric files). The software also generates the necessary documentation for the declaration of honour.

Once installed and for existing installations:

- LENI [kWh/m²/y] and Pl[W/m²] measurements are done using a MID certified kWh and power meter. It is straightforward and also described in EN 15232.
- Installed illuminance levels (EN 12464) can be measured with a lux meter[lx] at some important check points (desk, corridor, etc.). For enforcement this can sometimes be challenging when the minimum illuminance [lx] values are not reached because it can be due to deviating interior reflections and it might be difficult to hold someone accountable. When this is the case more complex measurements will be needed to settle an underperformance claim.

Currently the BACS lighting functions for existing installations are simply checked by means of a checklist to verify if those functions are available (see BACS compliance methods in section 1.3.5). This may still constitute a gap because it does not check if the occupancy and daylight dependant controls are properly fine-tuned. Therefore, this study could propose to analyse a time record of power consumption and check for anomalies with regard to energy use versus astronomic clock data and other building occupancy indicators (lift, ICT, etc.).

1.3.7 RES

EPBD requirements

Art. 9 of the EPBD (2010/31/EU) already required that all new buildings from 2021 (public buildings from 2019) should be nearly zero-energy buildings (NZEB) and therefore all Member States considered Renewable Energy Systems in their EPC calculation methods. Nearly Zero Energy Buildings means a building that has a very high energy performance and therefore one that often relies on a significant use of energy from renewable sources. It can be produced on-site or nearby with district heating or cooling. Therefore, it can be trapping solar heat gains due to the glazing and greenhouse effect, using solar collectors or panels but also a heat pump that uses free energy from the air or the ground.

All EPBD standards for thermal energy are ready for this and there is no gap or barrier to include RES in EPCs (see heating in section 1.3.1). Nor is there any methodological obstacle to set a clear requirement for a minimum share of RES to cover the required energy.

For photovoltaics this is more problematic because electricity cannot easily be stored on site and there can be a large seasonal and daily mismatch between the self-produced and self-needed energy of the building. The older set of EPBD EN standards was based on monthly energy balance methods but the recent update now includes an hourly method[23]. Also, incentives and metering schemes for photovoltaics can differ considerably across Europe, with some countries allowing annual net metering while others require real-time or hourly self-consumption metering. Therefore, the related data relevant for photovoltaics is discussed further below.

Normative requirements

Thermal renewable energy sources (RES) and domestic hot water, including biomass, are already largely covered by the existing EPBD standards, as can also be concluded from the status overview made by the CA EPBD in 2018[24] (Table 10).

For new buildings many MS set a minimum share (%) of RES to cover the energy needs of the building, for example (BE-VL), ES, BG and F. The Spanish building code[25] also sets requirements for DHW to be supplied with solar thermal energy in certain types of existing buildings.

Photovoltaics, smart grid and self-consumption of photovoltaic energy is a newer type of TBS[26], so there is still a gap in harmonising this use case over the EU27, which makes comparison difficult. The key difference is related to the per country/region different minimum time frame (20ms,…, hourly, … yearly) used for billing the different price components (energy, network cost, levies, taxes) and defining the photovoltaic self-consumption. This can be problematic because, for example, the new set of EPBD standards has been updated with an hourly method[27] but this could be insufficient when self-consumption relies on real-time metering (20 ms). In the real-time metering case it could be problematic under variable cloud conditions to control heat pumps with highly fluctuating power supply to achieve zero on the meter. In these conditions, battery energy storage solutions might be a better choice. On the other hand, it is, or was, sometimes allowed to use annual net metering, which is simple and does not require any additional control or calculation. In this case the grid is used as a free battery, but this can be contestable and net metering schemes are under pressure to be reviewed[28]. Following the logic and calculations of the new set of EPBD standards the preferential definition of self-consumption would be the hourly aggregated energy, meaning that the hourly sum of electricity supplied (+) and consumed (-) to the grid. In order to get a better view on the state of play on this topic supplementary questions were added to the general enquiry of this study (Table 11).

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

[24] https://epbd-ca.eu/wp-content/uploads/2019/09/CA-EPBD-2018-BOOK-VOLUME-II.pdf

[25] https://www.codigotecnico.org/pdf/Documentos/HE/DccHE.pdf

[26] https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/2020-12/jrc12431preparatory_study_for_solar_photovoltaic_modules_kj-na-30468-en.pdf

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

[28] https://www.energiesparen.be/uitspraak-grondwettelijk-hof-over-de-terugdraaiende-meter-voor-zonnepanelen

Table 10: Accountable RES solutions in Member State energy performance calculations.

solution \ country	specify	BE-BR	BE-FL	BE-WA	BG	CY	DE	DK	EE	GR	ES	FI	FR	HR	HU	IT	LT	LV	MT	NL	NO	PL	PT	SE	SK	SL	UK
RES as part of district heating	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Y		Y	N	Y	Y	Y
RES as part of district cooling	N	N	N	N	Y	Y	Y	N	Y	Y	N	Y	Y		N	Y	N	N	N	Y	Y	N	Y	N	N	Y	N
Solar thermal panels for DHW	Y/N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Solar thermal panels for heating support	Y/N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
PV for self-use	Y/N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
PV for feed-in	Y/N	Y	Y	Y	Y	Y	N	N	Y	Y	N	N	Y	Y	Y	N	Y	Y	Y	Y	Y	N	N	N	Y	Y	N
PV for heating (input to heat storage)	Y/N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
PV/T hybrid solar collectors for self-use	Y/N	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
PV/T: PV for feed-in, T for self-use	Y/N	Y	Y	Y	N	Y	Y	Y	Y	N	N	N	Y	Y	Y	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N
Micro wind-turbine for self-use	Y/N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
Micro wind-turbine for feed-in	Y/N	N	N		N	Y	Y	N	Y	Y	N	N		N	N	N	Y	Y	Y	Y	Y	N	N	N	Y	N	N
Local hydro for self-use	Y/N	N	N	N	N	N	N	Y	Y	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
Local hydro for feed-in	Y/N	N	N	N	N	N	N	N	Y		N	N	N	N	N	N	Y	Y	N	Y	Y	N	N	N	N	Y	N
Biomass boiler	Y/N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
Biomass CHP	Y/N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y/N	Y/N	Y	Y	Y	Y/N	N	Y	Y	Y	Y		Y	N	Y	Y	Y
HP coupled to external or exhaust air	Y/N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
HP coupled to ground/ground-water	Y/N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Direct geothermal	Y/N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Direct ground water cooling	Y/N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
RES elektricity via grid (specific contract)	Y	N	N	N	Y	N	N	N	N	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	N	N	N
Alternative: higher insulation level	Y	Y	Y	N	Y	N	Y	N	Y	Y/N	Y/N	N	N	N	N	Y	N	N	N	Y	Y	Y	N	Y/N	N	Y	N
PV with Battery Energy Storage System(BESS)	N	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?

Abbreviation: RES = renewable energy system.

Table 11: Survey questions on EPBD requirements for RES.

General questions on RES (Renewable Energy Sources) integration within their building energy performance regulations:	
What is the minimum time step of an EPC for an existing, large non-residential building?	Public buildings, this is based on annual measured data (meter reading) relative to a benchmark calculated with a spreadsheet tool
What is the minimum time step of an EPC for a new large non-residential building?	So far monthly energy balances are use (hourly method under consideration). Free software is available at: https://..

Abbreviation: EPC = energy performance certificate.

Review of compliance/enforcement methods

In the case of thermal energy (e.g. solar) the verification of the minimum share (%) of RES required to cover the energy needs of the building is commonly done with the certified EPC calculation tools. Installing calorimeters in order to work with measured data for this purpose is usually too expensive.

For the verification of the supplied photovoltaic energy both meters and certified EPC calculation tools can be used, but metered data is becoming more common due to the roll-out of smart electricity meters. In some countries it can become confusing and result in split incentives when the metering and billing scheme do not follow the calculation of the EPC certificate[29].

1.3.8 Summary of current requirements

As previously mentioned, readers of this interim report should be aware that the review findings presented here are incomplete due to the ongoing conduct of an enquiry of Member States activities with regards to technical building systems. Thus, the results presented in this report are necessarily provisional.

With these caveats in mind the following tentative findings can be reported:

- while all Member States have transposed Ecodesign and Energy labelling requirements applicable to elements within technical building systems only some

[29] In Flanders (BE) for example EPC tools used annual net metering versus the metering scheme is per quarter of hour: https://www.fluvius.be/nl/thema/meters-en-meterstanden/digitale-meter/digitale-meters-en-zonnepanelen-dit-moet-je-weten

Member States have gone beyond these and adopted overall TBS energy performance requirements

- when such requirements have been adopted they mostly apply to new TBS installations in either new or existing buildings or sometimes both
- such requirements appear to be most common for the HVAC TBS, especially heating and ventilation systems
- they appear to be least common for RES, BACS and lighting systems
- some Member States have adopted energy performance requirements for parts of a TBS, e.g. insulation of pipework, but have not necessarily set overall system performance requirements
- examples of requirements can be found that apply to all the aspects mentioned in Article 8(1) of the amended EPBD, i.e. overall energy performance, proper installation, appropriate dimensioning, adjustment and control of technical building systems but it is rare to find requirements set for all of these for any given TBS within any specific Member State
- while Article 8(9) of the amended EPBD requires 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 only a few examples of this have currently been identified – processing of the pending responses to the questionnaire should enable the situation to be clarified
- Articles 14 and 15 of the EPBD 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 – many Member States already have such inspection schemes
- for TBS installed in new buildings or major renovations by far the most common approach is to require their overall performance to be assessed as part of the whole building energy performance using the same software tools used to determine EPC ratings; however, it is rarer to complement this with specific overall TBS energy performance requirements
- many Member States have been, or still are, in the process of transposing the latest 2018 EPBD requirements into national regulations and thus the actual situation could alter as this transposition process is complete and the findings are reported to the study team.

1.4 Activity 2: Review of initiatives and measures relevant for the establishment and enforcement of technical building system requirements

This activity presents a review of initiatives and measures that are relevant for the establishment and enforcement of TBS requirements. It is structured such that the first section covers non-normative initiatives and measures that are applicable to TBSs in general, then subsequent sections provide TBS-specific information. These TBS-specific sections are structured first to present any Ecodesign or Energy Labelling requirements that may pertain to products used in the TBS, then to set out the EN standards that apply as a function of the specific aspects mentioned in Articles 8, 14 and 15 of the EPBD, and subsequently to present a summary of relevant non-normative initiatives and measures.

1.4.1 Overview of EU legislation relevant to TBS energy performance and enforcement of requirements

Ecodesign Directive and Energy Labelling Regulation

European 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 (known as the Ecodesign Directive or sometimes as the ErP Directive) requires that energy-related products fulfil Ecodesign requirements as defined in specific implementing measures, usually Commission Regulations, for the different products. Such regulations currently cover space heating and domestic hot water systems, air conditioners and air to air heat pumps, ventilation units, as well as some of their components (fans, pumps, electric motors), chillers, fan coil units, condensing units, solid fuel boilers, local room heating products, etc. The regulations include requirements on energy performance levels and how to assess energy efficiency, based on harmonised standards. Often, the regulations establish requirements with minimum performance thresholds that can become more stringent over time. The regulations also list which information and data must be published in technical documentation. The Directive requires that the manufacturer maintains and makes available an EC declaration of conformity and affixes the CE marking.

Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling, known as the Energy Labelling Regulation (ELR) sets provisions for the indication of the energy performance and other resources by energy-related products through labelling and information to end-users. Commission Delegated Regulations have already been published for air conditioners, space heaters and water heaters and residential ventilation units, defining energy efficiency classes, contents of the label and product information to be made available to consumers. A new feature of the ELR, compared to the former Energy Labelling Directive which it replaces, is that for new labelling regulations issued after 1 January 2019, suppliers (manufacturers, importers or authorised representatives) need to register their appliances, which require an energy label in the European Product Database for Energy Labelling (EPREL), before selling them on the European market. As of March 2021, the first four product categories will be available in the database: fridges and freezers, dishwashers, washing machines and electronic displays. Light bulbs and lamps will be added as of 1 September 2021 and more product categories will follow. Consumers can access the database by scanning the QR code featured on the new energy labels. The database offers detailed information for all registered products. The EPREL database provides the specific information sheet and displays the energy label, for each registered product. An Export Data feature is expected to be operational in late 2021 or in 2022, and it will give researchers the possibility to extract statistical data for in-depth analysis. Furthermore, developers will be able to use the database to perform queries and export data using application programming interfaces (APIs).

The specific Ecodesign and labelling regulations applicable to each TBS are presented in the sections below. It should be noted that the parameters and methods used in the regulations linked to these two policy instruments can be quite different from those used to take into account the performance of HVAC products and lighting in the calculation of the energy performance of buildings (national transpositions of the EPBD).

European Directive 2009/28/EC on the promotion of the use of energy from renewable sources

This directive requires, among other things, that Member States promote the use of renewable energy sources in buildings. Member States must have defined specifications for renewable energy systems to benefit from support schemes, based on European standards if they exist (Article 13). Such technical specifications must not prescribe where the systems are to be certified and should not impede the operation of the internal market.

For biomass, Member States are required to promote technologies that achieve a conversion efficiency of at least 85% for residential and commercial applications and 70% for industrial applications. Member States are required to promote heat pumps that fulfil the minimum requirements of the European eco-label and to promote certified solar thermal systems based on European standards if they exist.

Member States were also obliged to ensure that certification or qualification schemes were available by the end of 2012 for installers of small-scale biomass boilers and stoves, solar photovoltaic and solar thermal systems, shallow geothermal systems and heat pumps, with a mutual recognition of these certifications or qualifications between Member States (Article 14).

Finally, Article 5 defines how Member States must include heat pumps in the calculation of their share of renewable energy sources. The heat energy captured by heat pumps shall be taken into account for this calculation if the final energy output significantly exceeds the primary energy input required to drive the heat pumps. This is described by a formula (Annex VII) using a seasonal performance factor and requiring that only heat pumps for which this factor is higher than a given limit be taken into account, depending on the national ratio between gross production of electricity and the primary energy needed for this electricity production.

Construction Products Regulation

Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products, sets out conditions for the placing or making available on the market of construction products by establishing harmonised rules on how to express the performance of construction products in relation to their essential characteristics and on the use of CE marking on those products. Under the regulation a construction product is defined as any product or kit which is produced and placed on the market for incorporation in a permanent manner in construction works or parts thereof and the performance of which has an effect on the performance of the construction works with respect to the basic requirements for construction works. In this context 'kit' means a construction product placed on the market by a single manufacturer as a set of at least two separate components that need to be put together to be incorporated in the construction works and 'construction works' means buildings and civil engineering works.

Declaration of performance of a construction product (and its CE marking) must be based on the Construction Product Regulation ((EU) N° 305-2011) as soon as harmonised European standards apply to this product. It is therefore important that the procedures for determining and making available TBS conformity assessment input data do not contradiction these requirements.

Member States may specify national requirements for construction products only if no harmonised standard exists and if performances may not (or may not fully) be assessed on the basis of an existing harmonised standard. In such cases, they need to foresee an equivalence clause, allowing products that have already demonstrated compliance with the national regulatory requirement through an equivalent system in another country.

1.4.2 Non-normative initiatives and measures that are applicable to TBS requirements in general

Member States have implemented a variety of non-normative initiatives and measures to encourage improved efficiency of buildings. A considerable number of these are documented in the Eionet study[30]. In addition, there are a number of databases on energy efficiency and climate policies implemented by EU Member States which have been accessed by the study team in order to identify relevant policy measures applied to TBS. These include:

- The MURE II database[31]
- EEA catalogue of European environment and climate policy evaluations[32]
- Knowledge Base EPATEE (co-funded H2020)[33]
- Knowledge Base Capacity Building to Facilitate Implementation of the Effort Sharing Legislation, with Focus on Ex-post Evaluation and Policy Lessons Learned (DG CLIMA, 2021)[34]
- IEA's energy efficiency policy database[35].

In addition a number of sources are used for information on assessment, compliance and enforcement, a key one of which is the *qualicheck* site[36].

A number of Member States have adopted measures that would encourage any, or a wide variety, of energy efficiency measures in buildings that include measures concerning the efficiency of TBS. These include measures for:

- normative measures, i.e. regulations
- incentives (grants, fiscal incentives, financial incentives)
- information (guides, metering, promotion)
- professional support (guides, tools, training, certification/accreditation).

Sometimes the measures combine more than one of these elements. Some examples are discussed below, first for approaches that are transversal across TBS types and then illustrations of TBS-specific aspects are provided in the sub-sections immediately below. Note, at the time of writing Member State surveys have only just been distributed and so this section has not yet benefited from any responses to the survey.

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[30] *Ex post evaluation and policy implementation in the building sector* (2018) https://www.eionet.europa.eu/etcs/etc-atni/products/etc-atni-reports/eionet_rep_etcacm_2018_2_energy_efficiency_buildings

[31] http://www.measures-odyssee-mure.eu/

[32] http://poleval-catalogue.apps.eea.europa.eu/

[33] https://www.epatee-lib.eu/

[34] https://effortsharing.ricardo-aea.com/knowledge-bank

[35] https://www.iea.org/policiesandmeasures/

[36] http://qualicheck-platform.eu/

The White Certificate Scheme in France

In line with the requirement of the EED, Article 7, France has established an Energy Efficiency Obligation Scheme (EEOS) that requires energy suppliers (of all fuel types) to implement energy savings measures that are proportional in scale (but of a lower magnitude), to their energy sales. Each supplier's obligation must be met through the redemption of a predetermined quantity of energy savings certificates which are tradable on an open market. There are various ways in which a certificate can be generated, but in all cases the public regulator sets the rules against which the energy savings can be established and certified. In practice, the large majority of the energy savings certificates are issued in accordance with standardised methodologies issued by the regulator. These are derived from in-depth assessments of the current standard energy service solutions, the options to provide them in a more efficient manner and the expected outcomes from doing so. The majority of these standardised cases draw upon analyses of the average savings expected from satisfaction of a set of predetermined energy efficiency options and then application of these "deemed savings" as a function of the scale (magnitude) of application of the option(s). To date the regulator has published a large set of standardised options of which the following directly or indirectly concern the performance of TBSs[37]:

The "Residential" sector currently has the following standardised options related to TBS:

<u>"Services"</u>

- • BAR-SE-104: Balancing of a hot water heating installation
- • BAR-SE-105: Energy Performance Service Contract (CPE Services)
- • BAR-SE-106: Energy consumption monitoring service
- ""Thermal"
- • BAR-TH-101: Individual solar water heater (mainland France)
- • BAR-TH-102: Collective solar water heater (mainland France)
- • BAR-TH-104: Air/water or water/water type heat pump
- • BAR-TH-106: Individual boiler with high energy performance
- • BAR-TH-107: High energy performance collective boiler
- • BAR-TH-107-SE: High energy performance collective boiler with contract ensuring the operation of the installation
- • BAR-TH-110: Low temperature radiator for central heating
- • BAR-TH-111: Regulation by outside temperature sensor
- • BAR-TH-112: Independent wood heating device
- • BAR-TH-113: Individual biomass boiler
- • BAR-TH-116: Low temperature hydraulic heated floor
- • BAR-TH-117: Thermostatic valve
- • BAR-TH-118: Regulation system by intermittent programming
- • BAR-TH-122: Condensation heat recovery unit

[37] https://www.ecologie.gouv.fr/operations-standardisees-deconomies-denergie

- • BAR-TH-123: Boost optimiser in collective heating
- • BAR-TH-124: Individual solar water heater (France overseas)
- • BAR-TH-125: Self-adjusting or modulated high performance double flow ventilation system (mainland France)
- • BAR-TH-127: Humidity-controlled single flow mechanical ventilation (mainland France)
- • BAR-TH-129: Air/air type heat pump
- • BAR-TH-135: Collective solar water heater (France overseas)
- • BAR-TH-137: Connection of a residential building to a heating network
- • BAR-TH-139: Electronic speed variation system on a pump
- • BAR-TH-141: Efficient air conditioner (overseas France)
- • BAR-TH-143: Combined solar system (mainland France)
- • BAR-TH-148: Thermodynamic storage water heater
- • BAR-TH-150: Collective air/water or water/water absorption heat pump
- • BAR-TH-155: Humidity-controlled hybrid ventilation (mainland France)
- • BAR-TH-158: Electric transmitter with electronic regulation with advanced functions
- • BAR-TH-159: Individual hybrid heat pump
- • BAR-TH-160: Insulation of a hydraulic heating or domestic hot water network
- • BAR-TH-161: Isolation of singular points of a network
- • BAR-TH-162: Energy system comprising solar photovoltaic and thermal collectors with water circulation (mainland France)
- • BAR-TH-163: Flue for evacuation of combustion products
- • BAR-TH-165: Collective biomass boiler
- The Tertiary sector has the following standardised options concerning TBS:

"Equipment"

- • BAT-EQ-127: General lighting luminaire with LED modules
- • BAT-EQ-129: Skylights for overhead lighting (Metropolitan France)
- • BAT-EQ-131: Natural light pipes
- • BAT-EQ-133: Hydro-saving systems (mainland France)
- "Services:"
- • BAT-SE-103: Balancing of a hot water heating installation
- • BAT-SE-104: Energy performance contract Services (CPE Services) Heating
- • BAT-SE-105: Lowering the return temperature to a heating network

"Thermal"

- • BAT-TH-102: Communal boiler with high energy performance
- • BAT-TH-103: Low temperature hydraulic heated floor

- • BAT-TH-104: Thermostatic valve
- • BAT-TH-105: Low temperature radiator for central heating
- • BAT-TH-108: Regulation system by intermittent programming
- • BAT-TH-109: Boost optimiser in collective heating
- • BAT-TH-110: Condensation heat recovery unit
- • BAT-TH-111: Communal solar water heater (mainland France)
- • BAT-TH-112: Electronic speed variation system on an asynchronous motor
- • BAT-TH-113: Air/water or water/water type heat pump
- • BAT-TH-115: Efficient air conditioner (overseas France)
- • BAT-TH-116: Technical building management system for heating and domestic hot water
- • BAT-TH-121: Solar water heater (France overseas)
- • BAT-TH-122: Intermittent timer for air conditioning (overseas France)
- • BAT-TH-125: Single flow mechanical ventilation with constant or modulated air flow
- • BAT-TH-126: Double flow ventilation system with constant or modulated air flow exchanger
- • BAT-TH-127: Connection of a tertiary building to a heating network
- • BAT-TH-134: Regulation system on a cold production unit allowing for high floating pressure (mainland France)
- • BAT-TH-135: Regulation system on a cold production unit to have high floating pressure (overseas France)
- • BAT-TH-139: Heat recovery system on a cold production unit
- • BAT-TH-140: Air/water or water/water absorption heat pump
- • BAT-TH-141: Heat pump with gas engine, air/water type
- • BAT-TH-142: Destratifier or fan
- • BAT-TH-143: High performance fan coils
- • BAT-TH-145: Regulation system on a cold production unit allowing low floating pressure (mainland France)
- • BAT-TH-146: Insulation of a hydraulic heating or domestic hot water network
- • BAT-TH-153: Cold aisle and hot aisle containment system in a data centre
- • BAT-TH-154: Instant heat recovery from grey water
- • BAT-TH-155: Isolation of singular points of a network
- • BAT-TH-156: Freecooling by cooling water to replace a chiller for air conditioning
- • BAT-TH-157: Communal biomass boiler

For each of these options a standardised energy savings methodology has been determined that allows the attribution of certifiable energy savings to be acknowledged within the tradable white certificate scheme. This creates a market value for savings delivered under this scheme. To date, the majority of all the savings achieved under the French EEOS have been through standardised options and a high proportion of these are related to TBS energy performance.

Germany's Incentive Program "Bundesförderung für Effiziente Gebäude" BEG[38]

As part of the Climate Protection Programme 2030, the Federal German Government will extend the promotion of energy-efficient buildings under the new BEG-Program which will start on 01.07.2021.

The funding for single measures (which can be directly related to technical building systems) will be in the form of repayment subsidy for loans and will be valid for the following actions (among others):

- installation, renewal or optimisation of air-conditioning and ventilation systems with heat or cold recovery (20%)
- installation of measurement, control and regulation technology to realise a degree of building automation (20%)
- Installation of energy-efficient lighting systems (20%)
- installation of refrigeration technology for room cooling (20%).

Netherlands: Investment subsidies small renewable energy systems (ISDE)[39]

To complement the SDE+ with a scheme for smaller renewable energy systems, the investment subsidy scheme ISDE has started in 2016. This scheme was based on one of the agreements under the Agreement on Energy for Sustainable Growth forum 2013. The scheme operated in the period 2016-2020. Households and small commercial users can receive an allowance for the purchase of heat pumps, biomass boilers, solar water heaters, pellet stoves and small wood-fired boilers.

In 2016 and 2017 the budget was €70 million/year; in 2018 and 2019 the budget was €100 million/year.

Netherlands: National Heat Fund[40]

The Dutch government operates a subsidised loan scheme with a budget of €1 billion for households that wish to implement energy savings measures. While some of these measures relate to the building fabric many concern the TBSs, as shown in **Table** 12. Under the scheme an individual can take out an energy saving loan of from €2.5k to €66k to implement such measures and pay them off over an extended period (15 to 20 years) at a low fixed rate of interest. The loans are repaid monthly but can be paid off in full at any time with no early repayment penalty.

[38] https://www.kfw.de/inlandsfoerderung/Bundesf%C3%B6rderung-f%C3%BCr-effiziente-Geb%C3%A4ude/

[39] https://www.iea.org/policies/7728-investment-subsidies-small-renewable-energy-systems-isde?country=Netherlands&sector=Buildings

[40] https://www.energiebespaarlening.nl/

Table 12: Energy savings measures eligible for loans for individuals under the Netherlands National Heat Fund.

Energy-saving measures
Connecting to a heat network
CO_2-controlled ventilation
Energy monitor linked to smart meter
DC fan
DC pump
High-efficiency boiler
HRe boiler
Low temperature delivery systems
Tailor-made advice
Heat recovery system
Heat pump
Hydronic balancing
Very Energy Efficient Package
Very Energy Efficient Package + / Zero on the Meter
Solar water heater
Solar panels (incl. Home battery)

Italy's Conto Termico[41]

The Conto Termico 2.0, was launched in May 2016, to strengthen and simplify the support mechanism "Conto Termico" that was operational from the end of 2012 and which encourages measures to increase energy efficiency and the production of thermal energy from RE. The total annual budget is up to 900 million Euro, of which 200 million is for public administrations projects and 700 million for private initiatives. Once the cap is reached the programme is closed for new applications.

Conto Termico 2.0 provides financial incentives on the capital costs of the eligible initiatives that are paid on a annual basis for a variable period of 2 to 5 years depending on the type of improvement implemented, technology applied and its size.

Two categories of projects are eligible to benefit from the scheme:

A) energy efficiency improvements in an existing buildings

B) small-scale projects concerning systems (<2000kW) producing thermal energy from renewable and high-efficiency systems.

The eligible technologies are:

[41] https://www.gse.it/servizi-per-te/efficienza-energetica/conto-termico

A.1) insulation of opaque surfaces, replacement of transparent closures, installation of system shielding and shading and replacement of generators with condensing appliances

B.1) heat pumps, biomass boilers, heaters and fireplaces, solar thermal systems, including those based on solar cooling technology.

Public administration entities are eligible to benefit from incentives for both types of projects; however, private entities only eligible for small-scale projects concerning systems to produce thermal energy from renewables and high-efficiency systems (2nd category).

Belgium - Wallonia: Subsidy scheme for households supporting energy saving measures and housing refurbishment[42]

The Decree of 26 March 2015 established a subsidy scheme for households supporting energy saving measures and housing refurbishment. The Decree entered into force on 1st of April 2015.

The programme subsidises installation of certain renewable energy systems, such as heat pumps, solar water heaters or biomass-fired boilers that help with energy savings for households.

Amount of the subsidy differ per technology installed. The capital grant for biomass boiler installation amounts up to EUR 800. The subsidy cannot exceed 70% of the total installation costs of the boiler. Similar grant rules apply for installation of heat pumps and geothermal energy in households. Support for solar thermal installations amounts to EUR 1500 and cannot exceed 75% of the investment costs per project.

Spain: JESSICA-F.I.D.A.E Fund (Energy Saving and Diversification Investment Fund)[43]

Established in 2013 the aim of this fund is to finance urban sustainable development projects to improve energy efficiency, use renewable energies and be developed by energy services companies (ESCOs) or other private enterprises. This fund is to finance all the investments directly bound to the issue of energy efficiency and the use of renewable energies in urban environments, and it is compatible with other public or private funding sources, as well as with subsidies either co-funded or not by the FEDER. Priority issues: Energy efficiency and energy management (existing and new buildings) Renewable energy projects (solar thermal, solar PV, biomass) Projects related to clean transport, contributing to improvement of energy efficiency and the use of renewable energies These are the conditions that a project must meet to be fundable: Being located in one of the Spanish Regions included in F.I.D.A.E. – Andalusia, the Canary Islands, Castile & Leon, Castile-La Mancha, Ceuta, Valencia, Galicia, Melilla & Murcia Region. Being included in one of the eligible sectors of which public and private buildings are one. Take part in one of the priority issues: Energy Efficiency Projects and energy management: Renovation of existing buildings, with actions on the thermal envelope, heating installations, cooling, lighting, etc. New buildings with energy rating A or B. Renovation or enlargement of existing heating/cooling networks. Renewable Energy Projects: Solar thermal. Solar PV if integrated in an energy efficiency project. Ensuring an acceptable return of the investment.

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[42] https://wallex.wallonie.be/contents/acts/1/1926/1.html?doc=29199&rev=30705-20417

[43] https://www.idae.es/uploads/documentos/documentos_Guia_elegiblidad_v16_56e2ca80.pdf

UK: Building services compliance guides

The UK supports conformity assessment and compliance with the national building regulation requirements applicable to all building services, which includes TBSs by issuance of a building services compliance guide. Separate guides are issued for non-domestic building services[44] and for domestic building services[45]. These documents, which are updated whenever changes are made in the requirements, provide a comprehensive yet easy to follow reference for what the current energy performance requirements are for each TBS, by building type and building status (new build, major renovation, existing). They therefore provide building service engineers and professionals a single reference where they can see all the requirements pertaining to any project they are commissioned for or working on.

1.4.3 Initiatives and measures that are applicable to space heating and DHW

Ecodesign/ELR requirements

The following Ecodesign and energy labelling requirements apply to space heating and water heating products.

Space heaters

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. OJ L 239, 6.9.2013

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

Local space heaters

Commission Regulation (EU) 2015/1185 of 24 April 2015 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for solid fuel local space heaters. OJ L 193, 21.7.2015

Commission Delegated Regulation (EU) 2015/1186 of 24 April 2015 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of local space heaters. OJ L 193, 21.7.2015

Commission Regulation (EU) 2015/1188 of 28 April 2015 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for local space heaters. OJ L 193, 21.7.201E

Solid fuel boilers

Commission Regulation (EU) 2015/1189 of 28 April 2015 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for solid fuel boilers. OJ L 193, 21.7.2015

[44] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/453973/non_domestic_building_services_compliance_guide.pdf

[45] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/697525/DBSCG_secure.pdf

Commission Delegated Regulation (EU) 2015/1187 of 27 April 2015 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of solid fuel boilers and packages of a solid fuel boiler, supplementary heaters, temperature controls and solar devices. OJ L 193, 21.7.2015

Air heating products

Commission Regulation (EU) 2016/2281 of 30 November 2016 implementing Directive 2009/125/EC of the European Parliament and of the Council establishing a framework for the setting of Ecodesign requirements for energy-related products, with regard to Ecodesign requirements for air heating products, cooling products, high temperature process chillers and fan coil units. OJ L 346 of 20 December 2016

Water heaters and hot water storage tanks:

Commission Regulation (EU) No 814/2013 of 2 August 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for water heaters and hot water storage tanks. OJ L 239, 6.9.2013

Commission Delegated Regulation (EU) No 812/2013 of 18 February 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of water heaters, hot water storage tanks and packages of water heater and solar device Text with EEA relevance. OJ L 239, 6.9.2013

Circulation pumps

Commission Regulation (EC) No 641/2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to Ecodesign requirements for glandless standalone circulators and glandless circulators integrated in products. OJ L 191, 23.7.2009

Commission Regulation (EU) No 622/2012 of 11 July 2012 amending Regulation (EC) No 641/2009 with regard to Ecodesign requirements for glandless standalone circulators and glandless circulators integrated in products. OJ L 180, 12.7.2012

EN standards

Table 13 links the heating-related EN standards to the requirements defined in Article 8 and Article 14 that they target.

Table 13: Links between space heating and DHW-related EN standards and Article 8 & 14 provisions.

EN	Overall energy performance (Art.8)	Proper installation (Art.8)	Adjustment & control (Art.8)	Appropriate dimensioning (Art.8)	BAC & monitoring (Art.14)	Assess-ment of heat generator efficiency (Art.14)	Including DHW-systems
EN 1264-3	x						
EN 1264-4		x					
EN 12828	x		x		x		x
EN 12831-1	x						x
EN 12831-3	x						x
EN 14336	x	x		x			
EN 14337	x						
EN 15232	x		x		x		x
EN 15316-2	x		x		x		
EN 15316-3	x						x
EN 15316-4-1	x					x	x
EN 15316-4-2	x					x	x
EN 15316-4-3	x						x
.EN 15316-4-4	x						x
EN 15316-4-5	x					x	x
EN 15316-4-8	x					x	x
EN 15316-5	x	x					x
EN 15378-1	x		x	x	x	x	x
EN 15500-1	x		x		x		
EN 16946-1		x					

Abbreviations: BAC = building automation control; DHW = domestic hot water.

Other non-normative initiatives

Germany's Heating Optimisation Funding Programme[46]

It is reported that there is a lot of potential for saving energy in Germany's buildings sector, particularly when it comes to heating. This has to do with the fact that many of

[46] https://www.bmwi.de/Redaktion/EN/Artikel/Energy/heating-optimisation-founding-programme.html

the pumps installed for heating in buildings are outdated and therefore use more electricity than they should. By installing state-of-the-art high-efficiency pumps, electricity consumption can be reduced by up to 80 per cent. And there is still more that can be done: hydraulic balancing – which means making an existing heating system run more efficiently – can help bring down energy consumption even further. Plus, this optimisation process does not require any construction work.

In August 2016, the Federal Ministry for Economic Affairs and Energy launched its Heating Optimisation Funding Programme, giving a fresh boost to funding energy efficiency. The programme is based on the "Guideline for funding heating optimisation by using high-efficiency pumps and hydraulic balancing".

By optimising heating systems to make them run more efficiently, homeowners, businesses and clubs can save both energy and money, thus driving forward the energy transition. The funding programme helps improve energy efficiency in buildings, making a key contribution to ensuring that Germany's energy supply is efficient, secure and climate-friendly and to meeting the goal of achieving a climate-neutral building stock.

Under the programme, funding is provided for the following two measures:

- Replacing pumps: The German government provides funding for replacing old heating and hot water pumps with high-efficiency ones.
- Optimising heating systems: The German government also provides funding for submitting existing heating systems to a process of hydraulic balancing. This means that a specialised company is commissioned to adjust all the different components of the heating system in order to optimise it for use in the building. In addition to hydraulic balancing, funding is also provided for investing in or optimising existing heating systems (like replacing thermostat valves).

In some cases, it makes sense to replace a pump and optimise the heating system at the same time. The German government provides funding for these combinations of measures as well. The funding provided covers up to 30 per cent of the optimisation expenses or a maximum of 25,000 euros.

The above scheme ran from 2016 to the end of 2020. From January 1, 2021 the Federal Ministry for Economic Affairs and Energy (BMWi) promotes the hydraulic balancing of the heating system including the setting of the heating curve, the replacement of heating pumps as well as the adjustment of the flow temperature and the pump output as well as measures to lower the return temperature in building networks as a single measure in Framework of federal funding for efficient buildings (BEG).

Austria: Wohnbaufoerderung

The Wohnbaufoerderung is an incentives programme applied in the Austrian regions to promote energy savings in households. In the case of heating subsidies are offered for the replacement of fossil fuel heating systems with renewable heating systems. For example, the Tyrol offers a €3000 bonus for the replacement of old heating systems or boilers based on fossil fuels (Oil, gas, coal) with highly efficient alternative systems (e.g. heat pumps, biomass, district heating from 80% renewable energies).[47]

[47] https://www.tirol.gv.at/bauen-wohnen/wohnbaufoerderung/

1.4.4 Initiatives and measures that are applicable to space cooling

Ecodesign/ELR requirements

The following Ecodesign and energy labelling requirements apply to space cooling and related products.

Air conditioners and comfort fans

Commission regulation (EU) No 206/2012 of 6 March 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for air conditioners and comfort fans. OJ L 72, 10.3.2012

Commission Delegated Regulation (EU) No 626/2011 of 4 May 2011 supplementing Directive 2010/30/EU of European Parliament and of the Council with regard to energy labelling of air conditioners OJ L 178, 6.7.2011

Chillers, other packaged AC systems and fan coil units

Commission Regulation (EU) 2016/2281 of 30 November 2016 implementing Directive 2009/125/EC of the European Parliament and of the Council establishing a framework for the setting of Ecodesign requirements for energy-related products, with regard to Ecodesign requirements for air heating products, cooling products, high temperature process chillers and fan coil units OJ L 346 of 20 December 2016

Circulation pumps

Commission Regulation (EC) No 641/2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to Ecodesign requirements for glandless standalone circulators and glandless circulators integrated in products OJ L 191, 23.7.2009

Commission Regulation (EU) No 622/2012 of 11 July 2012 amending Regulation (EC) No 641/2009 with regard to Ecodesign requirements for glandless standalone circulators and glandless circulators integrated in products OJ L 180, 12.7.2012

EN standards

Table 14 links the cooling-related EN standards to the requirements defined in Article 8 and Article 15 that they target.

Other non-normative initiatives

Eurovent certification[48]

The industry association Eurovent offers a widely adopted set of voluntary energy performance certification programmes for cooling equipment, including some product types that are not covered by Ecodesign or labelling regulations. The full list is:

- Air Conditioners/Climatiseurs – AC
- CE marking flue pipes and free-standing chimneys – CE FP
- Chilled Beams – CB
- Chimneys and ducts – QB 40

[48] https://www.eurovent-certification.com/en/certification-programmes

Table 14: Links between cooling-related EN standards and Article 8 & 15 provisions.

EN	Overall energy performance (Art.8)	Proper installation (Art.8)	Adjustment & control (Art.8)	Appropriate dimensioning (Art. 8)	BAC & monitor-ing (Art.15)	Assess-ment of generator efficiency (Art.15)	Inspection (Art.15)
EN 16798-3	x						
EN 16798-4	x						
EN 16798-6	x						
EN 16798-9	x						
EN 16798-10	x						
EN 16798-11	x			x			
EN 16798-12	x			x			
EN 16798-13	x					x	
EN 16798-15	x						
EN 16798-16	x						
EN 15316-2	x		x		x		
EN 15316-3	x						
EN 15232	x		x		x		
EN 15500-1	x		x		x		
EN 16798-17							x
CEN/TR 16798-18							x
EN-ISO 52016-1				x			

- Chimneys and metal linings – NF 460
- Clay/ceramic chimney products – NF 052
- Domestic appliance using liquid or solid fuels – NF 009
- Domestic solar water heaters – NF 441
- Fan Coil Units – FCU
- Heat Interface Unit – HIU
- Liquid-to-liquid Plate Heat Exchangers – LPHE
- Mobile liquid fuel heaters – NF 128
- Radiators – NF 047
- Rooftop – RT
- Solar Keymark V– SK
- Solar processes – QB 39

- Temporal variation of thermostatic heads – TV
- Thermostatic radiator valves – KEYTV
- Variable refrigerant flow – VRF

Example from Germany

Under the efficiency campaign "Deutschland macht's effizient" of the German Federal Ministry for Economic Affairs and Energy a QuickCheck is offered to estimate the efficiency of cooling systems[49].

1.4.5 Initiatives and measures that are applicable to ventilation

Ecodesign/ELR requirements

The following Ecodesign and energy labelling requirements apply to ventilation units and related products.

Ventilation units

Commission Regulation (EU) No 1253/2014 of 7 July 2014 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for ventilation units. OJ L 337, 25.11.2014

Commission Delegated Regulation (EU) No 1254/2014 of 11 July 2014 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of residential ventilation units. Text with EEA relevance. OJ L 337, 25.11.2014

Fans

Commission regulation (EU) No 327/2011 of 30 March 2011implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for fans driven by motors with an electric input power between 125 W and 500 kW OJ L90, 6.4.2011

Air conditioners and comfort fans

Commission regulation (EU) No 206/2012 of 6 March 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for air conditioners and comfort fans. OJ L 72, 10.3.2012

Commission Delegated Regulation (EU) No 626/2011 of 4 May 2011 supplementing Directive 2010/30/EU of European Parliament and of the Council with regard to energy labelling of air conditioners OJ L 178, 6.7.2011

EN standards

Table 15 links the ventilation-related EN standards to the requirements defined in Article 8 and Article 15 that they target.

[49] https://www.deutschland-machts-effizient.de/KAENEF/Quickcheck/Kaelteerzeugung/Navigation/quickcheck-kaelteerzeugung.html

Table 15: Links between ventilation-related EN standards and Article 8 & 15 provisions.

EN	Overall energy performance (Art.8)	Proper installation (Art.8)	Adjustment & control (Art.8)	Appropriate dimensioning (Art. 8)	BAC & monitoring (Art.15)	Inspection (Art.15)
EN 16798-1	x			x		
EN 16798-3	x					
EN 16798-5	x					
EN 16798-7	x					
EN 15665				x		
EN 15780						x
EN 15232	x		x		x	
EN 15251				x		
EN 15500-1	x		x		x	
EN 16798-17						x
CEN/TR 14788				x		
EN 1886		x				x
EN 306		x				x
EN 13053		x		x		x
CEN/TR 16798-18						x

Other non-normative initiatives

A number of voluntary certifications of ventilation product performance exist at European or national levels.

The improvement of existing ventilations is furthermore also the subject of a variety of national grand and subsidy programmes.

At the European level, the Eurovent Certified Performance brand covers air handling units, ventilation ducts, heat exchangers and filters.

Examples from Germany

As part of the Climate Protection Programme 2030, the Federal German Government will extend the promotion energy-efficient ventilation systems under the new BEG-Program which will start on 01.07.2021.

In addition to the Labelling Regulation No 1254/2014 for residential ventilation units the German Manufacturers Association Air Handling Units (Herstellerverband Raumlufttechnischer Geräte e.V.) has developed a label for ventilation units, which is based on DIN EN 13053 and RLT-Richtlinie 01. The label specifies three classes A+, A and B. The label considers the air velocity, fan efficiency and the quality of heat recovery.

Although that label surely has an impact to improve the ventilation efficiency, it must be stated that it just addresses the ventilation unit itself but not the system performance.

Under the efficiency campaign "Deutschland macht's effizient" of the German Federal Ministry for Economic Affairs and Energy a QuickCheck is offered to estimate the efficiency of ventilation systems[50]:

1.4.6 Initiatives and measures that are applicable to BACS in existing buildings

Ecodesign/ELR requirements

Some Ecodesign/ELR heating products have BACS functions partially covered. As such for BACS there are not yet Ecodesign/ELR requirements. The preparatory work is ongoing and more details can be found in the preparatory study[51].

EN standards

Table 16 links the BACS-related EN standards to the requirements defined in Article 8 and Article 14 (15) that they target.

EN 15232 is an EPBD standard. The previous Activity 1 presented an overview of all the related BACS functional standards listed hereafter.

Table 16: Links between BACS-related EN standards and provisions in Articles 8 & 14/15 in the EPBD.

Control function		Standard
Automation and control		
HEATING, COOLING CONTROL, DOMESTIC HOT WATER		
	Emission control	EN 15500-1: 2017 EN 15316–2:2017, 7.2, 7.3 EN 15243:2007, 14.3.2.1 and Annex G EN 15316–2:2017, 6.5.1 EN ISO 52016-1 ISO 17772-1 (Annex G occupant schedules) EN 16798–1:2019
	Control of distribution network water temperature	EN 15316–2 EN 16798–9
	Control of distribution pump	EN 15316–3 EN 16798–9
	Intermittent control of emission and/or distribution	EN ISO 52016-1 EN 15316–3 EN 15243
	Interlock between heating and cooling control of emission and/or distribution	EN 15243

[50] https://www.deutschland-machts-effizient.de/KAENEF/Quickcheck/Raumluft/Navigation/quickcheck-raumluft.html

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

Control function		Standard
	Generation control and sequencing of generators	EN 15316–4–1 to EN 15316–4–5:2017, 7.4.6 EN 16798–9 EN 16798–13 EN 16947–1
	Thermal energy storage control	EN 15316 series EN 16798–15
	Hydronic balancing	ISO 52120-1
VENTILATION AND AIR-CONDITIONING CONTROL		
	Air-flow control at room level	EN 16798-7 EN 13779
	Air-flow or pressure control at air-handler level	EN 16798–5-1
	Heat exchanger defrost and overheating control	EN 16798–5-1
	Free mechanical cooling	EN 16798–13
	Supply temperature control	EN 16798–5-1
	Humidity control	EN 16798–5-1
LIGHTING CONTROL		EN 15193
	Combined light/blind/HVAC control (also mentioned below)	None
BLIND CONTROL		EN ISO 52016-1
Home automation/Building automation and controls		
Centralised adaptation of the home and building automation system to user needs, e.g. time schedule, set-points, etc.		EN 16947 series
Set-point management		EN 16947 series
Run-time management		EN 16947 series
Local energy production and renewable energies		EN 16947 series EN ISO 52016 IEC TS 62950: 2017
Waste heat recovery and heat shifting EN 16947 series		EN 16947 series

Abbreviations: BACS = building automation control systems.

Apart from the EPB standard CEN TC 247 has also developed other relevant European BACS standards, including:

- product standards for electronic control equipment in the field of HVAC applications (e.g. EN 15500) 19 | P a g e Savings with Building Automation Technology
- EN ISO 16484 is a series of 5 standards related to Building automation and control systems (BACS). ISO 16484-1:2010 specifies guiding principles for project design and implementation and for the integration of other systems into the building automation and control systems (BACS). ISO 16484- 2:2004 specifies the requirements for the hardware to perform the tasks within a building automation and control system (BACS). It provides the terms, definitions and abbreviations for the understanding of ISO 16484-2 and ISO

16484-3. ISO 16484-2:2004 relates only to physical items/devices, i.e. devices for management functions, operator stations and other human system interface devices; controllers, automation stations and application specific controllers; field devices and their interfaces; cabling and interconnection of devices; engineering and commissioning tools. ISO 16484-3:2005 specifies the requirements for the overall functionality and engineering services to achieve building automation and control systems. It defines terms, which shall be used for specifications and it gives guidelines for the functional documentation of project/application specific systems. It provides a sample template for documentation of plant/application specific functions, called BACS points list. ISO 16484-5:2007 defines data communication services and protocols for computer equipment used for monitoring and control of heating, ventilation, air-conditioning and refrigeration (HVAC&R) and other building systems. It defines, in addition, an abstract, object-oriented representation of information communicated between such equipment, thereby facilitating the application and use of digital control technology in buildings. ISO 16484-6:2009 defines a standard method for verifying that an implementation of the BACnet protocol provides each capability claimed in its Protocol Implementation Conformance Statement (PICS) in conformance with the BACnet standard.

- CEN/TS 15810 (Technical Specification) specifies graphical symbols for use on integrated building automation equipment.

Also, CENELEC CLC/TC 205 on 'Home and Building Electronic Systems (HBES)' produced the EN 50491 series "*General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS)*", and notably EN 50491-11 "*Smart metering. Application specifications. Simple external consumer display*" and has also launched a new work item on IoT Semantic Ontology Model Description (prEN 50090-6-2). Moreover, CLC/TC 205 is working on data modelling in the standard series EN 60491.

Furthermore, the work of ISO/TC 301 complements this with broader energy management practice and procedures which are addressed through the standard EN ISO 50001: 2011.

Other non-normative initiatives

In Germany a free online tool is available to assist the assessment of the BACS performance class (A, B, C, D) of the BACS in your building according to the EN 15232 functions[52].

Eu.bac has a building certification scheme[53] which provides certification for products and an audit to provide an Energy Efficiency Label for Building Automation Systems in line with the EN 15232 classes (A, B, C, D). The eu.bac certification and audit scheme is much more elaborated compared to the content of EN 15232 and includes publication of a series of books with more detailed requirements; for example, it contains more detailed requirements for Key Performance Indicators[54].

[52] https://gei.igt-institut.de/

[53] https://www.eubac.org/certification-labelling-audits/index.html

[54] https://www.eubac.org/system-audits/faq/index.html

1.4.7 Initiatives and measures that are applicable to lighting systems in existing buildings

Ecodesign/ELR requirements

The following Ecodesign and energy labelling requirements apply to lighting products.

Commission Regulation (EC) No 244/2009 of 18 March 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to Ecodesign requirements for non-directional household lamps. OJ L 76, 24.3.2009

Commission Regulation (EC) No 859/2009 of 18 September 2009 amending Regulation (EC) No 244/2009 as regards the Ecodesign requirements on ultraviolet radiation of non-directional household lamps. OJ L 247, 19.9.2009

Commission Regulation (EU) 2015/1428 of 25 August 2015 amending Commission Regulation (EC) No 244/2009 with regard to Ecodesign requirements for non-directional household lamps and Commission Regulation (EC) No 245/2009 with regard to Ecodesign requirements for fluorescent lamps without integrated ballast, for high intensity discharge lamps, and for ballasts and luminaires able to operate such lamps and repealing Directive 2000/55/EC of the European Parliament and of the Council and Commission Regulation (EU) No 1194/2012 with regard to Ecodesign requirements for directional lamps, light emitting diode lamps and related equipment. OJ L 224, 27.8.2015

Commission Regulation (EU) No 1194/2012 of 12 December 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for directional lamps, light emitting diode lamps and related equipment. OJ L 342, 14.12.2012

Commission regulation (EC) No 245/2009 of 18 March 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to Ecodesign requirements for fluorescent lamps without integrated ballast, for high intensity discharge lamps, and for ballasts and luminaires able to operate such lamps, and repealing Directive 2000/55/EC of the European Parliament and of the Council. OJ L76, 24.3.2009

Commission Regulation (EU) No 347/2010 of 21 April 2010 amending Commission Regulation (EC) No 245/2009 as regards the Ecodesign requirements for fluorescent lamps without integrated ballast, for high intensity discharge lamps, and for ballasts and luminaires able to operate such lamps. OJ L 104, 24.4.2010

Commission Delegated Regulation (EU) No 874/2012 of 12 July 2012 supplementing Directive 2010/30/EU of European Parliament and of the Council with regard to energy labelling of electrical lamps and luminaires. OJ L 258, 26.9.2012

Note that for Ecodesign on lighting systems a preparatory study has been completed[55] but so far no policy was elaborated for this, part of the policy recommendations that relate to installed lighting systems can be applied here in the EPBD.

EN standards

See discussion in section 1.3.5.

[55] Welcome | Lot 37 Ecodesign Lighting Systems (ecodesign-lightingsystems.eu)

Other non-normative initiatives

Some countries provide subsidies for relighting and they all have their own scaling methods and/or requirements to compute the level of financial support. For example, in the Netherlands there are tax incentives for investments in relighting in the form of allowing accelerated depreciations of investments wherein depreciations are capped per new presence or light sensor (max. 150 euro/item) or per efficient LED luminaire (max. 1000 euro/luminaire). In Belgium (Flanders) SMEs can receive a direct subsidy for new lighting installations paid out by the distribution system operator[56] which is relative to the energy savings obtained and requires a full lighting design.

It should be mentioned here also that indoor lighting design that satisfies the performance requirements of EN 12464 is usually done with lighting design software (DIALux (free), RELUX (free), LITESTAR 4D, etc.) which calculates the necessary EN 15193 metrics and has product databases inside to assess system performance. The software is often free for lighting designers and the luminaire manufacturers pay to feed their products into the databases provided with the software.

1.4.8 Initiatives and measures that are applicable to RES retrofitted on existing buildings

Ecodesign/ELR requirements

The Energy Label for water heaters (Commission Regulation N° 812/2013)

This includes already labels for packages of water heater and solar thermal devices.

Building Integrated (BIPV) or Building Attached (BAPV) Photovoltaics system requirements

Detailed information on retrofitting photovoltaic installations on existing buildings can extensively be found in the recently completed Ecodesign Study on photovoltaic systems[57], but much of the recommended policy in Task 8 policy recommendations at system level will also apply here (i.e. recommendations 2 to 4). It is also expected that much of the BAPV/BIPV will be retrofitted with Battery Energy Storage Systems (BESS)[58], this is a relative new domain. Good practice guidelines can be sourced from new initiatives such as the BVES efficiency guideline for BESS[59] and the recommendations from the Ecodesign Study for Batteries**Error! Bookmark not defined.** for what matters l ife-time, recycling and carbon footprint reporting guidelines.

EN standards

The EPBD EN 15316-4-3 standard on "*Method for calculation of system energy requirements and system efficiencies: Heat generation systems, thermal solar and photovoltaic systems*" provides already a simple methodology to estimate the energy yield of building integrated PV system. Nevertheless, for assessing photovoltaic system performance the standard EN 61724-1:2017 on '*Photovoltaic system performance –*

[56] https://www.fluvius.be/sites/fluvius/files/2020-12/e1-0010-21-relighting-ondernemingen-lokale-besturen-premie-2021-informatieblad-fluvius.pdf

[57] https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/2020-12/jrc12431preparatory_study_for_solar_photovoltaic_modules_kj-na-30468-en.pdf

[58] https://ecodesignbatteries.eu/documents

[59] https://www.bves.de/effizienzleitfaden_3_2019/

Part 1: Monitoring' gives a more detailed approach, it is intended to provide a common post-installation verification standard to perform contractual tests such as the capacity test (EN 61724-1) and the annual energy test (EN 61724-3). In that series EN 61724-3 defines steps to report the actual measured energy, outlining the required steps to report the actual annual energy generation and can therefore be utilised as a consistent measure of the system output.

The standard EN 62446-1 on "Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 1: Grid connected systems - Documentation, commissioning tests and inspection" contains the information and documentation that should be provided to the customer when the PV grid system is installed, and the requirements of inspection and testing that should be done during the system lifetime in order to verify the safe installation and correct operation of the system.

What is not included in EN standards is a prediction method for the reference energy yield (Yr) which is location and climate dependent.

Other non-normative initiatives

Despite the previous standards, what is often still missing at the photovoltaic system design stage is an accurate energy yield forecast which is location and climate dependent, that allows to forecast accurately the Performance Ratio (EN 61724-1). For that purpose, the EC offers a free Photovoltaic Geographical Information System (PVGIS[60]) that can be used for that purpose. It provides time series of hourly values of both solar radiation and PV performance. Apart from this there is also dedicated commercial photovoltaic system design software[61] on the market or it can also be included in the building energy monitoring software[62], [63]. These tools often contain product databases and allow for example also to take into account shading effect in to the Performance Ration (PR) calculations. The calculation of the Performance Ratio(PR) is however not entirely harmonised, which means that installers can be creative in selecting different approaches and software tools. Normally these calculations are important part of the tendering process, but when different tenderers used different calculation approaches there is no fair comparison possible between quotes. Hereby also, a good designer will model accurate the pessimistic Performance Ratio (PR), but if it is not recognized by the procurer he might risk loosing the tender.. This is an issue that can benefit from further new policy and/or standardisation[57] and create a fair level of playing field between installers and increase the trust from building owners to invest in PV.

After installation, real weather conditions however vary and therefore to evaluate the performance of a specific PV system one could monitor on site the in-plane solar radiation with a solarimeter (EN 61724-1). Nevertheless, this is expensive and therefore

[60] https://ec.europa.eu/jrc/en/pvgis

[61] https://www.pvsyst.com/

[62] https://knowledge.autodesk.com/search-result/caas/simplecontent/content/evaluating-pv-potential-revit.html

[63] https://www.energiesparen.be/EPB-pedia/EPB-software/3G

alternatively it can be estimated from a weather station[64],[65] or more accurately it can be sourced from commercial webservices that offer such data[66],[67].

To predict the solar power output also the reference yield (Yr) is needed which can be useful for demand response to increase self-consumption. In this case the webservices should also provide you with weather forecast data.

1.5 Activity 3: Identification of good practices

This section presents a short set of good practices identified among measures adopted and implemented by Member States that stimulate the deployment and optimisation of TBS in line with the provisions in Articles 8, 14 and 15 of the EPBD.

1.5.1 Space heating and DHW

Inspection requirements in Belgium

The 3 regions in Belgium have adopted requirements for the inspection of central heating systems powered by a boiler on gaseous, liquid or solid fuel.

For instance, the Flemish region has developed three types of inspections: inspection before first utilisation, maintenance and heating audit. Each of these inspection types has a specific periodicity and application scope. Table 17 summarises the different inspections.

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[64] https://www.dwd.de/EN/ourservices/solarenergy/solarenergy.html

[65] https://weerlive.nl/delen.php

[66] https://solarwebservices.ch/

[67] https://solardata.3e.eu/

Table 17: Implementation of the inspection requirements by the Flemish region in Belgium.

Type of inspection	Fuel	Nominal power	When?	What?	By whom?*
Inspection before first utilisation	Gaseous	All	Before using a new or modifier boiler (e.g. replaced burner, modified chimney)	Thorough inspection of several safety aspects and proper functioning of the boiler as defined by law, including adjustment of the boiler when deemed necessary.	RTG
	Liquid				RTL
	Solid				SC
Maintenance	Gaseous	≥ 20 kW	At least every two years		RTG
	Liquid		At least each year		RTL
	Solid	All			SC
Heating audit	Gaseous	≥ 20 kW and ≤ 100 kW	At least every five years	Inspection of the entire heating system by means of specialised software, provided by the government, in order to determine energy-saving methods. By using this software, the energy efficiency of the entire heating installation is estimated.	RTG
		>100 kW	At least every four years		RTH
	Liquid	≥ 20 kW and ≤ 100 kW	At least every five years		RTL
		>100 kW	At least every five years		RTH
	Solid	All	At least every five years		RTH

* Abbreviations: RTG (recognised technician gaseous fuel), RTL (recognised technician liquid fuel), RTH (recognised technician heating audit), SC (skilled craftsman).

Inspection requirements in France

France has adopted requirements for periodic inspections for boilers and reversible heat pumps: For boilers of between 4 and 400 kW, annual maintenance visits are required. For boilers larger than 400 kW 2-yearly inspection visits are required and for reversible heat pumps larger than 12 kW, inspections are required every 5 years.

Normative requirements in Portugal

Since 2014, it is mandatory for non-residential buildings to have energy consumption monitoring of heating ventilation and AC systems equipment with an electric power above 25 kW. The same happens for boilers with a thermal power above 100 kW. Buildings with a thermal power above 25 kW must have an installation and maintenance technician (TIM) that guarantees proper system installation and maintenance. This technician must also supervise these specific activities and manage all relevant technical information. One of their tasks is to promote the installation of energy metering systems in the buildings.

Documentation requirements in Italy

Designers of new heating systems and energy distributors are obliged to provide the documentation of both new heating systems and grid connected clients to the region; this facilitates the control of compulsory maintenance of the systems by the users. Regions are also responsible for the selection and qualification of the inspectors and for the organisation of annual campaigns for the compliance control of inspection reports.

Normative requirements in Germany

Several requirements address the performance of technical building systems in existing buildings. The following requirements have to be met, even without the "trigger" of a relevant modernisation.

- Water-based central heating systems have to be equipped with controls that adjust the temperature of the heating medium based on time and outside temperature, and which shut down circulating pumps accordingly; there are exemptions.
- Water-based central heating systems must be equipped with room-temperature controls; there are exemptions for small rooms with floor heating, old floor heating and for non-residential buildings, where rooms of similar type and use may share controls.

The following requirements must be met in case of relevant changes to the system.

- Circulation pumps in water-based heating systems with more than 25 kW heat output must be controlled automatically; there are exemptions.
- Circulation pumps in domestic hot water systems must have a time-control.

Normative requirements in the UK

The UK sets system efficiency requirements for heating systems for both new TBS installations (which includes new build, major renovation and replacement of systems in existing buildings cases) and retrofits of existing TBSs.

New installations of the predominant case of gas-fired combination heating/hot water systems in both new and existing dwellings[68] must satisfy minimum energy performance standards for:

- boiler efficiency, system circulation, hot water storage, system preparation and commissioning
- boiler interlock, zoning, and time temperature control of the heating and hot water circuits
- pipework insulation.

1.5.2 Space cooling

Austria: space cooling demand

Space cooling energy demand in major renovations of non-residential buildings must not exceed an average of 2 kWh/m^2/year.

Denmark: design, sizing, control, operation and metering requirements[69]

Heating and cooling systems must be sized, designed, controlled and operated as specified in the Danish Standard DS 469 "Varme - og køleanlæg I bygninger" ("Heating

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68 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/697525/DBSCG_secure.pdf

69 https://bygningsreglementet.dk/Tekniske-bestemmelser/19/Vejledninger/Termisk-indeklima/Kap-2_0#:~:text=DS%20469%20omfatter%20alle%20typer,for%20v%C3%A6kst%20af%20legionella%20minimeres.&text=DS%20439%20Norm%20for%20vandinstallationer.

and cooling systems in buildings”), which has different functional requirements for the commissioning of heating and cooling systems as well as additional requirements for use, operation and maintenance. All technical building systems must be insulated as required by DS 452 “Termisk isolering af tekniske installationer” (“Thermal insulation of technical installations”). Heat pumps/cooling plants must have individual energy meters if their annual consumption exceeds 3000kWh.

DS 452 must be observed to minimise heat loss and protect the installations from condensation. Pipes and containers should, as far as possible, be placed so that the heat dissipation from them benefits the building.

Germany: heat recovery requirements

AC systems with more than 12 kW output and ventilation systems with more than 4,000 m^3/h supply air must meet the following requirements in case of first-time installation and major changes:

- the specific fan power (SFP) value may not exceed class SFP 4 (EN 13779: 2007)
- the air-flow must be controlled automatically according to thermal and sensible load if thehourly flow exceeds 9 m^3/m^2; there are exemptions
- the systems must be equipped with heat recovery units of class H3 (EN 13053: 2007) or better.

Italy: temperature thresholds, logbooks and energy efficiency

Presidential Decree 74/2013 on heating/cooling systems lays down a set of obligations and criteria applicable to public and private buildings. They apply to most building uses and include ambient temperature limits for cooling (the weighted average air temperature measured in each cooled space must not be below 26°C - 2°C tolerance in all buildings). The Ministry of Economic Development (MISE) set up a template for a heating or cooling system logbook and another for an energy efficiency report, and asked the Italian Thermotechnical Committee (CTI) to publicise examples for the most common types of systems to facilitate and standardise completion of the log-books and energy efficiency reports. In the case of major and minor renovations, performance of the technical systems must comply with mandatory limit values.

Portugal: chiller efficiency limits

New chiller installations in any building need to satisfy the Eurovent Label B performance level, e.g. COP $\geq$ 3.0 W/W; EER $\geq$2.9 W/W.

Scotland: chiller efficiency limits

New vapour compression space cooling water-cooled chiller installations of >750 kW in any building need to satisfy EER $\geq$4.7 W/W.

1.5.3 Ventilation

A variety of member states have already implemented effective requirements. In the following the most relevant are listed.

Limitation of the specific fan power (P_{SFP})

Specification of minimum requirements on the P_{SFP} is an effective overall energy performance requirement to limit the fan electricity power of a ventilation system. An P_{SFP} requirement is in force in Poland, Finland, Germany, Portugal and UK. The P_{SFP} - thresholds are in the most cases dependant from the type of ventilation system and refer to operation design conditions. In all cases the regulation accounts for new and existing buildings, but for different trigger points and size limitations. Although a requirement independent of size and trigger is theoretically most effective, cost effectiveness and surveillance aspects should be considered.

Minimum requirements on controls

Minimum requirements on controls are set in France and Germany. While Germany requires an automatically controlled air flow according to thermal and sensible load for larger ventilation systems[70], France requires for ventilation systems in non-residential buildings the control to be dependent on occupancy or time. Both (occupancy and thermal load) are important parameters. In both countries first-time installation or replacement is the trigger for the regulation. Although the two countries have specified further requirements on controls (such as requirements for devices for manually changing the airflow rates or humidification control) the first mentioned are assumed to be the most effective ones.

Minimum heat recovery efficiency

The minimum heat recovery efficiency for new ventilation units is already specified in Ecodesign Regulation 1253/2014. Therefore, only requirements, which go beyond the requirement of the Ecodesign regulation will have a measurable impact.

That is fulfilled when:

i) the requirement is higher, or

ii) it is a requirement for an existing system (which would not necessarily require a new ventilation unit), or

iii) the requirement covers systems that are not covered by the Ecodesign regulation (e.g. individually designed ventilation systems, which are assembled from individual components (fans, heat exchangers, filters).

Germany, Finland, UK, Belgium and Estonia have set minimum requirements on heat recovery efficiency. UK (England) and Estonia have set a higher requirement than the Ecodesign requirement[71] for non-residential buildings. In all cases the regulation accounts for new and existing buildings, but for different trigger points and size limitations. Although a requirement independent of size and trigger is theoretically most effective, cost effectiveness and surveillance aspects should be considered (see Germany and Finland, Table 6).

1.5.4 BACS for existing buildings

Good examples identified to date include the requirements adopted in the Netherlands and France, which:

[70] design capacity of >4000 m^3/h

[71] Minimum efficiency of 70 %

- require an energy monitoring system for large non-residential buildings (>1000 m²) to provide input to an EPC database (function 7.4 out of EN 15232). Note that the Ecodesign BACS study[72] recommended to have a more detailed requirement as the very generic one which is currently part of EN 15232.
- require a minimum class C or B combability for a selected set of functions out of EN 15232, for example those listed in Table 7. Note also the Ecodesign BACS study proposed detailed minimum BACS product policy requirements which could complement these installation requirements.
- Also, it can be useful to have backstop policy requirements on installed TBS and BACS to warrant that the minimum functionalities are properly installed and activated, a good example was found in the Irish implementation of Art. 8.
- More detailed BACS requirements are proposed in the eu.bac certification scheme, in particular those for Key Performance Indicators to be used in BEMS could be relevant for larger buildings.

1.5.5 Lighting systems for existing buildings

Good practice for dedicated lighting system requirements can build on the Spanish requirements (see section 1.3.6).

1.5.6 RES

A good practice adopted in Spain is to require the retrofit of solar thermal energy for DHW in existing DHW systems (see section 1.3.7).

For photovoltaics, system requirements are proposed in the related Ecodesign Study on Photovoltaic Systems[73] and therefore requirements could build on these. For the future it is expected that many installations will be retrofitted with batteries, this is relatively new and data should be sourced from new initiatives. Good practice guidelines can be sourced from new initiatives such as the BVES efficiency guideline for BESS[74] and the recommendations from the Ecodesign Study for Batteries[75] with regard to life-time, recycling and carbon footprint reporting guidelines. In Germany a working group from the VDE Battery committee, DKE/AK 371.0.9, is active in creating a nameplate standard for stationary batteries to show their characteristic values[76].

1.6 Activity 4: Estimation of potential impacts

This section provides an overview of the energy saving potentials for the different technical building systems. The potentials are determined based on data provided in the literature. In cases where information was lacking qualified estimations are made. Where necessary simple calculations, but not sophisticated modelling, is performed.

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

[73] https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/2020-12/jrc12431preparatory_study_for_solar_photovoltaic_modules_kj-na-30468-en.pdf

[74] https://www.bves.de/effizienzleitfaden_3_2019/

[75] https://ecodesignbatteries.eu/documents

[76] https://www.dke.de/de/ueber-uns/dke-organisation-auftrag/dke-fachbereiche/dke-gremium?id=3007512&type=dke%7Cgremium

Initially, a baseline of the energy consumption per technical building system is determined. Dependant on the quality of data collected the origin of the consumption is broken down into at least the most crucial parameters necessary to characterise it such as the building- and systems-type and systems size.

In the second step, for every technical building system the potential savings of different measures/ requirements reported in the literature are summarised and assessed.

Based on this the potential impacts of individual measures/requirements are calculated considering the expected underlying developments regarding demolition and replacement of existing systems as well as additional new systems. As minimum quality for new or replaced systems is specified by the Ecodesign requirements, the savings accounted within the scope of this examination are only those, which go beyond the business-as-usual replacement cycles and new installations fulfilling Ecodesign requirements. The results of the detailed calculations are fed into the rankings used to determine the potential requirements presented in section 2. They are also available in an accompanying spreadsheet as discussed in section 2. The overall energy consumption impacts are now reported for each TBS in this section, while the savings associated with specific TBS measure recommendations are reported in section 2.

1.6.1 Space heating and domestic hot water

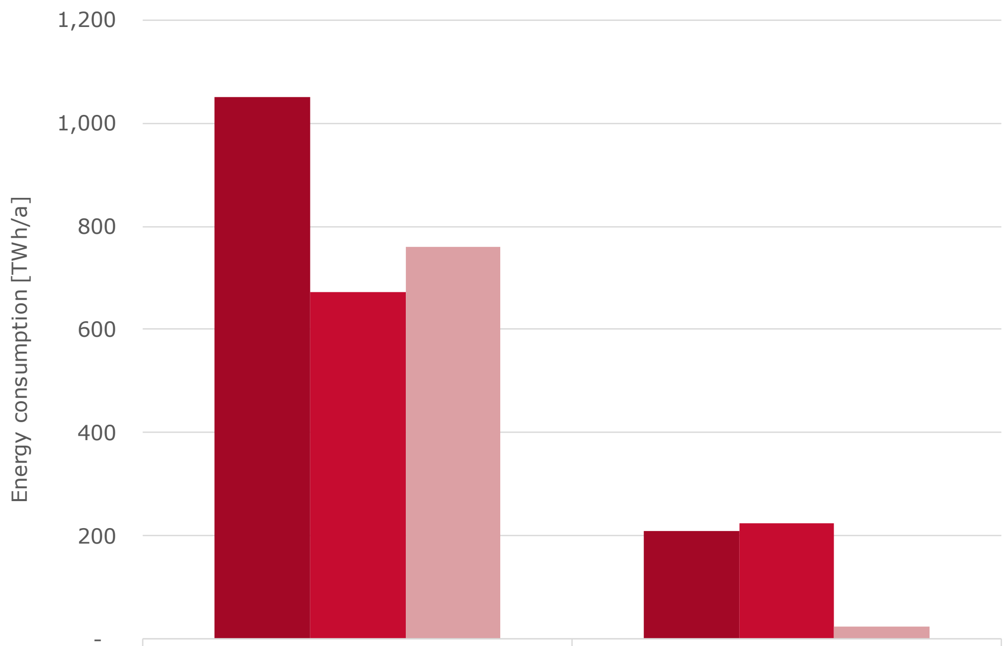
Heating and DHW EU energy consumption

Figure 3 shows the overall European energy consumption for space heating and DHW based on EU statistics[77] and the last EPBD Impact Assessment.[78] The total EU **final energy consumption** for heating and DHW in buildings is approximately **2939 TWh** per year, of which about 75% is for residential and 25% non-residential buildings. This provides a solid basis to make high level savings estimates of specific TBS measures in the following discussion.

Figure 4 shows the primary energy consumption shares per energy carrier in the EU residential building stock according to EU statistics.

[77] Eurostat - Questionnaire for statistics on final energy consumption in households; https://ec.europa.eu/eurostat/de/web/products-eurostat-news/-/DDN-20200626-1#:~:text=In%202018%2C%20households%20accounted%20for,and%20derived%20heat%20(8.7%25).

[78] European Commission (EC) (2016): Commission Staff Working Document - Impact Assessment. Accompanying the document: Proposal for a Directive of the European Parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings. Brussels (SWD(2016) 414 final).



	Heating	DHW
Small (SFH)	1,051	208
Medium (MFH)	672	225
Large (Non-residential)	759	24

Figure 3: Heating and DHW final energy consumption (TWh/annum) in the EU building stock per building type in 2018.

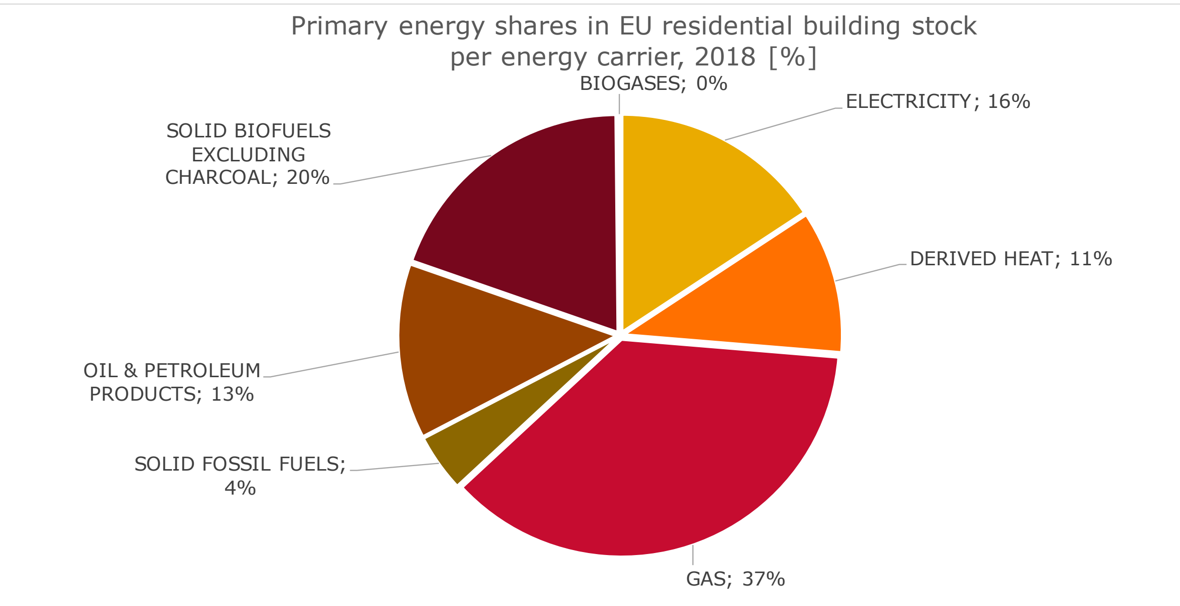


Figure 4: Primary energy consumption shares (%) in the EU residential building stock per energy carrier for 2018.

These energy carrier shares (with an average primary energy factor of 1.09) and the above-mentioned total EU final energy consumption for heating and DHW in buildings of about 2939 TWh leads to a total **primary energy consumption** figure for heating and DHW in buildings of about **3203 TWh** per year.

Estimation of potential impacts

Table 18 shows the result of a literature review on the savings potential by heating and DHW technical building systems in order to determine an order of magnitude for the overall EU27 savings potential.

Table 18: Comparison of literature on TBS savings potential for heating and DHW.

Study	Scope	Overall savings potential
Optimising the energy use of technical building systems, 2017[79]	Heating, cooling, DHW, ventilation, BACS, lighting	60–156 $MtCO_2$/year[80]
Energy and GHG emission savings potentials of thermostatic valves, 2016[81]	Heating (thermostatic valves only)	131 TWh_{final}/year[82] / 23 $MtCO_2$/year (11 EU countries only)
Erneutes Gutachten zur Umsetzung von Artikel 14 der Richtlinie über die Gesamtenergieeffizienz von Gebäuden (Heizungsinspektion), 2015[83]	Heating (heating inspections, Art. 14 EPBD)	0.4 $MtCO_2$/year (DE only, 2014–2016)
ICT impact study, 2020[84]	BACS (heating, DHW, cooling, ventilation, lighting)	1000 TWh_{final}/year[85]
Space and combination heaters. Ecodesign and Energy Labelling, 2019[86]	Heating	450 $TWh_{primary}$/year[87]/ 106 $MtCO_2$/year[88]

[79] Grözinger, Jan; Hermelink, Andreas; Manteuffel, Bernhard von; Waide, Paul (2017): Optimising the energy use of technical building systems. Unleashing the power of the EPBD's Article 8. Research report by order of Danfoss A/S. (Ecofys/Guidehouse).

[80] Annual carbon savings in 2030 (lower threshold: Get the basics right package; upper threshold: High performance package), **share of heating and DHW 85-100%** (non-residential to residential); average final energy savings potential of TBS packages over the investigated reference cases at appr. 30 % (including space heating, domestic hot water and auxiliary energy for residential buildings, and additionally ventilation, space cooling and lighting in non-residential buildings)

[81] Ecofys/Guidehouse (Ed.) (2016): Energy & GHG emission savings potentials of thermostatic valves. Final report. Report by order of EUnited Valves. B. von Manteuffel, M. Offermann, K. Bettgenhäuser.

[82] This corresponds to appr. 7 % annual final energy savings potential through radiator valves exchange for heating in residential buildings across the eleven countries investigated (DE, AT, FR, IT, CZ, ES, NL, PL, SE, UK, HU).

[83] Manteuffel, Bernhard von; Offermann, Markus; Jan Grözinger (2015): Erneutes Gutachten zur Umsetzung von Artikel 14 der Richtlinie über die Gesamtenergieeffizienz von Gebäuden (Heizungsinspektion). (BBSR-Online-Publikation, 03/2015).

[84] Maagøe, Viegand (2020): ICT impact study. Research report by order of European Commission. (VHK)

[85] Assuming a potential of 20% and 15% of the total building final energy consumption for non-residential and residential sectors, respectively, the total potential energy savings by full implementation of optimised Class A BACS in all buildings amount to about 1,000 TWh/year. Total energy consumption in buildings is approximately 6000 TWh/year (2017).

[86] van Holsteijn, Rob; Kemna, René; van Elburg, Martijn; Wierda; Leo (2019): *Space and combination heaters. Ecodesign and Energy Labelling.* Task 7 Scenarios (VHK).

[87] This saving derives from a shift in sales from lower-efficiency gas/oil products towards higher-efficiency hybrids, heat pumps, micro-CHPs and solar devices.

[88] This saving derives from replacing the natural gas – hydrogen mix by 100% hydrogen starting from 2040. To enable this saving, it should be made mandatory from 2025 for all gas-based space heating appliances to be H_2-ready.

The impact of the revision of the EPBD on energy savings from the use of building automation and controls, 2019[89]	BACS (heating, DHW , cooling, ventilation, lighting)	450 TWh_{final}/year

Abbreviation: BACS = building automation control systems; DHW = domestic hot water; TBS = technical building system.

Based on the above literature, an overall saving potential for EU27 of about **10–25%** seems realistic. In principle, this potential will decrease over time due to building demolitions and system and/or component replacements; however, on the other hand emerging technology opportunities may act to maintain or increase the magnitude of this savings potential.

1.6.2 Space cooling

Energy demand for space cooling

The energy consumption for space cooling is reported in different sources (mostly still referring to EU28[90]). The most elaborated and recent source seems to be the Ecodesign Impact Accounting Status report (2019) by VHK for the European Commission. According to that report the annual electricity consumption for space cooling amounts to 80 TWh (Figure 5). Of this, the largest share of 28% is accounted for by large and medium chillers, followed by RAC (26%), small chillers (16%) and other split units (14%).

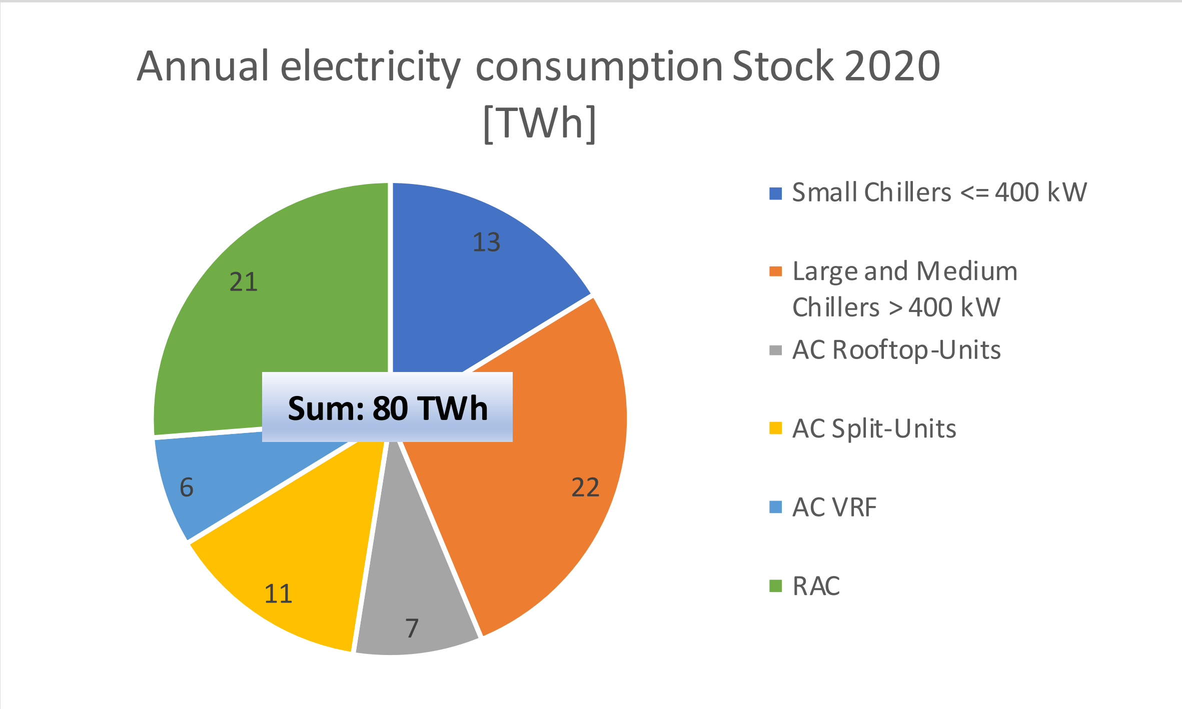


Figure 5: Space cooling final energy consumption (TWh/annum) in the EU 28 building stock per system type.

[89] Waide, Paul (2019): *The impact of the revision of the EPBD on energy savings from the use of building automation and controls* (Waide Strategic Efficiency Limited).

[90] Remark: The share of space cooling demand of UK on the EU28 demand is comparably small (<5%).

With a primary energy factor for electricity of 1.97[91] the total primary energy demand for space cooling in buildings amounts to 158 TWh/annum in 2020.

Data on the split between residential and non-residential consumption is obtained via the report *heat roadmap Europe* report (2018)[92]. According to that source the energy consumption of space cooling in non-residential buildings far outweighs the space cooling consumption in residential buildings (by 74% vs 26%) (Figure 6).

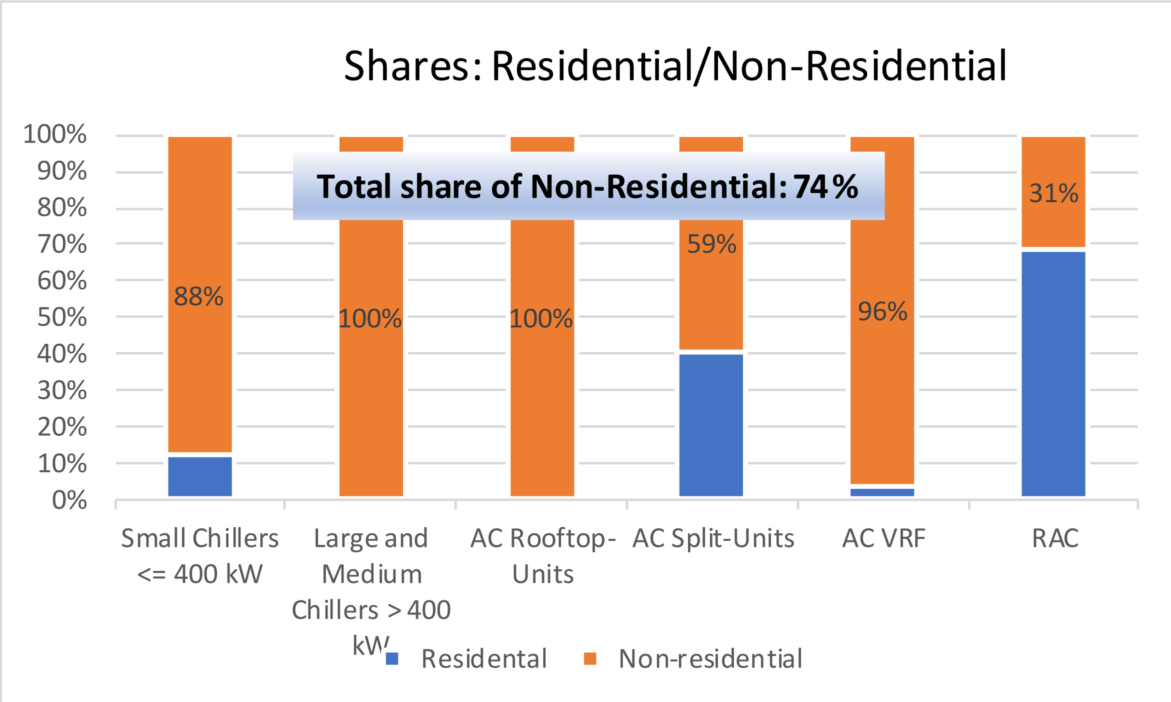


Figure 6: Share of space cooling energy consumption (TWh/annum) in the EU building stock per building and system type.

Whereas chillers are the most common cooling generator technology used in non-residential buildings; for residential buildings split units are the predominant technology.

Estimation of potential impacts

Measured saving potentials from the application of individual energy savings measures for space cooling systems are reported in the iSERVcmb Final Report 2014[93]. This report also provides the applicable occurrence frequency of those measures within a sample of 330 buildings that were evaluated in-depth across the EU. The highest saving potential[94] is reported for night-time ventilation (9.3%) and switching off circulation pumps when not needed (5.5%)[95]. For "sequencing of heating and cooling" saving potentials of 3.8% and 2.7% for "modifying the respective controls" are reported. Further significant saving potentials were stated for "shutting off the chiller plants when not required" (3.3%) and

[91] Derived from: Eurostat (https://ec.europa.eu/eurostat/web/energy/data/shares) with an assumption of a linear decrease till 2050 to 1.

92 https://heatroadmap.eu/wp-content/uploads/2018/11/HRE4_D3.2.pdf

[93] http://www.iservcmb.info

[94] As product of the per measure saving potential and the proportion of the cooling system stock energy consumption it applies to

[95] That measure is a generic measure apparently also including DHW, and space heating circulation pumps.

the "installation of cool storage" (3%). It is important to note that these savings potentials are the product of the average savings achieved per measure and the average applicability of that measure for the whole EU building stock, and thus the savings potential values shown in brackets are the estimated average values for the entire EU building stock. Nonetheless, as these saving potentials are only reported for individual measures and not for packages, the overall saving potential will be less than the collective sum of 42%, because of overlapping effects with some of the specific measures.

Another source that identified energy saving potentials for space cooling systems is a study for the German Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR)[96] that was conducted in 2014. According to that study, which was based on a sample of 33 inspected space cooling systems in Germany, the overall saving potentials (including superposition) from applying inspection recommendations is 3.5% for operational system improvements. It estimated that an additional 5.3% saving could be achieved from exchanging components.

Based on these sources the overall saving potential from measures that improve space cooling system performance beyond the impact of Ecodesign and ELR measures is estimated to be in a range between 8% and 35% of total EU cooling energy consumption.

1.6.3 Ventilation

Ventilation EU energy consumption

The number of ventilation systems is derived from the preparatory review study of Ecodesign and labelling for ventilation units[97]. Based on the same source the total energy consumption for ventilation (electricity and heating) has been derived. The electricity demand is determined by qualified assumptions concerning the efficiency of electrical ventilation (for SPI (for RVUs) and SFP (for NRVUs)) and annual operating hours[98].

[96] https://www.irbnet.de/daten/rswb/14019025698.pdf

[97] https://www.ecoventilation-review.eu/downloads/Ventilation%20Units%20TASK%202%20Final%20Report%202020-09-10.pdf

[98] https://www.eup-network.de/fileadmin/user_upload/Produktgruppen/Lots/Working_Documents/Task_4_Lot_6_Ventilation_Final_Report.pdf

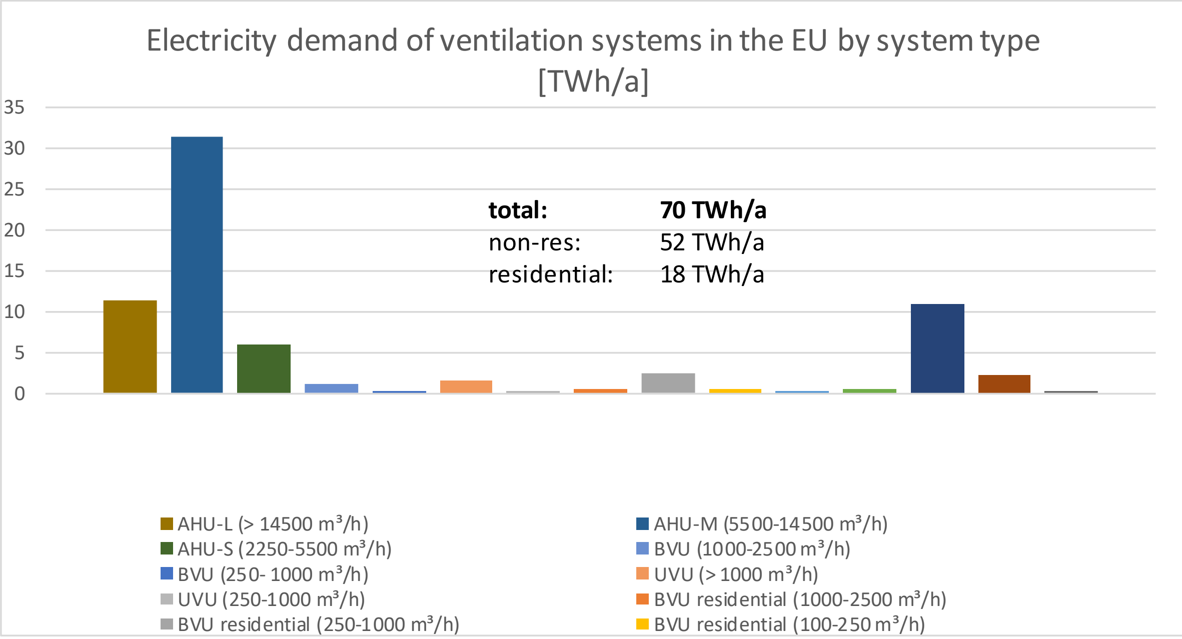


Figure 7: Ventilation electricity demand shares in the EU building stock per system type and size (TWh/annum)

The derived electricity demand, see Figure 7, is between the stated figures of the Ecodesign impact accounting status report 2019 (Eco-Scenario: 85 TWh/annum) and the Task 7 report of the preparatory review study of Ecodesign and labelling for ventilation units (42 TWh/annum).

With 74% of the total non-residential buildings have the highest share, of which 94% is attributed to air-handling units.

Figure 8 shows the required useful energy demand for ventilation heating of the supply air. The highest heating demands are observed for the unidirectional residential ventilation units (250–1000 m³/h) followed by the medium-sized air-handling units without heat recovery.

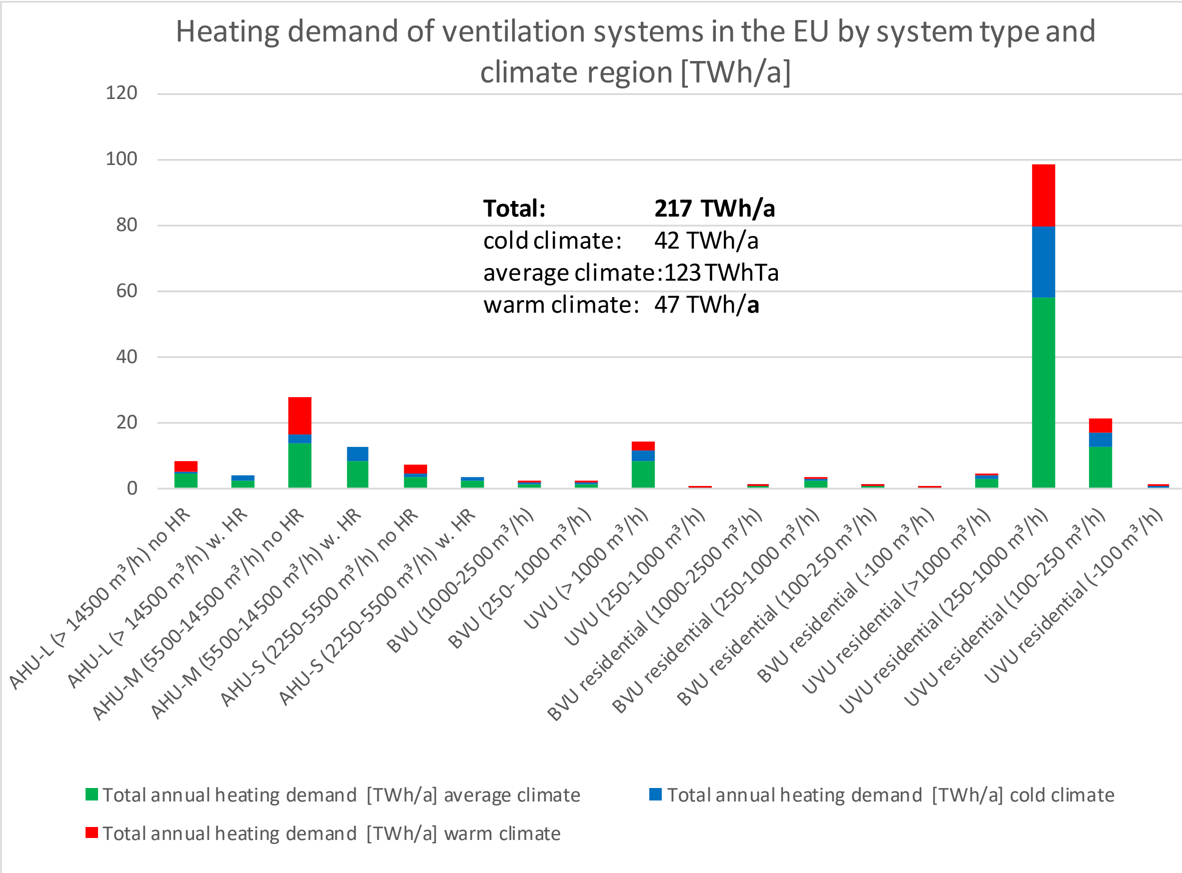


Figure 8: Shares of useful ventilation heating demand in EU building stock per system-, size- and climate-type (TWh/annum)

When assessing the climatic distribution of this consumption the average climate has the highest share at 57% of the total. Due to a lower share of heat recovery systems and the higher number of systems the ventilation heating demand for the warm climate is even a bit higher than the ventilation heating demand in cold climate regions.

The ventilation cooling and dehumidification demand (only air-handling units) is relatively low as shown in Figure 9.

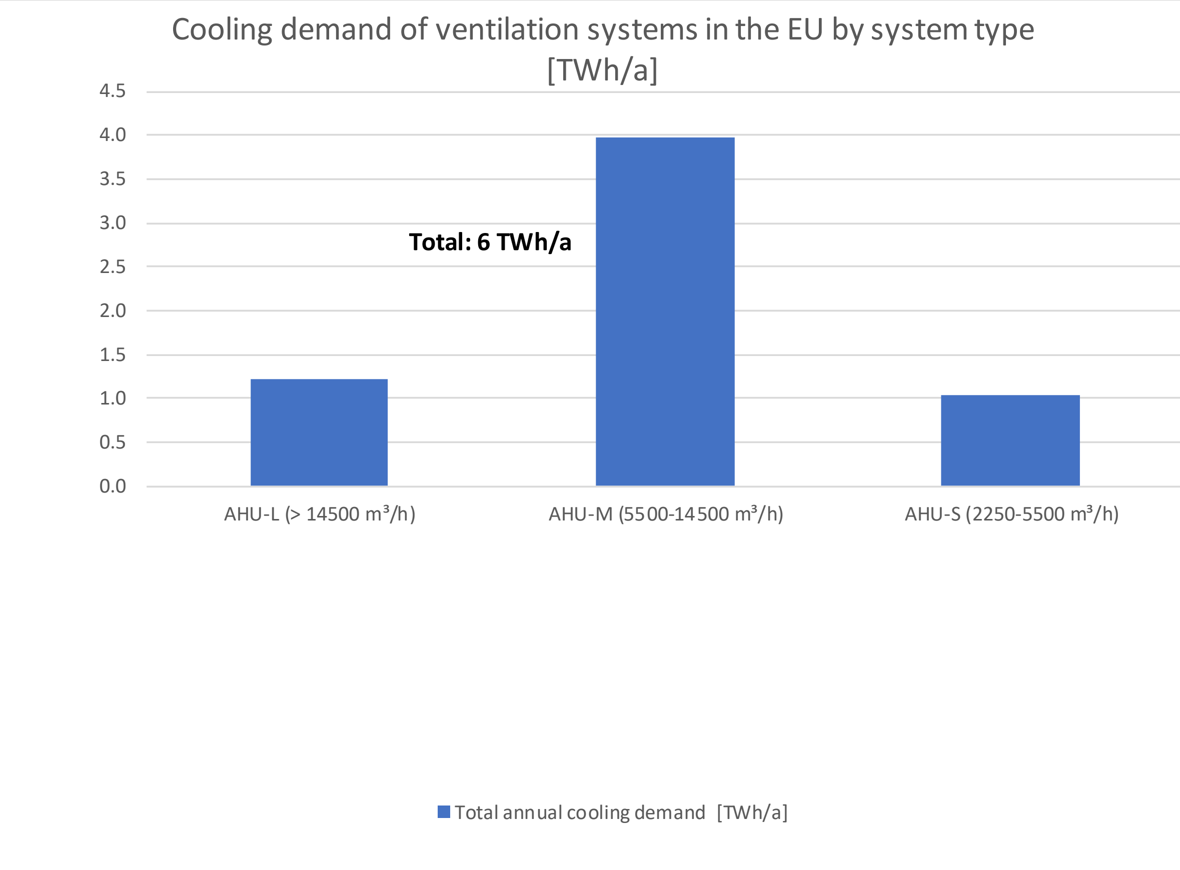


Figure 9: Shares of useful ventilation cooling and dehumidification demand in EU building stock per system type and size (TWh/annum).

Estimation of potential impacts

Only a few sources could be identified that enable estimation of the potential energy savings impacts of ventilation system energy performance requirements. The most detailed is a study for the German Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR)[99] conducted in 2014, which evaluated savings estimates from inspections of 113 air-handling units. According to the findings of that study there is a 31% electricity consumption savings potential and 26% heat consumption savings potential from operational improvements. With additional component replacement the saving potential increases to 51% for electricity and 43% for heating. Further saving potentials of individual measures for ventilation are reported in the iSERVcmb Final Report 2014[100]. In that report an average savings potential of 8% is achieved from regular replacement of filters. Further average savings opportunities were reported from the reduction of motor size (fan power) of 12% and installing a BEM-system of 7%.

Based on these sources the overall primary energy saving potential for ventilation is estimated to be between 30 and 60%[101].

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[99] https://www.irbnet.de/daten/rswb/14019025698.pdf

[100] http://www.iservcmb.info

[101] These saving potentials do not consider the compensation of existing insufficient ventilation.

1.6.4 BACS

The energy impact of BACS on the EU building stock has been assessed in two recent studies[102],[103] one of which is ongoing. The first of these directly considered the impact of BACS requirements under the revised EPBD. It considered the following scenarios:

- the EPBD compliant scenario (which is compliant with the recast EPBD including with regard to its BACS-related policy measures)
- the EPBD compliant without BACS scenario (which is the same as the above except that the BACS-related policy measures are not implemented).

The difference in impacts between these two scenarios is the estimated impact of the BACS measures within the recast EPBD.

The first of these scenarios complies with all the provisions of the EPBD and this can be considered to be EPBD compliant. This means that it is directly equivalent to the "Agreed Amendments" pathway reported in the EPBD Impact Assessment (Ecofys 2016). Thus, the above EPBD recast including the impact of BACS measures scenario is identical to the Agreed Amendments pathway and has the parameters and assumptions for the building sector pathways which were defined in the report and modelling work by Ecofys for the EC study "Ex-ante evaluation and assessment of policy options for the EPBD".

The EPBD compliant without BACS scenario estimates how the use and efficiency of BACS in the EU building stock would be expected to evolve without the additional stimulus of the BACS-related measures set out in the recast EPBD. While it could be argued that the original EPBD includes some indirect encouragement to BACS because it recognises building energy performance through EPCs and it sets whole building energy performance requirements for new construction and major renovations. In practice, these measures are only likely to provide a very limited stimulus to the use of BACS. This is because while some EPCs were based on energy bills, which would reflect the impact of BACS in practice, most are based on calculated performance. Yet for those using calculated performance only very few Member States have encoded BACS, even partially, into their calculation methodologies and only a small number have coded EN15232 into the performance calculation software. Even in the cases where EPCs are based on measured bills rather than calculations, there is no explanation of the performance attained and hence no means of making the BACS contributions visible and hence tangible. Without this transparency market actors are often likely to be unaware of the contribution that BACS can make to the energy performance of their buildings and hence the potential stimulus effect to the adoption of cost-optimised BACS solutions is heavily diluted.

The EPBD compliant scenario assumes Member States implement the revised EPBD provisions and do so in line with the guidance put forward in the eu.bac document *Summary of Guidelines for the transposition of the new EPBD in Member States*. Overall this tends towards class B BACS being installed as the minimum compliant response to the EPBD provisions whenever they trigger a BACS installation event; however, it varies depending on context. For example, in each of the scenarios if an existing BACS is renewed it is never replaced by BACS having in inferior energy performance class, thus it is assumed there is never any backsliding. Equally, while there is no backsliding there are varying probabilities ascribed to the likelihood that a renewed BACS installation will

[102] https://www.eubac.org/cms/upload/downloads/position_papers/EPBD_impacts_from_building_automation_controls.pdf

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

jump up one or more classes (depending on the start point). The scenarios are structured to take account of both the expected frequency of trigger events and the strength of stimulus to increase one or more energy performance classes – these vary as a function of: the specific BACS policy measure(s) which apply/applies to the TBS and building type, and the starting point of the existing BACS class.

The most dramatic stimulus to trigger BACS deployment is the requirement that non-residential buildings having >290 kW of effective installed capacity for heating, cooling and combinations thereof should have BACS installed by 2025. This means that if complied with all such building would have BACS by that time and thereby requires review and installation actions which are quite apart from standard building element replacement cycles. The Article 14 and 15 policy measures tied to the heating and cooling system inspection process follow the inspection cycle, and hence are dependent on how these are implemented in each Member State.

This translates into the total final energy savings due to the BACS policy measures in the recast EPBD as compared to the BACS business as usual case corresponding to the EPBD compliant without BACS scenario shown in Table 19 and Figure 10.

Table 19: Projected evolution in total final energy consumption (TWh) for EU building stock per scenario.

Scenario	2020	2025	2030	2035	2040	2045	2050
EPBD compliant	5135	3880	3544	3297	3050	2764	2478
EPBD compliant without BACS	5308	4273	3981	3746	3483	3157	2819

Abbreviation: BACS = building automation control system.

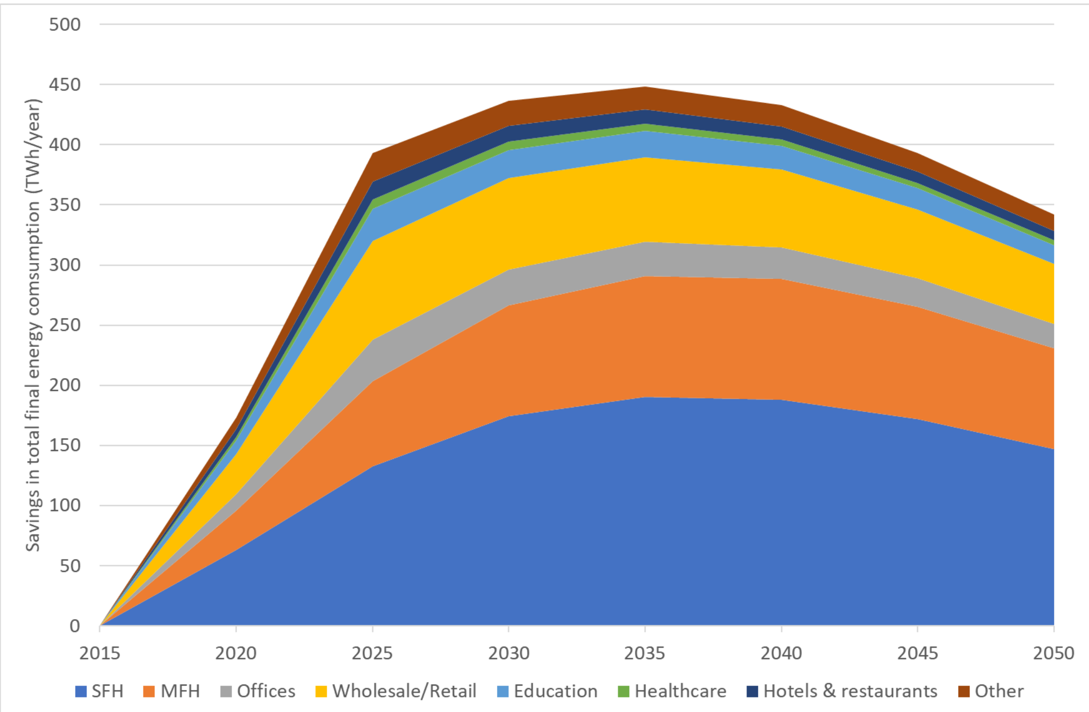


Figure 10: Savings in total final energy consumption of EU buildings for the EPBD compliant compared to the EPBD compliant without BACS scenario.

The total savings due to the BACS measures in the recast EPBD are projected to peak at 450 TWh of final energy in 2035. Thereafter the additional savings diminish as the BACS deployment in the business as usual (EPBD compliant without BACS case) begins to attain a similar rate while the total building energy consumption continue to decline.

The percentage savings in total primary energy consumption of EU buildings under the EPBD compliant scenario compared to the EPBD compliant without BACS scenario are shown in Figure 11. The percentage savings peak at about 14.2% in 2043. The difference in the peak (2043 compared with 2035) compared with Figure 6 is explained by the decline in total building energy consumption due to the ensemble of EPBD recast policy measures. It is important to appreciate that these percentage energy savings would be expected to be stable regardless of the pace of improvement in the energy performance of non-BACS-related aspects of the building stock. Thus, were the improvement in stock energy consumption not to be as rapid as projected in the Agreed Amendments scenario but the recast EPBD BACS measures to be implemented then the absolute level of energy savings would increase compared with the values shown in Figure 11.

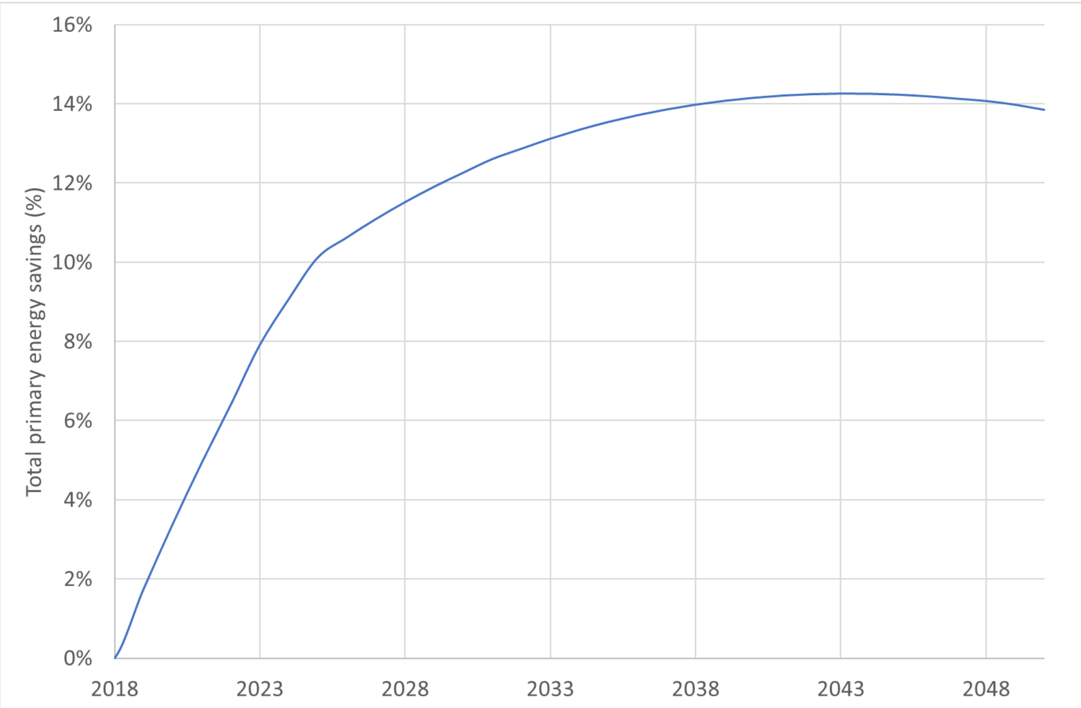


Figure 11: Total primary energy savings for all buildings for the EPBD compliant scenario compared to the EPBD compliant without BACS scenario.

The share of energy savings by energy type (thermal or electric) and building type (single family housing, multi-family housing and non-residential) is shown in Figure 12.

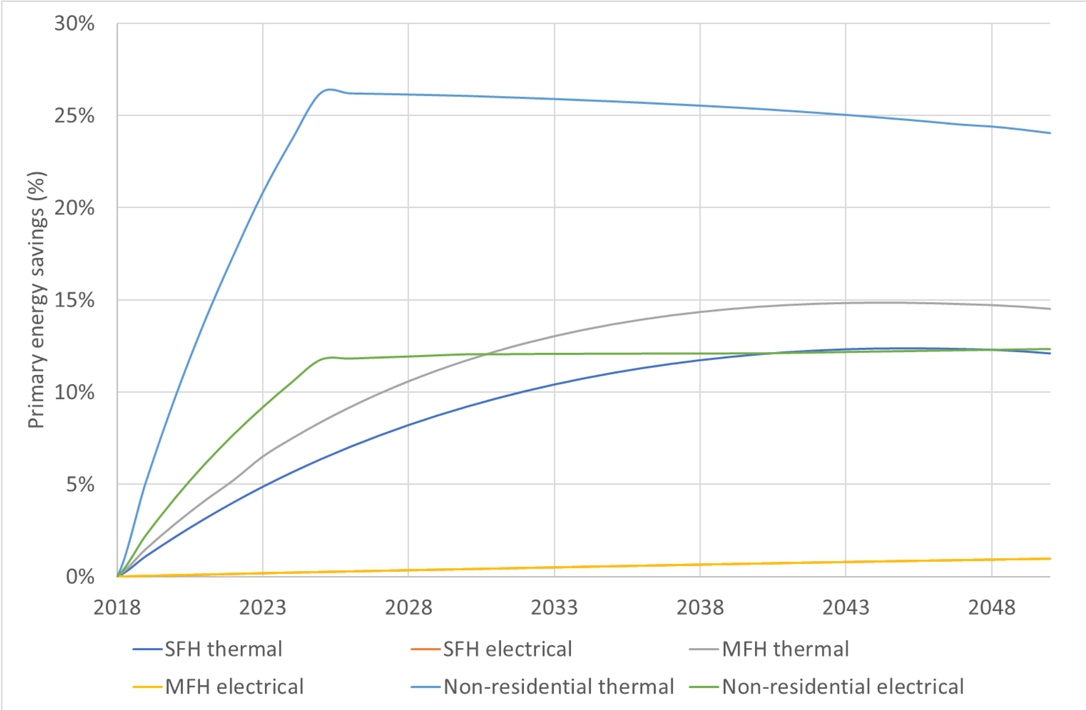


Figure 12: Total primary energy savings by principal building and fuel type for the EPBD compliant scenario compared to the EPBD compliant without BACS scenario.

The breakdown in these savings by TBS is relatively proportional to the share each TBS takes of thermal energy and electrical energy consumption in each of these building types.

The EPBD preparatory study on BACS is not yet finalised; however, the draft final report included provisional scenarios on the impact of potential BACS measures. Some of these concern specific temperature control accuracy options but others considered the impact of horizontal minimum EN15232 Class C, Class B or Class A requirements for all newly installed BACS while taking compliance with the existing EPBD requirements as the base case. The resulting estimated energy savings impacts should therefore be considered to be additional to the EPBD compliant scenario presented previously. The projected energy savings in the EU27 building stock are shown in Table 20.

Table 20: Additional savings above the EPBD from BACS scenarios considered in the draft final Ecodesign Preparatory Study[104] (TWh/year final energy).

Scenario	2025	2030	2035	2040	2045
Class C	3	11	18	26	33
Class B	22	76	130	184	239
Class A	32	112	192	272	352

Abbreviation: BACS – building automation control system.

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

1.6.5 Lighting systems

The Lot 37 Ecodesign study for lighting systems estimated[105] that in 2015 the total electricity demand for tertiary indoor lighting was 168 TWh/annum of which more than 50% could be saved through a combination of policy measures. Older lighting installations can benefit from adopting higher efficiency LED lighting as well as other system efficiency measures. Note, while the efficacy of new light sources is regulated by Ecodesign requirements most other system efficiency savings opportunities are not.

1.6.6 RES

The energy yield of solar collectors can in part substitute for DHW demand; in an average European climate when technically feasible, solar water heating can provide typical energy savings in the range of 50–60%[106].

According to the Business as Usual scenario of the Ecodesign Study on Photovoltaic Systems[107] the annual yield of residential PV is expected to be 45 TWh/annum in 2030 and 131 TWh/annum in 2050. For PV in non-residential buildings the forecast is 95 TWh/annum in 2030 and 275 TWh/annum in 2050.

1.6.7 Summary

EU energy consumption per technical building system

Summarising the findings presented above, the total primary energy consumption of buildings is about 3830 TWh. By far the biggest portion, with 64% of the total, is due to heating, followed by domestic hot water (13%) and ventilation (10%, including 6% for ventilation heating) (Figure 13).

[105] Lot 37 Table 7-6. https://ecodesign-lightingsystems.eu/

[106] https://www.energiesparen.be/zonneboiler

[107] https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/2020-12/jrc12431preparatory_study_for_solar_photovoltaic_modules_kj-na-30468-en.pdf

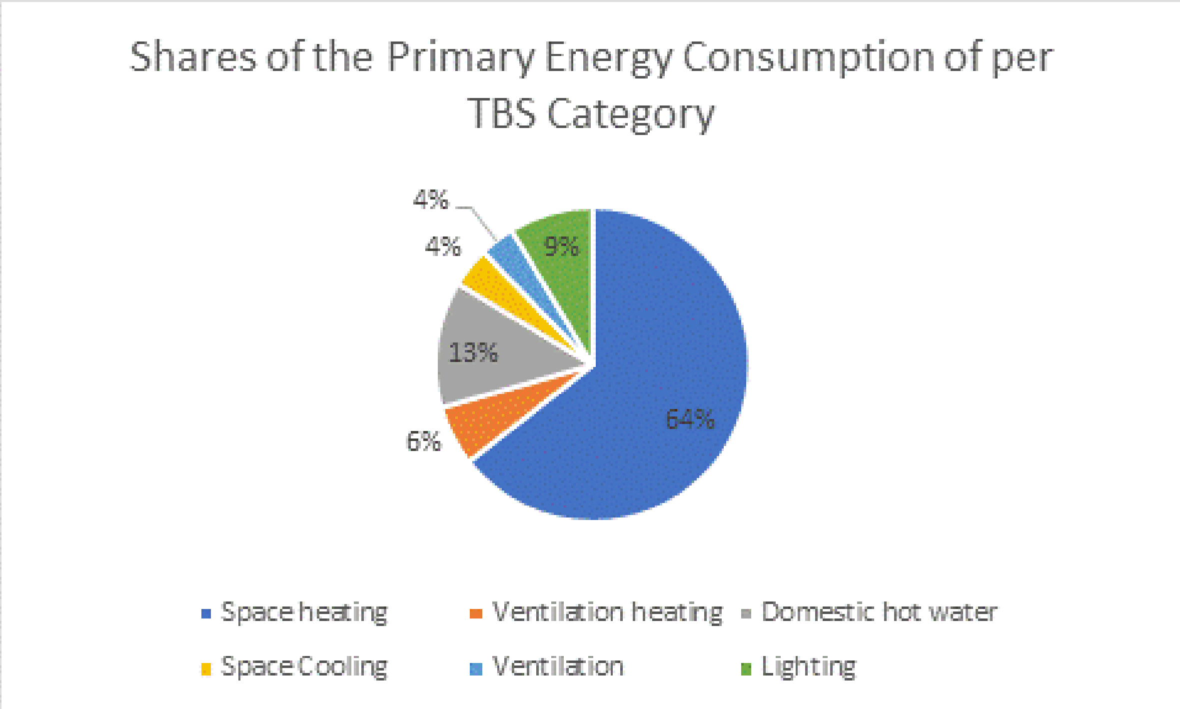


Figure 13: Shares of primary energy consumption per TBS category.

Estimation of potential impacts

To determine the potential overall impacts from the adoption of TBS systems level savings opportunities the upper and lower estimations for the potential savings as specified in previous sections are considered (Figure 14).

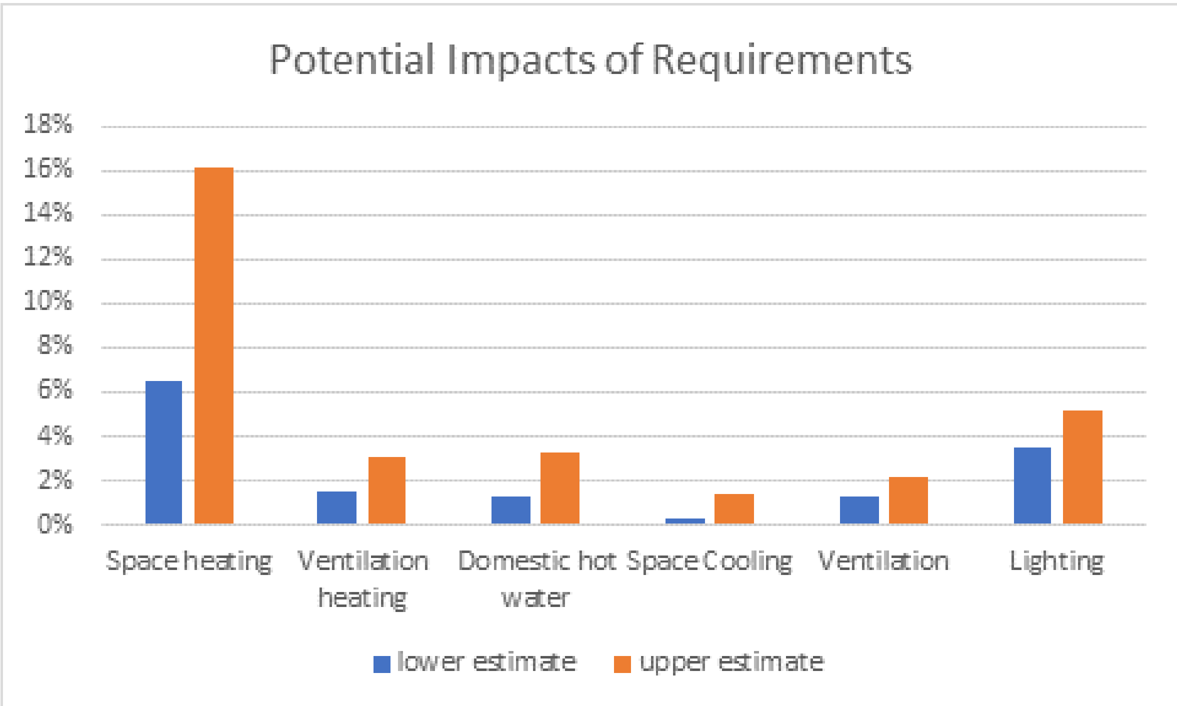


Figure 14: Shares of primary energy consumption per TBS category.

The highest saving potential, which accounts for between 6% and 16% of total building energy consumption, is attributed to space heating. Lighting comes second with a savings potential of between 3% and 5% of total building energy consumption, followed by domestic hot water (2% to 3%) and ventilation (1% to 3%). Summing up the individual potentials **the total saving potential** from systems level requirements for TBS **is estimated to be 14% to 31%**. The specified saving potentials already contain the BACS saving potential. As the BACS saving potential is estimated to reach up to 14% (see section 1.6.4), its share of the total TBS saving potential is at least of the order of 50%.

The additional maximum total saving potential of solar collectors for domestic hot water is estimated to be about 5%.

In addition, considering the actual primary energy factor for electricity of 1.97 the annual yields of 140 TWh in 2030 and 406 TWh/annum in 2050 would translate into a primary energy saving potential of 7–21%.

TASK 2. IDENTIFICATION AND ASSESSMENT OF POSSIBLE TECHNICAL BUILDING SYSTEM REQUIREMENTS

2.1 Objectives

The objective of this task is to identify potential energy performance requirements for technical buildings systems that can contribute to optimal system performance and to establish the boundary conditions where these requirements could be applied. A priori, these requirements should:

- be applicable in (and or differentiated by) the different design stage options applicable to technical building systems
- be, or be capable of being, referenced through standards, guidelines and other relevant documents
- be technically feasible and usable/practicable.

Specifically, the methodological activities foreseen under **Task 2** are:

- clarification of system scope and identification of key factors for energy performance (see section 2.2)
- determination of the potential requirements for technical building systems (section 2.3)
- establishment of the scope of application of the requirements (section 2.3).

2.2 Activity 1: Clarification of system scope and identification of key factors for energy performance

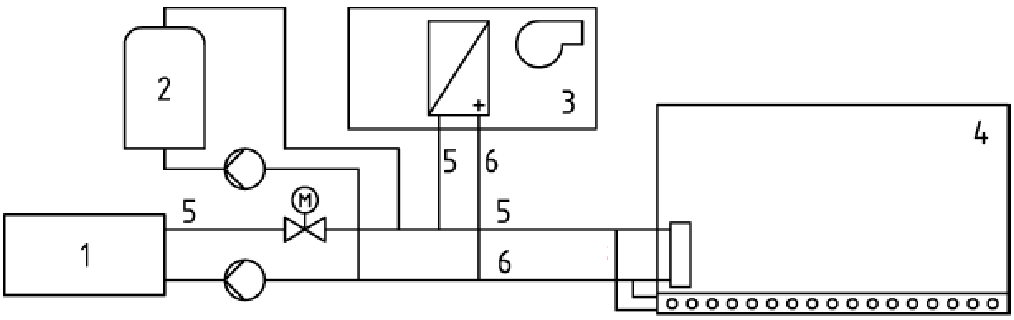
In this activity the scope of the technical building systems that are to be considered for prospective TBS energy performance requirements (in Activity 2) are defined on the three following levels:

- the description of function and service the TBS under consideration provides (e.g. space heating, space cooling, ventilation, DHW, lighting, BACS and on-site generation)
- description of the components used in these systems (e.g. for a ventilation system this could be: ventilation fan, heat exchanger, air ducts, manifolds and valves)
- the possible configuration variants that are applicable in practice (design options, such as the different types of heat generators that can be used for heating systems).

In addition, this activity includes an assessment of the key factors that can significantly influence the considered system's performance, e.g. design choices including dimensioning, energy performance of individual components, quality of installation, etc.

2.2.1 Clarification of system scope and key energy performance factors for space heating and domestic hot water in existing buildings

Clarification of system scope



Key

1 heat generator
2 thermal energy storage
3 air handling unit
4 room
5 heating water supply
6 heating water return

Figure 15: Heating system with single heat source and multiple heat emission systems (*source:* NBN EN 15232-1:2017).

Space heating systems are designed to satisfy the thermal comfort requirements of building occupants. They can be divided into direct and indirect acting heating. Direct systems convert fuel or electrical energy to heat within the space to be heated. Indirect systems, on the other hand, convert the fuel energy into heat in a central position from where it is distributed around the building (in the form of hot water) and emitted to the space. A schematic view of a typical central space heating system is shown in Figure 15. This system has multiple components, as described in what follows.

Heat generation

This is where the heat is produced by converting fuel or electrical energy into heat. There are multiple types of heat production systems:

- gas boilers: having a gas burner
- oil boilers: having an oil burner
- heat pumps: having a compressor
- district heating: in this case, the heat generator component is actually a substation that connects the building’s heating system to a district heating network that is implemented on neighborhood or city level.

Heat distribution

To distribute the heat from the heat generator to the heat emitters in the heated zones, a heat distribution system should be in place. This system consists of a combination of valves and pumps that circulate the water from the heat generator to the heat emitters and back. Also, heat storage such as water tanks can be present in the distribution system.

Heat emitters

The heat emitters supply the heat from the heat distribution to the heated spaces. Heat emitters can be classified as radiant or convective although most combine the two modes of heat transfer. Common heat emission systems are radiators, floor heating installations and convector radiators.

Control

Control allows to modulate the space heating installation depending on the demand. It also allows to adapt some of the parameters to optimise the installation. The control can be applied on the different components and sub-components of the space heating system and it can be centralised or decentralised. In what follows the major control approaches that can be applied are presented:

- room thermostat: a room thermostat reacts to the temperature of the air around it. It is usually in the hall or living room. The thermostat works by switching the circulating pump and/or the boiler on and off, but it is best if it switches both
- programmable control and timers: a timer or programmer allows for the space heating system to be set to be switched on and off automatically at pre-set times. Timers and programmers vary in levels of sophistication, and can be either analogue or digital
- thermostatic radiator valves (TRVs): allow different rooms to be kept at different temperatures and are fitted to the radiators. They work by opening or closing the valve controlling the flow of hot water through the radiator.

Domestic hot water

DHW is water intended for human consumption that has been heated. The primary use is for sanitary purposes such as bathrooms and showers and for cleaning uses such as dishwashing and clothes washing. The heating of this water can be done by the same heat generator used for the space heating installation (combination boilers or heat pumps) or via a separate dedicated water heater such as a gas burner or an electrical immersion heater. It is also common to have a water storage tank that stores the DHW.

Key energy performance factors

The key energy performance factors shown in Table 21 apply to space heating and DHW.

Table 21: Key energy performance factors for space heating and DHW.

Key factors	Explanation	Requirement specification
BEM system is present and includes clear building dashboard for heating	• Energy flow (sankey) for heating system is available and relates metered energy to primary energy metric of EPC and at least discriminates heating demand for generation, distribution and emission. For buildings using high amounts of DHW, it should be monitored separately from heating. For large buildings, multiple zones for emission must be considered. The measured values need to be compared to those of the EPC software.	• Monitor energy consumption of heating system, in combination with influencing parameters such as outdoor temperature, indoor temperature set-points, building occupancy, etc.
Efficiency of heat production	• Ensure high efficiency for production units: combustion, electrical…	• Measure efficiency of heat production, regularly • Compare measured efficiency with design specifications • In case of condensing boiler, check if flue gases are actually condensed
Heat-loss reduction in storage and distribution	• Limit heat losses in storage tanks, distribution pipes, valves and heat exchangers	• Insulation should be placed on storage vessels • Avoid water-flow through storage tanks during stand-by • Check pipes, valves and heat exchangers are insulated • Check insulation is still in good condition
Adequate choice of supply temperature	• Choose supply temperature set-point as function of heat demand. In case heat demand is climate-dependant, supply temperature could be variable. In general, lower working temperature improves efficiency of production and heat distribution	• Apply adequate supply temperature set-point • When possible, set supply temperature as a function of outside temperature
Control based on demand of end use and heat zoning	• Ensure heat is only delivered when needed • Heating system should be able to cope with need for delivery time, temperature and quantity in building comprising several zones	• There are several options to control heat delivery to end-user: – room thermostat – thermostatic valves – day, night and weekend programming – BEM system, combining different options • Ensure heating system layout matches variety of heating needs • Use a heat control per zone
Efficient control of multiple heating/cooling installations	• If heat is produced by multiple heating units, cascade regulation can ensure efficient use of different installations; the most energy efficient installations should get priority • In buildings with both heating and cooling systems, there is a risk that space heating and cooling are used simultaneously; such inefficient energy use should be avoided	• Use a control system that combines all heating installations and that can apply cascade control • Combine heating and cooling in one control system; ensure set-points for heating and cooling do not cause continuous switching between heating and cooling

Efficiency of heat distribution	• Distribution pumps should have high energy efficiency, in order to limit energy consumption: – use variable frequency control, if heat load is variable – choose appropriate energy efficiency index (EEI) • If some spaces are overheated and others underheated, hydraulic balance of heating system could be a problem, causing additional energy consumption	• Evaluate energy efficiency of distribution pumps • Check system's hydraulic balance and rebalance
Proper functioning of heat emission systems	• Heat emission systems should function according to specifications to avoid inefficiencies in heat emission	• If radiator is hot at bottom and cold at top, purge to remove excess air • If radiator is cold at bottom and hot at top, increase feed rate of radiator • Check requirements for other types of emission systems
Proper installation	• Requirements on 'proper installation' are a generic reference to need to ensure system is installed such that safe and optimal operation is ensured; usually this is linked to requirements on installer qualifications (e.g. certified installer) and to specific technical guidelines	• See requirements EN 16946-1
Appropriate dimensioning	• Appropriateness of system size or capacity given needs and characteristics of building under expected use conditions • Ensure nominal power of heat production system matches heat demand • In case of partial-load work, ensure efficient heat production by using modulating or frequency-controlled heat production technologies	• See requirements ISO 16484-1 • Estimate (equivalent) full-load operating hours of heat producer on yearly basis • Estimate if the nominal power of the producer is actually required • If number of full-load hours is low and nominal power is not required, consider a smaller heat producer • If number of full-load hours is low but nominal power is indeed required, check if system can be controlled by modulating frequency control • Consider heat storage for a better match between heat production and use

Abbreviation: BEM = building energy management; DHW = domestic hot water; EPC = energy performance certificate.

2.2.2 Clarification of system scope and key energy performance factors for space cooling in existing buildings

Clarification of system scope

Air conditioner systems are designed to provide comfort cooling in buildings. There are various ways of classifying cooling systems, e.g.:

- on whether the system components are provided in a packaged assembly or separately to be assembled on site
- the cold distribution and heat rejection medium
- the basic system configuration.

Some features are present in all cooling systems, e.g. cool generation, transfer of "coolth" into a room, removal of heat from the room and heat rejection. The simplest classification is into central and room type of cooling systems:

- central plant systems, which may be further classified into:
    - larger packaged systems that serve more than one room
    - larger built-on site systems that serve more than one room (often large numbers of rooms). They are generally bespoke systems designed for specific buildings, but are largely composed of standardised component products.
- room air conditioners, which are series-produced self-contained units or systems comprising a unit that conditions a single room. They should generally be installed professionally.

Table 22 lists the main types of air conditioning systems and summarises their principal characteristics.

Table 22: Principal types of air conditioning system.

Type	Description
Central plant systems	
Packaged systems:	
Split systems >12kW	Comprises both larger >12kW single-split systems and multi-split systems. Multi-split systems are similar to single-split systems except that there are multiple indoor units which serve separate rooms or zones. These are individually connected to a single outdoor unit via refrigeration pipework. The system may operate either in cooling-only mode or have a heat pump mode for heating
VRF (variable refrigerant flow)	VRF multi-split systems are a more sophisticated version of the multi-split system. These supply heating and cooling and can have 2- or 3-pipe refrigerant pipework system that enables heat transfer from a room that requires cooling to another within the same building that requires heating. A variable speed compressor allows the system capacity to be varied to accurately match the building heating and cooling loads
Rooftops	Packaged units where both sides of the refrigeration cycle are housed in a single unit located on building exterior (often on the roof) together with an AHU supplying conditioned air to the building via ducts
Built-on-site systems:	
All-air constant air volume (CAV)	These provide a constant volume air supply at a single temperature. Air cooling is normally via a chilled water or direct expansion (DX) cooling coil in an AHU and distributes cooled air to rooms via ductwork. The AHU is usually able to vary the proportion of fresh to recirculated air to meet the building's ventilation requirements and to minimise cooling requirements. Some systems also include terminal reheat coils to allow different air-supply temperatures in different rooms or zones
All-air variable air volume (VAV)	As for CAVs, but different cooling requirements of individual rooms or zones can be accommodated by varying the volume of air supplied to each room or zone. The AHU fan speed is varied to match the overall supply-air flow rate and therefore significant fan energy savings are possible when the overall cooling requirement is low
Water-based fan coil unit (FCU)	Chilled water (and sometimes also hot water) is circulated around the building to supply terminal units in the rooms where a fan blows room air over a cooling coil. Most fan coil systems are also supplied with conditioned fresh air from a central AHU. The room air and ducted fresh air are mixed at the FCU's inlet
Water-based induction	Similar to the above except that a minimum quantity of conditioned fresh air from an AHU is injected through nozzles to induce a flow of room air over a chilled water coil before the mixed air flow is supplied to the room
Heat pump loop	This system is based on a constant-temperature water loop circulated around the building with self-contained heat pumps, providing either heating and cooling of individual rooms or zones by transferring heat from or to the water loop. These systems are sometimes referred to by their historical trade name "Versatemp". Some versions are also fed with ducted conditioned fresh air from an AHU that is mixed with room air at the unit's inlet. The water loop is kept cool by a central chiller, cooling tower or dry air coolers
Chilled ceiling/passive chilled beam/other construction embedded cooling	High-temperature chilled water is circulated through embedded cooling pipes, passive coils or cooled ceiling panels to provide cooling by conduction and natural convection
Active chilled beam	As with passive chilled beams, high temperature chilled water is circulated within cooling coils but room air flow is induced through the coils by a minimum quantity of conditioned fresh air. The air is supplied from a central AHU and injected through nozzles but at a lower pressure than with induction units

Room air-conditioners	
Single-split systems <12 kW	The single split system has an outdoor unit which contains the condenser and compressor, and discharges heat to the outside air. This is linked via the refrigerant pipework to a single indoor unit which contains the evaporator and a fan which delivers cooling within the room and can be ducted or non-ducted
Window/wall units <12 kW	Both sides of the refrigeration cycle are housed in a single unit which is installed through a window or wall so that the heat rejection side of the system is on the outside of the building and the cooling side is on the inside. There is a fan in each side of the unit to facilitate the transfer of heat into the refrigerant on the inside, and into the air on the outside. This category also includes fixed dual duct systems which are functionally very similar, except that the unit is housed wholly within the building and is connected to the outside via an inlet and an outlet duct

Abbreviations: AHU = air-handling unit.

Note, a feature of air conditioning systems with air distribution systems is that the same fans and ventilation systems are often used to meet both cooling and ventilation demands. For reversible systems these may also be used to provide heating.

In addition to the AC technologies listed above there are a number of less common space cooling solutions which include:

- systems that do not use vapour compression technology for cold generation, including: adsorption-, absorption- and liquid and solid desiccant-cooling systems that can make use of waste- or renewable-heat
- engine-driven systems that replace the electric motor of the cooling generator by a fossil- or biomass-fuelled engine, sometimes as part of a combined heat and power system
- large, reversible ground-source heat-pump systems in which the ground provides seasonal thermal storage. These are now an established technology for large commercial developments and avoid the need for conventional heat rejection equipment on rooftops
- short-term thermal storage to reduce peak electricity demand can be provided by ice or other latent heat storage, but potentially at the expense of overall efficiency depending on the climate
- decentralised systems using local air-handling units may have lower fan energy consumption and can provide local time and temperature control, but require additional wall penetrations
- embedded emitters (typically within ceilings and floors) are used in some European countries. They enable the use of higher chilled water temperatures which should, in turn, improve cooling efficiency (as do conventional chilled ceilings) and lower peak cooling demands (because of the effect of the thermal capacity of the building structure) but are best suited to applications where 24-hour cooling is required.

The EBPD is concerned with all these systems as they are fixed systems and hence classify as TBS; however, elements of these, or within these, are addressed by Ecodesign and energy labelling requirements. The energy performance of air conditioning systems will depend on both the efficiency of the products and components that comprise the system and their configuration. It will also depend on their design, installation/commissioning and operation and maintenance (O&M). Only in the case of room air conditioners do the Ecodesign/ELR requirements address all system performance aspects aside from on-site design/commissioning and O&M aspects; but for all other systems the Ecodesign/ELR requirements only concern components within the overall system (if they are applicable at all). Thus, setting TBS performance requirements in line with the Article 8 provisions offers additional scope to save energy.

Key energy performance factors

The following key references were used to compile the set of energy performance factors and savings opportunities for space cooling TBS:

- AUDITAC[108]
- HARMONAC[109]
- iSERV[110]
- Energy Savings in Cooling and Ventilation Are Crucial for Achieving Climate Goals[111]
- Study on Energy Use by Air-Conditioning[112]

The energy efficiency of space cooling systems is dependent on the efficiency of all their constituent elements (cold generators, distribution and emission systems), how these are integrated into an overall system, the correctness of their sizing, the system part-load performance and control, its installation, commissioning, operation and maintenance. Depending on how broadly the system scope is defined it will also depend on the management of cooling loads, which can include the building's insulation quality, thermal mass and solar control aspects (such as fixed or mobile shading, solar control glass, etc.).

The overall efficiency of central systems using chilled water or air is less than that of the cooling generator because of additional energy losses by air leakage from ductwork and air-handling units and heat gain into chilled water pipes and air ducts.

The IEE AUDITAC project specified a comprehensive set of Energy Conservation Opportunities (ECOs) for AC systems broken down into the Plant level, the operation & maintenance (O&M) level and the building envelope level. Annex A presents this information in full while a relatively comprehensive list of system level AC energy savings measures based on these references is presented in section 2.3.2. The IEE HARMONAC project set out information on savings established from over 400 AC systems audits while the H2020 iSERV project also documented the savings achieved from good practice metering and monitoring in a large set of buildings across Europe. The sum experience from these projects informs the list of savings options and expected impact reported in section 2.3.2.

2.2.3 Clarification of system scope and key energy performance factors for ventilation systems in existing buildings

Clarification of system scope

The central function of ventilation systems is to supply internal zones with fresh air.

Often also additional functions are provided. These are:

- space heating (including heat recovery)
- space Cooling
- humidification
- de-humidification

[108] https://ec.europa.eu/energy/intelligent/projects/en/projects/auditac

[109] https://ec.europa.eu/energy/intelligent/projects/en/projects/harmonac

[110] https://www.iservcmb.info/

[111] https://www.navigant.com/news/energy/2019/energy-savings-in-cooling-and-ventilation-crucial

[112] https://www.bre.co.uk/ac_energyuse

- air cleaning (filtration).

Depending on the system-type and function, (mechanical) ventilation systems may consist of different components. These are:

- fans[113] (exhaust and or supply air, and or secondary fans for circulation air)
- controls (including sensors)
- air ducts (supply, exhaust and/or circulation)
- flaps (throttle flaps for normal operation and fire protection)
- heat exchangers (heating, cooling/ dehumidification, heat recovery)
- humidifiers
- filters.

For ventilation systems EN 16798-3:2017 distinguishes between the following six general configuration types:

- unidirectional supply air
- unidirectional exhaust air
- bidirectional
- bidirectional with humidification
- bidirectional air-conditioning
- full air-conditioning systems.

Table 23 provides an overview of the key functions for the different general configuration types.

[113] As natural ventilation is not considered within the scope of this report all ventilation systems in scope consist of at least one fan

Table 23: Overview of ventilation and air-conditioning systems and functions components according to EN 16798-3:2017.

System	Supply Air Fan	Extract Air Fan	Secondary Fan	Heat Recovery	Waste heat pump	Filtration	Heating	Cooling	Humidification	Dehumidification
Unidirectional supply air ventilation system (Positive pressure ventilation)	x	-	-	-		o	o	-	-	-
Unidirectional exhaust air ventilation system	-	x	-		o	-	-	-	-	-
Bidirectional ventilation system	x	x	-	x	o	x	o	-	-	-
Bidirectional ventilation system with humidification	x	x		x	o	x	o	-	x	-
Bidirectional air-conditioning system	x	x		x	o	x	o	(x)	o	(x)
Full air-conditioning system	x	x		x	o	x	x	x	x	x

x equipped with.
(x) equipped with, but function might be limited.
- not equipped with.
o may or may not be equipped with depending on requirements.

Key energy performance factors

Table 24 provides an overview about the key performance factors of ventilation systems and related potential requirements to address those.

Table 24: Overview of the key ventilation performance factors and related potential requirements.

Key factor	Explanation and references
Air-flow rate and related controls	Air-flow rate is the most fundamental and relevant parameter regarding the energy demand of a ventilation system. The air-flow rate affects not only the fan electricity demand but also the demand of other required air treatment steps (heating, ventilation, dehumidification). The air volume of a ventilation system should therefore be accurately adapted to the fresh air demand and also, if applicable, to the heating or cooling demand[114]. Apart from the design conditions it is necessary for an energy-efficient operation to adjust the ventilation air volume to actual demand, which can vary significantly by time and zone. Furthermore, any functional change of zones within a building that impacts on its (fresh) air demand should be considered EN 15251:2007 provides indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality (e.g. regarding air quality category II during the attendance/operation time for residential buildings 0.42 l/s m² and for single offices 1.4 l/s m²). Furthermore, with regard to design and dimensioning of ventilation systems, the standard CEN/TR 14788: 2006 is relevant for residential buildings and EN 16798-1 for non-residential buildings. Performance criteria for residential ventilation systems is dealt with in EN 15665. Additionally, there is also a variety of relevant national standards on fresh air requirements, e.g. DIN 1946-6:2019-12 for residential buildings in Germany
Air distribution	The air distribution system consists of ducts, air in- and/or outlets and potentially other components such as flaps or throttle valve. A highly relevant factor for energy efficiency is the air velocity within the system. The required power increases by a cubic law to the velocity. An efficient ventilation system therefore requires a carefully fitted duct system as well as suitably sized air inlets and outlets Last but not least, the functional and energetic quality of a ventilation system is also dependent on the absence of significant air leakages[115] To prevent unnecessary heat losses or in the case of cooling condensation the air duct systems (including air-handling unit) should be adequately insulated
Air filtering	Most ventilation systems have filters not least to prevent pollution of the ducting system and increase the supply air quality The pressure drop caused by filters is dependent upon their class, which itself depends on the specific purpose (see EN 16798-3) and the filter quality To maintain the system efficiency high efforts are required, for timely filter exchanges (see EN 15780)
Heat recovery	Although heat recovery is mandatory (in new) bidirectional systems according to EN 16798-3 and is also an Ecodesign requirement for new air-handling units (EC Regulation 1253/2014), many existing bidirectional ventilation systems still have no heat recovery. The overall efficiency of a heat recovery system depends on the temperature ratio and electric power consumption, which itself is dependent on the pressure drop, fan efficiency and potential further auxiliary consumption sources such as pumps or defrosters[116]. Heat recovery systems shall have controls (preferably automatic) or systems (e.g. a bypass) to prevent overheating or an unnecessary cooling demand. In most cases heat recovery systems require measures or additional components to prevent freezing. Dependent on the specifications and settings, those measures or additional components can significantly increase the energy demand.

[114] Air as thermal energy carrier for distribution to provide space heating and cooling is by far the least efficient option (e.g. compared to hydronic distribution) and should only be considered if no alternative solution is technically or economically feasible.

[115] Leakages shall be classified according to EN 16798-3 and EN 1886.

[116] To specify the performance characteristics of heat recovery systems EN 308 and EN 13053 shall be used.

	For exhaust air systems a heat pump, which uses the exhaust air as energy source could also be accounted as heat recovery. The cost-effectiveness of heat recovery is strongly dependent on the local climate conditions.
Fans	Besides the air flow rate and the pressure drop the overall fan efficiency is the third most relevant component impacting the total power demand of fans within a ventilation system. The overall fan efficiency is dependent upon its single components (impeller, motor, belt drive and controls). A common measure for efficiency of a ventilation system is the specific fan power P_{SPF}, which is defined in EN 16798-3:2017. The P_{SPF} considers the electrical power fan power and Volume. Its reference should be clearly specified. The P_{SFP} should refer to either the entire building ($P_{SFP,B}$) or the fan unit (supply or exhaust) at design volume and consider not only the internal pressure drop of the AHU but also external and additional pressure drops by the ducting system and other components of the ventilation system.
Humidification and dehumidification[117]	Some ventilation systems require humidification of the supplied air. Commonly there are two options to provide air humidification: (i) steam humidification, where steam is typically processed by use of an electrical resistance heater (ii) evaporative humidification, where water is mechanically added to the airstream (e.g. by spraying or ultrasound). As the latter is an adiabatic process the air needs to be reheated, which is typically done by a heating coil connected to an external heat generator. Evaporative humidification is therefore mostly more efficient than steam humidification Some cases need to consider specific aspects (e.g. the hygiene aspect in critical hospital zones) that may require steam humidification Dehumidification is achieved with cooling coils and may require reheating to reach the required supply air temperatures The energy demand for humidification and dehumidification is strongly dependent on the control accuracy and settings
Supply air temperature controls	A ventilation system that is designed to provide tempered air needs a control system with sufficiently accurate and adequately positioned temperature sensors. At a minimum the control systems should ensure that simultaneous heating and cooling is prevented and that the predefined minimum comfort requirements are fulfilled efficiently[118]. The energy demand for air heating and cooling (and humidification and dehumidification) is strongly dependent on adequate temperature settings.
Monitoring systems	A sustainably effective system optimisation requires monitoring, which in turn allows the above-mentioned key performance parameters of a ventilation system to be determined, by measuring and storing the required input parameters (such as fan electricity demand, temperatures, humidity, settings or air-flow rates). Contrary to the energy demand for heating, the electricity demand for fan systems is not usually part of the energy billing, so additional respective meters need to be installed. The monitoring effort should be adapted to its potential benefits. Since volume meters, for example, are comparably expensive, their installation can only be cost-efficient for systems at a certain minimum size. Modern building automation systems monitor and record all relevant system parameters for either manual or automatic system optimisation.

[117] Remark: Air-heating and -cooling including the related pump energy are covered under the specific sections.

[118] That includes an interaction between other heating and cooling systems.

2.2.4 Clarification of system scope and key energy performance factors for BACS in existing buildings

Clarification of system scope

According to Article 1 of the amended EPBD "Building automation and control system (BACS)" means a system comprising all products, software and engineering services that can support energy efficient, economical and safe operation of technical building systems through automatic controls and by facilitating the manual management of those technical building systems.

The BACS obligations arising from Article 8(1) and 8(9) of the EPBD apply to technical building systems as defined in Article 2(3). According to this definition, the term 'technical building system' means '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'.

Therefore, the scope of BACS is the scope of the related sections for heating, cooling, ventilation, built-in lighting and on-site electricity generation.

Article 14 (4) and 15 (5) of the EPBD requires that BACS shall be capable of:

(a) continuously monitoring, logging, analysing and allowing for adjusting energy use

(b) benchmarking the building's energy efficiency, detecting losses in efficiency of technical building systems, and informing the person responsible for the facilities or technical building management about opportunities for energy efficiency improvement, and

(c) allowing communication with connected technical building systems and other appliances inside the building and being interoperable with technical building systems across different types of proprietary technologies, devices and manufacturers.

Key energy performance factors

As explained in the discussion of scope BACS are a horizontal topic that overarches all previously discussed TBS service domains.

The EN 15232 standard defines[119] 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 (f_{BAC}) 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 = f_{BAC} x total energy demand BACS Class C

[119] http://built2spec-project.eu/knowledge-center/

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 ($f_{BAC,\,H}$), for cooling ($f_{BAC,\,C}$,) and for auxiliary electricity including ventilation ($f_{BAC,\,el}$). 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[120], shows how these can be computed or verified. How these BAC factors relate to the components of the building energy balance, the previous TBS service domains and the primary metric of the EPBD (which is primary energy demand) is presented graphically in Figure 16.

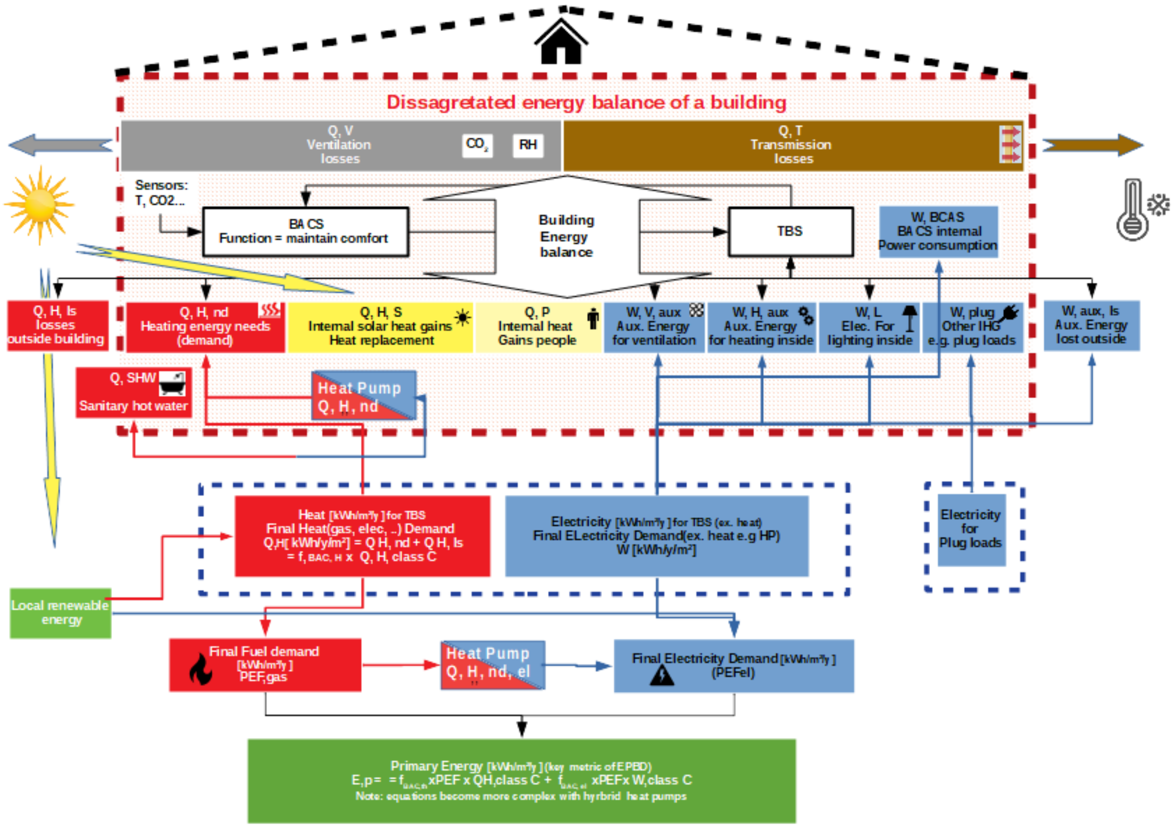


Figure 16: Overarching relationship of BACS factors with other TBS.

2.2.5 Clarification of system scope and key energy performance factors for lighting systems in existing buildings

Clarification of system scope

The new wording 'built-in lighting' 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.

There are two possible scope options or subcategories of requirements:

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

1. Scoping on non-residential built-in lighting for indoor workplaces where minimum lighting quality requirements according to EN 12464 apply. This scoping is recommended taking into account the scope discussion of the lot 37 lighting system study. That study addressed lighting systems that provide functional lighting where the focus was on providing illumination to make objects, persons and scenes visible and wherein the system design is based on minimum measurable quality parameters as described in the European standard EN 12464 on indoor lighting of workplaces. This excludes residential lighting and also the amenity lighting applications that can be found in hotels, restaurants, etc.
2. Scoping on residential built-in lighting and amenity lighting that has no functional indoor lighting requirements according to EN 12464.

Key energy performance factors for functional residential built-in lighting for indoor workplaces where EN 12464 is applied

The primary relevant parameter is the functional or useful luminous flux per square meter equal to the minimum required maintained average illumination.

All EN 15193 and EN 12464 parameters influencing the lighting system efficacy were explained in a previous section and illustrated in Figure 17. The meaning of these parameters is explained in EN 15193 and the Lot 37 Ecodesign study on lighting systems[121].

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

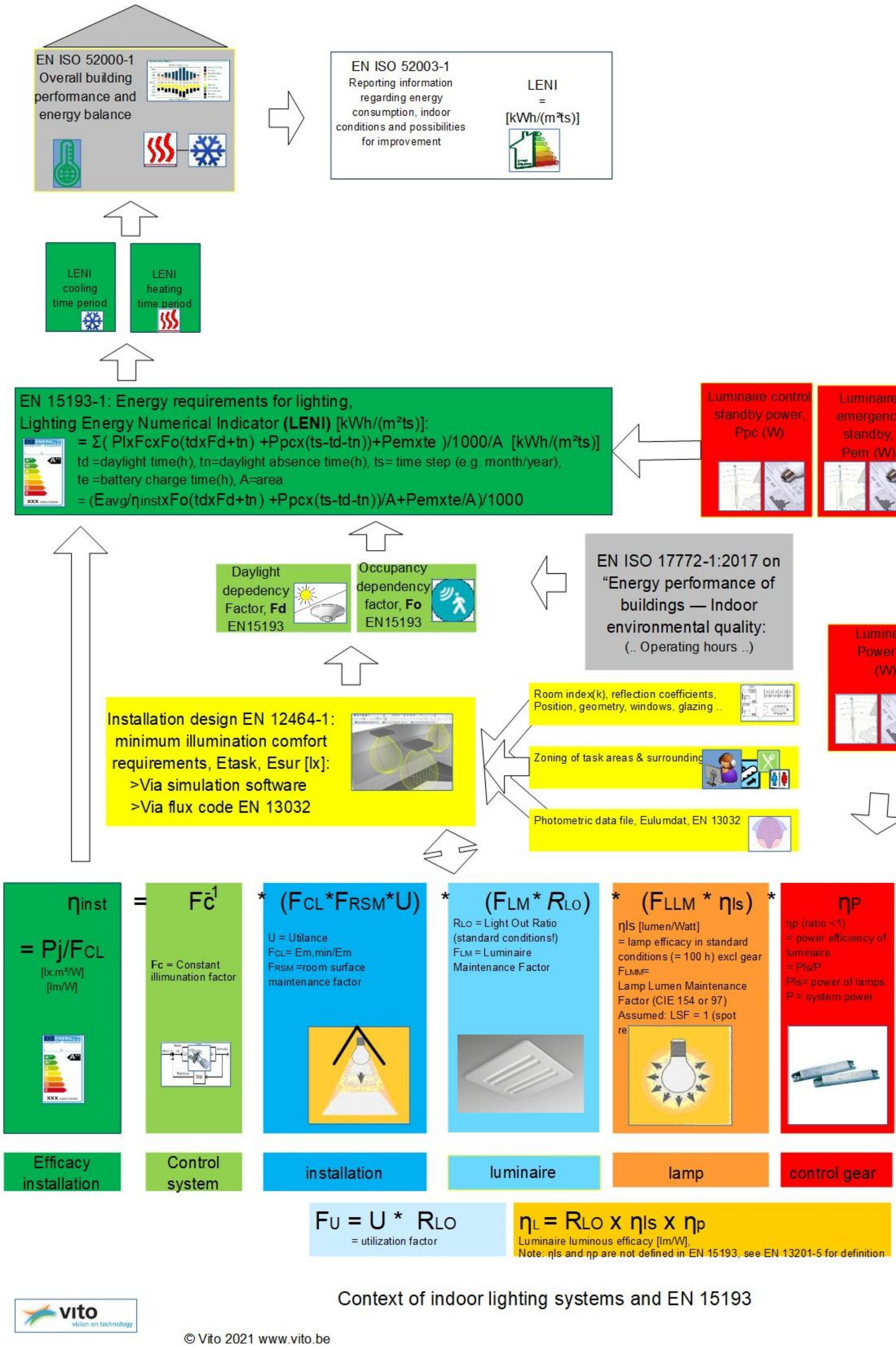


Figure 17: Overview of all the parameters involved in indoor lighting systems according to EN 15193.

Based on the examples presented in Task 1 and the preparatory study on lighting systems the key performance factors and typical range of values are summarised in Table 25, where the key factors are highlighted in blue. This same table also discriminates which parameters can be addressed at product level under standard test conditions (STC), at system or building level and at extended product level. Extended product level is a category in between which is not, per se, connected to the building and which could be addressed considering an extended product definition without the building being in scope.

Table 25: Key factors for quantifying the energy efficiency of lighting systems and typical range of values according to EN 15193 and EN 12464.

LENI = Lighting Numerical Indicator = LENI-o + LENI-u **Eavg = average maintained illuminance of the area [lx]** **PDi = lighting power density [W/l(x.m²)] = 1/ηins[lm/W]** **(LENI according to EN 15193 and Eavg to EN 12464)**	**lighting system**		**Extended Product**		**Product policy (STC)**		**typical value range**		
	overall	**detail**	**overall**	**detail**	**overall**	**detail**	**min**	**mid**	**max**
LENI occupied period = PlxFcxFo(tdxFd+tn)/1000/A [kWh/(m².y)]	**LENI-o**	-	-	-	-	-	**2**	**10**	**40**
td =daylight time(h) [h/y]	-	td	-	-	-	-	1000	2250	4000
tn=daylight absence time(h) [h/y]	-	tn	-	-	-	-	100	250	4000
to = td + tn = occupied period	-	to	-	-	-	-	calc	calc	calc
ts= time step e.g. month	-	ts	-	-	-	-	week	month	year
A = monitored area [m]	-	A	-	-	-	-	-	-	-
Fo = Occupancy dependency factor (= Foc + 0,2 – Fa (If 0,2 ≤ Fa < 0,9)	-	**Fo**	-	-	-	-	**0,7**	**0,8**	**1**
Foc = occupancy control factors									
Fa = absence factor									
Fd = Daylight dependency factor = = 1 - Fd,c x Fd,s	-	**Fd**	-	-	-	-	**0,27**	**0,61**	**1**
Fd,c = Lighting control factor									
Fd,s = Daylight supply factor									
Fc = constant illumination factor (can also account for oversizing luminaires)	-	-	-	-	**Fc**	-	0,70	0,90	1,00
Pl = luminaire power [W] = Eavg x Pdi x A **or** **Pl/A = luminaire power per m² [W/m²]**	-	-	-	-	**Pl/A**	-	**2**	**5**	**10**
Area covered by a luminaire [m²]	-	-	-	Al	-	-	-	-	-
Eavg = average maintained illuminance of the area [lx] (EN 12464)	-	-	-	**Eavg**	-	-	**150**	**500**	**750**
PDi = lighting power density [W/l(x.m²)] **PDi= 1/ηins = installation efficacy [lm/W]** **ηins = 1/Fc x U x FM x ηl**	-	-	**Pdi**	-	-	-	**0,5**	**1**	**3**
U = Utilance			U		-	-	0,8	1	1,5
FM = maintenance factor = FLM x FLLM x FRSM			FM		-	-	0,70	0,80	0,90
FLM = luminaire maintenance factor				FLM	-	-	0,91	0,95	0,98
FLLM = lamp lumen maintenance factor (for LED see LxBy)				FLLM	-	-	0,80	0,90	0,95
FRSM = room surface maintenance factor				FRSM	-	-	0,98	0,99	0,99
ηl = luminaire efficacy [lm/W]					**ηl**		**70**	**120**	**150**
LENI unoccupied period = Ppc x(ts-td-tn)))/1000/A [kWh/(m².y)]	**LENI-u**	-	-	-	-	-	**0,5**	**0,8**	**1**
Ppc = Total controls standby power [W/m²]	-	-	**Ppc**	-	-	-	**0,05**	**0,1**	**0,2**

Key energy performance factors for residential lighting and amenity lighting

For the light source this is the luminaire efficacy which is already covered by Ecodesign requirements. As a secondary metric the installed luminaire power (Pl [W/m²] can also be considered and for control systems, occupancy control (per EN 15232).

2.2.6 Clarification of system scope and key energy performance factors for RES for existing buildings

Clarification of system scope

When considering the scope the following definitions from the EPBD (2010/31/EU) apply:

- Art. 2 (6) defines 'energy from renewable sources' which means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases
- Art. 2 (2) defines 'nearly zero-energy building' as meaning a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or near by
- in Art. 2 (2) it remains unclear what should be understood by 'on-site production of photovoltaic energy', because it does not specify whether this is only the self-consumption (Figure 18) excluding grid injection versus, for example, simply all the annual photovoltaic energy produced. Across the EU a broad and very divergent set of self-consumption policies and financial support schemes have been implemented for photovoltaics; a recent overview is presented in IEA PVPS Task 1 [122]. Various schemes exist in the EU (Figure 19) and are regularly reviewed over time[123]. The design of these can have a large impact on the financial impact and how to implement Demand Response to increase self-consumption. Anyhow, the part of 'self-consumption' should be included in an EPC.

An important parameter in self-consumption schemes is the 'maximum time frame for credit compensation'[122]. 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 (real-time), etc. Many loads are on-/off-regulated with peak loads, meaning that if this time frame is not sufficiently long they cannot contribute in a precise manner to self-consumption. Apart from the mismatch between on/off control and the gradual PV output, also the reaction time of control dynamics can be of importance, depending on the timeframe that must be obeyed. Devices such as a battery or heat pump that should react on the PV inverter output show a delay between the solar output and the onset of the load. This is in the order of a second. This is of importance if a real-time timeframe is used.

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

[123] https://www.rijksoverheid.nl/documenten/rapporten/2020/03/25/bijlage-effect-afbouw-salderingsregeling-op-de-terugverdientijd-van-investeringen-in-zonnepanelen

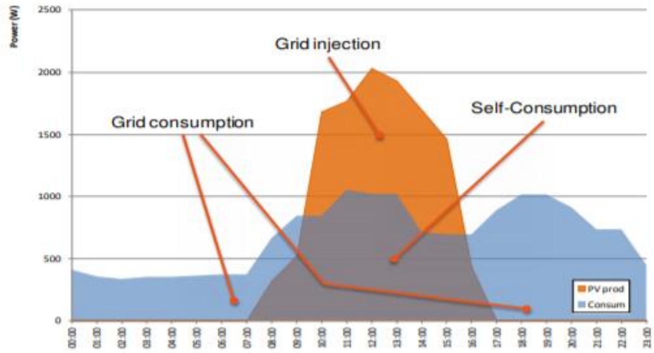


Figure 18: Comparison of production and consumption profiles for photovoltaic systems in buildings.

Onsite Self-Consumption	Right to self-consume	• Self-consumption is legally permitted
	Revenues for self-consumed PV electricity	• Savings on the variable price of electricity from the grid
	Charges to finance T&D costs	• Additional costs associated to self-consumption such as fees or taxes may exist
Excess PV Electricity	Value of excess electricity	• Net metering: energetic compensation (credit in kWh) • Net billing: monetary compensation (credit in monetary unit)
	Maximum timeframe for compensation	• Self-consumption: real time (e.g 15 minutes) • Net metering and net billing: time frame is typically one year although there are some exceptions (from credits that can be rolled over to the following billing cycle to quarterly compensation)

Key:
- Same between shemes (red)
- Main differences (blue)

Figure 19: Categories of self-consumption scheme.

Real-time solar yield can be very erratic under cloudy conditions (Figure 20), which means that the loads should be modulated accordingly. This can be problematic for heat pumps because speed modulations under variable cloud conditions could shorten the lifetime and also decrease the coefficient of performance. A battery energy storage system (BESS) can overcome this and likely in the future building owners will install BESS with photovoltaics. Still batteries cannot follow the real-time PV output exactly since the control lags some seconds behind. This is only an issue if a real-time timeframe is used.

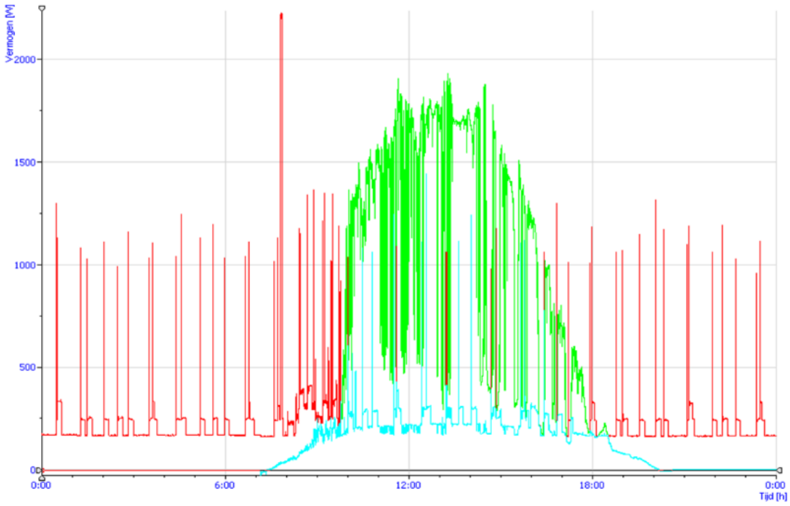


Figure 20: Real-time power consumption(1s) of a house (red), PV yield on a sunny day with some clouds (green) and self-consumption (blue) (data measured by VITO)

When considering the scope for renewable energies in buildings the following requirements from the Renewable Energy Directive ((EU) 2018/2001) also apply:

Art. 15 (2) requires that Member States shall clearly define any technical specifications which are to be met by renewable energy equipment and systems in order to benefit from support schemes. Where European standards exist, including eco-labels, energy labels and other technical reference systems established by the European standardisation bodies, such technical specifications shall be expressed in terms of those standards. Such technical specifications shall not prescribe where the equipment and systems are to be certified and shall not impede the proper functioning of the internal market.

Art. 15 (4) requires that Member States shall introduce appropriate measures in their building regulations and codes in order to increase the share of all kinds of energy from renewable sources in the building sector. It requires that Member States, in their building regulations and codes or by other means with equivalent effect, require the use of minimum levels of energy from renewable sources in new buildings and in existing buildings that are subject to major renovation in so far as technically, functionally and economically feasible, and reflecting the results of the cost-optimal calculation carried out pursuant to Article 5(2) of Directive 2010/31/EU, and in so far as this does not negatively affect indoor air quality. Member States shall permit those minimum levels to be fulfilled, inter alia, through efficient district heating and cooling using a significant share of renewable energy and waste heat and cold.

Art. 21 (4) requires that Member States shall ensure that renewables self-consumers located in the same building, including multi-apartment blocks, are entitled to engage jointly in activities referred to in paragraph 2 and that they are permitted to arrange sharing of renewable energy that is produced on their site or sites between themselves, without prejudice to the network charges and other relevant charges, fees, levies and taxes applicable to each renewables self-consumer.

Given Art. 15 (2) and considering that many TBS renewable energy requirements are already dealt with at packaged- or extended-product level the following can be excluded from further investigations of requirements:

- integration of thermal solar collectors with DHW ((EU) No 811/2013)

- space and/or water heaters to operate with biomass, landfill gas, sewage treatment plant gas and biogases
- share of renewable energy in electricity from the grid applied to HVAC equipment.

It should be noted that the establishment of an Ecodesign policy for photovoltaic systems[124] is still ongoing and it might overlap with the scope of this study.

Considering all this, it is proposed that Art. 8-related requirements on RES should focus on:

1. installed photovoltaic systems in buildings
2. installed BESS in buildings.

Key energy performance factors for photovoltaics

The primary performance metric of a PV installation (per IEC 61724-1:2017) is the system yield that depends on the performance ratio (PR) and the reference yield (Yr) [hours/period]. It is related to the Energy output to the building (Epv)[kWh/period]. The following formulas apply:

Yf [hours/period] = PR x Yr

Yr[hours/period] = Hi/Gi,ref

Epv [Wh/period] = Yf x Wp

wherein (per IEC 61724-1:2017),

Yf = system yield which is the energy output divided by the array power rating

Yr = reference yield which are the equivalent hours of solar radiation at Gi,ref

Hi = in plane irradiation [kWh/m²] over specified time period or plane-of-array (POA)

Gi,ref = in plane reference irradiance which is 1 kW/m² due to STC definition

PR = Performance ratio (pollution, degradation, thermal loss, etc.)

Wp = Installed rated power modules in STC (W).

For BIPV/BAPV panel size vs power output is also an important metric. The following formula applies:

Wp = ηA[%] x A

wherein,

ηA[%] = Module Efficiency (initial Standard Test Conditions (IEC 61853-1)).

A = the module area [m²].

The performance ratio is an important installation and monitoring factor which can be disaggregated into several derating factors (DR) and components. These are the relevant factors to model at the PV system design stage and to monitor afterwards. An overview of key factors is given in Table 26. The typical values to consider for these key factors are highlighted in blue.

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

Table 26: Key factors for quantifying the energy performance of photovoltaic systems and typical range of values according to IEC 61724-1 and IEC 61853-1.

Derate Factor(DF) **Performance Ratio = $DR_{capture}$ x DR_{BOS}** **(reference standard: IEC 61724-1:2017)**	**PV system**		**Extended Product (non under STC)**		**Product policy (Standard Test Conditions (STC))**		**typical value (range)**		
	overall	**detail**	**overall**	**detail**	**overall**	**detail**	**min**	**typ**	**max**
performance ratio(PR)= = $DR_{capture}$ x DR_{BOS}	**PR**						**0,7**	**0,8**	**0,85**
array capture losses derating	**$DR_{capture}$**	**-**	**-**	**-**	**-**	**-**	**0,75**	**0,8**	**0,85**
shading losses	-	$DR_{shading}$	-	-	-	-	0,9	0,95	1
snow cover losses	-	DR_{snow}	-	-	-	-			
soiling losses	-	SL	-	-	-	-			
DC array cable losses	-	DRarraywr	-	-	-	-			
array mismatch losses	-	DR_{MISM}	-	-	-	-			
optical reflection losses	-	DRrefl	-	-	-	-			
other module level capture losses	-	$DR_{cap\text{-}mod}$	$DR_{cap\text{-}mod}$	-	-	-			
module thermal capture loss	-	-	-	DR_{therm}	-	-			
module degradation capture loss = 1- MDR^year	-	-	-	DR_{degrad}	-	-	0,50%	1%	2%
annual module degradation rate(MDR)	I					MDR	0,50%	1%	2%
optical reflection losses	-	-	-	DRrefl	-	-			
spectral effects	-	-	-	DRspect	-	-			
module derating at STC	-	-	-	-	1	-			
Balance of system (BOS) efficiency	**DR_{BOS}**	**-**	**-**	**-**	**-**	**-**	**0,91**	**0,93**	**0,95**
AC wiring losses	-	DRacwire	-	-	-	-			
AC transformer losses (if available)	-	DRtrafo	-	-	-	-			
losses due to network availability (curtailment)	-	DRcurt	-	-	-	-			
losses due to inverter failures (drop out)	-	DRinv-fail	-	-	-	-			
inverter losses (= $DR_{inv\text{-}ns}$ x η_{inv})	-	DRinv	-	-	-	-	0,99	0,99	0,99
derating non standard inverter total	-	-	DRinv-ns	-	-	-			
derating non standard inverter loading	-	-	-	$DR_{inv\text{-}load}$	-	-			
derating non standard MPPT transients	-	-	-	$DR_{inv\text{-}MPPT}$	-	-			
total inverter efficiency standard conditions	-	-	$\eta_{t\text{-}inv}$	-	$\eta_{t\text{-}inv}$	-	93%	96%	98%
static inverter converter efficiency	-	-	-	-	-	ηconv	TBD	TBD	TBD
'Module Efficiency' ηA[%] (initial STC) = Wp/A	**-**	**-**		**-**	**-**	**ηA[%]**	**25%**	**18%**	**16%**
Annual Reference Yield Yr[KWh/KWp]							**site and weather condition dependent (ED PV was 975 h/y)**		

Key energy performance factors for battery energy storage systems (BESS)

BESS are a relatively new technology and a comparable IEC standard is not yet available; the closest available is described in section 1.4.8. Therefore, the study team's own draft proposal based on the input cited in section 1.5.6 is elaborated in Table 27. The key factors and their typical values to consider are highlighted in blue. The key metrics are round trip efficiency, no load losses, capacity fade and finally the achieved carbon footprint per stored kWh. This can link to the proposal for a new EC battery regulation[125] to report on carbon footprint from the manufacturing of BESS.

[125] https://ec.europa.eu/environment/topics/waste-and-recycling/batteries-and-accumulators_en

Table 27: Draft proposal for key factors for quantifying BESS and a typical range of values for consideration in residential BESS.

	Product policy		typical value (range)		
	overall	**detailed**	**min**	**typ**	**max**
BESS declared round trip efficiency and performance ratio (PR, BESS = DR x ηSTC)					
Derate factor for non STC charging profile			0,98		
Inverter battery charge efficiency (AC2BAT) STC	$\eta_{AC2BAT,stc}$		94%		
Derate factor for non STC discharging profile			**0,98**		
Inverter battery discharge efficiency (BAT2AC)	**$\eta_{BAT2AC,stc}$**		**94%**		
Derate Factor for non STC Balance of system losses (cables, solid state protection switch)			0,99		
cables losses	$\eta_{BAT,cab,stc}$		99%		
solid state protection switch losses (if not taken into account elsewhere)	$\eta_{BAT,SSR,stc}$		98%		
Derate factor for round-trip efficiency (e.g. due to increased cell resistance or additional cell balancing					
Battery pack round trip efficiency	$\eta_{BAT,RTE,stc}$		92%	96%	
No load losses (=when zero charge or discharge current)					
No load loss from the converter [W]	**P, conv, nl**		**1**	**4**	**8**
No load loss from the BMS(e.g. for balancing, H/C, ..) [W]	**P, BAT, nl**				
From additional EMS(if any) [W]	**P, EMS, nl**		**1**	**4**	**8**
Derate Factor for declared storage capacity fade					
DR capacity fade (current status)			**target >0,8 (at declared life time)**		
monitored equivalent cycles to date (L,BESS, mon= E, stored/E, init, STC)		L, BESS, mon			
design full life cycles (80 % capacity fade)		L, cycles	1000	2000	4000
initial storage capacity (= E, init, STC)		E, init, STC	2 kWh	5 kWh	..
Achieved battery storage system storage carbon footprint					
Achieved carbon intensity per kWh = GWPbat/Eout			**target <0,15 (at 5y)**		
kWh BESS output over life time					
initial carbon footprint from the manufacturing per kWh storage capacity [kgCO2eq/kWh]	GWPbat		140	155	300

Abbreviation: BESS = battery energy storage systems.

2.3 Activity 2: Potential requirements for technical building systems

Prospective TBS requirements will need to be designed to produce energy savings in the TBS system as a whole and/or in parts of the TBS system that are not addressed by Ecodesign. These systems requirements address an important policy gap between the overall building minimum energy performance standards and EPC ratings, which apply at the whole building energy performance level, and the component energy performance requirements that are set under the Ecodesign Directive and which may be complemented by energy labelling regulations. In between, these component and whole building performance level policies, there is a need to set measures that ensure TBS, as designed, installed, commissioned and operated, perform efficiently in a cost-optimal manner. In considering the need and additional added value of setting such measures it is important for policymakers to appreciate that:

- although Ecodesign/ELR requirements may ensure or encourage individual components within TBSs to be relatively energy-efficient, this does not ensure that the TBS as a whole is efficient – this is because dimensioning could be inappropriate, the configuration may not be optimal, individual aspects of the system that are not addressed by Ecodesign/ELR requirements (such as distribution losses and operating temperatures, balancing, control of emitters, control of the whole system against the actual user needs, etc. are not addressed by component efficiency requirements under standard test conditions), the quality of installation/commissioning and operation, which have an important impact of system performance are not addressed
- although whole-building energy performance requirements will encourage adoption of efficient TBS designs they do not necessitate it – rather, it is perfectly possible that a construction design will over-compensate on the fabric performance and under specify the TBS performance, not least because the TBS are among the last part of a building to be completed and their installers are not so likely to be core project team members. Arguably, failure to set specific TBS performance thresholds also makes it more challenging to meet net zero energy building (NZEB) targets. Furthermore, these cases apply to new build and major renovation events which occur at a lower frequency than the installation/ replacement/retrofit of TBS in existing buildings – therefore, setting TBS system requirements that apply at the moment a TBS is installed, replaced or retrofit would ensure energy savings occur at all the key trigger points in the lifecycle of TBS equipment and stimulate a more rapid improvement in the efficiency of the building stock
- in addition, setting TBS-specific energy performance requirements help to ensure that all market actors whose actions have an impact on building energy performance have clear responsibilities to provide solutions that contribute to the common goal of improving building energy performance.

Prospective TBS requirements can be broken down in the following ways:

- normative measures that apply to the energy performance of the TBS as a whole
- normative measures that apply to the energy performance of individual aspects of the TBS
- normative enabling measures
- capacity building measures

- information requirements.

Note, economic incentive measures such as financial incentives (subsidies, grants, favourable loans) and fiscal measures (tax breaks) can complement normative measures but while these are important they are not considered in detail in this study as they do not fall within the EPBD Article 8 and 14/15 provisions. Nonetheless, it is necessary to consider how such measures could interact with and complement prospective requirements that could be set in accordance with the provisions of Article 8 and 14/15.

Table 28 shows a taxonomy of potential normative TBS requirements versus their potential applicability.

Table 28: Taxonomy of potential normative TBS requirements and their applicability.

	Applicable to:			
	A whole new TBS	Part of a new TBS	A whole existing TBS	Part of an existing TBS
Overall energy performance (Art.8)	Y	N	Y	N
Energy performance of an element within a TBS (Art.8)	N	Y	N	Y
Appropriate dimensioning (Art. 8)	Y	–	–	–
Proper installation (Art.8)	Y	Y	–	–
Building automation, control & monitoring (Art.15)	Y	Y	Y	Y
Inspection (Art. 14/15)			Y	

Abbreviation: TBS = technical building system.

Based on the findings described in section 1.6, in the next sections the most promising prospective energy saving requirements are listed per TBS.

To establish this set and hierarchy of requirements a two-step process has been applied.

1. A) Longlist of potential requirements is compiled based on the review of existing national requirements and initiatives, the findings on reported saving potentials and the evaluation of the key performance parameters.

   B) Selection elaboration[126] and definition of scope for the most promising requirements in terms of saving potential and enforceability.

2. Evaluation, ranking and recommendation

   A) Quantitative evaluation: determination of the scope and saving potential of the selected requirements expressed as the average annual primary energy saving potential between 2023 and 2040. The determinations per TBS are based on approximate calculations considering reported standard demolition and exchange rates, projections for new and replaced systems and expected improvement of the primary energy factor for electricity[127].

[126] The elaboration depth is kept rather general as the scope of this examination is EU level. For national implementation local preconditions, such as climate, specific systems or -traditions need to be considered for a more specific prioritisation of the requirements.

[127] Starting from 2.03 in 2018 according to Eurostat (https://ec.europa.eu/eurostat/web/energy/data/shares) with linear decrease to 1.87 in 2023 and 1.32 in 2040 and finally to 1.00 in 2050.

For the calculations, the expected saving from the application of a saving measure on a specific TBS installation is considered as well as the shares of affected systems within scope (which for existing systems diminishes in time). Where possible, the inputs for the calculations are founded on values reported in qualified literature. In the event of inconsistent or insufficient information from such sources qualified estimations have been made.

B) Qualitative evaluation considering cost effectiveness, level of implementation effort required, enforceability including potentially via monitoring and the benefit from intelligent monitoring/metering.

C) Overall ranking based on the results of the quantitative and qualitative evaluation. For the final score the average of the three qualitative scores is determined and multiplied with the energy saving potential. The higher the resulting final score the higher the viability and saving potential of the specific requirements.

D) Recommendation on the most promising requirements per TBS.

Note, these ranking calculations are available in an accompanying spreadsheet.

2.3.1 Potential requirements and scope of requirement application for space heating and DHW systems

Potential requirements

Table 29 shows a set of energy saving measure requirements applicable to space heating in order of their ranking according to the mixed quantitative/qualitative methodology applied (see top of section 2.3). Also shown is a broad description of the system types they are applicable to; the estimated average percentage system-level energy savings the measures would produce in eligible system types; the estimated share of the entire EU heating stock that the measures are applicable to; the expected energy savings in TWh/year at the EU stock level from implementing the measures to all eligible systems.

The applicability of the measures is shown in Table 30.

Scope of application of the potential requirements

The scope of application of the requirements are shown in Table 31.

Table 29: Potential space heating energy savings requirements and their estimated applicability and impacts.

No.	Requirement specification	Applicable to	Estimated individual system performance impact	Share of primary energy demand of systems in scope	EU stock impact (TWh/ annum)	FINAL SCORE
VH1	Monitor energy consumption, compare to expected performance and adapt parameters when needed	Systems >70 kW	5%	24%	28	20.1
VH2	Night set-back - adjusted settings (e.g. 11pm to 6am, 2 K temperature reduction), if system and user allows to	All residential	8%	45%	21	17.1
VH3	Overall heating system performance requirement, in line with the 2030 reduction target for buildings (tbd?) (here e.g. -4%/annum)	Systems >70 kW	4%	24%	21	16.3
VH4	Replace old combustion (non-condensing) boiler (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	All	15%	70%	29	16.2
VH5	Individual heat emitter control – thermostatic radiator valves	All	3.8%	52%	14	11.4
VH6	Hydronic balancing and heat zoning	All	2.7%	52%	12	7.6
VH7	Night set-back – adjusted settings (e.g. for office use 5pm to 6am, 2 K temperature reduction), if system and user allows to	All non-residential	2.5%	24%	4	3.6
VH8	Heat pumps in new building need to be equipped with a monitoring system to visualise actual seasonal performance, for new buildings: in relation to the calculated value of the energy passport	All	5%	4%	5	3.3
VH9	Installation of insulation on pipes (100% of diameter) – accessible pipes outside heated zone	Systems ≤70 kW	1.9%	46%	6	3
Vh10	Avoid simultaneous heating and cooling, by implementing a central controller or ensuring separate controllers do not overlap	Systems >70 kW	15%	24%	3	2.3
Vh11	Use of weather compensation to adapt supply temperature	All	7%	52%	1	1.2
Vh12	Installation of insulation on pipes (100% of diameter) – accessible pipes outside heated zone	>70 kW	0.9%	24%	2	1

Table 30: Application scope of space heating energy saving measures.

No.	Applicable to	New or major renovation		Existing	
		Residential	Non-residential	Residential	Non-residential
VH1	Systems >70 kW	Y	Y	Y	Y
VH2	All	Y	N	Y	N
VH3	Systems>70 kW	Y	Y	Y	Y
VH4	All	Y	Y	Y	Y
VH5	All	Y	Y	Y	Y
VH6	All	Y	Y	Y	Y
VH7	All	N	Y	N	Y
VH8	All	Y	X	Y	Y
VH9	≤70 kW	Y	Y	Y	Y
Vh10	>70 kW	Y	Y	N	N
Vh11	All	Y	Y	Y	Y
Vh12	>70 kW	Y	Y	Y	Y

Table 31: Scope and trigger points of pre-selected space heating requirements.

No.	Description of requirement	Scope	Trigger point
VH1	Monitor energy consumption, compare to expected performance and adapt parameters when needed	Large systems (>70 kW) in existing and new residential and non-residential buildings	System replacement, inspection and maintenance
VH2	Night set-back – adjusted settings (e.g. 11pm to 6am, 2 K temperature reduction), if system and user allows to	Systems in existing and new residential buildings, independent of size	System replacement, inspection, maintenance and component replacement
VH3	Overall heating system performance requirement, in line with the 2030 reduction target for buildings (tbd?) (here e.g. 4%/annum)	Large systems (>70 kW) in existing and new residential and non-residential buildings	System replacement, inspection, maintenance and component replacement
VH4	Replace old (non-condensing) combustion boiler (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	Systems in existing buildings, independent of size	System replacement, inspection, maintenance and component replacement
VH5	Individual heat emitter control – thermostatic radiator valves	Systems in existing and new residential buildings, independent of size	System replacement, inspection, maintenance and component replacement
VH6	Hydronic balancing and heat zoning	Systems in existing and new buildings, independent of size	System replacement and repair and component replacement
VH7	Night set-back – adjusted (e.g. for office use 5pm to 6am, 2 K temperature reduction), if system and user allows to	Systems in existing and new non-residential buildings, independent of size	System replacement, inspection, maintenance and component replacement
VH8	Heat pumps in new building need to be equipped with a monitoring system to visualise actual seasonal performance, for new buildings: in relation to the calculated value of the energy passport	All systems	System installation
VH9	Installation of insulation on pipes (100% of diameter) – accessible pipes outside the heated zone	Systems ≤70kW	System replacement and repair and component replacement
VH10	Avoid simultaneous heating and cooling, by implementing a central controller or making sure that separate controllers do not overlap	Systems >70 kW in new residential and non-residential buildings (or major renovations)	System replacement, inspection and maintenance
Vh11	Use of weather compensation to adapt supply temperature	Systems in residential and non-residential buildings, independent of size	System replacement, inspection, maintenance and component replacement
Vh12	Installation of insulation on pipes (100% of diameter) – accessible pipes outside heated zone	Large systems (>70 kW)	System replacement, repair and inspection and component replacement

Performance indicators and monitoring suggestion

To evaluate the overall performance of a space heating system, monitoring a number of performance factors is crucial. The main performance indicators can be derived by monitoring the following:

- fuel or electricity consumption of heat generation
- heating energy flows in the main heating circuits
- ambient temperature in heated zones
- outdoor temperature.

For this, the following sensors and meters are needed:

- consumption meter on production side (gas meter, oil meter, electric energy meter)
- energy meters for the water side or equivalent: supply temperature, return temperature, volume flow
- heated zones temperature sensors
- outdoor temperature sensor.

It is also important to have a reasonable time resolution (10 mins to 1 hour) and a correct timestamp on the readings in order to facilitate accurate monitoring and diagnosis.

Ideally all data should be logged on the same BMS system or data logging platform to facilitate data handling and processing.

2.3.2 Potential requirements and scope of requirement application for space cooling systems

Potential requirements

Table 32 shows a long list of energy savings measures applicable to space cooling in order of their ranking according to the mixed quantitative/qualitative methodology applied (see section top of section 2.3). Also shown is: a broad description of the system types they are applicable to; the estimated average percentage system-level energy savings the measures would produce in eligible system types; the estimated share of the entire EU AC stock that the measures are applicable to; the expected energy savings in TWh/year at the EU stock level from implementing the measures to all eligible systems.

The applicability of the measures by building stage is shown in Table 33.

Table 32: Potential space cooling energy savings requirements and their estimated applicability and impacts.

No.	Requirement specification	AC system types measures are applicable to	Estimated individual system performance impact	Share of total AC stock measure applies to	EU stock impact (TWh/ annum)	Final score
C26	Overall cooling system performance requirement, in line with the 2030 reduction target for buildings (tbd?) (here e.g. 8%/annum)	All	25%	62%	**25.5**	25.5
C3	Switch off circulation pumps when not required	All non-packaged systems	7%		10.6	16.4
C2	Clean or replace filters regularly	All	8%	79%	11.3	16.3
CH9	Avoid simultaneous heating and cooling: by implementing a central controller or making sure that separate controllers do not overlap	All systems with heating	25%	74%	14.3	11.9
C5	Shut off auxiliaries when not required	All non-packaged systems	8%	30%	7.3	11.4
C4	Reduce motor size (fan power) when oversized	All non-packaged systems	12%	48%	9.4	10.4
C7	Shut chiller plant off when not required	Systems with chillers	6%	41%	6.3	9.8
C6	Sequence heating and cooling	All non-packaged systems	15%	55%	7.2	9.6
C9	Shut off AC equipment when not needed	All	12%	25%	5.0	7.8
C16	Reduce power consumption of auxiliary equipment	All	5%	22%	6.9	7.6
C8	Modify controls in order to sequence heating and cooling	All non-packaged systems	4%	72%	5.2	6.3
CH11	Ensure proper installation according to standards	All	7%	68%	8.7	6.3
C10	Check (reversible) chiller stand-by losses	Systems with chillers	6%	65%	4.6	6.1
CH7	Monitor energy consumption, compare to expected performance and adapt parameters when needed	All	9%	40%	4.9	3.3
C11	Install BEMS	All	7%	30%	3.6	4.0

C18	Replace or upgrade cooling equipment and heat pump	All	4%	27%	5.1	4.0
C19	Reduce compressor power or fit a smaller compressor	All	8%	67%	4.3	3.8
C17	Consider cool storage applications (chilled water, water: ice, other phase change)	All non-packaged systems	8%	28%	5.7	3.8
C12	Improve central chiller/refrigeration control	Systems with chillers	5%	37%	3.3	3.5
CH10	(Smart) control that considers the reaction speed of systems, especially for chilled beam/ceilings to avoid under-/over-heating/-cooling	High thermal mass systems	7%	35%	2.0	2.5
CH4	Hydronic balancing and coolth zoning. A 'heated zone' is to be understood as a zone of a building or building unit, located on a single floor, with homogeneous thermal parameters and corresponding temperature regulation needs (i.e. the equivalent of a 'thermal zone', a common concept in the scope of energy performance calculation)	Hydronic distribution systems + all systems (for zoning)	5.50%	15%	3.2	1.8
C13	Operate chillers or compressors in series or parallel	Systems with chillers	4%	30%	1.4	1.6
C14	Split the load among various chillers	Systems with chillers	3%	18%	0.9	1.0
CH3b	Optimisation of heat pumps operation based on monitoring data (assuming Ecodesign requires monitoring) – not clear in Ecodesign	Heat pumps	3%	16%	0.9	0.9

Abbreviations: AC = air-conditioning; BEMS = building energy management systems.

Table 33: Building stage application scope of space cooling energy saving measures.

No.	Applicable to		New or major renovation		Existing	
			Residential	Non-residential	Residential	Non-residential
C1	Systems with AHUs, VAV, rooftops		Y	Y	Y	Y
C3	All non-packaged systems				Y	Y
C2	All				Y	Y
C5	All non-packaged systems					Y
C4	All non-packaged systems					Y
C7	Systems with chillers					Y
C6	All non-packaged systems	>30 kW	Y	Y	Y	Y
C9	All				Y	Y
C16	All		Y	Y	Y	Y
C8	All non-packaged systems	>30 kW				Y
C10	Systems with chillers	>30 kW				Y
C11	All	>30 kW	Y	Y	Y	Y
C18	All				Y	Y
C19	All		Y	Y	Y	Y
C17	All non-packaged systems		Y	Y	Y	Y
C12	Systems with chillers	>30 kW		Y		Y
C13	Systems with chillers	>30 kW		Y		Y
C14	Systems with chillers	>30 kW		Y		Y
C15	Systems with chillers	>30 kW				Y

Abbreviations: AHU = air-handling unit; VAV = variable air volume.

The most significant energy savings potentials identified are listed in Table 34; however, these can be implemented via requirements that are set in a broader manner which capture both these opportunities and several others through the adoption of three broad classes of requirements as follows:

- overall cooling system energy performance requirements
- control and controllability requirements
- metering and monitoring requirements.

These are now addressed in turn.

Table 34: Most important energy saving measures for space cooling systems.

Type	Variant	Individual savings	Share of systems in scope affected		Total savings with existing systems in scope	Average annual savings 2023–40 (TWh)
			Existing	New		
Control	C3+C7+C9: switch off systems when not required (circulation pumps, chiller plant, AC equipment)	7%	50%	30%	4%	4.7
Control	C8: modify controls in order to sequence heating and cooling	4%	50%	30%	4%	1.2
System	C26: overall requirement to annual savings of 4% (could be adapted to climate targets)	4%	100%	100%	4%	25.5
Control	C11: install BEMS	7%	27%	14%	1.9%	1.0
Control	C12: improve central chiller/ refrigeration control	5%	35%	0%	1.8%	0.5
System	C18+C15: exchange old and inefficient pumps and compressors	50%	15%	0%	8%	1.3
Control	C6: sequence heating and cooling	15%	0%	25%	0%	2.0
Monitor	Monitoring & metering measures	5%	100%	100%	5%	3.0

Abbreviations: AC = air-conditioning; BEMS = building energy management system

Overall cooling system energy performance requirements

Overall cooling system energy performance requirements should be set for new AC systems installed in existing buildings per the requirements in the EPBD Article 8(1). There is often a significant difference in the performance of the system and that of its individual elements that are covered under Ecodesign and ELR thus it makes sense to complement Ecodesign/ELR requirements with system level SEER requirements (where, a priori, the system level SEER is calculated in a manner consistent with EPBD standards and could make use of the EPC software tool or similar). Note, the system level SEER requirements can ensure that inefficient cooling solutions are avoided in ways that Ecodesign/ELR cannot and can better match the system SEER attained to the circumstances of the installation in terms of climate, functionality and usage profiles.

In addition, to setting overall system performance requirements for new systems it is also possible to set them for existing systems, such that if an existing system has a system level SEER that is less than a given level the building owner would be obligated to replace it. As almost all AC systems operate for the large majority of their operational time at part load, their ability to adapt to part-load conditions is critical. Therefore, a simple requirement could be adopted for all fixed capacity systems, or the fixed capacity parts thereof (compressors, chillers, pumps, fans), to be replaced by new variable capacity installations. Note, if a retrofit control solution can also provide variable cooling capacity that avoids the losses due to on-off cycling that could also be a permitted option. Conformity with this requirement could be assessed through AC inspections via simple documentation checks. Such replacement requirements could also be linked to any F-gas requirements pertaining to existing AC systems in order to avoid duplicative regulatory measures.

Control and controllability requirements

The control-related options listed in Table 34 are:

- install BEMS system (C11)
    - to at least class B level
    - to at least class C level
- switch off equipment when not required (combination of C3+C7+C9)
- modify controls in order to sequence heating and cooling (C8).

All of these energy savings options concern the effective control of the AC system and related systems. Essentially these could be captured through adoption of a single broader requirement of providing effective control. Installing BACS that controls all aspects of the AC system to at least class B level under EN15232 would provide the required functional control capability, but this alone does not ensure that the functional capability is being properly exploited to save energy. Thus, a mix of AC inspections with a focus on control and monitoring could help to bridge this gap (see metering & monitoring below).

The EN15232 BACS energy performance standard sets out the following control functionalities for AC (class B or higher, there is a separate section for AC/Ventilation combinations):

Interlock between heating and cooling control of emission and/or distribution

Partial interlock (dependent on the HVAC system)	Class B
Total interlock	Class A

Note, implementing class A or B interlock capability might save a considerable amount of energy as anecdotally it is reported that simultaneous heating and cooling of the same zones is one of the biggest causes of energy waste in non-residential buildings.

Emission control:

Individual room control	Class C
Individual room control with communication	Class B (or A for slow reacting cooling emission systems e.g. floor/slab cooling)
Individual room control with communication and occupancy detection	Class A

Control of distribution network chilled water temperature (supply or return):

Outside temperature compensated control	Class C
Demand based control	Class A

Control of distribution pumps in networks:

Multi-Stage control	Class B
Variable speed pump control (pump unit (internal) estimations)	Class A
Variable speed pump control (external demand signal)	Class A

Intermittent control of emission and/or distribution:

Automatic control with optimum start/stop	Class B
Automatic control with demand evaluation	Class A

Generator control for cooling (the goal consists generally in maximising the chilled water supply temperature):

Variable temperature control depending on outside temperature	Class B
Variable temperature control depending on the load	Class A

Sequencing of generators for chilled water:

Priorities only based on loads	Class C
Priorities based on generator efficiency and characteristics	Class B
Load prediction based sequencing	Class A

It should be noted that it is also possible to express these as *à la carte* requirements rather than simply requiring a horizontal class B level. While class B is probably always justified from a cost-effective energy performance control perspective in some cases class A may also be warranted as a minimum functionality (and in several cases it is likely it would be the cost-optimal solution).

Metering and monitoring requirements

Metering and monitoring – require AC systems within scope of the requirements to be sub-metered and monitored. This is an additional recommendation in that it is not directly addressed in the earlier list of energy saving options but would help to ensure that control functionality was being properly utilised through provision of readily checkable performance indicators and benchmarks (KPIs). If implemented in conjunction with equivalent requirements for space heating it could detect a commonly reported cause of over consumption in HVAC systems from simultaneous heating and cooling in the same zone (and thereby be a trigger to adopt the interlock functionality for BACS).

In addition, it could:

- identify other poor operation of the AC system and its constituents and help both diagnose problems and quantify the cost-benefit of remedial actions
- identify deficiencies in installation and commissioning
- identify system performance degradation and maintenance needs.

Rationale: Metering and monitoring provides the key information that allows savings in TBS systems to be acted upon and makes it much more likely they will be acted upon, especially if implemented in conjunction with BACS capabilities that facilitate benchmarking, KPI analysis and identification of system performance issues. The iSERV project found that continuous metering and monitoring was much more effective than inspections at identifying energy savings, i.e. it estimated based on comparison of findings in a large number of European buildings that inspections were only likely to identify 20% of the savings opportunities that metering and monitoring would identify and that the results were much less likely to be acted upon. In addition, inspections are periodic (and hence intermittent) whereas metering and monitoring provides continuous feedback which allows prompt remedial action to be taken and make it easier to create a defensible business case for remedial action. Lastly, metering and monitoring has become simpler and cheaper to implement than was the case some years ago and there is considerably more knowledge in the market regarding its implementation.

The EN15232 BACS standard energy performance classifications set out the following functionalities per energy performance class (focused mostly on functionalities of class B or above):

Set-point management

Adaptation from distributed/decentralised plant rooms only	Class C
Adaptation from a central room	Class B
Adaptation from a central room with frequent set-back of user inputs	Class A

Runtime management

Individual setting following a predefined time schedule including fixed preconditioning phases	Class C

Individual setting following a predefined time schedule; adaptation from a central room; variable preconditioning phases	Class A

Detecting faults of technical building systems and providing support to the diagnosis of these faults

With central indication of detected faults and alarms	Class C
With central indication of detected faults and alarms/diagnosing functions	Class A

Reporting information regarding energy consumption, indoor conditions

Indication of actual values only (e.g. temperatures, meter values)	Class C
Trending functions and consumption determination	Class B
Analysing, performance evaluation, benchmarking	Class A

Waste heat recovery and heat shifting

Instantaneous use of waste heat or heat shifting	Class D
Managed use of waste heat or heat shifting (including charging/discharging TES)	Class A

In addition, the eu.bac handbook sets out the KPIs that should be tracked and monitored. Therefore, metering and monitoring requirements are likely to be more successful if they are implemented in conjunction with the BACS functionality required in EN15232 and the related KPIs. Three approaches could be used to specify such requirements:

a) an *à la carte* selection of BACS functionalities related to metering and monitoring from the set of functionalities indicated above

b) an across-the-board minimum BACS energy performance requirement, e.g. BACS class B

c) as b) but with some specific additional functionalities when warranted, e.g. class A functionality with regard to waste heat recovery (dependent on the AC system).

Installation and commissioning requirements

While problems in TBS functionality and energy performance due to poor installation, commissioning and handover are not uncommon it can be difficult to specify normative requirements to minimise these issues. However, if metering and monitoring requirements with the related BACS functionality as set out above were to be implemented then it would make it much simpler to promptly identify faults and to take remedial action. It would also facilitate a continuous commissioning paradigm. Some metering and monitoring can quickly identify faults and facilitate attribution to including to the initial installation and commissioning process. This would have the benefit of making it easier to hold responsible parties to contractual requirements and thereby stimulate improved service provision in the market as a whole.

Scope of application of the potential requirements

Table 35 provides an overview of the priority requirements proposed for space cooling.

Table 35: Scope of application and trigger points of the priority proposed space-cooling requirements.

Description of requirement	Scope	Trigger point
1.(a) Overall cooling system requirement (C26)	All new installations built in situ (i.e. not sold as complete packaged products)	New installations
1.(b) as above but for existing systems	Existing systems that fail a performance criterion check are replaced	On recommendation from inspection
2. Install BEMS (C11) **a) to at least class B level** **b) to at least class C level**	a) For all existing non-residential buildings with >270 kW of HVAC b) For all existing non-residential buildings with >70 kW of HVAC	a) Before 2025 b) On recommendation from inspection
3. Switch off equipment when not required (combination of C3+C7+C9)	All existing buildings	On recommendation from inspection or from monitoring
4. Modify controls in order to sequence heating and cooling (C8)	All existing buildings	On recommendation from inspection (and then immediate) or from monitoring
5. Sequence heating and cooling (C6) – new build/major renovations	All new buildings or major renovations	New build and major renovation
6. Retire/exchange old and inefficient pumps and compressors (C18+C15)	All existing buildings where the existing pumps and compressors fail performance criteria	Immediate, including on recommendation from inspection (and then immediate exchange)

Abbreviations: BEMS = building energy management system; HVAC = heating, ventilation and air-conditioning.

An example of the fully detailed scope of application of a requirement is shown in Annex B.

2.3.3 Potential requirements and scope of requirement application for ventilation systems

Potential requirements

Following consideration of the actual requirements adopted in the Member States and the evaluation of the key energy performance factors (see section 2.2.3) the flowing longlist of potential requirements specific for ventilation has been created.

Based on reported individual and overall saving potentials as well as expert judgement the most promising ones are selected for further specification and evaluation. The selected ones are marked in bold.

- **Overall ventilation system performance**
- **Specific fan power (replacement of inefficient fans)**
- Heat recovery efficiency
- **Filter efficiency and usage of suitable filter classes**
- Air tightness of ducts
- **Check and adapt design air volumes**
- **Check and adapt volume control settings**
- **Installation of volume control systems and related sensors**
- Adequate design of the air-distribution and -emission systems
- Adequate Insulation of duct system
- Take care of the required maintenance
- Installation of equipment to indicate and initiate maintenance actions
- **Installation of an efficient (energy and cost) heat recovery system**
- Adjust the settings for HR-bypass- or defrosting-controls
- Replacement of inefficient humidification system including an accurate controls
- Check and adapt the humidity control settings
- Installation of a and adequate temperature control system
- Check and adapt the temp. control parameters
- Install an adequate monitoring system (for energy demand and control parameters), which consists of a data storage and visualisation capability (ideally including benchmarking) to enable system optimisation.

The selected requirements were specified regarding content scope and trigger point.

Table 36 provides an overview of the specifications for the most promising requirements.

Table 36: Specification of selected ventilation requirements.

No.	Description of requirement	Scope	Trigger point
V1a	Limitation on average PSFP for all fans at design conditions[128]	Existing large and medium AHUs (>5500 m^3/h) in non-residential buildings	No specific trigger (immediate exchange)
V1b	Limitation on average PSFP for all fans at design conditions	Existing large and medium AHUs (>5500 m^3/h) in non-residential buildings	Component replacement (→ estimated 8-year cycles)
V2	Volume reduction to actual demand by parameter adjustment	Existing and new large and medium AHUs (>5500 m^3/h) in non-residential buildings	No specific trigger (immediate action)
V3a	Installation of air-volume controls	Existing and new large and medium AHUs (>5500 m^3/h) in non-residential buildings	No specific trigger (immediate action)
V3b	Installation of air-volume controls	Existing and new large and medium AHUs (>5500 m^3/h) in non-residential buildings	System inspection (→ estimated 4-year cycles)
V3c	Installation of air-volume controls	New large and medium AHUs (>5500 m^3/h) in non-residential buildings	System inspection (→ estimated 4-year cycles)
V4	Installation of a heat recovery system (or an exhaust air heat pump in case of space constraints)	Existing large and medium AHUs (>5500 m^3/h) in non-residential buildings at cold and average climate	Component replacement (→ estimated 8-year cycles)
V5	Improvement of filter exchange	All systems with filters (>100 m^3/h)	No specific trigger (immediate action)
V6	Installation of a monitoring system that allows comparison of actual performance with expected performance [129]	Existing and new large and medium AHUs (>5500 m^3/h) in non-residential buildings	Component replacement (→ estimated 8-year cycles)
V7	Overall ventilation system performance requirement, e.g. in line with the 2030 reduction target for buildings (assumption 4%/annum)[130]	Existing and new large and medium AHUs (>5500 m^3/h) in non-residential buildings	No specific trigger (immediate action)

Abbreviations: AHU = air-handling unit; PSFP = average specific fan power.

In most cases the scope has been limited to large and medium air-handling units. For those systems a high overall primary energy consumption has been reported. Furthermore, due to their size, measures become much more cost effective than for smaller systems.

Evaluation and recommendation

Table 37 provides an overview of the quantitative and qualitative evaluation of the pre-selected ventilation requirements as well as the final score.

[128] P_{SFP} may not exceed 2.0 kW/(m^3/s) for balanced systems 2.5 kW/(m^3/s) for balanced AC systems and 1.0 kW/(m^3/s) for unitary systems.

[129] At least a separate metering of the electricity consumption of the fans

[130] That requirement would need to specify a reference per usage type which would define the threshold. Ventilation systems with a monitored overall primary energy consumption (for fan power and air treatment) beyond that threshold would be required to improve their performance. The threshold would be adapted according to the set reduction goals (e.g. here 4 %/annum)

Table 37: Evaluation of pre-selected requirements for ventilation.

No.	Requirement	Scope	Trigger	EU stock impact (TWh/annum)	Cost-effectiveness	Level of implementation effort	Enforceability	FINAL SCORE
V1a	Limitation on average PSFP for all fans at design conditions[131]	Existing AHU >5500 m³/h)	No	12	2	1	1	5.3
V1b	Limitation on average PSFP for all fans at design conditions	Existing AHU >5500 m³/h	Component replacement	7	2	1	2	4.0
V2	Volume reduction to actual demand by parameter adjustment	Existing and new AHU >5500 m³/h	No	10	3	3	1	7.9
V3a	Installation of volume controls	Existing and new AHU >5500 m³/h	No	16	2	1	1	6.9
V3b	Installation of volume controls	Existing and new AHU >5500 m³/h	System inspection	12	2	1	2	6.6
V3c	Installation of volume controls	New AHU >5500 m³/h	System inspection	2	1	2	3	1.3
V4	Installation of a heat recovery system	Existing and new AHU >5500 m³/h at cold and average climate	Component replacement	1	2	1	1	0.4
V5	Improvement of filter exchange	All systems with filters (>100 m³/h)	No	5	2	1	1	2.2
V6	Installation of a monitoring system	Existing and new AHU >5500 m³/h	Component replacement	6	2	2	2	4.3
V7	Overall ventilation system performance requirement	Existing and new AHU >5500 m³/h)	No	44	1	1	1	19.4

Abbreviations: AHU = air-handling unit; PSFP = specific fan power

[131] PSFP may not exceed 2.0 kW/(m³/s) for balanced systems 2.5 kW/(m³/s) for balanced AC systems and 1.0 kW/(m³/s) for unitary systems

Due to the evaluation requirement V7 scores the highest. Due to the design of that requirement the saving potentials are by far the highest, which overcompensates the supposed difficulties for practical implementation (see next paragraph). Further, very high scoring requirements are related to volume reduction to demand (V2: Volume reduction to actual demand by parameter adjustment and V3a and V3b installation of volume control in existing air-handling units. Limitation of specific fan power is also very effective. Such a requirement is already in place at a variety of Member States (see Table 6).

Overall ventilation system energy performance requirements

A prerequisite for overall ventilation system energy performance requirements according to EPBD Article 8(1) the performance of monitoring (annual demands for electricity, heating and cooling) and the specification of benchmarks. Such benchmarks need to be defined per building-/usage-type to consider individual quality requirements. The most relevant qualities to consider are:

1. minimum required air volumes, which are dependent on the usage type and actual demand
2. specific fan power, which is specifically dependent on the system requirements regarding air quality (filters)
3. predefined minimum heat recovery rate.

Monitoring should also check whether the minimum required air volumes are met to allow for correction at the assessment.

As such overall ventilation system energy performance requirements would therefore need monitoring and a relatively comprehensive assessment they would only be cost-effective for larger systems.

By setting minimum overall performance requirements on ventilation systems the Member States would be able to ensure that specific predefined targets are achieved by adjusting the ambition level of those requirements.

Control and controllability requirements

The control-related options listed in the table above are:

- V2: volume reduction to actual demand by parameter adjustment
- V3a–c: installation of volume controls.

While V2 does not require new components to be installed, for V3a–c the installation of additional components and BACS is necessary. Installing BACS that control all aspects of the ventilation system to the class B level under EN15232 would provide the required, and some additional, functional control capability to stimulate significant energy savings.

Metering and monitoring requirements

Metering and monitoring will not directly produce energy savings, but they are a prerequisite for an informed judgment to detect failures in control and issues with the overall energy performance.

Installation and commissioning requirements

See textual explanations in section 2.3.2.

2.3.4 Potential requirements and scope of requirement application for BACS

Potential requirements

Requirements for installing or putting into service of BACS are discussed in the respective Ecodesign Study for BACS[132].

BACS is an important instrument for proper adjustment and control of heating, cooling, ventilation and lighting systems, meaning that it can play an important role in continuous commissioning. Those requirements are discussed in their respective section.

BACS requirements for heating and cooling (>290 kW) are also proposed under Art.14/15 (4) in Task 5.

2.3.5 Potential requirements and scope of requirement application for lighting systems

Overall lighting system energy 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 38 are exceeded for two consecutive years.

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

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[133] website with general building renovation advise (BE, W)
- newer data from Lot 37[134] but which might be too ambitious
- older data from the Swiss Standard 380/4(2006)[135] or the updated standard SIA 387/4(2017)[136] can also be considered.

Appropriate dimensioning requirements for new 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

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

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

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

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

- 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].

Proper installation requirements for lighting systems

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 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.

Appropriate control and adjustment installation requirements

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_17h_june) measured in June at 17 h >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).

2.3.6 Potential requirements and scope of requirement application for RES systems

Potential requirements for photovoltaic systems

For the overall performance requirements of Art. 8 (1) authorities should issue EPC schemes that:

- give clear information on how PV system yield energy is taken into account in the EPC and what the assumptions are with regard to self-consumption
- try to achieve long term consistency and therefore the recommended approach is to use over 1 hour as a maximum time frame for self-consumption credit compensation, because:
  - the EN EPBD standards has been updated to provide an hourly method[137]
  - see section 2.2.6 for the technical difficulties to achieve real-time self-consumption (20 ms) versus a 1-hour time frame, most notably a heat pump is unlikely to be able to follow in real time the variable PV yield under cloudy conditions
  - such PV output variations come from geospatial cloud conditions and can with a normal sized distribution grid easily be averaged out. Alternatively, battery storage systems (BESS) can be promoted but this might be inconsistent environmental policy, because battery storage losses are likely larger than grid losses[138] and on top comes the carbon footprint of the battery[139] that will wear out
  - Denmark has a large share of RES and uses the 1 hour as a maximum time frame for credit compensation – this can serve as an example[140].
- when deviating schemes are implemented also compliance with Art. 15 (2) of the EED should be checked.

When considering potential requirements for installed photovoltaic system one should be aware that this is also considered in the ongoing preparatory and impact assessment study for solar photovoltaic modules, inverters and systems[141]. The policy option that could be considered here is option 3.2 or the 'Residential system energy label option with the Yield and performance ratio-based approach'. This means that the policy option proposed could also partly cover Art. 8 requirements; therefore, they are indicated in green highlighted cells in Table 39. In this policy proposal it is strongly recommended to introduce a uniform reporting format for PV systems in line with IEC 61724-1:2017 (see Table 26), because:

- it allows proper adjustment and appropriate control in the sense of Art. 8
- it allows prospective PV system owners to easily compare quotes from different installers and check they do not overstate certain Derating Factors
- it is also a benefit for commissioning.

In addition, taking into consideration the future impact of self-consumption on the building EPC and the economic return on investment, it is proposed to require appropriate and consistent information. Unfortunately, this is not yet covered in standards and also various approaches are currently in use (see section 2.2.6). Nevertheless, it is

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

[138] https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/2020-12/jrc12431preparatory_study_for_solar_photovoltaic_modules_kj-na-30468-en.pdf

[139] https://ecodesignbatteries.eu/

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

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

recommended to always provide the hourly information needed to assess self-consumption. In the case that Member State authorities wish to apply a self-consumption definition with a time frame of below 1 hour for credit compensation purposes then they should provide a rationale and a statistical method to quantify the impact attributable to this.

The mapping of the key parameters identified and potential benchmark values on the different aspects of Art. 8 (overall performance, dimensioning, installation, adjustment, control) are shown in Table 39.

Once installed, a PV installation usually requires little maintenance. Mainly PV installations with low inclination (<20°) are cleaned periodically. The key metrics to follow are the Performance Ratio (PR); how this is calculated is explained in section 2.2.6. It only requires an electricity meter, while the location and orientation-dependent reference yield (Yr) can be sourced from a weather data server on the internet or a local installed solarimeter. When this PR ratio fails, additional checks can be performed as indicated in Table 39.

Table 39: Mapping of the key parameters for photovoltaic systems (part 1) to potential Article 8 requirements.

Derate Factor(DF) Performance Ratio = $DR_{capture}$ x DR_{BOS} (reference standard: IEC 61724-1:2017)	Art. 8 requirements				
	overall energy performance requirements	**appropriate dimensioning**	**proper installation**	**proper adjustment**	**appropriate control**
performance ratio(PR)= = $DR_{capture}$ x DR_{BOS}	x	x	x		**x (calculate PR = Yf/Yr) if PR deviates +/- 3 % check below**
array capture losses derating			x		
shading losses			x	**x(prune trees?)**	
snow cover losses			x	**x(consider removing snow?)**	
soiling losses			x	**x(consider regular cleaning?)**	
DC array cable losses		x	x		
array mismatch losses			x		
optical reflection losses			x		
other module level capture losses			x	**x(consider new modules if degradadated)**	
module thermal capture loss			x		
module degradation capture loss = 1- MDR^year			x		
annual module degradation rate(MDR)	x		x		
optical reflection losses			x		
spectral effects			x		
module derating at STC			x		
Balance of system (BOS) efficiency			x		
AC wiring losses		x	x		
AC transformer losses (if available)		x	x		
losses due to network availability (curtailment)			x	**x(check the error log file of the inverter and contact the network operator)**	
losses due to inverter failures (drop out)			x	**x(check the error log file of the inverter and contact the network operator)**	
inverter losses (= DR_{inv-ns} x η_{inv})			x	**x(consider another inverter when abnormali)**	
derating non standard inverter total			x		
derating non standard inverter loading		x	x		
derating non standard MPPT transients			x		
total inverter efficiency standard conditions	x		x		
static inverter converter efficiency			x		
'Module Efficiency' ηA[%] (initial STC) (~ Wp/A) (IEC 61853-1)	x		x		**x (check module degradation) x (optional monitoring: VDC & in plane solarimeter)**
Yf (measured) [h]			x		**x (from monitoring = Epv/Wp [h])**
Yf (forecasted) [h]	x		x		
Annual Reference Yield Yr[h]	x		x		**x (annual reference yield should be available from a weather server or in plane solarimeter)**

Potential requirements for BESS

BESS are a new and emerging technology and there are no standards yet for appropriate dimensioning and installation. Dimensioning will be very dependent on the applied definition of self-consumption and more in particular the maximum time frame for credit compensation[122]. Therefore, it is proposed to use 1 hour as a maximum time frame for credit compensation[122] which is the same as for photovoltaics. When schemes which deviate from this are implemented compliance with Art. 15 (2) of the EED should also be checked; in particular when there is a risk to indirectly prescribe BESS that would impede the proper functioning of the internal market.

Concerning the dimensioning of BESS it must be noted that it can fulfil more needs than renewables self-consumption. It can do peak shaving of PV power and thereby avoiding grid congestion. The ability for peak power can also influence the electricity tariff if a capacity-based component exists.

The mapping of the key parameters identified, based on those identified in section 2.2.6 versus different aspects of Art. 8 (overall performance, dimensioning, installation, adjustment, control), are shown in Table 40. This is a first attempt to do this, noting that standards and methodologies are often lacking and there would be benefit from more research and stakeholder input to elaborate this before it is deemed to be practical to implement.

Table 40: Mapping of the key parameters for battery energy storage systems (BESS) to the potential Article 8 requirements.

	Art. 8.1				
	overall energy performance requirements	**appropriate dimensioning**	**proper installation**	**proper adjustment**	**appropriate control**
BESS declared round trip efficiency and performance ratio (PR, BESS = DR x ηSTC)					
Derate factor for non STC charging profile		x			
Inverter battery charge efficiency (AC2BAT) STC					
Derate factor for non STC discharging profile		x			
Inverter battery discharge efficiency (BAT2AC)		x			
Derate Factor for non STC Balance of system losses (cables, solid state protection switch)					
cables losses		x			
solid state protection switch losses (if not taken into account elsewhere)	x				
Derate factor for round-trip efficiency (e.g. due to increased cell resistance or additional cell balancing		x			
Battery pack round trip efficiency	x				
No load losses (=when zero charge or discharge current)					
No load loss from the converter [W]		x (check if annual no load losses are > 3	x (measure no load losses)		
No load loss from the BMS(e.g. for balancing, H/C, ..) [W]		x (check if annual no load losses are > 3 % of average	x (measure no load losses)		x (monitoring)
From additional EMS(if any) [W]		x (check if annual no load losses are > 2 % of average	x (measure no load losses)	x (check control strategy for self consumption)	x (check control strategy for self consumption)
Derate Factor for declared storage capacity fade					
DR capacity fade (current status)			x (provide product data)		x (monitoring)
monitored equivalent cycles to date (L,BESS, mon= E, stored/E, init, STC)					
design full life cycles (80 % capacity fade)					
initial storage capacity (= E, init, STC)					
Achieved battery storage system storage carbon footprint					
Achieved carbon intensity per kWh = GWPbat/Eout			x (provide product data)		x (monitoring)
kWh BESS output over life time					
initial carbon footprint from the manufacturing per kWh storage capacity [kgCO2eq/kWh]					

TASK 3. POSSIBLE APPROACHES FOR ENFORCEMENT OF TECHNICAL BUILDING SYSTEM REQUIREMENTS AND ASSESSMENT AND DOCUMENTATION OF SYSTEM PERFORMANCE

3.1 Objectives and approach

The objectives of this task are to define and assess potential enforcement approaches and additionally, to assess prospective approaches for the assessment and documentation of system performance. These are examined for the whole list of potential requirements drawn up in Task 2 for each of the technical building systems defined under the EPBD.

Accordingly, the Task report is split into the two following sections:

- enforcement of system requirements
- assessment and documentation of system performance.

The approach to conducting these are now discussed in turn.

3.2 Activity 1: Enforcement of system requirements

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. This section explores the options to enforce systems level requirements for each type of TBS addressed in Tasks 1 and 2 and specifically examines the pathways by which enforcement could be provided for the specific TBS recommendations made in Task 2. In conducting this work the study team have:

- reviewed and analysed literature on the current approaches to building regulation enforcement utilised across the EU Member States and in particular those applicable to technical building systems (as identified in Tasks 1 and 2). The review builds upon the findings of Task 1 Activity 1 but strengthens it by identifying and classifying the distinct approaches currently in use (through determination of a taxonomy of their characteristics), assembling and reviewing the evidence with regard to their effectiveness, their cost and administrative burdens
- taken the assessment and analysis linked to this taxonomy and considered all the relevant potential enforcement approaches including assessment of compliance as part of the building Energy Performance Certificates (EPCs) for existing buildings, building permits for new and large renovations, obligations for public buildings, market surveillance, installer labels, obligatory on-site inspections for heating and/or cooling generators or electronic monitoring of system operation
- for each potential enforcement approach conducted a qualitative assessment covering at least: effectiveness (i.e. to what extent the considered approach would ensure compliance with applicable requirements), administrative burden

and costs for authorities responsible for enforcement, and costs for building owners

- where possible, identified potential synergies with existing schemes already in place (e.g. inspections of technical building systems under Article 14 and 15 of the EPBD, or training schemes) and identified and highlighted opportunities as a result of these.

For this version of the report the review part of this activity is only partially complete. In the final version of the report the study team also hope to indicate whether the approaches considered are already implemented within the Member States, although this is contingent on the strength of response the team receives to the Member State enquiry which has only recently been circulated.

It is noted that this task covers the enforcement of requirements within the scope of Article 8(1) of the EPBD, which means not only enforcement of requirements for new technical building systems, but also when these are upgraded and replaced.

In so doing, the intention is to ensure consistency with the analysis and outputs of Task 2 and, in particular, with the results of the 'scope for requirement application' activity therein.

In particular, the following aspects are (or will be, for the final report) covered:

- the implications for enforcement of the trigger points and circumstances which apply when TBSs are being installed for each of the cases considered in the following matrix, i.e. the matrix of building types (single family homes, multi-family residences, offices) and of building status (new build, major renovation and amendments of existing systems)
- relevant experience with regard to the inspections of heating and cooling systems per the requirements under Articles 14 and 15 of the EPBD
- relevant factors from the enforcement of Ecodesign and energy labelling requirements as applied to product components and systems (e.g. for heating and hot water systems (especially the so called "installer" energy label), air conditioning, ventilation, and lighting – the objective is to establish the distinctive scope and complementarity between the EPBD and Ecodesign/ELR enforcement actions and to clarify the scope of MSA responsibilities and methods.

The evaluation assesses the viability of the different approaches from the following perspectives:

- the level of compliance attained (i.e. blending the evidence of the level of compliance achieved due to the approach followed combined with a logical appraisal of the strengths and weaknesses of each approach from this perspective)
- the nature, ease and reproducibility of the conformity assessment process required by the responsible market actors
- the availability and applicability of technical standards and tools to support conformity assessment
- the level of professional training and skills required to establish conformity
- the steps that authorities responsible for compliance need to undertake to verify compliance

- the availability and applicability of standards and tools necessary to verify compliance
- the professional profiles and competences (including technical qualifications, certification and accreditation) of the inspectorate (when used) and compliance authority staff
- the type of institutional mandates and roles and the implications this may have when different compliance authorities/ Market Surveillance Authorities (MSAs) are responsible for ensuring compliance with different aspects of the TBS requirements (even for its energy performance, e.g. the scope of responsibility of Ecodesign/ELR MSAs and of authorities charged with building regulation compliance)
- the magnitude of resources necessary to apply the methods under consideration
- the technical and administrative burden entailed for Member State authorities
- the expected extent to which the approach is likely to ensure a level playing field for market actors
- the extent to which the compliance approach may add costs to the TBS which is subject to the requirements.

In doing this work an important distinction is made between the process of *conformity assessment* (the steps the market actors responsible for the design and installation of TBSs need to undertake to ensure their services comply with requirements) and the *enforcement processes* (the steps mandated regulatory authorities need to undertake to ensure the TBSs respect the requirements). The first aspect of enforcement is *conformity verification* and accordingly the main focus of this assessment is on the conformity verification actions. As conformity verification is closely linked to conformity assessment (which is the principal topic of section 3.3), this section also considers aspects of conformity assessment when they are relevant to verification.

It should be noted that well-structured and straightforward conformity assessment is as important as conformity verification in attaining a good compliance outcome, as the first factor that needs to be addressed is the ease with which responsible market actors can meet the requirements that apply to them. The review therefore considers the level of burden different approaches place on conformity assessment in conjunction with the degree of reliability of the results. Equally, it considers, the same for the actions implied by market surveillance authorities.

3.2.1 Introduction

Compliance frameworks applicable to technical building systems aim to ensure that obligated parties follow necessary steps so that their products, systems and services comply with normative requirements both when being first placed on the market, when putting into service or when already installed. These frameworks also help policymakers to monitor and verify that conformity is being achieved over time and to take corrective action to deter non-compliance. These actions are essential if the desired energy, economic, environmental and social benefits are to be achieved, while ensuring a free and fair market for suppliers and other obligated parties.

The three main pillars necessary for a high level of compliance are conformity assessment, conformity verification, and enforcement (Figure 21). All three are necessary for a good outcome. The calibre of conformity assessment can be further strengthened by the provision of professional training, appropriate conformity assessment tools and related certification and accreditation schemes.

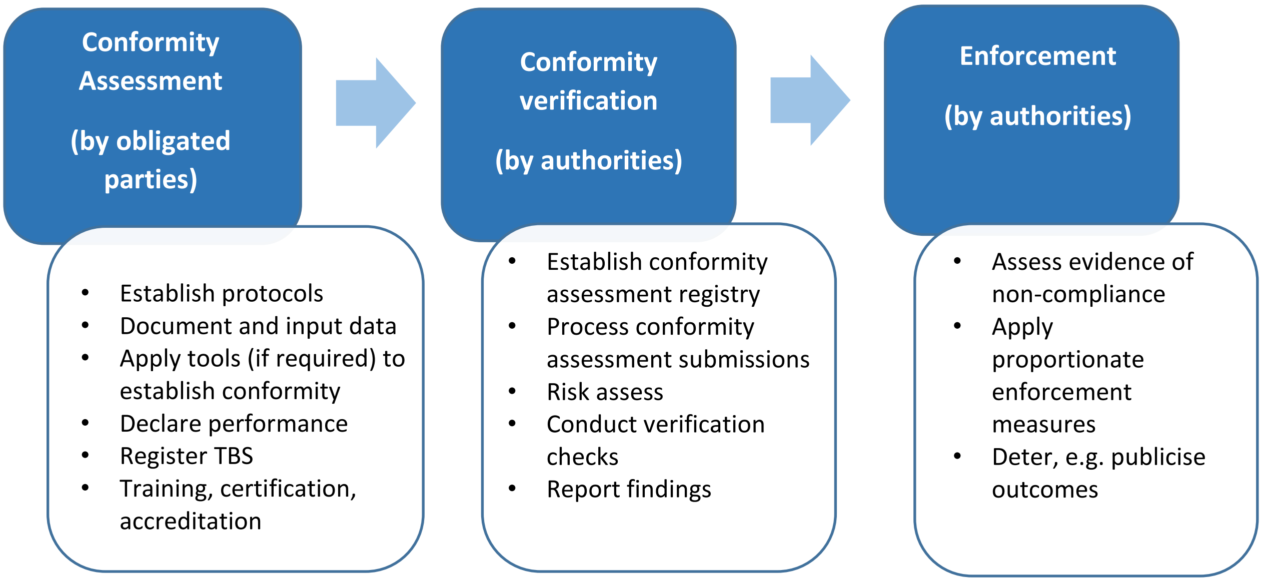


Figure 21: The pillars of compliance.

Current status of EPBD compliance checking

At the time of writing a Member State enquiry which includes questions on TBS-related compliance activity has been launched and the study team are awaiting the responses with regard to compliance practices for TBS; however, earlier work by the Concerted Action EPBD in compliance processes used with EPCs revealed that in 2014 most countries checked the compliance of energy performance requirements at the design stage as part of the building permit procedure. In many/most building projects design changes will occur in their execution, thus many Member States also require an additional check after construction or as part of the procedure of issuing the permit for use. In 2014, twenty-one Member States also required proof of compliance at a certain point after construction was complete while the other Member States checked compliance at different phases or via random checks (Figure 22). Understanding these practices is important for TBS compliance pathways as most likely the latter will need to complement existing EPBD compliance practice as much as possible in order to minimise the burden on the obligated parties and on the compliance authorities.

Evidently the compliance actions reported in Figure 22 are concerned with conformity verification of EPCs issued following a new build or major renovation event, whereas the Article 8(1) provisions mostly concern TBS in existing buildings, thus there is only an overlap in cases when the:

- TBS is installed in a new building or major renovation of an existing one
- the Member State applies the same conformity verification procedures for TBS installed in existing buildings as for new build or major renovation (e.g. were the installation of a new TBS to immediately trigger the issuance of a new EPC).

A priori, it is expected that neither case is likely to be prevalent for TBSs installed in existing buildings but the situation will verified once the Member State enquiry is complete.

It should be noted that when the CA EPBD EPC compliance assessment was conducted a significant proportion of Member States (26%) had no information on compliance rates with EPC provisions for new buildings and had no plans to gather such information, while another 22% had no information but were planning to assemble it (Figure 23). The extent to which this is still the case remains to be clarified.

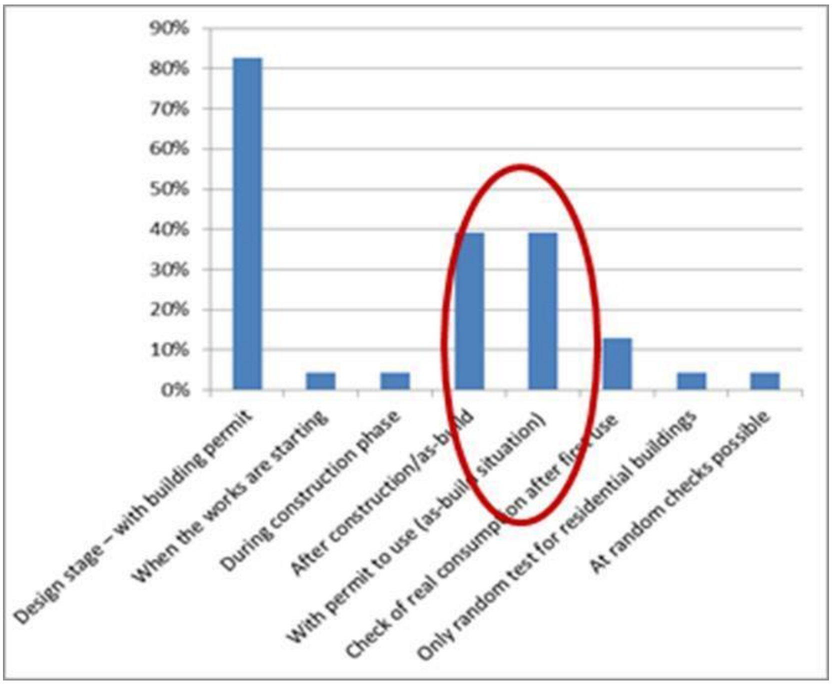


Figure 22: Timing of EPC compliance checks.

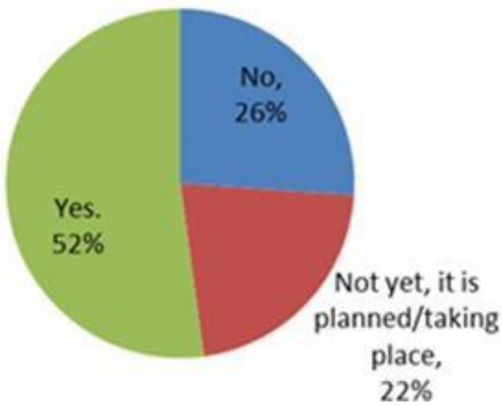


Figure 23: Countries with an idea of the compliance rates of new buildings.

A summary of enforcement characteristics as applied to whole building energy performance requirements for a sub-set of Member States and the UK is indicated in Table 41: Summary of building code enforcement for a selection of EU Member States.

	England & Wales	France	Germany	Netherlands	Spain	Sweden
Enforcement Status of Code:	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Type of Enforcement:	Local enforcement	Local enforcement	Accreditation of applicants	Local enforcement	Local enforcement	Local enforcement
	Accreditation of applicants	Third party inspection		Accreditation of applicants	Third party inspection	Third party inspection
	Post Occupancy control	Accreditation of applicants		Post Occupancy control		Post Occupancy control
On-site Inspections Occur	During construction	During construction	During construction	During construction	During construction	During construction
		Post completion	Post completion	Post completion	Post completion	Post occupancy
				Post occupancy		
Certification to Support Enforcement of Code:	Energy Performance Certificate support BC	Energy Performance Certificate support BC	Energy Performance Certificate support BC	Energy Performance Certificate support BC	Energy Performance Certificate support BC	Energy Performance Certificate support BC
	Positive labelling for building beyond the minimum BC level	Positive labelling for building beyond the minimum BC level	Positive labelling for building beyond the minimum BC level	Positive labelling for building beyond the minimum BC level	Positive labelling for building beyond the minimum BC level	Positive labelling for building beyond the minimum BC level
	Energy Offsets/Green Certificates	Energy Offsets/Green Certificates	Inspection of boilers	Energy Offsets/Green Certificates	Inspection of boilers	Energy Offsets/Green Certificates
	Number of certified buildings: 7161844	Inspection of boilers	Inspection of HVAC systems	Inspection of boilers	Inspection of HVAC systems	Number of certified buildings: 280000
		Inspection of HVAC systems		Inspection of HVAC systems		Inspection of boilers
						Inspection of HVAC systems
Penalties for Non-compliance:	Market censure that affects valuations and ability to sell/let properties	Fine	Refusal of permission to occupy	Refusal of permission to occupy	Refusal of permission to occupy	Fine
		Refusal of permission to occupy	Refusal of permission to construct	Refusal of permission to construct	Refusal of permission to construct	Refusal of permission to occupy

						Refusal of permission to construct
Measures Supporting Enforcement:	Commissioning requirements	Commissioning requirements	Mandatory Computer Modeling	Commissioning requirements	Commissioning requirements	Commissioning requirements
	Airtightness testing required prior to compliance	Airtightness testing required prior to compliance	Training of Inspectors	Airtightness testing required prior to compliance	Training of Inspectors	Training of Inspectors
	Mandatory Computer Modeling	Mandatory Computer Modeling		Mandatory Computer Modeling		
	Training of Inspectors	Training of Inspectors		Training of Inspectors		

Abbreviations: HVAC = heating, ventilation and air-conditioning.

Source: www.gbpn.org

Table 42. Any TBS-specific aspects within these are not referenced.

Table 41: Summary of building code enforcement for a selection of EU Member States.

	England & Wales	France	Germany	Netherlands	Spain	Sweden
Enforcement Status of Code:	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Type of Enforcement:	Local enforcement	Local enforcement	Accreditation of applicants	Local enforcement	Local enforcement	Local enforcement
	Accreditation of applicants	Third party inspection		Accreditation of applicants	Third party inspection	Third party inspection
	Post Occupancy control	Accreditation of applicants		Post Occupancy control		Post Occupancy control
On-site Inspections Occur	During construction	During construction	During construction	During construction	During construction	During construction
		Post completion	Post completion	Post completion	Post completion	Post occupancy
				Post occupancy		
Certification to Support Enforcement of Code:	Energy Performance Certificate support BC	Energy Performance Certificate support BC	Energy Performance Certificate support BC	Energy Performance Certificate support BC	Energy Performance Certificate support BC	Energy Performance Certificate support BC
	Positive labelling for building beyond the minimum BC level	Positive labelling for building beyond the minimum BC level	Positive labelling for building beyond the minimum BC level	Positive labelling for building beyond the minimum BC level	Positive labelling for building beyond the minimum BC level	Positive labelling for building beyond the minimum BC level
	Energy Offsets/Green Certificates	Energy Offsets/Green Certificates	Inspection of boilers	Energy Offsets/Green Certificates	Inspection of boilers	Energy Offsets/Green Certificates
	Number of certified buildings: 7161844	Inspection of boilers	Inspection of HVAC systems	Inspection of boilers	Inspection of HVAC systems	Number of certified buildings: 280000
		Inspection of HVAC systems		Inspection of HVAC systems		Inspection of boilers
						Inspection of HVAC systems
Penalties for Non-compliance:	Market censure that affects valuations and ability to sell/let properties	Fine	Refusal of permission to occupy	Refusal of permission to occupy	Refusal of permission to occupy	Fine

		Refusal of permission to occupy	Refusal of permission to construct	Refusal of permission to construct	Refusal of permission to construct	Refusal of permission to occupy
						Refusal of permission to construct
Measures Supporting Enforcement:	Commissioning requirements	Commissioning requirements	Mandatory Computer Modeling	Commissioning requirements	Commissioning requirements	Commissioning requirements
	Airtightness testing required prior to compliance	Airtightness testing required prior to compliance	Training of Inspectors	Airtightness testing required prior to compliance	Training of Inspectors	Training of Inspectors
	Mandatory Computer Modeling	Mandatory Computer Modeling		Mandatory Computer Modeling		
	Training of Inspectors	Training of Inspectors		Training of Inspectors		

Abbreviations: HVAC = heating, ventilation and air-conditioning.

Source: www.gbpn.org

Table 42: Summary of building code (BC) enforcement for a selection of EU Member States.

	England & Wales	France	Germany	Netherlands	Spain	Sweden
Enforcement status of code	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Type of enforcement	Local enforcement	Local enforcement	Accreditation of applicants	Local enforcement	Local enforcement	Local enforcement
	Accreditation of applicants	Third-party inspection		Accreditation of applicants	Third-party inspection	Third-party inspection
	Post-occupancy control	Accreditation of applicants		Post-occupancy control		Post-occupancy control
On-site inspections occur	During construction	During construction	During construction	During construction	During construction	During construction
		Post completion	Post completion	Post completion	Post completion	Post occupancy
				Post occupancy		
	Energy Performance Certificate support BC	Energy Performance Certificate support BC	Energy Performance Certificate support BC	Energy Performance Certificate support BC	Energy Performance Certificate support BC	Energy Performance Certificate support BC

Certification to support enforcement of code	Positive labelling for building beyond the minimum BC level	Positive labelling for building beyond the minimum BC level	Positive labelling for building beyond the minimum BC level	Positive labelling for building beyond the minimum BC level	Positive labelling for building beyond the minimum BC level	Positive labelling for building beyond the minimum BC level
	Energy Offsets/Green Certificates	Energy Offsets/Green Certificates	Inspection of boilers	Energy Offsets/Green Certificates	Inspection of boilers	Energy Offsets/Green Certificates
	Number of certified buildings: 7161844	Inspection of boilers	Inspection of HVAC systems	Inspection of boilers	Inspection of HVAC systems	Number of certified buildings: 280000
		Inspection of HVAC systems		Inspection of HVAC systems		Inspection of boilers
						Inspection of HVAC systems
Penalties for non-compliance	Market censure that affects valuations and ability to sell/let properties	Fine	Refusal of permission to occupy	Refusal of permission to occupy	Refusal of permission to occupy	Fine
		Refusal of permission to occupy	Refusal of permission to construct	Refusal of permission to construct	Refusal of permission to construct	Refusal of permission to occupy
						Refusal of permission to construct
Measures supporting enforcement	Commissioning requirements	Commissioning requirements	Mandatory computer modelling	Commissioning requirements	Commissioning requirements	Commissioning requirements
	Airtightness testing required prior to compliance	Airtightness testing required prior to compliance	Training of Inspectors	Airtightness testing required prior to compliance	Training of inspectors	Training of inspectors
	Mandatory computer modelling	Mandatory computer modelling		Mandatory computer modelling		
	Training of inspectors	Training of inspectors		Training of inspectors		

Abbreviations: HVAC = heating, ventilation and air-conditioning;

Source: www.gbpn.org

3.2.2 Legal framework

In general, two different approaches exist in the legal frameworks for energy performance requirements between Member States. The first approach is a building regulation approach. In this case, all requirements for new and renovated buildings are part of one building regulation. This building regulation can contain requirements for different technical areas, e.g., fire safety, structural safety, acoustics, toxics, waste disposal, accessibility to the building, electrical safety, ventilation and energy performance. Building regulations in the Netherlands, Ireland and the UK, among others, are typical examples of this approach.

The second approach is a dedicated regulation for energy performance requirements and calculations. Germany, Belgium (Flemish Region), France, Portugal and many other countries adopt this approach.

This difference in approach could influence the framework for application of sanctions on infringements. If the energy performance regulation is but one part of a global building regulation, the sanctions are in most cases not specific for energy performance infringements, but the same for all types of infringements. If the energy performance regulation is separate legislation, the control system and the sanctions could differ from those for other infringements related to new or existing buildings.

The manner in which TBS requirements, and explicitly those pertaining to existing buildings per the EPBD Article 8(1) requirements, are treated will be further clarified in the subsequent iterations of this report.

Sanctions and their application

A Concerted Action EPBD survey from 2014 showed that at that time very few Member States had applied sanctions for issues related to energy performance requirements. There are many reasons for the insufficient implementation such as limited resources for checking and lack of political will for enforcement. In general, it can be said that compliance requires sanctions that are proportionate to the nature of the non-compliance detected, that are an effective deterrent to non-compliance and that are seen to be applied when non-compliance occurs. Given the seeming limited application of sanctions for non-compliance with whole building energy performance there must be a risk that TBS specific energy performance requirements are being under enforced, and perhaps even more so for requirements that apply to installations in existing buildings.

3.2.3 Clarity of requirements

Arguably the single most important factor to achieving successful conformity with requirements is to ensure they are clearly expressed and presented to obligated parties in a single widely known reference. If obligated parties have to search through myriad legal texts to understand what obligations they are subject to they are far less likely to respect them than if the obligations are packaged into a single, easily read and comprehended reference document. The example of how the UK does this presented in Task 1 is a good practice illustration.

3.2.4 Responsibility for compliance

The owner of the building permit is generally the person responsible for compliance with building energy performance requirements; however, some countries have special provisions to protect private builders and buyers of new buildings wherein the legislation appoints the developer and/or the professional advisors (designer, architect, energy expert) as being (co)responsible for compliance of the building with energy performance requirements.

In principle, the same approach can be adopted for TBS requirements, i.e. making the professional advisor co-party to the obligation. In the case of TBS requirements and depending on their nature this could be any of:

- the TBS specifier (i.e. the entity who advises on the design of the system to be used for the premises and who may also supply the system to be used)
- the TBS installer
- the Facility Manager and related service providers, e.g. Energy Services Companies.

3.2.5 Instruments and methods used to conduct conformity verification

To a significant degree the instruments and techniques used to conduct conformity verification are essentially the same as used for conformity assessment – see section 3.3. The process involves the staff of the conformity verification authority checking that the obligated party who has submitted the conformity assessment report has correctly followed the legitimate conformity assessment process. These steps can be broken down as follows:

- checking that all required data fields are complete and that any values presented respect the requirements
- when inspection of visual evidence by way of proof, either on or off site via photographic evidence, is required then this would be conducted by the verifier and would tend to provide input into conformity assessment check lists which would be structured in parallel with conformity verification checklists
- where performance calculations are required then the verifier would:
    a) conduct any required validation of calculation tools used in the conformity assessment process, e.g. check that the tools used are permitted for the purpose
    b) check that the right data fields are populated in the calculation and that the appropriate calculation has been conducted
    c) potentially repeat the analytical steps required in the conformity assessment process
    d) check the veracity of the input values most commonly through inspection of visual evidence that the basis of the input values is correct – note this could entail combinations of:
        i) processing visual data to confirm the unique identification of a product and its components
        ii) processing visual data from a products and related components rating plates or technical specification manuals (often accessible on line)
        iii) inspection of values assumed for sizing and operation calculations which potentially could entail inspection of visual evidence, EPC data, BIM data, building energy passport data, metering and monitoring data, etc.
    e) check that the output of the calculation is consistent with conformity with the requirements.

Applicability by TBS life-cycle stage

It is noted that this task covers the enforcement of requirements within the scope of Article 8(1) of the EPBD, which means not only enforcement of requirements for new technical building systems, but also when these are upgraded and replaced.

3.2.6 Experience with regard to the inspections of heating and cooling systems per the requirements under Articles 14 and 15 of the EPBD

The EPBD requires the introduction of an independent control system for the EPC and for heating and AC systems inspection reports (Article 18). The conformity control calculations applied for EPCs is either very similar to or the same to the control of the 'energy performance calculations' for both new and renovated buildings.

Independent control systems on EPCs were already introduced for implementation of Directive 2002/91/EC in 12 Member States before 2010, when it became a requirement with the adoption of Directive 2010/31/EU. In eleven Member States, EPC quality control systems appeared more recently (from 2010–2013). By 2014, 27 countries (out of 29) had an operational independent control system for EPCs (Figure 22). The control systems situation for inspections, however, is different. Among the sixteen Member States where heating systems inspection is undertaken, only seven had established a control system. Among the twenty-one Member States that opted for AC inspections, at least six Member States organised a control system. The status of the other Member States was unclear.

3.2.7 Relevant experience from Ecodesign and ELR

As TBS include products and components that are subject to Ecodesign and energy labelling requirements the experience of enforcement of these requirements and resulting compliance is pertinent to the enforcement of the TBS requirements under the EPBD. While most Ecodesign and ELR requirements pertain to packaged products some, such as the labelling requirements for heating and hot water systems apply to an assembly of packaged products when they are put into service. For the most part the enforcement methods used by Ecodesign and ELR market surveillance authorities are quite different to those used for TBS enforcement because they pertain to suppliers, who are mostly manufacturers and their representatives, and are primarily concerned with ensuring that the declared energy performance of packaged products when tested under standard test conditions is correct and that it is in conformity with Ecodesign and ELR requirements. The conformity assessment applied for the heating and hot water labelling must necessarily be somewhat different, as this concerns how the product's energy performance is labelled when put into service.

3.2.8 Applicability of conformity verification pathways to the TBS recommendations of Task 2

This section considers the conformity verification pathways that could be applied for the recommended TBS requirements specified in Task 2 and then assesses each of them to consider the recommended requirement cases when they could be applied and when they could not.

Eligible conformity verification pathways

In principle, the following pathways (mechanisms) could be used to verify conformity with building regulations that apply to TBS:

- *on-site inspection* where an inspector visits the site and checks that the TBS meet the requirements
- *inspection of remotely submitted documents/data, with photographic evidence* (where relevant) – in this case the inspection takes place off site and is made on the evidence (documentation and data such as input data from technical data sheets and/or on-site measurements) which has been submitted remotely to a conformity verification database and may include photographic evidence taken on site. Note, when standardised conformity assessment software tools are used the data can be ported from them directly to the conformity verification database in a standardised format
- *inspection of metered data on site* – in this case an inspector checks on site metered data that helps to determine the conformity of the TBS with the requirements. As it entails on-site inspection it is a variant of the first option; however, in principle the use of metered/monitored data could help to provide both a more accurate conformity assessment and a faster one for some types of requirements. The types of data can be metered and monitored and the related KPIs that can be used for these purposes are discussed in Task 5 Activity 1
- *inspection of metered data off site* – this case is the same as as above except the metered/monitoring data is ported to an offsite conformity verification authority who can then assess it to verify conformity off site.

Applicability of the conformity verification pathways to the Task 2 TBS requirements

Table 43 indicates the study team's appraisal of the potential applicability of each of these compliance verification pathways with each of the HVAC requirements proposed in Task 2. For each of the requirements at least two of these conformity verification pathways would be applicable and often more. A priori on-site inspection, if supported by the appropriate resources, allows almost all of the TBS requirements to be assessed; however, as on-site inspections can be more costly than other options this does not mean to imply it is the best conformity verification mechanism to adopt. Rather the appropriateness of these conformity verification pathways is now assessed using a multi-criterion evaluation framework.

Note, in this interim report the main emphasis is given to HVAC-related compliance, but in subsequent versions more will be added on BACS, lighting and RES.

In general, visual inspection methods (either on- or off-site) are applicable and, when relevant, can be applied with checklists and suitable calculation tools. In principle, anything that can be inspected on site can also be inspected off site if the appropriate photographic/video evidence is provided, so there is little distinction between the applicability of either method; however, on-site inspection potentially carries less risk of something important not being seen providing the inspector can access the appropriate parts of the site. It also mitigates the risk of the supplied visual evidence not being comprehensive enough perhaps due to misunderstanding by the conformity assessor. On the other hand it carries greater cost and may face challenges accessing relevant parts of the site after the works are complete.

Currently, inspection of metering and monitoring data is often thought not to be sufficient to verify conformity with the Task 2 TBS requirements. This is because:

- only some of the proposed requirements can be verified through energy and performance monitoring data

- for those that could, there may be an absence of clarity about the performance benchmarks that would allow conformity to be confirmed
- for those that could and have adequate performance benchmarks there may be a necessary time delay to establish sufficient operational data to allow the assessment to occur.

Performance benchmarks are discussed further in Task 5 and there is clearly potential to develop them further to render them more operational, including for conformity verification purposes. In some cases, it is likely that assessment of metering and monitoring data could be an option for risk screening purposes to decide whether to conduct a comprehensive conformity verification of a specific TBS and associated requirements. Note, this could be done on site but also potentially off site, if the data are ported to the compliance authorities, and thus could be used as a screening tool against a potential site inspection.

Table 43: Applicability of conformity verification pathways for Task 2 TBS requirements.

Code	Space heating + DHW	Type	Scope	on site inspection	inspection of remotely submitted documents with photographic evidence to verification authority	Inspection of metered data on site	reporting of metered database
VH1	Monitor energy consumption, compare to expected performance and adapt pa	Monitor	> 70 kW			Y	Y
VH2	Night setback - Adjusted settings (e.g. from 11 pm to 6 am, 2 K temperature re	Control	All	Y	Y		Y
VH3	Overall heating system performance requirement, in line with the 2030 reduct	System	> 70 kW		Y		Y
VH4	Replace the old combustion (non-condensing) boiler (25-30 years old)- privatel	System	All	Y	Y		Y
VH5	Individual heat emitter control -Thermostatic Radiator Valves	Control	All	Y	Y		
VH6	Hydronic balancing and heat zoning	Control	All				Y
VH7	Night setback - Adjusted settings (e.g. for office use from 5 pm to 6 am, 2 K ter	Control	All	Y	Y		Y
VH8	Heat pumps in new building need to be equipped with a monitoring system to	Monitor	All		Y	Y	Y
VH9	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	<= 70 kW	Y	Y		
Vh10	Avoid simultaneous heating and cooling: by implementing a central controller	Control	> 70 kW	Y			Y
Vh11	Use of weather compensation to adapt the supply temperature	Control	All	Y	Y		Y
Vh12	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	> 70 kW	Y	Y		
	Space cooling						
C3+C	Switch off systems when not required (circulation pumps, chiller plant, A/C eq	Control		Y			Y
C8	Modify controls in order to sequence heating and cooling	Control		Y	Y		Y
C26	Overall requirement to annual savings of 4 % (could be adated to climate targe	System			Y		Y
C11	Install BEMS system	Control		Y	Y		
C12	Improve central chiller / refrigeration control	Control		Y	Y		Y
C18+	Exchange of old and inefficient pumps and compressors	System		Y	Y		Y
C6	Sequence heating and cooling	Control		Y	Y		Y
	Monitoring & metering measures	Monitor				Y	Y
	Ventilation						
V1a	Limitation on average specific fan power (PSFP) for all fans at design conditions	System	>5500 m³/h in non-res		Y		Y
V1b	Limitation on average specific fan power (PSFP) for all fans at design conditions	System	>5500 m³/h in non-res		Y		Y
V2	Volume reduction to actual demand by parameter adjustment	Control	>5500 m³/h in non-res	Y	Y		Y
V3a	Installation of volume controls	Control	>5500 m³/h in non-res	Y	Y		Y
V3b	Installation of volume controls	Control	>5500 m³/h in non-res	Y	Y		Y
V3c	Installation of volume controls	Control	New large and medium	Y	Y		Y
V4	Installation of a heat recovery System (or an exhaust air heatpump in case of s	System	>5500 m³/h in non-res				Y
V5	Improvement of filter exchange	O&M	filters > 100 m³/h	Y	Y		
V6	Overall ventilation system performance requirement, e.g. in line with the 2030	System	>5500 m³/h in non-res				Y
	All HVAC						
	Overall cooling system energy performance requirements				Y		Y
	Control and controllability requirements			Y			Y
	Metering and monitoring requirements					Y	Y
	Installation and commissioning requirements			Y			

Implications of the trigger point and building type for enforcement

Before evaluating the conformity verification pathways in detail it is important to consider the impact that the trigger points and building types related to the requirements may have on the viability of each conformity verification pathway.

The relevance of the trigger point/building type combinations to the viability of conformity assessment pathway is not a question of whether technically a particular compliance verification pathway could be used but rather about the synergies that are likely to exist with other activities and the overall viability of an approach. For example, the implementation of TBS sub-metering and monitoring is only likely to be economically justifiable for larger systems (at least currently) so conformity verification pathways that are contingent on this capability being present will not tend to be applicable to the smaller TBS capacities which are prevalent in small non-residential and residential buildings. Equally, differences in the trigger points of when the TBS requirements would come into effect will influence the viability of conformity verification mechanisms. In particular, for the case of on-site inspections a significant component of their costs is attributable to:

a) the time it takes to set up the appointment and gain access to the site

b) the time it takes to get to and from the site.

Thus, this becomes significantly more attractive as a TBS conformity verification pathway if it were already happening for another purpose at the same time that the TBS conformity verification process would need to occur.

Currently, Member States might organise on-site inspections for the following reasons:

- as-built checks for permits to use
- to issue an EPC
- to conduct a heating system inspection in accordance with Article 14 of the EPBD (required for systems >70kW)
- to conduct an air conditioning system inspection in accordance with Article 15 of the EPBD (required for systems >70kW)
- to conduct a combined HVAC system inspection (potentially including ventilation) in accordance with Articles 14 and 15 of the EPBD
- for safety compliance checks of a heating system
- for building and ventilation system air leakage tests
- for F-gas compliance checks for a heat pump or AC system
- for Ecodesign/ELR market surveillance checks for the energy labels applied for space heating systems and domestic hot water systems.

Only the first seven of these are likely to be done systematically and even here the practice, including the building/TBS types in scope, the frequency of inspections and the nature of the party checking conformity varies by Member State (or even within them). Nonetheless, all MS issue EPCs, all have heating and AC system inspections (at least for systems of >70kW), all are thought to require some kind of heating system safety conformity check and many are believed to require air leakage testing.

In principle, any of these inspection processes could be adapted to include/encompass conformity verification checks for TBS. Table 44 to Table 52 indicate which requirements *could* have their conformity verified as a function of the above set of on-site inspection verification pathways of the HVAC-related Task 2 TBS requirements.

Evidently, several of these other reasons for on-site inspections only occur for certain TBS (space-heating, space-cooling and combined HVAC inspections; heating systems safety checks; air-leakage tests; F-gas checks), while others (as built permit checks, and EPCs) are tied to the permitting and EPC issuance processes respectively. Both factors (scope and timing) would affect their potential applicability for TBS conformity control purposes in practice.

In addition, the skills required by the inspector/verifier also need to be taken into account. A priori, it is assumed that if an inspector is conducting energy performance checks for a TBS, such as is the case for heating and space cooling inspections, then they would already have the requisite skills (perhaps with a modest amount of additional training) to conduct the Task 2 TBS conformity verification checks. As AC and ventilation systems are often related then a modest additional training might be needed to broaden the scope of AC system inspectors to cover ventilation TBS requirements. With more training it is not unreasonable to imagine an AC system inspector could be qualified to do heating system conformity checks too. In theory, the same process could apply for heating system inspectors although the additional training might need to be more extensive and protracted. Some countries, such as Germany, already employ the inspectors who are responsible for conducting heating system safety checks to conduct heating energy performance checks. It is equally conceivable that an inspector used for ELR market surveillance of packaged energy labels for space and water heating systems could acquire the skill set needed to conduct TBS requirement inspections for such systems. While F-gas and space cooling system inspections may already be combined (in which case the F-gas inspection occurs at the same time as the AC inspection and hence there is no extra opportunity to combine with TBS inspections than for the AC inspection case already discussed) it would probably require a more extensive upskilling process to use F-gas inspectors (who are only doing that currently) for AC inspections.

In the case of EPC inspectors the applicability of their skill sets may depend on the type of building (e.g. residential or non-residential or both) they are qualified to verify EPCs for and the rigour of the EPC assessments currently required in the Member State in question. In principle, though EPC inspectors could be readily trained to also conduct TBS conformity verification checks and the software tools the inspectors (may) already apply to determine EPC compliance used to check system level performance conformity assessments for TBS. Obviously, the issue of the frequency/timing of EPC issuance compared to the moment a TBS conformity assessment declaration is made would need to be factored into the viability assessment as if an EPC is not issued until many years after a TBS is installed it can complicate the process of seeking remedial action from a contractor responsible for a non-compliant installation; however, viewed en masse linkage of TBS conformity verification with EPC inspections could offer an attractive synergy. The same could be true of linkage with as-built permitting inspections but these are only generally applicable to new build or major renovations building stages and hence would only capture a sub-set of the TBS installations subject to Article 8(1) requirements.

Table 44: Applicability of conformity verification for Task 2 TBS requirements linked to as-built checks for permits to use.

Conformity verification linked to as-built checks for permits to use:				SFH			MFH			Non-residential > 70kW (office)		
Code	Space heating + DHW	Measure Type	System scope	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existi
VH1	Monitor energy consumption, compare to expected performance and adapt pa	Monitor	> 70 kW	N	N	N	N	N	N	N	N	N
VH2	Night setback - Adjusted settings (e.g. from 11 pm to 6 am, 2 K temperature re	Control	All	Y	Y	N	Y	Y	N	N	N	N
VH3	Overall heating system performance requirement, in line with the 2030 reduct	System	> 70 kW	N	N	N	Maybe	Maybe	N	Y	Y	N
VH4	Replace the old combustion (non-condensing) boiler (25-30 years old)- privatel	System	All	N	N	N	Maybe	Maybe	N	Y	Y	N
VH5	Individual heat emitter control -Thermostatic Radiator Valves	Control	All	Y	Y	N	Y	Y	N	Y	Y	N
VH6	Hydronic balancing and heat zoning	Control	All	Y	Y	N	Y	Y	N	Y	Y	N
VH7	Night setback - Adjusted settings (e.g. for office use from 5 pm to 6 am, 2 K ter	Control	All	Y	Y	N	Y	Y	N	Y	Y	N
VH8	Heat pumps in new building need to be equipped with a monitoring system to	Monitor	All	N	N	N	N	N	N	Y	Y	N
VH9	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	<= 70 kW	Y	Y	N	Y	Y	N	N	N	N
Vh10	Avoid simultaneous heating and cooling: by implementing a central controller	Control	> 70 kW	Y	Y	N	Y	Y	N	Y	Y	N
Vh11	Use of weather compensation to adapt the supply temperature	Control	All	Y	Y	N	Y	Y	N	Y	Y	N
Vh12	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	> 70 kW	N	N	N	Y	Y	N	Y	Y	N
	Space cooling											
C3+C	Switch off systems when not required (circulation pumps, chiller plant, A/C eq	Control	All non-packaged	N	N	N	Maybe	Maybe	N	Y	Y	N
C8	Modify controls in order to sequence heating and cooling	Control	Non-packaged systems	N	N	N	N	N	N	N	N	N
C26	Overall requirement to annual savings of 4 % (could be adated to climate targe	System	All	N	N	N	N	N	N	N	N	N
C11	Install BEMS system	Control	All > 30kW	N	N	N	Y	Y	N	Y	Y	N
C12	Improve central chiller / refrigeration control	Control	Systems with chillers >3	N	N	N	N	N	N	Y	Y	N
C18+	Exchange of old and inefficient pumps and compressors	System	All non-packaged	N	N	N	Maybe	Maybe	N	Y	Y	N
C6	Sequence heating and cooling	Control	Non-packaged systems	N	N	N	N	N	N	Y	Y	N
	Monitoring & metering measures	Monitor	> 70kW	N	N	N	N	N	N	N	N	N
	Ventilation											
V1a	Limitation on average specific fan power (PSFP) for all fans at design conditions	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V1b	Limitation on average specific fan power (PSFP) for all fans at design conditions	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V2	Volume reduction to actual demand by parameter adjustment	Control	>5500 m³/h in non-res	N	N	N	Maybe	Maybe	N	Y	Y	N
V3a	Installation of volume controls	Control	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V3b	Installation of volume controls	Control	>5500 m³/h in res	Y	Y	N	Y	Y	N	N	N	N
V3c	Installation of volume controls	Control	New large and medium	N	N	N	Y	Y	N	Y	Y	N
V4	Installation of a heat recovery system (or an exhaust air heatpump in case of s	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V5	Improvement of filter exchange	O&M	filters > 100 m³/h	N	N	N	Y	Y	N	Y	Y	N
V6	Overall ventilation system performance requirement, e.g. in line with the 2030	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
	All HVAC											
	Overall system energy performance requirements			N	N	N	N	N	N	N	N	N
	Control and controllability requirements			Maybe	Maybe	N	Maybe	Maybe	N	Y	Y	N
	Metering and monitoring requirements			N	N	N	Maybe	Maybe	N	Y	Y	N
	Installation and commissioning requirements			Maybe	Maybe	N	Maybe	Maybe	N	Maybe	Maybe	N

Table 45: Applicability of conformity verification for Task 2 TBS requirements linked to the issuance of an EPC.

Conformity verification linked to Issuance of an EPC:				SFH			MFH			Non-residential > 70kW (office)		
Code	Space heating + DHW	Measure Type	System scope	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existi
VH1	Monitor energy consumption, compare to expected performance and adapt pa	Monitor	> 70 kW	N	N	N	N	N	N	N	N	N
VH2	Night setback - Adjusted settings (e.g. from 11 pm to 6 am, 2 K temperature re	Control	All	Y	Y	Y	Y	Y	Y	N	N	N
VH3	Overall heating system performance requirement, in line with the 2030 reduct	System	> 70 kW	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
VH4	Replace the old combustion (non-condensing) boiler (25-30 years old)- privatel	System	All	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
VH5	Individual heat emitter control -Thermostatic Radiator Valves	Control	All	Y	Y	Y	Y	Y	Y	Y	Y	Y
VH6	Hydronic balancing and heat zoning	Control	All	Y	Y	Y	Y	Y	Y	Y	Y	Y
VH7	Night setback - Adjusted settings (e.g. for office use from 5 pm to 6 am, 2 K ter	Control	All	Y	Y	Y	Y	Y	Y	Y	Y	Y
VH8	Heat pumps in new building need to be equipped with a monitoring system to	Monitor	All	N	N	N	N	N	N	Y	Y	Y
VH9	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	<= 70 kW	Y	Y	Y	Y	Y	Y	N	N	N
Vh10	Avoid simultaneous heating and cooling: by implementing a central controller	Control	> 70 kW	Y	Y	Y	Y	Y	Y	Y	Y	Y
Vh11	Use of weather compensation to adapt the supply temperature	Control	All	Y	Y	Y	Y	Y	Y	Y	Y	Y
Vh12	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	> 70 kW	N	N	N	Y	Y	Y	Y	Y	Y
	Space cooling											
C3+C	Switch off systems when not required (circulation pumps, chiller plant, A/C eq	Control	All non-packaged	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
C8	Modify controls in order to sequence heating and cooling	Control	Non-packaged systems	N	N	N	N	N	N	N	N	Y
C26	Overall requirement to annual savings of 4 % (could be adated to climate targe	System	All	N	N	N	N	N	N	N	N	N
C11	Install BEMS system	Control	All > 30kW	N	N	N	Y	Y	Y	Y	Y	Y
C12	Improve central chiller / refrigeration control	Control	Systems with chillers >3	N	N	N	N	N	N	Y	Y	Y
C18+	Exchange of old and inefficient pumps and compressors	System	All non-packaged	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
C6	Sequence heating and cooling	Control	Non-packaged systems	N	N	N	N	N	N	Y	Y	Y
	Monitoring & metering measures	Monitor	> 70kW	N	N	N	N	N	N	N	N	N
	Ventilation											
V1a	Limitation on average specific fan power (PSFP) for all fans at design conditions	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V1b	Limitation on average specific fan power (PSFP) for all fans at design conditions	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V2	Volume reduction to actual demand by parameter adjustment	Control	>5500 m³/h in non-res	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
V3a	Installation of volume controls	Control	>5500 m³/h in non-res	N	N	Y	N	N	Y	N	N	Y
V3b	Installation of volume controls	Control	>5500 m³/h in res	Y	Y	Y	Y	Y	Y	N	N	N
V3c	Installation of volume controls	Control	New large and medium	N	N	N	Y	Y	Y	Y	Y	Y
V4	Installation of a heat recovery system (or an exhaust air heatpump in case of s	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V5	Improvement of filter exchange	O&M	filters > 100 m³/h	N	N	N	Y	Y	Y	Y	Y	Y
V6	Overall ventilation system performance requirement, e.g. in line with the 2030	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
	All HVAC											
	Overall system energy performance requirements			N	N	N	N	N	N	N	N	N
	Control and controllability requirements			Maybe	Maybe	Maybe	Maybe	Maybe	Maybe	Y	Y	Y
	Metering and monitoring requirements			N	N	N	Maybe	Maybe	Maybe	Y	Y	Maybe
	Installation and commissioning requirements			Maybe	Maybe	Maybe	Maybe	Maybe	Maybe	Maybe	Maybe	Maybe

Table 46: Applicability of conformity verification for Task 2 TBS requirements linked to Article 14 space heating inspection.

Conformity verification linked to Article 14 space heating inspections				SFH			MFH			Non-residential > 70kW (office)		
Code	Space heating + DHW	Measure Type	System scope	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existi
VH1	Monitor energy consumption, compare to expected performance and adapt pa	Monitor	> 70 kW	N	N	N	N	N	N	N	N	N
VH2	Night setback - Adjusted settings (e.g. from 11 pm to 6 am, 2 K temperature re	Control	All	N	N	N	Y	Y	Y	N	N	N
VH3	Overall heating system performance requirement, in line with the 2030 reduct	System	> 70 kW	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
VH4	Replace the old combustion (non-condensing) boiler (25-30 years old)- privatel	System	All	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
VH5	Individual heat emitter control -Thermostatic Radiator Valves	Control	All	N	N	N	Y	Y	Y	Y	Y	Y
VH6	Hydronic balancing and heat zoning	Control	All	N	N	N	Y	Y	Y	Y	Y	Y
VH7	Night setback - Adjusted settings (e.g. for office use from 5 pm to 6 am, 2 K ter	Control	All	N	N	N	Y	Y	Y	Y	Y	Y
VH8	Heat pumps in new building need to be equipped with a monitoring system to	Monitor	All	N	N	N	N	N	N	Y	Y	Y
VH9	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	<= 70 kW	N	N	N	Y	Y	Y	N	N	N
Vh10	Avoid simultaneous heating and cooling: by implementing a central controller	Control	> 70 kW	N	N	N	Y	Y	Y	Y	Y	Y
Vh11	Use of weather compensation to adapt the supply temperature	Control	All	N	N	N	Y	Y	Y	Y	Y	Y
Vh12	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	> 70 kW	N	N	N	Y	Y	Y	Y	Y	Y

Table 47: Applicability of conformity verification for Task 2 TBS requirements linked to Article 14 space cooling inspection.

Conformity verification linked to Article 15 space cooling inspections				SFH			MFH			Non-residential > 70kW (office)		
Code	Space cooling	Measure Type	System scope	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existi
C3+C	Switch off systems when not required (circulation pumps, chiller plant, A/C eq	Control	All non-packaged	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
C8	Modify controls in order to sequence heating and cooling	Control	Non-packaged systems	N	N	N	N	N	N	N	N	Y
C26	Overall requirement to annual savings of 4 % (could be adated to climate targe	System	All	N	N	N	N	N	N	N	N	N
C11	Install BEMS system	Control	All > 30kW	N	N	N	Y	Y	Y	Y	Y	Y
C12	Improve central chiller / refrigeration control	Control	Systems with chillers >3	N	N	N	N	N	N	Y	Y	Y
C18+	Exchange of old and inefficient pumps and compressors	System	All non-packaged	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
C6	Sequence heating and cooling	Control	Non-packaged systems	N	N	N	N	N	N	Y	Y	Y
	Monitoring & metering measures	Monitor	> 70kW	N	N	N	N	N	N	N	N	N

Table 48: Applicability of conformity verification for Task 2 TBS requirements linked to Article 14/15 HVAC inspection.

Conformity verification linked to Article 14/15 HVAC inspection				SFH			MFH			Non-residential > 70kW (office)		
Code	Space heating + DHW	Measure Type	System scope	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existi
VH1	Monitor energy consumption, compare to expected performance and adapt pa	Monitor	> 70 kW	N	N	N	N	N	N	N	N	N
VH2	Night setback - Adjusted settings (e.g. from 11 pm to 6 am, 2 K temperature re	Control	All	N	N	N	Y	Y	Y	N	N	N
VH3	Overall heating system performance requirement, in line with the 2030 reduct	System	> 70 kW	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
VH4	Replace the old combustion (non-condensing) boiler (25-30 years old)- privatel	System	All	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
VH5	Individual heat emitter control -Thermostatic Radiator Valves	Control	All	N	N	N	Y	Y	Y	Y	Y	Y
VH6	Hydronic balancing and heat zoning	Control	All	N	N	N	Y	Y	Y	Y	Y	Y
VH7	Night setback - Adjusted settings (e.g. for office use from 5 pm to 6 am, 2 K ter	Control	All	N	N	N	Y	Y	Y	Y	Y	Y
VH8	Heat pumps in new building need to be equipped with a monitoring system to	Monitor	All	N	N	N	N	N	N	Y	Y	Y
VH9	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	<= 70 kW	N	N	N	Y	Y	Y	N	N	N
Vh10	Avoid simultaneous heating and cooling: by implementing a central controller	Control	> 70 kW	N	N	N	Y	Y	Y	Y	Y	Y
Vh11	Use of weather compensation to adapt the supply temperature	Control	All	N	N	N	Y	Y	Y	Y	Y	Y
Vh12	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	> 70 kW	N	N	N	Y	Y	Y	Y	Y	Y
	Space cooling											
C3+C	Switch off systems when not required (circulation pumps, chiller plant, A/C eq	Control	All non-packaged	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
C8	Modify controls in order to sequence heating and cooling	Control	Non-packaged systems	N	N	N	N	N	N	N	N	Y
C26	Overall requirement to annual savings of 4 % (could be adated to climate targe	System	All	N	N	N	N	N	N	N	N	N
C11	Install BEMS system	Control	All > 30kW	N	N	N	Y	Y	Y	Y	Y	Y
C12	Improve central chiller / refrigeration control	Control	Systems with chillers >3	N	N	N	N	N	N	Y	Y	Y
C18+	Exchange of old and inefficient pumps and compressors	System	All non-packaged	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
C6	Sequence heating and cooling	Control	Non-packaged systems	N	N	N	N	N	N	Y	Y	Y
	Monitoring & metering measures	Monitor	> 70kW	N	N	N	N	N	N	N	N	N
	Ventilation											
V1a	Limitation on average specific fan power (PSFP) for all fans at design conditions	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V1b	Limitation on average specific fan power (PSFP) for all fans at design conditions	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V2	Volume reduction to actual demand by parameter adjustment	Control	>5500 m³/h in non-res	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
V3a	Installation of volume controls	Control	>5500 m³/h in non-res	N	N	N	N	N	Y	N	N	Y
V3b	Installation of volume controls	Control	>5500 m³/h in non-res	N	N	N	Y	Y	Y	N	N	N
V3c	Installation of volume controls	Control	New large and medium	N	N	N	Y	Y	Y	Y	Y	Y
V4	Installation of a heat recovery System (or an exhaust air heatpump in case of s	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V5	Improvement of filter exchange	O&M	filters > 100 m³/h	N	N	N	Y	Y	Y	Y	Y	Y
V6	Overall ventilation system performance requirement, e.g. in line with the 2030	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
	All HVAC											
	Overall cooling system energy performance requirements			N	N	N	N	N	N	N	N	N
	Control and controllability requirements			N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
	Metering and monitoring requirements			N	N	N	Maybe	Maybe	Maybe	Y	Y	Maybe
	Installation and commissioning requirements			N	N	N	Maybe	Maybe	Maybe	Maybe	Maybe	Maybe

Table 49: Applicability of conformity verification for Task 2 TBS requirements linked to heating system safety checks.

Conformity verification linked to heating system safety checks				SFH			MFH			Non-residential > 70kW (office)		
Code	Space heating + DHW	Measure Type	System scope	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existi
VH1	Monitor energy consumption, compare to expected performance and adapt pa	Monitor	> 70 kW	N	N	N	N	N	N	N	N	N
VH2	Night setback - Adjusted settings (e.g. from 11 pm to 6 am, 2 K temperature re	Control	All	Y	Y	Y	Y	Y	Y	N	N	N
VH3	Overall heating system performance requirement, in line with the 2030 reduct	System	> 70 kW	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
VH4	Replace the old combustion (non-condensing) boiler (25-30 years old)- privatel	System	All	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
VH5	Individual heat emitter control -Thermostatic Radiator Valves	Control	All	Y	Y	Y	Y	Y	Y	Y	Y	Y
VH6	Hydronic balancing and heat zoning	Control	All	Y	Y	Y	Y	Y	Y	Y	Y	Y
VH7	Night setback - Adjusted settings (e.g. for office use from 5 pm to 6 am, 2 K ter	Control	All	Y	Y	Y	Y	Y	Y	Y	Y	Y
VH8	Heat pumps in new building need to be equipped with a monitoring system to	Monitor	All	N	N	N	N	N	N	Y	Y	Y
VH9	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	<= 70 kW	Y	Y	Y	Y	Y	Y	N	N	N
Vh10	Avoid simultaneous heating and cooling: by implementing a central controller	Control	> 70 kW	Y	Y	Y	Y	Y	Y	Y	Y	Y
Vh11	Use of weather compensation to adapt the supply temperature	Control	All	Y	Y	Y	Y	Y	Y	Y	Y	Y
Vh12	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	> 70 kW	N	N	N	Y	Y	Y	Y	Y	Y

Table 50: Applicability of conformity verification for Task 2 TBS requirements linked to ventilation system air leakage tests.

Conformity verification linked to ventilation system air leakage test				SFH			MFH			Non-residential > 70kW (office)		
Code	Ventilation	Measure Type	System scope	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existi
V1a	Limitation on average specific fan power (PSFP) for all fans at design conditions	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V1b	Limitation on average specific fan power (PSFP) for all fans at design conditions	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V2	Volume reduction to actual demand by parameter adjustment	Control	>5500 m³/h in non-res	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
V3a	Installation of volume controls	Control	>5500 m³/h in non-res	N	N	Y	N	N	Y	N	N	Y
V3b	Installation of volume controls	Control	>5500 m³/h in non-res	Y	Y	Y	Y	Y	Y	N	N	N
V3c	Installation of volume controls	Control	New large and medium	N	N	N	Y	Y	Y	Y	Y	Y
V4	Installation of a heat recovery System (or an exhaust air heatpump in case of s	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V5	Improvement of filter exchange	O&M	filters > 100 m³/h	N	N	N	Y	Y	Y	Y	Y	Y
V6	Overall ventilation system performance requirement, e.g. in line with the 2030	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N

Table 51: Applicability of conformity verification for Task 2 TBS requirements linked to F-gas compliance checks.

Conformity verification linked to F-gas compliance check				SFH			MFH			Non-residential > 70kW (office)		
Code	Space heating + DHW	Measure Type	System scope	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existi
VH1	Monitor energy consumption, compare to expected performance and adapt pa	Monitor	> 70 kW	N	N	N	N	N	N	N	N	N
VH2	Night setback - Adjusted settings (e.g. from 11 pm to 6 am, 2 K temperature re	Control	All	N	N	N	N	N	N	N	N	N
VH3	Overall heating system performance requirement, in line with the 2030 reduct	System	> 70 kW	N	N	N	N	N	N	N	N	N
VH4	Replace the old combustion (non-condensing) boiler (25-30 years old)- privatel	System	All	N	N	N	N	N	N	N	N	N
VH5	Individual heat emitter control -Thermostatic Radiator Valves	Control	All	N	N	N	N	N	N	N	N	N
VH6	Hydronic balancing and heat zoning	Control	All	N	N	N	N	N	N	N	N	N
VH7	Night setback - Adjusted settings (e.g. for office use from 5 pm to 6 am, 2 K ter	Control	All	N	N	N	N	N	N	N	N	N
VH8	Heat pumps in new building need to be equipped with a monitoring system to	Monitor	All	N	N	N	N	N	N	Y	Y	Y
VH9	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	<= 70 kW	N	N	N	N	N	N	N	N	N
Vh10	Avoid simultaneous heating and cooling: by implementing a central controller	Control	> 70 kW	N	N	N	N	N	N	N	N	N
Vh11	Use of weather compensation to adapt the supply temperature	Control	All	N	N	N	N	N	N	N	N	N
Vh12	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	> 70 kW	N	N	N	N	N	N	N	N	N
	Space cooling											
C3+C	Switch off systems when not required (circulation pumps, chiller plant, A/C eq	Control	All non-packaged	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
C8	Modify controls in order to sequence heating and cooling	Control	Non-packaged systems	N	N	N	N	N	N	N	N	Y
C26	Overall requirement to annual savings of 4 % (could be adated to climate targe	System	All	N	N	N	N	N	N	N	N	N
C11	Install BEMS system	Control	All > 30kW	N	N	N	Y	Y	Y	Y	Y	Y
C12	Improve central chiller / refrigeration control	Control	Systems with chillers >3	N	N	N	N	N	N	Y	Y	Y
C18+	Exchange of old and inefficient pumps and compressors	System	All non-packaged	N	N	N	Maybe	Maybe	Maybe	Y	Y	Y
C6	Sequence heating and cooling	Control	Non-packaged systems	N	N	N	N	N	N	Y	Y	Y
	Monitoring & metering measures	Monitor	> 70kW	N	N	N	N	N	N	N	N	N

Table 52: Applicability of conformity verification for Task 2 TBS requirements linked to on-site ED/ELR market surveillance checks for packaged labels.

Conformity verification linked to on-site ED/ELR market surveillance check (for packaged labels)				SFH			MFH			Non-residential > 70kW (office)		
Code	**Space heating + DHW**	Measure Type	System scope	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existing TBS	New	Major Renovation	Amendment to existi
VH1	Monitor energy consumption, compare to expected performance and adapt pa	Monitor	> 70 kW	N	N	N	N	N	N			
VH2	Night setback - Adjusted settings (e.g. from 11 pm to 6 am, 2 K temperature re	Control	All	Y	Y	Y	Y	Y	Y			
VH3	Overall heating system performance requirement, in line with the 2030 reduct	System	> 70 kW	N	N	N	Maybe	Maybe	Maybe			
VH4	Replace the old combustion (non-condensing) boiler (25-30 years old)- privatel	System	All	N	N	N	Maybe	Maybe	Maybe			
VH5	Individual heat emitter control -Thermostatic Radiator Valves	Control	All	Y	Y	Y	Y	Y	Y			
VH6	Hydronic balancing and heat zoning	Control	All	Y	Y	Y	Y	Y	Y			
VH7	Night setback - Adjusted settings (e.g. for office use from 5 pm to 6 am, 2 K ter	Control	All	Y	Y	Y	Y	Y	Y			
VH8	Heat pumps in new building need to be equipped with a monitoring system to	Monitor	All	N	N	N	N	N	N			
VH9	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	<= 70 kW	Y	Y	Y	Y	Y	Y			
Vh10	Avoid simultaneous heating and cooling: by implementing a central controller	Control	> 70 kW	Y	Y	Y	Y	Y	Y			
Vh11	Use of weather compensation to adapt the supply temperature	Control	All	Y	Y	Y	Y	Y	Y			
Vh12	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	> 70 kW	N	N	N	Y	Y	Y			
	Space cooling											
C3+C	Switch off systems when not required (circulation pumps, chiller plant, A/C eq	Control	All non-packaged	N	N	N	N	N	N	N	N	N
C8	Modify controls in order to sequence heating and cooling	Control	Non-packaged systems	N	N	N	N	N	N	N	N	N
C26	Overall requirement to annual savings of 4 % (could be adated to climate targe	System	All	N	N	N	N	N	N	N	N	N
C11	Install BEMS system	Control	All > 30kW	N	N	N	N	N	N	N	N	N
C12	Improve central chiller / refrigeration control	Control	Systems with chillers >3	N	N	N	N	N	N	N	N	N
C18+	Exchange of old and inefficient pumps and compressors	System	All non-packaged	N	N	N	N	N	N	N	N	N
C6	Sequence heating and cooling	Control	Non-packaged systems	N	N	N	N	N	N	N	N	N
	Monitoring & metering measures	Monitor	> 70kW	N	N	N	N	N	N	N	N	N
	Ventilation											
V1a	Limitation on average specific fan power (PSFP) for all fans at design conditions	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V1b	Limitation on average specific fan power (PSFP) for all fans at design conditions	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V2	Volume reduction to actual demand by parameter adjustment	Control	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V3a	Installation of volume controls	Control	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V3b	Installation of volume controls	Control	>5500 m³/h in res	N	N	N	N	N	N	N	N	N
V3c	Installation of volume controls	Control	New large and medium	N	N	N	N	N	N	N	N	N
V4	Installation of a heat recovery system (or an exhaust air heatpump in case of s	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
V5	Improvement of filter exchange	O&M	filters > 100 m³/h	N	N	N	N	N	N	N	N	N
V6	Overall ventilation system performance requirement, e.g. in line with the 2030	System	>5500 m³/h in non-res	N	N	N	N	N	N	N	N	N
	All HVAC											
	Overall system energy performance requirements			N	N	N	N	N	N	N	N	N
	Control and controllability requirements			Maybe	Maybe	Maybe	Maybe	Maybe	Maybe	N	N	N
	Metering and monitoring requirements			N	N	N	Maybe	Maybe	Maybe	N	N	N
	Installation and commissioning requirements			Maybe	Maybe	Maybe	Maybe	Maybe	Maybe	N	N	N

3.2.9 Evaluation of conformity verification for the Task 2 TBS requirements

In order to evaluate the overall viability of conducting conformity verification actions for each recommended Task 2 requirement a multi-criteria evaluation is conducted. The evaluation matrix applies a mix of: Yes/No applicability criteria, ordinal rankings and quantified values into a mixed evaluation framework.

Evaluation criteria

This assesses the conformity verification viability via assessment of the following criteria:

- the level of compliance attained (i.e. blending the evidence of the level of compliance achieved due to the approach followed combined with a logical appraisal of the strengths and weaknesses of each approach from this perspective)
- the nature, ease and reproducibility of the conformity assessment process required by the responsible market actors
- the availability and applicability of technical standards and tools to support conformity assessment
- the level of professional training and skills required to establish conformity
- the availability and applicability of standards and tools necessary to verify compliance
- the professional profiles and competences (including technical qualifications, certification and accreditation) of the inspectorate (when used) and relevant compliance authority/MSA staff
- the technical and administrative burden entailed for Member State authorities
- the magnitude of resources necessary to apply the methods under consideration
- the extent to which the compliance approach may add costs to the TBS which is subject to the requirements.

Table 53 shows the findings of the evaluation of the conformity verification pathways applicable to each of the Task 2 TBS requirements. It is comprised of:

- an ordinal qualitative ranking (from 5 to 1) of the expected level of professional skill/training that would be needed for the conformity verification staff to be able to conduct the assessment in a reliable manner where 5 indicates a very high level of skill/training and 1 a low level
- whether a site visit is a prerequisite of being able to verify conformity or not
- the estimated average Level of Effort (LOE) expressed in on-site hours spent to conduct such an assessment for a building with a floor area of 1000 m^2 (assuming on-site assessment were to occur)
- the estimated average Level of Effort (LOE) expressed in off-site hours spent to conduct such an assessment for a building with a floor area of 1000 m^2 (assuming off-site assessment were to occur)
- the estimated average Level of Effort (LOE) expressed in off-site hours spent to arrange an on-site visit and to get to and from the site for a building with a floor area of 1000 m^2 (assuming on-site assessment were to occur)

- an ordinal qualitative ranking (from 5 to 1) of the expected level of compliance that would arise from conducting the conformity verification exercise where 5 indicates a very high level of conformity and 1 a low level
- a multi-criteria magnitude ranking of the level of resources (time and skills) that would be required to conduct an on-site conformity verification check where the higher the number the greater the level of resources needed
- a multi-criteria magnitude ranking of the level of resources (time and skills) that would be required to conduct an equivalent off-site conformity verification check where the higher the number the greater the level of resources needed
- an overall multi-criteria ranking score for on-site conformity verification assessment (where the higher the number the more favourable the approach)
- an overall multi-criteria ranking score for off-site conformity verification assessment (where the higher the number the more favourable the approach).

It is important to note that these evaluations are also linked to the conformity assessment appraisal reported in section 3.3.1.

From this it can be observed that:

- conformity verification is achievable for all the TBS requirements proposed in Task 2, which is unsurprising as this was one of the factors considered in their original selection
- the options which entail on-site inspections are more costly than those which use off-site verification methods and hence score less well; however, this is because of the time taken to arrange visits and get to and from the site and if that is already happening for another purpose (e.g. the various inspections cases previously considered) then on-site methods become as viable as off-site ones
- while there could be some extra rigour from conformity verification via on-site visits it is not certain there would be providing off-site methods are sufficiently robust that they reject conformity assessment submissions that have insufficient evidence – for this reason off-site methods score as well as on-site ones with regard to the level of compliance attained
- in practice, off-site methods would probably only be effective if obligated parties are always required to submit conformity assessments into the system electronically when TBSs are installed or upgraded, otherwise it is highly likely that the required evidence would not be adequately retained by the obligated parties for verification efforts that occur substantially after the conformity assessment event
- there is currently the least certainty about the reproducibility of conformity verification methods that address real-time metering and monitoring related measures that require performance benchmarks to be assessed and acted upon.

Table 53: Evaluation of conformity verification methods applicable to each Task 2 TBS requirement.

TBS and Task 2 requirement				Conformity verification process										
Code	Space heating + DHW	Measure Type	System scope	professional profiles and competences needed of conformity verification authorities	Is site visit required?	LOE for conformity verification (on-site hrs per 1000m2)	LOE for conformity verification (off-site hrs per 1000m2)	LOE to arrange site visit and go to/from site (off-site hrs per 1000m2)	level of compliance attained	magnitude of resources necessary to apply the methods under consideration with on-site visit	magnitude of resources necessary to apply the methods under consideration without on-site visit	Overall score (with on-site inspection)	Overall score (with off-site assessment)	
VH1	Monitor energy consumption, compare to expected performance and adapt pa	Monitor	> 70 kW	4	N	2.0	1.2	4.5	2	5.3	2.6	0.9	2.2	
VH2	Night setback - Adjusted settings (e.g. from 11 pm to 6 am, 2 K temperature re	Control	All	1	N	0.3	0.2	4.5	4	2.9	0.6	3.1	4.2	
VH3	Overall heating system performance requirement, in line with the 2030 reduct	System	> 70 kW	4	N	2.0	1.2	4.5	4	5.3	2.6	1.9	3.2	
VH4	Replace the old combustion (non-condensing) boiler (25-30 years old)- privatel	System	All	3	N	1.0	0.6	4.5	5	4.3	1.8	2.9	4.1	
VH5	Individual heat emitter control -Thermostatic Radiator Valves	Control	All	2	N	1.0	0.6	4.5	5	3.8	1.3	3.1	4.4	
VH6	Hydronic balancing and heat zoning	Control	All	4	N	0.9	0.5	4.5	3	4.7	2.3	1.7	2.9	
VH7	Night setback - Adjusted settings (e.g. for office use from 5 pm to 6 am, 2 K ter	Control	All	1	N	0.3	0.2	4.5	4	2.9	0.6	3.1	4.2	
VH8	Heat pumps in new building need to be equipped with a monitoring system to	Monitor	All	3	N	1.0	0.6	4.5	4	4.3	1.8	2.4	3.6	
VH9	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	<= 70 kW	1	N	1.0	0.6	4.5	5	3.3	0.8	3.4	4.6	
Vh10	Avoid simultaneous heating and cooling: by implementing a central controller	Control	> 70 kW	4	N	1.0	0.6	4.5	3	4.8	2.3	1.6	2.9	
Vh11	Use of weather compensation to adapt the supply temperature	Control	All	2	N	0.3	0.2	4.5	4	3.4	1.1	2.8	4.0	
Vh12	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	> 70 kW	1	N	1.0	0.6	4.5	5	3.3	0.8	3.4	4.6	
	Space cooling													
C3+C	Switch off systems when not required (circulation pumps, chiller plant, A/C eq	Control	All non-packaged	3	N	1.0	0.6	4.5	3	4.3	1.8	1.9	3.1	
C8	Modify controls in order to sequence heating and cooling	Control	Non-packaged systems	4	N	1.0	0.6	4.5	3	4.8	2.3	1.6	2.9	
C26	Overall requirement to annual savings of 4 % (could be adated to climate targe	System	All	4	N	2.0	1.2	4.5	4	5.3	2.6	1.9	3.2	
C11	Install BEMS system	Control	All > 30kW	4	N	2.0	1.2	4.5	4	5.3	2.6	1.9	3.2	
C12	Improve central chiller / refrigeration control	Control	Systems with chillers >3	2	N	1.0	0.6	4.5	5	3.8	1.3	3.1	4.4	
C18+	Exchange of old and inefficient pumps and compressors	System	All non-packaged	3	N	1.0	0.6	4.5	5	4.3	1.8	2.9	4.1	
C6	Sequence heating and cooling	Control	Non-packaged systems	3	N	0.6	0.4	4.5	3	4.1	1.7	2.0	3.2	
	Monitoring & metering measures	Monitor	> 70kW	4	N	2.0	1.2	4.5	2	5.3	2.6	0.9	2.2	
	Ventilation													
V1a	Limitation on average specific fan power (PSFP) for all fans at design conditions	System	>5500 m³/h in non-res	4	N	2.0	1.2	4.5	4	5.3	2.6	1.9	3.2	
V1b	Limitation on average specific fan power (PSFP) for all fans at design conditions	System	>5500 m³/h in non-res	4	N	2.0	1.2	4.5	4	5.3	2.6	1.9	3.2	
V2	Volume reduction to actual demand by parameter adjustment	Control	>5500 m³/h in non-res	2	N	1.0	0.6	4.5	5	3.8	1.3	3.1	4.4	
V3a	Installation of volume controls	Control	>5500 m³/h in non-res	4	N	2.0	1.2	4.5	4	5.3	2.6	1.9	3.2	
V3b	Installation of volume controls	Control	>5500 m³/h in non-res	4	N	2.0	1.2	4.5	4	5.3	2.6	1.9	3.2	
V3c	Installation of volume controls	Control	New large and medium	4	N	2.0	1.2	4.5	4	5.3	2.6	1.9	3.2	
V4	Installation of a heat recovery System (or an exhaust air heatpump in case of s	System	>5500 m³/h in non-res	4	N	2.0	1.2	4.5	4	5.3	2.6	1.9	3.2	
V5	Improvement of filter exchange	O&M	filters > 100 m³/h	3	N	1.0	0.6	4.5	3	4.3	1.8	1.9	3.1	
V6	Overall ventilation system performance requirement, e.g. in line with the 2030	System	>5500 m³/h in non-res	4	N	2.0	1.2	4.5	4	5.3	2.6	1.9	3.2	
	All HVAC													
	Overall cooling system energy performance requirements			4	N	2.0	1.2	4.5	4	5.3	2.6	1.9	3.2	
	Control and controllability requirements			2	N	1.0	0.6	4.5	5	3.8	1.3	3.1	4.4	
	Metering and monitoring requirements			4	N	2.0	1.2	4.5	2	5.3	2.6	0.9	2.2	
	Installation and commissioning requirements			4	N	2.0	1.2	4.5	4	5.3	2.6	1.9	3.2	

3.2.10 Other factors affecting the compliance effect of conformity verification

This section reviews the other factors not disused previously that affect the conformity verification process and decisions to be made concerning it.

Frequency with which conformity verification is applied

Given that the purpose of conformity verification is to deter non-conformity through checking the quality of conformity assessment conducted by the obligated party and/or the entities they have engaged to provide the service the frequency with which conformity verification occurs is one of the key determinants of its likely effectiveness.

While for some building- and TBS-projects conformity verification is done for every project or installation (most notably for structural integrity checks and boiler safety checks) this is not necessarily the case for projects and installations that might be deemed to have less severe impacts from non-conformity. As previously discussed, new building and major renovation projects are almost always subject to conformity verification actions, at design stage, completion stage or both. For TBS energy performance requirements the following options exist:

- self-declaration by obligated parties with subsequent conformity verification checks on a sample of completed projects
- self-declaration by obligated parties with conformity verification checks on every project.

In theory, third-party conformity assessment (see section 3.3) and/or conformity verification is also possible but in practice this is not applied to TBS requirements for a conformity assessment process at the time a TBS is first installed or modified unless as part of a safety check.

Additional actions that authorities responsible for compliance need to undertake to facilitate compliance verification

Previous sections have considered inspection of evidence, either on-site or off-site, for conformity verification purposes, but in addition to assessing evidence the compliance authority needs to consider implementing a system to routinely process conformity assessment declarations and the related material. These could include on-line submissions of:

- Declarations of Honour
- checklists
- supporting video and photographic evidence
- supporting calculation files, e.g. input/output data sheets from permitted energy performance assessment tools in a standardised format
- product data sheets
- real-time performance data.

If on-line processes are set up through a conformity assessment registration database then it would greatly facilitate conformity verification actions and would likely considerably increase the conformity actually achieved as obligated parties would be reminded of the need for their assessments to be submitted and equally aware of the possibility these might be checked. With modern communications such systems are increasingly pragmatic to implement. Furthermore, non-conformity through avoidance of submission of such assessments could be readily identified via any of:

- inclusion of conformity assessment submission checks when EPCs are issued
- Article 14 and 15 heating system and AC inspections
- legal compliance checks when properties are sold or let.

Thus, the ability for obligated parties to avoid detection from non-submission of conformity assessments would be greatly limited.

In addition, implementing such a system (especially if complemented by heating system and AC system inspection reports related to Articles 14 and 15) would help cover one of the biggest gaps in many Member States EPBD conformity verification activities, which is not knowing what TBS are currently installed in the existing building stock. The lack of knowledge on the installed stock of TBS is understood to be a major hinderance to being able to systematically respect the Article 14 and 15 inspection requirements as inspectorate authorities can be unaware of which buildings should have their HVAC systems inspected. This, in turn, affects the ability to ensure compliance with the Article 14 and 15 provisions regarding the obligation to install BACS in buildings whose combined HVAC capacity exceeds 290kW as the authorities need to know which buildings have such systems in order to verify that they have complied with them.

With the implementation of on-line registration system for all conformity assessments then many checks could be automated so that cases would be automatically identified where:

- standardised data submissions and conformity assessment files are incomplete
- reported values do not meet requirements.

In addition, metering and monitoring data could be automatically benchmarked to identify systems that might be at higher risk of not meeting requirements and also where O&M actions are needed.

On the other hand, automated data submission and processing systems clearly entail issues regarding data privacy and cybersecurity and hence require careful implementation to respect building owner right as well as those of contractors.

3.2.11 BACS

Some details on Italy’s approach to conformity assessment and related enforcement techniques for BACS are presented in section 1.3.5. In addition, an extensive discussion of BACS KPIs and compliance with the EN15232 standard provisions is presented in **Error! Reference source not found.**.

3.2.12 Lighting systems

Some details on conformity assessment and related enforcement techniques for lighting are presented in section 1.3.6.

3.2.13 RES

Some details on conformity assessment and related enforcement techniques for RES are presented in section 1.3.7.

Nonetheless, the following QUALICHeCK fact sheets or presentations at QUALICHeCK events provide examples for how they are treated in EPC assessments of the main technologies covered, i.e. renewables in multi-energy systems:

- Renewable heating and cooling systems for buildings – Presentations at QUALICHeCK Workshop in Lyon, France, 17 January 2017
- Voluntary control scheme developed by the province of Salzburg: building services systems declaration based on as-built characteristics – Susanne Geissler – QUALICHeCK Factsheet #34, December 2016
- Voluntary schemes as a pool of ideas for designing and improving EPC compliance frameworks: the Boileff quality assurance scheme – Susanne Geissler – QUALICHeCK Fact Sheet #40, January 2017
    - Selecting EPC input data for HVAC systems: a series of French guidance sheets – Dominique Hantz, François Durier, Valérie Laplagne – QUALICHeCK Fact Sheet #42, January 2017
- baubook – Easily accessible product information for EPC calculation provided by the Austrian database – Christoph Sutter, Susanne Geissler – QUALICHeCK Factsheet #43, June 2016
    - European certification of HVAC products can provide EPC input data – Michèle Mondot, Sandrine Marinhas – QUALICHeCK Fact Sheet #50, February 2017
    - Views from the heat pump industry on quality and compliance issues – Thomas Nowak – Presentation at 1st QUALICHeCK Conference, Brussels, September 2014

3.3 Activity 2: Assessment and documentation of system performance

The assessment and documentation of system performance (Article 8(9) of the EPBD) and enforcement of technical building system requirements under Article 8(1) are closely connected (in that both apply under the same conditions: i.e. when a system is installed, replaced or upgraded) and that one aim of Article 8(9) is to ensure that building owners have sufficient and up-to-date information on their systems' performance, and in particular in relation to compliance with applicable requirements; it is important to determine effective pathways for providing such information.

To support this objective this section assesses prospective approaches for the assessment and documentation of system performance. This is done for the whole list of potential requirements drawn up in Task 2, which equally covers the whole set of technical building systems defined under the EPBD.

It should be noted that well-structured and straightforward conformity assessment is as important as conformity verification in attaining compliance outcomes, as the first factor that needs to be addressed is the ease with which responsible market actors can meet the requirements that apply to them. The review therefore considers the level of burden different approaches place on conformity assessment in conjunction with the degree of reliability of the results. Equally, it considers, the same for the actions implied by conformity verification authorities.

3.3.1 Conformity assessment

Conformity assessment is the set of actions that obligated parties have to undertake to demonstrate and document that their TBSs adhere to normative requirements. For new or retrofit TBS installations the obligated parties may be the TBS suppliers and service providers, and in this case the conformity assessment process is the actions they must undertake to demonstrate and document that their products and services adhere to normative requirements when being placed on the market and/or put into service. For existing TBS installations the obligated party may be the building owner.

The conformity assessment requirements need to be specified within the regulations that implement the regulatory requirements they pertain to so in this case they would be specified in any TBS energy performance requirement regulations that would affect the requirements proposed in Task 2.

Performance calculations and related design tools

While demonstration of conformity with several of the Task 2 TBS recommendations can be satisfied through simple inspection recorded against a checklist, others, including some of the most important from an energy savings perspective, require energy performance calculations to be conducted to demonstrate that the TBS satisfies the performance requirements. This is especially true of the overall system energy performance requirements that would apply to new or replacement TBS installations. In these cases it is necessary to gather technical input data on the different aspects of the system and then to simulate the system performance using an accepted standardised methodology. Happily, all the methodologies necessary to do this have already been created and integrated into EPBD standards and so conformity assessment calculations would only require application of a software tool with the appropriate input data.

Figure 24 shows the most important standards that apply to each TBS except RES. In many Member States these standards are understood to already be integrated into EPC assessment tools thus it should be possible to directly apply such tools to demonstrate conformity with the requirements. Similarly, there are commercially available design software tools that apply these standards to assess the performance of TBS installations.

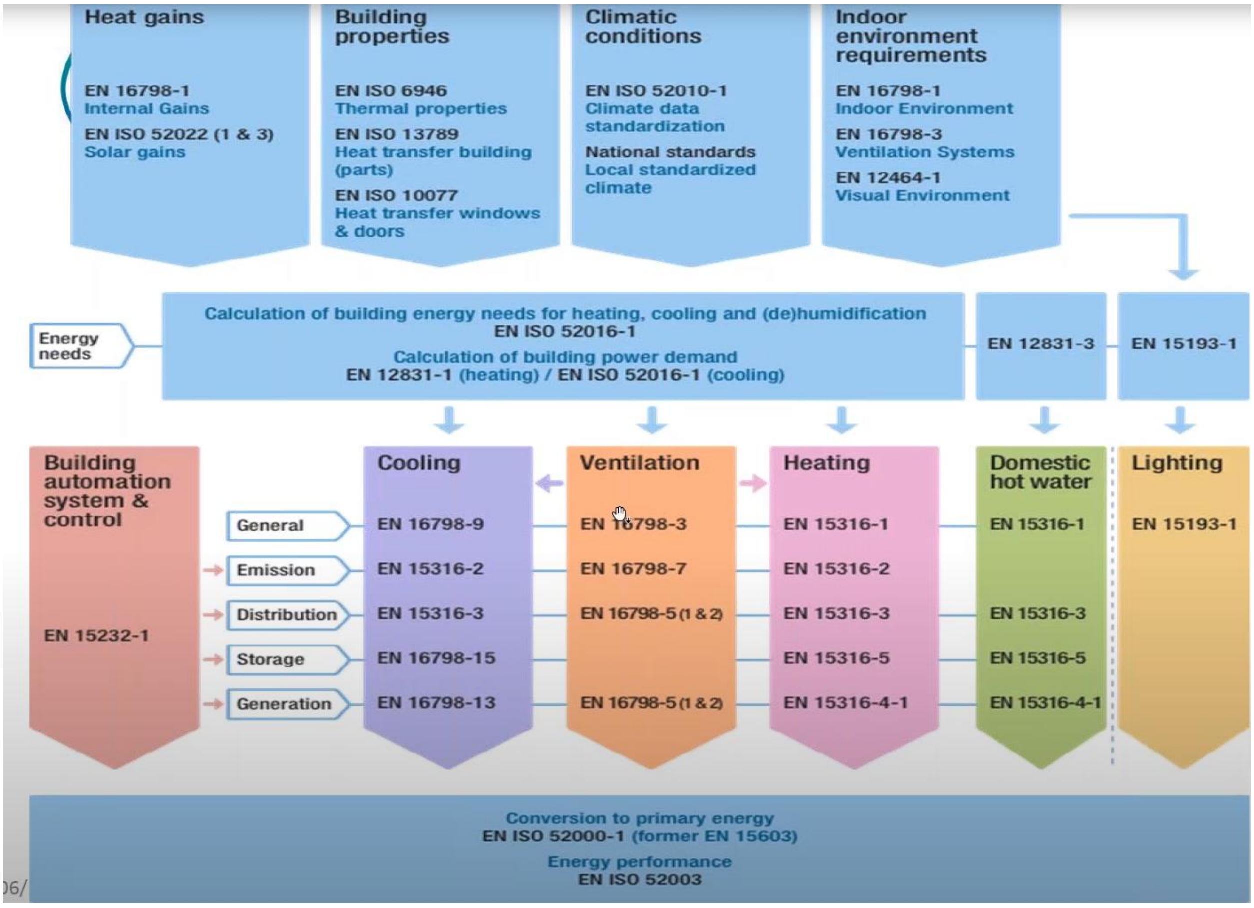


Figure 24: Key EPBD standards that can be used to assess TBS overall energy performance .

Conformity assessment and reporting for new build and major renovation projects

Member States are understood to use two means to conduct conformity assessment and report on compliance for whole building energy performance and related provisions for new buildings and major renovations:

- the builder must appoint a competent expert who makes the energy performance calculation. Depending on the Member State, this expert may have more or less responsibility
- the designer/architect must declare that the building complies with the requirements. Calculations may be done but are not mandatory in every Member State. Nonetheless, it is clear that requiring a calculation is more accurate and trustworthy than a simple declaration.

In these cases TBS performance would be assessed and reported as part of the same process.

Conformity assessment and reporting for EPCs

Ostensibly the same processes can be applied when issuing an EPC energy performance calculation and declaration and usually are.

The recently adopted regulations in Luxembourg[142], are an interesting example of how to bridge the conformity assessment process between new and existing buildings with a focus on the TBS. Under these regulations building owners must update their EPCs if technical installations (such as TBS) have been installed of a value of greater than:

- Euro 1500 in the case of a single-family building
- Euro 3000 for a multi-family building.

In updating the EPC a new energy performance calculation must be performed, and a new energy performance certificate established and presented to the authority responsible for building permits. Furthermore, within a period of 4 years following the establishment of an EPC for a new building, the owner must complete the EPC certificate with a measured energy expenditure index for heating and hot water.

Clarity of procedures on which data is needed to conduct conformity assessment

To achieve good conformity assessment outcomes, and hence good compliance outcomes, it very important for clear procedures to be established to explain exactly what data is required and how it can/should be obtained.

These procedures should clearly define:

- the quantity
- the unit of expression
- the method of determination
- for data that is made available by manufacturers, provide a clear reference to a testing and/or measurement method
- for data that is published in a database, provide clear reference to the database and where the data can be found within the database.

In addition, when data are recorded by an expert, clear methods should be specified for:

- recording data from the plans or description of a building
- recording data from on-site observations or simple measurements
- calculating the data.

On site data measurement should have clear reference to a measurement method, describing how to operate the measuring device to be used.

If data is fixed by the relevant legislation (default values, for example) then there should be a clear description of the data and the value to be used.

A good example in the case of TBS for HVAC systems is the provision of 23 guidance sheets for heat pumps, boilers, radiators, water heaters, hot water storage, solar thermal systems, ventilation fan boxes and air-handling units (among others) by the manufacturer association Uniclima and CETIAT[143].

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[142] https://guichet.public.lu/en/citoyens/logement/renovation-transformation/performances-energie/demande-passeport-energetique.html

[143] Selecting EPC input data for HVAC systems: a series of French guidance sheets – Dominique Hantz, François Durier, Valérie Laplagne – QUALICHeCK Fact Sheet #42, January 2017.

Clear procedures for demonstrating evidence of conformity for input data

Clear procedures are needed to facilitate demonstration that TBS conformity assessment input data is compliant with the procedures in force in the context of the relevant requirements legislation.

Problems may occur when:

- product data is available but there is no clear evidence that it has been established in line with the required procedures
- an expert has recorded data describing the building or its systems, but there is no evidence that the process used was in accordance with the procedures, or that the expert has the necessary competence to determine the data
- on-site data measurements have been made but there is no evidence that the measurement has been performed by a competent person and/or according to required procedures
- data has to be chosen as a pre-calculated value, for example in a building airtightness atlas, but there is no clear evidence that the choice has been made correctly.

3.3.2 Appraisal of conformity assessment options for Task 2 TBS requirements

Well-structured and straightforward conformity assessment is as important as market surveillance in attaining a good compliance outcome, as the first factor that needs to be addressed is the ease with which responsible market actors can meet the requirements that apply to them. The review therefore considers the level of burden different approaches place on conformity assessment in conjunction with the degree of reliability of the results. Equally, it considers, the same for the actions implied by market surveillance authorities.

Table 54 shows the various conformity assessment characteristics that could apply to the Task 2 TBS requirements. For each requirement it indicates:

- who would be responsible for conducting and submitting the conformity assessment, be it a facility manager (FM) or contractor
- the nature of the documentation produced and submitted, e.g. checklists, calculations or KPIs
- whether or not the conformity assessment data could be ported (i.e. submitted electronically) to a compliance authority
- the need to apply technical standards and related assessment tools in the conformity assessment process
- whether such standards and tools have already been developed and are in use in the EU
- an ordinal qualitative ranking (from 5 to 1) of the expected reproducibility of the conformity assessment process (i.e. of the extent to which different parties applying the same process would get the same outcomes, where a value of 5 indicates they would get exactly the same outcome and 1 that there would be considerable divergence)

- an ordinal qualitative ranking (from 5 to 1) of the expected level of professional skill/training that would be needed to conduct the assessment in a reliable manner where 5 indicates a very high level of skill/training and 1 a low level
- the estimated average Level of Effort (LOE) expressed in on-site hours spent to conduct such an assessment for a building with a floor area of 1000 m^2
- the expected cost of conducting the conformity assessment expressed in €/m^2 based on the LOE above, an average of 1500 hours worked per year and a staff cost of €55000 per year (wages plus other staff costs).

Table 54: Conformity assessment process applicable to each Task 2 TBS requirement.

TBS and Task 2 requirement				Conformity assessment process									
Code	Space heating + DHW	Measure Type	System scope	Who does conformity assessment	Nature of documentation produced	Could conformity assessment data be ported to a compliance authority?	Need for technical standards and tools to support conformity assessment	Availability & applicability of technical standards and tools to support conformity assessment	Reproducibility (reliability) of the required conformity assessment process	Level of professional training and skills required to establish conformity	LOE for conformity assessment (on-site hrs per 1000m2)	The extent to which the on-site conformity assessment may add costs to the TBS which is subject to the require (€/m2)	
VH1	Monitor energy consumption, compare to expected performance and adapt pa	Monitor	> 70 kW	FM	Checklist/KPIs	Y	Y	Y	2	4	1	€ 0.03	
VH2	Night setback - Adjusted settings (e.g. from 11 pm to 6 am, 2 K temperature re	Control	All	FM	Checklist/KPIs	Y	N	NA	4	1	0.2	€ 0.01	
VH3	Overall heating system performance requirement, in line with the 2030 reduct	System	> 70 kW	FM/Specifier/Ir	Checklist/Calcs	Y	Y	Y	4	4	1	€ 0.03	
VH4	Replace the old combustion (non-condensing) boiler (25-30 years old)- privatel	System	All	FM/Contractor	Checklist	Y	Y	Y	5	3	0.5	€ 0.02	
VH5	Individual heat emitter control -Thermostatic Radiator Valves	Control	All	FM/Contractor	Checklist	N	N	NA	5	2	0.5	€ 0.02	
VH6	Hydronic balancing and heat zoning	Control	All	FM/Contractor	Checklist	Y	?	?	3	4	0.5	€ 0.02	
VH7	Night setback - Adjusted settings (e.g. for office use from 5 pm to 6 am, 2 K ter	Control	All	FM	Checklist/KPIs	Y	N	NA	4	1	0.2	€ 0.01	
VH8	Heat pumps in new building need to be equipped with a monitoring system to	Monitor	All	Contractor	Checklist/KPIs	Y	N	NA	4	3	0.5	€ 0.02	
VH9	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	<= 70 kW	Contractor	Checklist	N	N	NA	5	1	0.5	€ 0.02	
Vh10	Avoid simultaneous heating and cooling: by implementing a central controller	Control	> 70 kW	FM/Contractor	Checklist	Y	N	NA	3	4	0.5	€ 0.02	
Vh11	Use of weather compensation to adapt the supply temperature	Control	All	FM/Contractor	Checklist	Y	N	NA	4	2	0.2	€ 0.01	
Vh12	Installation of insulation on pipes (100% of diameter)-accessible pipes outside	System	> 70 kW	FM/Contractor	Checklist	N	N	NA	5	1	0.5	€ 0.02	
	Space cooling												
C3+C	Switch off systems when not required (circulation pumps, chiller plant, A/C eq	Control	All non-packaged	FM	Checklist/KPIs	Y	Y	Y	3	3	0.5	€ 0.02	
C8	Modify controls in order to sequence heating and cooling	Control	Non-packaged systems	FM/Contractor	Checklist	Y	N	NA	3	4	0.5	€ 0.02	
C26	Overall requirement to annual savings of 4 % (could be adated to climate targe	System	All	FM/Contractor	Checklist/Calcs	Y	Y	Y	4	4	1.0	€ 0.03	
C11	Install BEMS system	Control	All > 30kW	Contractor	Checklist	Y	Y	Y	4	4	1.0	€ 0.03	
C12	Improve central chiller / refrigeration control	Control	Systems with chillers >3	FM/Contractor	Checklist	Y	Y	NA	5	2	0.5	€ 0.02	
C18+	Exchange of old and inefficient pumps and compressors	System	All non-packaged	FM/Contractor	Checklist/KPIs	Y	Y	Y	5	3	0.5	€ 0.02	
C6	Sequence heating and cooling	Control	Non-packaged systems	FM	Checklist	Y	N	NA	3	3	0.3	€ 0.01	
	Monitoring & metering measures	Monitor	> 70kW	FM	Checklist/KPIs	Y	Y	Y	2	4	1.0	€ 0.03	
	Ventilation												
V1a	Limitation on average specific fan power (PSFP) for all fans at design conditions	System	>5500 m³/h in non-res	Contractor	Checklist	Y	Y	Y	4	4	1.0	€ 0.03	
V1b	Limitation on average specific fan power (PSFP) for all fans at design conditions	System	>5500 m³/h in non-res	Contractor	Checklist	Y	Y	Y	4	4	1.0	€ 0.03	
V2	Volume reduction to actual demand by parameter adjustment	Control	>5500 m³/h in non-res	FM/Contractor	Checklist	Y	Y	NA	5	2	0.5	€ 0.02	
V3a	Installation of volume controls	Control	>5500 m³/h in non-res	Contractor	Checklist	Y	Y	Y	4	4	1.0	€ 0.03	
V3b	Installation of volume controls	Control	>5500 m³/h in non-res	Contractor	Checklist	Y	Y	Y	4	4	1.0	€ 0.03	
V3c	Installation of volume controls	Control	New large and medium	Contractor	Checklist	Y	Y	Y	4	4	1.0	€ 0.03	
V4	Installation of a heat recovery System (or an exhaust air heatpump in case of s	System	>5500 m³/h in non-res	Contractor	Checklist	Y	Y	Y	4	4	1.0	€ 0.03	
V5	Improvement of filter exchange	O&M	filters > 100 m³/h	FM	Checklist	Y	N	NA	3	3	0.5	€ 0.02	
V6	Overall ventilation system performance requirement, e.g. in line with the 2030	System	>5500 m³/h in non-res	FM/Contractor	Checklist/Calcs	Y	Y	Y	4	4	1.0	€ 0.03	
	All HVAC												
	Overall cooling system energy performance requirements			FM/Contractor	Checklist/Calcs	Y	Y	Y	4	4	1.0	€ 0.03	
	Control and controllability requirements			FM/Contractor	Checklist	Y	Y	NA	5	2	0.5	€ 0.02	
	Metering and monitoring requirements			FM	Checklist/KPIs	Y	Y	Y	2	4	1.0	€ 0.03	
	Installation and commissioning requirements			Contractor	Checklist	Y	Y	Y	4	4	1.0	€ 0.03	

3.4 Documentation and reporting

Conformity assessment documentation provides the evidence that conformity assessment has been conducted in accordance with the required procedures. The content of conformity assessment documentation is determined by the conformity assessment procedures but in principle it needs to be just sufficiently detailed to unambiguously demonstrate conformity with the requirements but no more detailed than that, to avoid unnecessary burdens on obligated parties.

Nature of documentation

The nature of conformity assessment documentation produced is also determined by the conformity assessment procedures and needs to be specified to facilitate:

- the provision of relevant information to the building owner
- the provision of all information necessary to verify conformity by the compliance authorities.

In principle, the documentation could comprise sets of any of the following:

- Declarations of Honour
- checklists
- supporting video and photographic evidence
- supporting calculation files, e.g. input/output data sheets from permitted energy performance assessment tools in a standardised format
- product data sheets
- BIM data sets
- measured data potentially including real-time performance data.

Examples of currently required TBS documentation

The examples discussed below illustrate cases of declarations of honour and checklists, and also of reporting real-time performance data.

H5 Germany's heating system inspection reports

Under section 26a of Germany's EnEV regulation building owners are required to prove that the requirements of the EnEV are satisfied in the event of modification of existing buildings to the Technical Building equipment. As Germany already requires mandatory annual inspection of heating systems for safety purposes these inspections have been extended in scope to include checking that heating systems satisfy the regulatory energy performance requirements, and if necessary carrying out remedial actions to bring the heating system into line with the requirements. The inspector, who may also carry out some of the remedial actions, then issues a report under a Declaration of honour declaring that the system either satisfies the requirements or is in a state of non-conformity. In particular, the inspection reports have been adapted to include reporting on compliance with each of the specific energy performance specifications.

The report, which is prepared and submitted by the inspector, comprises a checklist which sets out:

- the system technical characteristics including its type, energy source and capacity

- the nature of any work carried out on the system
- and a declaration by the inspector that the work conducted satisfies the EnEV requirements with regard to the heat generators, the insulation of pipework and storage, and the control and regulation of the system.

The latter includes checking that:

- the central heating system is equipped with central, automatic-acting control for reducing and switching off the heat supply depending on the outside temperature or any other guide and switching on and off the electric drives
- the heating system is equipped with automatic-acting devices for room-by-room control of room temperature
- the electrical power consumption of circulation pumps of the central heating system is automatically adapted to the demand
- hydraulic balancing of the heating system was carried out.

Each of which is confirmed separately on the checklist; see Annex C: for the full details.

H5 Electronic performance data benchmarking in France

In France, the national energy and environment agency, ADEME, has set up a platform called OPERAT[144] to allow building owners and, where applicable, lessees of buildings, parts of buildings or sets of buildings subject to the obligations of actions to reduce final energy consumption in tertiary sector buildings to meet the provisions of Articles L.111-10-3 and R.131-38 to R.131-44 of the Construction and Housing Code and the details provided in the implementing decree.

Under these requirements owners of tertiary sector buildings of >1000 m^2 are required to reduce their building's energy consumption.

Building owners have a choice of two compliance pathways that can be used, as follows:

- **Via absolute targets**, where the objective is determined:
    - for each category of activity
    - including all energy uses over a year
    - by a threshold expressed in kWh/m²/year in accordance with the energy consumption of new buildings in the same category of activity and application of best available techniques taking into account indicators of intensity of use specific to each type of activity.

  The values to be respected are set for each decade and the objectives must be achieved each deadline (2030, 2040, 2050

- **Via relative value (%) targets** where the objective corresponds to a reduction in the final energy consumption:
    - compared to a reference year (as of choice of taxable person) which cannot be prior to 2010
    - including all energy uses in 1 year
    - adjusted for climatic variations (correction methods defined by decree)

[144] https://operat.ademe.fr/#/public/home

    - qualified by occupancy data and corresponding intensity of use provided by the building owner.

  The values to be respected are established respectively from the reference energy consumption with a reduction of –40% (2030), –50% (2040) and –60% (2050).

The OPERAT platform is being designed to collect and monitor energy consumption data in the tertiary sector as a support tool for tertiary actors to demonstrate and achieve compliance with the requirements.

In addition to its objective of monitoring the reduction of final energy consumption in the tertiary sector, the platform's functionalities will notably allow:

- to use the database as a benchmark on energy in tertiary real estate, for all players in the sector, either at a global scope or by category of activity and at national and regional geographic levels of discretisation and departmental, in accordance with the provisions of Articles L.142-1 and L.142.3 of the Energy Code
- to allow managers of buildings, parts of buildings or sets of buildings subject to an annual assessment of their situation in terms of their energy performance, both at the level of a building and that of all or part of their heritage.

The planned schedule of deployment of functionality of the OPERAT platform is shown in Figure 25.

Both of these examples illustrate the type of data at can be collected and reported for TBS energy performance purposes, both to inform building owners and compliance authorities. The checklist approach is the traditional one and helps ensure a straightforward and systematic process, but the electronic data submission holds great promise for gaining better understanding of and deeper improvement in TBS energy performance over time.

In future iterations of this report additional details will be added regarding the type of data that could be gathered and documented for the specific Task 2 TBS recommendations and the applicable documentation and reporting processes.

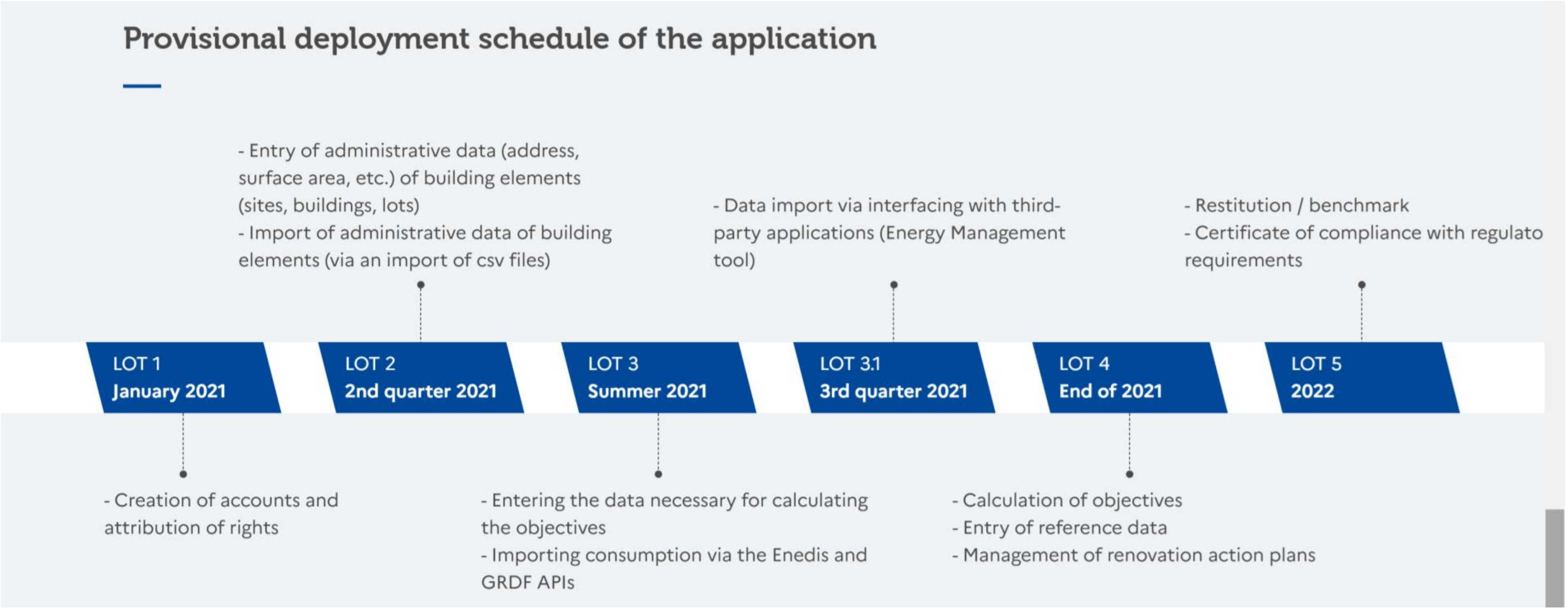

Figure 25: Deployment schedule of the OPERAT building energy data reporting and benchmarking system in France.

Submitting and processing conformity assessment documentation

It is important that the legal framework specifies both when information must be communicated to the authorities and building owners and the precise nature of the information which is to be communicated. This includes specifying:

- the point in the building/TBS process when communication with the authorities should occur
- the precise information that needs to be communicated
- the procedures in place to confirm receipt of (and, where relevant, approval) of the information.

Previous sections have considered inspection of evidence, either on-site or off-site, for conformity verification purposes, but in addition to assessing evidence the conformity authority needs to consider implementing a system to routinely process conformity assessment declarations and the related evidential material. These could include establishment of on-line submissions of:

- Declarations of Honour
- checklists
- supporting video and photographic evidence
- supporting calculation files, e.g. input/output data sheets from permitted energy performance assessment tools in a standardised format
- product data sheets
- real-time performance data.

If on-line processes are set up through a conformity assessment registration database then it would greatly facilitate conformity verification actions and would be expected to considerably increase the conformity actually achieved as obligated parties would be cognizant of the need for their assessments to be submitted and equally aware of the possibility these might be checked. With modern communications such systems are increasingly pragmatic to implement. Furthermore, non-conformity through avoidance of submission of such assessments could be readily identified via any of:

- inclusion of conformity assessment submission checks when EPCs are issued
- Article 14 and 15 heating system and AC inspections
- legal compliance checks when properties are sold or let.

Thus, the ability for obligated parties to avoid detection from non-submission of conformity assessments would be greatly limited.

In addition, implementing such a system (especially if complemented by heating system and AC system inspection reports related to Articles 14 and 15) would help cover one of the biggest gaps in many Member States EPBD conformity verification activities, which is not knowing what TBS are currently installed in the existing building stock. The lack of knowledge on the installed stock of TBS is understood to be a major hinderance to being able to systematically respect the Article 14 and 15 inspection requirements as inspectorate authorities can be unaware of which buildings should have their HVAC systems inspected. This, in turn, affects the ability to ensure compliance with the Article 14 and 15 provisions regarding the obligation to install BACS in buildings whose combined

HVAC capacity exceeds 290kW as the authorities need to know which buildings have such systems in order to verify that they have complied with them.

With the implementation of on-line registration system for all conformity assessments then many checks could be automated so that cases would be automatically identified where:

- standardised data submissions and conformity assessment files are incomplete
- reported values do not meet requirements.

In addition, metering and monitoring data could be automatically benchmarked to identify systems that might be at higher risk of not meeting requirements and also where O&M actions are needed.

On the other hand, automated data submission and processing systems clearly entail issues regarding data privacy and cybersecurity and hence require careful implementation to respect building owner right as well as those of contractors.

Annex A: Energy savings measures for space cooling from the IEE AUDITAC project

The IEE AUDITAC project specified a comprehensive set of Energy Conservation Opportunities (ECOs) for AC systems broken down into the Plant level, the operation and maintenance (O&M) level and the Building envelope level.

The first two are shown in Table A-1 and Table A-2. Several of the ECOs of each of the above categories may be effectively implemented with the aid of a Building Energy Management System (BEMS). Such circumstance is highlighted in a specific column of the ECO list.

The Plant level ECO measures are structured into the following sub-groups:

- BEMS and controls/Miscellaneous
- Cooling equipment/Free cooling
- Air handling/Heat recovery/Air distribution
- Water handling/Water distribution
    - Terminal units
    - System replacement (in specific limited zones)

"Plant" ECOs involve more or less radical intervention on the HVAC system. Their applicability should therefore be carefully assessed both from the technical and economic standpoint.

Table A-1: Plant-level energy conservation opportunities for AC systems.

PLANT			
CODE	**ECO**	**BEMS control**	
BEMS AND CONTROLS/MISCELLANEOUS			
P1.1	Install BEMS system		
P1.2	Define best location for new electrical and cooling energy meters		
P1.3	Modify controls in order to sequence heating and cooling	Y	
P1.4	Modify control system in order to adjust internal set-point values to external climatic conditions	Y	
P1.5	Generate the possibility to adopt variable speed control strategy	Y	
P1.6	Use high efficiency electric motors (e.g. IE4 or IE5)		
P1.7	Reduce power consumption of auxiliary equipment	Y/N	
COOLING EQUIPMENT/FREE COOLING			
P2.1	Minimise adverse external influences (direct sunlight, air flow obstructions, etc.) on cooling tower and air cooled condenser (AHU, packaged, split, VRF systems)	Y	
P2.2	Reduce compressor power or fit a smaller compressor		
P2.3	Split the load among various chillers		
P2.4	Repipe chillers or compressors in series or parallel to optimise circuiting		
P2.5	Improve central chiller/refrigeration control	Y	

P2.6	Replace or upgrade cooling equipment and heat pumps		
P2.7	Consider feeding condenser with natural water sources	Y	
P2.8	Apply evaporative cooling	Y	
P2.9	Consider using ground water for cooling	Y	
P2.10	Consider indirect free cooling using the existing cooling tower (free chilling)	Y	
P2.11	Consider Indirect free cooling using outdoor air-to-water heat exchangers	Y	
P2.12	Consider the possibility of using waste heat for absorption system	Y	
P2.13	Consider cool storage applications (chilled water, water ice, other phase-changing materials)	Y	
P2.14	Consider using condenser rejection heat for air reheating	Y	
AIR HANDLING/HEAT RECOVERY/AIR DISTRIBUTION			
P3.1	Reduce motor size (fan power) when oversized		
P3.2	Relocate motor out of air stream		
P3.3	Use the highest efficiency class of fans (e.g. per EUROVENT)		
P3.4	Use the best class of AHU		
P3.5	Consider applying chemical de-humidification		
P3.6	Apply variable flow rate fan control		
P3.7	Consider conversion to VAV		
P3.8	Exhaust (cool) conditioned air over condensers and through cooling towers	Y	
P3.9	Introduce exhaust air heat recovery	Y	
P3.10	Consider applying demand-controlled ventilation	Y	
P3.11	Generate possibility to increase outdoor air flow rate (direct free cooling)		
P3.12	Replace ducts when leaking		
P3.13	Modify ductwork to reduce pressure losses		
P3.14	Install back-draught or positive closure damper in ventilation exhaust system	Y	
WATER HANDLING/WATER DISTRIBUTION			
P4.1	Use the best class of pumps		
P4.2	Modify pipework to reduce pressure losses		
P4.3	Convert 3-pipe system to 2-pipe or 4-pipe system		
P4.4	Install separate pumping to match zone requirements	Y	
P4.5	Install variable volume pumping	Y	
TERMINAL UNITS			
P5.1	Consider applying chilled ceilings or chilled beams		
P5.2	Consider introducing re-cool coils in zones with high cooling loads		
P5.3	Increase heat exchanger surface areas		
P5.4	Consider displacement ventilation		
P5.5	Install localised HVAC system (in case of local discomfort)	Y	
SYSTEM REPLACEMENT (IN SPECIFIC LIMITED ZONES)			
P6.1	Consider water loop heat pump systems	Y	
P6.2	Consider VRF (Variable Refrigerant Flow) systems		

Table A-2: O&M-level energy conservation opportunities for AC systems.

O&M			
CODE	**ECO**	**BEMS control**	
FACILITY MANAGEMENT			
O1.1	Generate instructions (“user guide”) targeted to the occupants		
O1.2	Hire or appoint an energy manager		
O1.3	Train building operators in energy – efficient O&M activities		
O1.4	Introduce an energy – efficient objective as a clause in each O&M contract		
O1.5	Introduce benchmarks, metering and tracking as a clause in each O&M contract, with indication of values in graphs and tables		
O1.6	Update documentation on system/building and O&M procedures to maintain continuity and reduce troubleshooting costs		
O1.7	Check if O&M staff are equipped with state-of-the-art diagnostic tools		
GENERAL HVAC SYSTEM			
O2.1	Use an energy accounting system to locate savings opportunities and to track and measure the success of energy – efficient strategies	Y	
O2.2	Shut off A/C equipment when not needed	Y	
O2.3	Shut off auxiliaries when not required	Y/N	
O2.4	Maintain proper system control set-points	Y	
O2.5	Adjust internal set-point values to external climatic conditions	Y	
O2.6	Implement pre-occupancy cycle	Y	
O2.7	Sequence heating and cooling	Y	
O2.8	Adopt variable speed control strategy	Y	
COOLING EQUIPMENT			
O3.1	Shut chiller plant off when not required	Y	
O3.2	Sequence operation of multiple units	Y	
O3.3	Operate chillers or compressors in series or parallel		
O3.4	Track and optimise chillers operation schedule	Y	
O3.5	Maintain proper starting frequency and running time of (reversible) chillers	Y	
O3.6	Improve part-load operation control	Y	
O3.7	Maintain proper evaporating and condensing temperatures	Y	
O3.8	Raise chilled water temperature and suction gas pressure	Y	
O3.9	Lower condensing water temperature and pressures	Y	
O3.10	Check sensor functioning and placement for (reversible) chillers	Y	
O3.11	Maintain efficient defrosting (reversible chillers)	Y	
O3.12	Maintain proper heat source/sink flow rates	Y	
O3.13	Maintain functioning of (reversible) chiller expansion device	Y	
O3.14	Check (reversible) chiller stand-by losses	Y	
O3.15	Maintain full charge of refrigerant	Y/N	
O3.16	Clean finned tube evaporator/condenser air side and straighten damaged fins		
O3.17	Clean condenser tubes periodically		
O3.18	Repair or upgrade insulation on chiller		
O3.19	Clean and maintain cooling tower circuits and heat exchanger surfaces		
O3.20	Apply indirect free cooling using the existing cooling tower (free chilling)	Y	
FLUID (AIR AND WATER) HANDLING AND DISTRIBUTION			
O4.1	Consider modifying the supply air temperature (all–air and air–and–water systems)	Y	

O4.2	Perform night-time overventilation	Y	
O4.3	Shut off coil circulators when not required	Y	
O4.4	Replace mixing dampers		
O4.5	Adjust fan belts (AHU, packaged systems)		
O4.6	Eliminate air leaks (AHU, packaged systems)		
O4.7	Increase outdoor air flow rate (direct free cooling)	Y	
O4.8	Adjust/balance ventilation system	Y	
O4.9	Reduce air flow rate to actual needs	Y/N	
O4.10	Check maintenance protocol in order to reduce pressure losses		
O4.11	Reduce air leakage in ducts		
O4.12	Clean fan blades		
O4.13	Maintain drives		
O4.14	Clean or replace filters regularly		
O4.15	Repair/upgrade duct, pipe and tank insulation		
O4.16	Consider the possibility to increase the water outlet – inlet temperature difference and reduce the flow rate for pumping power reduction		
O4.17	Balance hydronic distribution system	Y	
O4.18	Bleed air from hydronic distribution system	Y	
O4.19	Switch off circulation pumps when not required	Y	
O4.20	Maintain proper water level in expansion tank	Y	
O4.21	Repair water leaks		
O4.22	Reduce water flow rates to actual needs	Y/N	

The ECOs of the "Plant" type always imply some modification or replacement work on the HVAC system; they are subdivided into six sub-categories:

- BEMS and Controls/Miscellaneous: ECOs implying an improvement in control strategies at the hardware level
- Cooling equipment/Free cooling: ECOs concerning chillers and cooling towers; energy-efficient cooling strategies (such as free cooling, cold storage, use of ground eater, etc.)
- Air handling/Heat recovery/Air distribution: ECOs concerning air-handling and distribution equipment; energy-efficient air treatment strategies
- Water handling/Water distribution: ECOs concerning water handling and distribution equipment; energy-efficient water distribution strategies
- Terminal units
- System replacement (in specific limited zones).

The possibility of BEMS implementation is indicated with a Y in the ECO list third column.

BEMS and controls/miscellaneous

Building energy management systems (BEMS) are more and more becoming a standard in new buildings, thanks to the availability of digital controls and powerful, low-cost computers – ECO P1.1. BEMS make it possible to monitor from a remote location the main building and HVAC system operation parameters (occupancy, indoor temperatures, system components on-off status, fluid flow rates and temperatures, etc.) and to modify the HVAC system control parameters (set-points, component operation timing, etc.). BEMS can monitor energy consumption, provided electrical and thermal energy meters are installed (ECO P1.2). BEMS also make it possible to implement advanced control strategies, such as optimal equipment start-stop, free cooling, demand-controlled ventilation, variable speed pumping and air flow, sunshades operation, artificial light trimming based on occupancy and daylight. To take full advantage of such features, the existing controls and HVAC hardware may require some modification (ECOs P1.3 – 1.5).

The auditor should not overlook the energy consumption of electrical motors (ECO P1.6) and auxiliary equipment (ECO P1.7) present in HVAC systems that should be replaced when inefficient.

Cooling equipment/free cooling

The generation of a cooling effect is probably the single major cause of energy consumption in air conditioning. With this respect, several energy conservation options are available that may be implemented by optimisation of the existing equipment, or by system upgrading/replacement. The efficiency of the cooling equipment may be increased by different actions that are listed below.

- The optimal placement of cooling towers, air-cooled water chillers, air-handling units, packaged, split or VRF systems should be considered by taking into account the negative effects that may derive from impinging solar radiation, obstructions to air flow, etc. (ECO P2.1).
- The efficiency of chillers and heat pumps can be increased by reducing the power if oversized (ECO P2.2), or by splitting the load among multiple chillers of smaller size (ECO P2.3): the latter ECO enhances the regulation capabilities by increasing the number of possible power steps.
- Multiple chillers can be hydraulically connected in series or parallel, with effects the overall performance of the system; the auditor is advised to verify the hydraulics of the cooling plant, check the water flow rates and inlet/outlet temperatures, and make a judgment if such values are optimally matched with the equipment characteristics and load profiles (ECO P2.4). The auditor should also check that the control strategies of the refrigeration equipment are adequate, or if improvements can be implemented (ECO P2.5). If feasible from the technical and legal standpoint, chiller (heat pump) efficiency may be increased by feeding the condenser (evaporator) with a constant temperature natural water sources, such as the water table, a river, a lake or the sea (ECO P2.7). As a more radical alternative, equipment replacement may be considered (ECO P2.6); such decision may be influenced by maintenance conditions, type of refrigerant fluid employed (it is not unlikely to encounter refrigeration units employing CFCs that are no longer produced), excessive noise or vibration emissions, etc.
- A significant cooling effect may sometimes be obtained by directly exploiting free sources of cooling, such as the outdoor air, ground water, or the soil. Evaporative cooling (ECO P2.8) is particularly effective in dry climates. Ground water – local regulations permitting – is an excellent source of cooling (ECO P2.9) for HVAC systems that may be fed with relatively high temperature cold water (e.g. radiant panels, chilled beams, etc.). Free chilling/cooling using the existing cooling tower (ECO P2.10) or air-to-water heat exchanger (P2.11) is practicable when the outdoor air enthalpy is low enough.
- If relatively high temperature waste heat is available – a common circumstance in industry – the auditor should evaluate the option of installing absorption-cycle refrigeration equipment (P2.12). It is important to point out that, compared with vapour compression-cycle equipment, absorption chillers have normally lower efficiencies and higher initial costs: therefore, the economic feasibility of such

option strongly depends on the cost differential between the thermal and electrical energy input.

- Short-term storage of cooling energy in chilled water, water ice, or other phase-changing materials, may be an effective way of reducing electricity costs (by shifting the peak power demand to the night-time), or equipment sizing (a smaller chiller running for more hours + storage may substitute a larger chiller running only when cooling is needed, e.g. in buildings with non-continuous occupancy, such as offices, shopping centres, etc.) – ECO P2.13. Due consideration should be paid to high initial costs, space requirements, and to the fact that this solution – albeit being a cost saver – may actually increase the energy consumption, particularly if the temperature of the storage medium is significantly lower than the required chilled water temperature.
- It is well known that any refrigeration process implies the rejection of heat to a suitable heat sink (outdoor air, cooling tower water, ground water, etc.). Since the air conditioning process often implies reheating for humidity control, the possibility arises to recover condensation heat for air reheating (ECO P2.14). Most refrigeration equipment manufacturers offer condensation heat recovery as a standard option for their water chillers.

Air handling/heat recovery/air distribution

A significant source of electrical and thermal energy demand in HVAC systems is air handling and distribution: air filtration, heating, cooling, humidification, dehumidification are the processes taking place in the air-handling unit (AHU), which normally incorporates one or two fans for air movement. Normally a hot heat carrier fluid is needed for air preheating, reheating and humidification (indirect steam production); a cold heat carrier fluid is needed for air cooling and dehumidification, electricity for direct steam production, air and water movement, and occasionally for air reheating. For most of the above processes the auditor may consider the ECOs that are discussed below.

- Fan electrical input may be reduced by correct motor sizing (ECO P3.1) and selection of high performance components according to Eurovent classification (ECO P3.3); such classification applies to the AHU as well (ECO P3.4). If feasible, the fan motor should also be placed outside the air stream, to avoid air heating in the air cooling regime (ECO P3.2).
- Chemical de-humidification (ECO P3.5) may be considered as an alternative to the conventional process based on reducing the air temperature below its dew-point. This approach reduces the chiller consumption, but implies the availability of heat (possibly recovered without extra consumption) in order to regenerate the dehumidifier.
- Variable flow rate systems have become very popular with the diffusion of low-cost inverters (solid state electronic devices that allow motor speed control by varying the AC supply frequency). Such options may be considered as retrofits of existing constant air flow systems (ECO P3.6, P3.7).
- Energy may be recovered from exhaust air by using a heat recuperator giving up heat (and possibly water vapour) from the warm/humid outdoor air and the cool/dry exhaust indoor air (ECO P3.9). Alternatively, the indoor air may be exhausted to heat-rejection equipment such as condensers and cooling towers (ECO P3.8).

- Demand-controlled ventilation (DCV) is particularly suited for variable occupancy buildings, such as theatres, auditoria, conference rooms, classrooms, etc. (ECO P3.10). DCV techniques imply variable fan speed control, adjustable outdoor/recirculated air dampers, and sensors estimating occupancy by measuring a suitable tracer pollutant (e.g. CO_2, VOCs, etc.). A similar system concept applies to direct free cooling (ECO P3.11): the percentage of outdoor air is automatically increased, thus reducing recirculation, to take advantage of suitable climatic conditions for space cooling.
- An inspection of the ductwork and measurements of fan flow rate and pressure may help in identifying and eliminating excessive duct leakage (ECO P3.12) and pressure loss (ECO P3.13). Back-draught or positive closure dampers may be installed to reduce unwanted ventilation losses in exhaust systems (ECO P3.14).

Water handling/water distribution

Considerations similar to those in the above section apply to water handling and distribution.

- As for fans, pumps of the best quality class should be selected (ECO P4.1). Variable flow pumping is achieved with inverter-driven electric motors (ECO P4.5), a solution particularly suited when two-way regulation valves are present in the fluid network.
- If feasible the pipework layout should be modified to correct excessive pressure losses (ECO P4.2), reduce mixing losses in 3-pipe systems (conversion to 2-pipe or 4-pipe – ECO P4.3), match zone requirements by installing separate pumping (ECO P4.4).

Terminal units

Older HVAC systems normally adopt a limited range of terminal units (e.g., fan coils, induction units, complete mixing air diffusers, etc.). When such terminals are obsolete, too noisy, or causing discomfort, their replacement may be advisable. Under such circumstances and if technically feasible, switching to more innovative terminals may be evaluated:

- Chilled ceilings or cold beams (ECO P5.1) provide excellent comfort, and can be nicely integrated in the room architecture; as any low-temperature heating/high-temperature cooling units, they help increasing the heating/cooling generating equipment performance
- Displacement ventilation (ECO P5.4) increases the ventilation and pollutant removal efficiency; this technique is applicable in the cooling mode only in spaces with significant internal loads from people or equipment
- Introducing re-cool coils in zones with high cooling loads (ECO P5.2), increase heat exchanger cooling areas (ECO P5.3), install localised HVAC systems in case of local discomfort (ECO P5.5) are other possible retrofits on existing plants.

System replacement (in specific limited zones)

When more radical renovation work on existing HVAC systems is needed, options such as the water loop heat pump system (ECO P6.1) or the variable refrigerant flow (VRF) system (ECO P6.2) may be considered. The former system is indicated when, in a large building, different zones simultaneously require either heating or cooling. The latter system uses the refrigerant as the heat carrying fluid, and therefore eliminates the need for producing and distributing chilled water; the presence of large quantities of refrigerant inside inhabited areas may however pose a safety problem and may not be compatible with present or future regulations.

O&M measures

The O&M ECOs are structured into the following groups:

- Facility management
- General HVAC system
    - Cooling equipment
    - Fluid (air and water) handling and distribution

The "O&M" ECOs include all actions that may in general be implemented in a building, HVAC system, or facility management scheme. The costs involved by such ECOs are generally limited if not negligible: application is therefore normally recommended, provided their technical feasibility is assessed.

O&M diagnosis and assessments

Building operation and maintenance (O&M) is the ongoing process of sustaining the performance of building systems according to design intent, the owner's or occupant's changing needs, and optimum efficiency levels. The O&M process helps sustain a building's overall profitability by addressing tenant comfort, equipment reliability, and efficient operation. Efficient operation, in the context of O&M, refers to activities such as scheduling equipment and optimising energy and comfort-control strategies so that equipment operates only to the degree needed to fulfil its intended function. Maintenance activities involve physically inspecting and caring for equipment. These O&M tasks, when performed systematically, increase reliability, reduce equipment degradation, and sustain energy efficiency. Building operation and maintenance programs specifically designed to enhance operating efficiency of HVAC can save 5 to 20 percent of the energy bills without significant capital investment.

An O&M assessment is a systematic method for identifying ways to optimise the performance of an existing building. It involves gathering, analysing, and presenting information based on the building owner or manager's requirements. Owners generally perform an O&M assessment for the following reasons:

- to identify low-cost O&M solutions for improving energy efficiency, comfort, and indoor air quality (IAQ)
- to reduce premature equipment failure
- to insure optimal equipment performance
- to obtain an understanding of current O&M practices and documentation.

O&M assessments may be performed as a stand-alone activity that results in a set of O&M recommendations or as part of a more comprehensive approach to improving existing-building performance. The goal of the assessment is to gain an understanding of how building systems and equipment are currently operated and maintained, why these O&M strategies were chosen, and what the most significant problems are for building staff and occupants. Implementing O&M changes without fully understanding the owner's operational needs can have disappointing and even disastrous effects. Most projects require the development of a formal assessment instrument in order to obtain all the necessary O&M information. This instrument includes a detailed interview with the facility manager, building operators and maintenance service contractors who are responsible for the administration and implementation of the O&M programme. Depending on the scope of the project, it may also include an in-depth site survey of equipment condition and gathering of nameplate information. An O&M assessment can take from a few days to several weeks to complete depending on the objectives and scope of the project.

The assessment identifies the best opportunities for optimising the energy-using systems and improving O&M practices. It provides the starting point for evaluating the present O&M programme and a basis for understanding which O&M improvements are most cost effective to implement.

O&M assessments identify low-cost changes in O&M practices that can improve building operation. The O&M assessment may be performed first of all as part of an energy audit because it offers ways to optimise the existing building systems, reducing the need for potentially expensive retrofit solutions, besides because implementing the low-cost savings identified in the assessment can improve the pay-back schedule for capital improvements resulting from the energy audit.

The greatest benefit of performing a building O&M assessment is informational. The information resulting from an O&M assessment can be used to help prioritise both financial and policy issues regarding the management and budget for the facility. It presents a clear picture of where and what improvements may be most cost effective to implement first. The assessment process, depending on the owner’s or manager’s requirements, can also provide direct training and documentation benefits for O&M staff. Depending on the goals for performing the assessment, typical benefits may include:

- Identifying operational improvements that capture energy and demand savings
- Identifying operational improvements that positively affect comfort and IAQ
- Improving building control
- Developing a baseline report on the condition of major HVAC equipment
- Developing an updated and complete equipment list (nameplate data)
- Identifying issues contributing to premature equipment failure
- Identifying ways to reduce staff time spent on emergencies
- Increasing O&M staff capabilities and expertise
- Determining whether staff require additional training
- Identifying and gathering any missing critical system documentation
- Developing a complete set of sequences of operation for the major HVAC systems
- Evaluating the BEMS for opportunities to optimise control strategies
- Recommending energy-efficiency measures for further investigation
- Determining original design intent and the cost to bring the building back to original design
- Providing a cost/benefit analysis of implementing the recommended O&M improvements

- Developing an operating plan and policy to maintain optimal building performance over time.

The best benefits keep on giving long after the process is completed. For example, the final master log of recommended improvements along with the estimated savings allows an owner or building manager to prioritise and budget accurately for the implementation process. Also, minor problems that could be solved during the assessment may begin to reduce energy costs and improve comfort immediately; equipment life may be extended for equipment that may have failed prematurely due to hidden problems, short-cycling, or excessive run time.

How much an O&M assessment costs is influenced by several factors:

- the number and complexity of the buildings, systems, and equipment involved
- the number and type of assessment objectives
- the availability and completeness of building documentation
- the availability and expertise of the O&M staff.

A project with several objectives will naturally cost more than a project with fewer objectives. Also, a project with complicated controls and numerous pieces of equipment will cost more than a simple building with only a few pieces of equipment. Scoping the project to obtain the most benefit at the least cost can be challenging. The owner must have a clear vision for what the assessment needs to accomplish and impart that vision to the O&M consultant. In some cases, the owner may want to hire an O&M consultant to help scope the project.

Annex B: Detailed tabulation of scope of application of proposed requirements

In the final report this annex will include a comprehensive set of tables listing the scope of application of each of the requirements set out in Task 2. An illustrative, but incomplete, example for a space cooling requirement is shown in Table B-1.

Table B-1: Scope of application for requirement C26 for space cooling.

Name of requirement						
Requirement C26: Overall cooling system performance						
Type of requirement						
	Overall energy performance	Appropriate dimensioning	Proper installation	Proper adjustment	Appropriate control	
	☒	☐	☐	☐	☐	
Scope of application of the requirement						
Type of building purposes covered:						
	Residential:			Non-residential:		
	All	SFH	MFH	All	Offices	Etc.
	☒	☐	☐	☒	☐	☐
Type of building sizes covered:						
	All	>*x* m² (specify)				
	☒					
Installation stage covered:						
	New installations:				Existing installations:	
	All	New build	Major renovation	Existing buildings	All	Partial retrofits
	☒	☐	☐	☐	☐	☐
Types of TBS covered (technology, type, capacity range, etc.)						
		All	A	B	C	D
Technology		☒	☐	☐	☐	☐
		All	A	B	C	D
Type		☒	☐	☐	☐	☐
		All	>X			
Capacity range		☒	☐			
Parts of the system covered (e.g. whole system, ductwork, fan, etc.)						

	All	A	B	C	D
Whole system	☒	☐	☐	☐	☐
Generation	☐	☐	☐	☐	☐
Distribution	☐	☐	☐	☐	☐
Emission	☐	☐	☐	☐	☐
Etc.					

Annex C: Example of a heating system conformity assessment form from Germany

This annex contains an English translation of the German (Berlin) heating system conformity assessment form.

Please tick where applicable ☒ or fill in! Please delete what does not apply!

Entrepreneur's declaration in accordance with Section 26a EnEV to prove the requirements of the EnEV in the event of modification of existing buildings to the Technical Building equipment

Specialist companies	
Street, house number	
Postcode, City	
Telephone, Fax, E-mail	

Builder	
Street, house number	
Postcode, City	
Telephone, Fax, E-mail	

For handover to the building authority.

Note:
The owner's declaration must be kept for at least five years and presented to the responsible building supervisory authority on request. The entrepreneur's declaration can be used as evidence of the obligations according to § 26b EnEV.

Location of the building

Street, house number	
Postcode, City	
Number of floors	

☐ Residential buildings

☐ Non-residential building Type of use / building category ____

Type of installation

☐ Heating system	☐ as central heating	☐ with single heaters	☐ WW generation integrat
☐ Hot water system	☐ as central system	☐ with individual units	
☐ Ventilation system	☐ as central system	☐ w/ single appliances	
	☐ with heat recovery	☐ w/ air conditioning	

☐ Nominal output of the heating system ____ kW
☐ Nominal output of the hot water system ____ kW
☐ Nominal output of the air conditioning system (ventilation) ____ kW_{el}

The system is operated with:

☐ Boiler	☐ Solid fuel	☐ Liquid fuel	☐ Gaseous fuel
☐ District heating	☐ Electric storage heating	☐ Heat pump	☐ Renewable energy[1]
☐ Other heat source[1]			

Scope of the work carried out

☐ **New construction** ☐ **Replacement** ☐ **Extension** ☐ **Conversion**

☐ Heater with CE mark (Section 13 paragraph 1 EnEV) Number ____
☐ District heating station
☐ Electrically operated units and appliances Number ____
☐ Heat distribution system (pipe network, heating surface)
☐ Control and regulation devices (Section 14 (1) Sentence 1 and Section 14 (2) Sentence 1 EnEV)
☐ Air-conditioning system (ventilation system)
☐ Other[1] (Explanatory Note [1])

Other parts of the system have been carried out by other companies: ☐ **yes** ☐ **no**

[1] The Reasons And Explanations Are in The Plant To Form to be added.

Please tick where applicable ☒ or fill in! Please delete what does not apply!

Declaration:

With the measures I carried out, the requirements of the Energy Saving Ordinance (EnEV) 2009 ☐ 2013 ☐ mentioned below were met. I also declare the following:

1. Heat generators

☐ The requirements of Section 13 paragraphs 1, 2 and 4 i. V.m. of Appendix 4 a EnEV are met. These are:

- ☐ Boilers for liquid/gaseous fuels with CE mark — Number
- ☐ Low-temperature boilers — Number
- ☐ Condensing boilers — Number
- ☐ Boilers for solid fuels (e.g. pellets, piece wood) — other Number
- ☐ boilers (e.g. standard boiler) — other heat Number
- ☐ generator systems: Heat pump ☐
  - ☐ Combined heat and power generation
  - ☐ Electrical storage heating
  - ☐ Other[1]

☐ These are heat generators in accordance with Section 13 (3) of the EnEV:

- ☐ Individually produced boilers
- ☐ Boilers designed to run on fuels whose properties differ significantly from market liquid or gaseous fuels
- ☐ Systems exclusively for water heating
- ☐ Kitchen stove or appliance designed mainly for heating the room in which it is installed, but which also supplies hot water for central heating and other uses
- ☐ Device with a nominal output of less than 6 kW for supplying a hot water storage system with gravity circulation

2. Thermal insulation

2.1 The pipelines are insulated against heat dissipation (§14 paragraph 5, Appendix 5EnEV)

☐ in total ☐ in part (reason [1]) ☐ no (reason [1])

2.2 ☐ The storage tank is insulated against heat dissipation (Section 14 paragraph 6 EnEV).

3. Facilities for control and Regulation

3.1 The central heating system is equipped with central, automatic-acting devices (§14 paragraph 1 EnEV)

☐ to reduce and switch off the heat supply* ☐ to switch the electric drives on and off*

* depending on ☐ the outside temperature or ☐ another reference variable (explanation[1])

☐ and the time

3.2 The heating system is equipped with automatic devices for the room-by-room control of room temperature (Section 14 (2) EnEV) ☐ yes ☐ no (reason [1])

3.3 The circulating pumps of the central heating system

☐ (Section 14 para. 3 EnEV) are dimensioned and

according to the technical rules:

☐ designed, ☐ equipped, ☐ not so designed or equipped,

that the electrical power consumption is automatically adapted to the funding requirement in at least three stages.

- ☐ The boiler capacity is less than 25 kW.
- ☐ There are safety concerns.
- ☐ Operational support requirement is constant.

3.4 A hydraulic balance of the heating system was carried out.

☐ yes ☐ no (reason [1])

[1] The reasons and explanations must be attached to the form in the annex.

Please tick where applicable ⊠ or fill in! Please delete what does not apply!

1. Hot water system

The hot water system is equipped with automatic-acting devices for switching the circulation pump on and off depending on the time (Section 14 (4) EnEV)

☐ yes ☐ no circulation pump available

2. Fulfillment of the retrofit obligation

☐ Boiler (Section 10 (1) EnEV)

☐ Thermal insulation of the pipe network (Section 10 (2), Appendix 5 EnEV)

☐ Facilities for control and regulation (Section 14 (1) sentence 2 and section 14 (2) sentence 5 EnEV)

3. Air conditioning and other indoor air technology systems (Section 15 EnEV)

3.1 General information:

☐ The air conditioning system has a nominal output for refrigeration requirements > 12 kW

☐ The air conditioning system is designed for a supply air volume flow > 4000 m³/h Renewal of central units and air duct systems

3.2 ☐ Limit of category SFP 4 according to DIN EN 13779:2007-09 is complied with or extended (§15 (1) EnEV) yes no (reason [1])

☐ Humidification and dehu☐midification (Section 15 (2) EnEV)

3.3 ☐ Self-acting control devices with separate setpoints for humidification and dehumidification (§15 (2) EnEV) yes no (reason [1])

3.4 ☐ The retrofitting obligations ☐ have been complied with (Section 15 para. 2 EnEV) yes no (reason [1])

3.5 ☐ Supply air volume flow per ☐ m² net floor area or usable building area for apartments (Section 15 (3) EnEV)

☐ < 9 m³/h

☐ > 9 m³/h

3.6 Automatic regulating devices for the volume flows (Section 15 (3) EnEV) the thermal or material loads or time

3.7 ☐ The pipes are insulated against heat absorption (Section 15 (4), ☐ Appendix 5 EnEV) in total in part (reason [1]) no

☐ (reason [1]) ☐ ☐

3.8 ☐ The system is equipped with a device for heat recovery (§ 15 (5) EnEV)

Date	Signature Specialist company

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