FINAL REPORT
Ecodesign preparatory study for Building Automation and Control Systems (BACS) implementing the Ecodesign Working Plan 2016 -2019

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Version history:
Version 1: First draft (published before the first stakeholder meeting)
Version 2 (draft final): Stakeholder comments have been processed (stakeholders will also receive their comment sheets with replies) and a version V11 with track changes will be made available.
Important changes made due to these comments:
- the functional unit definition has been reworded and updated accordingly also in Task 3
- the auxiliary power of BACS has been added to the definition of self-consumption
The table with gaps and recommendations for standards has been updated, especially standards that might be relevant for Task 7 policy considerations.
This version also contains an update of the relevant European Regulations and Directives including a review of the EPBD.
Version 3(final): This version is the final report

ISBN

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List of Abbreviations and Acronyms

AC	Alternating Current
AHU	Air handling unit
AI	Artificial Intelligence
AP	Acidification Potential
avg	Average
BAC	building automation and control
BACS	Building Automation and Control System
BAS	Building automation system
BAT	Best Available Technology
BAU	Business As Usual
B2B	Business-to-Business
BC	Base Case
BEMS	Building Energy Management System
BM	Building Management
BMS	Building Management System
BNAT	Best Not yet Available Technology
BOM	Bill of Materials
CA	Control Accuracy
CAPEX	Capital Expenditure
CEM	Customer Energy Manager
CEN	European Committee for Normalisation
CENELEC	European Committee for Electro technical Standardization
CHP	Combined Heat and Power
CO2	Carbon Dioxide
DER	Distributed Energy Resources
DHW	Domestic hot water
DR	Demand Response
ED	Ecodesign Directive
eDR BACS	Explicit Demand Response
EE	Energy Efficiency
EED	Energy Efficiency Directive
Elec	Electricity
ELR	Energy Labelling Regulation
EMS	Energy management system
EN	European Norm
EoL	End of Life
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
ErP	Energy related Products
EU	European Union
EV	Electrical Vehicle
fBAC	BAC efficiency factor (EN 15232)
FU	Functional Unit

GER	Gross Energy Requirement
GDP	Gross Domestic Product
GPP	Green Public Procurement
GWP	Global Warming Potential
HAN	Home Automation Network
HBES	Home and building electronic systems
HP	Heat Pump
HVAC	Heating Ventilation and Air Conditioning
I/F	Interface
IAQ	indoor air quality
iBACS	integrated building automation and control system
iDR BACS	Implicit Demand Response BACS
IHG	Internal Heat Gains
I/O	Input/Output
IoT	Internet of Things
IP	Internet Protocol
ISO	International Organization for Standardization
KPI	Key Performance Indicators
kWh	Kilowatt hour
kWp	kilowatt peak (power output of PV panels)
lBAC	local building controls
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LLCC	Least Life Cycle Costs
LEB	Low Energy Buildings
LED	Light emitting diode
MEErP	Methodology for Ecodesign of Energy-related Products
MFH	Multi-Family House
n.e.c.	not elsewhere classified
niBACS	non-integrated building automation and control system
NM	Not modelled
NZEB	Nearly Zero Energy Building
NPV	Net Present Value
O&M	Operation and Maintanence
OPEX	Operational Expenditure
PE	Primary energy
PEF	Primary energy factor
PID	proportional–integral–derivative controller
PRODCOM	Production Communautaire
PV	Photo-voltaic panels (solar panels)
PWM	pulse width modulation
RES	Renewable Energy Sources
SCOP	Seasonal Coefficient of Performance
SEER	Seasonal Energy Efficiency Ratio
SFH	Single Family House
SG	Smart Grid

SHW	Sanitary Hot Water
SRI	Smart Readiness Indicator
SRT	Smart Readiness Technologies
TABS	Thermo Active Building Systems
TBC	To Be Confirmed
TBD	To Be Defined
TBM	Technical building management
TBS	Technical Building System
TBW	To Be Written
TES	Thermal Energy Storage
TOR	Terms of Reference
TP	Twisted Pair
TRV	Thermostatic Radiator Valve
VA	Volt-ampere
VSD	variable speed drive
WAN	Wide Area Network
WEEE	Waste Electrical & Electronic Equipment

Executive summary

This study was done under a framework contract (ENER/C3/2015-619 LOT1) for preparatory studies on specific product groups listed in the Ecodesign Working Plans adopted under the Ecodesign Directive (2009/125/EC) and involved analysing the technical, economic, environmental, market and societal aspects of Building Automation and Control Systems (BACS) on behalf of the European Commission Directorate-General for Energy – Directorate C3: Renewables, Research and Innovation, Energy Efficiency.

According to the principle of better regulation, preparatory studies will collect evidence, explore all policy options and recommend the best policy mix, if any, to be deployed on the basis of the evidence and stakeholder input. For some of the identified product groups, there is the possibility that overlaps exist with a number of on-going preparatory studies and regulations due for review. In this context, an exploratory scoping study was undertaken to confirm that from the energy and environmental perspective, BACS offer an impressive, cost-effective potential to reduce building energy consumption through the provision of improved management of the Technical Building System (TBS).

The exploratory study recommended that this preparatory study should follow a BACS function-oriented approach with a focus on the TBS related functions for which the standard EN 15232 can serve as an appropriate starting point. The definitions of BACS functions could cover various hardware, including those that implement a single function or a set of functions, and those bundled with a TBS or sold as standalone units. The exploratory study concluded that Ecodesign product regulation could play an important role in ensuring that product information allows optimal BACS solutions to be specified.

In line with the recommendation of the exploratory study, this preparatory study follows the lifecycle methodology for Ecodesign of energy-related products (MEErP) 1 Tasks 1-7, which consists of:

Task 1 – Scope (definitions, standards and legislation);

Task 2 – Markets (volumes and prices);

Task 3 – Users (product demand side);

Task 4 – Technologies (product supply side, includes both BAT and BNAT);

Task 5 – Environment & Economics (Base case LCA & LCC);

Task 6 – Design options;

Task 7 – Scenarios (Policy, scenario, impact and sensitivity analysis).

In a multi stakeholder consultation, a number of groups and experts provided comments and input on a preliminary draft of this report. The report was then revised, benefiting from stakeholder perspectives and input. The views expressed in the report remain those of the authors, and do not necessarily reflect the views of the European Commission or the individuals and organisations that participated in the consultation. A list of stakeholders that participated in this consultation and further information on project meetings, project website2 and comments can be found in Annexes G to L.

Task 1

The Task 1 report analyses the scope, definitions, standards and assessment methods as well as other legislation of relevance to the product group and to assess their suitability for classifying and defining products for the purposes of analysing Ecodesign and Energy Label requirements. The main finding of Task 1 is that BACS and their functions are clearly defined in EN standards, as follows:

- 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, optimization, for operation, human intervention and management to achieve energy–efficient, economical and safe operation of building services. Controls herein do also refer to processing of data and information".
- BACS functions are as defined in EN 15232.

The following definition of the functional unit was adopted for this study:

The primary functional unit (FU) is 1 m² of building floor area, where the thermal comfort, sanitary hot water (SHW), indoor air quality (IAQ) and lighting requirements (per EN 16798–1:2019) – for health, productivity and comfort of the occupants – are maintained.

In line with the proposed functional unit definition, this study only considered BACS whose primary function is to control the Technical Buildings Systems (TBS) in order to maintain the indoor environmental requirements for thermal comfort, sanitary hot water (SHW), indoor air quality (IAQ) and lighting. The scope of the study did not extend to, for example, fire alarm, access, security or data network functions, as these would require the definition of additional functional units whose treatment would require complex and inconsistent multi-objective optimisations under the MEErP methodology. Nevertheless, these additional building automation functions could be considered in future studies.

Task 2

The Task 2 report presents an economic and market analysis of building automation control system (BACS) products. The key findings of Task 2 were:

- There is considerable uncertainty about the overall value of the EU27 BACS market, but the best estimate derived from reconciling many sources of information, including responses to a stakeholder survey, is €8.1bn for the year 2020 for the final installed BACS product i.e. the final price paid by consumers

- the total floor area that this is applied to is estimated to be 448 Mm2 across all residential and non-residential building types for which Table ES1 presents a summary of the estimated proxy BACS sales floor area addressed by the base cases considered in Tasks 4 to 6
- the average installation cost for consumers is estimated to be €18.1/m2
- 42.5% of the market value is estimated to be for BACS product and the remaining 57.5% for other aspects in the value chain
- an estimated 3% is due to maintenance costs
- the average energy performance of BACS already installed in EU27 buildings is between class D and class C but the most typical newly installed systems have class C energy performance
- there is considerable uncertainty about the near-term growth trends in the BACS market due to the unknown influence of the Covid 19 pandemic and other market key drivers including the influence of the amended EPBD provisions and the Renovation Wave.

Task 3

The Task 3 report presents eight reference buildings that are considered in the subsequent Tasks 4 to 6, for which a graphical overview is included in Figure 01 below. The technical details and assumptions for these reference buildings are described in the Task 3 report.

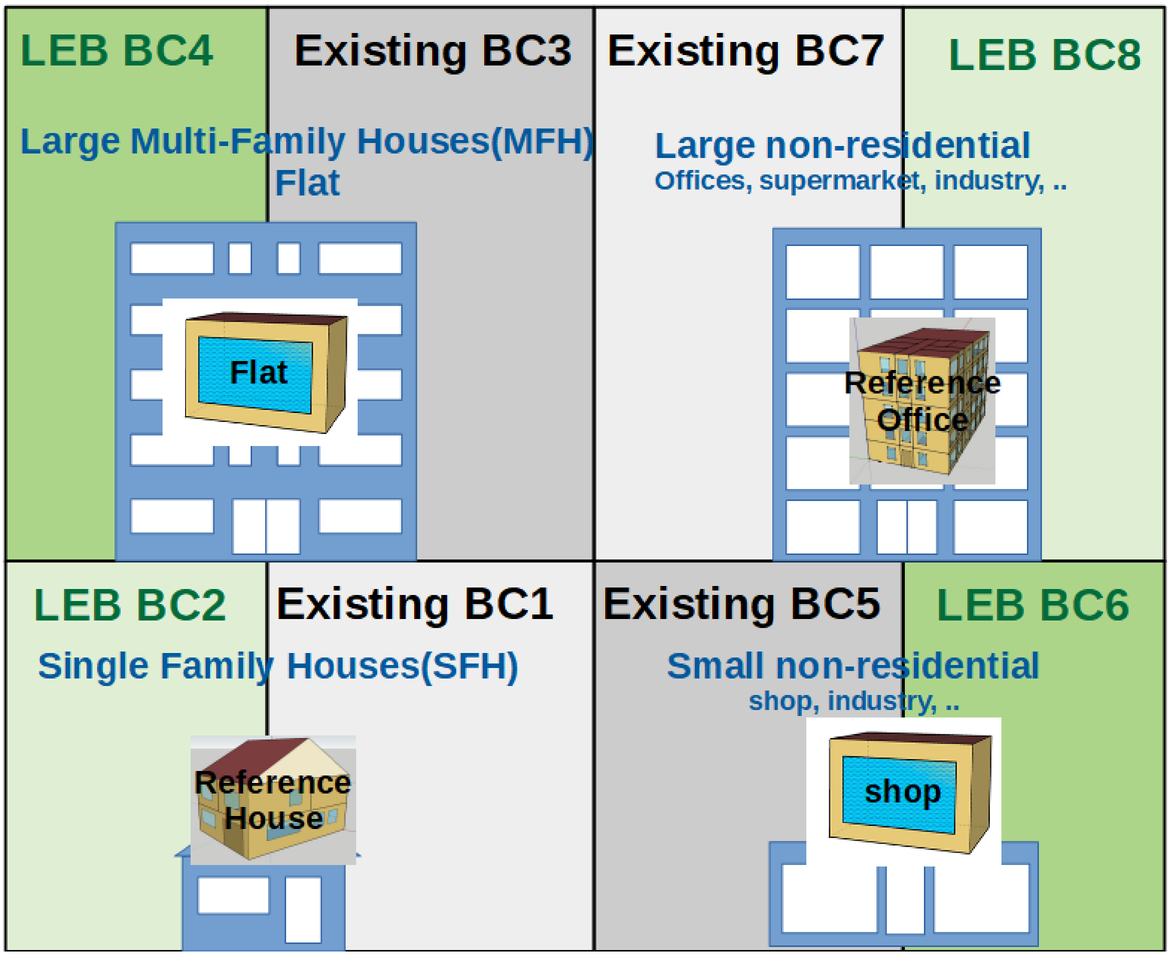

Figure 01 Overview of the eight base case reference buildings for this study

The Task 3 report also explains how indirect energy savings obtained with BACS can be calculated in line with EN 15232 with the aid of BACS efficiency factors (fBAC). It also explains the detailed method of EN 15232 used to BACS efficiency factors in Task 4 for a set of buildings and BACS functions. This calculation analyses all energy flows for heating and cooling within a building. More details on this method are given in the Task 3 report.

This task report also discusses BACS lifetime and repair from a user perspective, which are important input to analyse a least life cycle cost optimization in Task 6.

Task 4

The Task 4 report provides a technical introduction to the design process of a BACS and the energy saving methods used by EN 15232-1 to realise energy savings through BACS.

The base cases for BAC functions are defined in respect of the reference buildings and then the results of the modelling work are presented, including estimates of energy savings realised by implementing a selection of Best Available Technology (BAT) design options for different BAC functions defined in EN15232-1:2017, a Class B and a Class A BACS.

An analysis of the additional costs of implementing each BAT option instead of the Business as Usual solution is presented. The Best Not (yet) Available Technology is also discussed.

The main conclusions and recommendations of the Task 4 report are that:

- the energy saving functionality defined by EN15232-1: 2017 Class A BACS could be considered as a starting point for defining BAT for larger buildings with a total useful floor area greater than 1,000 square metres; however, not all of the BAC functions are applicable to all types of buildings and TBS, and some additional BAC functions not in EN15232-1 may merit inclusion in BAT.

- for smaller buildings with a total useful floor area less than 250 square metres; the energy saving functionality defined for a Class B BACS could be considered as a starting point for defining BAT particularly in residential buildings, but that consideration should be given to adding some Class A BAC functions.

The study team found that it was difficult to cost some of the BAT design options, due to a lack of detailed case studies on the costs and benefits of Class A and Class B BACS solutions in buildings, particularly in individual family homes and smaller non-residential buildings. It also appears that the EN15232-1 Class of the BACS solutions fitted to most buildings is not known or not reported and that the solutions presented in case studies did not represent full implementations of either Class A and Class B BACS solutions. This lack of awareness of the EN15232-1 BACS Classifications is a major market failure.

In considering what minimum functionality should be required for BACS, it is likely that different specifications will be needed for new and existing buildings, for residential and non-residential buildings, and for different sizes of building (e.g. small and large).

As improved control accuracy is one of the keys to maximizing energy savings delivered by BACS, the study team recommended that further research should be undertaken into the merits of introducing minimum accuracy requirements for the sensors, controllers and actuators that are placed on the EU market for application in BACS products or systems.

Task 5

The Task 5 report presents an environmental and economic assessment of the Base-Cases identified in Task 4 using the Ecoreport tool (VHK, 2014), which calculates life cycle costs and 14 environmental impact indicators including global warming potential (CO2eq).

This task builds on the BACS Base Cases, which represent eight different reference buildings (from Task 3) equipped with typical BACS (from Task 4). The Task 5 report uses the three different BACS factors (fBAC,th, H, fBAC,th, C, fBAC,el) reported in Task 4 for the eight reference buildings equipped with typical BACS to individually model the energy impact of BACS on different sources of final energy demand (gas, electricity, etc.). These impacts are converted into a set of MEErP impact indicators (14 in total) using the Ecoreport tool.

These 14 impact indicators also include the Gross Energy Requirement (GER) [MJ], which is the LCA equivalent of Primary Energy (PE). Consequently, this aligns with the Energy Performance of Buildings Directive (EPBD) that requires the energy performance of a building to be expressed by a numeric indicator of primary energy use in $kWh/m^2/y$ for the purpose of both energy performance certification (EPCs) and compliance with minimum energy performance requirements. The approach followed in the Task 3 Report is first to calculate the impact from the use phase of 1 kWh per year of energy with the Ecoreport tool over the BACS product lifetime, typically 15 years. Afterwards considering the energy demand per Base Case in $kWh/m^2/y$ they are scaled-up for each Base Case.

The report's main conclusion is that the potential environmental impact from BACS is large.

Task 6

Task 6 calculates the Least Life Cycle Cost (LLCC) for the improved functionality options identified in Task 4 for BACS fitted to the reference buildings. The main conclusions are:

- all Task 4 BAT BACS options proposed for existing renovated well-insulated buildings were assessed to be Least Life Cycle Cost (LLCC) solutions.
- the existing reference buildings defined in Task 3 already assumed relatively high insulation levels and therefore correspond to well renovated buildings.
- for new LEB not all BAT BACS options correspond to the LLCC or have a pay back period of <15 years, since they have have a very low energy demand.
- that the number of distinct control zones within the building also contribute to the performance and cost of BACS and there is an economic optimum level. The importance of zoning was also pointed out in the Lot 37 lighting system study.
- if existing buildings were renovated more deeply and attain air-tightness and insulation levels closer to the new high LEB levels then the cost-effectiveness of the BAT options would decline relatively to a less well insulated building.
- the study did not identify any significant negative impacts due to the additional hardware, or increased auxiliary energy use, for the proposed improvements.

Task 7

Task 7 considers prospective EU Ecodesign and energy labelling policy options which are intended to save energy and serve other environmental objectives such as those related to the circular economy. It also seeks to provide an understanding of the impacts of a set of these measures through the development of future scenarios in line with policy measures that could be introduced at EU-level. As inputs it draws upon the results of all previous tasks to derive estimates of the impacts of different Ecodesign policy measures and design options, and thereby is aimed at providing an analytical basis in support of the Ecodesign decision-making process. A set of quantitative scenarios are provided of the market penetration levels of various BACS technologies and the consequences for the environment, users and industry.

To support this assessment of policy scenario impacts a stock model was developed to estimate future sales and stocks of BACS under different policy scenarios. The outcomes of the various policy scenarios are then compared with a Business-as-Usual scenario to determine energy savings and other environmental, economic and social impacts. In addition, a limited sensitivity analysis is presented which examines how findings might depend upon key working assumptions.

A key point to consider for Ecodesign BACS policies is the interrelationship with the EPBD – Articles 8, 14 & 15 and the smart readiness index (SRI) – and the extent to which Ecodesign measures can help to empower the EPBD measures – thus understanding the product/system interface and how it overlays with these existing policies is important. The impact of the recently amended EPBD was taken into account in the Business as Usual scenario, thus all policy measures proposed in this report are intended to address barriers and market failures for BACS that the EPBD has not yet addressed (these are elaborated in the main report).

Ecodesign policy measures may be classified into those which set specific requirements and those which set generic requirements. In addition, an important distinction is whether the prospective policy measures would apply to products when placed on the market (applicable to so called "installed BACS" or when put into service (applicable to BAC products and components). For BACS this distinction matters because many of the largest energy savings potentials apply to configurations of BACS products (i.e. installed BACS) when they are put into service yet these tend to be more challenging to implement than measures which apply when products are placed on the market. Accordingly, prospective policy measures of both types are proposed, while the rationale and pros and cons of each are explored.

A large number of prospective policy measures are put forward, as reflects the diversity and opportunity of BACS and their constituent products and the nature of market barriers and/or failures which currently result in sub-optimal choices being common from a sustainability and economic perspective. A full listing of these prospective measures, each of which is explained in full in the main report, is as follows.

Prospective Ecodesign measures for products placed on the market:

- Specific minimum performance limits for packaged products:
  - Accuracy
  - Internal power consumption
- Specific minimum functionality requirements for packaged products:
  - Controllability of room temperature schedulers
  - BACS measuring and reporting of KPIs by packaged building energy management systems
  - Demonstrate EN 15232 class B or A compatibility with an EU27 benchmark building
  - Lifetime, material content and repair at packaged product level
  - Interoperability
  - Minimum functionality requirements for TBS-related products with BAC functionality that claim Smart Grid capability
  - Minimum requirements for room thermostats/ room temperature controllers to be declared smart grid ready
- Generic BACS information requirements for packaged products:
  - Information on accuracy
  - Compatibility with BACS systems based on their energy performance class
  - Internal power consumption
  - Interoperability
  - Lifetime, material content and related information for installers of BACS.

Prospective Ecodesign measures for products put into service:

- Specific requirements for products put into service (installed products):
  - Specific BACS energy performance limits (C, B or A) for installed products
  - Specific BACS internal power consumption limits for installed products
  - Specific BACS minimum functionality requirements for installed products
  - Specific BACS minimum functionality requirements for installed products: BACS measuring and reporting of KPIs at installed product level
  - Specific BACS minimum functionality requirements for installed products: Lifetime at installed product level
  - Specific BACS minimum functionality requirements for installed products: Interoperability

- Generic BACS information requirements for products put into service:
    - Generic BACS information requirements for installed products: Information on energy performance
    - Generic BACS information requirements for installed products: Information on demand response (DR)
    - Generic BACS information requirements for installed products: Information on interoperability and other factors
    - Generic BACS information requirements for installed products: Providing a design configuration file needed for fine tuning and further updates

In addition, prospective policy proposals were also elaborated for:

- Updating the energy label for space heaters, water heaters and solid fuel boilers
- Labelling of the BACS energy performance at the installed product level.

To assess impacts the following set of policy scenarios were examined:

- BAU scenario: this scenario reflects the expected developments were there to be no new policy measures adopted beyond those that have already been adopted (e.g. under the EPBD and Ecodesign and labelling requirements for specific product types used in technical building systems)
- Accuracy gain of 0.5°C: as the BAU except that the control accuracy of room temperature controllers improves by 0.5°C from the year 2024 onward
- Accuracy gain of 1.0°C: as the BAU except that the control accuracy of room temperature controllers improves by 1.0°C from the year 2024 onward
- Class C: as the BAU except from the year 2024, all new installed BACS must attain at least an energy performance of class C
- Class B: as the BAU except from the year 2024, all new installed BACS must attain at least an energy performance of class B
- Class A: as the BAU except from the year 2024, all new installed BACS must attain at least an energy performance of class A
- Declaration of BACS class: as the BAU except from the year 2024, all new installed BACS must have their energy performance class declared.

Even though the BAU scenario already assumes significant improvement in TBS energy performance due to the transposition of the BACS related policy measures in the revised EPBD into Member State building energy performance legislation, the results of the impact assessment for these scenarios show that significant additional savings can be attained. The class C installed BACS scenario has the lowest impact but even this (which in many regards is a backstop measure to the EPBD provisions) is projected to result in annual final energy consumption savings of 25 TWh final energy by 2040. In order of increasing magnitude, the annual final energy savings due to the other policy measure scenarios in 2040 are:

- 42 TWh (Declaration of BACS class scenario)
- 66 TWh (Accuracy gain of 0.5°C scenario)
- 108 TWh (Accuracy gain of 1.0°C scenario)
- 181 TWh (Class B scenario)
- 267 TWh (Class A scenario).

These are very substantial savings potential compared to most other product groups considered for Ecodesign policy measures but three of these scenarios concern policy measures applicable to product put into service (Declaration of BACS class, Class B and Class A scenarios) and two (Accuracy gain of 0.5°C and the Accuracy gain of 1.0°C scenarios) are applicable to product when placed on the market. Policy scenario impacts on CO2 emissions, product prices, investment costs, energy bills, business revenues and employment are also examined and found to be highly favourable with the greater benefits generally associated with the policy packages that produce the larger energy savings.

0 General introduction to the study

Building Automation and Control Systems (BACS) are defined in European and International standards as "comprising all products and engineering services for automatic controls (including interlocks), monitoring, optimization, for operation, human intervention and management to achieve energy–efficient, economical and safe operation of building services". The term "controls" also refers to "processing of data and information". In practice, BACS present a wide range of services related to systems that provide Heating Ventilation Air Conditioning (HVAC), domestic hot water (DHW), lighting, electrical power distribution, metering, technical building management, systems for communications, access control, security, fire safety, etc. Hence, BACS cover a wide range of heterogeneous product types.

This study fits within the Ecodesign Working plan 2016-2019 of the European Commission (EC)[1] that identified BACS as potential candidates for future Implementing Measures within the Ecodesign Directive or the Energy Labelling Regulation and an exploratory study that was carried out to regroup or narrow the product scope and to identify the focus areas and directions of this full preparatory study. This exploratory scoping report can be found on the project website[2] and is recommended reading as an introduction and background for this study. The full preparatory study was based on the feedback of that report.

The exploratory scoping study reconfirmed that from the energy and environmental perspective, BACS offer an impressive, cost-effective potential to reduce building energy consumption through the provision of improved management of the Technical Building System (TBS). The study looked at different types of building applications on which the full study could focus, for example: renovated versus new, residential versus non-residential, large versus small, etc. One finding was that BACS have an important role to play in delivering the low energy consumption of newly constructed Nearly Zero Energy Buildings (NZEB). The exploratory study recommended that this study follow a BACS function oriented approach with the focus on the TBS related functions, for which EN 15232 standard can serve as an appropriate starting point. Hence, the definition according to BACS functions could cover various hardware, including: those that implement a single function or a set of functions, including those bundled with a TBS or sold as standalone units. This function-oriented approach should therefore provide a level playing field for all types of BACS products.

The exploratory study concluded that Ecodesign product regulation can play an important role in ensuring that product information allows optimal BACS solutions to be specified. Therefore, a key need for the full BACS preparatory study is to define standardized informational needs that can be mandated via Ecodesign and/or energy labelling measures. It is noted that following the EN 15232 standard and the related set of Energy Performance of Buildings Directive (EPBD) standards[3], that setting information requirements on BACS products, would facilitate the inclusion of BACS within the calculation of building energy performance certificates (EPC). Similarly, this standardized

[1] http://ec.europa.eu/growth/industry/sustainability/ecodesign_en

[2] https://ecodesignbacs.eu/documents

[3] https://epb.center/support/epbd

BACS product information could simplify the work required to calculate, for example, the Smart Readiness Indicator (SRI) for a building[4] or could generally facilitate new applications to support consumers specifying BACS requirements and verify commissioning

For some specific BACS functions the exploratory scoping study also recommended the consideration of Ecodesign limits on accuracy and/or minimum functionality levels. The scoping study identified 24 BACS functions, that could be suitable for minimum level of functionality specifications under Ecodesign regulations. It also identified 13 BACS functions for which there are likely to be significant energy savings opportunities from Ecodesign limits on accuracy. Examples of product groups providing these services are: electronic radiator valves and room temperature controllers; room/zone temperature controls for different emission equipment, or to avoid concurrent heating and cooling emission; air dampers combined with CO_2 or occupancy sensors, etc. This study builds on these findings and in some cases narrows down the set of preselected functions it considers for detailed investigation. Similarly, as for other products the scoping study concluded that minimum lifetime, upgradability and reparability requirements could be evaluated for BACS. According to the scoping study, Ecodesign requirements (i.e. information requirements and/or energy efficiency requirements) on BACS' self-consumption could also be proposed. Furthermore, as the degree of interoperability of BACS can be a limiting factor affecting the functionality level of the TBSs that they manage it was therefore recommended that the full study should examine at these aspects.

In order to have an Energy label for BACS there is a need for an Energy Efficiency Index (EEI), expressed in units of kWh/m²/y or a corresponding factor relative to a benchmark. The study recognized the complexity of estimating the energy impacts of BACS that arises from the many components that influence the building energy balance in combination with a broad range of possible building technical properties, climate conditions and usage patterns. Therefore, the study launched a new notion which is an on-line Energy Efficiency Index or a 'smart BACS energy saving calculator' that can build on the product level information and user specific inputs. The aim of this study is not to develop such a calculator but it could form the basis of subsequent work to be carried out in the case such policy comes into place.

According to the terms of reference, this full preparatory study should focus on and therefore conduct all MEErP Tasks 1 to 7 by:

- following a BACS-function oriented approach with the focus on the Technical Building System (TBS) related functions using the EN 15232 standard as a starting point. The study should propose Ecodesign requirements on accuracy and functionality for the identified functions by applying the MEErP methodology for a number of reference buildings
- defining standardized informational needs through Ecodesign and/or energy labelling measures in accordance with the EN 15232 and the related set of Energy Performance of Buildings Directive standards. These requirements are expected to support consumers in energy management and system dimensioning, and to facilitate the calculation of the energy performance certificates (EPC) and the Smart Readiness Indicator (SRI).

[4] https://smartreadinessindicator.eu/

In addition, in the case of the MEErP Tasks 1 (Definitions), 4 (Technology) and 7 (policy options), this study should also:

- assess the capability and appropriateness of the existing standards to facilitate interoperability among BACS functions, and, to the extent possible, assess handling demand response flexibility; the study should also look into/link to existing relevant studies (i.e. smart appliances)
- define Ecodesign requirements (including information requirements) with regard to interoperability aspects, to the extent possible. Potential missing elements/standardization gaps that could prevent the formulation of such requirements should be clearly identified and solutions for addressing them should be proposed
- assess requirements for durability, reparability and upgradability by examining *inter alia* the availability of spare parts and repair/maintenance information for end-users and professional repairers, the availability of software/firmware updates and the possibility for BACS solutions to support new functionalities
- define Ecodesign/ energy labelling requirements for information on, or limits to, self-consumption of BACS for components that are common to most BACS, or an energy consumption budget per BACS function and its functionality level
- align with other product groups that already have or might have BACS functions in their Ecodesign or energy labelling requirements, such as the ongoing review of the Ecodesign and energy labelling requirements for space heaters and water heaters.

Finally, this study should:

- include proposals for the definition of relevant terms and methods for the assessment of compliance with potential requirements by Member State market surveillance authorities.

This study will follow, as much as possible, the lifecycle Methodology for the Ecodesign of Energy related products (MEErP)[5], which consists of:

Task 1 – Scope (definitions, standards and legislation);

Task 2 – Markets (volumes and prices);

Task 3 – Users (product demand side);

Task 4 – Technologies (product supply side, includes both BAT and BNAT);

Task 5 – Environment & Economics (Base case LCA & LCC);

Task 6 – Design options;

Task 7 – Scenarios (Policy, scenario, impact and sensitivity analysis).

Tasks 1 to 4 can be performed in parallel, whereas 5, 6 and 7 are sequential.

The MEErP structure makes a clear split between:

- Tasks 1 to 4 (product definitions, standards and legislation; economic and market analysis; consumer behaviour and local infrastructure; technical analysis) that have a clear focus on data retrieval and initial analysis;

[5] https://ec.europa.eu/growth/industry/sustainability/product-policy-and-ecodesign_en

- Tasks 5 (assessment of base case), 6 (improvement potential) and 7 (policy, scenario, impact and sensitivity analysis) with a clear focus on modelling.

Considering the limited time, data availability and resources versus the large array of potential BACS solutions and configurations it is necessary to prioritise and identify the most important cases to model in Tasks 4/5/6. Therefore the views of stakeholders were sought to assist in the identification of the cases to model to define a limited number of specific reference designs[6] with two improvement scenarios each. Therefore the following approach was agreed at the kick-off meeting:

- the broad range of building typologies and climate zones to represent the overall EU needs to be narrowed down to a feasible set that is manageable for the work to be conducted in the subsequent Tasks 4-6 of this study
- to consider the influence of 3 climates, specifically by using the three climate zones specified in the MEErP i.e. as they were used in the air conditioning study
- to give special attention to the modelling of functions where there high energy savings are expected and a minimum threshold may be proposed including investigation of potential negative impacts on cost
- the study will use a small set of reference buildings including both residential and non-residential buildings which can be used as base cases (BC) in the assessment of the level of energy savings that can be obtained by installing a BACS system, including for both new build and retrofit cases.
- the detailed modelling and analytical work in Task 4/6 will be focused on a selection of up to 16 cases that best demonstrate the energy savings that can be realised through the deployment of BACS.
- because the cost/benefit model in Task 5 and 6 is simplified, a set of Task 3-4 parameters (location, cost, etc.) will be selected for a sensitivity analysis, to verify the range of impacts from any minimum thresholds proposed in Task 6 and/or 7.

Note, that this reduced set of cases subject to analysis within Tasks 4-6 should not limit the scope and nature of policy measures to be proposed in Task 7. If necessary, a larger set of cases could always be subjected to a more simplified cost/benefit analysis in any subsequent regulatory impact assessment.

[6] A reference design means a specific building with a defined climate, user profile and technical characteristics which is used to assess a single BACS function

1 MEErP Task 1 report on Scope

1.1 Aim of Task 1

The aim of Task 1 is to analyse the scope, definitions, standards and assessment methods as well as other legislation of relevance to the product group and to assess their suitability for classifying and defining products for the purposes of analysing Ecodesign and Energy Label requirements.

1.2 Summary of Task 1

BACS and their functions are clearly defined in EN standards.

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, optimization, for operation, human intervention and management to achieve energy–efficient, economical and safe operation of building services. Controls herein do also refer to processing of data and information".

As explained in the introduction and in alignment with the recommendation of the preceding exploratory study, the proposed scope of this study is the BACS functions. BACS functions are defined in EN 15232 and they are investigated in more depth in Tasks 2 to 6.

Accordingly, this task proposes the following definition of the functional unit (see section 1.4):

> *the primary functional unit (FU) is 1 m² of building floor area, where the thermal comfort, sanitary hot water (SHW), indoor air quality (IAQ) and lighting requirements (per EN 16798–1:2019) – for health, productivity and comfort of the occupants – are maintained.*

This definition of the functional unit plays an important role in the subsequent Task reports and allows the investigation of the best available BACS which minimise the environmental impact due to the building energy demand while maintaining indoor comfort.

It was also concluded that the PRODCOM data is too generic to be useful for ED/ELR purposes for BACS and is mixed up with a large range of products and PRODCOM codes that serve other non-BACS functions. In order to be useful Eurostat codes would need to be reviewed and specific sub categories added to address BACS.

In principle, the main finding is that the BACS scope can be defined clearly based on existing standards, nevertheless this task includes a list of standards which might need to be updated when considering policy options in Task 7.

BACS self-consumption or internal power consumption is a part of the auxiliary power consumption as defined in the EPBD standard EN ISO 52000-1.

In line with the proposed functional unit definition the proposed scope of this study is on BACS whose primary function is to control the Technical Buildings Systems (TBS) in order to maintain the indoor environmental requirements for thermal comfort, sanitary hot water (SHW), indoor air quality (IAQ) and lighting according to EN 16798–1:2019.

It is not recommended to consider a much broader scope than the one proposed for the functional unit, for example to extend it to include fire alarm, access, security or data network functions. This is because each of these have another functional unit whose treatment would lead to the need to conduct complex and inconsistent multi-objective optimisations. As a consequence Tasks 4 to 6 would not easily fit within the MEErP. Nevertheless, these additional building automation functions could be considered in future studies. With regard to demand response the study still found many uncertainties in the policy framework and business cases that will complicate European wide BACS product requirements, mainly due to:

- the highly variable end use electricity price components for energy, network cost and levies within the EU27. This in particular in combination with the different time frames used for billing those price components
- different requirements on the minimum time frame to meter the self-consumption within the EU27

in practice, there is not yet a strong dynamic incentive to use BACS with demand response to increase the real time (hourly) renewable electricity from the grid. Achieving this would require refinement of the existing EECS (European Energy Certificate System) for the European Guarantees of Origin (GOs), for example shifting to hourly trading instead of yearly.

1.3 Definitions used to scope this BACS study

1.3.1 Objective

According to the MEErP approach the classification and definition of the products within this Task should be based, primarily, on the following categorisations:

- the product categories used in Eurostat’s Prodcom database;
- product categories defined within EN- or ISO-standard(s);
- other ‘product’-specific categories (e.g. labelling, sector-specific categories), if not defined by the above.

In principle, Prodcom should be the first basis for defining the product categorisation, since Prodcom allows for precise and reliable calculation of trade and sales volumes (Task 2). However, for BACS this is not evident as the BACS definitions concern functions that do not correspond to (i.e. map to) the product categories defined by Eurostat. Nevertheless in Task 2 we look at building statistics (permits, floor area) from Eurostat and other data sources.

The product categorisations set out above are a starting point for classifying and defining the products and can be completed or refined using other relevant criteria that address the functionality of the product, its environmental characteristics and the intended end use application (e.g. room temperature control, aquarium temperature control, oven temperature control, ..) . In particular, it is noted that the classification and definition of the products should be linked to the assessment of the primary product performance parameter (the "functional unit") that is defined in section 1.4. If necessary, a further segmentation can be applied on the basis of the secondary product performance parameters, defined in section 1.5. In that case, the segmentation would be based on functional performance characteristics and not on technology.

Where relevant, a description of the energy systems affected by the energy-related products are included, as this may influence the definition of the proposed product scope.

1.3.2 General definitions and an introduction

BACS is a term that addresses a wide variety of hardware and functions so it is important for it to be properly defined for this study to have a clear scope. A number of European and international standards address BACS (see section 1.6 for details) and many of these are alluded to in the following text.

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, optimization, for operation, human intervention and management to achieve energy–efficient, economical and safe operation of building services. Controls herein do also refer to processing of data and information". As a consequence, BACS cover a wide range of heterogeneous products.

For scoping purposes, it helps to categorise BACS in terms of their capabilities. Figure 1-1 illustrates the different levels of energy-related BACS hardware that can be identified within the context of European energy policy and which are explored in the remainder of this task. It also indicates the **BACS functions** that have an energy impact as defined within the standard **EN 15232** (see section 1.3.3). The various definitions used within the figure are explained in the subsequent sections.

The **lowest level in the figure shows the hardware components of the technical buildings systems** (e.g. heat pumps, boilers, water heaters, air conditioners, lighting etc.) **or appliances** that provide various technical building services. These do not comprise a distinct BACS hardware level according to ISO 16484-2 (see below), because they are primarily designed to provide a non-BACS specific service, but they may incorporate such a level and/or interface to the general BACS hardware levels and hence have been included within the figure.

The three general **BACS hardware levels** defined in ISO 16484-2 which apply to BACS products are shown in the middle and top layers in Figure 1-1.

The **lowest level** is the **BACS hardware at the field level** (the second from bottom level in the figure) which is the interface that consists of gateways, inputs, outputs, sensors and actuators.

Above this is the **Building Automation Controls** (**BAC) hardware at the building automation level** or intermediate level, wherein most of the control tasks and functions are implemented.

The highest overarching level is the **BACS at the building management level**, which contains high level control functions and also the user interface. This top level shows the energy-related **BACS functions** that have an energy management impact. Products operating at this level may have an interface with the lower levels or can be bundled to incorporate parts of the full potential array of **BACS functionality**.

For this full set of BACS hardware, several BACS functions (see EN 15232 for definitions of these in the case of energy-related functions) can be identified. These are represented by vertical columns in Figure 1-1 and may overlay several BACS hardware levels.

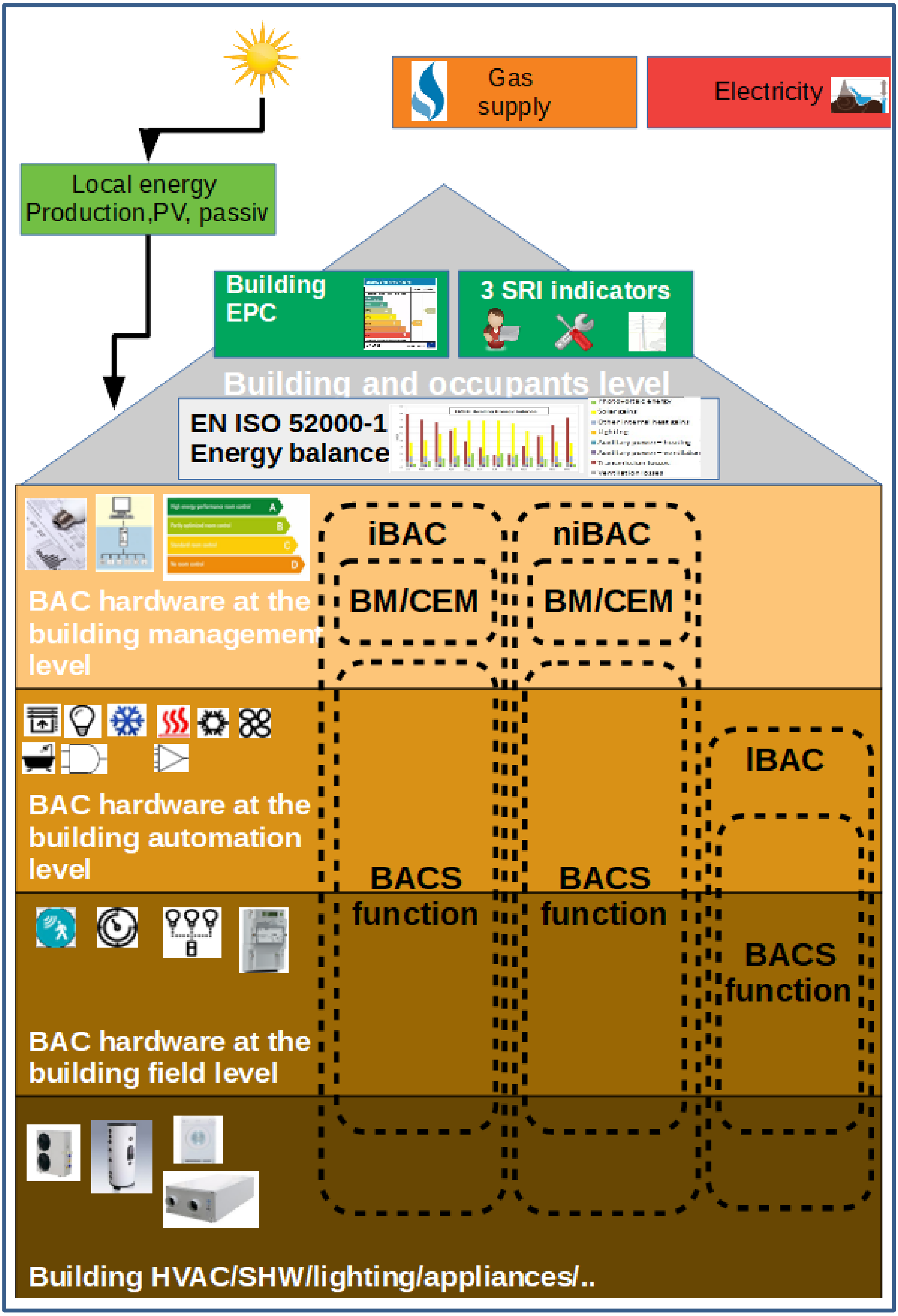

Figure 1-1: BACS functions and different hardware levels in which it can be implemented

The terminology and definitions that apply to the main BACS elements are as follows:

BACS, which according to EN ISO 16484-2 refers to "Building Automation and Control Systems comprising all products and engineering services for automatic controls (including interlocks), monitoring, optimization, for operation, human intervention and management to achieve energy–efficient, economical and safe operation of building services. Controls herein do not only refer to control but also to processing of data and information".

BAC according to EN 15232 refers to building automation controls that are "products, software, and engineering services for automatic controls, monitoring and optimization, human intervention, and management to achieve energy-efficient, economical, and safe operation of building services equipment".

Integrated BACS (iBACS), according to EN 15232 refers to "BACS designed to be interoperable and with the ability to be connected to one or more specified 3rd party building automation and control devices/systems through open data communication network or interfaces performed by standardized methods, special services and permitted responsibilities for system integration".

Examples of integrated BACS are systems providing interoperability between 3rd party BACS devices/systems for HVAC, domestic hot water, lighting, electrical power distribution, energy metering, technical building management, elevators and escalators, and other plant, as well as systems for communications, access control, security, safety etc. Within this context, in particular, building management (BM) means the totality of services involved in the management operation and monitoring of buildings including plant and installations.

In contrast, **non-integrated BACS (niBACS)** are simply all others which are not iBACS.

Technical Buildings Systems (TBS), such as HVAC products, **can be bundled with BACS functions**. These are BACS functions that are implemented in a bundle with (i.e. incorporated within) a Technical Building System product; for example, a gas boiler which includes a smart thermostat. This subcategory of 'TBS products bundled with BACS functions' can be a useful distinction to denominate products that are covered by existing policy applicable to the TBS product itself.

1.3.3 The BACS scope defined according to the EN 15232 energy control functions

The standard EN 15232 defines a **BAC function** as "the BAC effect of programs and parameters. BAC functions are referred to as control functions, I/O (input/output), processing, optimization, management and operator functions".

This technical definition of a "BAC control function" is quite abstract and can be better understood with an example such as a room thermostat that implements the "heat emission control" function from EN 15232, i.e. function 1.1. Herein the "input" can be a temperature sensor signal that controls an "output" which is typically a 24 Volt or 230 Volt AC operated valve. The "control function" or "BAC effect of a program" should be to open or close the valve or "output" to fit to the local room temperature or "input". Herein the local temperature is the most important control "parameter" together with the desired room temperature which is also called the room temperature "set point". Other relevant "parameters" are control accuracy (+/- 0.2 °C) and for example the set points for on/off control, PID (proportional, integral, derivative) controller[7] parameters (P-value [%], I-value [t], D-value [t], temperature set point [°C], actual temperature [°C]). Complex BACS functions may have many more parameters, e.g. in the case of artificial intelligence control function parameters to model weather and user behaviour[8].

Hereafter is a listing of all control functions that are included in EN 15232. Note that this standard was developed in the context of the EPBD[9] and therefore, only targets functions that are energy-related and connected to the technical building system (TBS). This excludes some functions which are not related to the TBS such as those that concern home appliances (refrigerators ovens, washing machines, etc.).

For heating control, typical BACS control functions are:

- "emission control", e.g. individual room temperature control with BACS including schedulers and presence detection which can lower the general heat demand
- "control of distribution pumps in networks", e.g. switching off circulation pumps when not required or modulating the flow to meet the system needs
- "heat generator control for combustion and district heating", e.g. the heat generator set point is variable depending on the outdoor temperature to minimize generation losses which occur when the boiler temperature is higher.
- "heat generator control for heat pump", e.g. controlling the exit temperature based on load forecasting
- "heat pump control system", e.g. inverter driven variable frequency compressor depending on the load
- other functions are "sequencing of different heat generators", "Thermal Energy Storage (TES)" or "control of Thermally Activated Building Systems (TABS)".

For domestic hot water (DHW) supply:

- reduce standby losses in hot water storage tank (if any) with automatic on/off control based on forecasted demand
- control of DHW pump (if any).

For cooling control:

- many of those functions are similar to heating (see EN 15232)
- "interlock between heating and cooling" to avoid simultaneous heating and cooling.

For air supply or ventilation (if any):

- demand driven variable outside air supply
- heat recovery unit, icing protection

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[7] https://www.eurotherm.com/pid-control-made-easy

[8] https://www.techemergence.com/artificial-intelligence-plus-the-internet-of-things-iot-3-examples-worth-learning-from/

- “free cooling” at night time by automatic mechanical opening of windows and/or operating the ventilation unit to let in cooler air
- humidity controls (if any).

For lighting controls:

- control of the use of artificial lighting, e.g. based on presence detection and/or monitoring indoor luminosity by natural light
- Indirect effects wherein reducing the lighting energy demand by proper control can decrease the building cooling demand or increase the heating demand.

For blind control (if any):

- prevention of overheating
- reduction of glare
- controls can be combined with HVAC and lighting.

For the ‘Technical Building Management’ (TBM) function group[10]

- set point management, e.g. web interface to heating/cooling temperature set points (20°C/26°C) with frequent resetting to default values where relevant
- run time management, e.g. predefined schedule (e.g. a night time set back temperature) with variable preconditions (e.g. no presence in the room)
- manage local renewable sources or CHP (Combined Heat and Power plants) to optimize own consumption and use of renewables
- control of Thermal Energy Storage of heat recovery (if available)
- smart grid integration
- detect faults in the Technical Building System (TBS), for example:
    - read out alarms (error codes) from the TBS (e.g. heat pump, gas boiler, etc.) and provision of comprehensible feedback to occupants and alarm (error codes) logging
    - continuous monitoring of SCOP (Seasonal Coefficient of Performance) or SEER (Seasonal Energy Efficiency Ratio) of a heat pump to verify maintenance needs (e.g. clogged heat exchanger, cooling fluid leakage, etc.)
    - regular checking to verify the maximum power output of a heat pump or gas boiler to establish maintenance needs (e.g. contaminated gas burner, dirt on heat exchanger, valve errors, damage on pipe insulation, installation errors such as reverse connection of heat exchangers, correct control logic and set point of circulation pumps, etc.)

[10] These are always integrated BAC functions which according to EN 15232-1:2017 refers to: “the effect of programs, shared data points and parameters for multi-disciplinary interrelationships between various building services and technologies”. The Technical Building Management (TBM) functions are only described briefly in EN 15232 but it references a more detailed definition in the standard EN 16947 standard on “Energy Performance of Buildings” – see the main body of text.

  - checking the power consumption of an Air Handling Unit (e.g. increased power consumption due to clogged filter or air inlet/outlet, leakages in or clogged ventilation duct work, broken air dampers/fans, etc.).
- Reporting energy consumption relative to indoor conditions:
  - displaying the current values and logged trends
  - calculation of performance parameters, e.g. it is possible to format data according to EN ISO 52003-1 & -2 that describes possible EPBD Indicators and therefore allows to track performance and eventually report any performance gaps. Therefore, it could help to identify problems in the construction and commissioning of the building and its TBSs.

Note, that this BACS monitoring reporting feature could reveal design faults and/or help to increase the accuracy of building energy performance calculations (e.g. expressed in units of kWh/(m².y)). As a consequence, data collection and analysis can help to decrease the performance gap between the calculated Energy Performance Certificate (EPC) and the measured energy expenditure, which has been reported in many case studies[11],[12].

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 often also describe more detailed control functions. For example, EN 15193 for lighting (see Annex A or the Lot 37 study).

1.3.4 The BACS energy performance classes of EN 15232

The EN 15232 standard defines[13] BACS energy performance classes that range from D (less efficient) to A (more efficient) and that are an expression of the degree of sophistication that the BACS functionality provides. An example are the specifications for heat generation and heat pumps shown in Figure 1-2 wherein the shaded areas indicate the extent to which the described functionality attains the higher energy performance classes.

These BACS classes can be applied in the simplified BACS factor methodology (method 1) to derive estimated whole building energy impacts from the use of BACS with different energy performance functionalities.

[11] http://built2spec-project.eu/knowledge-center/
[12] https://www.ecn.nl/publicaties/PdfFetch.aspx?nr=ECN-E--16-056
[13] http://built2spec-project.eu/knowledge-center/

			Definition of classes			
			Non residential			
			D	C	B	A
1.6	Heat generator control (combustion and district heating)					
	0	Constant temperature control	■			
	1	Variable temperature control depending on outdoor temperature	■	■		
	2	Variable temperature control depending on the load	■	■	■	■
1.7	Heat generator control (heat pump, outdoor unit)					
	0	On/Off-control of heat generator	■			
	1	Multi-stage control of heat generator capacity depending on the load or demand (e.g. on/off of several compressors)	■	■	■	
	2	Variable control of heat generator capacity depending on the load or demand (e.g. hot gas bypass, inverter frequency control)	■	■	■	■

Figure 1-2: Requirements for heat generation and BACS classes according to EN 15232-1:2017

1.3.5 Other BACS functions not related to the EN 15232 functions

BACS can also serve other functionalities than those related to EN 15232 energy management functions. For example, Home and Building Electronic Systems[14](HBES) is a very broad and generic umbrella that can include BACS components but also many other home electronic components not related to EN 15232 BACS functions. Their work also addresses standardisation for the communication systems used by BACS (for example, the EN 50090 series which are a set of KNX[15] standards). Note, that not all HBES are necessarily BACS based on EN 15232. For example, HBES may also include intercom door openers, multi-room audio, etc. and thus do not necessarily concern energy-related functions. Therefore, HBES extend beyond the scope of a potential BACS Ecodesign study and reference to these is only kept as a source of information in this report. Nevertheless, some of the standardization work of BACS technology components, such as a communication system, is defined within CENELEC TC 205.

EN 15232 defines BACS EPBD functions that mainly target the scope of the EPBD[16]. They address EPBD regulated loads and consequently are concerned with the Technical Buildings Systems (TBSs) but not de facto with plug loads such as tumble dryers and other plug-in/portable appliances that are not addressed by the EPBD.

Therefore, aside from these BACS EPBD functions consideration also needs to be given to BACS plug load functions that control electrical loads and/or appliances (e.g. floor lamps, set top boxes, etc.) and which are not taken into account by EPBD-related control functions. There are several examples of BACS plug load functions that do not require the appliance to be smart. For example, a "home away BACS function", that shuts down wall outlets with one push of a button when you leave the house to reduce consumption.

[14] See CEN committee CLC TC 205 on 'Home and building electronic systems'

[15] https://www.knx.org/knx-en/knx/technology/standardisation/index.php

[16] http://epb.center/support/documents-introduction

Such a 'home away BACS functions'[17] are a common feature in high end home automation systems; they also check if the doors are closed properly, shut down the water supply against leakage, put the ventilation system to its lowest setting, etc. Another example is demand response control of hot water storage tanks, which can also be implemented by externally installed smart relays[18] added to any existing (non-smart) storage tank.

When they are not related to EN 15232 functions, they are also not in the scope of this study.

1.3.6 BACS hardware definitions according to EN ISO 16484-2 and/or PRODCOM

The EN ISO 16484-2 standard on building automation and control systems addresses BACS hardware and provides a useful overview of the **typical hardware definitions** and how hardware is used in relation to: the field, automation/control and management level of BACS services.

This standard includes rudimentary and generic descriptions of BACS hardware terminology but does not include an extended hardware catalogue that can be linked to it. The hardware that relates to these levels therefore potentially encompasses a very large array of different products.

PRODCOM categories[19] also need to be considered for BACS hardware in accordance with the MEErP. Generic economic data within the MEErP refers to data that is available in official EU statistics (e.g. PRODCOM) and in principle this could help to identify and report on the EU BACS product consumption and market size. Moreover, in a later stage it could help to track the impacts of Ecodesign policy measures through analysis of the official Eurostat PRODCOM data. The text below presents a review of the applicable PRODCOM data and an assessment of how useful it could be for a BACS ED/ELR preparatory study and subsequent work to establish prospective policy impacts.

There are a **wide range of BACS products and consequently of applicable product codes**. A first screening exercise was done for this study and revealed as much as 141 products that could contain BACS functions. These include products that might contain BACS but that also provide other completely distinct functions.

This remains a very generic list that **does not contain sufficient disaggregation of BACS** to provide useful data. It is therefore suggested that a future update of Eurostat product classes might consider adding new subclasses for BACS. For example:

- 26.51.70.15 Electronic thermostats

  Should be converted to comprise two newly created categories, such as:

  - 26.51.70.15 Electronic thermostats (n.e.c. = not elsewhere classified)
  - 26.51.70.16 Electronic thermostats for room temperature control.

[17] https://www.teletask.be/en/solutions/end-user/power-sockets/

[18] https://www.legrand.fr/pro/catalogue/31907-bipolaires-250-v/contacteur-domestique-cx3-silencieux-bobine-230v-2p-250v-25a-contact-2f-1-module

[19] http://ec.europa.eu/eurostat/web/prodcom

In this case electronic thermostats intended for use in ovens would remain in category 26.51.70.15 whereas those concerned with room temperature control would move over time to the 26.51.70.16 category.

A full list of applicable PRODCOM codes was included in Annex E of the exploratory scoping study[20].

As can be seen from the Figure 1-3 there are a large range of product codes that would need to be converted to provide greater distinctions for the PRODCOM data on BACS products if this is to be useful for Ecodesign/ELR purposes.

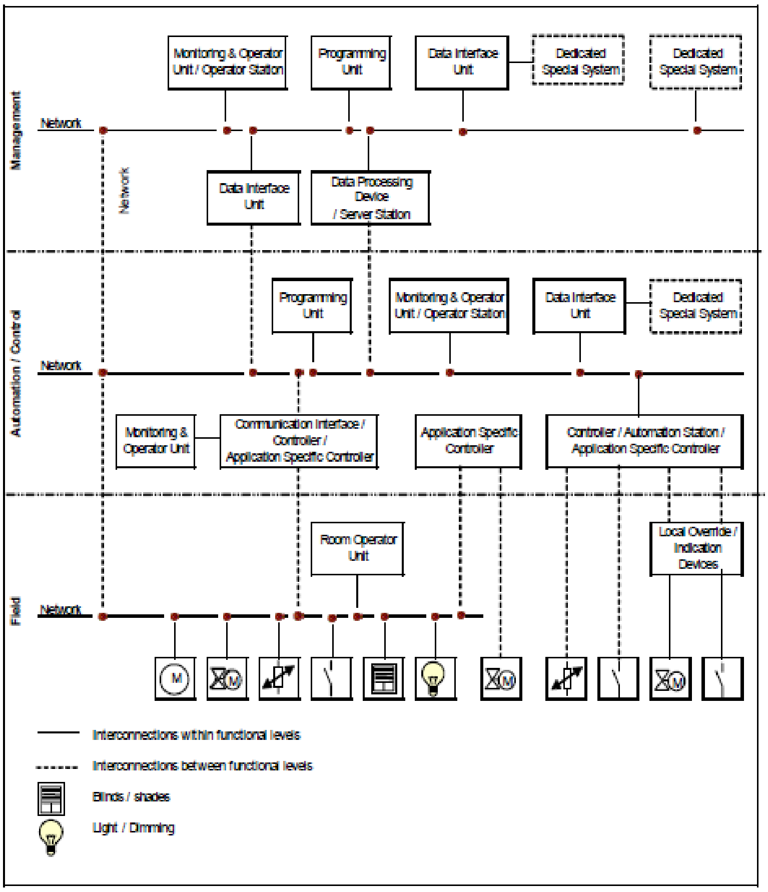

Figure 1-3: A generic architectural model of the BACS network and its different levels according to EN ISO 16484 part 2, which is often referred as the 'BACnet standard[21,22]

It should also be noted that the individual **BAC components**, described in this section, are not always exclusively used for building automation purposes. For example, a BAC programming unit or temperature sensor can be used for industrial processes (e.g. oven control) and vice versa. This is likely to be an important consideration when developing

[20] https://ecodesignbacs.eu/sites/ecodesignbacs.eu/files/attachments/BACSscopeReport Annexes.pdf

[21] BACnet is a data communication protocol for BAC networks - see http://www.bacnet.org/

[22] REHVA Guidebook No.22, 'Introduction To Building Automation, Controls And Technical Building Management', A. Litiu et al., 2017

potential product policy measures (in the Task 7), because they could inadvertently have an impact outside the intended application area unless appropriately delimited.

Conclusions

The range of BACS hardware is very broad as well as their functions. This poses a challenge in this preparatory study. If all potential product types are analyzed using the full MEErP process, the number and variety of product reference cases would be too numerous to be practicable.

Note that "Local Building Controls" (lBAC) were included in the review study on Standby for Commission Regulation[23] (EC) 1275/2008) on standby and off mode electric power consumption of electrical and electronic household and office equipment. It should be noted that the standby mode is rarely relevant for BACS, because they control climate conditions inside a building and hence are in continual operational mode except for the case of empty or unoccupied buildings.

It can also be concluded that the PRODCOM **data is too generic** to be useful for ED/ELR purposes and is mixed up with a large range of products and PRODCOM codes that serve other non-BACS functions. In order to be useful Eurostat codes would need to be reviewed and specific sub categories added to address BACS.

1.3.7 Definitions for BACS self-consumption or auxiliary energy consumption of BACS hardware

Within the set of EPBD EN standards the 'BACS self-consumption' is part of the 'auxiliary energy' which is defined as 'electrical energy used by technical building systems to support energy transformation to satisfy energy needs' (ISO 52000-1:2017). This auxiliary energy however is not only for BACS but also includes other energy for fans, pumps, electronics, etc. Also, within this definition the electrical energy input to a ventilation system for air transport is not considered as auxiliary energy, but defined separately as energy use for ventilation (ISO 13612-2:2014).

It is important to be aware that the term 'self-consumption' is in European regulatory[24] and in general in the photovoltaics[25] context this term refers to the energy consumption of on-site production. In this context 'BACS self-consumption' would mean the consumption of on-site produced photovoltaic energy which is a different meaning. In order to avoid this confusion the term internal power consumption will be used in subsequent chapters as much as possible.

For the remaining tasks the "additional self-consumption of BACS necessary to operate at more than a basic reference level corresponding to class C according to EN 15232", will be investigated in order to check if there is any trade off with the indirect energy savings provided. For example, when an actuator is required to go from level 0 (no automatic control) to level 2 (individual room control) the energy consumption of this actuator will be considered as the additional self-consumption.

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23 http://www.ecostandbyreview.eu/

24 https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_autre_document_travail_service_part1_v6.pdf

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

Therefore also, one complex topic necessary to define the self-consumption of BACS is to establish the boundaries of the BACS. For example, in the case of a speed-controlled circulator pump it could be the controller logic and/or motor speed controller inverter and/or the motor and/or pump impeller losses. Also, often BACS functions are incorporated within other equipment making it more complex to assign the part of the consumption associated purely with the provision of the BACS function.

Task 4 will attempt to quantify the additional self-consumption of BACS functions, for example for an automatic valve actuator.

As the study is required to perform a Life Cycle Analysis (LCA) that optimizes the product performance relative to a single functional unit it is not possible to consider power consumption of related devices that serve other functions such as: fire alarms, video surveillance, internet router, etc. This would require another Ecodesign study.

Conclusions

'Internal energy consumption' of BACS is a fraction of the auxiliary power consumption as defined in (ISO 52000-1:2017).

In the remaining section the aforementioned term will be used to avoid confusion with the term self-consumption that is often used to define the consumption of on-site produced photovoltaic energy.

It is not recommended to consider other building automation functions within MEErP Tasks 4 to 6 such as a fire alarm or internet routers because they will have a different functional unit and end up with complex multi-objective optimizations to be done within Tasks 4 to 6.

1.3.8 BACS interoperability definitions related to demand response in a smart grid scenario

In the future there is expected to be an increasing need for Demand Response Management (DRM) in buildings to support the Smart Grid26,27 to provide electrical load flexibility to cope with fluctuations in renewable energy supply, and to manage and dispatch local energy production, such as photovoltaics or storage. For appliances or plug loads, including thermal appliances such as domestic hot water (DHW) storage tanks, an Ecodesign preparatory study is completed28 and therefore this issue should be omitted from the analysis in Tasks 2 to 6 . The smart appliance study does not, however, include the building and TBSs as a whole. Within the smart grid context the part of the BACS at building management (BM) level that is dedicated to DRM is called the Customer Energy Management (CEM)29, see

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https://www.cencenelec.eu/standards/Sectors/SustainableEnergy/SmartGrids/Pages/default.aspx

[27] http://smartgridstandardsmap.com/

[28] http://www.eco-smartappliances.eu/Pages/welcome.aspx

[29] The CEM is defined by CENELEC as "internal automation function of the role customer for optimizations according to the preferences of the customer, based on signals from outside and internal flexibilities

EXAMPLE A demand response approach uses variable tariffs to motivate the customer to shift consumption in a different time horizon (i.e. load shifting). On the customer side

Figure 1-4. Obviously, BACS can also play an important role for CEM **as a central management unit that integrates** control of distributed energy resources (DER), the Home Automation Network (HAN) gateway, home building integration bus, interfacing with the electricity meter, etc. For example, the Home Automation Network gateway connects the building automation systems to the internet. The building automation bus[30] can, for example, be a twisted pair to connect BACS hardware, e.g. KNX TP[31].

Basically, there are two types of Demand Response (DR) service categories[32]:

Implicit Demand Response (**iDR BACS**) refers to BACS services to participate in the wholesale energy market, it is mostly price driven with variable tariffs or peak load tariffs

Explicit Demand Response (eDR BACS) refers to BACS services that support the grid operators to provide balancing or congestion management. It can be, for example, curtailment-based on-line voltage or grid frequency.

This technology and its implementation in BACS are still under development. Aside from the issues linked to the development of the technology the future added value of DR in BACS will depend on:

- the DR service that buildings can offer and the degree to which electricity is used as a heat source for example when a heat pump is used instead of a gas heater
- the relative share of intermittent renewables (PV, Wind)
- the relative share of biofuels in electricity production
- the curtailment cost of renewables
- the roll out of smart meters and its local user interface, for which utilities can select different protocols(5 in IEC-62056-21) and physical interfaces (USB, Infrared head, ..)
- competitiveness with DR in industry
- the competitiveness versus other electricity storage solutions (e.g. pumped hydro, batteries, power to gas).
- the minimum time frame (quarterly, … yearly) used for billing the different price components (energy, network cost, levies, taxes) of electricity. Discussion in

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the signals are automatically evaluated according to the pre-set customer preferences like cost optimization or CO_2 savings and appropriate functions of one or more connected devices are initiated.”

[30] In computer architecture, a bus (a contraction of the Latin omnibus) is a communication system that transfers data between components inside a computer, or between computers. This expression covers all related hardware components (wire, optical fibre, etc.) and software, including communication protocols.

[31] http://www.knx.org – note different technologies are available as a medium for transmission when using building automation bus systems: wireless communication, a 230 V power network, also known as “power line” and the two-wire bus line, often as a Twisted Pair, abbreviated to TP.

[32] http://www.europarl.europa.eu/cmsdata/119722/3_JStromback_ITRE_300517.pdf

many regions are ongoing[33] and this is not harmonized at the EU level and nor is it yet included in the Guarantees of Origin for Electricity(EN 16325). For example, in the residential sector there is large hourly and seasonal mismatch between the generation and consumption[34] and a larger time frame for metering will increase self-consumption[35], but how this should be addressed in the EU27 has not yet been decided.

[33] https://www.vreg.be/nl/tariefmethodologie-2021-2024

[34] See Task 3 of Ecodesign Study on PV systems (section3.2.3 on self-sufficiency and self-consumption by prosumers and 3.4.1.6 on metering schemes: https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/contentype/product_group_documents/1581689975/180611_PV_Prep_study_Task_3_Consultation_final.pdf

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

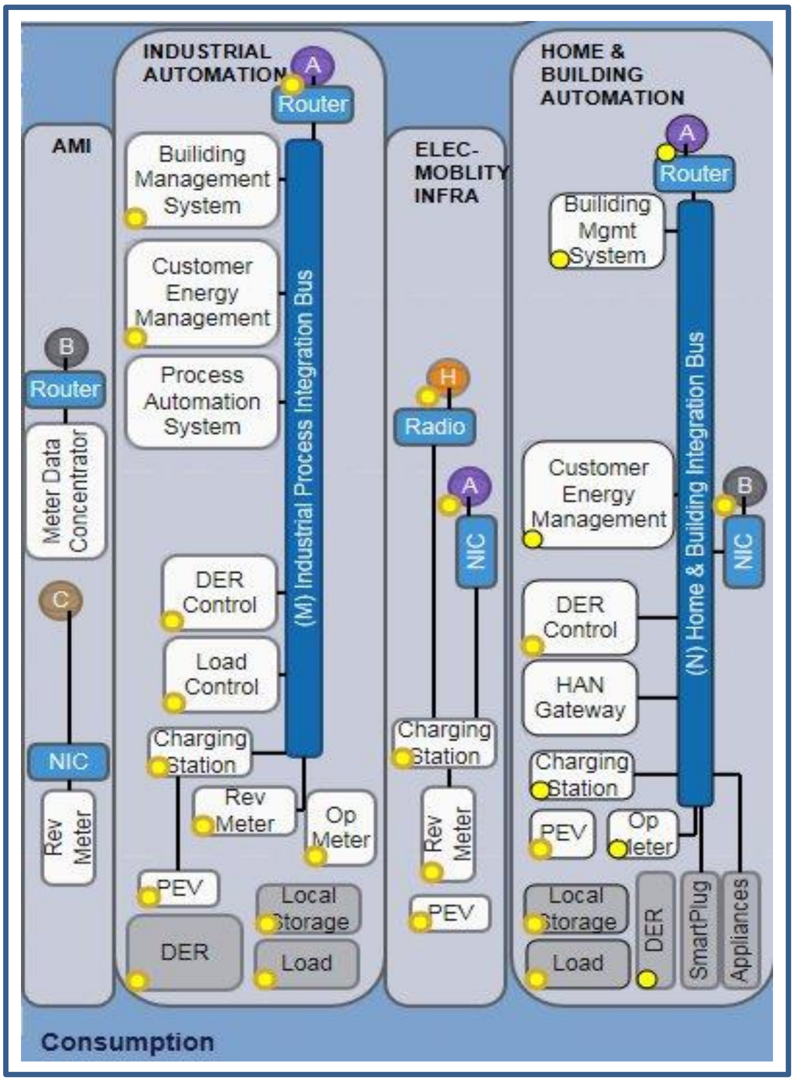

Figure 1-4: BACS and its role to support smart grids36

For some **standards** related to interoperability please also **consult section 1.6.4**.

Conclusion

Smart grid features for smart appliances and DHW storage tanks were, in principle, already covered by the ongoing Ecodesign study on smart appliances. BACS are likely to play an important role in interfacing and controlling smart grid components via the **BACS CEM.**

Two types of Demand Response can be discriminated, **iDR BACS** and **eDR BACS**.

Demand response is also one of the domains being treated in the Smart Readiness Indicator (SRI)[37] and it will be important for any necessary ED/ELR-related DR aspects of BACS required by the SRI e.g. information requirements, to be considered in Task 7.

Lastly, as LEB or NZEB are quite likely to use heat pumps and these can offer flexibility in smart grids the DR aspects of BACS will be a **valuable aspect to consider for future**

[36] http://smartgridstandardsmap.com/
[37] https://smartreadinessindicator.eu/

proofing NZEB. There are **still many uncertainties in the policy framework and business case for demand response that hinder the ability to create European wide BACS product requirements,** mainly due to:

- variable impacts per country/region from electricity prices related to their price components (energy cost, network cost, levies).
- different requirements on the minimum time period to meter and define self-consumption of local produced renewable energy[35] which can range from the average power per quarter of hour until average power per year and/or net metering. For photovoltaics there is often a large mismatch between supply and demand and the larger the time period the higher so-defined self-consumption will be.
- Also similarly, there is no clear hourly incentive to implement Demand Response as long as Europe's electricity markets permit the sale of green electricity based on annual Green Certificates of Origin.

1.3.9 BACS and their building application categories

The range of BACS or BAC hardware covered by the previous section 1.3.6 is very extensive. Nonetheless, there is the potential to make further segmentation according to their intended application.

Building type definitions are available in Eurostat definitions[38] and related nomenclature[39].

An overview is included in Figure 1-5 and the subcategories are discussed hereafter.

[38] http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Building

[39] http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=CC_1998&StrLanguageCode=EN&IntPcKey=2984615&StrLayoutCode=

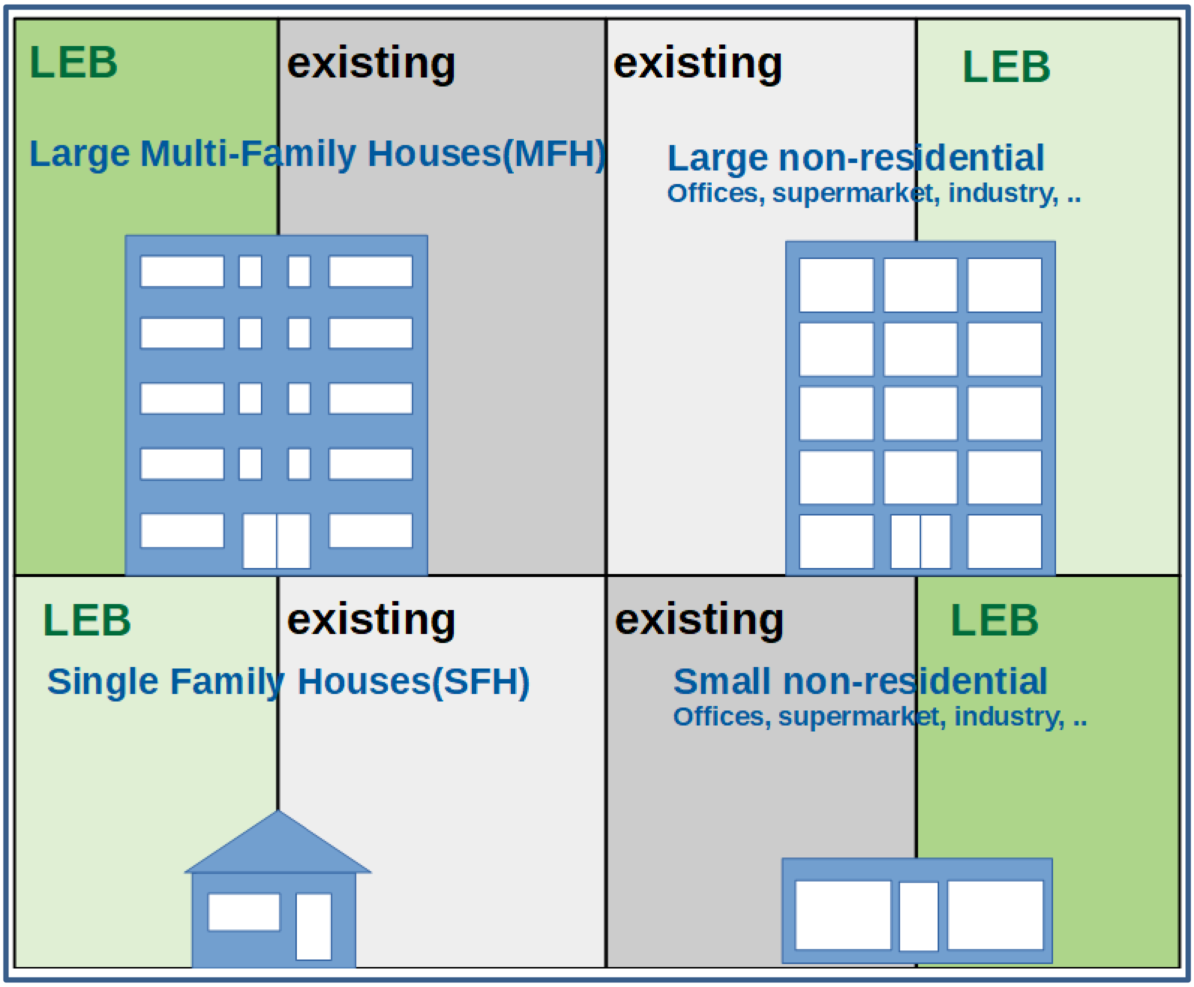

Figure 1-5: Overview of building categories for BACS

Residential versus non-residential

First, it is possible to discriminate **residential BACS** versus **non-residential building BACS.** Residential buildings can be clearly discriminated from non-residential buildings based on citizens' registrations in the municipality.

A rationale for discriminating residential-sector BACS from non-residential sector BACS might arise from differences in products, market players and how products are sold and installed, for example in smaller residential application BACS might come as packaged or bundled products with other TBS . Larger non-residential buildings might typically use 'integrated BACS' that are interoperable with on-site assembled third party TBSs while small residential buildings might also often use 'sBAC' that often come together with preassembled TBSs. The latter solution often has a closed protocol which isn't always interoperable with a third-party solution.

Within residential BACS there could also be significant differences between **multi-family houses (MFH BACS)** or apartments versus **single family houses (SFH BACS)** due to differences in the TBS (e.g. common infrastructure) and relative importance of transmission losses through the building envelope.

Within the non-residential BACS, a further distinction might be justified by building type (office, hotel, retail, school, hospital, etc.) is that the usage profiles can vary systematically, leading to very different averages, environmental impacts and cost-benefits. Despite this, the previously described BACS hardware (see 1.3.6), are in many cases the same for residential and non-residential buildings which could provide a rationale to keep them all in the scope.

It is also possible to discriminate **existing** versus **deeply renovated** or **new** buildings wherein deeply renovated/new buildings are characterized by the need for EPBD compliance certification. Due to EPBD requirements, deeply renovated/new buildings will tend to be **Low Energy Buildings (LEB)** or **Near Zero Energy Buildings (NZEB)** and therefore often have more complex TBSs, i.e. they are likely to include mechanical ventilation due to air tightness requirements for energy savings. Due to the need for more complex TBSs they often have relatively greater auxiliary energy consumption (e.g. more and larger fans due to increased air tightness and the heat recovery ventilation heat exchanger, more and larger circulation pumps for low temperature radiators or underfloor heating, more control of shading devices and blinds, increased BACS self-consumption, etc.) while on the other hand their energy need for heating or cooling is significantly lower. Consequently, their saving potential in relation to the respective BAC control functions can be very different. Also, these NZEB have a more complex Technical Building System (TBS) and due to this they most often already have an advanced BACS or sBAC installed. This could result in systematic differences when considering MEErP case studies and eventually the resulting policy recommendations. **Existing buildings in this study are typically constructed before 2005** and include older existing buildings (<1990) which may have had a basic renovation to add roof insulation, double-glazed windows and outer wall insulation. Task 3 defines sample buildings for this study.

Conclusion

When considering the MEErP and potential policy measures it is possible to consider residential versus non-residential and existing versus deeply renovated or new buildings. Within residential buildings also SFH and MFH could be discriminated. Within the non-residential sector further differentiation might be needed to take into account different usage profiles, e.g. discriminating between offices, healthcare facilities, retail buildings, etc.

Even though LEB/NZEB consume less than typical buildings, BACS are likely to also provide significant energy savings for both existing buildings and LEB/NZEB. This is because NZEB tend to have more complex TBS and therefore more EN 15232 functions will apply. The source of their energy savings will tend to be found more in the electrical auxiliary energy of the TBS. The average projected electrical energy savings from using class A BACS in EN 15232 are likely be an underestimate for NZEB and might need to be reviewed. Nevertheless, due to the lower share of NZEB in the whole building stock the study could focus first on functions that affect both existing buildings and NZEB.

1.4 Proposals for the primary functional unit

1.4.1 Objective

Knowing the definitions of BACS as set out previously, what is considered to be the "functional unit" for BACS is now further explained.

In standard ISO 14040 on life cycle assessment (LCA) the functional unit is defined as "the quantified performance of a product system for use as a reference unit in life cycle assessment study". The primary purpose of the functional unit is to provide a calculation reference to which environmental impacts (such as energy use), costs, etc. can be related and to allow for comparison between functionally *equal* BACS.

Defining a "functional unit" is an important aspect of the MEErP Task 1 because other tasks, e.g. consideration of the improvement options and their impacts will be scaled to this.

1.4.2 Conclusion

The primary function of a BACS is to control the Technical Buildings Systems (TBS) in order to maintain the indoor environmental requirements for thermal comfort, sanitary hot water (SHW), indoor air quality (IAQ) and lighting according to EN 16798–1:2019 and therefore:

the primary functional unit (FU) is 1 m² of building floor area, where the thermal comfort, sanitary hot water (SHW), indoor air quality (IAQ) and lighting requirements (per EN 16798–1:2019) – for health, productivity and comfort of the occupants – are maintained

1.5 The basic secondary product performance parameters

This section lists some of the basic secondary parameters that are required to describe and characterize the identified product on a functional level. These are important parameters that are mainly provided and defined based on European and International standards. Note, however, that when deemed necessary additional parameters will added in subsequent tasks.

1.5.1 Important building energy definitions

When considering the energy performance of a building it is important to be aware of the following definitions that will be used in the course of this study.

delivered energy (EN ISO 52000-1): energy, expressed per energy carrier, supplied to the technical building systems through the assessment boundary, to satisfy the uses taken into account or to produce the exported energy.

primary energy (EN ISO 52000-1): energy that has not been subjected to any conversion or transformation process.

*Note, if both, non-renewable energy and renewable energy, are taken into account it can be called **total primary energy**.*

non-renewable primary energy factor (EN ISO 52000-1) (PEF): non-renewable primary energy for a given energy carrier, including the delivered energy and the considered energy overheads of delivery to the points of use, divided by the delivered energy.

Notes:

- *in this study **delivered energy** will also sometimes be referred to as **final energy demand or energy needs**.*
- ***different types of heating supply and the relation to primary energy is defined in the MEErP.***
- *the Energy Performance of Buildings Directive (EPBD) of 2018 requires that the numeric indicator of a building's primary energy consumption is expressed in kWh/m² per year. The proposed primary functional unit [1m²] in this study is consistent with this, meaning that all energy consumption referred in this study is expressed per m² or per functional unit.*

1.5.2 Secondary parameters to calculate the delivered and primary energy needs to provide thermal comfort

Hereafter is a summary of the main parameters useful for this study, conducting a whole building energy calculation according to the new set of EPBD standards requires much more than 1000 parameters. More information is available at: https://epb.center/documents/

The most typical parameters used to characterise the delivered energy for thermal comfort are in Table 1-1. The type of energy supplied has an impact on the calculation of the primary energy, see Table 1-2. With a BACS the energy demand will also depend on the operating mode of a room, where the key BACS parameters are shown in Table 1-3.

Table 1-1: Key parameters for components of the building energy balance to provide thermal comfort to the building (EN 15XXX series of standards)

Component of the building energy balance (EN 15232 & EN ISO 52000-1)	Unit	Acronym	Type
the heating energy needs of the building;	kWh/m²/y	Q H,nd, B	Table 1-2
the energy losses of the heating system;	kWh/m²/y	Q H,ls	Table 1-2
note: this is understood as losses outside the heated area + inside when they are not contributing to the heating			
the Sanitary Hot Water needs for the building	kWh/m²/y	Q DHW,nd	Table 1-2
the Sanitary Hot Water losses for the building	kWh/m²/y	Q DHW,ls	Table 1-2
the cooling energy needs of the building;	kWh/m²/y	Q C,nd,B	Table 1-2
the energy losses of the cooling system;	kWh/m²/y	Q C,ls	Table 1-2
the electrical auxiliary energy for heating;	kWh/m²/y	W H, aux	Elec
the electrical auxiliary energy for cooling;	kWh/m²/y	W C, aux	Elec
The electrical energy for ventilation;	kWh/m²/y	W V, aux	Elec

Table 1-2: Key types of building energy supply (according to the MEErP(2014))

MEErP Ref.	Type of energy supply
66 or Elec	Electricity per MWh
67	Electric, η 96%, per GJ
68	Elec. GSHP, η 288%, GJ
69	Gas, η 86%, atmospheric
70	Gas, η 90%, atmospheric
71	Gas, η 101%, condensation

72	Gas, η 103%, condensation
73	Oil, η 85%, atmospheric
74	Oil, η 95%, condensation
75	Wood pellets, η 85%
76	Wood pellets, η 88%
77	Wood logs, η 67%
78	Wood logs, η 74%
79	Extra for fossil fuel extraction & transport: Gas +7%, Oil +10%), for Wood pellets and logs add 5%

Table 1-3: BACS operating mode of a room

BACS operating mode of a room (EU.BAC system handbook part 4)	Description
Economy mode	The room is not in use
Comfort mode	The room is in use
Protection mode	This can be activated when the room is not in long term use and might for example also deactivate the sensors in a room to reduce self-consumption

Note:

- EN ISO 51000-1 defines a larger set of types compared to Table 1-2.It allows to take local production of renewables such as solar thermal and photovoltaics into account and the new set of standards allow to calculate on an hourly basis[40] its local or self-consumption by the building for HVAC
- Standard EN ISO 52016 on 'Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads' enables to calculate the self-consumption of renewables per period of one hour Note however that a full new EN standard compliant code to compute these hourly building HVAC energy needs is work in progress[40] and therefore was not available for this study. As a consequence this study had to use other simulation tools and concepts in Task 4.

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

1.5.3 Secondary parameters to calculate the final energy needed to provide the indoor air quality

The most typical parameters to characterise energy demand for indoor air quality are shown in Table 1-4. With a BACS the energy demand will also depend on the operating mode of a room, key BACS parameters are in Table 1-3.

Table 1-4: Key secondary parameters of the building energy balance to provide the energy demand related to indoor air quality to the building (EN 15XXX series of standards)

Component of the building energy balance (EN 15232 & EN ISO 52000-1	Unit	Acronym	Type
the electrical auxiliary energy for ventilation;	kWh/m²/y	W V, aux	Elec
The (electrical) auxiliary energy for humidification or dehumidification;	kWh/m²/y	W DH, aux	Elec

1.5.4 Secondary parameters to calculate the final energy needed to provide indoor lighting

Lot 37 on lighting systems already analysed those aspects in detail; the key parameter was:

Component of the building energy balance (EN ISO 52000-1& EN 15193)	Unit	Acronym	Type
Lighting Energy Numeric Indicator;	kWh/m²/y	LENI	Elec

1.5.5 Other important energy components of the building energy balance

The most typical parameters to characterise the delivered energy for thermal comfort are in Table 1-1. With BACS the energy demand will also depend on the operating mode of a room, key BACS parameters are reported in Table 1-3.

Table 1-5: Other key secondary parameters of that are important components to calculate a building's energy balance (EN 15XXX series of standards)

Component of the building energy balance (EN ISO 52000 or own definitions)	Unit	Acronym
the electrical energy for the plug loads/appliances within the building per m² (own definition)	kWh/m²/y	W plug
W lift is the energy need for elevators (own definition)	kWh/m²/y	W lift

Auxiliary energy for internal energy consumption of BACS (definition applied in this study)	kWh/m²/y	W BACS
EV is the electrical auxiliary energy for EV charging (own definition)	kWh/m²/y	W EV
the self-produced energy such as photovoltaics	kWh/m²/y	W PV
Internal Heat Gains (IHG)- passive solar-heat replacement	kWh/m²/y	Q H,S
Internal Heat Gains (IHG)- solar-cooling load	kWh/m²/y	Q, C,S
Internal Heat Gains (IHG)- people	kWh/m²/y	Q,P
transmission losses	kWh/m²/y	Q,T
ventilation losses	kWh/m²/y	Q,V

1.5.6 Important secondary functional parameters to set the comfort requirements and calculate energy performance indicators of buildings with BACS

There is a large set of such parameters. The most typical (source: EU.BAC Certification Handbook- part 4) are:

- Temperatures, for example for comfort/economy set points
- Relative Humidity (RH), for example for comfort min/max set points
- Running hours, for example for time schedules
- Position of actuators such as control valves and air dampers (on/off/% position)
- Pressure sensors
- Air flow meters
- CO_2 meters
- Brightness/illuminance meters
- Window/door/screen position sensor
- Room presence detectors
- Energy meters.

1.6 Overview of the most relevant European Standards

1.6.1 Objective

According to the MEErP the aim of this task is to: Identify and shortly describe EN or ISO/IEC test standards, mandates issued by the European Commission to the European Standardisation Organisations (ESOs), test standards in individual Member States and third countries (if relevant) regarding the test procedures for primary and secondary functional performance parameters on: resources use, emissions, safety, noise and vibrations (if applicable) or other factors that may pose barriers for potential Ecodesign measures. The purpose is also to conduct a comparative analysis for overlapping test standards. Finally, the aim is also to: analyse and report new test standards under development; identify possible problems concerning accuracy, reproducibility and to what extent the test standards reflect real-life conditions; draft outlines of mandate(s) to the ESOs as appropriate; and identify differences between standards covering the same subjects (comparative analysis).

1.6.2 Summary of the main standards committees

The main CEN standards committees developing standards for BACS are:

- CEN/TC 247 - Building Automation, Controls and Building Management (Business Plan)
- CEN/TC 247/WG 3 - Building Automation and Control and Building Management Systems
- CEN/TC 247/WG 4 - Open System Data Transmission
- CEN/TC 247/WG 6 - Electronic control equipment for HVAC applications, integrated room automation, controls and management systems

The key standards related to BACS functions are set out below.

1.6.3 Key standards related to EN 15232

The most relevant standard for a BACS in the scope of this study is EN 15232 and was discussed extensively in section 1.3.3.

Function		Standard
Automation and control functions		
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

Function		Standard
	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
	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 the room level	EN 16798-7, EN 13779
	Air flow or pressure control at the 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		
Centralized adapting of the home and building automation system to users needs: e.g. time schedule, set points etc.		EN 16947 series
Setpoint 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

Function	Standard
Waste heat recovery and heat shifting EN 16947 series	EN 16947 series

The full set of EPBD standards (EN 15XXX and EN ISO 52XXX series) are described in the dedicated website: https://epb.center/

In Table 1-6 is a listing with gaps identified during the course of this study, it is advised to consider them in a next review.

Table 1-6: Standards with identified gaps during this study

Standard	Gap
EN 15232-1:2017 And prEN ISO 52120-1	• Definitions and control functions for natural ventilation (window openers) do not match well with the state of art modelled in Task 4 and should be reviewed. • The standard could be better aligned with the temperature control classification under Commission Regulation 615 (EU) No 813/2013 and Commission Delegated Regulation (EU) No 811/2013 (see Task 4) and for the control factors of ELR for residential ventilation units in No 1254/2014. For this purpose a third more simplified method could be considered that fully aligns with the packaged system label factors. Similar approach could be considered for ventilation systems. The aim should be to have a maximum synergy and compatibility between Ecodesign and EPBD EPCs. • Could benefit from a broader range of default BACS factors for the simplified method 2 taking into account the findings from the sensitivity analysis in Task 6 to cover more types of buildings and climates. Also, when research is undertaken to cover more buildings types a third hybrid method in between method 1 and 2 could be considered as a smarter BACS factor calculator for existing buildings, as the detailed method might be too complex for existing buildings and the simple method not accurate enough. This could be useful in future BACS policy. • It did not cover all BACS functions that have an impact on the real in use HVAC energy consumption because they mainly serve to support the EPC calculation that only uses pre-defined user or occupancy profiles (ISO 17772-1). For example, this does not include the benefits of window contacts.

	Note, the eu.bac BACS System Certification scheme Part 2 with technical recommendations contains a more extensive list referred to as EN 15232+ and this could be considered. Also, in residential buildings night time set back temperatures can result in additional savings but this is not included in the EN 15232 and it is worth considering this. • Demand Response functions should be more detailed (see proposal in Task 7). Hydronic balancing is missing. Note that this standard is now also elaborated at ISO level in prEN ISO 52120-1. • Also, for historical reasons, the current version is focused on modelling the impact of BACS on new building EPCs; which in principle cannot be based on metered data. When considering existing buildings, aspects and requirements for monitoring could be added and further elaborated. This work could support the new EC Renovation Wave strategy[41] and also help to improve the data sources used to model the impact of BACS. • Also connected to the previous remark, the requirements for monitoring or KPIs could be more detailed.
EN 15500-1/2: 2017	• the available test methods for control accuracy according to EN15500 are not comparable with CA values from other standards • Test methods could be further to simplify market surveillance, one can think of smaller test set ups and/or hardware in the loop simulations.
ISO 17772-1 and EN 16798-1:2019 and EN 15232-1	• The standard ISO 17772-1 specifies the occupancy schedules in Annex G to be used in standard energy calculations. For residential applications this assumes a relative flat and high occupancy and therefore not all benefits of BACS are modelled, schedules with more variance in occupancy due to school, work, holiday, recreation, etc could be considered to better model the benefits of BACS. Also, other user profiles could be added or updated as they are very useful to assess the saving potential of BACS (see Task 4). • Occupancy schedules are also included in EN 15232-1:2017 (Annex C) and EN 16798-1:2019 (Annex G), when reviewing and/or updating all of these it is recommended efforts are made to align with the other relevant standards.

[41] https://ec.europa.eu/energy/sites/ener/files/eu_renovation_wave_strategy.pdf

EN 13203-2:2015	•	This standard deals with gas-fired domestic appliances producing hot water – Part 2: Assessment of energy consumption. The standard works with assessments based on pre-defined test cycles but does not include input for simulation models[42] for dynamic building simulations. This made it more difficult to conduct the Task 4 building simulations using test cycles other than the standard one. Therefore, the standard could be amended to fill this gap by adding an annex with a template for such models that is connected with the ongoing research for building simulations.[42]
EN 16147:2011	•	This standard deals with heat pumps with electrically driven compressors - Testing and requirements for marking of domestic hot water units. As for EN 13203-2, it is also recommended here to consider a adding a template with simulation modelling data[42].
EN 16325:2013+A1:2015	•	This standard specifies requirements for guarantees of origin (GO) of electricity from all energy sources. Section 7 deals with Issuing and content of a GO and it is recommended to review/extend this to include hourly data in order to support demand response. Also, hourly data would allow the outputs to fit with the hourly calculation methods introduced in the new set of EPBD standards which is currently missing in GOs.

1.6.4 Standards for interoperability and life-time of BACS components

Interoperability:

According to ISO/IEC 2382-01 on 'Information Technology Vocabulary, Fundamental Terms', **interoperability** is defined as follows: 'The capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units'.

Despite this ISO/IEC 2382-01 definition there are several other definitions of interoperability in formal standards[43]. For example, within standard (FDIS IEC 63105) interoperability is defined as 'ability of systems or systems components to transmit, receive, interpret, and/or react to data and/or power and function in a specified manner'.

[42] For example see ongoing work: https://github.com/ibpsa/modelica-ibpsa

[43] http://www.internet-of-things-research.eu/pdf/IERC_Position_Paper_IoT_Semantic_Interoperability_Final.pdf

Also ETSI[44] defined, several **levels of interoperability (**Figure 1-6**)** in an ETSI white paper[45] which can be applied to a multitude of topics and applications:

- **Technical Interoperability** is usually associated with hardware/software components, systems and platforms that enable machine-to-machine communication to take place. This kind of interoperability is often centred on (communication) protocols and the infrastructure needed for those protocols to operate. (e.g. KNX[46] TP (EN 50090, ISO/IEC 14543), DALI[47], SHIP[48]; IPv6, MODBUS[49], Zigbee wireless protocol, Enocean (ISO/IEC 14543-3-10), Blue tooth, Wifi, Z-wave, etc.)
- **Syntactical Interoperability** is usually associated with data formats (e.g. BACNET (ISO 16484), XML[50], KNX, DALI[51], SPINE[52], MODBUS[53]). Accordingly, the messages transferred by communication protocols need to have a well-defined syntax and encoding, even if it is only in the form of bit-tables. Today, many protocols specify data or content using high-level transfer syntaxes such as HTML, XML or ASN.
- **Semantic Interoperability** is usually associated with the meaning of content and concerns the human rather than machine interpretation of the content (e.g. KNX Application layer, DALI[54], Smart Appliances REFerence (SAREF) ontology[55], MODBUS[56], Zigbee stack and certified products, etc.). Interoperability at this level means that there is a common understanding of the meaning of the content (information) being exchanged.
- **Organizational Interoperability**, as the name implies, is the ability of organizations to effectively communicate and transfer (meaningful) data (information) even though they may be using a variety of different information systems over widely different infrastructures, possibly across different geographic regions and cultures. Organizational interoperability depends on successful technical, syntactical and semantic interoperability.

[44] https://www.etsi.org/

[45] http://www.etsi.org/images/files/ETSIWhitePapers/IOP%20whitepaper%20Edition%203%20final.pdf

[46] https://en.wikipedia.org/wiki/KNX_(standard)

[47] https://www.digitalilluminationinterface.org/

[48] https://www.eebus.org/en/technology/communication-channels/

[49] http://modbus.org/about_us.php

[50] https://www.w3.org/TR/xml/

[51] https://www.digitalilluminationinterface.org/

[52] https://www.eebus.org/en/technology/data-model/

[53] http://modbus.org/about_us.php

[54] https://www.digitalilluminationinterface.org/

[55] https://sites.google.com/site/smartappliancesproject/ontologies/reference-ontology

[56] http://modbus.org/about_us.php

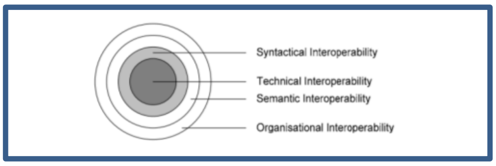

Figure 1-6: ETSI defined different levels of interoperability

Unfortunately, today there is not one universal overarching BACS operating system, but rather there are several systems available on the market and a building can often include a multitude of them (e.g. KNX, DALI, IP user interface server). Provision of interoperability between these systems is often a point of concern. The common solution for this is to add **gateways** or bridges to the BACS system, for example a DALI-to-KNX gateway to integrate lighting and KNX IP gateway and router for the user interface with a web browser. Nevertheless, such gateways come at extra cost and also require additional power consumption. For example, BACnet (ISO 16484 series) achieves syntactical interoperability and therefore divides the task of device interoperability into three distinct areas:

- Objects (information)
- Services (action requests)
- Transport systems (internetworking, electronic messages).

BACnet defines methods and requirements for implementation of each of these areas.

In addition, MODBUS is a simple royalty-free communication protocol that provides syntactical interoperability, it can run on both a simple RS 485 network or IP. It is often used for thermostats. MODBUS Sunspec[57] adds a Semantic interoperability layer to the MODBUS protocol by providing, for example, semantic interoperability for inverters and battery chargers.

As another example, KNX TP (EN 50090, ISO/IEC 14543) achieves Technical interoperability and therefore provides 'interworking' which allow for products that send and receive messages to properly understand signals and react to them without any additional equipment, therefore they provide:

- KNX certified products
- A manufacturer independent configuration tool (ETS™)
- When realizing a specific BACS function it may only be coded according to their KNX interworking specifications and for a whole set of functions (switching, dimming, blinds control, etc.) they have a standardised set of data types.

As another example, DALI (IEC 62386 & IEC 60929) is specifically used for lighting and provides all levels of interoperability. The protocol is simple and straightforward to configure for standard lighting control functions (switching, dimming, colour control, configuration, scenes).

[57] https://sunspec.org/sunspec-modbus/

With regards to interoperability, reparability and upgradability the following BACS classifications could also be relevant:

- **BACS single source provider** as opposed to **BACS multiple source providers** (e.g. KNX[58])
- **Public standard I/F BACS** (e.g. DALI[59]), for which a public interface standard is available, versus **closed I/F BACS**, for which the system description is not publicly available and reserved for members or a single manufacturer (e.g. Openterm[60]).
- Within public standard I/F BACS it is also possible to discriminate between open standards which are free of charge (e.g. IPv4 according to IETF publication RFC 791) and paid membership BACS (e.g. KNX) and paid membership BACS with an acceptance protocol. An acceptance protocol means that existing members can decide which new members are allowed to participate. However, this only relates to the BACS cost, market competition and funding for maintaining the activity and is therefore only indirectly related to the BACS life time. Nevertheless, it can play a role when considering policy requirements while maintaining market competition.

Life-time:

Some aspects that can play a role in the BACS lifetime and its sustainability are (as sourced from the draft standard EN 45554:2020):

- **Repair,** process of returning a faulty product to a condition where it can fulfil its intended use.
- **Upgrade**, process to enhance the functionality, performance, capacity or aesthetics of a product.

Reparability and upgradability are addressed in a new standard **EN 45554** on 'General methods for the assessment of the ability to repair, reuse and upgrade energy related products'. This is a generic standard which in essence only contains definitions and therefore the type of Ecodesign criteria which can be set for products. In an informative annex there is an extended description on how to report and assess methods for repair, re-use and upgrade. This informative annex is mostly related to hardware (repair tools, spare parts, etc.) but does not contain specific methods for software.

The related standard **EN 45558** addresses 'general method to declare the use of critical raw materials in energy-related products'. It contains therefore a generic proposal for a prototype declaration on content of Critical Raw Materials that refers for the electrotechnical industry to a new material declaration standard(**IEC 62474**). The standard IEC 62474 will also have a database.

[58] https://www.knx.org/be-nl/

[59] http://www.dali-ag.org/

[60] https://www.opentherm.eu/

Conclusion

When considering the BACS lifetime and potential impact according to the MEErP software interoperability, reparability and upgradability can be important properties to consider for sustainability. Standards on these software life time aspects are often still generic. It could be possible to put requirements on interoperability depending on the BACS functions, for example as currently proposed for minimum Ecodesign requirements for a monitoring function included in photovoltaic inverters[61].

New standards on hardware reparability and upgradability (EN 45554) and critical raw materials (EN 45558) have recently been published. For electrotechnical products it contains generic proposals for: a material declaration/database (IEC 62474), a prototype declaration on content of Critical Raw Materials(EN 45558), and to assess/report on hardware repair or reuse(EN 45554). EN 45554 is hardware oriented and does not address the effective service lifetime of software.

1.6.5 Summary of main relevant standards

The principal standards addressing BACS are:

EN ISO 16484 Building automation and control systems (BACS)

- Part 1: Project specification and implementation
- Part 2: Hardware
- Part 3: Functions
- Part 4: Control applications
- Part 5: Data communication protocol
- Part 6: Data communication conformance testing

EN 15232 Building automation, controls and technical building management

- Part 1: Impact of building automation, controls and technical building management (EN ISO 52120)
- Part 2: Accompanying Technical Report

Also, the full set of standards that are included in the references in EN 15232 for details on control systems, such as EN 15316-2 on the method for calculation of system energy requirements and system efficiencies for space emission systems (heating and cooling).

EN 16947 Building management system

- Part 1: Building management system (EN ISO 52127)
- Part 2: Accompanying Technical Report

EN 16946 Inspection of building automation, controls and technical building management

- Part 1: Inspection of building automation, controls and technical building management
- Part 2: Accompanying Technical Report

EN 15500 Control for heating, ventilation and air conditioning applications

[61] https://susproc.jrc.ec.europa.eu/solar_photovoltaics/documents.html

- Part 1: Electronic individual zone control equipment
- Part 2: Accompanying Technical Report

There are additional IEC and ISO standards which are reported in the resources chapter of REHVA GB 22 in cooperation with eu.bac 'Introduction to building automation, controls and technical building management' (https://www.rehva.eu/publications-and-resources/eshop.html)

1.6.6 Overview and description of legislation

Objective

According to the MEErP the aim of this task is to identify and shortly describe the relevance for the product scope of:

- EU legislation (legislation on resources use and environmental impact, EU voluntary agreements, labels)
- Member State legislation (as above, but for legislation indicated as relevant by Member States), including a comparative analysis)
- Third country legislation (as above, but for third country legislation), including a comparative analysis.

1.6.7 Overview of existing BACS related legislation

Currently, some of the non-energy-related environmental impacts of BACS are covered by the WEEE, RoHS and REACH Directives while some of the energy-related aspects are addressed by the EPBD. BACS as a whole are not yet subject to Ecodesign, Energy Labelling or Ecolabel requirements with the exception of some product types that have BACS functions incorporated within them, these are:

- space heaters, water heaters and solid fuel boilers: EU Regulations No. 811/2013, 812/2013 and 2015/1187
- local space heating products: EU Regulations No. 2015/1188, 2015/1185 and 2015/1186
- BACS could potentially also be more included or aligned with the regulation 1253/2014 and 1254/2014 on ventilation units, for which a review is ongoing[62] in parallel to this study
- Commission Regulation (EU) 2019/1781 for electric motors and variable speed drives
- The European regulation for circulators within Regulation No 641/2009 amended by Regulation No 622/2012.

EU Regulations 811/2013, 812/2013 and 2015/1187 with regard to the energy labelling of space heaters, water heaters and solid fuel boilers respectively have introduced so-called *package labels* for the product systems they apply to, e.g. energy labelling requirements for heating systems that have to be implemented by the supplier or the dealer (in the case when the supplier only offers the components) of the system. Within these regulations the impact of controls is taken into account to the extent that they

[62] https://www.ecoventilation-review.eu/

apply to the heating generator, but not fully with regard to the distribution or emission of heat where many of the largest energy savings potentials arise.

The regulations for space and water heaters are currently under review[63], [64]. This review work is still ongoing at the time of completion of this Task and therefore readers should consult the respective websites for current information.

The existing package label defines eight classes of temperature controller and attributes a saving percentage (-%) for the calculation of the space heating energy efficiency label. For example, class 1 is a mechanical on/off room thermostat that is ascribed a 1 % energy saving impact whereas class 8 is a multi-sensor room temperature control for use with modulating heaters which is ascribed a 5 % energy saving impact. The highest savings bonus attributed to any type of temperature controls is 5%.

These bonuses were developed in the course of the respective Lot 1, Lot 2 and Lot 20 preparatory studies but appear to have been developed as an aside to the main focus of both studies and may not reflect the state of the art in terms of the savings potentials. For example, EN 15232 awards energy savings bonuses for weather compensation of 9% for residential space heating and even more for non-residential buildings, which is significantly greater than the bonus allocated in the space heater package label regulation.

Overall, the bonuses currently presented in the Ecodesign and Energy Labelling regulations seem not to be aligned with EN 15232.

The review study for ventilation units is still ongoing[62]. So far BACS functions are not incorporated within this but it is an option that could be considered and the results of this study could also be used (as may arise from Task 7 recommendations).

The European regulation for circulators, Regulation No 641/2009 amended with Regulation No 622/2012 is currently based on the pump efficiency and does not award credits for the incorporation of control functionality.

1.6.8 The broader scope of EPBD including linkages with the SRI and the EPC

The amended Energy Performance of Buildings Directive (Directive (EU) 2018/844) was approved on 30 May 2018 and entered into force on 9 July 2018. Amongst other changes it clarifies and strengthens the requirements on Member States with regard to the imposition of minimum energy performance specifications for technical building systems (TBSs) that would apply whenever a TBS is replaced within a building. This includes the impact of BACS controlling the TBSs; which is likely to offer the greatest energy savings potential associated with the use of BACS. The amended EPBD includes several elements that have the potential to address the market failures currently preventing the benefits of BACS being fully realised. It was understood that the performance of the technical building systems (TBS) have an important impact on overall building energy efficiency that can be equally important as energy efficiency measures set at the component level and should therefore receive sufficient attention. The Building Automation and Control System (BACS) was added to the list of technical building system definitions. Certain articles of the EPBD (e.g. new art. 8(1), 8(2), 14 and 15) put this into practice by requiring Member States to set system requirements on overall energy performance,

[63] https://www.ecoboiler-review.eu/

[64] https://www.ecohotwater-review.eu/study.htm

proper installation, appropriate dimensioning, adjustment and control. More details on these measures are given in Task 7.

In addition, a new study has recently been launched[65] that focuses on providing guidance on how best to implement these measures (new art. 8/14/15), including with regard to BACS. In combination with the recently announced renovation wave[41] much impact can be expected for BACS.

Aside from the TBS measures, the amended EPBD also introduces a new policy instrument, the Smart Readiness Indicator (SRI), whose methodology is being developed by the Commission and which is to be implemented on a voluntary basis by Member States. Details of the ongoing work to develop the SRI can be found at: https://smartreadinessindicator.eu/.

Since its inception the EPBD has required energy performance certificates (EPCs) to be issued for buildings whenever there is a change of ownership/occupancy of existing buildings as well as for new buildings. Many Member States use EPC calculation tools supported by a comprehensive suite of EN standards. In principle, these should require the input of BACS performance data and therefore the calculations would benefit from BACS data compiled in a standardised manner. Nevertheless, the energy savings potential from BACS solutions are not currently captured in many EPC calculation methods, which might partly be due to a current lack of effective functionality classifications and performance data for the various BACS solutions.

The SRI methodology further classifies BACS performance into prescribed functionality levels in accordance with EN 15232 (see below) and thus it will be important that BACS products supply product information that enables them to be positioned within this framework. Thus, here again, there is likely to be a benefit from standardised BACS product functionality information and performance requirements which can be further developed under ecodesign and energy labelling.

[65] https://ec.europa.eu/energy/studies_main/preparatory-studies/technical-assistance-study-ensuring-optimal-performance-technical-building-systems-under-energy_en

2 Task 2: Markets

2.1 The Objective

The objective of Task 2 is to present an economic and market analysis of building automation control system (BACS) products. The aims are:

- to place the products i.e. BACS, within the context of EU industry and trade policy (subtask 2.1)
- to provide market size and cost inputs for the EU-wide environmental impact assessment of the product group (subtask 2.2)
- to provide insight into the latest market trends to help assess the impact of potential Ecodesign measures with regard to market structures and ongoing trends in product design (subtask 2.3, which are also relevant for the impact analyses in Task 3); and finally,
- to provide a practical data set of prices and rates to be used for Life Cycle Cost (LCC) calculations (subtask 2.4). It should be noted that further price information will also be supplied in Task 4.

Note, the current report is the 2nd version of the Task 2 report which updates the previous edition circulated to shareholders. It takes into account stakeholder comments received on the first draft, the findings from a stakeholder market survey and additional analysis by the study team.

2.2 Summary of Task 2

BACS somehow differ from many other products examined in Ecodesign preparatory studies as they are designed in advance but ‘assembled in situ’ rather than produced, imported or exported as a whole. This means they can be considered in terms of the installed BACS product which is assembled on site from a set of constituent packaged BAC products and software. The functionality of installed BACS products only comes into being when they are installed and the functional unit for this study reflects this reality. Therefore, it is only viable in Ecodesign terms to consider the BACS market in terms of the additional building floor area each year that receives a given level of BACS functionality. For this reason, the primary BACS market size indicator in this study is the measure of the total building stock floor area that newly receives a given level of BACS functionality each year. A secondary indicator is to track the sales of packaged BAC products that are integrated into the installed BACS products; however, this is currently very challenging to assess due to a lack of differentiation in how product trade codes are classified. Specifically, packaged products that could be used for BACS are not distinguishable from those that could be used for other purposes in trade statistics.

Some market data are available for some packaged products used in BACS such as those to do with lighting (light sources, control gears, luminaires and some lighting controls) and thermostats in general (but not the thermostats used in BACS applications only). The report presents some of this data. The focus of the report, however, is on estimating:

- the magnitude of building floor area that has BACS installed each year in units of square metres
- the proportion of this floor area which has BACS installed differentiated as a function of the BACS energy performance (i.e. energy performance class and/or BACS factor under EN15232)
- the total market value
- how value is distributed through the supply chain
- the cost of BACS for consumers
- and parameters and trends that are helpful to understand how the market is likely to develop in the future, informing the scenarios of Task 7.

Key findings are:

- there is considerable uncertainty about the overall value of the EU27 BACS market, but the best estimate derived from reconciling many sources of information, including responses to a stakeholder survey, is €8.1bn for the year 2020 for the final installed BACS product i.e. the final price paid by consumers
- the total floor area that this is applied to is estimated to be 448 Mm^2 across all residential and non-residential building types for which Table ES1 presents a summary of the estimated proxy BACS sales floor area addressed by the base cases considered in Tasks 4 to 6
- the average installation cost for consumers is estimated to be €18.1/m^2
- 42.5% of the market value is estimated to be for BACS product and the remaining 57.5% for other aspects in the value chain
- an estimated 3% is due to maintenance costs
- the average energy performance of BACS already installed in EU27 buildings is between class D and class C but the most typical newly installed systems have class C energy performance
- there is considerable uncertainty about the near-term growth trends in the BACS market due to the unknown influence of the Covid 19 pandemic and other market key drivers including the influence of the amended EPBD provisions and the Renovation Wave.

In addition, the total EU27 building stock floor area is projected to grow as shown in Table ES2 below from 2020 to 2050. The average estimated price of installed BACS per unit floor area as a function of the building type and their energy performance class (under EN15232) is indicated in Table ES3. The estimated final energy consumption of technical building systems (TBSs) in the EU27 that is addressable by BACS is shown in Table ES4 for the base year of 2020.

Table ES1: Estimated EU27 annual BACS sales for 2020 expressed via proxy building stock useable floor area per Task 4 - 6 Base Case

Indicator	Base Case							
	BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8
EU27 annual BACS proxy sales area for each Base Case (Mm2) in 2020	58	63	21	23	12	10	17	14
Primary building type	SFH existing	SFH new	MFH existing	MFH new	Retail existing	Retail new	Office existing	Office new
EU27 annual BACS proxy sales area by corresponding primary building type (Mm2) in 2020	177	84	57	72	28	13	40	18
Base Case sales share of all the corresponding primary building type sales	37%	65%	42%	27%	47%	69%	45%	69%

Table ES2: Projected EU27 building stock to 2050 (derived from EBPD Impact Assessment)

Sector	Floor Area (Mm²)			
	2020	2030	2040	2050
Single Family Homes	10102	10831	11812	12788
Multi-Family Homes	7956	8653	9425	10193
Offices	1874	1979	2143	2328
Retail	1694	1790	1938	2105
Education	1137	1200	1300	1412
Other non-residential	4897	5172	5601	6084
Total Residential	18058	19484	21237	22981
Total Non-Residential	9601	10141	10981	11930

Table ES3: Estimated cost (final price paid by the procurer) of BACS as a function of the basic building reference case and the EN15232 energy performance class of BACS[66]

Related reference case	Single family house	Single family house	Multi-family apart-ment	Multi-family apart-ment	Retail outlet	Retail outlet	Office	Office
Age type	existing	new built	existing	new built	Existing	new built	existing	new built
BACS class	C	C	C	C	C	C	C	C
Product cost (€/m2)	1.5	3.0	1.5	3.0	7.0	7.0	9.0	9.0
Installed price (€/m2)	2.8	5.6	2.8	5.6	16.5	16.5	21.2	21.2
Related reference case	**Single family house**	**Single family house**	**Multi-family apart-ment**	**Multi-family apart-ment**	**Retail outlet**	**Retail outlet**	**Office**	**Office**
Building type	House	house	Flat	Flat	Shop	shop	office	office
Age type	existing	new built	existing	new built	Existing	new built	existing	new built
BACS class	A	A	A	A	A	A	A	A
Product cost (€/m2)	4.7	7.1	4.3	7.0	12.0	13.2	13.3	14.7
Installed price (€/m2)	11.1	16.8	10.1	16.5	28.2	31.1	31.2	34.6

[66] Note – these are not identical to the specific, more detailed, reference cases considered in Tasks 4-6 but are best estimates of the average cost of class C and class A BACS for the stated building types (existing/new low energy building, and SFH, MFH, Retail and Office). Prices are ex VAT.

Table ES4: Estimated EU27 final energy consumption by TBS for 2020 in residential and service sector buildings respectively

TBS	Final energy consumption (TWh)
Residential buildings	
Space heating	1679
Sanitary hot water	404
Space cooling	11
Ventilation	14
Lighting	NA
Service sector buildings	
Space heating	644
Sanitary hot water	294
Space cooling	116
Ventilation	53
Lighting	231

2.3 Placing BACS within the context of EU industry and trade policy

This section considers how BACS are placed within the context of EU industrial and trade policy. It begins with information on the building stock, then the general economic data required under the MEErP and subsequently considers other relevant data necessary to frame drivers of the BACS market. The reason to focus first on the building stock, and especially the floor area that is addressed by installed BACS sales each year, is that, as explained in Task 1, BACS functionality only comes into being when the product is installed. Therefore, the most important parameter for assessing the market is the floor area equipped with BACS of a certain energy performance level each year.w

2.3.1 Building stock data

For this study, the building stock can be characterised in terms of the useable floor area by principal building type. The most important building types in terms of total useable floor area are single family homes, multi-family homes, offices and retail outlets. For this reason, these four types are modelled in the base cases considered in Task 4. Excluding industrial buildings, non-residential buildings with the largest share of floor area are education buildings, hospitals and healthcare, hotels and restaurants and sports buildings.

The Commission's Building Stock Observatory[67] contains detailed data on the building stock. However, it is currently under review and data that were previously published have been withdrawn pending completion of the review process.

Data on the installed BACS per type of building can be related to the data on their floor area. By way of illustration, the floor area values for different types of non-residential building that were used in the 2016 Lot 37 Ecodesign preparatory study on Lighting Systems[68] are shown in Table 2-1.

Table 2-1: Estimate of the relative share of non-residential floor area across the EU28 for 2015 (source: Lot 3769).

Sector	Mm²	share [´%]
Education	1302	11%
Hotels & Restaurants	754	6%
Hospitals & Healthcare	907	8%
Retail & Wholesale	2382	20%
Offices	2115	18%
Sports	544	5%

[67] Building Observatory (2019) https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings/eubuildings

[68] http://ecodesign-lightingsystems.eu/documents

[69] Preparatory study on lighting systems 'Lot 37': Specific contract N° ENER/C3/2012-418 Lot 1/06/SI2.668525. VITO, WSE, VHK: 2016.

Implementing framework contract ENER/C3/2012-418 Lot 1 "Average EU building heat load for HVAC equipment", final report, René Kemna (VHK) for the European Commission, August 2014 (chapter 4, volumes and surfaces)

Industry	2461	21%
Other	1308	11%
Total Non-Residential	11773	100%

The EPBD's impact assessment study[70] includes estimates of the useable floor areas of the EU building stock for 2020. The originally published values were for the EU28 so they have been post-processed, using previously published information from the Building Stock Observatory on the floor area shares of each of the former EU28 member states, to derive the EU27 estimates shown in Table 2-2.

Table 2-2: Estimated EU27 building stock for 2020 (derived from the EBPD Impact Assessment)

Sector	**Floor Area (Mm²)**
	2020
Single Family Homes	10102
Multi-Family Homes	7956
Offices	1874
Retail	1694
Education	1137
Other non-residential	4897
Total Residential	18058
Total Non-Residential	9601

2.3.2 General economic data

In the MEErP generic economic data refers to data that is available in official EU statistics (e.g. PRODCOM) and the aim is to identify and report:

- EU Production
- extra-EU Trade
- intra-EU Trade
- and EU sales and trade = production + import – export.

Ideally, the information required for this subtask should be derived from official EU statistics in order to be coherent with official data used in EU industry and trade policy.

Packaged versus installed BACS products

[70] ECOFYS (2016) Ex-ante evaluation and assessment of policy options for the EPBD, Final report for EC DG-ENER

BACS are designed, sold, installed, commissioned, operated and maintained and as such they are 'products', but they are products which come into being on site as installed products. The installed BACS product is assembled on site from a subset of packaged BAC products and includes both hardware and software. Only packaged BAC products that are produced, shipped and imported or exported as a whole can be traced in any from within Eurostat trade statistics (Europroms-PRODCOM). Consequently, the installed BACS product which corresponds to the definitions used in this study (i.e. Task 1), is not distinguished as a product in the Eurostat production and trade statistics. As the functional unit used in this study is expressed in terms of useful building floor area, it is appropriate to consider the installed BACS product on the same basis i.e. in terms of the functionality that it provides per unit floor area for which it is installed. This means that the physical sales volumes (i.e. number of units sold) of installed BACS product can be expressed in terms of the additional floor area that is served (i.e. has BACS installed) to a given level of energy performance functionality per year.

Generic economic data

Generic economic data within the MEErP refers to data that is available in official EU statistics (e.g. PRODCOM) and in principle this could help to identify and report on the EU BACS product consumption and market size, especially for packaged BAC products. Moreover, in a later stage it could help to track the impacts of Ecodesign policy measures through analysis of the official Eurostat PRODCOM data. The text below presents a review of the applicable PRODCOM data and an assessment of how useful it could be for a BACS ED/ELR study and subsequent work to track policy impacts.

There are a wide range of BACS products and consequently of applicable product codes. A screening exercise was done for the BACS scoping study and revealed as much as 141 products that could contain BACS functions. These are products that might contain BACS but can also serve other functions, or no BACS function at all.

This remains a very generic list that does not contain sufficient disaggregation of BACS to provide useful data and therefore a suggestion for a future update of Eurostat product classes might be to add new subclasses 'for BACS', for example, in the view of the study team the product class:

26.51.70.15 Electronic thermostats

should be converted into two newly created categories, for example:

26.51.70.15 Electronic thermostats (n.e.c. = not elsewhere classified)

26.51.70.16 Electronic thermostats for room temperature control.

In this case electronic thermostats intended for use in ovens would remain in category 26.51.70.15 whereas those concerned with room temperature control would move over time to the 26.51.70.16 category.

As can be seen from the Annex in the scoping study there are a large range of product codes that would need to be amended to provide greater distinctions for the PRODCOM data on BACS products to be useful for Ecodesign/ELR purposes.

An overview picture with BACS functions and the different hardware levels in which it can be implemented is in Task 1 (Figure 1-1).

Also, it should be noted that the individual BAC components, hereafter referred to as packaged BAC products, are not always exclusively used for building automation purposes. For example, a BAC programming unit or temperature sensor can be used for an industrial process (e.g. oven control) and vice versa. This is likely to be important when considering potential product policy measures (in the MEErP Task 7), because they could have an impact outside the intended application area unless appropriately delimited.

By way of example, the PRODCOM EU27 production and trade statistics for electronic thermostats in 2019 are shown in Table 2-3. While the majority of these may be used for room temperature control applications there is no attribution to the function of these thermostats so the actual proportion attributable to room temperature control is unknown. Nonetheless, these values constitute an upper boundary.

Table 2-3: PRODCOM data for the production, import and export of electronic thermostats in the EU27 for 2019

No. of units				Value			
Production	Import	Export	Apparent market	Production	Import	Export	Apparent market
30,000,000	16,257,349	10,533,156	24,275,807	787,045,570	98,146,960	126,232,040	815,130,650

Conclusions

The range of packaged BAC hardware is very broad and so are their related functions in installed BACS. This poses a challenge in the preparatory study as were all potential product types (even just for installed BACS products) to be analysed using the full MEErP process the number and variety of product reference cases would be far too numerous to be practicable.

Note that 'Local Building Controls' (lBAC), were already included within the review study on Standby for Commission Regulation[71] (EC) 1275/2008 and could therefore be excluded from the BACS study.

It can also be concluded that the PRODCOM data is too generic to be useful for ED/ELR purposes and is mixed up with a large range of products and PRODCOM codes that serve other non-BACS related functions. In order to be useful, Eurostat codes would need to be reviewed and specific sub-categories 'for BACS applications' added.

2.3.3 Macro-economic and demographic data

The trends in Europe's population are available from Eurostat. Figure 2-1 shows how this has evolved for the EU27 from 2011 to 2020.

[71] http://www.ecostandbyreview.eu/

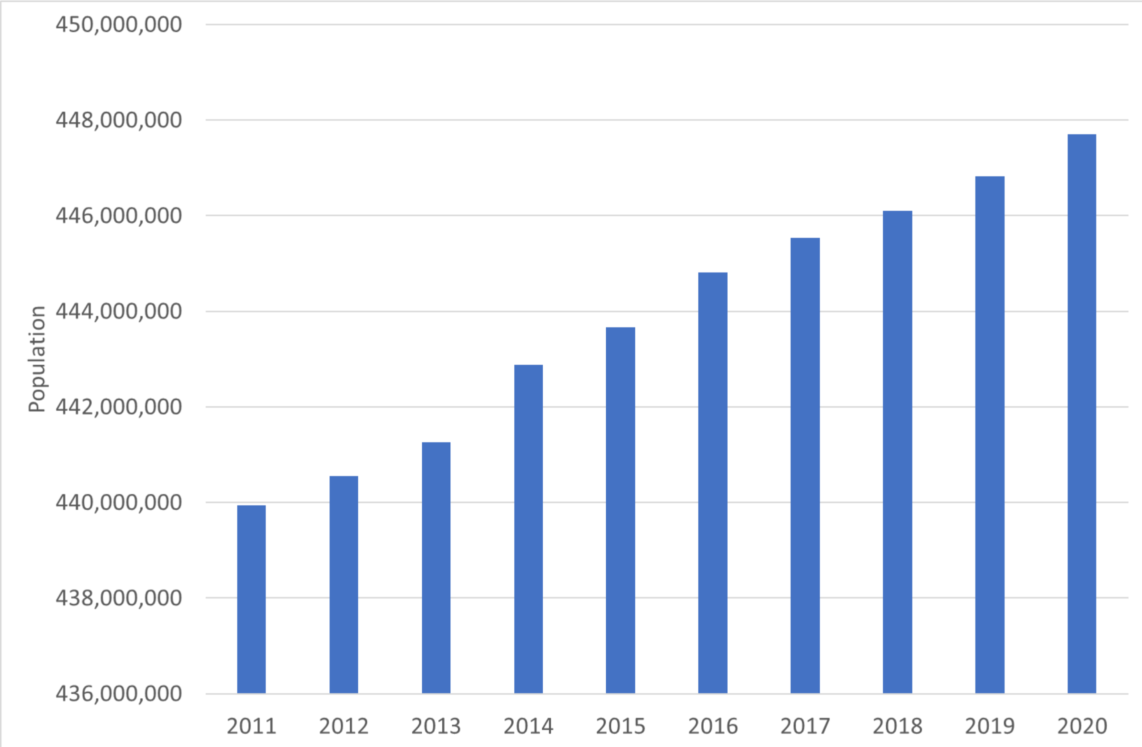

Figure 2-1: Evolution in the EU27's population (source: Eurostat)

GDP data is also available from Eurostat. Figure 2-2 shows how GDP per capita has evolved for a set of EU countries from 2000 to 2019. Both GDP/capita and population are important underlying drivers of BACS demand as discussed in subsequent sections.

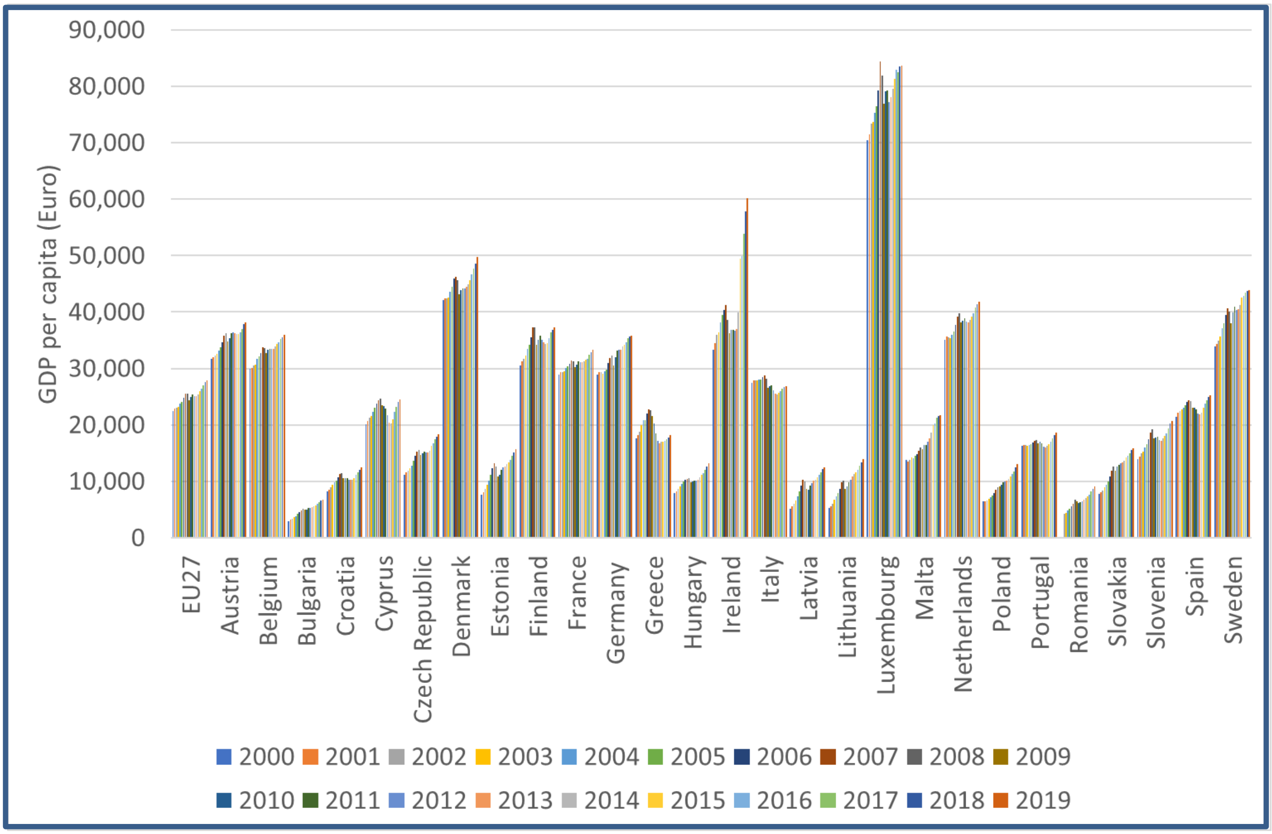

Figure 22: Real GDP per capita, growth rate and totals (source: Eurostat)

On average GDP per capita has increased by 1.2% per annum in the EU27 from 2010 to 2019. This rate of growth may be instructive for the future too as it traverses the period of the financial crash from 2007 and the associated economic disruption, thus it was also a period of economic contraction and recovery much as may occur in the years following the current pandemic.

2.4 Market and stock data

The objective of this task is to compile market and stock data in physical units (m²) for the EU-27 for the reference year 2010, combined with a forecast for presumable entry into force of measures for 2020-2030 (forecast, years in which all newly pending Ecodesign actions will be absorbed by the market). Therefore, the following parameters are to be identified:

- installed base ('stock') and penetration rate
- annual sales growth rate (% or physical units)
- average product life (in years), in service, and a rough indication of the spread (e.g. standard deviation)
- total sales/ real EU-consumption, (also in euros, when available)
- replacement sales (derived)
- new sales (derived).

2.4.1 Approach

The primary market size of interest to the Ecodesign MEErP approach used in this study is the size of additional building floor area addressed by BACS of a given energy performance functionality each year. The market value is also of interest, not least to determine costs and trends. As mentioned in section 2.1 PRODCOM data are not suitable to derive the sales of either installed BACS products or packaged BAC products. Consequently, it cannot be used to derive either installed BACS or packaged BACS stock and penetration rates, thus other approaches are required. Instead the approach followed to estimate the market size in both value and floor area terms is to combine all available sources and types of information and then reconcile them in a common accounting framework.

This section begins by considering the available sources of market data in terms of market value, then the information on the floor area addressed by BACS is discussed and then a value attribution process undertaken. These are then applied in subsequent sections to acquire the necessary stock, unit sales, cost, and lifetime data to be used in the subsequent MEErP tasks.

2.4.2 Market size estimates

This section reports on the general data available on the value of the European BACS market.

2.4.3 Information sources

The study team are aware of a variety of market research studies that attempt to address the size of the European BACS market or elements within it. None of these precisely match the geography, building sectors, or product scope of the current study and most are commercially available and hence are confidential. Thus, while some insights from these studies are known to the study team their values are not reported here directly.

2.4.4 National market data for Germany

The study team has received the following data on the size of the German national BACS market from VDMA[72].

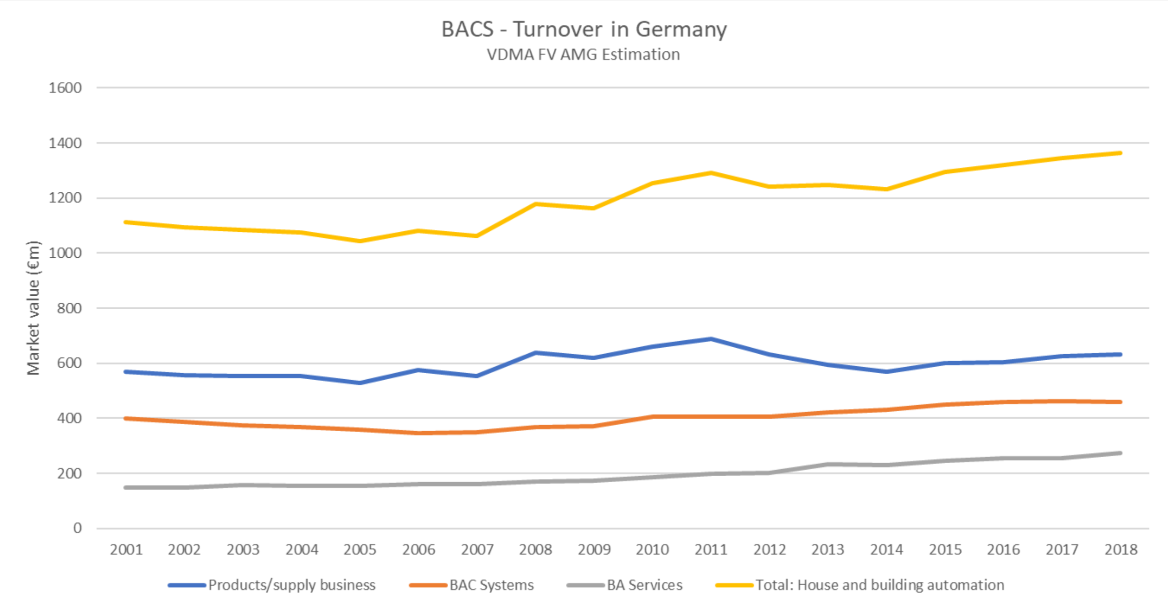

Figure 2-3 The value of the German BACS market (source: VDMA)

The data on the German market includes the residential sector, but it is not clear if it also includes non-energy related BACS services such as access, security and fire safety.

The other aspect of the German data is that it differentiates by products (i.e. BACS equipment for heating, ventilation and air-conditioning technology and pure heating applications), BAC systems (e.g. building automation: control technology, automation stations, field devices, switch cabinets and cabling, services) and Building Automation services.

2.4.5 Attributing market size to the BACS definitions and scope used in this study

The data sources previously alluded to are helpful but their scope is often not in line with the treatment of BACS in this study.

In general, market value sources make the following types of distinctions when discussing their market value figures:

- "BAC Product" - includes all types of direct digital control (DDC) controllers plus display panels, supervisory software and hardware, communication elements, programmable logic controls (where used in a building control application) and sensors at factory gate prices (i.e. first point of distribution). It excludes conventional controls, valves, actuators and variable speed drives.

[72] http://www.vdma.org/en/ueber-den-vdma

- “Total Product" - includes all BAC Product plus conventional controls, valves, actuators and variable speed drives at factory gate prices (i.e. first point of distribution).
- "BAC Systems" - includes “Total Product” plus electrical panels at engineered, commissioned and installed prices.
- “BACS Service and Maintenance” – includes the service and maintenance of BACS Systems plus any managed services associated with these
- "Total BACS Manufacturers Turnover" -includes the total sales turnover by manufacturers for all their “BAC Product", their value add (engineering, commissioning and installation), their maintenance and any managed services they provide that are associated with BAC Systems. It excludes other types of building services controls such as fire and security but may include some lighting controls systems where automated controllers are used.

These distinctions are important to understand the boundaries of what value is being discussed. In particular, the importance of each element in the value chain (distribution/wholesale, retail, design, integration/installation, service/maintenance, end of life) can be delineated. This also enables the final costs from the consumer/procurer perspective to be properly characterised and accounted for.

In addition, even if informal sources of market value data were to precisely match the scope of interest to the study, by being aggregate market value data across the BACS product group they are not sufficiently disaggregated to meet the purposes of the market and economic analyses required by the MEErP.

In consequence, there is a need to do the following:

a. map and attribute market size information to the reference case BACS solutions considered in Task 4
b. scale these up to reflect the proportion of the EU building stock which is concerned by these reference case installed BACS products
c. determine what proportion of the BACS market within the scope of this study is not directly addressed by the reference cases selected in Task 4
d. determine the extent to which the reference cases could serve as proxies for other parts of the market
e. scale-up the reference cases to derive market value and cost information for the entire EU BACS market in support of the analyses required in Task 7
f. clarify the nature of and quantify the value of the parts of the supply chain which are currently unaccounted for.

This exercise is considered to be the only viable way to develop the required level of detail necessary to derive the values required by the MEErP.

To facilitate this the study team developed and circulated a **survey questionnaire** among representatives of the BACS industry and the preparatory study stakeholder community, to allow the steps set out above to be completed. Findings from this survey are reported in the relevant sections below.

2.4.6 Mapping and attributing market size information to the Task 4 reference cases

As the functional unit used in the study is a square metre of the building stock the BACS market size can be apportioned to this by type and age of building. The basic framework applied in the study is shown in Figure 2-4. For these segments the BACS market can be distinguished based on sales for: new build, major renovations, or retrofit sales - each of which can be expressed in terms of the annual square metres of building floor area equipped with BACS[73].

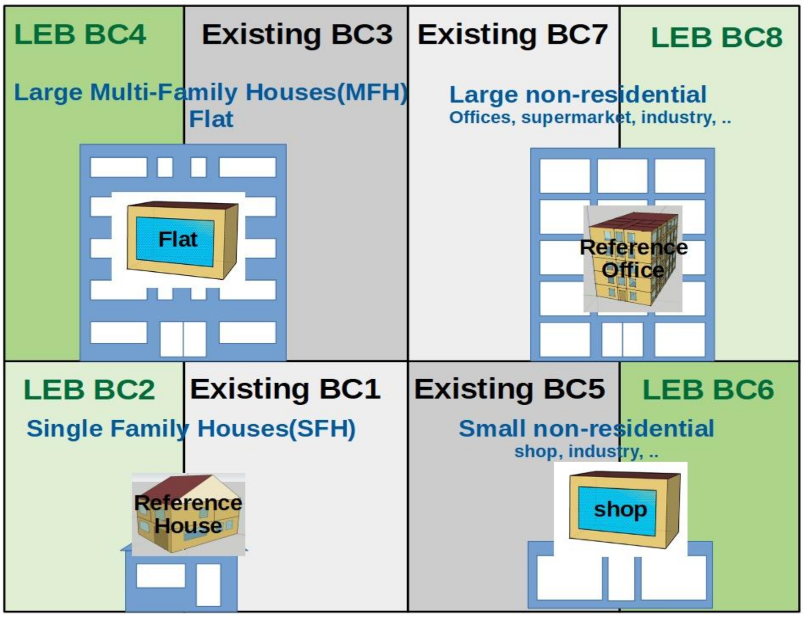

Figure 2-4: Summary of reference cases considered in this study

The building type reference cases considered in Task 4 are as follows:

- House (i.e. a Single-family house (SFH))
- Apartment (i.e. within Multi-family housing (MFH))
- Shop (i.e. a Retail outlet)
- Office.

These are then expressed in terms of existing buildings which have either been built or renovated since ~1980 and new low energy buildings.

In addition, the reference cases considered in Task 4 are further distinguished by the type of TBS systems they use, which further narrows down the proportion of the total BACS market floor area that they address.

[73] Note, while new-build and major renovations will entail entirely new BACS being installed, the retrofit market will entail a mix of complete reinstallations and partial reinstallations (e.g. in cases where just a subset of BACS product is replaced). Thus, the process used in this analysis is to ascribe a floor area for retrofit on an equivalent basis to a new installation.

A detailed analysis of the available data on the EU27 building stock floor area by these characteristics has been undertaken and gives the estimates shown in Table 2-4 for the year 2020. It should be stressed that this is mostly based on forecast floor area trends from the EPBD Impact Assessment (for the new build and major renovation values). The effective floor areas for the retrofit market are proxy values based on the presumption that the retrofit market accounts for a fixed share of the total market, derived using values informed by the stakeholder survey. Until recently the values for new build and major renovation floor areas had been relatively stable and ordinarily are presumed to remain so; however, this takes no account of the impact of the Covid-19 pandemic and so the actual values for 2020 could be quite different. The impact of the pandemic on future sales is considered in the market trends section.

Table 2-4: Estimated EU27 annual BACS sales for 2020 expressed via proxy building stock useable floor area per Task 4 - 6 Base Case

Base Case	BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8
EU27 annual BACS proxy sales area for each Base Case (Mm2) in 2020	58	63	21	23	12	10	17	14
Primary building type	SFH existing	SFH new	MFH existing	MFH new	Retail existing	Retail new	Office existing	Office new
EU27 annual BACS proxy sales area by corresponding primary building type (Mm2) in 2020	177	84	57	72	28	13	40	18
Base Case sales share of all the corresponding primary building type sales	37%	65%	42%	27%	47%	69%	45%	69%

Scaling to reflect the proportion of the whole EU27 building stock and other factors

It is estimated that the primary buildings corresponding to the base cases have proxy EU27 annual floor area sales as shown in the penultimate row of Table 2-5. Although these principal base cases cover the entire residential market they are missing key segments of the non-residential market. In floor area terms the other non-residential building types are estimated to correspond to annual proxy sales of ~118 Mm^2, although it is important to appreciate the density and hence value of installed BACS products per unit area may be somewhat lower than for the office and retail sectors.

2.4.7 Attributing market size to different parts of the BACS value chain

The distribution of revenues within the BACS value chain is likely to vary systematically for the large non-residential buildings market, the smaller non-residential buildings market, and the residential buildings market (single family homes and multi-family homes). In the residential and small non-residential building segments a proportion of the market will be via retail sales channels. Systems integrators will also be more prevalent than in the large non-residential buildings market - where turnkey solutions sold by a single vendor are more common. Sales through wholesale distribution channels will be a feature of the BACs market for both smaller and larger buildings.

Understanding the distribution of revenue by elements in the value chain is important to be able to derive stock and unit sales figures. This is because to do the mapping and attribution exercise discussed in step a) of section 2.2.1 there is a need to determine the typical costs associated with the reference installed BACS products in terms of their:

- components and hardware costs
- software costs
- design costs
- engineering, installation and commissioning costs
- service and repair costs
- end of life costs.

If these costs can be determined on an average normalised per unit area basis then it becomes possible to scale them up for the proportion of the building stock which is addressed by these installed BACS products.

It should be noted that there are various sources available which give an insight into these aspects.

As a starting template the Ecodesign Impact Accounting study[74] investigates the value chains of a variety of product groups. This data was recently post-processed in the 2nd Smart Readiness Indicator Technical Study[75] to establish estimates of the value chain breakdowns and to determine both employment and material circularity impacts for smart readiness technologies (SRTs). In practice, BACS are the dominant aspect in these SRTs and hence the SRT analysis should be a good proxy for the BACS market. The same study has derived estimates of the value of the SRT market under a set of reference (BAU) and policy scenarios (related to a set of different pathways under which the SRI could be implemented by the EU and Member States).

In the Ecodesign Impact Accounting study the value chain for product groups subject to Ecodesign regulations is broken down into the following elements:

- manufacture
- wholesale
- retail
- installation
- maintenance.

Interestingly, the proportion of value attributable to each is relatively consistent across business to business (B2B) product groups and equally for business to consumer (B2C) product groups. The analysis of the SRT value chain presented in the SRI study exploited this to make assumptions about the average breakdown of the final market value i.e. the

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[74] https://ec.europa.eu/energy/sites/ener/files/documents/eia_ii_-_overview_report_2016_rev20170314.pdf

[75] https://smartreadinessindicator.eu/

market value as paid by the final procurers of BACS. This resulted in the following assumptions for the distribution of the SRT final market value by value chain actor:

- manufacture = 42%
- wholesale = 10%
- retail = 11%
- installation = 35%
- maintenance = 3%.

These values are a blend of the value shares across the residential and non-residential sectors. These sectors will tend to have quite different value chain shares, i.e. retail sales will account for a larger share of total residential BACS market share than is the case for the non-residential sector, as mentioned previously. Furthermore, they may be incorrect and/or inappropriate for BACS so access to better data is required to have confidence in the value distributions to be expected for the installed BACs products considered in Task 4 and Task 6.

The study team has also received some old and confidential data that it has post processed to determine provisional market value shares as a function of the final BACS system sales value. This results in the following market value breakdown estimates:

- BACS product = 42%
- Engineering, installation, wiring etc. = 27%
- Additional third-party services = 31%.

Service and maintenance, which falls within the above breakdown, is valued at 18% of the installed systems market value for non-residential buildings. This figure is much higher than the typical EIA maintenance values alone, but can be explained by the much greater importance of the BACS-as-a-service business model whose value is incorporated in the higher figure. This service should not be confused with the actual maintenance costs.

While the proportion of systems value taken by product seems to be consistent across the sources the estimated maintenance value as a proportion of the systems value varies substantially, although this may be explained by the inclusion of BACS service business value as previously remarked.

2.4.8 Findings from the stakeholder survey

The survey findings were synthesised and the results reported below.

Market share by residential/non-residential

Opinions differed on this topic with some believing the residential market to be larger than the non-residential and others the inverse. The average response is about 50:50 i.e. that each is valued the same; however, when considering the likely visibility that the respondents have to the whole market (based on their business activities and geographic scope) the study team's interpretation is that the EU27 residential BACS market is likely to be slightly larger than the non-residential once the study's scope is applied.

Attributing market value share by BACS product type

Again, there was some variation among the responses, but the average estimated breakdown is expressed in Table 2-5.

Table 2-5: Estimate of the EU27 BACS market value share in 2020 by product

BACS product type	Share of market
Software	9.3%
Hardware	17.2%
Controllers	33.9%
Field devices	39.7%

Attributing market value to different parts of the BACS value chain

While there was strong consensus on the share of the BACS market value taken by the BACS product there was much more variation in responses regarding the parts attributable to Engineering/installation/Wiring and that due to Additional third-party services. It seems likely this difference is related to the differences in the nature of the business of the survey respondents and the visibility they have of the market. Taking this into account the best estimates derived from the survey responses are shown in Table 2-6.

Table 2-6: Estimate of the EU27 BACS market value share in 2020 across the BACS value chain

BACS value chain	Share of market
BACS product	42.5%
Engineering, installation, wiring etc.	34.5%
Additional third-party services	23.0%

Attributing market value to residential and non-residential sectors

The survey enquired if stakeholders agreed with the earlier suggestion based on VDMA data for the German market, i.e. that the residential sector accounted for 56% of the EU27 BACS market and the non-residential sector 44%. The responses ranged from those that agreed to those that thought the non-residential market was considerably larger than the residential. Again, the responses tended to correlate to the part of the market that the respondents serve and the range in reported values may simply reflect unintentional bias due to the market visibility each respondent has. Overall, the responses imply that the distribution of the market between the residential and non-residential is likely to be slightly greater for the non-residential.

2.4.9 Stakeholder survey market value estimates and derivation of the market value for the EU-27

Overall market value estimates from the stakeholder survey

The overall EU27 market value estimates for 2020 exhibited the greatest variation in responses, however, there was consensus that the market was considerably larger than estimated in the earlier analysis (presented in section 2.2.2.2 of the first version of this report). The average of the responses was €9.75bn, but there are reasons to think there could be some overcounting in some responses – perhaps due to inclusion of BACS functionalities that are outside the scope of this study and to applying a wider geography than the EU27.

Best estimate

Overall, after taking account of the different factors involved into account the study team have derived an overall EU27 BACS market value for 2020 of €8.1bn. This is the value paid by the final client. If the previously reported product value share of 42.5% is applied it gives a total BACS product value of €3.4 billion, with the remaining value due to engineering, installation, wiring etc. and additional third-party services. This value is determined through an effort to reconcile all the information sources in a common accounting framework and find the value which minimises the variation needed to reconcile the data sets; however, there is clearly some uncertainty about what the actual value is.

2.4.10 Market cost estimation

As previously discussed, the cost of installed BACS needs to be estimated on a per m^2 basis as a function of the energy performance of the BACS. Due to the complexity of the blend of physical products used in specific installed BACS products and the lack of disaggregated trade and stock data, a different approach from that applied in most Ecodesign preparatory studies is necessary to estimate the cost of installed BACS products. The approach adopted by the study team is as follows:

- determination of typical installed BACS products and reference cases, per the discussion in the Task 3 and 4 reports.
- mapping of BACS hardware and costs to these to derive a mix of the following:
  - average bill of hardware required (e.g. a breakdown of the number of each principal components required such as actuators, valves, sensors, meters, displays, controllers, etc.) for each typical reference case solution
  - the average cost of each hardware element within the bill of hardware
  - typical average hardware costs per unit area per BACS reference case (see discussion in Task 4)
- comparison of the bottom-up unit area costs derived above with data on typical costs for projects that match the reference cases and after adjustment to ensure consistency
- inclusion of cost/price data from the stakeholder survey
- conduct of the mapping exercises mentioned at the beginning of section 2.2 (i.e. steps a) to f)) and application of the data discussed above to derive bottom-up BACS product stock and costs estimates
- reconciliation of these with the top-down data to determine the average installed BACS prices as paid by the consumer.

The results for the specific base case values used in Task 4-6 are reported in section 4.3.4 of the Task 4 report. The estimated average consumer price of BACS by principal building type are reported in section 2.4.2 below.

2.4.11 Product lifetime data

As with other products the useful lifetimes of BACS will be dependent on the interaction between their physical lifetime and their useful functional lifetime. The latter will be dependent on:

- how valued the BACS function is considered to be in the market compared to newer emerging functionalities that may have been introduced since the product was installed i.e. the perceived functional obsolescence of the product
- the extent to which the perceived functional obsolescence of existing BACS can be overcome by upgrading e.g. via software updates, or replacement of specific parts or modules
- building renovation rates and the extent to which the existing BACS are jettisoned when a renovation takes place (this is likely to be linked to how major the renovation is)
- technical building system renewal rates and the extent to which the existing BACS associated with them are jettisoned when a TBS is renewed.

The above will depend on:

- the physical failure rates of BACS and their specific components
- the extent to which failure of a BACS component triggers the renewal of the entire BACS or simply the replacement of the failed component.

In the absence of detailed field data on this, the discussion with stakeholders has coalesced around a consensus estimate of 15 years average lifetime for BACS with a range of from a few years (if prematurely retrofitted, or if there is a software obsolescence/conflict, or for premature component failure) up to 30 years (the technical lifetime some BACS could achieve).

In addition, see the discussion on BACS lifetime in later Task 3 and 4 reports.

2.4.12 Addressable energy consumption

The energy consumption of the building stock which can be influenced by i.e. is addressable by, BACS is a key parameter that affects the total energy and costs savings potentials achievable by BACS.

BACS affect the energy consumed by technical building systems – space heating, water heating, air conditioning, ventilation and lighting but do not directly influence non-fixed plug loads. Unfortunately, there is currently no single set of EU data that is the reference for this and hence it has been necessary to derive values from a variety of sources. Firstly, the energy used by such TBSs is constrained by the total energy consumed by the residential and service sectors as reported in Eurostat statistics (most recently for 2018 for the EU27)[76] after correction to a normalised climate. Other key sources are:

[76] https://ec.europa.eu/eurostat/web/energy/data/database

- the Ecodesign Impact Accounting study[77]
- the EPBD Impact Assessment based on supporting analysis by Ecofys using the BEAM model[78]
- the Odyssee-Mure database[79]
- the Building Stock Observatory[80]
- a 2016 study by Fraunhofer of the total energy consumed by residential and tertiary sector buildings[81].

The Ecodesign Impact Accounting study provides detailed estimates of historical and projected energy consumption of equipment subject to Ecodesign regulatory requirements including equipment used for all of the relevant TBS end-uses. However, its scope is not exactly the same as this study's as it only addresses heating and cooling equipment with a capacity of up to 70kW and does not address district heating. Therefore, the values it reports will tend to be underestimates for these end-uses. On the other hand, for some end-uses (e.g. lighting) it includes estimates of equipment plug loads that are not addressable by BACS and hence are overestimates. It does, however, align with all other Ecodesign sources and helps set clear maximum or minimum boundaries. In addition, it projects these impacts to 2020 which is the accounting base year used in this study.

The EPBD Impact Assessment reports several building energy consumption values and projects them to 2050, including for 2020. Again, the breakdowns reported for each TBS are helpful but incomplete, as much of the required data is not reported in the Impact Assessment directly. Similar issues apply to the data reported in the other sources. Accordingly, the study team have post-processed the available sets of information to derive the estimated energy consumption by TBS. The results are reported separately for residential and non-residential buildings in Table 2-7. This data is consistent with the boundaries imposed by the Ecodesign Impact Accounting study and is aligned with Eurostat 2018 data projected to 2020 via trends analysis applied to the overall projected trend in the Ecodesign Impact Accounting values. While these values present the best estimates based on reconciliation of the above sources there is some uncertainty in their precision.

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https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20200626-1#:~:text=In%202018%2C%20households%20accounted%20for,and%20derived%20heat%20(8.7%25).

[77] https://ec.europa.eu/energy/sites/ener/files/documents/eia_status_report_2017_-_v20171222.pdf

[78] https://ec.europa.eu/energy/sites/ener/files/documents/1_en_impact_assessment_part1_v3.pdf

[79] https://www.odyssee-mure.eu/

[80] https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/eu-bso_en

[81] https://ec.europa.eu/energy/sites/ener/files/documents/Report%20WP1.pdf

Table 2-7: Estimated EU27 final energy consumption by TBS for 2020 in residential and service sector buildings respectively

TBS	Final energy consumption (TWh)
Residential buildings	
Space heating	1679
of which electricity	*250*
Sanitary hot water	404
of which electricity	*122*
Space cooling	11
Ventilation	14
Lighting	NA
Service sector buildings	
Space heating	644
of which electricity	*189*
Sanitary hot water	294
of which electricity	*83*
Space cooling	116
Ventilation	53
Lighting	231

2.5 Market trends

The objective of this task is to identify market trends such as:

- general market trends (growth/ decline, if applicable per segment), trends in product-design and product-features;
- market channels and production structure; identification of the major players (associations, large companies, share SMEs, employment);
- trends in product design/ features, illustrated by recent consumer association tests (valuable, but not necessarily fully representative of the diversity of products put on the market).

2.5.1 Trends in product design and features

The BACS market has traditionally been focused on serving the control needs of HVAC (heating, ventilation and air conditioning equipment), such that current BACS provide fully integrated building controls on a single platform and related media service. This is intended to optimise the usage of building service functions whenever they are required. This service, of intelligent networking of all building systems improves energy efficiency, integration of renewables and provides better human experience and comfort. There has been an ongoing trend of convergence across information communication and technology (ICT) industries with the building technologies industry and this is creating improved functionality at lower costs.

Most companies servicing the BACS market offer complete integrated systems that can control all relevant building systems on a single software platform and a platform as a service approach.

Asides from the traditional players in the BACS market some large IT companies have started to provide products and services, especially in the home market, and this is reported to be encouraging the traditional incumbents to adopt more innovative business models. This included the adoption of open source platforms that can allow different applications to operate on them. Interoperability of building automation systems is thus a growing trend.

In the non-residential sector, office and health sector sales are reported to continue to be the largest segments of the market, with education sector buildings also being important.

Relatively recent developments which are already having a major impact on the nature of BACS technologies are:

- the advent of enhanced energy efficient, environmentally conscious and indoor environmentally conscious data management and analysis capabilities
- control of BACS through smart devices
- networking of BACS on the cloud
- converged technology allowing all devices to be controlled using a single IP-based communication control.

In the near future these are likely to be joined by artificial intelligence (AI) and voice-over-control technologies that will facilitate greater user interaction with the BACS. Predictive capabilities allowing better performance optimisation are also set to improve.

2.5.2 Trends in BACS energy performance classes

The EN 15232-1:2017 standard defines BACS energy performance classes that range from D to A and that are an expression of the degree of sophistication that the BACS functionality provides. An example are the specifications for heat generation and heat pumps (Figure 2-5) wherein the shaded areas indicate the extent to which the described functionality attains the higher energy performance classes. A summary of these BACS energy performance classes and associated BAC factors is provided in the Task 4 report.

			Definition of classes			
			Non residential			
			D	C	B	A
1.6	Heat generator control (combustion and district heating)					
	0	Constant temperature control				
	1	Variable temperature control depending on outdoor temperature				
	2	Variable temperature control depending on the load				
1.7	Heat generator control (heat pump, outdoor unit)					
	0	On/Off-control of heat generator				
	1	Multi-stage control of heat generator capacity depending on the load or demand (e.g. on/off of several compressors)				
	2	Variable control of heat generator capacity depending on the load or demand (e.g. hot gas bypass, inverter frequency control)				

Figure 2-5: Requirements for heat generation and BACS classes according to EN 15232-1:2017

A detailed breakdown of the estimated distribution of average BAC factors by building type (based on processing confidential industry data on the proportion of buildings having a specific BACS energy performance class) across the EU are reported in the appendix of WSE (2018)[82]. Stakeholders were asked to comment on these values in the survey and reported that they considered them to be credible with the exception of the ventilation values that were reported to be too high. Accordingly, these have been lowered in line with the survey respondent recommendations. The estimated values for 2020 are reported in Annex A. From these it is clear that the average energy performance of BACS in the existing building stock is between class D and C bar a few specific exceptions. Nonetheless, class C is believed to be the most common performance level of new installations and is hence used as the reference case in the Task 4 to 6 analyses.

2.5.3 Market value trends

This section reports on the general market trends (growth/ decline, if applicable per segment) as well as trends in product-design and product-features.

2.5.4 Drivers of BACS sales

To understand the likely trends in BACS sales its necessary to first understand the drivers and their relative importance.

The growth in the BACS market is understood to be driven by a focus on energy-efficient and environmentally friendly buildings combined with the increasing adoption of automated security systems and other automated systems (e.g. fire safety). This leads to the desire to be able to control the ensemble on a common platform. There is also a

[82] The impact of the revision of the EPBD on energy savings from the use of building automation and controls, WSE for eu.bac (2018), https://www.eubac.org/cms/upload/downloads/position_papers/EPBD_impacts_from_building_automation_controls.pdf

strong impact from economic growth and the frequency of building cycle trigger events which are now discussed in turn.

2.5.5 Impact of economic growth

Historically, the value of BACS sales has been strongly correlated with economic growth such that the per capita spend on BACS has been proportional to the nominal GDP per capita. For example, a study by Waide Strategic Efficiency[83] reports the following relationship:

$BACS\text{-}Sales_{Capita} = 0.9095 * \exp(0.0876 * GDP_{Capita})$

where:

- $BACS\text{-}Sales_{Capita}$ is the value (in Euro) of per capita sales of BACS in service sector buildings in a given European country
- GDP_{Capita} is the average gross domestic product per capita (in Euro) of the European country in question.

Thus, all other factors being equal the BACS market could be expected to continue to follow this kind of relationship as economies and GDP per capita evolve. However, expenditure is also expected to evolve in response to the key drivers of public policy (especially that related to energy performance and climate change) and the emergence of new products and services.

There seems to be a general consensus in the trade literature that the drive towards greater energy efficiency in the EU's building stock is the key driver of market growth for the non-residential sector and may also be for the residential sector.

Other key trends include the advent and increasing penetration of the Internet of Things (IoT), Big Data, and cloud platforms. The associated solutions are shifting from traditional centralised platforms to distributed ones that integrate various inputs and outputs from different systems. These are further facilitating the collection and processing of a huge amount of building related data, which permits the analysis of energy usage trends and optimisation of the building's energy performance including via predictive analysis.

2.5.6 Impact of building and equipment cycle trigger events

Sales of BACS are strongly correlated with key building trigger events such as new build and major renovations. To a lesser extent they can be driven by the sale of individual technical building systems (TBS) and their replacement cycles. It should be noted that while part of these TBS sales are driven by major building renovations, a larger part is driven by replacement sales due to TBS failures, or to a desire to update the TBS. In addition, some part of the BACS sales are also be driven by replacement sales due to a BACS failure or to a desired BACS upgrade. These sales not triggered by a major building renovation, are called retrofit sales.

Previous (older) market estimates have indicated that for the non-residential market about 45% of BACS sales are associated with new-build, 34% with building refurbishment and 21% with retrofit, but these shares will be contingent on the underlying new build and refurbishment rates, as well as the strength of retrofit market drivers; and may well have evolved in recent years. Study team dialogues with industry stakeholders have

[83] http://www.leonardo-energy.org/white-paper/building-automation-scope-energy-and-co2-savings-eu

revealed that the share of sales taken by retrofit might be higher than this e.g. 40% for residential markets and 33% for non-residential markets.

In the case of failures, the replacement is most likely to simply result in replacing a failed BACS component rather than a whole new BACS installation; however, such moments (triggers) can also be an opportunity to take a decision to upgrade the BACS as a whole (i.e. to retrofit).

The Smart Readiness Indicator study examines these triggers in some detail and attempts to quantify the effects. It takes as its starting point the historical data and projected data of the EPBD Impact Assessment on new build and building renovation rates, and adds additional layers on TBS replacement rates from relevant sources, such as the Ecodesign Impact Assessments for different types of HVAC equipment.

2.5.7 Projected BACS sales

2.5.7.1 Projected market values

All market projections reported in the trade press are positive with annual average growth in market value of between 2.6% and up to 7% being reported; thus, there seem to be a range of projected growth rates where the actual trend will likely depend on the strength of the drivers and inhibitors for sales. Historical growth rates seem to be slightly slower than this e.g. the VDMA data shows that the BACS market in Germany had an annual average growth rate of 2.7% from 2007 to 2018; however, this value is probably lower than it would have otherwise been due to the impacts of the financial crisis. In fact, the BACS market seems to have only been modestly affected by that crisis. The fact that BCS sales continued to grow in this period suggests that other drivers were strong enough to compensate for the impacts of a downturn in construction and, hence, may also be suggestive of a relative resilience during the current pandemic compared to the construction sector as a whole.

Prior to the Covid 19 pandemic there was a conviction in the BACS sector that growth rates in the coming years would exceed the historic levels. At the time of writing, EU Member States are in the midst of the pandemic and its impact on the market outlook is far from clear. Most Member States have experienced a significant decline in GDP and in construction sector activity, which would be expected to depress demand for BACS. Conversely, there may be a greater need to retrofit AC/ventilation systems which could increase demand for BACS. Furthermore, the duration of these effects is highly uncertain. Should effective remedies to the virus be developed and applied in the coming months/year then the impacts may be relatively temporary. Thus, it is too soon to say to what extent economic activity will be suppressed compared to historic trends in the future. Thus, in the absence of clearer data it seems most prudent to ignore the impact of the pandemic for the purposes of this study as the scenarios considered in Task 7 are projections to 2045. If this assumption needs to be changed, this can be done in the context of an impact assessment linked to a proposed ecodesign measure.

2.5.7.2 Projected stock and unit sales

The projected trends in stock and unit sales are necessary for the Task 7 scenario analyses. In principle, there are two available methods to do this;

- The bottom-up approach, where the stock drivers, such as building renovation rates etc. are projected into the future and then the associated unit sales and impacts on the stocks are derived from them; and,

- The top-down approach, where projections of the market value are used to derive sales.

This section presents information on both top-down market value growth forecasts and evolution of the building stock drivers, but the approach used to reconcile these and derive stock and unit projections is discussed in the scenario section of Task 7.

Note that several studies[84] have tended to coalesce around a business-as-usual BACS deployment rate of 1.2% per year; however, these do not take account of the impacts of the 2018 revisions to the EPBD. If account is taken of the provisions in the amended EPBD this is likely to be too conservative, especially for the segment addressing larger non-residential buildings to 2025.

Work has already been done to project the EU's building stock into the future for the recent impact assessment in support of the revised EPBD[85] and these assumptions can be used as the reference to project the building stock into the future (up to 2050) in the Task 7 scenario analyses. Table 2-8 reports these values after they have been adjusted from EU28 to EU27 values in line with the methodology used for Table 2-3.

Table 2-8: Projected EU27 building stock to 2050 (derived from EBPD Impact Assessment)

Sector	Floor Area (Mm^2)			
	2020	2030	2040	2050
Single Family Homes	10102	10831	11812	12788
Multi-Family Homes	7956	8653	9425	10193
Offices	1874	1979	2143	2328
Retail	1694	1790	1938	2105
Education	1137	1200	1300	1412
Other non-residential	4897	5172	5601	6084
Total Residential	18058	19484	21237	22981
Total Non-Residential	9601	10141	10981	11930

[84] Including: *ECOFYS & WSE (2017) Optimising the energy use of technical building systems – unleashing the power of the EPBD's Article 8, https://www.ecofys.com/files/files/ecofys-2017-optimising-theenergy-use-of-tbs-final-report.pdf*

VITO et al (2018) Support for Setting-up A Smart Readiness Indicator for Buildings and Related Impact Assessment: Final Report, VITO, Waide Strategic Efficiency, Ecofys, Offis for DG Energy, https://smartreadinessindicator.eu/1st-technical-study-outcome

WSE (2014) Building Automation: the Scope for Energy and CO2 Savings in the EU, Waide Strategic Efficiency Ltd, http://www.leonardo-energy.org/resources/249/building-automation-the-scope-forenergy-and-co2-savings-in--57f7a23e8b452

[85] ECOFYS (2016) Ex-ante evaluation and assessment of policy options for the EPBD, Final report for EC DG-ENER

These building stock projections are derived from underlying assumptions about new build, retirement and renovation rates. The latter, in particular, are sensitive to the policies adopted by Member States and the strength of stimulus offered to renovate their buildings.

2.5.8 Market channels and actors

There are two primary sales channels to the market used by BACS manufacturers: direct and indirect sales. For large and high-end buildings/projects direct Turnkey solutions predominate where a single supplier provides the whole solution. This makes accountability easier and often brings some economies of scale resulting in lower costs and greater reliability. At the other end of the market, i.e. smaller buildings, systems-integrators are predominant. It should also be noted that a certain part of the market, will be installed by building owner/occupiers themselves. This is more prevalent in the residential sector. It is hard to quantify this as it is not visible to commercial actors other than those that sell packaged BAC products, but it will be limited to products that are easy to install by amateurs/building-managers and hence will be modest in size.

A 2015 BSRIA study[86] estimated the global HVAC controls related supply chain market share for each sales channel to be as shown in Table 2-9. Older market data suggests that about 70% of the EU non-residential BACS are sold directly to the end-customer/building and 30% indirectly. Thus, the current situation is likely to be quite different from the data shown in the table.

In principle, this kind of information could be used to inform and complement the earlier supply chain value discussion of section 2.2.2.1; however, this would necessitate having accurate values for the European market which are not reported in this source.

Table 2-9: BSRIA estimate of market shares by sales channel

Sales channel	Market share
Mechanical contractor/installer	22%
Energy service/Facilities Management Company	4%
Controls contractor/systems integrator	27%
Reseller/Wholesaler/Distributor	13%
OEM	9%
Direct with end-customer/building	21%
Sales to maintenance businesses	4%

The study team's discussions with market actors have shown that most only have visibility of the sales channels through their own business operations. However, taking this exercise further seems to be unnecessary, as there is a seeming consensus that on average BACS product accounts for ~42.5% of the installed cost. This is sufficient to

[86] Cited in https://www.slideshare.net/BSRIA/bsria-world-market-intelligence-industry-briefing-ahr-expo-2016

determine the supply chain value distribution necessary for the Task 7 scenario impact analyses.

2.5.9 Manufacturers and trade associations

The major BACS suppliers are:

- Siemens Building Technologies Ltd
- Honeywell Technologies S.à.r.l.
- Johnson Controls, Inc.
- Schneider Electric Buildings AB
- Kieback & Peter GmbH & Co.

The first four of these have been reported to account of 54% of the non-residential market in value terms. Other important suppliers are cited in the list of eu.bac members shown below.

Eu.bac[87] are the principal BACS trade association representing the product manufacturers (and in most cases also provision of full turnkey solutions and related services). They claim their members account for 85% of the European BACS market by value.

The list of members is:

Member	Head office
BELIMO Automation AG	Switzerland
Caleffi	Europe
Centraline	Europe
Comap SA	France
Danfoss A/S	Denmark
Delta Dore SA	France
DISTECH CONTROLS SAS	France
Fr. Sauter AG	Switzerland
Frese A/S	Denmark
GFR - Gesellschaft für Regelungstechnik und Energieeinsparung m.b.H.	Germany
HERZ Armaturen GmbH Österreich (Zentrale)	Austria
Honeywell Technologies S.à.r.l.	Switzerland
IMI Hydronic Engineering	Germany
Johnson Controls, Inc.	Belgium
Kieback&Peter GmbH & Co. KG	Germany
LOYTEC electronics GmbH	Austria
Oventrop GmbH & Co. KG	Germany
Priva B.V.	Netherlands
Saia-Burgess Controls AG	Switzerland
Schneider Electric Buildings AB	Sweden
Siemens Building Technologies Ltd.	Switzerland
Somfy	Switzerland
Theben AG	Germany

[87] https://www.eubac.org/about/current-members/index.html

Thermozyklus GmbH & CO. KG	Germany
Trend Control Systems Ltd.	Great Britain
Tridium Europe Ltd.	Great Britain
WAGO Kontakttechnik GmbH & Co. KG	Germany

Other relevant associations are:

REHVA (the federation of European, Heating, Ventilation and Air Conditioning associations)[88]

EHI (European Heating Industry) association[89]

EPEE[90] - European Partnership for Energy and the Environment, an association representing the refrigeration, air-conditioning and heat pump industry in Europe.

Eurovent[91] - the European association for indoor climate, process cooling and food cold chain technologies.

Europump[92] - the European pump manufacturer's association.

EVIA - European Ventilation Industry Association.

Lighting Europe[93] - the European lighting industry association.

EHPA – European heat pump industry association

2.6 Consumer expenditure

2.6.1 Objectives

The objective of subtask 2.4 is to establish for each of the product categories defined in Task 1 (and subsequently Task 4) the following:

- average EU consumer prices, incl. VAT (for consumer/procurer prices)/ excl. VAT (for B2B products), in euros
- consumer prices of consumables
- repair and maintenance costs (euro/product life)
- installation costs (for installed products only)
- disposal tariffs/ taxes (euro/product).

These are discussed in the subsequent sections.

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88 https://www.rehva.eu/

89 http://www.ehi.eu/

90 https://www.epeeglobal.org/

91 https://eurovent.eu/

92 https://www.europump.org/

93 https://www.lightingeurope.org/

2.6.2 Average consumer prices

In keeping with the functional unit used for this study the average costs for BACS is reported on a per m2 of useable building floor area basis. In order to derive this, the study team conducted a survey of BACS sector stakeholders to ascertain the typical per m2 costs that would apply for class A and class C BACS as a function of the building type they are installed in.

The results of this survey were complemented by a literature review to provide a reality check on the answers received and the findings were then post-processed to produce the averaged values reported in Table 2-11. Note these are the average values for the basic type of building (single family home, multi-family home, retail outlet or office) differentiated for an existing building or a new building. However, these cases do not correspond to the detailed specifics of the BACS, reference buildings and HVAC configurations considered in the Task 4 to 6 analysis. In addition, the BAT cases in Task 4 do not always correspond to Class A performance levels. Further work was done in those tasks to derive the cost values cited for the specific reference cases analysed in Task 4 to 7. Nonetheless, the values in Table 2-10 are indicative of the types of costs to be expected for class C and class A BACS in general within these building segments.

Table 2-10: Estimated cost (final price paid by the procurer) of BACS as a function of the basic building reference case and the EN15232 energy performance class of BACS[94]

Related reference case	**Single family house**	**Single family house**	**Multi-family apart-ment**	**Multi-family apart-ment**	**Retail outlet**	**Retail outlet**	**Office**	**Office**
Age type	existing	new built	existing	new built	Existing	new built	existing	new built
BACS class	C	C	C	C	C	C	C	C
Product cost (€/m2)	1.5	3.0	1.5	3.0	7.0	7.0	9.0	9.0
Installed price (€/m2)	2.8	5.6	2.8	5.6	16.5	16.5	21.2	21.2
Related reference case	**Single family house**	**Single family house**	**Multi-family apart-ment**	**Multi-family apart-ment**	**Retail outlet**	**Retail outlet**	**Office**	**Office**
Building type	House	house	Flat	flat	Shop	shop	office	office
Age type	existing	new built	existing	new built	Existing	new built	existing	new built
BACS class	A	A	A	A	A	A	A	A
Product cost (€/m2)	4.7	7.1	4.3	7.0	12.0	13.2	13.3	14.7
Installed price (€/m2)	11.1	16.8	10.1	16.5	28.2	31.1	31.2	34.6

[94] Note – these are not identical to the specific, more detailed, reference cases considered in Tasks 4-6 but are best estimates of the average cost of class C and class A BACS for the stated building types (existing/new low energy building, and SFH, MFH, Retail and Office). Prices are ex VAT.

2.6.3 Consumer prices of consumables

The energy prices (with a base year of 2016) are taken to be the same as those reported in the Task 2 report of the Ecodesign study for Water Heaters[95] - see Table 2-11.

Table 2-11: Energy prices for a base year of 2016 to be used in Tasks 5 and 6

Electricity residential (BC1-4)	0.205 €/kWh (incl. VAT)
Electricity for non-residential (BC 5-8)	0.1104 €/kWh (ex. VAT & non recoverable taxes)
Natural gas residential (BC 1-4)	0.064 €/kWh (incl. VAT)
	17.778 €/GJ (incl. VAT)
Natural gas non-residential (BC 5-8)	0.030 €/kWh (ex. VAT)
	8.334 €/GJ (incl. VAT)

2.6.4 Repair and maintenance costs

Estimating the repair and maintenance costs of BACS is very challenging due to their extremely diverse nature. The study team discussed this topic with numerous industrial and commercial practitioners and have settled on an average maintenance cost of 3% of the CAPEX.

2.6.5 Installation costs

The installation costs have already been discussed and are reflected in the difference between the installed price and product costs reported in Table 2-8. In essence the average costs of installation are a factor of (1-0.425)/0.425 = 1.35 of the BACS product costs.

2.7 Recommendations

The market analysis of BACS is challenging due to their functionality only taking form when they are installed on site. Even in the case of packaged BAC products it is challenging to have unambiguous market information due to the lack of adequate differentiation in national and PRODCOM trade statistics. Currently, it is not possible to distinguish packaged products destined for BACS applications from those intended for other applications. It is therefore recommended that more detail be added to the trade statistic definitions to enable packaged BAC products to be distinguished in line with the suggestions made in section 2.1.1 of this report.

[95] https://www.ecohotwater-review.eu/documents.htm Tables 24-26 in Task 2

3 MEErP Task 3 User Behaviour and System Aspects

3.1 Aim of Task 3

The objective of Task 3 is to present an analysis of the actual utilization of BACS in different applications and under varying boundary conditions.

Therefore, this task will:

- analyse users, procurers and installers behavioural practices;
- identify the barriers and opportunities for BACS products and systems
- make recommendations for a refined product scope and on the barriers and opportunities for Ecodesign.
- provide inputs and assumptions for the assessment in later tasks of the environmental impact and cost of the product and how the standard measurement conditions may vary. Any related variation from the measurement conditions specified in standards will also be identified.

3.2 Summary of Task 3

This task includes a proposal for 8 reference buildings to consider in the subsequent Tasks 4 to 6, for which a graphical overview is included in Figure 3-1 Herein LEB stands for a new low energy building with high level insulation and air tightness and the existing building represents a more average building with double glazing and insulation. Clear data for defining the average existing EU27 house is missing[96] and therefore also a poorer insulated version is added that can be used for a sensitivity analysis. The technical details and assumptions for these reference buildings are described in this report.

This task report also explains how indirect energy savings obtained with BACS can be calculated in line with EN 15232 with the aid of BACS efficiency factors (f_{BAC}), which are defined as:

Total Energy demand BACS planned = f_{BAC} x Total Energy demand BACS Class C

Wherein class C is an average performing I.e. Business-as-Usual BACS.

Following the detailed method of EN 15232, this study will also calculate its own BACS efficiency factors in Task 4 for a set of buildings and BACS functions. For this calculation it is necessary to analyse all energy flows for heating and cooling within a building; more details on the method are given in this task report.

This task also discusses lifetime and repair from a user perspective, which are important input to analyse a least life cycle cost optimization in Task 6.

[96] Most countries still have incomplete and/or poor data coverage of the existing stock (6/2020): https://ec.europa.eu/energy/eu-buildings-datamapper_en

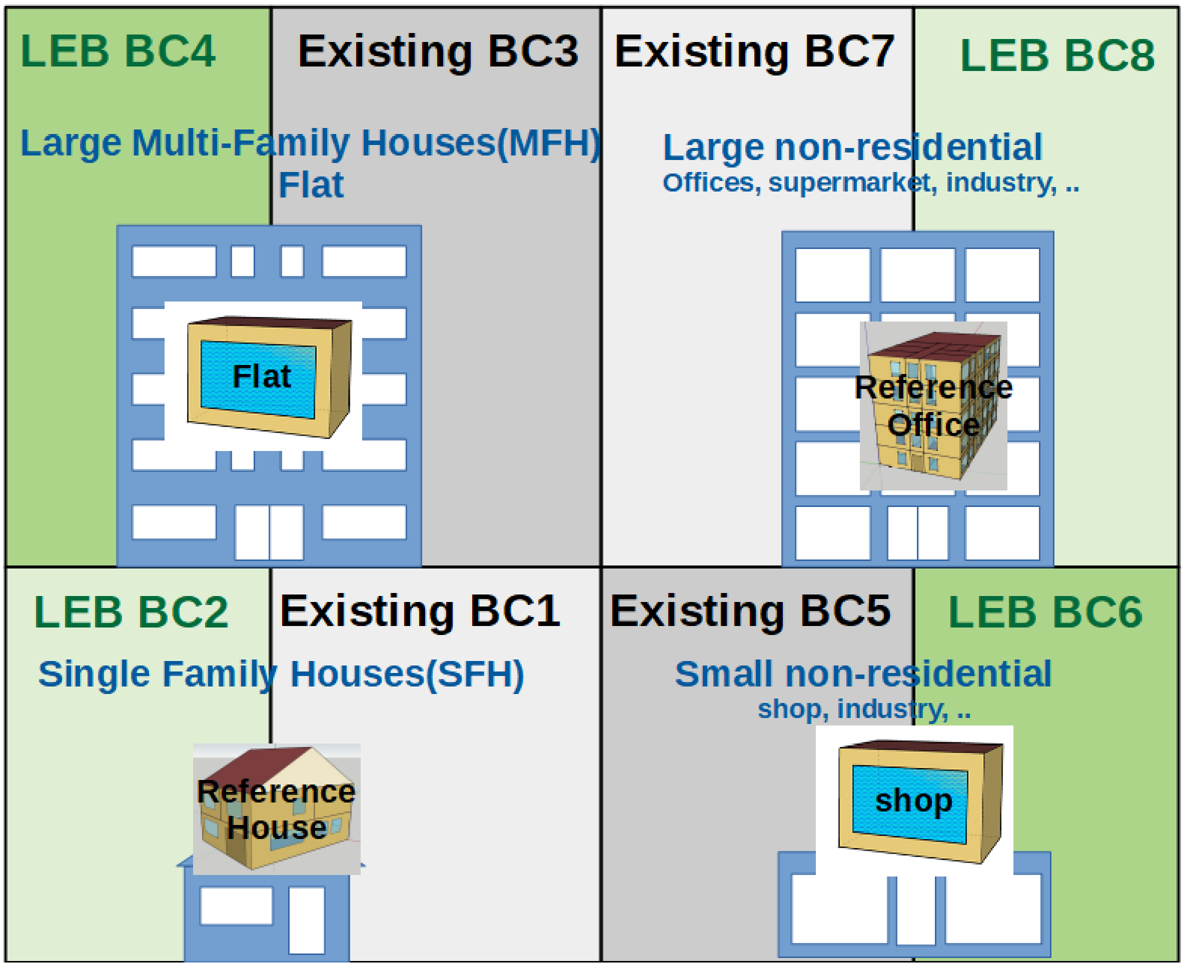

Figure 3-1: Overview of the eight base case reference buildings for this study

3.3 How to define MEErP system aspects of BACS

This section defines some of the relevant system aspects and terminology related to the MEErP methodology[97] followed in this study.

3.3.1 Introduction and definition of direct and indirect energy impacts

For the purpose of introducing the MEErP methodology[97] the concepts of: Energy related Products (ErP) with direct impact, ErP with indirect impact and ErP with direct + indirect impact, are illustrated in Figure 3-2.

The MEErP proposed that in principle, three large groups of products can be distinguished:

- products that are using energy during the use phase (hereafter referred to as 'direct ErP'),
- products that - in the use phase - do not use energy but have a significant impact on the energy consumption of products that are using energy (hereafter referred to as 'indirect ErP'),

[97] http://www.meerp.eu/

- the combination of both.

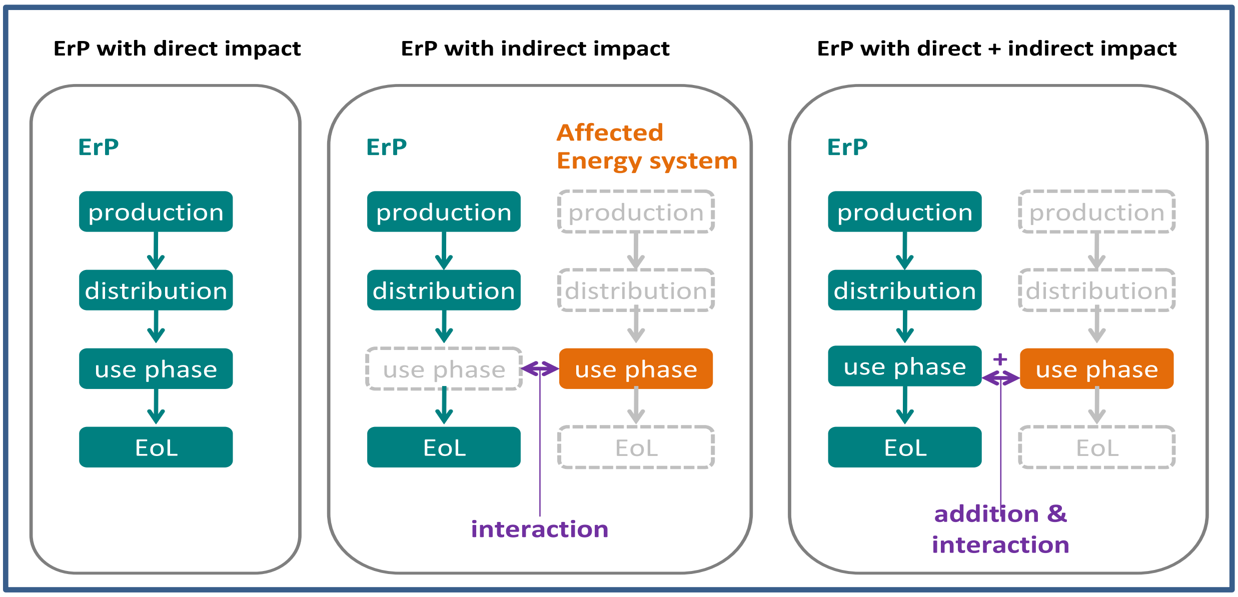

Figure 3-2: Diagram illustrating how the system boundaries can be extended (Source: MEErP, 2011)

The MEErP defines the following set of potential product scope levels:

- strict product approach: In the strict product approach, the system boundary just contains the BACS hardware. Nominal operating conditions would apply as defined in traditional standards
- extended product approach: In the extended product approach, the influence of usage and real-life deviations from the test standard will be considered
- technical system approach: When viewed from the technical system perspective, the BACS is embedded in the surrounding building system
- functional approach: In the functional system approach, the basic function is maintained.

The latter fits better with the primary function of a BACS as defined in Task 1, which is to control the Technical Buildings Systems (TBS) in order to maintain thermal comfort, sanitary hot water (SHW), indoor air quality (IAQ) and lighting parameters for the health, productivity and comfort of the occupants (per EN ISO 17772-1:2017).

3.3.2 Proposal for application of system boundaries within this study

The MEErP does not include a strict, nor a clear, definition of what is a product or a system. Because this study is concerned with 'BACS' functions, this study will follow **the functional approach** and the so-called **indirect impacts** refer than to the **energy consumption of the building**. Hence, reduction of the energy consumption of the building, while respecting the indoor comfort requirements, will be the leading parameter considered in Task 6.

The MEERP guidance (2011) refers to **direct impacts** as those related to energy consumption in the use phase, for BACS this is **the BACS internal energy**

consumption of the BACS (See Task 1)., Consideration of other indirect impacts is also possible. For example, the impact of BACS on local on-site production.

In order to provide a clear analysis in the subsequent tasks it is necessary to **provide a clear BACS boundary definition**, which is not evident or easy when following the functional approach, because it entails an abstraction from the hardware in which it can be embedded. Nevertheless, the underlying hardware will matter when considering, for example, the least life cycle cost optimization to be done in Task 6 and/or to account for self-consumption. Hence considering these hardware related issues, this study proposes to define the **BACS boundary** as that which incorporate the **BACS function**[98]**, needed to move from the functionality required to belong to EN 15232 class C to a higher class B or A**.

For examples and illustration one can consult Task 1.

3.3.3 Reference buildings for this study

In order to collect and discuss real user data in Task 3 and later on in Task 4, the development and selection of some reference BACS applications is necessary. This includes the types of building and TBS configurations. These reference buildings, together with some selected BACS in Task 4, are used as MEErP Base Cases in Tasks 5 to 7. Under the conditions of the contract it has been agreed that eight BACS base cases will be modelled in Tasks 5/6.

As the purpose of this study is to build on the EN 15232 standard, the standardised room and applications defined in Annex C of that standard will serve as the main reference building. This is a simple single-zone "shoe box" model, see section 3.3.3.1. which will therefore be used as much as possible. In order to better account for the large variety of actual buildings (see Task 2) a reference semi-detached Single Family House (SFH) and an office building are also added. These are better suited to consideration and modelling of multi-zone building applications and their related BACS functions. The EN 15232 standardised room will serve to model a flat in an apartment building and a retail area application. For modelling a large multi-zone non-residential building an office building was selected because these account for an important proportion of total non-residential building floor area and energy use (see Task 2).

All buildings will be allocated to one of the 3 EU climates as defined in the MEErP, and explained in section 3.6.1.

For all reference buildings we will consider two variants:

- a newly constructed state of art Low Energy Building (LEB)
- an existing, previously renovated, building.

Clear data and predictions for defining the average existing EU27 house[99] in which BACS will come on the market in 2025 is missing but we assume that many will have this basic insulation. Note that considering the stock in the year 2025 is important because it would be around this time that any policy measures arising from this study would be likely to come into effect. Nonetheless, even by 2025 it is likely a substantial part of the stock will still have poorer insulation levels and to cover this data gap another more poorly

[98] See definition in Task 1

[99] Most countries still have incomplete and/or poor general data coverage of the existing building stock (6/2020): https://ec.europa.eu/energy/eu-buildings-datamapper_en

insulated reference building is defined to check potential impact on the conclusions in Task 6, see also section 3.6.2.

3.3.4 The 'shoe-box' flat or shop reference building from EN 15232

The BACS standard EN 15232-1 already defines a reference building which is a simple "shoebox-model" (Figure 3-3), it consists of one thermal zone that has the following properties:

- Dimensions: 5x4x3 m
- Floor surface: 20m²
- Outer wall:
  - surface 15 m² with window 8 m²
  - Orientation: west
- Thermal capacity: medium C= 50Wh/m²K.

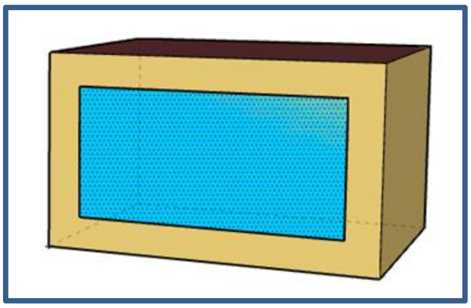

Figure 3-3: Shoe-box reference building from EN 15232

Not specified in EN 15232, but assumed for the sake of completeness in this study are:

- Window 2 m height and 4 m long
- Window 0.5 m above the floor area
- There is assumed to be no shading from nearby trees or buildings.

Detailed building plans are given in Annex B.

3.3.5 A more complex multi-zone, semi-detached house for a residential reference building

In order to be able to analyse the impact of BACS on the energy demand of an important part of the building stock a sample home is chosen as one of the simulation reference buildings. The study team have opted for a generous, semi-detached home[100], with three bedrooms and an attic with a pitched roof. The expectation is that the total consumption

[100] This is a reference building used Flanders(B) to asses EPBD requirements: https://www.energiesparen.be/sites/default/files/atoms/files/verslag_REN_20150703.pdf

and the energy performance of this home will be in between those of an apartment and a detached home. The characteristics of the reference building chosen are as follows:

- The rear wall is south-facing and the side wall faces east.
- The gross floor area is 187 m² and net floor area 150 m², while the insulated and heated volume is 548 m³.
- The south wall measures 39 m², 20% of which is glazed.
- The east wall measures 64 m², 20% of which is glazed.
- The west wall is a common wall with the neighbours.
- The north wall measures 42 m², 15% of which is glazed.
- It is assumed that there is no shading from nearby trees or buildings.

Detailed building plans are presented in Annex C.

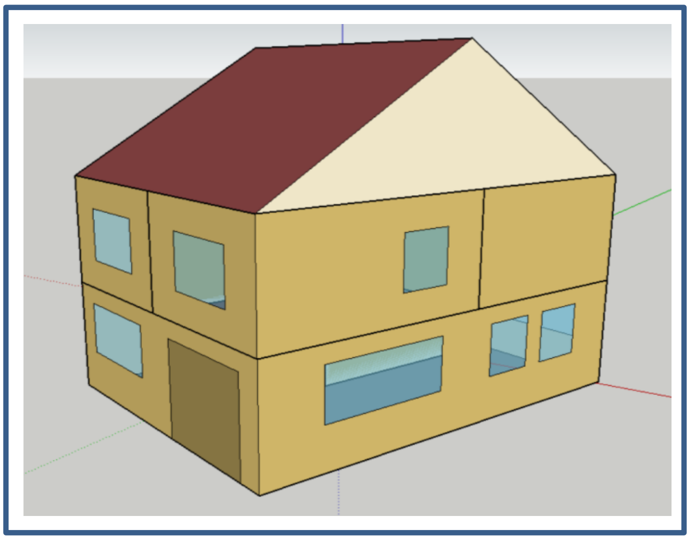

Figure 3-4: 'House' reference building used in this study

3.3.6 A more complex multi-zone non-residential office building

Based on the market data of Task 2 and in line with the previous Ecodesign Lot 37 study on lighting systems an 'office' reference building is also defined for further analysis. This building was selected to be of a sufficient size to be representative of offices as a whole and it uses, to the extent possible, the reference office rooms from the Lot 37 study, i.e. a cellular office, an open plan office and corridor. In addition, lunch, storage, rest and meeting rooms have been added.

The characteristics of the reference building chosen for simulation are as follows:

- The entrance wall is south-facing.
- The net floor area is 2000 m² and the protected volume is 2000x2.5 m³.
- The south wall measures 242 m², 18% of which is glazed.
- The north wall measures 242 m², 15% of which is glazed.

- The west wall measures 425 m², 42 % of which is glazed.
- The east wall measures 425 m², 35 % of which is glazed.

Detailed building plans are presented in Annex C and D.

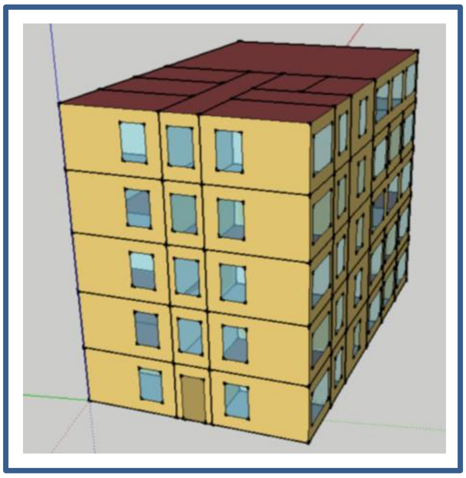

Figure 3-5: 'Office' reference building used in this study

3.3.7 Scope of Technical Building System proposed for Tasks 4 to 6

Task 1 established that the primary function of a BACS is to control the Technical Buildings Systems (TBS) in order to maintain thermal comfort, sanitary hot water (SHW), indoor air quality (IAQ) and lighting parameters for the health, productivity and comfort of the occupants.

As the introduction to Task 1 explained this study cannot analyse all BACS for every type of TBS combined with all types of buildings, therefore to select TBS for Task 4 to 6 the following factors were considered:

- The TBS for lighting has already been elaborated in Lot 37[101] hence the BACS relevant parts of Lot 37 will be post-processed and integrated directly into Task 7.
- Domestic Hot Water (DWH), also known as Sanitary Hot Water (SHW), is a relatively self-standing part that can operate independently from heating and cooling and was already considered in previous Ecodesign studies for the product and smart appliances. Hence results from existing studies can be integrated directly into Task 7.
- Photovoltaic systems[102] and battery energy storage systems[103] were also already part of previous Ecodesign preparatory studies and here also results can be directly integrated into Task 7.

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[101] http://ecodesign-lightingsystems.eu/

[102] https://susproc.jrc.ec.europa.eu/solar_photovoltaics/index.html

[103] https://ecodesignbatteries.eu/consortium

- Please note these studies have already proposed relevant minimum information and interfacing requirements for BACS and applicable policy measures could already be decided before this study is concluded.

3.4 Indirect impact of BACS on energy demand in the use phase

The objective of this section is to identify, retrieve and analyse data and report on the environmental & resource impacts during the use phase for ErP with an *indirect* energy consumption effect. The scope, calculation approach and terminology used, are as much as possible in line with EPBD-related EN standards[104] but are simplified as much as possible for the purposes of this study.

3.4.1 Approach for modelling the indirect building energy consumption in the use phase

An important question for this study is to consider how to calculate and assess the indirect impact which BACS can have on reducing the primary energy demand of a building. The two methods set out in the EN 15232 standards are discussed below and, based on this, a proposal is made for how to address this effect within the Task 4 to 6 analyses, in accordance with the MEErP methodology.

3.4.2 The detailed approach to model energy savings from BACS - method 1 in EN 15232

The standard EN 15232-1:2017 refers to the individual EPBD standards and their secondary parameters for calculating detailed impacts on the energy needed, wherein three generic approaches are used:

- The **time approach** (E = P.Δt.kctr) which can be used when the control system has a direct impact on the operating time of a device (e.g. control of a fan or a luminaire). For example, standard EN 15193-1:2017 on lighting follows this approach. Herein, the following parameters are typically used:
  - E is the energy consumption for the time period
  - P is the input power of the controlled system
  - Δt is the duration of the time period
  - kctr is a characteristic coefficient which represents the impact of the control system.
- The **setpoint approach** (E = ktrans ·((ϑset + Δϑctr) −ϑref) Δt) which can be can be used when the control system has a direct impact on control accuracy, i.e. the deviation between the controlled variable and the corresponding setpoint. For example, EN ISO 52016-1 on energy needs for heating and cooling follows this approach. Herein, the following parameters are also defined:
  - ktrans is a transfer coefficient
  - ϑset is the setpoint which shall be maintained by the control system
  - Δϑctr represents the impact of the actual control system

[104] https://epb.center/documents/

- ϑ ref is a reference value, e.g. temperature e.g. the outside temperature
- ϑset + Δϑctr is called the equivalent setpoint.

- The **Correction coefficient approach** (E = Eref·kctr) when the control system has a more complex impact e.g. a combined effect on time, temperature etc. In this case the following parameters are defined:
  - Eref is the energy consumption in the reference case
  - kctr is the correction coefficient which represents the increase or decrease of energy consumption as compared to the energy consumption Eref of the reference case.

EN 15232-1:2017 includes a reference list to the individual standards to be used to calculate detailed impacts.

3.4.3 The simplified method from EN 15232 i.e. the BAC factor method 2

The impact of BACS functions from an energy class on a building's energy demand is established with the aid of BACS efficiency factors (f_{BAC}) whichprovide a simplified method to estimate savings. 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:

Total Energy demand BACS planned class = f_{BAC} x Total Energy demand BACS Class C

The annex of the standard provides some reference values that can be applied to the following components of the energy balance with a set of three BACS factors ($f_{BAC, H}$, $f_{BAC, C}$, $f_{BAC, el}$) see standard EN 15232, wherein:

- Q H,nd is the heating energy needs of the building
- Q H,ls is the energy losses of the heating system
- Q DHW,nd is the Sanitary Hot Water needs for the building
- Q DHW,ls is the Sanitary Hot Water losses for the building
- Q C,nd is the cooling energy needs of the building
- Q C,ls is the energy losses of the cooling system
- W H, aux is the electrical auxiliary energy for heating
- W C, aux is the electrical auxiliary energy for cooling
- W V, aux is the electrical auxiliary energy for ventilation

Energy use		Energy need[a]		System losses[b]	Auxiliary energy[c]	BAC factor
Heating	=	$Q_{H,nd}$	+	$Q_{H,ls}$		$f_{BAC,H}$
			+		$W_{H,aux}$	$f_{BAC,el}$
Cooling	=	$Q_{C,nd}$	+	$Q_{C,ls}$		$f_{BAC,C}$
			+		$W_{C,aux}$	$f_{BAC,el}$
Ventilation	=				$W_{V,aux}$	$f_{BAC,el}$
Lighting[d]	=				W_L	$f_{BAC,el}$
DHW	=	$Q_{DHW,nd}$		$Q_{DHW,ls}$		$f_{BAC,DHW}$

Figure 3-6: Relations between building energy systems and BAC efficiency factors

Note: a, b, c, d refer to the respective standards to be used for calculating these values which are respectively EN ISO 52016-1, EN 15316+ EN 15255, EN 15316+ EN 15241+ EN 15193-1, EN 15193-1)

3.4.4 Proposed approach to be followed within this study

To address the indirect energy savings effects of BACS it is proposed to follow a hybrid of Method 1 and Method 2. Task 4 will compute the BACS efficiency factors (f_{BAC}) defined in the simplified Method 2 based on literature or simulations following the detailed Method 1 for an individual or a specific set of BACS function.

The consideration of building envelope elements and their influence on the energy performance of buildings will depend on the calculation methodologies applied. In order to apply the detailed Method 1 the study team will calculate the so-called building energy balance. It is the approach used within the EPBD set of standards which takes into account both energy losses on one hand versus the internal heat gains (IHG) from passive capture of solar irradiance, lighting, persons and appliances on the other. When there is an imbalance between the 'internal heat gains (IHG)' and the losses the building will need more, or less heating.

Tasks 4/6 will technologically assess which BACS options can best control the TBS of the reference buildings while maintaining their functional Unit (see Task 1). The highest BACS classes B and A are designed do thiswith a minimum of final energy demand For example they may achieve this by using a thermostat with a night time set back temperature when the building is unoccupied or with demand driven ventilation.

Therefore, the analysis will also consider Energy balance losses for heating/cooling, as follows:

- Q,T transmission losses or the heat lost through the building envelope
- Q,V ventilation losses or heat lost through mechanical ventilation and infiltration.

In addition, the analysis will also have to address other Internal Heat Gains (IHG) which are:

- Q H,S IHG from solar radiation or heat replacement from solar radiation
- Q,P IHG from people in the building.

This can be combined with the parameters defined previously in the simplified method, see 3.4.3. Using this energy balance, the heating, cooling and other auxiliary energy needs can be calculated and therefore the related BACS factors or energy savings too. How this all works collectively is illustrated in Figure 3-7. It is based on partial energy flows for gains and losses that collectively form the energy balance of the building. These partial energy flows can be obtained from building simulation tools and/or with measurements and thus, overall this approach provides a means for the impact of BACS improvement options to be assessed in Tasks 4 and 6.

To simplify the complexity of the analysis required to treat the ventilation and heating requirements this study will only calculate sensible heat requirements and neglect the latent heat requirements in Tasks 4 to 6. Latent heat requirements are related to air humidity . This is quite common practice in simplified EPC calculation methodologies; nevertheless it should be noted that it can have important effects in buildings with HVAC systems that include air humidity control. In principle, it also has some impact on the loading of cooling systems through dehumidification, transpiration and other effects but this will also be neglected in order to render the subsequent calculations manageable.

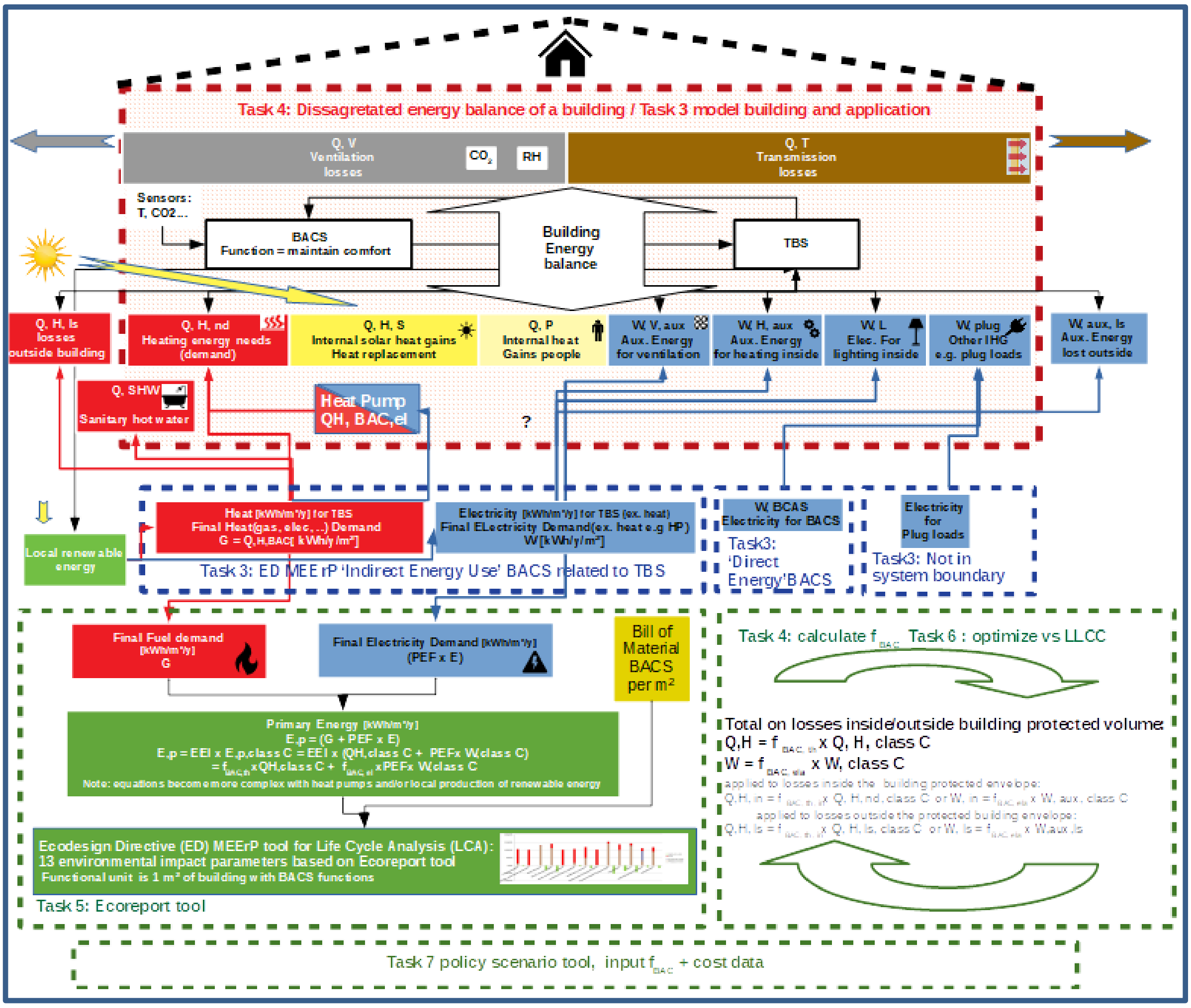

Figure 3-7: Approach for modelling the indirect impact from BACS on building energy needs by considering the disaggregated energy balance of a building and key parameters considered for modelling

3.4.5 Influence of usage parameters on indirect energy use

User behavior can have a large impact on the indirect energy saving impact of BACS. This section discusses the key parameters.

3.4.6 Influence from occupancy

Many of the previously discussed building energy flows are dependent on occupancy, e.g. minimum required ventilation rates.

For this reason, typical occupancy data is defined in the EN 15232 standard itself, which is aligned with other EPBD standards.

For the selected reference applications these are (see Annex C):

Office: with workday (5)/weekend (2) see

- Figure 3-4 for workday occupancy.

Retail: with workday (6)/weekend (1) see

- Figure 3-5. For workday occupancy.

Herein 'Normalized level of Occupancy (Y)' means how much occupancy is assumed relative to the maximum possible occupancy per m². Note, because persons produce heat (75-150 W) this has an impact on the Internal Heat Gains (IHG persons).

Under auspices of the EPBD set of standards, in principle, this occupancy data is defined in EN ISO 17772-1:2017 on "Energy performance of buildings — Indoor environmental quality — Part 1: Indoor environmental input parameters for the design and assessment of energy performance of buildings". The data used in this study is a simplified version of this, which has been adapted to be usable by simulation modelling tools used in the subsequent tasks. Note, similar values are also included in EN 15232-1 but the values for lighting and appliances used in this study have been reduced to account for recent energy savings in lighting and ICT equipment. Occupancy has also an impact on internal heat gains (IHG) from occupants and appliances used that will impact the needs for heating and cooling as illustrated in Figure 3-6, a summary of data proposed for use in later tasks is included in Table 3-1.

For residential buildings EN 15232 does not define an occupancy pattern, however for the purposes of this study a day/sleep zone occupancy ratio of (16h/8h) will be assumed, e.g. for demand driven mechanical ventilation.

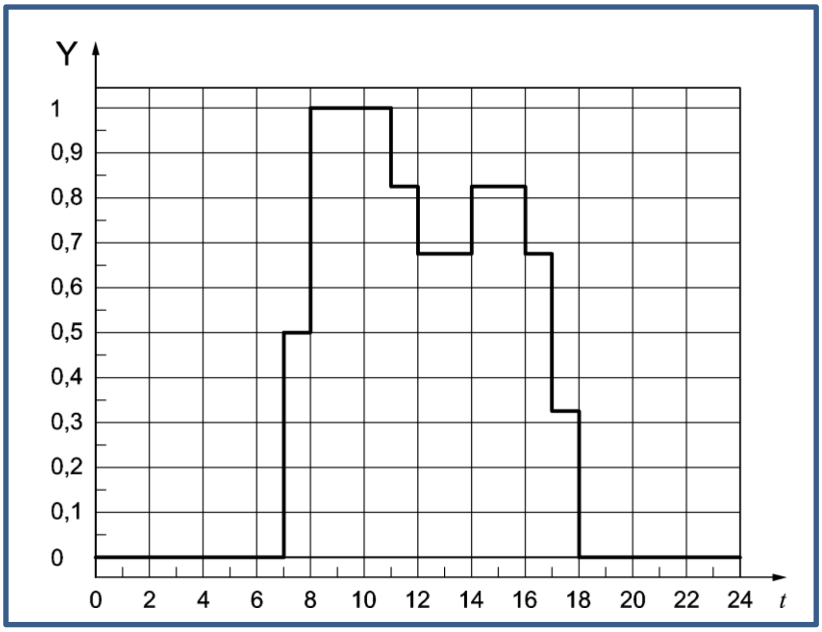

Figure 3-8: Normalised level of occupancy for an Office (source: EN 15232)

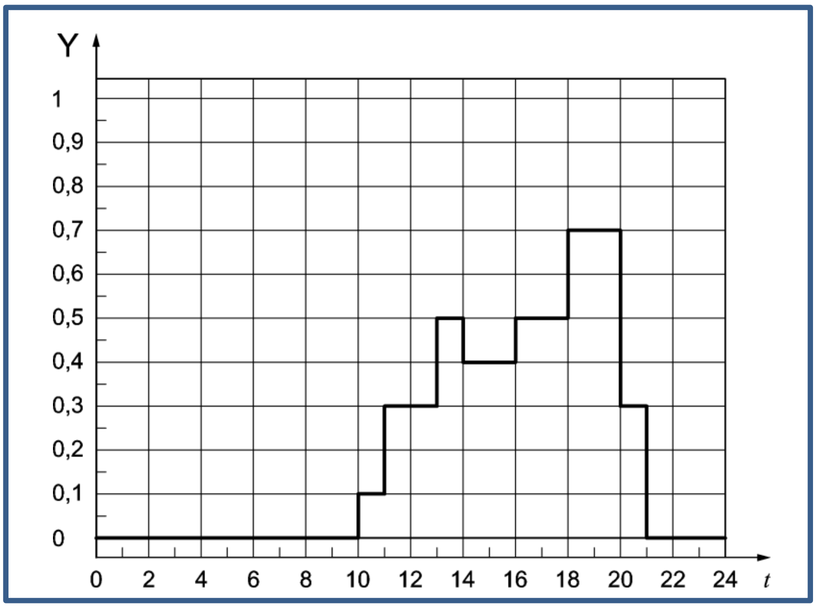

Figure 3-9: Normalised level of occupancy for a retail outlet (source: EN 15232)

Table 3-1: Assumptions made for internal heat gains due to persons and appliances related to occupancy

application	max. persons	heat emission per person	max. IHG appliances	max. IHG lighting	average occupancy (per 24h)	IHG tot persons yearly average	lights on Fd x FOC	max. air changes needed	Max. light for Energy plus
unit	m²/person	W/person	W/m²	W/m²		W/m² avg		per hour	W/m²
non residential									
single office	13,3	64	*8*	*7*	*0,23*	*1,10*	*0,14*	*0,75*	*4,20*
group office	*10*	64	*8*	*7*	*0,23*	*1,47*	*0,14*	*1,00*	*4,20*
cafetaria	*5*	64	*5*	*7*	*0,13*	*1,60*	*0,08*	*2,00*	*4,20*
storage room	*100*	64	*0*	*5*	*0,04*	*0,03*	*0,01*	*0,10*	*1,50*
circulation area	*50*	64	*0*	*5*	*0,67*	*0,85*	*0,67*	*0,20*	*5,00*
welcome desk	*10*	64	*8*	*10*	*0,67*	*4,27*	*0,40*	*1,00*	*6,00*
wholesale area	5	64	*8*	*10*	*0,14*	*1,76*	*0,08*	*2,00*	*6,00*
residential									
sleeping room	*10*	*64*	*2,5*	*2,5*	*0,33*	*2,13*	*0,33*	*1,00*	*2,50*
bathroom	*10*	*64*	*5*	*2,5*	*0,07*	*0,45*	*0,04*	*1,00*	*1,25*
living/kitchen	*20*	*64*	*10*	*3*	*0,60*	*1,92*	*0,18*	*0,50*	*0,90*
flat	*30*	*64*	*4*	*3*	*1*	*2,13*	*0,11*	*0,33*	*0,33*

Note: values in italic are missing in the standard and hence are the study team's own working assumptions. Lighting has also been updated to reflect the current situation.

3.4.7 Comfort set points and their user impact

Comfort requirements and particularly the temperature set points, are also important factors for BACS. Much of the expected energy savings in later Task 4 to 6 comes from BACS emission control function, set point and run time management, which are EN 15232 BAC function groups 1/1, 3/1, 7/1 and 7/2. Therefore these set point and occupancy assumptions will have much impact on the modelled savings. Comfort, economy and protection modes are defined in Task 1 and can be invoked by the BACS depending on occupancy.

Typical values for BACS are proposed in the informative annexes of EN 15232. An extract of these that can be applied to the reference buildings in this study is shown in Table 3-2 and Table 3-3. Obviously, class D BACS have no control mode possibilities and therefore no economy- or protection-mode set points. As one can see in Table 3-2, the higher heating set points for class D and C BACS already account for the relative lack of control which is inherent in such systems. f To a large extend this is related to user behaviour assumptions because skilled and aware users might in theory achieve the same results by operating these set points and schedules manually. In a large multi-occupant building one would assume that this manual control is very difficult to achieve. In practice it can be challenging even for a house; for example, the end-user would have to wake up early (7h) to open TRVs for starting heating up the living room. In a small residential house this might be possible but the standard does not account for this. Note also that occupancy patterns are aligned with those of the EPBD set of standards but in reality they might be higher or lower, for example due to Covid-19 the current(2020) office occupancy might be much lower.

Table 3-2: Comfort set points for heating per types of EN 15232 class of BACS (note: values in italic are missing in the standard and hence are the study team's own working assumptions)

	EN 15232 class D				EN 15232 class C				EN 15232 classes B and A			
application	operating time	comfort mode heating	Economy mode heating	Protection mode heating	operating time	comfort mode heating	Economy mode heating	Protection mode heating	operating time	comfort mode heating	Economy mode heating	Protection mode heating
unit		°C	°C	°C		°C	°C	°C		°C	°C	°C
non residential												
single office	0-24h	22,5	NA	NA	5- 21h	22	15	*8*	6-20h(B)/6-19h(A)	21	15	*8*
group office	0-24h	22,5	NA	NA	5- 21h	22	15	*8*	6-20h(B)/6-19h(A)	21	15	*8*
cafetaria	0-24h	22,5	NA	NA	*11-14h*	22	15	*8*	*11-14h*	21	15	*8*
storage room	0-24h	21	NA	NA	*16-17h*	*20*	*15*	*8*	*16-17h*	*21*	*15*	*8*
circulation area	0-24h	21	NA	NA	*5- 21h*	*20*	*15*	*8*	*5- 21h*	*21*	*15*	*8*
welcome desk	0-24h	22,5	NA	NA	5- 21h	22	15	*8*	6-20h(B)/6-19h(A)	21	15	*8*
wholesale area	0-24h	22,5	NA	NA	9-24h	22	15	*8*	10-23h(B)/11-22h(A)	21	15	*8*
residential												
sleeping room	*0-24h*	*20*	*NA*	*NA*	*0-24h*	*20*	*18*	*8*	*22-8h*	*21*	*18*	*8*
bathroom	*0-24h*	*22,5*	*NA*	*NA*	*0-24h*	*22*	*20*	*8*	*0-24h*	*21*	*19*	*8*
living/kitchen	*0-24h*	*22,5*	*NA*	*NA*	*0-24h*	*22*	*18*	*8*	*7-23h*	*21*	*15*	*8*
flat	*0-24h*	*22,5*	*NA*	*NA*	*0-24h*	*22*	*15*	*8*	*4-23h*	*21*	*15*	*8*

Table 3-3: Comfort set points for cooling per types of EN 15232 class of BACS (note: values in italic are missing in the standard and hence are the study team's own working assumptions)

	EN 15232 class D		EN 15232 class C		EN 15232 classes A/B	
application	operating time	comfort mode cooling	operating time	comfort mode cooling	operating time	comfort mode cooling
unit		°C		°C		°C
non residential						
single office	0-24h	22,5	5- 21h	23	6-20h(B)/6-19h(A)	23(B) / f(Tamb) (A)
group office	0-24h	22,5	5- 21h	23	6-20h(B)/6-19h(A)	23(B) / f(Tamb) (A)
cafetaria	0-24h	22,5	*11-14h*	23	*11-14h*	23(B) / f(Tamb) (A)
storage room	0-24h	21	*16-17h*	*20*	*16-17h*	*21*
circulation area	0-24h	21	*5- 21h*	*20*	*5- 21h*	*21*
welcome desk	0-24h	22,5	5- 21h	22	6-20h(B)/6-19h(A)	23(B) / f(Tamb) (A)
wholesale area	0-24h	22,5	9-24h	22	10-23h(B)/11-22h(	23(B) / f(Tamb) (A)
residential						
sleeping room	*0-24h*	*22,5*	*0-24h*	*23*	*22-8h*	*24*
bathroom	*0-24h*	*25*	*0-24h*	*25,5*	*0-24h*	*26*
living/kitchen	*0-24h*	*25*	*0-24h*	*25,5*	*7-23h*	*26*
flat	*0-24h*	*25*	*0-24h*	*25,5*	*4-23h*	*26*

3.5 End-of-Life behaviour

The subject of this section is the identification, retrieval and analyse of data, and reporting on consumer behaviour (average pan-EU behaviour) with regard to end-of-life aspects of BACS. It includes: product use & stock life, repair- and maintenance practice and other impact parameters.

3.5.1 BACS product life

The End-of-Life of the BACS is related to the technical BACS hardware and software but is also related to the technical lifetime of the Technical Buildings System (TBS) to which it is connected, and of the building.

The **End-of-Life of a BACS function will be a combination** of the following life times:

- **BACS software technical lifetime:** the BACS functional life can end when it is dependent on other software that stops functioning or its service expires, also called a software dependency
- **BACS hardware technical lifetime**: the life of the BACS function can end when the hardware fails on which it is embedded
- **TBS failure:** the BACS functional life can end or become obsolete when the TBS fails or is changed
- **Functional life of the building:** A BACS can become obsolete and be disposed of at the end of the functional lifetime of a building, this mostly occurs for deep renovations whereby a building undergoes significant construction work and is unoccupied for a significant period of time. Very often this also requires issuance of a new building permit.

In practice one can assume that **whatever is reached first** out of the previous list **will define the End of Life** of a BACS function, however with an exception of a like-for-like replacement of a failed TBS component.

It is very difficult to find typical lifetime data for BACS functions. Based on stakeholder input and our own estimates the values shown in Table 3-4 were elaborated for this study and can be used for cost analysis in Task 5 and 6.

In general software changes much more quickly than hardware, both for updates from manufacturers and third parties. The energy transition and other aspects of energy use/supply/storage external to the building make it very difficult to determine an accurate lifetime for software. Also, clients' agendas can change. In general, the following software updates exist and can impact the lifetime of BACS:

- regular updates (e.g. 6 monthly) for BACS functionality
- updates for cyber security in internet connected devices (IoT)
- Updates of the TBS interfacing software (e.g. new plugin[105], add-on[106], etc, ..) TBS when they are replaced
- changes in software platforms, necessitating updates, and which may have finite lifetimes themselves.

In this list the BACS software technical lifetime can be particularly complex to define when software dependencies are involved.

Best practices are discussed in the next section 3.5.2..

[105] https://market.jeedom.com/index.php?v=d&p=market&type=plugin

[106] https://www.openhab.org/addons/

Table 3-4: Assumed typical lifetime values for components that impact the lifetime of a BACS function

	BACS EMS software technical life time	BACS field valve devices technical life time	BACS actuators technical life time	BACS sensors technical life time	TBS failure	Functional life time of the building
unit	y	y	y	y	y	y
office building						
typ.	15	30	15-20	10-20	15	30
wholesale area						
typ.	15	30	15-20	10-20	15	20
residential building						
typ.	15	30	15-20	10-20	15	60

3.5.2 Repair & maintenance practice including best practices

To the study team's knowledge, the following repair and maintenance practices exist for BACS functions:

- Like for like replacement of the modular hardware, typically BACS functions are embedded on modular DIN rail hardware, see Figure 3-10 (single module) and Figure 3-11 (full installation). A DIN rail (Figure 3-12) is a standardized (EN 50022) metal rail used for mounting circuit breakers and industrial control equipment inside equipment racks.
- Much hardware allows for the reprograming of BACS functions and is therefore a multi-functional device, e.g. in KNX a software tool called ETS is available to configure the BACS.
- Some hardware components allow for the firmware to be upgraded, typically, for example, best in class IP KNX routers. Note, however, that this upgrading functionality is often limited by the amount of memory available inside the device. In particular internet connected devices could require frequent cyber security updates and therefore upgrading of the software.
- Today several BACS hardware configurations have software dependencies. A software dependency means that a program relies on other programs to work. The consequence is that when one program stops working it can stop other programs that are dependent. Therefore, the negative drawback is that this could reduce the BACS functional life in a way which might be hard to predict, an effect which is also commonly referred as the "software dependency hell" [107]. Also, the lifetime of devices might be reduced remotely when software

[107] https://en.wikipedia.org/wiki/Dependency_hell

dependencies are included to connect to a remote server over the internet[108,109], including regular updates for compliance with cyber security requirements.

- Best practices in data communication and software is to use open standardized and third party verified communication protocols and data semantics ensuring that software containing components can easily be replaced and repaired.
- A known failure of BACS outputs is the failure of electromechanical relays inside the BACS DIN rail modules, best in class hardware reported that modules can be sent back to the manufacturer to replace the relays. It is also possible for the installer to use relay sockets that allow a quick replacement, see Figure 3-13.
- The use of wireless BACS sensors can result in higher maintenance costs when a professional has to replace the battery. Therefore, best practice wireless sensors will use energy harvesting techniques[110]. Typically, wireless components are more energy-efficient, need less hardware installation (cables), and are easier to replace, upgrade and exchange.

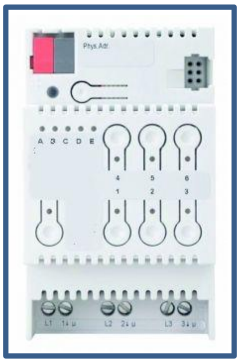

Figure 3-10: Example of a modular DIN rail BACS component that can embed part of the BACS

Figure 3-11: BACS hardware mounted on a DIN rail in an electrical control cabinet

[108] https://www.engadget.com/2020/01/30/sonos-smart-device-die/?guccounter=1

[109] OSRAM's LIGHTIFY system had serious lifetime limitations due their software dependency which in this case means a full functionality is given for 7 years or less The system was introduced in 2014 and on March 9 2020 OSRAM announced to switch off the related cloud server on August 31 2021.

[110] https://www.enocean.com/en/technology/energy-harvesting/

Figure 3-12: DIN rail to which modular components can be attached

Figure 3-13: Example of an easy to replace electromechanical relay mounted in a DIN rail socket to control an output for a BACS function

3.5.3 Recycling and disposal of the BACS

BACS hardware falls mostly under the WEEE Directive and is therefore collected and recycled as electronic waste. Data for Europe that is provided by each Member State in the new WEEE calculator tool has been brought together through the ProSUM project which resulted in the online Urban Mine Platform (www.urbanmineplatform.eu). To the study team's knowledge waste from BACS are not so far reported as large waste streams relative to other electronic waste.

Note, however, that Article 4 (a) of the WEEE includes provisions that exempt "large-scale fixed installations, except any equipment which is not specifically designed and installed as part of those installations'. Hereby 'large-scale fixed installation' means a large-size combination of several types of apparatus and, where applicable, other devices, which: (i) are assembled, installed and de-installed by professionals; (ii) are intended to be used permanently as part of a building or a structure at a pre-defined and dedicated location; and (iii) can only be replaced by the same specifically designed equipment. The consequence of this is that some actuators for example used in windows could be exempted. Nevertheless, this is of course not the majority of BACS hardware.

The dismantling of BACS typically follows the logic of a business-to-business (B2B) waste management scenario. It may also be assumed that private household BACS will also eventually end up in a B2B context as the dismantling is mostly done by trained professionals. Despite all this, it can't be excluded that some fraction is simply disposed of in a general waste collection bin at the construction site,.

Because this study considers BACS at the functional level this information is not relevant for the further tasks to be addressed within this study.

3.6 Local infrastructure (barriers and opportunities)

The objective of this section is to identify, retrieve and analyse data, and report on barriers and opportunities relating to the local infrastructure regarding energy water, telecom, installation, physical environment, etc.

3.6.1 Reference outdoor climate conditions

The outdoor climatic conditions have a major impact on the energy use considered in this study.

The MEErP methodology already supplies a common set of climate data in the last chapters of the Methodology Report Part 2, see chapters 6 and 7 that can be used for the MEErP Task analyses.

MEErP defines three climates, which are differentiated in terms of outdoor temperatures and solar irradiance, as follows:

- Average climate (Strasbourg, F)
- Warmer climate (Athens, GR)
- Colder climate (Helsinki, FI).

The MEErP specifies that for the derivation of minimum Ecodesign requirements the Average climate should be used. The other climates can be used for specification of Ecodesign information requirements, which can then be used in complementary measures (e.g. labelling). This approach is incorporated in the preparatory study work on practically all space heating and cooling devices.

However, the EN 15232 standard used Würzburg (D) in Germany as the basis for its reference climate conditions. Nonetheless as this is only about 200 km from Strasbourg (F) it can therefore be considered as a representative average climate condition.

Note:

- for dynamic simulations that are undertaken in Task 4 with the Energyplus[111] software, the needed sub-hourly weather data profiles are however not included in the MEErP reference data. Therefore, real weather data from data sources[112] based on measured data for the previous three locations is used.
- Historical climate data in standards and/or MEErP do not take into account global warming and climate change which might underestimate the needs for cooling and overestimate the needs for heating.
- Because the PHPP software[113] that is used in Task 4 provides more detailed weather data for the city of Volos (GR), which is similar to Athens, this city's data is used.
- Region Mannheim (D) data, which is close to Strasbourg, can be used in the Enercalc software[114] utilised in Task 4.
- In the event of any future regulation, it is recommended to further elaborate and streamline this reference data in an impact assessment when it is deemed relevant. It is also recommended to consider including sub-hourly weather data.

<u>Conclusion and proposal:</u>

Three MEErP locations can be considered for use in the subsequent Task 4 to 6 analyses:

[111] https://energyplus.net/

[112] https://rcccm.dwd.de/DWD-RCCCM/EN/home/home_node.html

[113] https://passivehouse.com/04_phpp/04_phpp.htm

[114] https://www.enec.de/page/EnerCalC/index.html

- Average climate (Strasbourg, F) or Mannheim(D)
- Warmer climate (Volos, GR)
- Colder climate (Helsinki, FI).

It is proposed to always simulate the base cases for the average climate but in the specific case of considering external shading devices, a warmer climate could be considered as the default for Task 4-6. The other locations can be used for a sensitivity analysis Task 7 when deemed relevant.

3.6.2 Impact of the building envelope level and year of building construction

The insulation and air tightness of the building will also have a major impact on the energy use to be considered in this study and this can differ appreciably depending on the year of construction.

In a poorly insulated home, the energy balance is dominated by the transmission losses. For which the usual remedy is to improve the insulation. The absolute impact from the use of BACS will obviously be larger in such buildings than better insulated ones.

In the Low Energy Building (new LEB), the impact of transmission and ventilation losses is significantly lower and the auxiliary power and internal heat thermal gains, in particular solar gains, increase in relative importance.

EN 15232-1:2017 already includes envelope data for reference buildings that could be applied in the current study. This takes 2006 as the year of the reference building data, as follows:

U-Values:

a) 0.34 W/m²/K (exterior wall);

b) 0.65 W/m²/K (internal wall);

c) 0.4 W/m²/K (floor/ceiling);

d) 1.4 W/m²/K (window, SHGC = 0,58).

thermal mass: 'medium C' = 50 Wh/m².K.

This is, however, already a well-insulated building and hence it is proposed to assume this as being representative of renovated existing building in 2025 in this study.

Clear data and predictions for defining the average existing EU27 house in which BACS will come on the market in 2025 is unfortunately missing[99] (see 3.3.5), but we assumed thus that they will have this basic insulation on our Tasks 4 to 6 base cases. 2025 is important because this is likely the typical system environment when the potential policy out of this study might come into force.

This, however, may well not represent the average European building in 2025. Therefore it was agreed to use Tabula project data[115], [116] from a SFH constructed in Germany 1984 and which will be also be used in Task 6 to verify the potential negative or positive impact

[115] https://episcope.eu/welcome/

[116] Data used comes from tabula spreadsheet house: 'DE.N.SFH.09.Gen.ReEx.001.002' in sheet 'Calc.Set.Buildings'

from this. This represents a first generation of insulated homes and the main thermal characteristics of this building are:

U-Values:

a) 0.50 W/m²/K (exterior wall);

b) 0.65 W/m²/K (internal wall);

c) 0.4 W/m²/K (ceiling), 0.6 W/m²/K(floor);

d) 2.74 W/m²/K (window, SHGC = 0,58).

thermal mass: 'medium C' = 90 Wh/m².K.

The rationale for selecting these characteristics is that those houses have already some basic level of insulation and it might be more difficult to convince owners to renovate and improve insulation any further. It will not be used as a base case but as input for a sensitivity analysis on the conclusions in Task 6.

Newer Low Energy Buildings and renovation requirements under current building codes will go beyond this, a key differentiator between 'renovated' and 'new LEB' in this study is therefore mainly the level of air tightness and availability of mechanical ventilation to maintain air quality requirements. These 'new LEB' buildings are always selected at the same location with the same geometry as the 'existing buildings'. Considering this the study team have opted to use the data in the predefined reference buildings, described in Table 3-5. This data has been reviewed and complemented taking into account current EPBD regulations based on calculations on the proposed reference buildings. For the reference buildings behind 'house', 'EN 15232 shoe box' and 'office' please consult section 3.3.3 that contains detailed plans.

Table 3-5: Proposed reference building envelope data to be used in this study

Task4+5(BAU)/4+6(BAT) references:		BC1hoBAU	BC2hoBAU	BC3apBAU	BC4apBAU	BC4apSEN00	BC5whBAU	BC6whBAU	BC7ofBAU	BC8ofBAU
market	Unit	Residential					Non Residential			
building type (& design)		L38 house		EN 15232 shoe box model			EN 15232 shoe box model		L38 'office'	
Activity (EN 15232)		not defined	not defined	not defined	not defined	=BC4A	Shop R	Shop N	office	office
age type		renovated	new LEB	renovated	new LEB	=BC4A	renovated	new LEB	renovated	new LEB
Task 5 Base Case #		**1**	**2**	**3**	**4**	=BC4A	**5**	**6**	**7**	**8**
study reference		**house R**	**house N**	**flat R**	**flat N**	=BC4A	**Shop R**	**Shop N**	**office R**	**office N**
EU climate zone (see MEErP)		average	average	average	warm	average	average	average	average	average
key building envelope characteristics										
Thermal transmittance of wall(average)	W/(m².K)	0,34	0,2	0,34	0,34	=BC4A	0,34	0,2	0,34	0,2
Thermal transmittance of roof(average)	W/(m².K)	0,4	0,14	0,4	0,14	=BC4A	0,4	0,14	0,4	0,14
Thermal transmittance of floor(average)	W/(m².K)	0,4	0,23	0,4	0,23	=BC4A	0,4	0,23	0,4	0,23
Thermal transmittance of window(average)	W/(m².K)	1,4	1	1,4	1,4	=BC4A	1,4	1	1,4	1
g-factor glass		0,58	0,5	0,58	0,58	=BC4A	0,58	0,5	0,58	0,5
maximum heating control zones	#	7	7	1	1	=BC4A	1	1	41	41
max. ventilation zones	#	0	2	1	1	=BC4A	1	1	41	41
Thermal capacity	Wh/(m²K)	130	90	130	50	=BC4A	50	50	90	50
Test Air tightness-Natural air changes per hour, n50 (@50Pa)	m3/(h.m2)	15	0,6	10	10	=BC4A	10	0,6	7	0,45
real pressure factor for infiltration (= 2Pa)		0,04	0,04	0,04	0,04	=BC4A	0,04	0,04	0,04	0,04
floor area used(+/-)	m²	186	186	20	20	=BC4A	20	20	2000	2000
total levels	#	2	2	1	1	=BC4A	1	1	5	5

One should be aware that the insulation level, building air tightness and building thermal mass, etc. could affect the performance of BACS, such as the impact of more accurate control. Therefore, a range of buildings is selected here; however, when it comes to policy impact assessment the conduct of a more detailed and broadly representative impact assessment may be required.

3.6.3 Impact of local production of renewables and self-consumption in Nearly Zero Energy buildings

A particular class of buildings are low energy buildings (LEB) that have an integrated photovoltaic system, which can also be referred to as Nearly Zero Energy Buildings (NZEB). The following trends in smart energy management can be identified with regard to heating/cooling and ventilation for NZEB:

- Typical NZEB homes require a greater number of measures to prevent overheating, in order to limit or eliminate the need for cooling, for example automatically controlled blinds.
- If active cooling is used, there is a large overlap in time in relation to the local electricity production of the PV panels.
- On an annualised basis, it is possible to compensate for the total energy demand using PV panels. Viewed on a monthly basis, there are surpluses in summer and shortages in winter.
- A battery for local storage is useful in order to increase the local use of the energy produced by the PV panels. In the event of a mains failure, such a battery can also provide the power required to operate systems such as the ventilation.
- The increased risk of overheating in a NZEB home and the additional comfort offered by an air conditioning system will lead to increased interest in heat pumps. An additional advantage is that heat pumps use electricity as their power source, which is produced locally by PV panels. It also means that less CO_2 is produced by using local PV instead of carbon intensive electricity from the grid (if any).
- A modern, airtight home requires auxiliary power to operate the ventilation system. Smart controls can help to make savings in this regard.
- The auxiliary power required for heating and cooling increases. Consider for example circulation pumps for underfloor heating, which require more power than heating by means of radiators. Here too, smart controls can result in savings.
- The thermal inertia of the low-energy home increases, as a result of which fluctuations in the outdoor temperature have less of an impact on the indoor temperature. This means that night cooling is often a sustainable option. This also creates possibilities for controlling the demand based on variable tariffs. In a home of this type, the losses generated by the heat buffer, if present, will also be smaller.
- The energy balance and its energy management are determined by a number of factors. They depend not only on the outdoor temperature, but also on the solar gains and other thermal gains. As a result, energy management becomes more complex.

Conclusion:

Despite these trends being identified it should be noted that the Ecodesign and Energy label preparatory Study on Photovoltaic systems[117] is completed and has already included the relevant policy recommendations. This is also the case for residential battery energy storage systems (ESS)[118]. Therefore, aspects concerning photovoltaic energy production, self-consumption and storage will not be reconsidered in the subsequent Tasks 4 to 6 of this study.

3.6.4 Impact of the Technical Building System

Design and selection of an optimised BACS has to be contingent on a thorough understanding of the operation of the Technical Building System (TBS). When validation

[117] https://susproc.jrc.ec.europa.eu/solar_photovoltaics/index.html

[118] https://ecodesignbatteries.eu/

based on measured data and functioning is included in the procurement contract, the BACS designer, installer and TBS manufacturer are intimately involved with operation during the first 12 months or more of occupation. Involvement in validation enables the supply side to learn from rich and immediate feedback on how the specified design and products perform in real life operation. This helps to ensure that TBS including BACS deliver or surpass the energy savings, carbon reduction and occupant satisfaction intended by the design.

In this context it should be noted that a performance gap has been detected between calculated Energy Performance Certificate (EPC) building performance and measured energy consumption. This gap has been reported in many case studies[119],[120]. The cause of this gap could be partially due to poor commissioning of the TBS including the BACS. In principle, BACS can play an important role in TBS commissioning and can help to overcome or reduce this performance gap.

3.6.5 Impact of data communication and cabling infrastructure

Data communication and cabling are an integral part of the local infrastructure required to deliver some BACS functions.

A class A BACS will require a sufficient amount of sensors and actuators to be installed. All sensors and actuators will need a small amount of power and a medium for communication, for example twisted pair cables. Wireless sensors and actuators can use batteries but this can create additional cost for battery replacement over its lifetime, which is especially in the non-residential sector an issue due to the associated labour cost. If no wireless signals are used most BACS will need dedicated signal wiring for actuators and sensors, as shown for example in Figure 3-14 and Figure 3-15. Therefore, the lack of a proper cabling infrastructure or cable ducts can be an important barrier to installation of a high class of BACS. These issues could be addressed in building permitting policies and/or a smart readiness indicator[121]. When considering wireless sensors, additional security protocols and measures might be needed because the signal might also be available outside the building for intruders.

[119] http://built2spec-project.eu/knowledge-center/
[120] https://www.ecn.nl/publicaties/PdfFetch.aspx?nr=ECN-E--16-056
[121] https://smartreadinessindicator.eu/

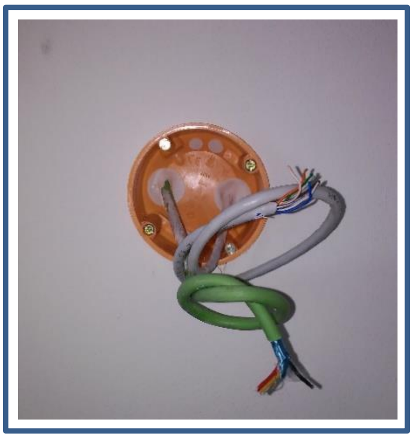

Figure 3-14: Wall box with European Installation Bus (EIB) and FTP cabling to host a wall switches, digital inputs from a door contacts and a room thermostat

Figure 3-15: Window open/close sensing contact with wiring

Some of the BACS functions might also require the availability of an IP WAN connection device, or modem including a BACS IP gateway device but this is present in most buildings today.

3.6.6 Opportunities in installation and commissioning

The process of installing BACS creates an interface with the Technical Building System and therefore the quality of installation can affect the TBS functioning, both with regard to indoor comfort a well as energy performance.

For example, improperly installed sensors can affect performance, or the activation of control functions might be overlooked, or control feedback loops may be inadequately fine-tuned; all of which may result in additional losses.

BACS design expertise is paramount for the adequate specification of BACS. It should take into consideration the owner’s requirements for comfort, operational efficiency (including energy and labour costs), control functionality and adequate commissioning process. In general, the design expertise of the contractor relies on having the right level of design, operational and management expertise throughout the process. Occupants are not usually involved in the design, or commissioning of the building. Therefore, the building owner is responsible for the current project requirements. An integrated design process (see LEED[122]) with all parties involved ensures better results than the traditional General Contractor approach.

There are many building procurement models in use throughout the EU; however, the procurement model is less important to the outcome than having the right level of operational and management expertise throughout the process. Figure 3-16 shows the conventional route to market. This often leaves the operation to the purchaser of the product, or to a tenant, without any direct input from the manufacturer. The result is that the purchaser/tenant may have no direct or contractual access to the manufacturer's knowledge of how the product should be operated to deliver its intended operational benefits. Therefore, Operation and Maintenance Manuals (O&M) are important BACS deliverables to owners/tenants. This O&M documentation should contain the following information with regard to BACS:

- functional description
- list of points or nodes
- data sheets for the control products.

When properly conducted, commissioning ensures that O&M documentation exists. Also, operator's training is part of any proper handover, therefore the COPILOT certification protocols[123] can be used. For buildings that use the BACNET protocol, open standard templates for project documentation are provided by STLB-BAU[124]. For BACNET, for example, the AMEV[125] recommendation and attestation was elaborated to support building owners and planners of public buildings. In general, most BACS software will produce documentation and project files and it is important that the building owner should receive and properly maintain this over the lifetime of the building.

[122] https://www.usgbc.org/leed

[123] https://copilot-building.com/

[124] https://www.gaeb.de/en/service/downloads/stlb-bau/

[125] https://www.amev-online.de/AMEVInhalt/Planen/Gebaeudeautomation/BACnet%202017/

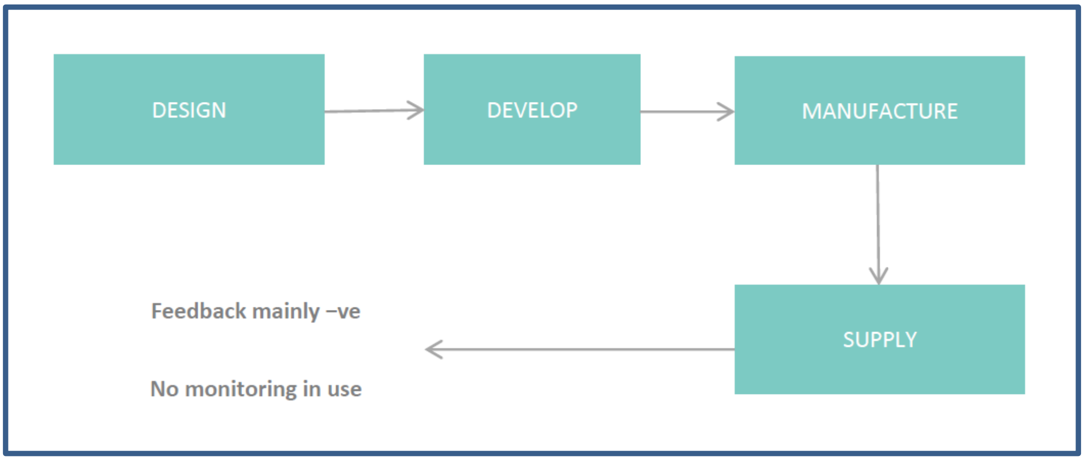

Figure 3-16: Traditional approach to procuring and operating building automation technology (source: Waide 2014[126])

Figure 3-17 shows the lifetime product management route to market which enables the manufacturer of the product to deliver the benefits of its product to the end user and in the process receive an income stream over the life of the product that can be linked to its performance. With this process the manufacturer is encouraged to replace or enhance the product where this can improve performance and income.

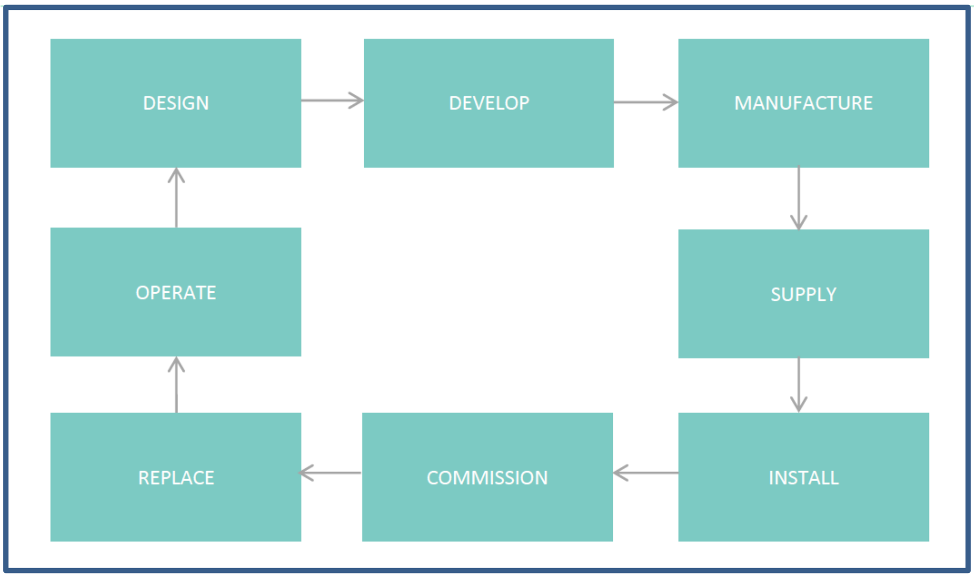

Figure 3-17: Lifetime product management approach to procuring and operating building automation technology

In general, it is also important to be aware that a BACS needs to be trained or tuned for optimal performance depending on the TBS and user requirements, which is a process that can take several years of operation after building occupancy It is also good practice to have ongoing optimization as the building requirements change, e.g. in response to changes in space use, operator's priorities, climate requirements, TBS's, etc. Therefore, this entails continuous building performance optimization enabled by the BACS.Note, that the specific case of commissioning and installation was discussed in the Lot 37 Ecodesign

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

preparatory study on lighting systems[127] and the outcomes of this discussion could also apply to BACS. This includes the recommendations in Task 7 of that study, excluding improvements of the optical lighting system design. The latter are outside the scope of the present study.

3.6.7 Opportunities for performance-based service contracts and/or energy service companies

One of the main barriers to strategic operation of BACS is the traditional approach to specifying and procuring operation and maintenance (O&M) services. Traditionally, property owners, occupiers and managers seek proposals for maintenance when what they really need is operation. Maintenance supports operation and only needs to be carried out to the level that ensures the desired operational requirements of the BACS are met. The emphasis must therefore be on operation and not on maintenance. BACS will only deliver at its best if they are operated to provide best value for occupant requirements. Maintenance alone is not enough.

3.6.8 Opportunities for real-time energy monitoring

The right energy-monitoring software is able to provide real-time and historic data on the energy consumption of both individual items of plant and equipment and a building as a whole. Real time monitoring can also be considered to issue and/or verify Energy Performance Certificates (EPCs) which are part of the Energy Performance of Buildings Directive.

3.6.9 Opportunities for continuous commissioning

Continuous commissioning is an operational strategy that continues commissioning beyond the original working settings of equipment and seeks to understand and optimise performance in use via an expert monitoring feedback and diagnostics process empowered with the authority to intervene to remedy significant failures when identified. Ideally it is part of a process, focused on operation, by which a building and its services are conceived, designed, constructed, commissioned, operated, maintained and decommissioned to provide the optimum of cost and value for the occupant. Occupants are usually not involved in the design or commissioning of the building. Therefore, the building owner is responsible for the current project requirements which also opens possibilities for continuous commissioning.

3.6.10 Lack of interest of building owner

The interest of the building owner can have an impact on the quality of the BACS because she/he can influence the subcontractors. The case with regard to BACS is similar to that described in the previous Lot 37 study on Ecodesign of lighting systems, which is summarised below. A simple overview of 'metrics for defining success' related to the contractor or subcontractor is shown in Table 3-6. All market actors will try to influence the 'building owner' to take decisions that align to their own interests. Finally, the BACS designer (if involved) needs to look for a compromise solution and the products which best meet this. From the table it is also clear that there are many more factors involved than energy efficiency, or comfort. The Building Owner (or their representative) is

[127] http://ecodesign-lightingsystems.eu/

responsible for specifying the current requirements and must ensure they are well described involving the appropriate design and operation experts, see also section 3.6.6.

Table 3-6: Motivating factors that may influence the selection and design of lighting systems in a manner that compromises the energy performance'

subcontractor/contractor	**performance metric**
Building developers*	euro per square meter
Electrical engineers*	Watt per square metre, code compliance
Lighting engineers*	illuminance, quality of light
Construction managers*	Planning and specifications/adherence to drawings
Contractors*	Budget and schedule (no call-backs)
Suppliers*	Sales and margins
Construction workers*	Signoff
Leasing agents*	Quick rental; euro per square metere
Building operators*	Simple payback
Maintenance staff*	Complaints
Architects**	Creative expression, Pride, Profit
Utility DSM (Demand Side Management) staff*	Euro per avoided kilowatt and kilowatt-hour

* Adapted from Energy Efficient Buildings: Institutional Barriers and Opportunities by E-Source, Inc., 1992

** Adapted from Commercial and Industrial Lighting Study by Xenergy, Inc., 2000

3.6.11 Lack of knowledge or skilled subcontractors

The proliferation of more advanced BACS can require additional skills that might not be sufficiently available in the supply chain and thus can form a market barrier to successful outcomes.

3.6.12 Lack of user acceptance for automatic control systems

It is important to take 'user acceptance' into account especially with automatic control systems. For example, experiences with complex daylight responsive control systems showed that problems may occur when users do not know the purpose or how it works (IEA task 21 (2001)). These problems can vary from complaints to completely overruling the system through bypassing or deactivating it, which will normally lead to reduced energy savings.

In addition, certain automation functions in residential buildings can be done simply by the owner and occupant themselves, e.g. a room thermostat control. This is different for larger multi-occupant buildings where often nobody feels they have direct responsibility and a consensus might be needed between the occupants to agree on the comfort set points, or to agree on the lowest possible set point taking the user preferences into consideration (often users can accept a lower set point when they see the benefits of it). In this case a BACS central set point management function is a strong asset which is not usually present in smaller residential buildings.. Therefore, the user requirements, training, necessary documentation (e.g. User Handbook, O&M documentation) and expectations with regard to BACS should be present during and after commissioning, see also section 3.6.6.

Another important user aspect to consider is the risk of low acceptance of BACS if by using them users feel they are exposed to cyber-security threats, or potentially unpredictable lifetime and cost figures. This could occur, for example, due to software dependencies when BACS functions would come over the internet and rely on external services, see also 3.5.2.

3.7 Recommendations

3.7.1 Recommendations on refined product scope

As already concluded in the exploratory study it is recommended that the product scope be specified on the functional level with the functional unit as defined in Task 1. This will fit in the MEErP approach to be followed in subsequent Tasks and aligns with the EPBD set of standards.

3.7.2 Recommendations related to barriers and opportunities

Important user aspects and improvement potential are related to the commissioning, maintenance, repair and the possibility to upgrade or fine tune the BACS after they have been installed.

However, it is difficult the address this with requirements on the BACS hardware itself but mainly the following requirements can help:

- using a minimum set of standardised hardware documentation addressing functionality to simplify commissioning and maintenance
- using standardized communication protocols that are interoperable across technologies, devices and manufacturers can support both repair as it is easier to find replacement components from multiple suppliers and also the upgrade of the BACS as an open standard can make it simpler for any installer familiar with BACS compared to a proprietary system.
- Clear specification on what the Energy Management System should report to the user so that the owner/facility manager is motivated to fine tune and maintain it.
- ,..

4 MEErP Task 4 report on Technologies

4.1 Aim of Task 4

The objectives of this task are to:

- analyse the technical aspects of Building Automation and Control System (BACS) products and systems on the EU market
- describe typical business-as-usual (BAU) BACS products and systems on the market, and of the main alternatives to the use of a centralised BACS network, including those which will be used as the base case
- analyse the energy savings realised by BACS as well as their costs and explore their internal power consumption
- define the Best Available Technologies (BAT) and Best Not yet Available Technologies (BNAT) in accordance with the MEErP methodoloy definitions[128]:
  - 'Best' shall mean most effective in achieving a high level of environmental performance of the product
  - 'Available' technology shall mean that it is developed on a scale which allows implementation for the relevant product under economically and technically viable conditions, taking into consideration the costs and benefits, whether or not the technology is used or produced inside the Member States in question or the EU-27, as long as they are reasonably accessible to the product manufacturer. Barriers for take-up of BAT should be assessed, such as cost factors or availability outside Europe
  - 'Not yet' available technology shall mean that it is not yet developed on a scale which allows implementation for the relevant product but that it is subject of research and development. Barriers for BNAT should be assessed, such as cost factors or research and development outside Europe.
- assess the barriers to the introduction of BNAT, including cost factors and current levels of technical and commercial readiness.

BACS products and systems are described both in terms of the energy saving functions defined in EN 15232 for the reference buildings defined during Task 3. Within the context and scope of this study on BACS, the considered BAT design options are thus in principle the improved functionality options of EN 15232.

4.2 Summary of Task 4

This report provides a technical introduction to the design process of a BACS and the energy saving methods used by EN 15232-1 to realise energy savings through BACS.

The base cases for BAC functions are defined in respect of the reference buildings and then the results of the modelling work are presented, including estimates of energy savings realised by implementing a selection of Best Available Technology (BAT) design

[128] The methodology for the ecodesign of energy-related products (MEErP) is published at: http://ec.europa.eu/growth/industry/sustainability/ecodesign/

options for different BAC functions defined in EN15232-1:2017, a Class B and a Class A BACS.

An analysis of the additional costs of implementing each BAT option instead of the Business as Usual solution is then presented.

Finally, there is a discussion of the Best Not (yet) Available Technology.

The main conclusions and recommendations of study are that:

- the energy saving functionality defined by EN15232-1: 2017 Class A BACS could be considered as a starting point for defining BAT for larger buildings with a total useful floor area greater than 1,000 square metres; however, not all of the BAC functions are applicable to all types of buildings and TBS, and some additional BAC functions not in EN15232-1 may merit inclusion in BAT.
- for smaller buildings with a total useful floor area less than 250 square metres; the energy saving functionality defined for a Class B BACS could be considered as a starting point for defining BAT particularly in residential buildings, but that consideration should be given to adding some Class A BAC functions.

The study team found that it was difficult to cost some of the BAT design options, due to a lack of detailed case studies on the costs and benefits of Class A and Class B BACS solutions in buildings, particularly in individual family homes and smaller non-residential buildings. It also appears that the EN15232-1 Class of the BACS solutions fitted to most buildings is not known or not reported and that the solutions presented in case studies did not represent full implementations of either Class A and Class B BACS solutions. This lack of awareness of the EN15232-1 BACS Classifications is a major market failure.

In considering what minimum functionality should be required for BACS, it is likely that different specifications will be needed for new and existing buildings, for residential and non-residential buildings, and for different sizes of building (e.g. small and large). However, the evidence base needed to underpin the development of these specifications is not available and information needs to be systematically gathered on what BAC functionality is deployed, the level of savings realized, and the costs of implementation.

Other issues that the study team was not able to model due to the lack of systematic data, include the impact of user behaviour on the energy performance of different classes of BAC functions and the internal power consumption of BACS and individual BAC functions. Note, with regard to the internal power consumption of BACS it is important that this should not be considered in isolation to the energy savings functionality and other co-benefits that the BACS provide.

The technical home and building management (TBM) systems within a Class A BACS should be capable of recording Key Performance Indicators (KPIs) that Building Managers can use to raise awareness of the impact of user behaviour building control and energy performance and for benchmarking against other similar buildings. However, the study team found little evidence that these important data are used for dynamic benchmarking.

As improved control accuracy is one of the keys to maximizing energy savings delivered by BACS, the study team recommends that further research should be undertaken into the merits of introducing minimum accuracy requirements for the sensors, controllers and actuators that are placed on the EU market for application in BACS products or systems.

4.3 Technical product description of BACS

As outlined in Task 1, BACS are defined in European and International standards as comprising "all products and engineering services for automatic controls (including interlocks), monitoring, optimization, for operation, human intervention and management to achieve energy–efficient, economical and safe operation of building services. The term "controls" also refers to "processing of data and information".

This definition covers a wide variety of different types of product ranging from standalone pre-programmed central or room control units to flexible modular distributed control and automation systems that can be programmed after installation to user requirements. It also covers distributed systems where the components are physically connected using wires, as well as systems that use wireless connections, or cloud-based data exchange.

The selection of particular BACS design solution depends on a number of factors, including the size of the building, the complexity of the lighting, heating, ventilation and air conditioning systems and the range of ancillary management and control functions (e.g. building access control) that the building owner or user specifies at the design stage. For residential buildings, the selection of a BACS design solution may also be the result of introducing Technical Building System (TBS) with inbuilt controls. Cost is also a significant factor in system design and installation, with wireless products increasingly being used to minimise the amount of new cabling, particularly in homes.

The EN 16484 series of standards provides guidance on BACS design for new buildings and retrofit of existing buildings to ensure an acceptable indoor environment, practical energy conservation, and efficiency. This series of standards sets out a process for the creation of project specifications, where functionality and the quality of the solution are clearly defined, including standard interfaces and communication protocols that can be used to ensure interoperability, and facilitate the integration of individual components products and systems into a BACS. These standards are not intended to restrain the evolution of new products, systems or applications, and hence they do not seek to standardise the hardware and software design, the architecture of a BACS, or method for programming functions and applications, which can be implemented in many ways[129].

The diversity of BACS architectures, technologies and application specific functionality means it is difficult to categorise the different types of BACS products and components sold across the EU in terms of their hardware, components or other design features.

Instead this study categorises BACS products and systems in terms of the types (and level) of BAC functions that they are capable of implementing as defined in section 5.5 (Table 4) and Annex B of EN 15232-1:2017, and the minimum requirements needed to be classified as conforming to one the four BAC efficiency classes (A-D) as defined for residential and non-residential buildings in sections 5.5, 5.6 of EN 15232-1:2017:

- Class A: High energy performance BACS and TBM functions
- Class B: Advanced BACS with some TBM functions
- Class C: Standard BACS
- Class D: Non-energy efficient BACS.

This approach enables us to define a selection of options for extra or improved BAC functionality, which will be referred to in this study as "BAT design options", and to calculate the energy performance improvement that can be realised by each BAT option.

[129] Derived from introductory sections of EN ISO 16484-2:2004 and EN ISO 16484-4:2005.

These BAT design options include options that involve upgrading Class C building automation and controls to Class B or Class A., options based on subsets of EN15232-1 Class A or B functionality, and some based on BACS improvement options recommended by other EN standards.

The improvement resulting from upgrading Class D BACS is not assessed as EN15232-1 specifies that a Class D BACS should not be installed, and that existing Class D BACS installations should be upgraded to Class C, which is considered the reference design.

This study has assessed the energy savings realised by the BAT design options using three different methods:

1. EN 15232 Method 1 (Detailed simulation approach) is used to simulate the business as usual (BAU) energy performance of the eight reference buildings set out in Task 3 and to simulate the impact of applying seven of the BAT design options.
2. EN 15232 Method 2 (BAC factor based approach) is used to estimate the impact of applying two BAT design options.
3. The results of a literature study is used to estimate the impact of applying six further BAT design options on building energy performance.

Three standard building energy modelling software packages were used to calculate the energy balance of the eight reference buildings or base cases (BC) as follows:

- the Energyplus[130] building simulation software was used for multi-zone dynamic calculations in BC4 and BC8 on a minute by minute basis.
- the PHPP spreadsheet tool[131], was used for monthly energy balances in BC1 to BC3.
- the ENECALC spreadsheet tool[132] was used for multi-zone monthly energy balances in BC1 to BC3.

Some limitations of applying EN15232 Method 2 (BAC factors) should be noted:

- Whilst EN 15232-1 defines the minimum requirements for the control of building services, and for technical and home building management under Classes A to D, the BACS designer only needs to implement BAC control functions related to equipment that is installed in the building. The BACS designer can omit BAC functions that do not offer a control performance benefit or would not have a significant impact on energy used or apply to less than 5% of energy use. This means that the results derived using BAC factors should only be treated as indicative of the potential impact on energy performance that can be achieved.
- In practice, BACS installers may not implement all of the BAC functions required by EN15232 to meet a specific classification, particularly where existing HVAC systems need substantial modifications to implement them, or if a BAC function requires a lengthy commissioning period. As a result, the full benefits of fitting the BACS are not always realised. The impact of these substandard installations is not modelled

[130] https://energyplus.net/

[131] https://passivehouse.com/04_phpp/04_phpp.htm

[132] https://projektinfos.energiewendebauen.de/en/project/enercalc-simplified-energy-balancing-to-din-v-18599/

in this study but will be considered in Task 7 as part of the discussion of possible information requirements around BACS performance certification.

- The definition of BACS referenced in EN ISO 52000-1: 2017 uses inclusive language to cover all type of digital controllers used to automatically control building services, including fixed function, configurable and programmable products. Older mechanical, electro-mechanical and electronic controllers also fall within the scope of the definition, and the definition of a BAC function in section 3.5 of EN15232-2 implies they cannot be used to implement BAC functions. However, references to thermostatic valves or electronic controls in Table 4 (e.g. 1.1) of EN15232-1 indicate digital processing is not always required. The BAC factor method cannot fully address the potential energy savings that could be realised by upgrading older building automation and control hardware.
- Furthermore, the energy performance calculation methodologies in EN15232-1 do not address the issue of the internal power consumption of BACS and what proportion of it is due to the nature of the control task (i.e. type of building service equipment being controlled, the number of individual rooms that separate zone controls and the number of sensors and actuators needed to implement the specified BAC function) and what is due to component selection. To address this, the options for derivation of simple metrics for the internal power consumption based on published research and manufacturers' data is examined in section 4.4.1.

It should also be noted that whilst EN15232-1 classifies BACS in terms of the minimum functionality required for specific levels of energy performance, it does not define how this functionality should be implemented in a way that complies with the overriding requirement in Section 5.4 of EN15232-1: 2017 to ensure comfortable conditions in the rooms with regard to temperature, humidity, air quality and light as needed and with due consideration of minimum or maximum requirements specified in local regulations. As a result, energy efficiency is generally a secondary consideration to that of user comfort.

4.3.1 BACS Energy Saving Methods & Functions

As outlined in Section 1.3.2 of Task 1, EN 15232 defines 43 BAC functions that have an impact on the energy performance of buildings, including variations covering the specific control requirements of thermally activated building systems (TABS), of different sources of heating and cooling, and of different types of ventilation and air conditioning system.

An overview of these BAC functions by application area is shown in Figure 4-1.

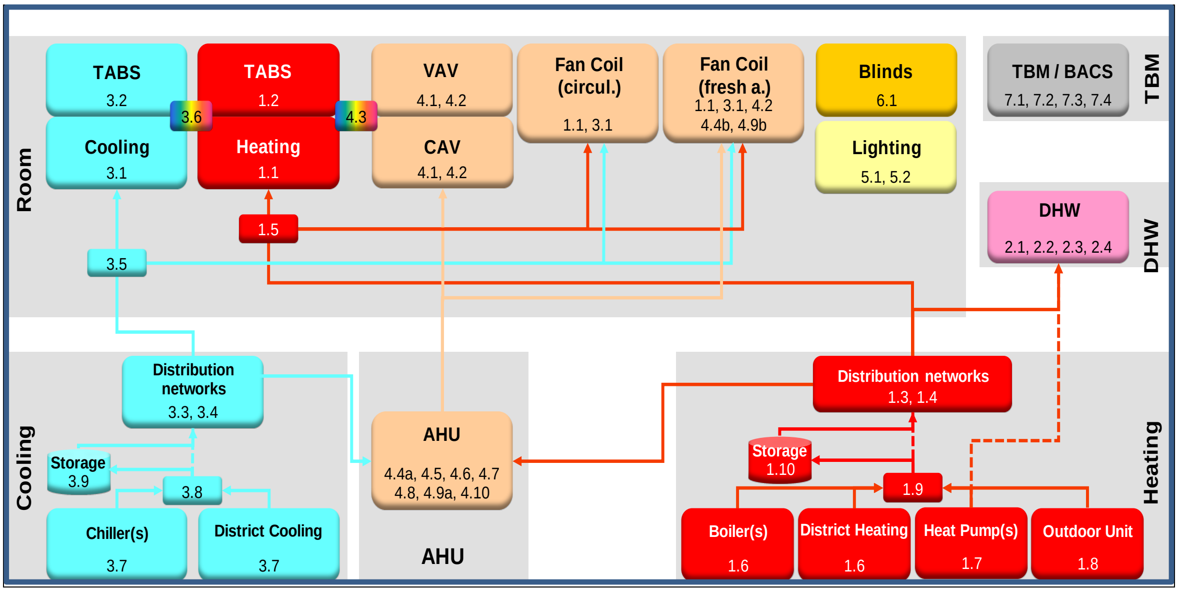

Figure 4-1: Overview of the BACS functions

For each BAC function, between 2 and 5 types of control functionality are defined. These are arranged in increasing levels or degrees of sophistication, with level 0 generally referring to a Class D BACS solution where no automatic control or simple on/off control is applied and the highest level of control corresponding to a Class A BACS. There are some exceptions to this layout, for example heating and cooling emission control where level 1 covers central automatic control, which is also considered a Class D BACS solution.

No specific requirements are stated for technical and home building management for Class D, which is not expected to be fitted. Otherwise, where no specific control functionality is specified for a particular BACS Class then the next lowest level is required.

The BACS A to D classification method also states that the control system should provide the control functionality specified for lower classes of BACS, i.e. a Class A BACS must implement the functionality specified for Class B and Class C in addition to those specified for Class A. This means that BACS will generally provide facilities to manually override automatic control, or to disable higher levels of control functionality, locally or centrally.

The different types of control functionality specified for the BAC functions realise energy savings through a combination of methods:

- improved control accuracy
- individual room or zone control
- adaptive room setpoint scheduling
- demand orientated control and optimisation
- adaptive generation sequencing
- energy management & optimisation measures.

These energy saving methods are described in Section 5 of CEN/TR 15232-2: 2015 which is the accompanying technical report to EN 15232-1:2015.

Other important energy saving methods used by BACS systems that are not specifically identified in EN15232-1: 2015, include:

- Hydronic balancing of wet (hydronic) heating systems
- Heat curve optimization (supply temperature control)

These are considered under improved control accuracy and demand orientated control.

This section will focus on outlining the technical basis for energy savings in building heating, cooling, ventilation and air conditioning systems. There are also requirements for the management and control of artificial lighting systems by Class A and B BACS in EN 15232-1, but in line with the scope of this study, these will not be discussed.

A large number of case studies on the impact of different aspects of BACS have been published by suppliers, trade bodies, academics and consultants. The range of energy savings cited at c. 30% to 80% is large, and reflects the fact that the level of savings actually realised is dependent on the building's size, location, design and use, type of Technical Building System (TBS) fitted, occupation patterns, number of occupants, the nature and setup of the existing controls and user behaviour[133,134] in respect of adjusting set points, maintenance and optimisation of controls, and level of control upgrade applied [135].

In order to illustrate the potential benefits of each method, this section will refer to the results of selected peer reviewed studies that have simulated the energy savings and compared the results with actual performance improvement realised in buildings that are similar to the representative buildings for which EN 15232-1 provides BAC factors. The modelling methods used to develop the BAC factors in EN 15232-1 are then described and compared to the methods used to model the representative buildings in this study.

4.3.2 Improved control accuracy

According to EN15232-2, control accuracy is "degree of correspondence between the ultimately controlled variable and the ideal value in a feedback control system". Some key variables controlled by a BACS include the air temperature, humidity, flow and pressure, and light levels within occupied and unoccupied spaces. The ideal value is the target value for the controlled variable, or "Set Point" entered into the BACS by the occupants or building manager to maintain a comfortable working, social or living space[136].

However, in practice there is frequently a difference between the actual mean value of the variable and the target value, due to limitations in the control system's ability to adjust for disturbances in space conditions or TBS operation. This means that, for example a room heating controller is likely to be configured to maintain room temperature above the ideal value to ensure comfort, which increases energy consumption. The control accuracy depends on the components used to implement temperature control i.e. the sensors, valves and actuators and the type of controller used (see Figure 4-2). It also depends on the type of heating system used and building design factors, including, for example the location of temperature sensors and radiators in a wet heating system.

These hardware design aspects are not covered by EN15232-1, which focuses on control functionality. However, they are often defined in design standards for buildings and TBS.

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[133] The impact of occupants' behaviours on building energy analysis: A research review, Delzendeh, E. et al., Renewable and Sustainable Energy Reviews, 80, 2017, pp1061-1071.

[134] Occupant behaviour lifestyles and effects on building energy use: Investigation on high and low performing building features, Barthelmes, V. et al., Energy Procedia, 140, 2017, pp 93-101.

[135] Energy Use in Residential Buildings: Impact of Building Automation Control Systems on Energy Performance and Flexibility, Mancini et al, Energies, MDPI, vol. 12(15), pp 1-21, 2019.

[136] Section 5.1 of EN15500-1: 2017 on Individual Electronic Zone Controls also indicates that room controllers to contribute to acceptable levels of hygiene, health and comfort.

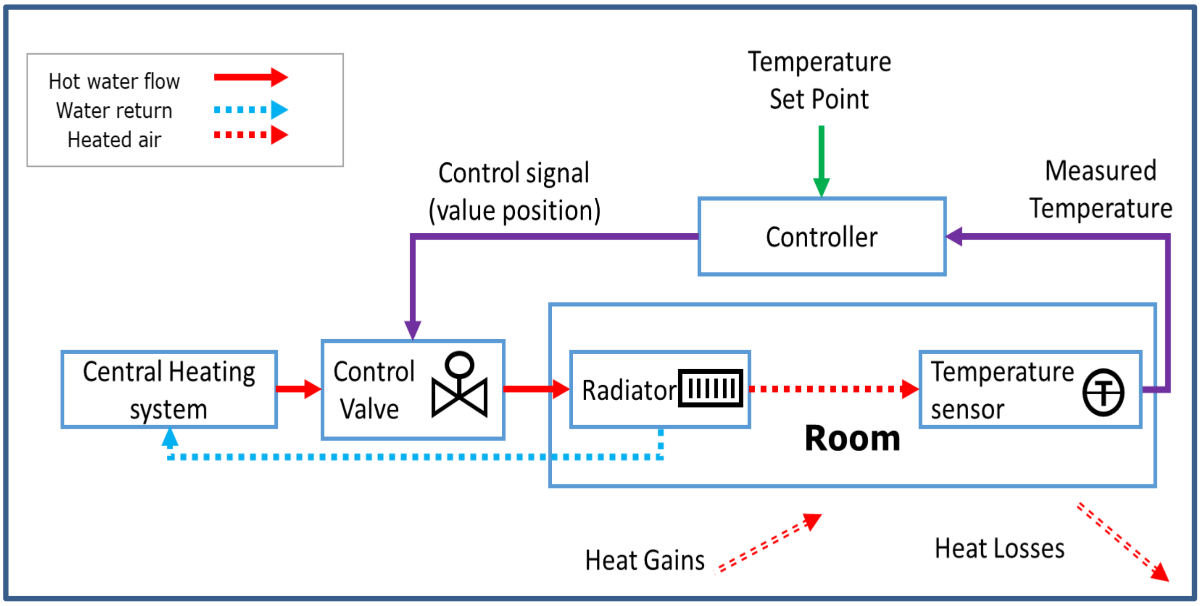

Figure 4-2: The components of an illustrative automatic room heating controller

EN 15232-1 uses a number of different measures to improve control accuracy, including:

- reducing the volume of space controlled by each controller through room control (see next topic), thereby enabling more precise localised control.
- upgrading on-off control to modulating control functions that continuously adjust the flow or temperature of air, heat, cooling etc entering the controlled space, thereby improving the stability and accuracy of the control system.
- implementing control strategies that enable controllers to adjust for changes in external factors such as weather, solar gain and daylight levels, and internal factors such as heat generated by equipment, thereby adapting to local demand.

By applying these measures, a 1°C reduction in heating setpoint (and a 1°C increase in cooling setpoint) typically can be realised by upgrading from a Class C to a Class A BACS[137].

Further improvements in control accuracy can be achieved by selecting more accurate sensors, controllers[138], actuators and final control elements (e.g. flow valves), by ensuring controllers are correctly tuned, by applying advanced control algorithms, or by using a supervisory control algorithm that optimises the operation of basic controllers[139].

The impact of improved control accuracy is modelled within the BAC factors in EN15232-1 by reducing the heating setpoints by 1°C and increasing cooling setpoints by an average of 1°C during occupation periods. There are no corresponding changes in setpoints during unoccupied periods when the heating and cooling systems are assumed to be off. The improvements that could be obtained through supervisory control are not modelled.

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[137] See Annex B of EN 15316-2:2017 for estimates of the typical variations in room temperature associated with different types of temperature controller commonly found.

[138] As defined in EN 15500-1: 2016 and measured in accordance with EN 15500-2:2016

[139] Review of applied and tested control possibilities for energy flexibility in buildings, A technical report from IEA EBC Annex 67 Energy Flexible Buildings, Finck, C. et al., 2018.

The same approach has been adopted by the authors when modelling the representative buildings for this report. This entails examining the energy savings realised in an existing residential house by applying three different levels of improved controller accuracy to Base Case 1.

The impact of BACS supervisory control functions on energy use is considered under adaptive room set point scheduling (see section 4.3.4) and the identification of incorrectly tuned controllers is discussed under energy management and optimisation measures (see section 4.3.7).

One aspect that is not modelled within the BAC factors of EN15232-1 is that of dynamic hydronic balancing of wet heating systems, which EN 15316-2 indicates can improve control accuracy by a further 0.5^{o}C relative to the use of static hydronic balancing. This control improvement measure was not modelled as part of this study, but an analysis of literature indicates that thermal energy savings of 5 to 10% can be realised by dynamic hydronic balancing of wet heating systems, which can also reduce the electricity used by pumps by 25 to 50%[140]. These savings are considered further in section 4.3.5.

4.3.3 Individual room or zone control

Changing from centralised control of heating, cooling and ventilation to room control is a minimum requirement for a Class C BAC system (except for TABS). Room control allows the local control of temperature and/or air flow into each room and enables set points to be adjusted to reflect local heat gains and losses, thereby realising energy savings.

To meet the requirements for a Class B BACS, room controllers must be able to communicate with the BACS system, so that, for example setpoints, demand and status information can be exchanged and adjusted by the central set point management system.

To meet the requirements for a Class A BACS, individual room controllers must also automatically adjust set points based on room occupancy. Room occupancy can be assessed using occupancy (presence) detectors, air quality (e.g. CO_2) sensors, etc.

The impact of applying room control to buildings is not fully modelled within the BAC factors presented in EN15232-1, as only a single standardised room was modelled (see Annex C.1 for details). However dynamic simulations of the impact on building thermal energy use of applying individual zone control to residential[141] and non-residential buildings[142] have reported large energy savings of 8-43% by operating different rooms or functional areas at different temperatures. To address this gap in EN15232-1, this study has selected a multizone office building for detailed modelling under Base Case 8. Zone control for ventilation is also assessed for Base Case 2, wherein two ventilation zones are considered.

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[140] Potential Energy Savings and Economic Evaluation of Hydronic Balancing in Technical Building Systems, ITG Dresden, 2019.

[141] Potential energy savings achievable by zoned control of individual rooms in UK housing compared to standard central heating controls, Cockroft, J et al., Energy and Buildings, 136, 2017, pp 1-11.

[142] Demand Controlled Ventilation Indoor Climate and Energy Performance in a High-Performance Building with Air flow Rate Controlled Chilled Beams, Ahmed, K. et al. Energy and Buildings 109, 2015, pp 115-126.

4.3.4 Adaptive room setpoint scheduling

Under a Class C BACS, room controller set points may be manually set with operating hours controlled by using a fixed time schedule within the HVAC distribution system. Alternatively, electronic room/zone controllers with set point scheduling capabilities can be used (for example using controllers complying with EN 15500-1). Outside temperature compensated control must also be applied to wet heating and cooling distribution systems, for example using electronic controllers complying with EN12098-1 or EN12098-3.

For Class B, there is a requirement to include an optimum start and stop[143] capability as part of the intermittent control of heating and cooling emissions and/or distribution systems, and for room controller set point changes to be scheduled using predefined operating modes, and managed and adapted from distributed/decentralised plant rooms. Within the underlying product standards four operating modes are defined (Table 4-1).

Table 4-1: Standard operating modes

Comfort	Mode of operation for a normally occupied room
Pre-comfort	Reduced operating mode for the room to quickly reach the comfort range upon changing to a comfort operating mode
Economy	Mode of operation for an energy saving operating for a non-occupied room that does not need to be in the comfort operating mode for an extended period of time.
Frost/building protection	Mode of operation to reach a minimum acceptable positive temperature preventing freezing

BACS equipment suppliers may also define additional operating modes to simplify building management e.g. holiday mode, or to address specific requirements e.g. a boost mode to turn on hot water heating for a short one-off period of time prior to running a bath.

For Class A, there is an additional requirement for room set points and operating mode schedules to be managed from a central room with frequent "set back of user inputs" and for variable preconditioning phase with adaption based on demand evaluation.

By applying this requirement for central set back of user inputs (i.e. manual overrides), an additional 1°C reduction in heating setpoint and an additional 1°C increase in cooling setpoint typically can be realised by upgrading from a Class C to a Class A BACS[144].

The impact of applying adaptive room set point scheduling strategies to buildings is partly modelled within the BAC factors presented in EN15232-1, through a reduction in

[143] An optimum start function calculates the pre-heating or cooling needed for the room to reach the temperature comfort setpoint before scheduled start of occupation. The optimum stop function calculates the earliest time that room heating or cooling can be turned off prior to the end of scheduled occupation whilst maintaining comfort conditions.

[144] These figures are based on Table 5 in Section 6 of EN 16947:2017 which provides estimates of the impact on setpoints of the central management of set points in Building Management Systems.

operating hours at comfort mode for heating and cooling of 3 to 4 hours between a Class A and Class C BACS, and a corresponding increase in economy mode operating hours.

The set point for economy mode is 15°C for heating, and cooling is assumed to be off, and the reduction in the energy need by the variable speed pump to distribute heating to the room and maintain the set point is included in the estimated savings.

This approach has been adopted in modelling the multi-zone office (Base Case 8), with the potential additional impact of central set back of user inputs being considered separately under energy management and optimisation measures (see Section 4.3.7).

4.3.5 Demand orientated control and optimisation

Traditionally the operating times of centralised HVAC systems are controlled by the building management system or by the controllers fitted to individual HVAC plant.

Under EN15232-1, a distributed demand orientated control strategy is specified for Class A BACS, in which the level of heating and/or cooling generated, and air distributed around the building, is determined by evaluation of the level of demand communicated by room controllers (Figure 4-3). This is supported by the requirement for variable control of the temperature and/or flow of distributed air, heating and cooling depending on load.

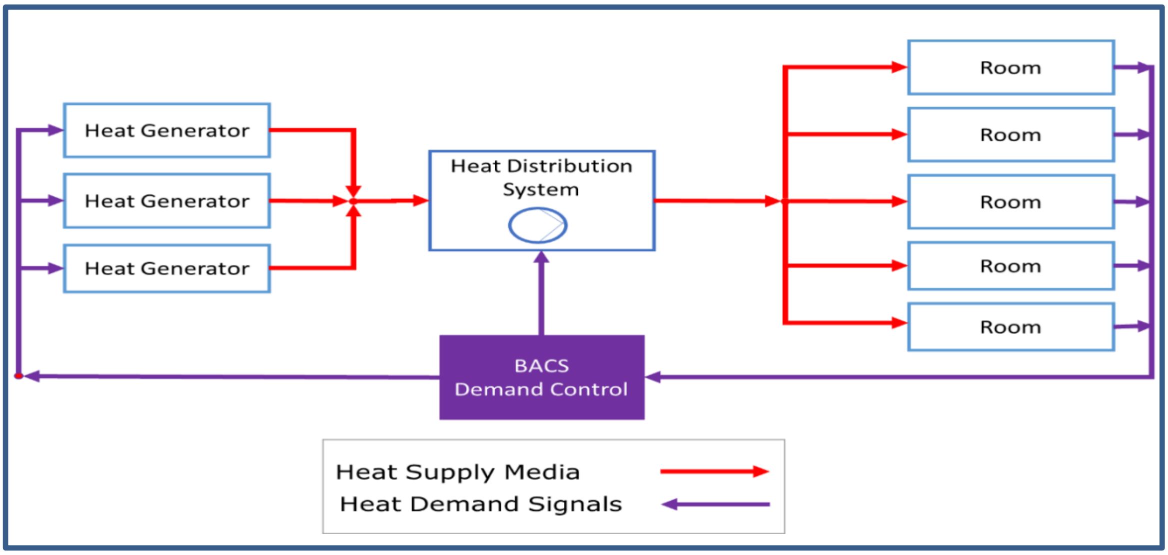

Figure 4-3: Demand orientated control[145]

Class A and B BACS must also factor outside temperature into the control of supply flow temperature in hydronic heat distribution systems through an energy saving method known as "weather compensation". This is normally implemented using heat curves that the BACS will adjust in a manner that ensures the desired room temperature can be reached, whilst optimising generator efficiency and minimising heat distribution losses.

The impact of applying demand orientated control strategies to buildings is not fully modelled within the BAC factors presented in EN15232-1, as the representative buildings are modelled as a single thermal control zone with identical temperatures and occupancy levels in each room (Annex C.1), and thus do not fully reflect the opportunity to reduce thermal distribution resulting from inter-room variations in occupancy levels, set points and heat gains and losses when a Class A BACS is fitted to a large multi-room building.

[145] This figure is based on figure 2 of EN15232-1:2017.

The energy savings due to heat curve optimisation is not modelled within the simulations used to produce the BAC factors, but the impact of seasonal variations in exterior temperature on the heat losses through the room's walls, ceiling and floor is modelled.

In this study, the impact of demand orientated control is modelled for a representative office building by calculating the reduction in fan energy realised by reducing air flow into unoccupied rooms and in pumping energy required to distribute hot or chilled water.[146].

The potential impact of dynamic hydronic balancing on energy use will be examined in respect of another representative building (BC3) connected to a district heating scheme in light of evidence that it can reduce the electricity used by pumps by 25 to 50%.

The potential impact of heat curve optimisation is included within the savings realised by a Building Energy Management System in an existing multizone office (Base Case 7).

4.3.6 Adaptive Generation Sequencing

Where multiple generators are used to meet building heating and/or cooling needs[147], the BACS must be able to control them. Traditionally many building management systems were designed to control two or three boilers of similar design, and hence used a simple control logic that rotated the order in which generators where used according to running hours. This was designed to even out wear on burners and extend maintenance intervals.

Under a Class C BACS system, the sequencing controls must be able to operate generators according to a predefined priority list, so that, for example priority can be given to the most efficient renewable generation (e.g. heat pumps, solar, biomass), which may vary according to ambient air conditions and size of the heating/cooling load.

For Class B, the BACS must use a dynamic priority list to schedule generators that takes account of the capacity and current efficiency of the generators, while a Class A BACS, must also factor in the predicted and current heating or cooling load into the dynamic priority list. This feature can be used, for example with boiler systems to minimise standby losses by reducing the number of boilers being operated during periods of reduced demand and to minimise energy losses associated with cycling burners on and off.

A Class A BACS system is also required to include BAC functions within the technical building management system that coordinates the use of CHP, RES and energy storage systems in a way that optimises the consumption of on-site renewable sources and the cost effective use of on-site generation, manages interactions with smart grid including demand side management, heat recovery and shifting using thermal storage. These functions could implement this by adjusting the dynamic priority list in response to time of day tariffs, switching to operating modes that implement predefined demand reduction actions (including use of stored energy), or switching to back-up generators.

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[146] Dynamic simulation of BACS (Building Automation and Control Systems) for the energy retrofitting of a secondary school, Vecchio, C, et al. Proceedings of BS2013, 13th Conference of International Building Performance Simulation Association, Chambéry, France, August 26-28.

[147] Multiple generators are mostly used in larger buildings to provide redundancy in the event of failure, and to improve heat load matching and generator efficiencies. In smaller buildings, single generators of heating and cooling are normally fitted on cost grounds.

The impact of adaptive generation sequencing is not modelled within the BAC factors presented in EN15232-1, which only model the percentage saving in HVAC demand (Annex C.1). A methodology for calculating the potential energy savings realised by adaptive generator scheduling is identified in EN 16947: 2017, but the published data on typical energy savings realised is limited, and the results of simulations are also limited.

The potential impact of adaptive generation sequencing has not been modelled within this study as the representative buildings are assumed to have a single heat or cooling generator per TBS, but it should be noted that energy savings of 2% to 40% can be realised by preventing on-off cycling of large or oversized multi-boiler systems[148] or in poorly control domestic boilers, where non-modulating controls have not been fitted and the combustion chamber is be purged frequently of hot gases for safety reasons[149].

4.3.7 Energy management & optimisation measures

EN 15232-1 describes various energy management and control measures that must be implemented as part of the control strategy implemented by a Class A BACS, including:

- adaptive scheduling of HVAC plant/TBS system run times to a predefined schedule and/or calendar, including variable preconditioning phases
- interlocks to prevent simultaneous heating and cooling of rooms.
- automatic TBS fault detection with alarms and diagnostic functions to support the optimisation of controller tuning, and detection of extreme set points.
- information reporting on energy consumption and indoor conditions, including functions to enable their analysis, performance evaluation and benchmarking.

A number of other energy management and optimisation measures are mentioned in EN 15232-2, EN 15500-1 and EN 12098-1 but not in EN 15232-1, including:

- summer/ winter switch over function for wet heat systems which switches off heat generators and activates isolation valves to reduce standby losses.
- set point change limitation – to prevent users exceeding present limits
- night set back function to enable users to signal an early end for occupation
- window open protection function that turns off TBS when windows are open.

A considerable amount of research has been published on the potential energy savings (c. up to 30%) that can be realised by preventing, detecting and correcting abnormal or inefficient operation of TBS or BACS through monitoring building energy performance.

These energy management and optimisation measures were not modelled within the BAC factors presented in EN 15232-1, so their potential impact on an existing multizone office building (Base Case 7) has been assessed based on the results of the literature review.

4.3.8 Other plant specific functions

In addition to the functions outlined in the previous sections, EN 15232-1 specifies a range of other plant-specific BAC functions for a Class A BACS, including (for example):

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[148] A Boiler Room in a 600-Bed Hospital Complex: Study, Analysis, and Implementation of Energy Efficiency Improvements, Fraile, J. et Al, Energies 2014, 7, 3282-3303.

[149] Domestic boiler anticycling controls: An evaluation (by BRE), GIL083, DETR 1996.

- automatic blind control to prevent overheating due to solar radiation, which is analysed for Base Case 4.
- automatic on/off control and scheduled charging enablement of DHW storage and demand-based temperature control or multi-sensor storage management
- control of DHW circulation pumps using a time program
- load prediction-based control of Thermal Energy Storage (TES) charging
- control functions to maximise use of free mechanical & night cooling, including the control of automatic window openers and other natural ventilation systems which is analysed for Base Case 4 and 7.
- overheating and icing protection on heat recovery on air handling systems
- the direct control of air humidification and dehumidification equipment to a given setpoint and based on measurement of the humidity of supply or room air.
- automatic control of lighting to switch off lighting in unoccupied rooms and maximise use of daylight. These functions have been considered under Lot 37 and are analysed in Base Case 5
- control of distribution pumps which is analysed for Base Case 2.

The potential impact of these plant-specific functions on energy performance can be simulated, but only the improved control of shading devices and DHW energy use was modelled within the BAC factors presented in EN15232-1. For DHW, a 3°C reduction in average mean storage tank temperature and 3-hour reduction in operating times between a Class C and Class A BACS is assumed. For automatic blind control, the shading factor is assumed to improve from 0.5 to 0.7 between a Class C and a Class A BACS.

The impact of automatic blind control on a new residential flat was selected for modelling for Base Case 4, as audited case studies indicated a potential energy savings of 3% to 11% in air-conditioned buildings[150].

The impact of using automatic window openers to control the temperature of a new residential flat (Base Case 4) and an existing office (Base Case 7) was also modelled.

4.3.9 BACS business-as-usual (BAU)

BACS, in some form or other, are present in all buildings. Very simple BACS, such as basic thermostats and light switches, have been incorporated in buildings for many decades and most would meet the minimum requirements for Class D, which covers situations where no automatic controls are installed on technical building services[151].

Most existing Building Management Systems (BMS) and Building Energy Management Systems (BEMS) designed for non-residential premises should be able to meet the requirements for EN15232 Class C if standalone room controls or thermostatic values are fitted to heating and cooling emitters. They may also be able to meet the Class B requirements, if room controllers are networked to the central control unit, so that

[150] A simulation of solar shading control on UK office energy use, Littlefair, P. et al, Building Research & Information, 38:6, pp 638-646, 2010.

[151] One possible exception to coverage is open hearth fires or wood burners, where constant temperature control is not directly applied to the heat generated by combustion.

changes in operating times and temperature setpoints can be updated from the central unit. However, some BAC functions required by Class B are not commonly found in older products, including, for example the dynamic prioritisation in the sequencing of generators of heat and chilled water based on generator efficiency and characteristics.

Most standalone Heating, Ventilation and Air Conditioning (HVAC) Zone Controls as defined in EN-15550-1:2017 also should meet the minimum requirements of Class C[152].

The classification of existing BAC systems used in residential premises is more difficult. In principal, most new central heating controls for boiler-based systems should be able to meet the Class C requirements, provided some form of individual room control is installed. However, a large number of existing residential buildings still do not have TRVs fitted to radiators, so temperature control is implemented at a whole house or floor level.

Many existing lower cost central heating control systems also do not implement variable temperature control of heat generators depending on the outside temperature (EN15232-1 requirements 1.6 and 2.7). Whilst this capability can be retrofitted and is a common feature of many smart heating controllers and some new boilers[153], in practice, its absence means that most small residential properties are likely to have Class D control solution.

For consistency with the approach adopted in EN15232-1, this study assumes that the existing BACS solution in the eight reference buildings is Class C, which in summary is:

- individual room controls are applied to heating and cooling emitters (using TRVs or electronic controllers), but air flow rates are not controlled at room level
- automatic central control of HVAC systems operation using a fixed time program with load-based scheduling of multiple heating and cooling generators (if fitted)
- outside temperature compensated control is applied to the control of hot and chilled water distribution networks, with on/off control of distribution pumps
- no interlocks to prevent simultaneous operation of heating and cooling
- ventilation and air conditioning systems include constant air supply temperature and dewpoint (humidity) controls, and are designed to use night cooling
- lighting is based on manual on/off switches (per room)
- blind control is manually controlled.

4.3.10 BACS Best Available Technology (BAT)

For the purposes of this study, the Best Available Technology (BAT) was initially defined as a BACS that meets the Class A requirements of EN 15232-1[154]. However, stakeholders indicated that some Class A BAC functionality may not be applicable to all buildings and

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152 https://www.bre.co.uk/filelibrary/pdf/rpts/115133EMandBuildingControls.pdf

153 Load compensation, which delivers similar levels of energy savings to basic outdoor air temperature correction is a standard feature of many domestic condensing boilers, see: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/648337/heating-controls-compensation-tpi-bre.pdf

154 EN15232-1:2017 should be consulted for a detailed description of the functional requirements of a Class A, B and C BACS.

that it would be better to use Class B functionality as the starting point for modelling and to explore the cost effectiveness adding of selected Class A energy saving BAC functions.

As outlined in the introduction to Task 1, the BAT design options selected for modelling were based on the shortlist of high impact BACS functions that was elaborated in the previous scoping study (Table 3, 2018)[155]. This study was focussed on a selection of up to 16 cases that best demonstrate the energy savings available from the application of BACS. Accordingly, with the assistance of stakeholders, the study identified a selection of Best Available Technology (BAT) design options for different BAC functions defined in EN15232-1:2017 that could be applied to each of the base cases for the eight reference buildings, and modelled within the resources available for this task. The BAT design options were designed to explore the different energy saving methods and functions outlined in section 4.3.1 and includes: some control improvements in respect of a single BAC function; some combinations of BAC functions; as well as examples of full upgrades to a Class A BACS and a Class B BACS.

The BAC functions that were modelled for each base case are briefly outlined in Table 4-2 for each BAT option. Further information on the data and assumptions used in modelling is presented in Annex A, while Annex B presents the output from an Energy Performance Certification (EPC) tool that was used by stakeholders to illustrate the EN15232-1 BAT functions for Base Case 8 (a new office block), which consists of a mix of Class A and B BAC functions.

A brief overview of the BAT design options modelled for each Base Case is as follows:

- For Base Case 1, the impact of improved control accuracy on heat emission in an existing house is modelled using a stepwise approach (0.5 – 1 degree Celsius) in BC1hoBAT05 and BC1hoBAT10. The impact of applying Class VIII temperature control from EU No 813/2013 is also modelled in BC1hoBATLot1. This uses multi-sensor room temperature control to modulate heater output. Keeping the temperature for heating as close as possible to the minimum required temperature is an important function of a BACS and is considered one of the most important BAC functions for a well-insulated existing house.
- For Base Case 2, the impact of demand driven ventilation on a new low-energy house is modelled in option BC2hoBAT1. A two-zone model has been used instead of a single-zone model. In addition, the two-zone model is of a new airtight low energy building with a high level of insulation. For this type of low energy building transmission losses are low, but ventilation remains an important factor to control which makes it suitable for simulating the impact of this control function. The impact of applying a pressure-controlled circulator to the base case is also modelled in BC2hoBAT2.
- For Base Case 3, the impact of dynamic hydronic balancing on heat emissions and auxiliary electricity consumption of an existing apartment is modelled in BC3apBAT1. The dynamic hydronic balancing has no impact on cooling energy

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

demand in this example, but it may have an impact on other types of space cooling system.

- For Base Case 4, the impact of automatically controlling blinds fitted to a new apartment is modelled. Overheating is a known challenge in well insulated buildings and in warm climates, and cooling demand can be reduced by controlling external blinds; see BC4apBAT1. These types of controls are needed to resolve overheating and maintain thermal comfort in better insulated buildings. Note, that when buildings become more insulated and airtight the demand for such controls might increase even in regions with an average climate[156]. For BC4apBAT1, the additional auxiliary power needed to operate the actuators has been modelled in detail. The results indicate that the increased auxiliary energy is less than the reduction in cooling demand.
- For Base Case 5, the impact of installing automatic lighting controls on an existing wholesale shop is modelled in BC5whoBAT1. This causes the demand for heating to increase in the BAT case, as automatic lighting control reduces the internal heat gain available from artificial lighting. The annual energy savings realised by automatic lighting control are slightly larger than the increase in total heating demand. This BAT Option was added to check the heat replacement effect, which was not considered by Lot 37. The result is that its impact is minimal.
- For Base Case 6, the impact of upgrading a Class C BACS to Class B is modelled in BC6whBAT1, and from a Class C to a Class A BACS is modelled in BC6whBAT2 for a new shop. The change in energy demand was calculated using the BAC factors in EN15232-1: 2017. This is a generic simulation that in principal accounts for the overall set of BACS functions. The BAC factors in EN15232-1 were based on the results of a large number of simulations using Method 1.
- For Base Case 7, the impact of retrofitting a Building (Energy) Management System to an existing office has been modelled in BC7ofBAT1. In line with the other BAT design options, the benefits of energy management and optimisation is modelled as improving on Class C energy performance. However it should be noted that the estimated savings are conservative as the Class C reference conditions in EN15232-1 Annex C standardised room do not allow for the effects of users overriding setpoints or time schedules, poorly tuned room controllers, simultaneous heating and cooling, and other uncorrected faults in the BACS. In BC7ofBAT2, the BMS benefits related to natural ventilation are modelled based on the results of a literature review and modelling assumptions. BC7ofBAT2 also models the additional auxiliary power needed to operate the window actuators in detail but this turns out to be neglectable compared to the energy savings.
- For Base Case 8 option BC8ofBAT1, the impact of installing a Class A BACS in a new office building was modelled. The original aim was to model as many Class A BAC functions as possible within multi-zone simulation using EnergyPlus. However, stakeholders considered that some Class A BAC functions were not applicable to the TBS, so some Class B BAC functions were modelled instead. More details of the BAC functions that stakeholders indicated could be specified for this type of multi-zone office building (Base Case 8) are given in Annex B.

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156 https://www.ad.nl/wonen/te-goed-geisoleerd-extreme-zomerhitte-gaat-niet-meer-weg-uit-nieuwbouwflat~a16ca256/

The results of modelling the impact on the energy performance of implementing these BAT design options on the eight Base Cases are presented in Table 4-3 to Table 4-15. A comparison of the BAC factors produced by the study team's modelling work and those provided in Annex A of EN15232-1: 2017 is set out in Table 4-16.

It should be noted that:

- in each table, the energy demands and BAC factors for a Business as Usual (BAU) scenario and a Best Available Technology (BAT) scenario are presented
- the study-team used data on energy savings realised in actual buildings and published in peer reviewed papers wherever possible. However, this "real life evidence" was only available for a small number of the BAT design options modelled
- the study-team used several modelling methods and tools to derive the results presented in these tables (see data source at the bottom of each table). The capabilities of each tool and level of detail modelled varies, and some aspects are not modelled (NM). For example, the internal heat gain energy balance data available from EnergyPlus is different from that provided by PHPP and Enercalc.

The main conclusions of the modelling work are summarised as follows:

- Base Case 1 shows that a substantial proportion (53%) of the energy savings realised by a Class A BACS in residential buildings are due to a 1°C improvement in control accuracy
- Base Case 2 illustrates the significant energy savings that can be realised by fitting demand-controlled ventilation to a new low energy house with high levels of insulation and air-tightness. The installation of a pressure-controlled circulator realised additional electricity savings that are not modelled in the EN15232-1 BAC factors
- Base Case 3 illustrates the substantial thermal and electricity savings that can be realised by application of a combination of dynamic hydronic balancing and variable speed pump control to an existing residential apartment connected to a district heating scheme
- Base Case 4 illustrates that upgrading BACS in a new, low energy, well-insulated, apartment can result in decreased energy use, as the issue of overheating due to solar gain is addressed and the levels of comfort are then better controlled.
- Base Case 5 illustrates that fitting automatic light controls to an existing wholesale shop may result in an increase in heating energy demand as the heat generated by lighting is replaced. However overall energy savings are still realised.
- Base Case 6 illustrates that upgrading a shop from a Class C to a Class B BACS realises around half of the savings realised by upgrading from Class C to Class A
- Base Case 7 illustrates that retrofitting a Building Energy Management System (BEMS) to an existing office block realises 50-60% of the energy savings realised by upgrading to Class A
- Base Case 8 illustrates that significant energy savings that can be realised by fitting a combination of Class A BACS functions to a new, multizone, low energy office block.

Table 4-2: The BAT design options considered for the 8 representative buildings (with details of EN15232-1 BAC functions modelled.)

No.	Model Reference	Base Case	Building	Energy Saving Method	Modelling Approach	EN15232-1 BAC functions modelled
1	BC1hoBAT05	1	Existing House	4.3.2.1 Improved control accuracy	Simulate impact of more accuracy from class C type control systems (22°C to 21,5 °C).	1.1 Emission control (Level 2 / Class C)
2	BC1hoBAT10	1	Existing House	4.3.2.1 Improved control accuracy	Simulate impact of more accuracy from class C type control systems (22°C to 21 °C)	1.1 Emission control (Level 2 / Class C)
3	BC1hoBATLot1	1	Existing House	4.3.2.1 Improved control accuracy	Application of Class VIII temperature control from EU No 813/2013 (Multi-sensor room temperature control, for use with modulating heaters)	1.1 Emission control (Level 2 / Class C) 1.3 Control of distribution network hot water temperature (Level 2 / Class C) 1.5 Intermittent control of emission and/or distribution (Level 1 - fixed time programme / Class C) 1.6 Heat generator control (Level 2 - variable temperature control / Class A)
4	BC2hoBAT1	2	New House	4.3.2.4 Demand orientated control and optimisation	Simulates demand driven ventilation	4.1 Supply air flow control at the room level (Level 2 occupancy detection sleep vs living / Class A) 4.5 Air flow or pressure control at the air handler level (Level 3 – automatic flow control / Class A)
5	BC2hoBAT2	2	New House	4.3.2.4 Demand orientated control and optimisation	Application of a pressure-controlled circulator pump	1.4 Control of distribution pumps in networks (Level 4 – external demand signal / Class A)
6	BC3apBAT1	3	Existing Apartment	4.3.2.1 Improved control accuracy	Simulates benefits of hydronic balancing + pump control (correction factor app)	1.4 Control of distribution pumps in networks (Level 4 – external demand signal / Class A)
7	BC4apBAT1	4	New Apartment	4.3.2.7 Other plant specific functions	Simulates smart outdoor screens for shading (time schedule approach)	6.1 Automatic blind control (only considered overheating prevention). (Level 2 / Class B)
8	BC5whoBAT1	5	Existing Shop (Wholesale)	4.3.2.7 Other plant specific functions	Check for heat replacement effect combined with Lot 37 lighting	5.1 Occupancy control of Lighting (level 3 / Class A) 5.2 Automatic dimming. (Level 3 / Class A)

9	BC6whBAT1	6	New Shop (Wholesale)	All	Apply the EN 15232 simple BAC factor method (BAU=Class C vs BAT=Class B)	As specified in EN15232-1: 2017 (Annex C)
10	BC6whBAT2	6	New Shop (Wholesale)	All	Apply the EN 15232 simple BAC factor method (BAU=Class C vs BAT=Class A)	As specified in EN15232-1: 2017 (Annex C)
11	BC7ofBAT1	7	Existing Office Block	4.3.2.6 Energy management & optimisation measures	Model BMS benefits based on literature findings (exc. Ventilation)	7.1 Set point management (Level 3 / Class A) 7.2 Runtime management (Level 2 / Class A) 7.3 Fault detection and diagnosis (Level 2 / Class A) 7.4 Energy consumption reporting (Level 1 / Class B)
12	BC7BAT2	7	Existing Office Block	4.3.2.6 Energy management & optimisation measures	Model BMS benefits related to natural ventilation based on literature findings (incl. window openers)	7.1 Set point management (Level 3 / Class A) 7.2 Runtime management (Level 2 / Class A) 7.3 Fault detection and diagnosis (Level 2 / Class A) 7.4 Energy consumption reporting (Level 1 / Class B) 4.8 Free mechanical cooling (Level 2 / Class B)
13	BC8ofBAT1	8	New Office Block	All	Occupancy based emission control of heating and ventilation (time + temp set points approach), individual room control and other functions. See Annex B for details.	1.1 & 3.1 Emission control (Level 4 / Class A) 1.3 & 3.3 Control of distribution network hot or chilled water temperature (Level 2 / Class A) 1.4 & 3.4 Distribution pump control (Level 4 /Class A) 1.5 & 3.5 Intermittent control of emission and/or distribution (Level 3 / Class A) 1.7 & 3.8 Generator control (Level 2 / Class A) 3.6 Interlock between heating and cooling (Level 2 / Class A) 4.1 Supply air flow control at the room level (Level 2 occupancy detection / Class A) 4.2 Room air temp. control (Level 4 / Class A) 4.5 Air flow or pressure control at the air handler level (Level 4 – automatic flow control / Class A) 6.1 Automatic blind control (Level 2 / Class A) 7.1 to 7.4 (as above) assume to be fitted, but not explicitly modelled within simulation.

Table 4-3: Impact of an 0.5°C improvement in control accuracy on an existing house

Base Case 1, Existing, residential, house			**BC1hoBAU**	**BC1hoBAT05**
aim: simulate impact of improved accuracy from class C type control systems (22°C to 21.5 °C)				
Energy balance losses for heating (main source)				
Transmission losses for heating	Q,T	kWh/(m².y)	81.5	78.1
Ventilation losses (infiltration loss)	Q,V	kWh/(m².y)	89.0	85.3
Energy balance Internal Heat Gains (IHG) supplied from electricity				
Electrical auxiliary energy for heating	W H, aux	kWh/(m².y)	0.5	0.5
Electrical auxiliary energy for ventilation	W V, aux	kWh/(m².y)	0.0	0.0
Lighting Energy Numeric Indicator	LENI	kWh/(m².y)	NM	NM
Electrical energy for non TBS appliances inside heated area	W plug	kWh/(m².y)	NM	NM
Total electrical load inside the heated area	W, int	kWh/(m².y)	NM	NM
Total IHG electrical inside the heated area	W, int	kWh/(m².y)	11.2	12.5
Energy balance internal heat gains (IHG) supplied free				
IHG - passive solar-heat replacement	Q H,S	kWh/(m².y)	35.8	35.1
IHG - people	Q,P	kWh/(m².y)	6.3	4.7
Energy Balance final annual heating demand				
Heating energy needs of the building	Q H,nd, B	kWh/(m².y)	117.2	111.2
Energy Balance final annual cooling demand				
Cooling energy needs of the building	Q C,nd, B	kWh/(m².y)	NM	NM
Final energy demand (including gen. and dist. losses) and BAC factors				
Distribution energy losses for heating (outside heated area + non functional);	Q H,ls	kWh/(m².y)	0.4	0.4
Heat demand for generation		kWh/(m².y)	117.6	111.6
Type of energy supplied for heating	type	gas or elec.	gas	gas
heat generation efficiency	SEER/SCOP	%	94%	94%
Final heating demand	Q, H, tot, BAC	kWh/(m².y)	125.1	118.8
BAC factor for thermal energy (heating)	fBAC,th, H		1.00	0.95
BAC factor for auxiliary energy	fBAC,el		1.00	1.00
BAC factor for lighting energy	fBAC,el, L		NM	NM
Cooling generation efficiency	SEER		NM	NM
Final electricity needed for cooling	Q, C, tot, BAC	kWh/(m².y)	NM	NM
BAC factor for thermal energy (cooling)	fBAC,th, C	kWh/(m².y)	NM	NM
Data source			**PHPP**	**PHPP**

Table 4-4: Impact of an 1°C improvement in control accuracy on an existing house

Base Case 1, Existing, residential, house			BC1hoBAU	BC1hoBAT10
aim: simulate impact of more accuracy from class C type control systems (22°C to 21 °C)				
Energy balance losses for heating (main source)				
Transmission losses for heating	Q,T	kWh/(m².y)	81.5	74.8
Ventilation losses (infiltration loss)	Q,V	kWh/(m².y)	89.0	81.6
Energy balance Internal Heat Gains (IHG) supplied from electricity				
Electrical auxiliary energy for heating	W H, aux	kWh/(m².y)	0.5	0.5
Electrical auxiliary energy for ventilation	W V, aux	kWh/(m².y)	0.0	0.0
Lighting Energy Numeric Indicator	LENI	kWh/(m².y)	NM	NM
Electrical energy for non TBS appliances inside heated area	W plug	kWh/(m².y)	NM	NM
Total electrical load inside the heated area	W, int	kWh/(m².y)	NM	NM
Total IHG electrical inside the heated area from electrical loads	W, int	kWh/(m².y)	11.2	10.7
Energy balance internal heat gains (IHG) supplied free				
IHG - passive solar-heat replacement	Q H,S	kWh/(m².y)	35.8	34.3
IHG - people	Q,P	kWh/(m².y)	6.3	6.0
Energy Balance final annual heating demand				
Heating energy needs of the building	Q H,nd, B	kWh/(m².y)	117.2	105.3
Energy Balance final annual cooling demand				
Cooling energy needs of the building	Q C,nd, B	kWh/(m².y)	NM	NM
Final energy demand (including gen. and dist. losses) and BAC factors				
Distribution energy losses for heating (outside heated area + non functional);	Q H,ls	kWh/(m².y)	0.4	0.4
Heat demand for generation		kWh/(m².y)	117.6	105.7
Type of energy supplied for heating	type	gas or elec.	gas	gas
heat generation efficiency	SEER/SCOP	%	94%	94%
Final heating demand	Q, H, tot, BAC	kWh/(m².y)	125.1	112.5
BAC factor for thermal energy (heating)	fBAC,th, H		1.00	0.90
BAC factor for auxiliary energy	fBAC,el		1.00	1.00
BAC factor for lighting energy	fBAC,el, L		NM	NM
Cooling generation efficiency	SEER		NM	NM
Final electricity needed for cooling	Q, C, tot, BAC	kWh/(m².y)	NM	NM
BAC factor for thermal energy (cooling)	fBAC,th, C	kWh/(m².y)	NM	NM
Data source			PHPP	PHPP

Table 4-5: Impact of improved control accuracy on an existing house (Multiple sensors)

Base Case 1, Existing, residential, house			BC1hoBAU	BC1hoBATLot1
aim: Application of Class VIII from EU No 813/2013				
Energy balance losses for heating (main source)				
Transmission losses for heating	Q,T	kWh/(m².y)	81.5	NM
Ventilation losses (infiltration loss)	Q,V	kWh/(m².y)	89.0	NM
Energy balance Internal Heat Gains (IHG) supplied from electricity				
Electrical auxiliary energy for heating	W H, aux	kWh/(m².y)	0.5	NM
Electrical auxiliary energy for ventilation	W V, aux	kWh/(m².y)	0.0	NM
Lighting Energy Numeric Indicator	LENI	kWh/(m².y)	NM	NM
Electrical energy for non TBS appliances inside heated area	W plug	kWh/(m².y)	NM	NM
Total electrical load inside the heated area	W, int	kWh/(m².y)	NM	NM
Total IHG electrical inside the heated area from electrical loads	W, int	kWh/(m².y)	11.2	NM
Energy balance internal heat gains (IHG) supplied free				
IHG - passive solar-heat replacement	Q H,S	kWh/(m².y)	35.8	NM
IHG - people	Q,P	kWh/(m².y)	6.3	NM
Energy Balance final annual heating demand				
Heating energy needs of the building	Q H,nd, B	kWh/(m².y)	117.2	NM
Energy Balance final annual cooling demand				
Cooling energy needs of the building	Q C,nd, B	kWh/(m².y)	NM	NM
Final energy demand (including gen. and dist. losses) and BAC factors				
Distribution energy losses for heating (outside heated area + non functional);	Q H,ls	kWh/(m².y)	0.4	NM
Heat demand for generation		kWh/(m².y)	117.6	NM
Type of energy supplied for heating	type	gas or elec.	gas	NM
heat generation efficiency	SEER/SCOP	%	94%	NM
Final heating demand	Q, H, tot, BAC	kWh/(m².y)	125.1	118.9
BAC factor for thermal energy (heating)	fBAC,th, H		1.00	0.95
BAC factor for auxiliary energy	fBAC,el		1.00	1.00
BAC factor for lighting energy	fBAC,el, L		NM	NM
Cooling generation efficiency	SEER		NM	NM
Final electricity needed for cooling	Q, C, tot, BAC	kWh/(m².y)	NM	NM
BAC factor for thermal energy (cooling)	fBAC,th, C	kWh/(m².y)	NM	NM
Data source			PHPP	Lot 1

Table 4-6: Impact of demand orientated control of ventilation on a new house

Base Case 2, New, residential, house			BC2hoBAU	BC2hoBAT1
aim: simulates demand driven ventilation (note: interior temperature winter set to 20°C in BAU and BAT and 25 °C for summer)				
Energy balance losses for heating (main source)				
Transmission losses for heating	Q,T	kWh/(m².y)	35.6	33.7
Ventilation losses (infiltration loss)	Q,V	kWh/(m².y)	8.2	5.3
Energy balance Internal Heat Gains (IHG) supplied from electricity				
Electrical auxiliary energy for heating	W H, aux	kWh/(m².y)	0.5	0.5
Electrical auxiliary energy for ventilation	W V, aux	kWh/(m².y)	2.8	1.4
Lighting Energy Numeric Indicator	LENI	kWh/(m².y)	NM	NM
Electrical energy for non TBS appliances inside heated area	W plug	kWh/(m².y)	NM	NM
Total electrical load inside the heated area	W, int	kWh/(m².y)	NM	NM
Total IHG electrical inside the heated area from electrical loads	W, int	kWh/(m².y)	6.2	4.9
Energy balance internal heat gains (IHG) supplied free				
IHG - passive solar-heat replacement	Q H,S	kWh/(m².y)	15.5	13.4
IHG - people	Q,P	kWh/(m².y)	5.7	5.8
Energy Balance final annual heating demand				
Heating energy needs of the building	Q H,nd, B	kWh/(m².y)	16.5	14.9
Energy Balance final annual cooling demand				
Cooling energy needs of the building	Q C,nd, B	kWh/(m².y)	NM	NM
Final energy demand (including gen. and dist. losses) and BAC factors				
Distribution energy losses for heating (outside heated area + non functional);	Q H,ls	kWh/(m².y)	0.5	0.5
Heat demand for generation		kWh/(m².y)	17.0	15.4
Type of energy supplied for heating	type	gas or elec.	elec	elec
heat generation efficiency	SEER/SCOP	%	388%	388%
Final heating demand	Q, H, tot, BAC	kWh/(m².y)	4.4	4.0
BAC factor for thermal energy (heating)	fBAC,th, H		1.00	0.91
BAC factor for auxiliary energy	fBAC,el		1.00	0.59
BAC factor for lighting energy	fBAC,el, L		NM	NM
Cooling generation efficiency	SEER		NM	NM
Final electricity needed for cooling	Q, C, tot, BAC	kWh/(m².y)	NM	NM
BAC factor for thermal energy (cooling)	fBAC,th, C	kWh/(m².y)	NM	NM
Data source			**PHPP**	**PHPP**

Table 4-7: Impact of fitting a pressure controlled circulator pump to a new house

Base Case 2, New, residential, house			BC2hoBAU	BC2hoBAT2
aim: apply pressure controlled circulator pump				
Energy balance losses for heating (main source)				
Transmission losses for heating	Q,T	kWh/(m².y)	35.6	35.6
Ventilation losses (infiltration loss)	Q,V	kWh/(m².y)	8.2	8.2
Energy balance Internal Heat Gains (IHG) supplied from electricity				
Electrical auxiliary energy for heating	W H, aux	kWh/(m².y)	0.5	0.4
Electrical auxiliary energy for ventilation	W V, aux	kWh/(m².y)	2.8	2.8
Lighting Energy Numeric Indicator	LENI	kWh/(m².y)	NM	NM
Electrical energy for non TBS appliances inside heated area	W plug	kWh/(m².y)	NM	NM
Total electrical load inside the heated area	W, int	kWh/(m².y)	NM	NM
Total IHG electrical inside the heated area from electrical loads	W, int	kWh/(m².y)	6.2	6.2
Energy balance internal heat gains (IHG) supplied free				
IHG - passive solar-heat replacement	Q H,S	kWh/(m².y)	15.5	15.5
IHG - people	Q,P	kWh/(m².y)	5.7	5.7
Energy Balance final annual heating demand				
Heating energy needs of the building	Q H,nd, B	kWh/(m².y)	16.5	16.5
Energy Balance final annual cooling demand				
Cooling energy needs of the building	Q C,nd, B	kWh/(m².y)	NM	NM
Final energy demand (including gen. and dist. losses) and BAC factors				
Distribution energy losses for heating (outside heated area + non functional);	Q H,ls	kWh/(m².y)	0.5	0.5
Heat demand for generation		kWh/(m².y)	17.0	17.0
Type of energy supplied for heating	type	gas or elec.	elec	elec
heat generation efficiency	SEER/SCOP	%	388%	388%
Final heating demand	Q, H, tot, BAC	kWh/(m².y)	4.4	4.4
BAC factor for thermal energy (heating)	fBAC,th, H		1.00	1.00
BAC factor for auxiliary energy	fBAC,el		1.00	0.96
BAC factor for lighting energy	fBAC,el, L		NM	NM
Cooling generation efficiency	SEER		NM	NM
Final electricity needed for cooling	Q, C, tot, BAC	kWh/(m².y)	NM	NM
BAC factor for thermal energy (cooling)	fBAC,th, C	kWh/(m².y)	NM	NM
Data source			**PHPP**	**PHPP**

Table 4-8: Impact of hydronic balancing and pumps control on an existing apartment

Base Case 3, Existing, residential, apartment			BC3apBAU	BC3apBAT1
aim: simulates the benefits of hydronic balancing + pump control (correction factor app)				
Energy balance losses for heating (main source)				
Transmission losses for heating	Q,T	kWh/(m².y)	123.8	NM
Ventilation losses (infiltration loss)	Q,V	kWh/(m².y)	54.3	NM
Energy balance Internal Heat Gains (IHG) supplied from electricity				
Electrical auxiliary energy for heating	W H, aux	kWh/(m².y)	3.3	2.4
Electrical auxiliary energy for ventilation	W V, aux	kWh/(m².y)	0.0	0.0
Lighting Energy Numeric Indicator	LENI	kWh/(m².y)	NM	NM
Electrical energy for non TBS appliances inside heated area	W plug	kWh/(m².y)	NM	NM
Total electrical load inside the heated area	W, int	kWh/(m².y)	NM	NM
Total IHG electrical inside the heated area from electrical loads	W, int	kWh/(m².y)	22.3	NM
Energy balance internal heat gains (IHG) supplied free				
IHG - passive solar-heat replacement	Q H,S	kWh/(m².y)	68.1	NM
IHG - people	Q,P	kWh/(m².y)	4.0	NM
Energy Balance final annual heating demand				
Heating energy needs of the building	Q H,nd, B	kWh/(m².y)	83.7	83.7
Energy Balance final annual cooling demand				
Cooling energy needs of the building	Q C,nd, B	kWh/(m².y)	NM	NM
Final energy demand (including gen. and dist. losses) and BAC factors				
Distribution energy losses for heating (outside heated area + non functional);	Q H,ls	kWh/(m².y)	15.1	9.2
Heat demand for generation		kWh/(m².y)	98.8	92.9
Type of energy supplied for heating	type	gas or elec.	district heat/gas	district heat/gas
heat generation efficiency	SEER/SCOP	%	89%	89%
Final heating demand	Q, H, tot, BAC	kWh/(m².y)	111.0	104.4
BAC factor for thermal energy (heating)	fBAC,th, H		1.00	0.94
BAC factor for auxiliary energy	fBAC,el		1.00	0.75
BAC factor for lighting energy	fBAC,el, L		NM	NM
Cooling generation efficiency	SEER		NM	NM
Final electricity needed for cooling	Q, C, tot, BAC	kWh/(m².y)	NM	NM
BAC factor for thermal energy (cooling)	fBAC,th, C	kWh/(m².y)	NM	NM
Data source			**PHPP**	**literature**

Table 4-9: Impact of automatic blind control on a new residential apartment

Base Case 4, New, residential, flat			BC4apBAU	BC4apBAT1
aim: simulates smart outdoor screens for shading (time schedule approach)				
Energy balance losses for heating (main source)				
Transmission losses for heating	Q,T	kWh/(m².y)	48.1	42.7
Ventilation losses (infiltration loss)	Q,V	kWh/(m².y)	27.7	27.3
Energy balance Internal Heat Gains (IHG) supplied from electricity				
Electrical auxiliary energy for heating	W H, aux	kWh/(m².y)	0.5	0.5
Electrical auxiliary energy for ventilation	W V, aux	kWh/(m².y)	0.0	0.0
Lighting Energy Numeric Indicator	LENI	kWh/(m².y)	2.9	2.9
Electrical energy for non TBS appliances inside heated area	W plug	kWh/(m².y)	35.0	35.0
Total electrical load inside the heated area	W, int	kWh/(m².y)	37.9	37.9
Total IHG electrical inside the heated area from electrical loads	W, int	kWh/(m².y)	NM	NM
Energy balance internal heat gains (IHG) supplied free				
IHG - passive solar-heat replacement	Q H,S	kWh/(m².y)	150.8	58.8
IHG - people	Q,P	kWh/(m².y)	17.3	17.6
Energy Balance final annual heating demand				
Heating energy needs of the building	Q H,nd, B	kWh/(m².y)	2.9	2.9
Energy Balance final annual cooling demand				
Cooling energy needs of the building	Q C,nd, B	kWh/(m².y)	134.7	48.7
Final energy demand (including gen. and dist. losses) and BAC factors				
Distribution energy losses for heating (outside heated area + non functional);	Q H,ls	kWh/(m².y)	0.0	0.0
Heat demand for generation		kWh/(m².y)	2.9	2.9
Type of energy supplied for heating	type	gas or elec.	elec	elec
heat generation efficiency	SEER/SCOP	%	300%	300%
Final heating demand	Q, H, tot, BAC	kWh/(m².y)	1.0	1.0
BAC factor for thermal energy (heating)	fBAC,th, H		1.00	1.00
BAC factor for auxiliary energy	fBAC,el		1.00	1.06
BAC factor for lighting energy	fBAC,el, L		NM	NM
Cooling generation efficiency	SEER		3.10	3.10
Final electricity needed for cooling	Q, C, tot, BAC	kWh/(m².y)	43.46	15.70
BAC factor for thermal energy (cooling)	fBAC,th, C	kWh/(m².y)	1.00	0.36
Data source			**EnergyPlus**	**EnergyPlus**

Table 4-10: Impact of automatic lighting control on an existing shop building

Base Case 5, Existing, non-residential, shop			BC5whBAU	BC5whoBAT1
aim: check for heat replacement effect combined with Lot 37 lighting				
Energy balance losses for heating (main source)				
Transmission losses for heating	Q,T	kWh/(m².y)	115.6	115.6
Ventilation losses (infiltration loss)	Q,V	kWh/(m².y)	99.9	99.9
Energy balance Internal Heat Gains (IHG) supplied from electricity				
Electrical auxiliary energy for heating	W H, aux	kWh/(m².y)	1.7	1.7
Electrical auxiliary energy for ventilation	W V, aux	kWh/(m².y)	2.7	2.7
Lighting Energy Numeric Indicator	LENI	kWh/(m².y)	19.4	8.2
Electrical energy for non TBS appliances inside heated area	W plug	kWh/(m².y)	15.0	15.0
Total electrical load inside the heated area	W, int	kWh/(m².y)	32.5	27.6
Total IHG electrical inside the heated area from electrical loads	W, int	kWh/(m².y)	29.3	24.8
Energy balance internal heat gains (IHG) supplied free				
IHG - passive solar-heat replacement	Q H,S	kWh/(m².y)	43.7	44.8
IHG - people	Q,P	kWh/(m².y)	5.0	5.0
Energy Balance final annual heating demand				
Heating energy needs of the building	Q H,nd, B	kWh/(m².y)	137.6	140.9
Energy Balance final annual cooling demand				
Cooling energy needs of the building	Q C,nd, B	kWh/(m².y)	NM	NM
Final energy demand (including gen. and dist. losses) and BAC factors				
Distribution energy losses for heating (outside heated area + non functional);	Q H,ls	kWh/(m².y)	45.2	45.2
Heat demand for generation		kWh/(m².y)	182.8	186.1
Type of energy supplied for heating	type	gas or elec.	district heat	district heat
heat generation efficiency	SEER/SCOP	%	100%	100%
Final heating demand	Q, H, tot, BAC	kWh/(m².y)	182.8	186.1
BAC factor for thermal energy (heating)	fBAC,th, H		1.00	1.02
BAC factor for auxiliary energy	fBAC,el		1.00	0.87
BAC factor for lighting energy	fBAC,el, L		1.00	0.85
Cooling generation efficiency	SEER		NM	NM
Final electricity needed for cooling	Q, C, tot, BAC	kWh/(m².y)	NM	NM
BAC factor for thermal energy (cooling)	fBAC,th, C	kWh/(m².y)	NM	NM
Data source			**Enercalc**	**EN standards**

Table 4-11: Impact of upgrading from a Class C to a Class B BACS on a new shop building

Base Case 6, New, non-residential, shop			BC6whBAU	BC6whBAT1
aim: apply the EN 15232 simple BAC factor method (BAU=ClassC vs BAT=ClassB)				
Energy balance losses for heating (main source)				
Transmission losses for heating	Q,T	kWh/(m².y)	71.6	NM
Ventilation losses (infiltration loss)	Q,V	kWh/(m².y)	49.3	NM
Energy balance Internal Heat Gains (IHG) supplied from electricity				
Electrical auxiliary energy for heating	W H, aux	kWh/(m².y)	1.7	NM
Electrical auxiliary energy for ventilation	W V, aux	kWh/(m².y)	13.3	NM
Lighting Energy Numeric Indicator	LENI	kWh/(m².y)	16.5	NM
Electrical energy for non TBS appliances inside heated area	W plug	kWh/(m².y)	15.0	NM
Total electrical load inside the heated area	W, int	kWh/(m².y)	46.5	NM
Total IHG electrical inside the heated area from electrical loads	W, int	kWh/(m².y)	27.9	NM
Energy balance internal heat gains (IHG) supplied free				
IHG - passive solar-heat replacement	Q H,S	kWh/(m².y)	30.8	NM
IHG - people	Q,P	kWh/(m².y)	3.9	NM
Energy Balance final annual heating demand				
Heating energy needs of the building	Q H,nd, B	kWh/(m².y)	58.3	NM
Energy Balance final annual cooling demand				
Cooling energy needs of the building	Q C,nd, B	kWh/(m².y)	NM	NM
Final energy demand (including gen. and dist. losses) and BAC factors				
Distribution energy losses for heating (outside heated area + non functional);	Q H,ls	kWh/(m².y)	45.2	NM
Heat demand for generation		kWh/(m².y)	103.5	NM
Type of energy supplied for heating	type	gas or elec.	district heat	district heat
heat generation efficiency	SEER/SCOP	%	100%	NM
Final heating demand	Q, H, tot, BAC	kWh/(m².y)	103.5	73.5
BAC factor for thermal energy (heating)	fBAC,th, H		1.00	0.71
BAC factor for auxiliary energy	fBAC,el		1.00	NM
BAC factor for lighting energy	fBAC,el, L		NM	NM
Cooling generation efficiency	SEER		NM	NM
Final electricity needed for cooling	Q, C, tot, BAC	kWh/(m².y)	NM	NM
BAC factor for thermal energy (cooling)	fBAC,th, C	kWh/(m².y)	1.00	0.85
Data source			**Enercalc**	**EN15232**

Table 4-12: Impact of upgrading from a Class C to a Class A BACS on a new shop building

Base Case 6, New, non-residential, shop			BC6whBAU	BC6whBAT2
aim: apply the EN 15232 simple BAC factor method (BAU=ClassC vs BAT=ClassA)				
Energy balance losses for heating (main source)				
Transmission losses for heating	Q,T	kWh/(m².y)	71.6	NM
Ventilation losses (infiltration loss)	Q,V	kWh/(m².y)	49.3	NM
Energy balance Internal Heat Gains (IHG) supplied from electricity				
Electrical auxiliary energy for heating	W H, aux	kWh/(m².y)	1.7	NM
Electrical auxiliary energy for ventilation	W V, aux	kWh/(m².y)	13.3	NM
Lighting Energy Numeric Indicator	LENI	kWh/(m².y)	16.5	NM
Electrical energy for non TBS appliances inside heated area	W plug	kWh/(m².y)	15.0	NM
Total electrical load inside the heated area	W, int	kWh/(m².y)	46.5	NM
Total IHG electrical inside the heated area from electrical loads	W, int	kWh/(m².y)	27.9	NM
Energy balance internal heat gains (IHG) supplied free				
IHG - passive solar-heat replacement	Q H,S	kWh/(m².y)	30.8	NM
IHG - people	Q,P	kWh/(m².y)	3.9	NM
Energy Balance final annual heating demand				
Heating energy needs of the building	Q H,nd, B	kWh/(m².y)	58.3	NM
Energy Balance final annual cooling demand				
Cooling energy needs of the building	Q C,nd, B	kWh/(m².y)	NM	NM
Final energy demand (including gen. and dist. losses) and BAC factors				
Distribution energy losses for heating (outside heated area + non functional);	Q H,ls	kWh/(m².y)	45.2	NM
Heat demand for generation		kWh/(m².y)	103.5	NM
Type of energy supplied for heating	type	gas or elec.	district heat	district heat
heat generation efficiency	SEER/SCOP	%	100%	NM
Final heating demand	Q, H, tot, BAC	kWh/(m².y)	103.5	47.6
BAC factor for thermal energy (heating)	fBAC,th, H		1.00	0.46
BAC factor for auxiliary energy	fBAC,el		1.00	NM
BAC factor for lighting energy	fBAC,el, L		NM	NM
Cooling generation efficiency	SEER		NM	NM
Final electricity needed for cooling	Q, C, tot, BAC	kWh/(m².y)	NM	NM
BAC factor for thermal energy (cooling)	fBAC,th, C	kWh/(m².y)	1.00	0.55
Data source			**Enercalc**	**EN15232**

Table 4-13: Impact of fitting a BMS to an existing office building (heating only)

Base Case 7, Existing, non-residential, office			BC7ofBAU	BC7ofBAT1
aim: model the BMS benefits based on literature findings (exc. Ventilation)				
Energy balance losses for heating (main source)				
Transmission losses for heating	Q,T	kWh/(m².y)	65.7	NM
Ventilation losses (infiltration loss)	Q,V	kWh/(m².y)	82.3	NM
Energy balance Internal Heat Gains (IHG) supplied from electricity				
Electrical auxiliary energy for heating	W H, aux	kWh/(m².y)	3.1	NM
Electrical auxiliary energy for ventilation	W V, aux	kWh/(m².y)	3.1	NM
Lighting Energy Numeric Indicator	LENI	kWh/(m².y)	5.6	NM
Electrical energy for non TBS appliances inside heated area	W plug	kWh/(m².y)	5.0	NM
Total electrical load inside the heated area	W, int	kWh/(m².y)	16.8	NM
Total IHG electrical inside the heated area from electrical loads	W, int	kWh/(m².y)	10.1	NM
Energy balance internal heat gains (IHG) supplied free				
IHG - passive solar-heat replacement	Q H,S	kWh/(m².y)	37.5	NM
IHG - people	Q,P	kWh/(m².y)	8.1	NM
Energy Balance final annual heating demand				
Heating energy needs of the building	Q H,nd, B	kWh/(m².y)	92.3	NM
Energy Balance final annual cooling demand				
Cooling energy needs of the building	Q C,nd, B	kWh/(m².y)	15.1	NM
Final energy demand (including gen. and dist. losses) and BAC factors				
Distribution energy losses for heating (outside heated area + non functional);	Q H,ls	kWh/(m².y)	4.8	NM
Heat demand for generation		kWh/(m².y)	97.1	NM
Type of energy supplied for heating	type	gas or elec.	gas(heat) + elec (cool)	gas(heat) + elec (cool)
heat generation efficiency	SEER/SCOP	%	92%	NM
Final heating demand	Q, H, tot, BAC	kWh/(m².y)	105.5	86.5
BAC factor for thermal energy (heating)	fBAC,th, H		1.00	0.82
BAC factor for auxiliary energy	fBAC,el		1.00	0.86
BAC factor for lighting energy	fBAC,el, L		NM	NM
Cooling generation efficiency	SEER		4.40	NM
Final electricity needed for cooling	Q, C, tot, BAC	kWh/(m².y)	3.43	NM
BAC factor for thermal energy (cooling)	fBAC,th, C	kWh/(m².y)	1.00	NM
Data source			**Enercalc**	**literature**

Table 4-14: Impact of fitting a BMS to an existing office building (ventilation only)

Base Case 7, Existing, non-residential, office			BC7ofBAU	BC7BAT2
aim: model the BMS benefits related to natural ventilation based on literature findings (incl. window openers)				
Energy balance losses for heating (main source)				
Transmission losses for heating	Q,T	kWh/(m².y)	65.7	65.7
Ventilation losses (infiltration loss)	Q,V	kWh/(m².y)	82.3	82.3
Energy balance Internal Heat Gains (IHG) supplied from electricity				
Electrical auxiliary energy for heating	W H, aux	kWh/(m².y)	3.1	3.1
Electrical auxiliary energy for ventilation	W V, aux	kWh/(m².y)	3.1	0.2
Lighting Energy Numeric Indicator	LENI	kWh/(m².y)	5.6	5.6
Electrical energy for non TBS appliances inside heated area	W plug	kWh/(m².y)	5.0	5.0
Total electrical load inside the heated area	W, int	kWh/(m².y)	16.8	13.9
Total IHG electrical inside the heated area from electrical loads	W, int	kWh/(m².y)	10.1	8.3
Energy balance internal heat gains (IHG) supplied free				
IHG - passive solar-heat replacement	Q H,S	kWh/(m².y)	37.5	37.5
IHG - people	Q,P	kWh/(m².y)	8.1	8.1
Energy Balance final annual heating demand				
Heating energy needs of the building	Q H,nd, B	kWh/(m².y)	92.3	92.3
Energy Balance final annual cooling demand				
Cooling energy needs of the building	Q C,nd, B	kWh/(m².y)	15.1	3.0
Final energy demand (including gen. and dist. losses) and BAC factors				
Distribution energy losses for heating (outside heated area + non functional);	Q H,ls	kWh/(m².y)	4.8	4.8
Heat demand for generation		kWh/(m².y)	97.1	97.1
Type of energy supplied for heating	type	gas or elec.	gas(heat) + elec (cool)	gas(heat) + elec (cool)
heat generation efficiency	SEER/SCOP	%	92%	92%
Final heating demand	Q, H, tot, BAC	kWh/(m².y)	105.5	105.5
BAC factor for thermal energy (heating)	fBAC,th, H		1.00	1.00
BAC factor for auxiliary energy	fBAC,el		1.00	0.71
BAC factor for lighting energy	fBAC,el, L		NM	NM
Cooling generation efficiency	SEER		4.40	4.40
Final electricity needed for cooling	Q, C, tot, BAC	kWh/(m².y)	3.43	0.69
BAC factor for thermal energy (cooling)	fBAC,th, C	kWh/(m².y)	1.00	0.20
Data source			**Enercalc**	**literature**

Table 4-15: Impact of occupancy based individual room control on a new office building

Base Case 8, New, non-residential, office			BC8ofBAU	BC8ofBAT1
aim: occupancy emission control of heating and ventilation (time + temp set points approach), individual room control and other functions.				
Energy balance losses for heating (main source)				
Transmission losses for heating	Q,T	kWh/(m².y)	28.1	27.2
Ventilation losses (infiltration loss)	Q,V	kWh/(m².y)	3.3	3.1
Energy balance Internal Heat Gains (IHG) supplied from electricity				
Electrical auxiliary energy for heating	W H, aux	kWh/(m².y)	2.6	1.1
Electrical auxiliary energy for ventilation	W V, aux	kWh/(m².y)	3.3	2.9
Lighting Energy Numeric Indicator	LENI	kWh/(m².y)	6.1	6.1
Electrical energy for non TBS appliances inside heated area	W plug	kWh/(m².y)	7.8	7.8
Total electrical load inside the heated area	W, int	kWh/(m².y)	19.8	17.9
Total IHG electrical inside the heated area	W, int	kWh/(m².y)	NM	NM
Energy balance internal heat gains (IHG) supplied free				
IHG - passive solar-heat replacement	Q H,S	kWh/(m².y)	23.1	23.2
IHG - people	Q,P	kWh/(m².y)	5.9	5.9
Energy Balance final annual heating demand				
Heating energy needs of the building	Q H,nd, B	kWh/(m².y)	7.3	4.6
Energy Balance final annual cooling demand				
Cooling energy needs of the building	Q C,nd, B	kWh/(m².y)	20.2	18.3
Final energy demand (including gen. and dist. losses) and BAC factors				
Distribution energy losses for heating (outside heated area + non functional);	Q H,ls	kWh/(m².y)	NM	NM
Heat demand for generation		kWh/(m².y)	NM	NM
Type of energy supplied for heating	type	gas or elec.	elec	elec
heat generation efficiency	SEER/SCOP	%	NM	NM
Final heating demand	Q, H, tot, BAC	kWh/(m².y)	5.8	3.4
BAC factor for thermal energy (heating)	fBAC,th, H		1.00	0.58
BAC factor for auxiliary energy	fBAC,el		1.00	0.67
BAC factor for lighting energy	fBAC,el, L		NM	NM
Cooling generation efficiency	SEER		NM	NM
Final electricity needed for cooling	Q, C, tot, BAC	kWh/(m².y)	5.28	4.29
BAC factor for thermal energy (cooling)	fBAC,th, C	kWh/(m².y)	1.00	0.81
Data source			**EnergyPlus**	**EnergyPlus**

Table 4-16: Comparison between BAC factors produced by the study team and the BAC factors for Class A BACS in EN15232-1:2017

BAT Option	Model Reference	Results of Modelling Work				Class A EN15232-1				Results of modelling work as a % of Class A EN15232-1 BAC factors			
		fBAC,th, H	fBAC,th, C	fBAC,el, aux	fBAC,el, L	fBAC,H	fBAC,C	fBAC,el, aux	fBAC,el, L	fBAC,H	fBAC,C	fBAC,el, aux	fBAC,el, L
1	BC1hoBAT05	0.95	NM	1.00	NM	0.81	NM	0.92	NM	27%	NM	0%	NM
2	BC1hoBAT10	0.90	NM	1.00	NM	0.81	NM	0.92	NM	53%	NM	0%	NM
3	BC1hoBATLot1	0.95	NM	1.00	NM	0.81	NM	0.92	NM	26%	NM	0%	NM
4	BC2hoBAT1	0.91	NM	0.59	NM	0.81	NM	0.92	NM	49%	NM	515%	NM
5	BC2hoBAT2	1.00	NM	0.96	NM	0.81	NM	0.92	NM	0%	NM	46%	NM
6	BC3apBAT1	0.94	NM	0.75	NM	0.81	NM	0.92	NM	31%	NM	313%	NM
7	BC4apBAT1	1.00	0.36	1.06	NM	0.81	NM	0.92	NM	0%	NM	-75%	NM
8	BC5whoBAT1	1.02	NM	0.87	0.85	0.46	0.55	0.91	1.00	-3%	NM	147%	NM
9	BC6whBAT1	0.71	0.85	NM	NM	0.46	0.55	0.91	1.00	54%	33%	NM	NM
10	BC6whBAT2	0.46	0.55	NM	NM	0.46	0.55	0.72	0.72	100%	100%	NM	NM
11	BC7ofBAT1	0.82	NM	0.86	NM	0.70	0.57	0.72	0.72	60%	NM	50%	NM
12	BC7ofBAT2	1.00	0.20	0.71	NM	0.70	0.57	0.72	0.72	0%	186%	104%	NM
13	BC8ofBAT1	0.58	0.82	0.67	NM	0.70	0.57	0.72	0.72	139%	42%	118%	NM

It should be noted that each BAT option only represents a sub-set of the EN15232-1 Class A BAC functions applicable to a Base Case.

4.3.11 Additional Costs associated with adopting BAT

To enable an assessment of the least life cycle costs (LLCC) in Task 5, research was undertaken to estimate the additional costs of implementing each of the BAT design options outlined in Section 4.3.11 above the functionality of a Class C BACS solution.

A number of sources of cost data were reviewed including:

- architects and builders project costing assumptions
- case studies published in academic journals
- typical BACS costs cited in trade journals.

The costs of installing a BACS or BMS system in these sources ranged between:

- Non-residential: 6 €/m^2 to 60 €/m^2
- Residential: 8 €/m^2 to 45 €/m^2

The lower end of these cost ranges are broadly in alignment with the costs for upgrading an existing BACS to a Class B/C BACS outlined in eu.bac's "Guidelines for the transposition of the new Energy Performance Buildings Directive (EU) 2018/844 in Member States" (June 2019). The upper end probably reflects the inclusion of other non-EN15232 functionality in the project cost e.g. plant controls, meters, digital services, etc.

A bottom-up method was used to fill the gaps in the available cost data. This involved identifying the additional BACS hardware components required to implement each BAT option and pricing these up using manufacturers' list prices and on-line trade prices. An assumption was then made that the 30-40% trade discount available to installers would be sufficient to cover the cost of installation and commissioning of the hardware.

Typically, at least two potential hardware solutions were considered for each BAT option, including a hardware solution from a major supplier and a low-cost alternative available via trade outlets. Hardwired solutions were generally priced-up for installations in new buildings and wireless solutions were priced-up for retrofitting to existing buildings. The cost of the BAU solution was deducted from each base case to obtain the additional costs. The results of this BAT option cost analysis are presented in Table 4-17 below.

Average annual O&M costs were assumed to be 3-5% of the initial capital cost per year based on data obtained from stakeholders, and articles in the trade press on life cycle costs.

The technical life of a BACS system has historically been reported as c. 20 years, but a life of 15 years[157] has been assumed for this work reflecting shortening product lifetimes. This is based on a shelf life of 5 years and spare part commitment period of 10 years.

Management level components of a BACS are normally refreshed via a front-end upgrade every 5 to 10 years in line with the typical lifecycles for computer operating systems. Some sensors and actuators may also need to be replaced after 8 to 10 years[158], and a proportion of controllers regularly retuned to maintain the control accuracy of the BACS.

These mid-life upgrades and component replacements generally do not change the BAC functions which are programmed into automation controllers, and which can be recreated in a replacement unit should the original fail. Automation controllers will often be replaced

[157] ASHRAE Equipment Life Expectancy chart, 2012. Electronic controls.

[158] Maintenance engineering and management, Guide M, 2nd Edition, CIBSE, 2014

when there are major changes to the HVAC plant, and the tools, skills or knowledge needed re-programming the automation controllers is no longer available or obsolete.

Table 4-17: Analysis of BACS lifecycle costs for each reference building

No.	Model Reference	Base Case	Representative Building	Floor Area (m2)	Rooms or Zones	Basis of costing	Additional cost (€ / m2)
1	BC1hoBAT05	1	Existing House	186	7	6 TRV with built in digital thermostat (no communication with other controllers)	0.3
2	BC1hoBAT10	1	Existing House	186	7	6 TRV with built in digital thermostat with wireless communication to a central control unit	2.6
3	BC1hoBATLot1	1	Existing House	186	7	6 TRV with built in digital thermostat (smart thermostat) with additional temperature and occupancy sensors.	3.0
4	BC2hoBAT1	2	New House	186	7	1 central control unit, 6 presence detectors, 2 humidity sensors, 2 air dampers	14.8
5	BC2hoBAT2	2	New House	186	7	1 pressure controller circulator pump with built-in controller.	1.6
6	BC3apBAT1	3	Existing Apartment	20	1	1 circulator pump with built in controller with wireless adjustment by smart phone, 1 set of hydronic balancing valves per apartment.	5.6
7	BC4apBAT1	4	New Apartment	20	1	Smart room thermostat linked by wireless network to interior temperature sensors and blind actuator	19.0
8	BC5whoBAT1	5	Existing Shop (Wholesale)	20	1	Use costs from Lot 1 study.	Lot 1
9	BC6whBAT1	6	New Shop (Wholesale)	20	1	Based on 50% average price of Class A BACS determined in Task 2	7.5
10	BC6whBAT2	6	New Shop (Wholesale)	20	1	Based on average price of Class A BACS determined in Task 2	5.1
11	BC7ofBAT1	7	Existing Office Block	2,000	41	41 local controllers, 41 occupancy detectors and 41 temperature sensor per room, connected to a BMS system via a wireless network.	6.0
12	BC7BAT2	7	Existing Office Block	2,000	6	6 zone controllers with PSU networked with 1 central controller, 41 window actuators, 6 Indoor air quality and 6 temperature sensors,	5.0
13	BC8ofBAT1	8	New Office Block	2,000	41	Based on analysis of AECOM Guide to fit out costs for offices (2018) and Spon's Architects and Builders Price Book, 2019	16.0

Note: The additional costs (€ / m2) exclude VAT.

4.3.12 Best Not (yet) Available Technology (BNAT)

Over the last 20 years, BACS have evolved from building management systems that controlled the operation of central HVAC plant into a distributed network of controllers that are designed to control, optimise and coordinate the operation of a wide range of most technical building services (TBS) in a user orientated but energy-efficient manner.

This change has been enabled by developments in information and computing technology that have increased the capabilities of building automation controllers and reduced their cost to the point where it is cost effective to implement adaptive control strategies to ensure TBS output reflects occupancy patterns and comfort needs of users in each room. It is also been driven by a global standardisation process that is encouraging manufacturers to produce products that are designed to work together, use standard communications protocols to increase interoperability, and offer similar types of basic control functionality.

This process of standardisation is accelerating as manufacturers seek to maintain competitive position in a market that is beginning to be transformed by digital and smart technologies, changing user needs, and by regulatory requirements to reduce energy consumption in buildings. In particular, the increased integration of multimedia digital services with BACS and adoption of Internet of Things (IoT) technology is expected to reduce the cost of installing higher specification BACS by 30%[159]. However, it could potentially shorten BACS lifetimes as users need to periodically replace hardware with more processing power and memory to address new vulnerabilities to cyberattack.

As set out in section 4.3.10, stakeholders recommended that the energy saving BAC functionality requirements for a Class A and B BACS according to EN15232-1 should be considered to be a starting point for defining the Best Available Technology (BAT). However, a review of recent research and the product base indicates that there may be scope to extend the requirements, to reflect the following technological improvements:

- extension of BAC room and occupancy control functions to reflect additional savings resulting from the multiple temperature and presence sensors. This approach has been adopted in the temperature control classifications defined in EU Regulations (see Table 4-18). As outlined in the section 1.7.1 of the Task 1 report these classifications are under review by Lot 1. However, they would benefit from being more closely aligned with the requirements of EN15232-1.
- the development of 'smart' building controls, particularly for residential buildings, that can learn from occupancy patterns and automatically adjust system operation to optimise performance, or provide control with consideration for external demand response signals (e.g. time of day electricity tariff, dynamic gas pricing, day ahead weather forecasts, and load shedding signals).
- the potential to use self-learning AI (Artificial Intelligence) techniques in combination with automatic model based predictive control to optimise building control performance based on indoor sensor data, weather data, user behaviour and building thermodynamics. In this context, the functional requirements in

159 https://enterpriseiotinsights.com/20160808/buildings/building-management-system-tag31-tag99

EN15232-1 would benefit from being updated to require the models used in demand evaluation, optimum start/stop and weather compensation functions (for example) to be automatically updated to reflect changes in building use and changes in the thermal response of the building, zone, room and generators.

- Best practice in the reporting key performance indicators (KPI) for energy use to building users through dynamic displays to increase social accountability, and in sharing of this KPI data externally to enable benchmarking of performance.

There is also ongoing research around the need to modify building control and automation systems to enable more energy flexibility in buildings in order to maximise the use of renewable energy and to provide demand response needed by future Smart Grids[160]. Whilst EN15232-1: 2017 requires Class A BACS to be able to integrate with Smart Grids, this part of the standard does not specify how this should be done, and the standard would benefit from being updated to define specific demand response functionality.

In this context, additional control requirements could be added to the definition of an EN15232-1 Class A BACS to make it easier for buildings to participate in the provision of ancillary services[161] needed to address current and future electricity grid congestion. This could include, for example, requirements to:

- provide an external interface to make it easier for grid operators and demand side response aggregators to implement demand management actions
- predict future heat and electricity demand to enable the assessment of available demand response both immediately and up to a day ahead
- include control functions that increase demand response flexibility, for example by adding boost control and interrupt control modes for heat pumps[162]
- manage the charging of electrical batteries and thermal stores in a manner that minimise carbon emissions not only of the building but also the grid.

It is likely that some of these requirements will necessitate the deployment of more advanced control algorithms than is currently the norm in BACS products and systems.

[160] Review of applied and tested control possibilities for energy flexibility in buildings, A technical report from IEA EBC Annex 67 Energy Flexible Buildings, Finck, C. et al, 2017.

[161] https://www.dena.de/en/topics-projects/energy-systems/electricity-grids/ancillary-services/

[162] https://www.waermepumpe.de/sg-ready/

Table 4-18: Temperature Control Classification under Commission Regulation (EU) No 813/2013, and Commission Delegated Regulation (EU) No 811/2013 as defined in OJEU 2014/C 207/1

Class	Type	Definition	%
I	On/off Room Thermostat:	A room thermostat that controls the on/off operation of a heater. Performance parameters, including switching differential and room temperature control accuracy are determined by the thermostat's mechanical construction.	1.0
II	Weather compensator control, for use with modulating heaters	A heater flow temperature control that varies the set point of the flow temperature of water leaving the heater dependent upon prevailing outside temperature and selected weather compensation curve. Control is achieved by modulating the output of the heater.	2.0
III	Weather compensator control, for use with on/off output heaters	A heater flow temperature control that varies the set point of the flow temperature of water leaving the heater dependent upon prevailing outside temperature and selected weather compensation curve. Heater flow temperature is varied by controlling the on/off operation of the heater.	1.5
IV	TPI room thermostat, for use with on/off output heaters	An electronic room thermostat that controls both thermostat cycle rate and in-cycle on/off ratio of the heater proportional to room temperature. TPI control strategy reduces mean water temperature, improves room temperature control accuracy and enhances system efficiency.	2.0
V	Modulating room thermostat, for use with modulating heaters	An electronic room thermostat that varies the flow temperature of the water leaving the heater dependent upon measured room temperature deviation from room thermostat set point. Control is achieved by modulating the output of the heater.	3.0
VI	Weather compensator and room sensor, for use with modulating heaters	A heater flow temperature control that varies the flow temperature of water leaving the heater dependent upon prevailing outside temperature and selected weather compensation curve. A room temperature sensor monitors room temperature and adjusts the compensation curve parallel displacement to improve room comfort. Control is achieved by 3/modulating the output of the heater.	4.0
VII	Weather compensator and room sensor, for use with on/off output heaters	A heater flow temperature control that varies the flow temperature of water leaving the heater dependent upon prevailing outside temperature and selected weather compensation curve. A room temperature sensor monitors room temperature and adjusts the compensation curve parallel displacement to improve room comfort. Heater flow temperature is varied by controlling the on/off operation of the heater.	3.5
VIII	Multi-sensor room temperature control, for use with modulating heaters	An electronic control equipped with 3 or more room sensors that varies the flow temperature of the water leaving the heater dependent upon the aggregated measured room temperature deviation from room sensor set points. Control is achieved by modulating the output of the heater.	5

4.4 Other particular topics of Task 4

4.4.1 The internal power consumption of BACS

4.4.1.1 Issue

While the BACS automatically control and manage the energy used by TBS, they also consume auxiliary energy in doing so. Generally, this internal power consumption is much less than the energy savings realised through the improvements in control and management that they deliver, particularly if a higher class of BACS (i.e. Class A or B) is implemented. However, the initial scoping work (Task 0)[163] identified a potential scope to reduce the internal power consumption of BACS by specifying Ecodesign limits that encourage technical solutions that implement the BAC functions more efficiently than alternative designs.

4.4.1.2 Initial Research

A recent Swiss research project[164]. examined the internal power consumption of BACS and concluded that the specific annual electricity consumption of room automation across a selection of six highly automated buildings was between 2 and 5 kWh/m²/year, or between 3 and 6 kWh/m2 if the entire building automation system was included. Several reasons for this variation in internal power consumption were identified and recommendations made to reduce it:

- improving the efficiency of BACS power supplies which account for between 15% and 65% of electricity consumption and are often oversized
- selecting components and actuators to maximise use of no power consumption modes across the duty cycle, for example the controls for a normally open valve should be in no power consumption mode when the value is open
- for electromechanical switches, bi-stable or latching relays should be used in preference to traditional relays that need permanent power to maintain the opposite mode to their default mode (i.e. normally open or normally closed)
- shutting down the complete lighting control gear and circuits when the building is unoccupied to reduce their standby power consumption
- using energy harvesting technologies e.g. solar cells and piezo actuators (where applicable) to reduce the demand on BACS power supplies
- reducing the number of servers, gateways or vendor specific solutions.

On the basis of the Swiss research, the Task 0 Scoping Study estimated that it should be possible to reduce internal power consumption by an average of at least 1 kWh/m2/year in non-residential buildings by the establishment of energy labelling measures or energy performance ratings that address the internal power consumption based on the relative efficiency of their principal components. The suggested approach to determining maximum limits for internal power consumption involved establishing ranges (from base case to best available technology (BAT)) of energy consumption per BAC function implemented, so that energy budgets could be established for the most

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163 https://ecodesignbacs.eu/sites/ecodesignbacs.eu/files/attachments/BACS_scopeReport.pdf

164 Electricity consumption of building automation, P. Kräuchi et al. Energy Procedia 122 (2017) 295–300.

commonly used individual BACS components (such as sensors, actuators, communications, displays etc.).

This proposed approach was limited to automation and control functions, as defining limits for higher level building management functions was considered too complex to be practicable given the diversity of potential BACS solutions available on the EU market.

4.4.1.3 Detailed Analysis

The starting point for an analysis of the internal power consumption of BACS involves defining the boundaries of the system. The Swiss research included the electricity consumption of all components required to automate processes in the building i.e. to control flows (of water, air, light) and to control the conversion between forms of energy (e.g. burners). The energy flow through energy converters was excluded, as was the energy used by pumps, fans and lamps. However, the energy used to control pumps, fans and lighting was included, as was the standby power of electronic ballasts for lighting. The energy use of BACS power supplies, control and regulation units, sensors and actuators was included[165].

The Swiss research work also subdivided building automation into "room automation" and "primary building automation" (which covers the control of the central HVAC plants). A procedure for calculating internal power consumption on this basis has also been published[166].

Following discussions with stakeholders, the study team suggest that this boundary should be redrawn to exclude components that are an essential aspect of TBS operation, including:

- blind motors, as in many cases these are required to manually operate blinds
- electronic lighting ballasts, as these are not optional items and are required to operate the lighting and may be integrated into the luminaire. The efficiency of electronic ballasts is covered by energy labelling and Ecodesign regulations
- local controls that are essential to HVAC plant operation: this would exclude, for example boiler control units, that control fuel and air flow to burners and implement safety control protocols during start up and shut down. It would also exclude controllers that have been integrated into generators and central TBS plant, but not controls fitted to HVAC distribution and emission systems
- variable speed drives (VSDs) are an energy saving measure for pumps and fan motors that could either be considered part of the BACS if retrofitted, or part of the TBS, so clear rules would be needed as to which VSD should be included, and which excluded. VSD efficiency is covered by Ecodesign regulations from 2021, so these could provide a starting for deriving a maximum allowance[167]. The losses associated with fitting a VSD to a pump or fan are between 2 and 8% at full power, but they can reduce the energy consumption of pumps and fans used in HVAC systems by 30% to 60% depending on load factor[168]

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165 Kräuchi, P et al. Projekt „Eigenenergieverbrauch der Gebäudeautomation" (EEV-GA). Ergebnisbericht, Bundesamt für Energie BFE, 2016.

166 Electricity consumption of building technology: a calculation method, Philipp Kraeuchi and Olivier Steiger 2019 J. Phys.: Conf. Ser. 1343 012125

167 Commission Regulation (EU) 2019/1781.

168 https://www.carbontrust.com/media/13063/ctg070_variable_speed_drives.pdf

(Stakeholders have recommended that all VSDs should be excluded due to the complexity of developing an applicable allowance for different applications in building control).

This revised boundary means that the additional power used by the sensors and actuators that must be fitted to implement the BAC functions specified for a class of BACS and are directly connected to the inputs and outputs of a BACS controller, would be included. Sensors and actuators that are indirectly connected to the BACS controller only by means of a network connection to an item of HVAC plant would be excluded, but the power consumption of "additional" sensors and actuators would be included whether they were connected to the controller directly or indirectly by wired or wireless network connections.

This approach makes it easier to measure the electrical consumption of a BACS by removing the need to evaluate the consumption of controllers, sensors and actuators that are normally integral to an item of plant, and not readily accessible during operation. However, a number of other factors would need to be considered in deriving energy budgets that could be used to set Ecodesign limits on BACS energy consumption, as follows:

- The number and types of sensors and actuators required to implement room control varies considerably depending on the type of HVAC equipment deployed. The number of sensors also increases substantially as the level of control increases from Class C to Class A, because more sophisticated control requires more sensors.
- The location of room controllers varies considerably. In some cases, the room control is located inside the room being controlled, but in most buildings it is located in central or local plant rooms, where it may be combined with plant control and with other room controllers to reduce the number of controllers and plant rooms required. Some HVAC equipment, for example those designed for use in smaller premises, may include the options to control one or two rooms. Smaller building management systems (BMS) may include room controllers.
- The number and type of sensors and actuators required to control different types of central TBS plant and distribution networks varies considerably and depends on how much of the plant control is handled by integrated controllers.

In the next section, further consideration is given to how these factors could be reflected in the energy budgets in the context of one example BAC function: room control, which is one of the major strategies used to reduce energy consumption and which is also responsible for a substantial increase in Class A BACS internal power consumption in larger buildings.

4.4.1.4 An Example: Room control

The key components in room control are sensors, a room controller and user interface, actuators, network communication devices, a power supply and wiring. In this example, the room controller is implemented using a general-purpose automation controller.

The types of **sensors** used in room control include sensors that provide analogue inputs e.g. temperature, pressure, humidity, CO_2 and light level sensors, and those that provide digital (binary) inputs e.g. presence detectors and window open sensors.

The types of **actuators** used in room control include devices that require digital outputs e.g. relays and thermal activators for on/off control, and those that require analogue outputs e.g. variable speed drives and continuously adjustable motorised valves. Some sensors and actuators may be connected to the controller by a communications network, and some inputs (e.g. outside air temperature) may be shared by several controllers.

For historical reasons, sensors and actuators use a number of different types of signalling standards, including: 4-20 mA, 0-20 mA, 0-10 Vdc, pulse width modulation (PWM), frequency for analogue signals, and 0-5 Vdc, 0-10 Vdc, and 0-24 Vac for digital signals. There are also volt free outputs that can switch loads of different voltages using relays, and a range of signalling standards for networking devices, e.g. BACNet, KNX, Modbus. A considerable proportion of the energy consumption of a room controller is used to power the sensors, to drive actuators, and by the controller's signal processing circuits.

The complexity and power consumption of room control **user interfaces** varies with the number of TBS services controlled, degree of local control permitted, and type of user information provided. They can be connected to the controller's inputs or network ports. Some manufacturers also provide mobile applications that enable building users to adjust room conditions and operating schedules, thus avoiding the need for room unit interfaces.

Most **multipurpose automation controllers** have a mixture of digital and analogue input and outputs that enable them to work with sensors and actuators that use different signalling standards, and if needed, add-ons can be fitted to increase the number of inputs and outputs or to enable them to work with less common signalling standards.

A general purpose automation controller needs between 4 and 12 inputs and between 5 and 18 outputs to implement Class A BAC room control functions depending on the type of TBS within the room that it has to control, and the type of sensors and actuators used.

A small automation controller would also typically have at least two communications ports, one to connect to the building management system e.g. via ethernet, and a second to connect to field devices e.g. room interfaces, remote sensors. Larger room controllers typically have 4 - 6 communications ports or buses, but some have up to 12 ports[169].

The number of communication ports or buses included is generally increasing to enable integration of other digital services, and newer multi-purpose automation controllers may include:

- Bluetooth transceivers to enable interaction with mobile devices/interfaces
- a multi-port network router for connection to other room controllers and devices
- a USB hub/ports for external memory devices, local displays and WiFi dongles.

Newer products are also fitted with more powerful microprocessors to support advanced control strategies, web and mail servers, data loggers, and enhanced cyber security measures. Most manufacturers offer general purpose automation controllers in a range of sizes (e.g. 8, 16 and 32 inputs and outputs) with options to extend to up to 1,600 inputs and output. The number of digital and analogue inputs and outputs per controller is expected to decrease as more sensors and actuators are connected via network ports.

Providing an energy budget for the BAC room control function that reflects each of the different types of equipment controlled would result in a complex set of allowances. A possible simplification would be to adopt the approach used by EN 15316-2 of specifying a maximum power consumption for a room automation controller in terms of:

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[169] How can We Tackle Energy Efficiency in IoT Based Smart Buildings?, Moreno, V. et al. Sensors 2014, 14, 9582-9614.

- 0.1 W per output designed to drive an electrical motor actuator
- 1.0 W per output designed to drive an electrothermal actuator
- 1.0 W per output designed to drive an electromagnetic actuator.

There is a risk that this simpler approach would be quickly out of date because of the changing nature of the technology, unless it can be reworked to provide allowances for:

- different types and number of inputs, outputs and communications ports
- different types of sensors, actuators and interface units, some of which may be powered by the field bus and some independently from local power supplies
- signal processor requirements which are dependent on the number of data points handled by the control, and the sophistication of the algorithms used
- common add-ons to automation controllers e.g. wireless transceivers, communication units, webservers, electricity meters, dataloggers etc.
- electrical losses in transformers, power supplies and signal cabling, including power supplies for field buses, networked devices, and extension buses.

The maximum power consumption that automation controllers may require to operate the controller and its sensors and actuators is generally published in manufacturers datasheets to enable dimensioning of **power supplies and signal cables**. However, the maximum power consumption is often not expressed in Watts and needs to be calculated from the rated current and voltage of inputs and outputs, or apparent power (VA) ratings.

Manufacturers also provide engineering guidance for installers on how to assess the power consumption of a BACS system in order to size electrical connections and design rules to prevent thermal overloading by switching on too many outputs simultaneously.

This engineering guidance often includes example wiring diagrams that illustrate how to connect the inputs and outputs for different applications, and software libraries are used to enable rapid commissioning of the most common applications. Installers can adjust the controller's configuration to use a different type of relay (i.e. normal open or closed), but the selection is often determined by equipment factors or fail-safe actions/positions.

Design rules may also include nominal power allocations for any unassigned (i.e. unused) inputs and outputs. Many building owners and designers will specify that the controllers must have 10% to 20% spare capacity to allow for future HVAC equipment upgrades, and to allow on-going optimisation without significant new capital investment.

Redundant power supplies along with battery backup are specified in larger buildings and redundant hot standby controllers may also be installed to guarantee high availability.

The energy consumption of the BACS in kWh/year depends on the diversity of operating times and load factors of the equipment being controlled, and although adjustments for diversity can be made, power supplies are often sized to cover the worst case scenario.

Stakeholder feedback suggests that specifying a maximum power consumption for components such as actuators is not the right approach, since an actuator with a short running time will have a higher power consumption compared to an actuator with a longer running time. The power consumption of an actuator is dependent on:

- the runtime (speed) of the actuator
- the force required to move the application
- the technology used within the actuator

- the state of the actuator i.e. running (depending on actual load) or on standby

Instead stakeholders suggest that it would be better to derive an energy budget for each BAC function that increases as the level of sophistication of the BAC function increases. However, the data needed to derive these energy budgets is not currently available.

4.5 Conclusions and Recommendations

During this task, the study team reviewed the full range of energy saving BAC functions outlined in EN15232-1:2017, and identified with the help of stakeholders a selection of options for extra or improved BAC functionality, which will be referred to in this study as "BAT design options" that could be applied to the base cases for the eight reference buildings, and modelled within the resources available for this task. The BAT design options were designed to explore the different energy saving methods outlined in section 4.3.1 and included some control improvements in respect of a single BAC function, some combinations of BAC functions as well as examples of full upgrades to a Class A BACS and a Class B BACS.

One of the key conclusions of this work, was that the energy saving functionality defined by EN15232-1: 2017 Class A BACS could be considered as a starting point for defining BAT for larger buildings with a total useful floor area greater than 1,000 square metres. However not all of the BAC functions are applicable to all types of buildings and TBS, and some additional BAC functions may merit inclusion in BAT.

For smaller buildings with a total useful floor area less than 250 square metres, the energy saving functionality defined by EN15232-1: 2017 Class B BACS could be considered as a starting point for defining BAT particularly in residential buildings, but that consideration should be given to adding some Class A BAC functions.

The study team found that it was difficult to cost some of the BAT design options, due to a lack of detailed case studies on the costs and benefits of Class A and Class B BACS solutions in buildings, particularly in individual family homes and smaller non-residential buildings. It also appears that the EN15232-1 Class of the BACS solutions fitted to most buildings is not known or not reported and that the solutions presented in case studies did not represent full implementations of either Class A and Class B BACS solutions. This lack of awareness of the EN15232-1 BACS Classifications is a major market failure.

In considering what minimum functionality should be required for BACS, it is likely that different specifications will be needed for new and existing buildings, for residential and non-residential buildings, and for different sizes of building (e.g. small and large). However, the evidence base needed to underpin the development of these specifications is not sufficiently available and more information needs to be systematically gathered on what BAC functionality is deployed, the level of savings realized, and the costs of implementation.

The technical home and building management (TBM) systems within a Class A BACS should be capable of recording Key Performance Indicators (KPIs) that Building Managers can use to raise awareness of the impact of user behaviour building control and energy performance and for benchmarking against other similar buildings. However, the study team found little evidence that this important data is used for dynamic benchmarking.

In most cases, the data needed to model the impact of user behaviour on building energy performance is available within technical and home building management (TBM) systems, but it is not reported. The availability of such building energy performance data would enable external benchmarking and raise user awareness of the impact of their behaviour.

As improved control accuracy is one key to maximizing energy savings delivered by BACS, the study team recommends that further research should be undertaken into the merits of introducing minimum accuracy requirements for the sensors, controllers and actuators that are placed on the EU market for application in BACS products or systems.

5 MEErP Task 5 report: Environmental and Economics Assessment

5.1 Scope

The current Task 5 involves undertaking an environmental and economic assessment of the Base-Cases identified in Task 4 using the Ecoreport tool (VHK, 2014). The Ecoreport tool, that was developed as part of the Methodology for the Ecodesign of Energy Related Products (MEErP), is used in all Ecodesign Preparatory Studies. The tool provides a streamlined life cycle assessment of the product, together with a life cycle cost assessment. The purpose of this assessment is to provide an indication of the representative environmental impacts of a typical product across the different life cycle phases. This allows the importance of a range of different environmental impacts at different life cycle stages to be analysed. The Ecoreport tool includes a set of input modelling parameters and calculates life cycle cost and 14 environmental impact indicators including global warming potential (CO_2eq). A set of product-specific inputs have been compiled in order to generate the environmental and cost assessment outputs.

Task 5 comprises the following subtasks:

- Subtask 5.1 - Product specific inputs
- Subtask 5.2 - Base-Case Environmental Impact Assessment (using Ecoreport 2014)
- Subtask 5.3 - Base-Case Life Cycle Cost
- Subtask 5.4 - EU totals.

Task 5 collects appropriate information for each of the Base-Cases from the previous tasks. Using the Ecoreport tool and the above inputs, the emission/resources categories are calculated in the MEErP format for the different life cycle stages of a BACS and for the different Base-Cases. In addition, the Life Cycle Costs experienced by consumers are calculated. Subsequently the Base-Case environmental impact data and the Life Cycle Cost data are aggregated up to the EU-27 level, using the stock and market data from Task 2.

5.2 Summary of Task 5

This task builds on the previously defined eight BACS Base Cases, which represent eight different reference buildings (from Task 3) equipped with typical BACS (from Task 4). In principle, it is not obvious how an abstract BACS function should be modelled within a product policy tool; however, it has been shown to be possible when considering this in terms of 1 m² of building equipped with BACS, which is in line with the functional unit defined in Task 1. The impact modelled with the tool is mainly from indirect and direct energy consumption.

Task 4 reports three different BACS factors ($f_{BAC,th,H}$, $f_{BAC,th,C}$, $f_{BAC,el}$) to individually model the energy impact of BACS on different sources of final energy demand (gas, electricity, etc.). Task 5 takes these impacts and converts them into a single set of MEErP impact indicators (14 in total) using the Ecoreport tool.

These 14 impact indicators also include the Gross Energy Requirement (GER) [MJ], which is the LCA equivalent of Primary Energy (PE). Consequently, this aligns with the Energy Performance of Buildings Directive (EPBD) that requires the energy performance of a building to be expressed by a numeric indicator of primary energy use in kWh/m²/y for the purpose of both energy performance certification (EPCs) and compliance with minimum energy performance requirements. Thus, 3.6 MJ (GER) in the MEErP corresponds to 1 kWh (PE) in the EPBD. Therefore and because most of the expected impact of BACS comes from indirect energy use in the building this task recommends that the GER be used as the principle optimization parameter in Task 6.

The approach followed in this study is first to calculate the impact from the use phase of 1 kWh per year of energy with the Ecoreport tool over the BACS product lifetime, typically 15 years. Afterwards considering the energy demand per Base Case in kWh/m²/y they are scaled-up for each Base Case.

As already was reported in the previous Ecodesign working plan study the potential environmental impact from BACS is large, see 5.6.

5.3 Subtask Product specific inputs

Aim: This objective of this section is to present all the relevant quantitative Base-Case information collated from the previous MEErP tasks, which is necessary to conduct the life cycle assessment and life cycle costing.

5.3.1 Selection of Base-Cases

A total of eight Base Cases (BC) are selected which are the 8 reference buildings proposed in Task 3 combined with the BACS class D or C performance proposed in Task 4.

Note, that all Base Cases are represented in line with the functional unit defined in Task 1 which is 1 m² of building area (see 5.1.2). To model the EU-wide energy consumption impacts this will be scaled-up using proxy-relationships for building stock/BACS floor areas.

5.3.2 Functional unit for the LCA

Task 1 of this study defines the primary functional unit (FU) of Life Cycle Analysis (LCA) for BACS as follows: the primary functional unit (FU) is 1 m² of building floor area, where the thermal comfort, sanitary hot water (SHW), indoor air quality (IAQ) and lighting requirements (per EN 16798–1:2019) – for health, productivity and comfort of the occupants – are maintained.

5.3.3 Economic input information for the Base Cases per functional unit

Aim: this section presents the input data that’s used to calculate the EU wide impact and life cycle cost. First the concept of the Life Cycle Cost is explained.

5.3.4 Introduction to Life Cycle Cost calculations used in MEErP

The MEErP methodology is based on an analysis of life cycle costs (LCC). A LCC calculation provides a summation of all of the costs incurred for the end-user along the life cycle of the product. This information is relevant to consumers because this cost can then be related to potential savings. It is used in Task 6 to find the Least Life Cycle Cost (LLCC) for the identified design options.

The LCC is a concept that aims to estimate the full cost of a system. Therefore, the Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) are calculated.

CAPEXstart is used to indicate BACS acquisition costs and is mainly comprised of product costs. The cost for decommissioning is expressed as CAPEXeol. The OPEX is the ongoing cost of running the BACS and consists of costs for replacement services and electricity costs for energy losses.

The purpose of the discount rate in LCC calculations is to convert all life cycle costs to their net present value (NPV) taking into account OPEX for energy and other consumables.

The LCC in MEErP studies is calculated using the following formula:

$$LCC\,[€] = CAPEX\text{start} + PWF \times OPEX + \text{CAPEXeol}/(1+r)^N$$

Where:

LCC is the life cycle costing,

CAPEXstart is the total purchase price (including installation) or so-called capital expenditure

CAPEXeol is the decommissioning cost at the End-of-Life

OPEX are the total operating expenses per year or so-called operational expenditure

PWF is the present worth factor with PWF = = $(1 - 1/(1+r)^N)/r$ or N if r=0

N is the product life in years

r is the discount rate which represents the return that could be earned in alternative investments.

In this study CAPEXstart is the installed product price [€/m²] and OPEX is the maintenance cost per year which is modelled as a mark-up [%] on the product price. CAPEXeol is assumed to be included in the installed product price, e.g. as is required with the producer responsibility principle of the WEEE Directive.

5.3.5 BACS economic input data per Base Case for LCC calculations

Lifetime assumptions:

The Ecoreport LCC and LCA calculations are based on the BACS product lifetime: considering the findings in Task 2 and 3, this study will use a Base Case lifetime of 15 years

Note: in Task 7 a sensitivity analysis can be considered of 7.5 years and 30 years when deemed relevant for the proposed policy. See Task 3 for more data and discussion on lifetime.

Product price:

This study is only concerned with determining the additional cost and benefits from using higher functionality BACS compared to the default (BAU) solutions. This means that only the incremental cost of the higher functionality options needs to be entered and the BAU input price can be set to zero by default.

Discount rate and escalation rate for energy:

The discount rate is defined as interest minus inflation. The MEErP 'discount rate' is set at 4%, in accordance with the rules used for EU impact assessments.

The MEErP defines an 'escalation rate' for energy costs. The default 'escalation rate' is also set at 4%, which is consistent with other Ecodesign preparatory studies.

Energy prices:

The energy prices (base year of 2016) used are taken to be the same as those in Task 2 of the Ecodesign preparatory study for Water Heaters[170].

Table 5-1: Energy prices base 2016 for use in Tasks 5 and 6

Electricity residential (BC1-4)	0.205 €/kWh (incl. VAT)
Electricity for non-residential (BC 5-8)	0.1104 €/kWh (ex. VAT & non recoverable taxes)
Natural gas residential (BC 1-4)	0.064 €/kWh (incl. VAT) 17.778 €/GJ (incl. VAT)
Natural gas non-residential (BC 5-8)	0.030 €/kWh (ex. VAT) 8.334 €/GJ (incl. VAT)

5.3.6 Stock and/or sales per functional unit

This data is sourced from Task 2 and is a proxy for modelling the impact of annual BACS sales mapped on the Base Cases of the study, expressed in m², see Table 2-. This data is used to scale-up the environmental impacts to EU27 level later in this report. . These can be seen as representative for the near future and potential impact from improvement options.

Table 5-2: Annual BACS sales proxy m² per Base Case for Task 5 and 6 EU27 total impact calculations

	BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8
2020 EU27 annual sales proxy Mm²	66,0	55,0	24,0	20,0	13,0	9,0	18,0	13,0

5.3.7 Production phase input LCA data

This section provides the bill of materials (BOM) information for the selected Base-Cases. BOM information is provided in the required Ecoreport format in order to perform an LCA. In the Ecoreport tool the BOMs associated with material use for repair or replacement of products is assigned to the production phase. Energy use and emissions occurring during production have been entered into the tool as well. For the Base Case systems, no material inputs were added into the Ecoreport tool because the analysis only considers additional material (if any) used above the BAU hence is zero by default. So far, there is little or no evidence that a higher functionality BACS has different production needs to a lower functionality BACS; however, Task 6 analyses whether there might be any negative impacts from the improved BACS functionality options considered in Task 4 for some Base Cases. This means that in Task 6 a BOM is considered.

[170] https://www.ecohotwater-review.eu/documents.htm Tables 24-26 in Task 2

5.3.8 Distribution phase input LCA data

For the distribution phase, the Ecoreport tool requires the volume and product type of the final packaged product to be entered as an input. Based on this volume, the impact of transport of the product to the site of installation is calculated.

For the Base Case systems, no material inputs were added in the Ecoreport tool because there is no evidence that a higher functionality BACS has different transportation needs than a lower functionality BACS and hence it does not make sense to model it.

5.3.9 Use phase input LCA data

For BACS, as they are defined in the scope of this study, this is the most important input data for the LCA. The input data is the direct and indirect energy calculated per Task 4 Base Case. The relevant values are shown in Table 5-3. In this analysis both the direct electricity (e.g. auxiliary energy) and the indirect electricity for HVAC are summed up and counted as final electricity demand[171] i.

Table 5-3: Energy use input data per Base Case used in the Ecoreport tool

Task4+5(BAU)/4+6(BAT) references:		**BC1hoBAU**	**BC2hoBAU**	**BC3apBAU**	**BC4apBAU**
building type (& design)		L38 house		EN 15232 shoe box model	
age type		renovated	new LEB	renovated	new LEB
Task 5 Base Case #		**1**	**2**	**3**	**4**
study reference		**house R**	**house N**	**flat R**	**flat N**
EU climate zone (see MEErP)		average	average	average	warm
final electricy demand (LENI only included in BC5)	kWh/m²/y	0,55	19,78	3,25	19,25
final fuel demand for gas	kWh/m²/y	125,11	0	111,00	0
ErP Product (service) Life in years	y	15,0	15,0	15,0	15,0

Task4+5(BAU)/4+6(BAT) references:		**BC5whBAU**	**BC6whBAU**	**BC7ofBAU**	**BC8ofBAU**
building type (& design)		EN 15232 shoe box model		L38 'office'	
age type		renovated	new LEB	renovated	new LEB
Task 5 Base Case #		**5**	**6**	**7**	**8**
study reference		**Shop R**	**Shop N**	**office R**	**office N**
EU climate zone (see MEErP)		average	average	average	average
final electricy demand (LENI only included in BC5)	kWh/m²/y	23,76	0,00	9,63	11,12
final fuel demand for gas	kWh/m²/y	182,8	103,5	105,5	0
ErP Product (service) Life in years	y	15,0	15,0	15,0	15,0

Note that in Task 4 district heating with gas heating was modelled for BC3, BC5 and BC6 but data on this option is not directly included within the Ecoreport Therefore, a gas boiler was selected in MEErP as a simple proxy.

5.3.10 End-of-life input LCA data

Default end-of-life values from the MEErP Ecoreport tool have been used, however, they are irrelevant for the Base Case because no input materials for manufacturing were entered. There is no evidence that a higher functionality BACS has different End-of-Life needs than a lower functionality BACS and therefore it is not considered useful to model it, but this will be cross-checked for some Base Cases in Task 6.

[171] In the Ecoreport tool they are entered together in the field 212

5.4 Subtask Base Case Environmental Impact Assessment

5.4.1 Aim

Life cycle environmental impacts have been calculated for the Base-Cases using the Ecoreport tool (2014 version). The data and assumptions used are listed in the previous sections.

Emission and resource use results have been derived for each of the different impact categories required by the MEErP methodology for the following life cycle stages:

- Raw Materials Use and Manufacturing
- Distribution
- Use phase
- End-of-Life Phase.

5.4.2 Approach

Given the particular nature of BACS and in order to facilitate processing of results, the first step is to calculate the impact from the use phase of 1 kWh/y of gas and electricity energy demand over the BACS product lifetime with the Ecoreport tool. Afterwards this is scaled by the energy demand per Base Case in kWh/m²/y and then scaled-up to the EU27 level for each Base Case in a separate spreadsheet specifically developed for this study. This approach also facilitates derivation of the primary energy which is the principal metric used in the Energy Performance of Buildings Directive (EPBD) (EU 2018/844).

The key additional EPBD parameters added are the primary energy factor and of primary energy (PE) use in kWh/m²/y. This is because Annex 1 of the EPBD requires the energy performance of a building to be expressed by a numeric indicator of primary energy use in kWh/m²/y for the purposes of both energy performance certification (EPCs) and compliance with minimum energy performance requirements.

In principle, the last subsection of this subtask should consider the Critical Raw Material (CRM) indicators but for BACS at the functional product level such materials are not directly involved; therefore, this section is not included.

Note that the MEErP method uses simplified approaches, but when it is deemed useful this modelling can be reviewed in a subsequent impact assessment.

5.4.3 Per kWh environmental profile from the Ecoreport tool for electricity

Based on the previous input data the Ecoreport calculation spreadsheet tool[172] allows calculation of the environmental profile of 1 kWh electricity used annually over the defined product life time i.e. for 15 years and hence for 15 kWh of electricity. The results are reported in Table 5-4.

In addition to the Ecoreport tool the primary energy and primary energy factor have also been calculated and are presented in Table 5-4; for which it is noted that:

[172] https://ec.europa.eu/growth/industry/sustainability/product-policy-and-ecodesign_en

- The concept of primary energy used in the EPBD facilitates comparison of different energy sources (electricity, gas, renewables, etc.) within a single parameter that can be applied to set a target level. This is similar to the Ecoreport tool used in this study which calculates the corresponding Gross Energy Requirements (GER). Hereby 3.6 MJ GER in the MEErP corresponds to 1 kWh of primary energy in the EPBD, see the calculated results in Table 5-4.
- The EPBD approach allows for the inclusion of local renewable energy to be taken into account for electricity but this is not yet in the Ecoreport tool because it has a fixed carbon intensity value (0.384 kgCO2eq./kWh). Yet, were one to consider modelling demand response, it would require a significant extension and additional complexity of the Ecoreport tool, which was outside the scope of this study.
- The methodology used to calculate primary energy (kWh/m²/y) within EPBD is left up to each Member State (MS) and is based on primary energy factors[173] per energy carrier, which may be weighted averages or a specific value for on-site production. For electricity the primary energy factor used in the Ecoreport tool is 2.50 (see Table 5-4). Nevertheless, with an increased share of renewable energy for the production of electricity this could obviously become much lower in the future. This study calculations, however, apply the default value which is used for all Ecodesign studies in order to be comparable and compatible. Should it be relevant for the assessment of the Task 7 policy options, other values could be used in any impact assessment done subsequently to this study.
- This comparability between the impacts of different energy sources (gas, electricity) simplifies the optimization analysis within Task 6 as it can be done for a single common parameter i.e. Gross Energy Requirements (GER).
- Considering the previous arguments this study uses the MEErP Gross Energy Requirements and thus also the Primary Energy (per the EPBD) as the leading parameter to be optimized. In consequence, this study also aligns with the performance metric used in the EPBD.

[173] https://ec.europa.eu/energy/sites/ener/files/documents/final_report_pef_eed.pdf

Table 5-4: Environmental profile of 1 kWh of final electricity demand by the building over the product life time (15 years)

Other Resources & Waste over life time		
Total Energy (GER)	MJ	135,000
Water (process)	ltr	6,000
Waste, non-haz./ landfill	g	69,570
Waste, hazardous/ incinerated	g	2,130
Emissions (Air) over life time		
Greenhouse Gases in GWP100	kg CO2 eq.	5,763
Acidification, emissions	g SO2 eq.	25,500
Volatile Organic Compounds (VOC)	g	3,015
Persistent Organic Pollutants (POP)	ng i-Teq	0,315
Heavy Metals to air	mg Ni eq.	1,365
PAHs	mg Ni eq.	0,315
Particulate Matter (PM, dust)	g	0,540
Emissions (Water) over life time		
Heavy Metals	mg Hg/20	0,581
Eutrophication	g PO4	0,026
Calculated parameters related to EPBD		
Greenhouse Gases in GWP100 per 1 kWh	kg CO2 eq.	0,384
Primary energy based on GER per life time	kWh	37,500
Primary energy factor(primary energy per 1 kWh)	kWh/kWh	2,500

5.4.4 Per kWh environmental profile from the Ecoreport tool for gas

The environmental profile of 1 kWh of gas determined over the specified product lifetime with the Ecoreport tool is reported in Table 5-5. This includes a calculation of the primary energy (PE), which is the leading parameter of the EPBD.

Table 5-5: Environmental profile of 1 kWh final gas demand by the building over the product life time (15 year typically)

Other Resources & Waste over life time		
Total Energy (GER)	MJ	60,317
Water (process)	ltr	0,000
Waste, non-haz./ landfill	g	0,000
Waste, hazardous/ incinerated	g	0,000
Emissions (Air) over life time		
Greenhouse Gases in GWP100	kg CO2 eq.	3,005
Acidification, emissions	g SO2 eq.	2,625
Volatile Organic Compounds (VOC)	g	0,039
Persistent Organic Pollutants (POP)	ng i-Teq	0,000
Heavy Metals to air	mg Ni eq.	0,000
PAHs	mg Ni eq.	0,002
Particulate Matter (PM, dust)	g	0,015
Emissions (Water) over life time		
Heavy Metals	mg Hg/20	0,000
Eutrophication	g PO4	0,000
Calculated parameters related to EPBD		
Greenhouse Gases in GWP100 per 1 kWh	kg CO2 eq.	0,200
Primary energy based on GER per life time	kWh	16,755
Primary energy factor(primary energy per 1 kWh)	kWh/kWh	1,117

5.4.5 Environmental profile per m² Base Case

Taking into account the modelled energy consumption of the use phase per Base Case (see 5.3.9), one can calculate the environmental impact per Base Case, as reported in Table 5-6.

In addition to the Ecoreport tool results Table 5-6 also include the primary energy use in kWh/m²/y, which is the key metric applicable in the EPBD. When comparing these results with the equivalent values to reported under EPCs it is important to take into account that not all building energy use was accounted in this study (e.g. DHW, lifts, etc. were not assessed); meaning that existing EPCs of similar buildings should ordinarily have higher primary energy values.

Table 5-6: Environmental profile per m² for each Base Case over its lifetime and related EPBD metrics

Task4+5(BAU)/4+6(BAT) references:		BC1hoBAU	BC2hoBAU	BC3apBAU	BC4apBAU
building type (& design)		L38 house		EN 15232 shoe box model	
age type		renovated	new LEB	renovated	new LEB
Task 5 Base Case #		**1**	**2**	**3**	**4**
study reference		**house R**	**house N**	**flat R**	**flat N**
EU climate zone (see MEErP)		average	average	average	warm
Other Resources & Waste					
Total Energy (GER)	MJ	7620,355	2670,294	7133,875	2598,615
Water (process)	ltr	3,290	118,680	19,500	115,494
Waste, non-haz./ landfill	g	38,151	1376,092	226,103	1339,153
Waste, hazardous/ incinerated	g	1,168	42,131	6,923	41,000
Emissions (Air)					
Greenhouse Gases in GWP100	kg CO2 eq.	379,066	113,986	352,234	110,926
Acidification, emissions	g SO2 eq.	342,355	504,389	374,207	490,850
Volatile Organic Compounds (VOC)	g	6,590	59,637	14,179	58,036
Persistent Organic Pollutants (POP)	ng i-Teq	0,173	6,231	1,024	6,063
Heavy Metals to air	mg Ni eq.	0,749	27,000	4,436	26,275
PAHs	mg Ni eq.	0,384	6,231	1,211	6,063
Particulate Matter (PM, dust)	g	2,200	10,681	3,444	10,394
Emissions (Water)					
Heavy Metals	mg Hg/20	0,183	0,183	0,183	0,183
Eutrophication	g PO4	0,035	0,035	0,035	0,035
Calculated parameters related to EPBD					
Primary energy based on GER in kWh over life	kWh	2116,765	741,748	1981,632	721,838
Primary energy based on GER in kWh per year	kWh/m²/y	141,1	49,4	132,1	48,1

Task4+5(BAU)/4+6(BAT) references:		BC5whBAU	BC6whBAU	BC7ofBAU	BC8ofBAU
building type (& design)		EN 15232 shoe box model		L38 'office'	
age type		renovated	new LEB	renovated	new LEB
Task 5 Base Case #		**5**	**6**	**7**	**8**
study reference		**Shop R**	**Shop N**	**office R**	**office N**
EU climate zone (see MEErP)	Badd	average	average	average	average
Other Resources & Waste					
Total Energy (GER)	MJ	14230,474	6242,777	7666,328	1501,870
Water (process)	ltr	142,560	0,000	57,791	66,750
Waste, non-haz./ landfill	g	1652,983	0,000	670,086	773,964
Waste, hazardous/ incinerated	g	50,609	0,000	20,516	23,696
Emissions (Air)					
Greenhouse Gases in GWP100	kg CO2 eq.	686,005	310,972	372,617	64,110
Acidification, emissions	g SO2 eq.	1085,530	271,648	522,623	283,687
Volatile Organic Compounds (VOC)	g	78,848	4,084	33,205	33,542
Persistent Organic Pollutants (POP)	ng i-Teq	7,484	0,000	3,034	3,504
Heavy Metals to air	mg Ni eq.	32,432	0,000	13,147	15,186
PAHs	mg Ni eq.	7,793	0,175	3,213	3,504
Particulate Matter (PM, dust)	g	15,612	1,575	6,808	6,007
Emissions (Water)					
Heavy Metals	mg Hg/20	0,183	0,183	0,183	0,183
Eutrophication	g PO4	0,035	0,035	0,035	0,035
Calculated parameters related to EPBD					
Primary energy based on GER in kWh over life	kWh	3952,909	1734,105	2129,536	417,186
Primary energy based on GER in kWh per year	kWh/m²/y	263,5	115,6	142,0	27,8

Cross-checking the results:

Some example cross-checks of these results are as follows:

For BC1 (existing Single Family house) in Germany it is reported[174] that on average a 140 m² house consumes 19600 kWh/y of gas, or 156 kWhEP/m²/y metered, which is relatively close to the modelled value of 141 kWhEP/m²/y. In Spain, which is a warmer climate, this is about two times lower (8250 kWh/y)[175] for space heating. In Sweden, which is a colder climate, a household typically consumes 23200 kWh/y of gas[176] (space heating, DHW, cooking) and would be similar.

For example BC2 (new LEB SFH): in France the RT 2012[177] requires new residential buildings to consume less than 65 kWhEP/m²/y calculated, while the Base Case value modelled in this study is 49 kWhEP/m²/y. Hence this is in line, considering that DHW is not accounted for in the Base Case.

For example, for BC7 (existing office building): in Brussels[178] an existing office building has a metered EPC of 288 kWhEP/m²/y. This is higher than the 142 kWh/m²/y modelled for the Base Case but includes more technical building systems/plug loads (e.g. lighting, lifts, ICT, cafeteria, ..) and can use different energy sources and primary energy factors as modelled.

When comparing the measured EPC(kWh/m²/y) data with the calculated or forecasted data one should be aware that the EPC only includes primary energy for HVAC and for non-residential buildings also lighting. Nevertheless, for new LEB, such as BC4, large part of heating comes from the heat replacement effect due to: occupants, building electrical loads(appliances, ICT, ..) and solar radiation. Meaning that often no heating is required due to this highly variable effect and therefore the data of occupancy, all electrical loads and the solar radiation should always be monitored to enable a comparison of measured EPC data with the modelled data.

In conclusion, these findings support the view that the study values are aligned or not contradicted with other building energy data sources given the many factors that can influence these results.

5.5 Subtask Base Case life cycle cost

5.5.1 Base Case life cycle cost for consumer

Aim:

[174] https://www.eon.de/de/pk/erdgas/gasverbrauch.html

[175] Table 5.7 in: https://www.idae.es/publicaciones/spahousec-ii-analisis-estadistico-del-consumo-de-gas-natural-en-las-viviendas

[176] https://www.energimyndigheten.se/en/news/2011/new-regional-energy-statistics-for-single--or-two-dwelling-buildings/#:~:text=The%20level%20of%20energy%20use,per%20square%20metre%20last%20year.

[177] https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-France-2018.pdf (limit is 50 kWh/m²/y with a x1.3 correction factor for the Strasbourg region.

[178] Rue de Mot 24, European Commission, data consulted on: https://www.peb-epb.brussels/pub-frontoffice/pages/anybody.xhtml

To calculate the Life Cycle Costs (LCC) experienced by the consumer for each Base Case (BC).

Note that the MEErP uses simplified approaches for the energy cost and thus, if it is deemed useful, a subsequent impact assessment could consider using the time dependant values reported in the EU reference scenario derived from the more sophisticated PRIMES model[179]. The simplified Ecoreport tool itself does not allow to use time dependant electricity prices.

Approach:

See section 5.3.4.

Results:

The modelled value is in essence the HVAC energy cost over the life time of the BACS per Base Case per m², see Table 5-7.

Table 5-7: Calculated Life Cycle Cost per Base Case

Task4+5(BAU)/4+6(BAT) references:		**BC1hoBAU**	**BC2hoBAU**	**BC3apBAU**	**BC4apBAU**
building type (& design)		L38 house		EN 15232 shoe box model	
age type		renovated	new LEB	renovated	new LEB
Task 5 Base Case #		**1**	**2**	**3**	**4**
study reference		**house R**	**house N**	**flat R**	**flat N**
EU climate zone (see MEErP)		average	average	average	warm
LCC data from Ecoreports					
ErP Product (service) Life in years	y	15,0	15,0	15,0	15,0
Product price (Task 6)	Euro/m²	0,000	0,000	0,000	0,000
Maintenance cost per year	Euro/m²	0,000	0,000	0,000	0,000
Fuel rate (gas, oil, wood)	Euro/kWh	0,064	0,064	0,064	0,064
Electricity rate	Euro/kWh	0,205	0,205	0,205	0,205
General discount rate (interest minus inflation)	%	4%	4%	4%	4%
Escalation rate (project annual growth of running co	%	4%	4%	4%	4%
Corrected discount rate used for Energy	%	0%	0%	0%	0%
Present Worth Factor (PWF) for elec. & gas	(years)	15,00	15,00	15,00	15,00
Present Worth Factor (PWF) for maintenance	(years)	9,59	9,59	9,59	9,59
Life Cycle Cost elec per kWh	Euro/kWh/m²	1,69	60,82	9,99	59,19
Life Cycle Cost gas per kWh	Euro/kWh/m²	120,11	0,00	106,56	0,00
Life Cycle Costs total	Euro/m²	121,79	60,82	116,55	59,19

[179] https://ec.europa.eu/energy/data-analysis/energy-modelling/eu-reference-scenario-2016_en

Task4+5(BAU)/4+6(BAT) references:		BC5whBAU	BC6whBAU	BC7ofBAU	BC8ofBAU
building type (& design)		EN 15232 shoe box model		L38 'office'	
age type		renovated	new LEB	renovated	new LEB
Task 5 Base Case #		**5**	**6**	**7**	**8**
study reference		**Shop R**	**Shop N**	**office R**	**office N**
EU climate zone (see MEErP)	Badd	average	average	average	average
LCC data from Ecoreports					
ErP Product (service) Life in years	y	15,0	15,0	15,0	15,0
Product price (Task 6)	Euro/m²	0,000	0,000	0,000	0,000
Maintenance cost per year	Euro/m²	0,000	0,000	0,000	0,000
Fuel rate (gas, oil, wood)	Euro/kWh	0,030	0,030	0,030	0,030
Electricity rate	Euro/kWh	0,1104	0,1104	0,1104	0,1104
General discount rate (interest minus inflation)	%	4%	4%	4%	4%
Escalation rate (project annual growth of running cc	%	4%	4%	4%	4%
Corrected discount rate used for Energy	%	0%	0%	0%	0%
Present Worth Factor (PWF) for elec. & gas	(years)	15,00	15,00	15,00	15,00
Present Worth Factor (PWF) for maintenance	(years)	9,59	9,59	9,59	9,59
Life Cycle Cost elec per kWh	Euro/kWh/m²	39,35	0,00	15,95	18,42
Life Cycle Cost gas per kWh	Euro/kWh/m²	82,24	46,58	47,49	0,00
Life Cycle Costs total	Euro/m²	121,58	46,58	63,44	18,42

5.5.2 Base Case Life Cycle Costs for society

Aim:

To model the societal LCC which includes marginal costs for so-called external damage i.e. the externalities related to LCA emissions to air. This is introduced in the Ecoreport tool to test the robustness of the Least-Life-Cycle-Cost targets not just from the perspective of the individual customer but also from the viewpoint of external damages e.g. health impacts.

Approach:

Within the Ecoreport tool, these costs are calculated (only) for the emissions to air by multiplying the emissions mass with predefined external marginal costs to society, see Table 5-8. This allows a cost basis comparison of different environmental impact categories via a single unit (metric), which is the societal cost.

Table 5-8: External marginal costs to society rates within Ecoreport

Emissions to air	Unit	EUR/unit
Greenhouse gases in GWP100 (GHG)	kg CO2 eq.	0.014
Acidification potential (AP)	g SO2 eq.	0.0085
Volatile organic compounds (VOC)	G	0.00076
Persistent Organic Pollutants (POP)	ng i-Teq	0.000027
Heavy metals: other (HM1)	mg Ni eq.	0.000175
Heavy metals: stainless steel, CRT, bitumen (HM2)	mg Ni eq.	0.00004
Heavy metals: electricity, copper (HM3)	mg Ni eq.	0.0003
Polycyclic aromatic hydrocarbons (PAH)	mg Ni eq.	0.001279

Particulate matter (PM)	G	0.01546

Results:

The calculated results for the societal life cycle cost are reported in Table 5-9. These values are slightly higher than those modelled for the consumer life cycle cost, for example in Base Case 1 from 121.79 euro to 135.72 euro.

Table 5-9: Calculated societal Life Cycle Cost per Base Case

Task4+5(BAU)/4+6(BAT) references:		BC1hoBAU	BC2hoBAU	BC3apBAU	BC4apBAU
building type (& design)		L38 house		EN 15232 shoe box model	
age type		renovated	new LEB	renovated	new LEB
Task 5 Base Case #		**1**	**2**	**3**	**4**
study reference		**house R**	**house N**	**flat R**	**flat N**
EU climate zone (see MEErP)		average	average	average	warm
Societal Life Cycle Cost total	Euro/kWh/m²	135,72	66,86	129,75	65,06

Task4+5(BAU)/4+6(BAT) references:		BC5whBAU	BC6whBAU	BC7ofBAU	BC8ofBAU
building type (& design)		EN 15232 shoe box model		L38 'office'	
age type		renovated	new LEB	renovated	new LEB
Task 5 Base Case #		**5**	**6**	**7**	**8**
study reference		**Shop R**	**Shop N**	**office R**	**office N**
EU climate zone (see MEErP)	Badd	average	average	average	average
Societal Life Cycle Cost total	Euro/kWh/m²	144,28	55,27	75,29	21,86

5.6 Subtask 5.4 – EU totals

Aim:

To provide a notion of the total EU environmental and macro-economic impact of potential policy measures.

Approach:

The annual sales data from section 5.3.6 is multiplied by the data reported for each Base Case.

Note that these outcomes are subjective to the simplified market modelling and building models that were used in this study and built on the few data sources available. When deemed useful and should more data become available this can be reviewed in a subsequent impact assessment, conducted after this study.

5.6.1 Total environmental impact of annual sales

As discussed before this study uses the total Gross Energy Requirements (GER) that corresponds to Primary Energy as the leading parameter. Other impact indicators are simply proportional to this.

The results obtained in terms of GER [TWh[180]] are reported in Table 5-10 and give a clear notion on how much energy can be ultimately be saved or can be addressed by policy measures (see Task 7). (see Task 7).

[180] MJ was converted to TWh to allow comparison with EPBD and Task 2 reporting.

When considering these results one should be aware that the lifetime GER values are expressed for the life time assumptions made for the BACS i.e. 15 years.

Table 5-10: EU27 total environmental impact in GER for annual sales in 2020

Task4+5(BAU)/4+6(BAT) references:		BC1hoBAU	BC2hoBAU	BC3apBAU	BC4apBAU
Simulation used in the study		PHPP	PHPP	PHPP	EnergyPlus
Study system base case building application					
market	Unit	Residential			
building type (& design)		L38 house		EN 15232 shoe box model	
age type		renovated	new LEB	renovated	new LEB
Task 5 Base Case #		1	2	3	4
study reference		house R	house N	flat R	flat N
EU climate zone (see MEErP)		average	average	average	warm
2020 annual sales Mm² proxy	Mm²	66,00	55,00	24,00	20,00
EU27 GER from 2020 sales over BACS life time	TWh/life time	139,71	40,80	47,56	14,48

Task4+5(BAU)/4+6(BAT) references:		BC5whBAU	BC6whBAU	BC7ofBAU	BC8ofBAU
Simulation used in the study		Enercalc	*Enercalc*	Enercalc	EnergyPlus
Study system base case building application					
market	Unit	Non Residential			
building type (& design)		EN 15232 shoe box model		L38 'office'	
age type		renovated	new LEB	renovated	new LEB
Task 5 Base Case #		5	6	7	8
study reference		Shop R	Shop N	office R	office N
EU climate zone (see MEErP)		average	average	average	average
2020 annual sales Mm² proxy	Mm²	13,00	9,00	18,00	13,00
EU27 GER from 2020 sales over BACS life time	TWh/life time	51,39	15,61	38,33	5,44

5.6.2 Total Net Present Value of annual sales

The modelled total Net Present Value (NPV) for BACS sold in 2015 and 2020 is reported in Table 5-11. In essence, this value is the HVAC energy cost over the lifetime of the BACS.

Table 5-11: Total Net Present Value of annual sales in 2015 and 2020 per Base Case

Task4+5(BAU)/4+6(BAT) references:		BC1hoBAU	BC2hoBAU	BC3apBAU	BC4apBAU
Simulation used in the study		PHPP	PHPP	PHPP	EnergyPlus
Study system base case building application					
market	Unit	Residential			
building type (& design)		L38 house		EN 15232 shoe box model	
age type		renovated	new LEB	renovated	new LEB
Task 5 Base Case #		1	2	3	4
study reference		house R	house N	flat R	flat N
EU climate zone (see MEErP)		average	average	average	warm
2020 annual sales Mm² proxy	Mm²	66,00	55,00	24,00	20,00
EU27 NPV from 2020 sales over BACS life time	Meuro	8038	3345	2797	1187

Task4+5(BAU)/4+6(BAT) references:		BC5whBAU	BC6whBAU	BC7ofBAU	BC8ofBAU
Simulation used in the study		Enercalc	*Enercalc*	Enercalc	EnergyPlus
Study system base case building application					
market	Unit	Non Residential			
building type (& design)		EN 15232 shoe box model		L38 'office'	
age type		renovated	new LEB	renovated	new LEB
Task 5 Base Case #		5	6	7	8
study reference		Shop R	Shop N	office R	office N
EU climate zone (see MEErP)		average	average	average	average
2020 annual sales Mm² proxy	Mm²	13,00	9,00	18,00	13,00
EU27 NPV from 2020 sales over BACS life time	Meuro	1581	419	1142	240

5.7 Conclusion

It is recommended to use the Gross Energy Requirement (GER) [MJ], which is the LCA equivalent of Primary Energy (PE), as leading parameter for Task 6.

The potential total EU energy impact is large as was already indicated[181] previously [182].

181 https://www.buildup.eu/en/practices/publications/building-automation-scope-energy-and-co2-savings-eu

182 https://ec.europa.eu/docsroom/documents/20374

6 MEErP Task 6 report: Design options

6.1 Scope

The aim of this task is to identify the monetary consequences of the design options in terms of Life Cycle Cost for the user, their economic and possible social impacts, and to identify the solution with the Least Life Cycle Cost (LLCC) and that corresponding to the Best Available Technology (BAT). Therefore, this task relies on input from Tasks 4 and 5.

The BAT indicates a target in the shorter term that would probably be more likely to be a subject for promotional measures than restrictive actions. The Best Not (yet) Available Technology (BNAT) indicates the potential for progress in the longer term and helps to define the exact scope and definition of possible measures. Intermediate options between the LLCC and the BAT may also be assessed. Within the context and scope of this study on BACS, the considered 'BAT design options' are in principle the improved functionality options of the BACS.

Note that BNAT is a relative term and does not say that it is not yet available nor out of the product development phase but means here also that it is not broadly applied or available, for example for economic reasons.

The subsequent Task 7 analysis draws up scenarios which quantify the improvements that can be achieved versus a Business-as-Usual (BAU) scenario and compares the outcomes with EU environmental targets, societal costs, etc.

6.2 Summary of Task 6

This task calculated the Least Life Cycle Cost(LLCC) with the in Task 4 identified improved functionality options BACS according to the Ecoreport tool method from Task 5 for the reference buildings, the main conclusions are:

- all Task 4 BAT BACS options proposed for existing renovated well-insulated buildings were assessed to be Least Life Cycle Cost (LLCC) solutions.
- the existing reference buildings defined in Task 3 already assumed relatively high insulation levels and therefore correspond to well renovated buildings. However, from an energy savings perspective this was a conservative assumption, as many buildings might still be of a lower insulation standard when the Task 7 proposed policy might come into effect. When assuming this , there are likely even more energy savings and thus greater pay-back on investment. Therefore in this task also an analysis was done on a poorer insulated reference house; it did not change the conclusion on LLCC but it does show that in these cases the BAT results in even greater saving and a shorter economic pay-back period.
- for new LEB not all BAT BACS options correspond to the LLCC or have a pay back period of <15 years, which should not be a surprise as they have already have a very low energy demand. It was therefore also demonstrated that this will vary according to the building type, TBS, control zones and BAT options considered. Considering the larger Societal Life Cycle Cost did not change this conclusion. It's also important to appreciate that LEB have different and more complex TBS compared to less well-insulated buildings, which includes

ventilation control and generally more controls to maintain comfort, see Task 3. The lack of robust cost data and complexity makes defining an LLCC for LEB BACS even more complex.

- that the number of distinct control zones within the building also contribute to the performance and cost of BACS and will have an economic optimum level, as was illustrated in BC2BAT1. Also BC8BAT1 savings were built on a large multi-zone office buildings and had much of the energy savings attributed to individual zone control. This importance zoning was also pointed out in Task 3 and already in the Lot 37 lighting system study. Zoning is much influenced by the building application and lay out and therefore it might be difficult to address with BACS product without considering installation. It should be noted that in EN 15232:2017 in Annex C used a single zone reference building while this study modelled also additionally multi-zone buildings, see Task 3.
- if existing buildings were renovated much more deeply and therefore attain air-tightness and insulation levels closer to the new high LEB levels (as modelled in BC2/4/6/8) then the cost-effectiveness of the BAT options would decline relatively to a less well insulated building. Nevertheless, such invasive renovations are unlikely to occur systematically, because they would also require a high level of air-tightness and, accordingly, retrofitting with mechanical ventilation, and would need to remove so-called complex thermal bridges in the building envelope (e.g. reconstruct the building foundation, roof, window attic, ..). Such invasive deep renovation might be unlikely but the BC 1/3/5/7 that modelled existing buildings already assumed high insulation and are therefore more representative
- for the proposed improved functionality options the study did not identify any significant negative impacts due to the additional hardware, nor increased auxiliary energy needed.

6.3 Subtask: Design options

6.3.1 Aim

The aim of this subtask is to identify and describe the BACS design options that can improve the environmental performance of buildings.

These design options (referred to as “BAT design options”, or in some figures/tables “BAT options” for short) are all listed in Task 4 per base case building (1-8) as defined in Task 3; hence readers should consult the Task 4 report for details. Within the context and scope of this study on BACS, the considered BAT design options are in principle the improved functionality options of the BACS. These BAT design options are always defined and modelled relative to the Business-as-Usual (BAU) cases which are modelled in Task 5.

6.4 Subtask: Environmental impacts of the design options

6.4.1 Aim

The aim of this subtask is to describe the environmental impacts of the design options on the base cases using the Ecoreport tool (2014) which is part of the MEErP methodology[183]. This task will follow the same approach as explained in Task 5 for the Business-as-Usual (BAU) reference cases.

Results:

In line with many other energy using products and the approach already followed in Task 5; the environmental impact is proportional to the sum of the direct (BACS auxiliary energy) and indirect energy (HVAC energy) consumption. Those results, obtained by using the MEErP tool (see Task 5), are included in subsequent tables in this section, see Table 6-1, Table 6-2, Table 6-3 and Table 6-4. A sensitivity analysis is done on the potential impact due to BACS hardware manufacture and end of life in section 6.6.4.

All the BAT design options considered in Task 4 resulted in improved LCA compared to the BAU case because they have lower relative energy use. A qualitative discussion is presented following consideration of the costs, in section 6.6.

Table 6-1: LCA results for Base Case 1 and 2 which are for an existing renovated and new single family house and their improvement options for Task 4

Task4+5(BAU)/4+6(BAT) references:		BC1hoBAU	BC1hoBAT05	BC1hoBAT10	BC1hoBATLot1	BC2hoBAU	BC2hoBAT1	BC2hoBAT2
building type (& design)		L38 house						
age type		renovated				new LEB		
study reference		**house R**				**house N**		
EU climate zone (see MEErP)		average				average		
Per m² LCA data calculated								
Other Resources & Waste								
Total Energy (GER)	MJ	7620,355	7236,767	6859,595	7169,007	2670,294	2274,074	2653,601
Water (process)	ltr	3,290	3,290	3,290	0,000	118,680	101,070	117,938
Waste, non-haz./ landfill	g	38,151	38,151	38,151	0,000	1376,092	1171,906	1367,489
Waste, hazardous/ incinerated	g	1,168	1,168	1,168	0,000	42,131	35,880	41,868
Emissions (Air)								
Greenhouse Gases in GWP100	kg CO2 eq.	379,066	359,958	341,170	357,110	113,986	97,072	113,273
Acidification, emissions	g SO2 eq.	342,355	325,663	309,251	311,952	504,389	429,547	501,236
Volatile Organic Compounds (VOC)	g	6,590	6,339	6,093	4,690	59,637	50,788	59,264
Persistent Organic Pollutants (POP)	ng i-Teq	0,173	0,173	0,173	0,000	6,231	5,306	6,192
Heavy Metals to air	mg Ni eq.	0,749	0,749	0,749	0,000	27,000	22,993	26,831
PAHs	mg Ni eq.	0,384	0,374	0,363	0,201	6,231	5,306	6,192
Particulate Matter (PM, dust)	g	2,200	2,104	2,008	1,809	10,681	9,096	10,614
Emissions (Water)								
Heavy Metals	mg Hg/20	0,183	0,183	0,183	0,183	0,183	0,183	0,183
Eutrophication	g PO4	0,035	0,035	0,035	0,035	0,035	0,035	0,035
Calculated parameters related to EPBD								
Primary energy based on GER in kWh over life	kWh	2116,8	2010,2	1905,4	1991,4	741,7	631,7	737,1
Primary energy based on GER in kWh per year	kWh/m²/y	141,1	134,0	127,0	132,8	49,4	42,1	49,1

[183] Kemna R. (2011): Methodology for Ecodesign of Energy-related Products, MEErP 2011, 704 Methodology report, Part 1, methods.

Table 6-2: LCA results for Base Case 3 and 4 which are for an existing renovated and new multi-family house and their improvement options for Task 4

Task4+5(BAU)/4+6(BAT) references:		BC3apBAU	BC3apBAT1	BC4apBAU	BC4apBAT1
building type (& design)		EN 15232 shoe box model			
age type		renovated		new LEB	
study reference		**flat R**		**flat N**	
EU climate zone (see MEErP)		average		warm	
Per m² LCA data calculated					
Other Resources & Waste					
Total Energy (GER)	MJ	7133,875	6627,019	2606,175	994,073
Water (process)	ltr	19,500	14,625	115,830	44,181
Waste, non-haz./ landfill	g	226,103	169,577	1343,049	512,279
Waste, hazardous/ incinerated	g	6,923	5,192	41,120	15,684
Emissions (Air)					
Greenhouse Gases in GWP100	kg CO2 eq.	352,234	327,767	111,249	42,434
Acidification, emissions	g SO2 eq.	374,207	336,206	492,278	187,769
Volatile Organic Compounds (VOC)	g	14,179	11,469	58,205	22,201
Persistent Organic Pollutants (POP)	ng i-Teq	1,024	0,768	6,081	2,320
Heavy Metals to air	mg Ni eq.	4,436	3,327	26,351	10,051
PAHs	mg Ni eq.	1,211	0,944	6,081	2,320
Particulate Matter (PM, dust)	g	3,444	2,905	10,425	3,976
Emissions (Water)					
Heavy Metals	mg Hg/20	0,183	0,183	0,183	0,183
Eutrophication	g PO4	0,035	0,035	0,035	0,035
Calculated parameters related to EPBD					
Primary energy based on GER in kWh over life	kWh	1981,6	1840,8	723,9	276,1
Primary energy based on GER in kWh per year	kWh/m²/y	132,1	122,7	48,3	18,4

Table 6-3: LCA results for Base Case 5 and 6 which are for an existing renovated and new small non-residential building and their improvement options for Task 4

Task4+5(BAU)/4+6(BAT) references:		BC5whBAU	BC5whoBAT1	BC6whBAU	BC6whBAT1	BC6whBAT2
building type (& design)		EN 15232 shoe box model				
age type		renovated		new LEB		
study reference		**Shop R**		**Shop N**		
EU climate zone (see MEErP)		average		average		
Per m² LCA data calculated						
Other Resources & Waste						
Total Energy (GER)	MJ	14230,474	12920,293	6242,777	4432,371	2871,677
Water (process)	ltr	142,560	75,360	0,000	0,000	0,000
Waste, non-haz./ landfill	g	1652,983	873,799	0,000	0,000	0,000
Waste, hazardous/ incinerated	g	50,609	26,753	0,000	0,000	0,000
Emissions (Air)						
Greenhouse Gases in GWP100	kg CO2 eq.	686,005	631,516	310,972	220,790	143,047
Acidification, emissions	g SO2 eq.	1085,530	808,712	271,648	192,870	124,958
Volatile Organic Compounds (VOC)	g	78,848	45,212	4,084	2,900	1,879
Persistent Organic Pollutants (POP)	ng i-Teq	7,484	3,956	0,000	0,000	0,000
Heavy Metals to air	mg Ni eq.	32,432	17,144	0,000	0,000	0,000
PAHs	mg Ni eq.	7,793	4,271	0,175	0,124	0,081
Particulate Matter (PM, dust)	g	15,612	9,615	1,575	1,118	0,725
Emissions (Water)						
Heavy Metals	mg Hg/20	0,183	0,183	0,183	0,183	0,183
Eutrophication	g PO4	0,035	0,035	0,035	0,035	0,035
Calculated parameters related to EPBD						
Primary energy based on GER in kWh over life	kWh	3952,9	3589,0	1734,1	1231,2	797,7
Primary energy based on GER in kWh per year	kWh/m²/y	263,5	#VALUE!	115,6	82,1	53,2

Table 6-4: LCA results for Base Case 7 and 8 which are for an existing renovated and new large non-residential building and their improvement options for Task 4

Task4+5(BAU)/4+6(BAT) references:		**BC7ofBAU**	**BC7ofBAT1**	**BC7BAT2**	**BC8ofBAU**	**BC8ofBAT1**
building type (& design)		L38 'office'				
age type		renovated			new LEB	
study reference		**office R**			**office N**	
EU climate zone (see MEErP)		average			average	
Per m² LCA data calculated						
Other Resources & Waste						
Total Energy (GER)	MJ	7666,328	6520,442	6897,442	1506,953	1047,860
Water (process)	ltr	57,791	57,791	23,618	66,976	46,572
Waste, non-haz./ landfill	g	670,086	670,086	273,853	776,583	539,997
Waste, hazardous/ incinerated	g	20,516	20,516	8,384	23,776	16,533
Emissions (Air)						
Greenhouse Gases in GWP100	kg CO2 eq.	372,617	315,537	339,796	64,327	44,730
Acidification, emissions	g SO2 eq.	522,623	472,761	377,389	284,647	197,929
Volatile Organic Compounds (VOC)	g	33,205	32,455	16,033	33,655	23,402
Persistent Organic Pollutants (POP)	ng i-Teq	3,034	3,034	1,240	3,516	2,445
Heavy Metals to air	mg Ni eq.	13,147	13,147	5,373	15,237	10,595
PAHs	mg Ni eq.	3,213	3,180	1,418	3,516	2,445
Particulate Matter (PM, dust)	g	6,808	6,518	3,732	6,028	4,191
Emissions (Water)						
Heavy Metals	mg Hg/20	0,183	0,183	0,183	0,183	0,183
Eutrophication	g PO4	0,035	0,035	0,035	0,035	0,035
Calculated parameters related to EPBD						
Primary energy based on GER in kWh over life	kWh	2129,5	1811,2	1916,0	418,6	291,1
Primary energy based on GER in kWh per year	kWh/m²/y	142,0	120,7	127,7	27,9	19,4

6.5 Subtask: Life Cycle Costs

6.5.1 Aim

The aim of this subtask is to estimate the change in life cycle cost due to the implementation of the options. According to the MEErP methodology, this analysis should be carried out based on market prices of the products.

Results:

In these analysis the product installation and maintenance cost are added; using the Life Cycle Cost analysis with the method explained in Task 5. The results are shown in Table 6-5, Table 6-6, Table 6-7 and Table 6-8. As can be seen, not all identified BAT improvement options correspond to the least life cycle cost case. This is discussed in section 6.6.

Table 6-5: LCC and EU totals results for Base Case 1 and 2 which are for an existing renovated and new single family house and their improvement options for Task 4

Task4+5(BAU)/4+6(BAT) references:		BC1hoBAU	BC1hoBAT05	BC1hoBAT10	BC1hoBATLot1	BC2hoBAU	BC2hoBAT1	BC2hoBAT2
building type (& design)		L38 house						
age type		renovated				new LEB		
study reference		**house R**				**house N**		
EU climate zone (see MEErP)		average				average		
LCC data from Ecoreports								
ErP Product (service) Life in years	y	15,0	15,0	15,0	15,0	15,0	15,0	15,0
Product price (Task 6)	€/m²	0,000	0,300	2,600	3,000	0,000	14,800	1,600
Maintenance cost per year	€/m²	0,000	0,009	0,078	0,090	0,000	0,444	0,048
Fuel rate (gas, oil, wood)	€/kWh	0,064	0,064	0,064	0,064	0,064	0,064	0,064
Electricity rate	€/kWh	0,205	0,205	0,205	0,205	0,205	0,205	0,205
General discount rate (interest minus inflation)	%	4%	4%	4%	4%	4%	4%	4%
Escalation rate (project annual growth of running costs)	%	4%	4%	4%	4%	4%	4%	4%
Corrected discount rate used for Energy	%	0%	0%	0%	0%	0%	0%	0%
Present Worth Factor (PWF) for elec. & gas	(years)	15,00	15,00	15,00	15,00	15,00	15,00	15,00
Present Worth Factor (PWF) for maintenance	(years)	9,59	9,59	9,59	9,59	9,59	9,59	9,59
Life Cycle Cost elec per kWh	€/kWh/m²	1,69	1,69	1,69	0,00	60,82	51,80	60,44
Life Cycle Cost gas per kWh	€/kWh/m²	120,11	114,00	108,00	114,10	0,00	0,00	0,00
Life Cycle Costs total	€/m²	121,79	116,07	**113,03**	**117,96**	**60,82**	70,85	62,50
Societal Life Cycle Costs elec. per kWh	€/kWh x life	3,38	3,38	3,38	3,38	3,38	3,38	3,38
Societal Life Cycle Costs gas per kWh	€/kWh x life	1,07	1,07	1,07	1,07	1,07	1,07	1,07
Societal Life Cycle Cost total	€/kWh/m²	135,72	129,30	**125,58**	**131,04**	**66,86**	75,99	68,50
EU27 totals								
2020 annual sales Mm² proxy	Mm²	66,00	66,00	66,00	66,00	55,00	55,00	55,00
EU27 GER from 2020 sales over BACS life time	TWh/life time	139,71	132,67	125,76	131,43	40,80	34,74	40,54
EU27 NPV from 2020 sales over BACS life time	M€	8038	7661	7460	7786	3345	3897	3438

Table 6-6: LCC and EU totals results for Base Case 3 and 4 which are for an existing renovated and new multi-family house and their improvement options for Task 4

Task4+5(BAU)/4+6(BAT) references:		BC3apBAU	BC3apBAT1	BC4apBAU	BC4apBAT1
building type (& design)		EN 15232 shoe box model			
age type		renovated		new LEB	
study reference		**flat R**		**flat N**	
EU climate zone (see MEErP)		average		warm	
LCC data from Ecoreports					
ErP Product (service) Life in years	y	15,0	15,0	15,0	15,0
Product price (Task 6)	€/m²	0,000	5,600	0,000	19,000
Maintenance cost per year	€/m²	0,000	0,168	0,000	0,570
Fuel rate (gas, oil, wood)	€/kWh	0,064	0,064	0,064	0,064
Electricity rate	€/kWh	0,205	0,205	0,205	0,205
General discount rate (interest minus inflation)	%	4%	4%	4%	4%
Escalation rate (project annual growth of running costs)	%	4%	4%	4%	4%
Corrected discount rate used for Energy	%	0%	0%	0%	0%
Present Worth Factor (PWF) for elec. & gas	(years)	15,00	15,00	15,00	15,00
Present Worth Factor (PWF) for maintenance	(years)	9,59	9,59	9,59	9,59
Life Cycle Cost elec per kWh	€/kWh/m²	9,99	7,50	59,36	22,64
Life Cycle Cost gas per kWh	€/kWh/m²	106,56	100,24	0,00	0,00
Life Cycle Costs total	€/m²	116,55	**114,94**	59,36	**47,11**
Societal Life Cycle Costs elec. per kWh	€/kWh x life	3,38	3,38	3,38	3,38
Societal Life Cycle Costs gas per kWh	€/kWh x life	1,07	1,07	1,07	1,07
Societal Life Cycle Cost total	€/kWh/m²	129,75	**127,17**	65,25	**49,35**
EU27 totals					
2020 annual sales Mm² proxy	Mm²	24,00	24,00	20,00	20,00
EU27 GER from 2020 sales over BACS life time	TWh/life time	47,56	44,18	14,48	5,52
EU27 NPV from 2020 sales over BACS life time	M€	2797	2759	1187	942

Table 6-7: LCC and EU totals results for Base Case 5 and 6 which are for an existing renovated and new small non-residential building and their improvement options for Task 4

Task4+5(BAU)/4+6(BAT) references:		BC5whBAU	BC5whoBAT1	BC6whBAU	BC6whBAT1	BC6whBAT2
building type (& design)		EN 15232 shoe box model				
age type		renovated		new LEB		
study reference		**Shop R**		**Shop N**		
EU climate zone (see MEErP)		average		average		
LCC data from Ecoreports						
ErP Product (service) Life in years	y	15,0	Lot 37	15,0	15,0	15,0
Product price (Task 6)	€/m²	0,000	Lot 37	0,000	7,555	15,110
Maintenance cost per year	€/m²	0,000	Lot 37	0,000	0,000	0,000
Fuel rate (gas, oil, wood)	€/kWh	0,030	Lot 37	0,030	0,030	0,030
Electricity rate	€/kWh	0,1104	Lot 37	0,1104	0,1104	0,1104
General discount rate (interest minus inflation)	%	4%	Lot 37	4%	4%	4%
Escalation rate (project annual growth of running costs)	%	4%	Lot 37	4%	4%	4%
Corrected discount rate used for Energy	%	0%	Lot 37	0%	0%	0%
Present Worth Factor (PWF) for elec. & gas	(years)	15,00	Lot 37	15,00	15,00	15,00
Present Worth Factor (PWF) for maintenance	(years)	9,59	Lot 37	9,59	9,59	9,59
Life Cycle Cost elec per kWh	€/kWh/m²	39,35	Lot 37	0,00	0,00	0,00
Life Cycle Cost gas per kWh	€/kWh/m²	82,24	Lot 37	46,58	33,07	21,42
Life Cycle Costs total	€/m²	121,58	Lot 37	46,58	40,62	36,53
Societal Life Cycle Costs elec. per kWh	€/kWh x life	1,965	Lot 37	1,965	1,965	1,965
Societal Life Cycle Costs gas per kWh	€/kWh x life	0,534	Lot 37	0,534	0,534	0,534
Societal Life Cycle Cost total	€/kWh/m²	144,28	Lot 37	55,27	46,80	40,53
EU27 totals						
2020 annual sales Mm² proxy	Mm²	13,00	Lot 37	9,00	9,00	9,00
EU27 GER from 2020 sales over BACS life time	TWh/life time	51,39	Lot 37	15,61	11,08	7,18
EU27 NPV from 2020 sales over BACS life time	M€	1581	Lot 37	419	366	329

Table 6-8: LCA and EU totals results for Base Case 7 and 8 which are for an existing renovated and new large non-residential building and their improvement options for Task 4

Task4+5(BAU)/4+6(BAT) references:		BC7ofBAU	BC7ofBAT1	BC7BAT2	BC7BAT1+2	BC8ofBAU	BC8ofBAT1
building type (& design)		L38 'office'					
age type		renovated				new LEB	
study reference		**office R**				**office N**	
EU climate zone (see MEErP)		average				average	
LCC data from Ecoreports							
ErP Product (service) Life in years	y	15,0	15,0	15,0	15,0	15,0	15,0
Product price (Task 6)	€/m²	0,000	6,000	5,000	11,000	0,000	16,0
Maintenance cost per year	€/m²	0,000	0,180	0,150	0,000	0,000	0,480
Fuel rate (gas, oil, wood)	€/kWh	0,030	0,030	0,030	0,030	0,030	0,030
Electricity rate	€/kWh	0,1104	0,1104	0,1104	0,1104	0,1104	0,1104
General discount rate (interest minus inflation)	%	4%	4%	4%	4%	4%	4%
Escalation rate (project annual growth of running costs)	%	4%	4%	4%	4%	4%	4%
Corrected discount rate used for Energy	%	0%	0%	0%	0%	0%	0%
Present Worth Factor (PWF) for elec. & gas	(years)	15,00	15,00	15,00	15,00	15,00	15,00
Present Worth Factor (PWF) for maintenance	(years)	9,59	9,59	9,59	9,59	9,59	9,59
Life Cycle Cost elec per kWh	€/kWh/m²	15,95	15,95	6,52	6,52	18,49	12,85
Life Cycle Cost gas per kWh	€/kWh/m²	47,49	38,95	47,49	38,95	0,00	0,00
Life Cycle Costs total	€/m²	63,44	62,62	60,45	56,46	18,49	33,46
Societal Life Cycle Costs elec. per kWh	€/kWh x life	1,965	1,965	1,965	1,965	1,965	1,965
Societal Life Cycle Costs gas per kWh	€/kWh x life	0,534	0,534	0,534	0,534	0,534	0,534
Societal Life Cycle Cost total	€/kWh/m²	75,29	72,87	70,53	64,95	21,93	35,85
EU27 totals							
2020 annual sales Mm² proxy	Mm²	18,00	18,00	18,00	18,00	13,00	13,00
EU27 GER from 2020 sales over BACS life time	TWh/life time	38,33	32,60	34,49	28,76	5,44	3,78
EU27 NPV from 2020 sales over BACS life time	M€	1142	1127	1088	1016	240	435

6.6 Subtask: Analysis of BAT and LLCC

6.6.1 Aim

The aim of this task is to combine the previous design options (if possible) and to identify the Best Available Technology and also the Least Life Cycle Cost (LLCC) solution.

Therefore, the design option identified in subtask 6.1 should be ranked regarding the Best Available Technology (BAT) and the Least (minimum) Life Cycle Costs.

6.6.2 Ranking of individual options and discussion

The identified least life cycle costs (LLCC) are indicated in **green bold** text in the previously shown cost data tables: Table 6-5, Table 6-6, Table 6-7 and Table 6-8.

One can conclude that all Task 4 design options considered for existing renovated well-insulated buildings, which are BC1/3/5/7; resulted in a lower life cycle cost and that the least life cycle cost (LLCC) options correspond to the one with the lowest modelled energy consumption.

For the new low energy buildings (LEB), however, not all BAT options proposed had a lower LCC. Note, that those newer LEB (see Task 3) assumed, amongst other factors, an increased air-tightness and therefore also the use of mechanical ventilation with heat recovery.

In particular, the following BAT options did not correspond to the LLCC option:

- the two-zone demand driven ventilation instead of a single zone in BC2BAT1 option in a LEB which already had heat recovery mechanical ventilation in the BAU. It also addresses the question of how many fine-grained control zones are needed.
- the variable speed pressure controlled circulator pump in BC2BAT2 option
- the new LEB office building BC8ofBAT1 option wherein, as much as possible, class A BACS functions were modelled.

Also, considering the Societal Life Cycle Cost did not change the above conclusions on the LLCC.

Nevertheless, the following new LEB cases did correspond to the LLCC:

- the residential LEB BC4BAT1 option that reduced air-conditioning demand with smart outdoor screen control
- the shop LEB BC6BAT1 and BC6BAT2 options for implementing class B or A BACS (EN 15232), because shops have modelled a relatively high energy demand per m² in the BAU so the savings obtained become economical.

Therefore, it can be concluded that for new LEB not all BACS BAT options corresponds to the LLCC and thus may have pay back periods of >15y. In principle, this should not be a surprise as these LEB already have a very low energy demand. It also demonstrates that this will vary according to the building type, TBS, control zones and BAT options considered, such that if the magnitude of energy savings falls below a certain absolute value there is a no longer a sufficient pay-back for higher performance BACS compared to their additional costs on the basis of pure energy savings considerations alone. Precisely defining this threshold for new buildings is, however, very complex and not possible within the constraints of this study due to the large variety of buildings applications, geography and TBS that would need to be considered to determine this. It's also important to appreciate that LEB have different and more complex TBS compared to less well-insulated buildings, which includes ventilation control and generally more controls to maintain comfort, see Task 3. It should also be noted that the cost-effectiveness of BACS is not compared against renovating/constructing buildings to a LEB standard, which could show that BACS is the more cost effective way to achieve energy-efficiency but this was out of the scope of this study.

6.6.3 Combined BAT options

It should be noted that many of the modelled Task 4 BAT options are already combinations of BACS functions and therefore BAT; e.g. BC6BAT1, BC6BAT2 and BC8BAT1. Therefore considering additional combinations will result in similar conclusions.

As an extra illustration of this point the analysis presented below shows an additional combination of BC7BAT1 (BMS function) and BC7BAT2, which is BC7BAT1+2 (see Table 6-9).

Table 6-9: Combination of BC7ofBAT1 and BC7ofBAT2 and impact on LCC

Task4+5(BAU)/4+6(BAT) references:		**BC7ofBAU**	**BC7ofBAT1**	**BC7ofBAT2**	**BC7ofBAT1+2**
market	**Unit**	**Non Residential**			
building type (& design)		L38 'office'			
age type		renovated			
study reference		**office R**			
EU climate zone (see MEErP)		average			
Basic energy use input for LCA					
final electricy demand (LENI only included in BC5)	kWh/m²/y	9,63	9,63	3,94	3,94
final fuel demand for gas	kWh/m²/y	105,5	86,5	105,5	86,5
ErP Product (service) Life in years	y	15,0	15,0	15,0	15,0
Life Cycle Cost elec per kWh	€/kWh/m²	15,95	15,95	6,52	6,52
Life Cycle Cost gas per kWh	€/kWh/m²	47,49	38,95	47,49	38,95
Life Cycle Costs total	€/m²	63,44	62,62	60,45	56,46
Societal Life Cycle Costs elec. per kWh	€/kWh x life	1,965	1,965	1,965	1,965
Societal Life Cycle Costs gas per kWh	€/kWh x life	0,534	0,534	0,534	0,534
Societal Life Cycle Cost total	€/kWh/m²	75,29	72,87	70,53	64,95

For this combination BC7ofBAT1+2 it is obvious that benefits can be combined, however this is not as easy for other more complex TBS and BACS functions as was already illustrated in LEB BC4BAT2. Also BC5BAT1 illustrated a minor heat replacement effect, meaning that due to energy savings on lighting a little more energy was needed for heating. In general one can conclude there are often many routes to achieve energy savings in buildings, but they do not produce a simple cumulative effect when applied in combination and therefore building energy balances needs to be computed as explained in Task 3 and as was done in Task 4. Finally, were one to do so one would ultimately end up with a LEB and as explained in previous section it is difficult to claim that implementing all possible BACS functions results in the LLCC option.

6.6.4 Possible positive or negative ('rebound') side effects of the individual design measures

The previous chapter highlighted the positive influence of the design options on the environmental impact of BACS. Nonetheless, besides these positive effects the design options also have a potential for negative effects due to a potentially increased need for electronic hardware.

The major aim of this section is to do scrutinize whether a significant impact can be expected from the manufacturing and end-of-life phase of the additional hardware needed for the improvement options. Given the very large potential range of hardware and potential use cases, this has only been done for a selection of products which are deemed worst case, for example because of the inclusion of additional motors and/or electronic hardware. Base Case 7 and its Task 4 improvement options was selected because this is considered by the research team as a mainstream electronic product with typical electronic BACS hardware.

6.6.5 Potential negative impacts from material and conclusion

For this analysis we have selected the existing office building BC7 and the BAT1 option which aims to model the BMS benefits based on findings in the literature. To model if the manufacturing and recycling of BMS hardware is significant based on desk research we assumed that this would typically need 16 DIN rails modules with 0.9 kg ABS plastic housing and 3.51 kg printed circuits including components[184] in total, see BC7BOM in Table 6-10. When comparing the merits of BC7ofBAT with BC7ofBAU for most impact parameters it has much lower impact relative to that of the BC7BOM apart from heavy metals, POP and some additional waste. This is also obvious because savings are on gas for heating that has emission to air benefits but not any other waste (landfill) but the extra electronic hardware of BC7BOM, however, still has some landfill and/or incinerated waste.

Conclusion:

Therefore one can conclude that the approach applied in this study of optimize towards energy efficiency is justified. Nevertheless, it should not be used as an argument to exempt electronic hardware from WEEE requirements and of course all actions to reduce electronic waste can help lower the product's environmental footprint.

Table 6-10: LCA for Base Case 7 wherein the BC7ofBAT1 option is compared to the impact from the bill of materials to implement that option

Task4+5(BAU)/4+6(BAT) references:		BC7ofBAU	BC7ofBAT1	BC7BOM
Total Energy (GER)	MJ	7666,328	6520,442	3,353
Water (process)	ltr	57,791	57,791	0,600
Waste, non-haz./ landfill	g	670,086	670,086	3,200
Waste, hazardous/ incinerated	g	20,516	20,516	0,142
Emissions (Air)				
Greenhouse Gases in GWP100	kg CO2 eq.	372,617	315,537	0,180
Acidification, emissions	g SO2 eq.	522,623	472,761	1,424
Volatile Organic Compounds (VOC)	g	33,205	32,455	0,006
Persistent Organic Pollutants (POP)	ng i-Teq	3,034	3,034	0,016
Heavy Metals to air	mg Ni eq.	13,147	13,147	0,610
PAHs	mg Ni eq.	3,213	3,180	0,073
Particulate Matter (PM, dust)	g	6,808	6,518	1,223
Emissions (Water)				
Heavy Metals	mg Hg/20	0,183	0,183	0,152
Eutrophication	g PO4	0,035	0,035	0,004
Calculated parameters related to EPBD				
Primary energy based on GER in kWh over life	kWh	2129,5	1811,2	0,9
Primary energy based on GER in kWh per year	kWh/m²/y	142,0	120,7	0,062

6.6.6 Potential negative impact from increased direct energy consumption for auxiliary power

It is also relevant to know if the indirect energy savings obtained with BACS are not partly offset by the internal and auxiliary power consumption of the BACS. Auxiliary and internal power consumption is already included in the Task 4 input data which are used for these Task 6 calculations and therefore is taken into account as much as possible. Hereby in Task 4 particular attention were given to BAT options that would

[184] MEErP Ecoreport Material [row 98] 'Controller board' is an aggregate assembly with fractions of Printed Wiring Board, port, caps&coils, ics, LEDs and solder.

need an increased amount of mechanical energy because one would expect that they will be most challenging and also there is data available for this. This was in particular modelled for screen and window motors BC4BAT1 and BC7BAT2 but the resultant auxiliary energy needs were much lower than the energy savings achieved in the TBSs that the BACS control. A similar finding was also obtained for valve actuators[185]. Note that due to a lack of systematic data in Task 4 on internal power consumption the study could not investigate the optimization of this.

6.7 Subtask: Long-term targets (BNAT) and systems analysis

6.7.1 Aim

This final subtask within Task 6 looks beyond the specific design options that are available as BAT currently to consider how this may evolve over the longer term. It has two aims. First, to discuss the long-term technical potentials based on expected outcomes of applied and fundamental research to address the context of the present product archetype as best not yet available technologies (BNAT). Second, the long-term potential based on changes to the total system beyond BACS is discussed.

6.7.2 Long-term technical potentials based on BNAT for BACS

The most important BNAT identified in Task 4 is related to Demand Response (DR) and smart grid integration which might matter for LEB that use a heat pump for heating, in particular. As explained in Task 4 such BNAT with full DR functionality is likely to have largely similar hardware requirements to current class A BACS but mostly the software requirements might be different. Therefore installing the necessary hardware that can be upgraded later on could stimulate additional environmental and economic benefits for BC8BAT1 that could not be modelled currently within this study.

6.7.3 Long-term changes to the total building system beyond BACS

There is a clear trend towards more efficient buildings and greater levels of renovation in the EU27 and therefore also the EC recently launched its renovation wave strategy[186].

Hence, it is likely that many buildings are or will be renovated towards the level that we already assumed for the reference existing buildings BC1/3/5/7. Note that, as explained in Task 3, this is already a relatively high level of insulation.

It could be, however, that this level of renovation of existing buildings does not take place or is postponed, an aspect that might be addressed when considering future policy scenarios (Task 7). Therefore in Task 3 a less well-insulated reference house was defined, that has some basic insulation only. For this purpose the simulated performance of BC1BAU can be compared to BC1SEN00 and that of BC1BAT1 to BC1SEN01 when comparing a well versus poorly-insulated house, see the results in Table 6-11. This sensitivity analysis with poorer insulation does not change the conclusion that the BAT cases correspond to the LLCC but it does show that in these cases the BAT results in greater saving and has a shorter economic pay-back period.

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[185] https://www.belimo.com/mam/corporate-communications/corporate-governance/HSLU_Belimo_CO2_Review_2019_09_06.pdf

[186] https://ec.europa.eu/energy/sites/ener/files/eu_renovation_wave_strategy.pdf

Table 6-11: Impact of having a much poorer insulated existing house in BC1

Task4+5(BAU)/4+6(BAT) references:		BC1hoBAU	BC1hoBAT10	BC1bhoSENS00	BC1bhoSENS01
market	**Unit**	**Residential**			
building type (& design)		L38 house			
age type		renovated		not renovated	not renovated
Task 5 Base Case #		**1**		**1**	
study reference		**house R**		**house R**	
EU climate zone (see MEErP)		average		average	
key building envelope characteristics					
Basic energy use input for LCA					
final electricy demand (LENI only included in BC5)	kWh/m²/y	0,55	0,55	0,55	0,55
final fuel demand for gas	kWh/m²/y	125,11	112,50	155,96	127,85
ErP Product (service) Life in years	y	15,0	15,0	15,0	15,0
Life Cycle Cost elec per kWh	€/kWh/m²	1,69	1,69	1,69	1,69
Life Cycle Cost gas per kWh	€/kWh/m²	120,11	108,00	149,72	122,73
Life Cycle Costs total	€/m²	121,79	**113,03**	151,41	**127,43**
Societal Life Cycle Costs elec. per kWh	€/kWh x life	3,38	3,38	3,38	3,38
Societal Life Cycle Costs gas per kWh	€/kWh x life	1,07	1,07	1,07	1,07
Societal Life Cycle Cost total	€/kWh/m²	135,72	**125,58**	168,73	**141,66**

On the other hand it might also be possible that existing buildings do undergo a much more extensive or deeper renovation that would bring their insulation and air-tightness performance closer to the new LEB BC2/4/6/8. Then of course the conclusions with regards of those improvement options would apply (i.e. see section 6.6.2). In our opinion this 'deep LEB renovation' remains unlikely because it might be too invasive and expensive. Only to name a few out of the more than 500 pages recommendations and data[187], a deep LEB renovation requires removal of thermal bridges (foundation, windows, doors, ..), increase of air tightness (roof structure, technical shafts, ductwork, doors/windows, etc.) and mechanical ventilation (ductwork, fans, heat exchangers, etc.). This deep LEB renovation is complex and buildings will have to remain unoccupied for a while, therefore for residential buildings deep renovations are unlikely unless they change ownership.

[187] https://iea-annex61.org/files/results/Subtask_A_Guide_2017-11-06.pdf

7 Task 7 Policy and scenarios

The objective

The purpose of this task is to provide an understanding of the impacts of future scenarios in line with policy measures that could be introduced at EU-level. This is a key task as it requires the combination of the results of all previous tasks to derive estimates of the impacts of different Ecodesign policy measures and design options, and thereby is aimed at providing an analytical basis in support of the Ecodesign decision-making process. A set of quantitative scenarios are provided of the market penetration levels of various BACS technologies and the consequences for the environment, users and industry.

To this end, a stock model has been developed to estimate future sales and stocks of BACS under different policy scenarios. The outcomes are then compared with the Business-as-Usual scenario.

The sub-tasks conducted within Task 7 include:

- subtask Task 7-1 policy options aimed at reducing the impacts on the environment analysed in previous tasks.
- subtask 7-2 on scenarios
- subtask 7-3 on expected impacts related to the Task 7-1 proposals
- subtask 7-4 a sensitivity analysis of the Task 6 findings taking into account the policies proposed and Task 3/4 recommendations for sensitivity analysis relative to the proposed base cases of Task 5

A key point to consider for Ecodesign BACS policies is the interrelationship with the EPBD – Articles 8, 14 & 15 and the smart readiness index (SRI) – and the extent to which Ecodesign measures can help to empower the EPBD measures – thus understanding the product/system interface and how it overlays with these existing policies is important.[188]

Summary of Task 7

BACS differ from many other products examined in Ecodesign preparatory studies as they are designed in advance but 'assembled in situ' rather than produced, imported or exported as a whole. Consequently BACS are not distinguished as traded products in the Eurostat Prodcom statistics. Such data are available for some of the BACS components such as light sources, control gear, luminaires and some lighting controls, and where available these data are used.

In the absence of direct market data at the individual product level it is nevertheless possible to estimate the energy savings due to BACS improvements by linking the Task 7 scenario analysis to a dedicated BACS impact assessment model. A model was previously developed by WSE for use in the study to assess the impact of the BACS-related measures within the EPBD, and this has been adapted for the current purposes.

[188] Note, the policy recommendations in the EPRS Implementation Assessment of the Ecodesign Directive (EPRS 2017), state that "(...) considering not only the product but the whole system required for its functioning in the Ecodesign process would be another important success towards resource efficiency"

7.1 Analysis of policies

Based on the review of the policies and standards which have already been implemented (see Task 1), the position of the European Commission and the main stakeholders and on the cost-optimized technical improvement potential of the technologies (see Task 6), this task identifies and discusses policy options aimed at fostering the energy efficiency of BACS and reducing their impacts on the environment.

Such policy options include:

- Ecodesign requirements setting minimum (or maximum) limits and/or information requirements
- labelling or rating, which might be dynamic (if the market will need time to be prepared), in combination with incentive programmes (e.g. public procurement specifications), or
- alternative policy options such as self-regulation e.g. a voluntary agreement.

Furthermore, this task includes identification and discussion of measurement and product standards addressing installation and user information.

Drawing upon the previous tasks, clearly defined sets of policy options for new products are developed. These options are then translated into impacts on new products entering the stock which are input into the stock model.

To support this, the stakeholders' positions received on the earlier draft report have been summarised (7.1.1) and taken into account as well as the barriers to the market penetration of efficient BACS. Existing standards and legislation are included and modelled together with different additional policy options.

7.1.1 Stakeholder consultation during the preparatory study

During this Ecodesign preparatory study, stakeholders have been invited and encouraged by the project team and the European Commission to contribute to the study by providing inputs and their views. In this way stakeholders have the opportunity to actively engage in the process and to improve the preparatory study and the quality of its' outcomes.

Stakeholder meetings are a crucial element for exchange in Ecodesign preparatory studies and two such meetings were held during the course of this study:

- The 1st Stakeholder was held in Brussels on 3rd of March 2020. The discussion covered the scope (Task 1), the market analysis (Task 2) and the users (Task 3).
- The 2nd and final Stakeholder Meeting was held virtually (due to the pandemic constraints) on 15th of December 2020. The discussion addressed all the findings form Tasks 1 to 5 (Scope, Markets, Users, Technology, LCA/LCC results) in the morning session and the Task 6(LCA & LCC for the selected design options) and Task 7 (Policies and Scenarios) in the afternoon.

The minutes from both meetings are published on the project website. In addition, stakeholders have had the opportunity to provide written comments on the Task Reports prior to and after each of these meetings.

The positions of the main stakeholders can be summarized as follows:

1) eu.bac (European Building Automation Controls Association). Eu.bac submitted comment on the draft Task 7 report which can be summarised as:

- Eu.bac appreciate the Study Team's findings that increased use of advanced BACS technologies will ensure higher energy savings
- Eu.bac welcomed the clear distinction between packaged and installed BACS

For packaged products they:

- believe the success of policy options to address the temperature control accuracy of room temperature controllers will depend on how it is proposed e.g. the testing process
- oppose setting maximum limits for internal power consumption
- believe that temperature schedulers having a controllability intervals of ≤ 15 minutes is reasonable, but requiring < 5 minutes is not justified
- support the introduction of a minimum functionality requirement with regard to the reporting of KPIs based on EN 15232 and EN 16947 providing the BACS industry is involved n defining it
- in general, in terms of minimum requirements in the framework of Ecodesign, support setting class EN15232 class C as a minimum for every European building, except for large non-residential buildings, where the minimum should be class B, consistently with EPBD mandatory requirements and believe the requirements at packaged BACS product level should follow this holistic approach
- consider that the minimum functionality requirements with regard to lifetime, material content and repair proposed in the draft Task 7 report constituted an "excessive burden" on industry (note – these proposals have been amended in this final report)
- support the proposed minimum functionality requirements for interoperability as long as there is a catalogue of industry-supported standard communication protocols
- believe the proposed minimum functionality requirements for products to be declared smart grid ready from the draft Task 7 report need more work and discussion
- believe that minimum requirements for hydronic balancing and dynamic hydronic balancing should be established for class A BACS
- endorse the establishment of requirements to provide data on: internal power consumption, lifetime, material content and related information in product datasheets on the proviso that standard definitions of how these are to be measured has been established to ensure they can be compared across different products.

For installed products they:

- support the proposal to set a minimum EN15232 energy performance class of B for installed BACS in large non-residential buildings and of class C in other buildings, albeit noting the need to provide more expert training to ensure conformity in the assessment
- support the introduction of minimum functionality requirements for the measurement and reporting of KPIs by installed BACS based on EN 15232 and EN 16947 if the BACS industry is involved in their definition

- oppose the establishment of minimum functionality requirements with regard to lifetime, material content and repair as proposed in the draft Task 7 report (note – these proposals have been amended in this final report)
- support the study team's conclusions with regard to interoperability
- support the proposal to require the EN15232 energy performance of installed BACS to be declared, albeit noting the need to provide more expert training to ensure conformity in the assessment – note, eu.bac support options for doing this through either energy labelling or through Ecodesign information requirements
- support the revision of the BACS standards, in particular, to reflect demand response capability
- support the establishment of requirements to provide information on interoperability, operation and maintenance and commissioning.

Other comments were received from

- BAM (Federal Institute for Materials Research and Testing, Germany)/Federal Environment Agency, Germany/Fraunhofer IZM
- CECAPI
- Daikin
- ECI
- ECOS-EEB
- EHPA
- EPEE
- Eurovent argued that the focus of the study should be confined to installed BACS. They opposed the proposals with regard to packaged BACS and argued many of the proposals concerning installed BACS were immature and required further investigation.
- EVIA
- Lighting Europe
- WindowMaster
- ZVEI.

Some brief summaries of these now follow (see stakeholder position papers for more details):

- Several stakeholders queried the viability of the proposals regarding lifetime, material content and repair – these have since been revised
- Some stakeholders requested greater clarity regarding the proposals concerning accuracy of products such as temperature controllers – these have since been revised
- Some stakeholders commented on the need to clarify responsibility for conformity and applicability of market surveillance – these have been addressed as far as is possible within the confines of this study but more work may be needed depending on policymaker priorities.

Other comments were received with regard to proposals concerning:

- compatibility with BACS systems based on their energy performance class
- internal power consumption
- compatibility with BACS systems based on their energy performance class
- interoperability
- minimum requirements for packaged products to be declared smart grid ready
- measuring and reporting of KPIs
- product information requirements
- Operations and maintenance (O&M)
- specific BACS energy performance limits (C, B or A) at the installed product level
- energy labelling.

Comments were also received on:

- ventilation
- hydronic balancing
- lighting
- cabling
- commissioning tools
- updating the energy label for space heaters, water heaters and solid fuel boilers.

Some stakeholders commented on the substantial savings potentials identified from more efficient BACS and the need to put in additional development effort as needed so they can be accessed.

In light of these comments a number of alterations and improvements have been made to the policy proposals put forward in this final report.

7.1.2 Barriers and opportunities for Ecodesign measures

Barriers to energy efficiency

Table 7-7-1 shows a set of generic barriers to energy efficiency. Those circled in red apply to BACS.

Table 7-7-1: Barriers to energy efficiency – circled are those that apply to BACS.

	Barrier	Effect	Remedial policy tools
VISIBILITY	EE is not measured	EE is invisible and ignored	Test procedures/measurement protocols/efficiency metrics
	EE is not visible to end users & service procurers	EE is invisible and ignored	Ratings/labels/disclosure/benchmarking/audits/real-time measurement and reporting
PRIORITY	Low awareness of the value proposition among service procurers	EE is undervalued	Awareness-raising and communication efforts
	Energy expenditure is a low priority	EE is bundled-in with more important capital decision factors	Regulation, mechanisms to decouple EE actions from other concerns
ECONOMY	Split incentives	EE is undervalued	Regulation, mechanisms to create EE financing incentives for those not paying all or any of the energy bill
	Scarce investment capital or competing capital needs	Underinvestment in EE	Stimulation of capital supply for EE investments, incubation and support of new EE business and financing models, incentives
	Energy consumption and supply subsidies	Unfavourable market conditions for EE	Removal of subsidies
	Unfavourable perception and treatment of risk	EE project financing cost is inflated, energy price risk under-estimated	Mechanisms to underwrite EE project risk, raise awareness of energy volatility risk, inform/train financial profession
CAPACITY	Limited know-how on implementing energy-saving measures	EE implementation is constrained	Capacity-building programmes
	Limited government resources to support implementation	Barriers addressed more slowly	
FRAGMENTATION	EE is more difficult to implement collectively	Energy consumption is split among many diverse end uses and users	Targeted regulations and other EE enhancement policies and measures
	Separation of energy supply and demand business models	Energy supply favoured over energy service	Favourable regulatory frameworks that reward energy service provision over supply
	Fragmented and under-developed supply chains	Availability of EE is limited and it is more difficult to implement	Market transformation programmes

Abbreviation: EE = energy efficiency.

In summary, the following principal barriers and opportunities for Ecodesign measures result from the product and characteristics of its application:

- Due to a lack of standardised information and/or energy labelling BACS energy performance is not visible to procurers nor users, which means that it is seldom factored into procurement decisions and cost-effective energy savings achievable from BACs are not being accessed
- The potential savings from using more efficient BACs is generally not known by market actors
- Even when higher energy performance is claimed there is a lack of application of standardised means of comparing performance, which means procurers cannot easily check the claims of one supplier against another
- The above issue, combined with the highly technical and specialised nature of BACS, means there is often a strong asymmetry of knowledge between the suppliers and the procurers which adds to an elevated perception of risk from the procurement perspective - this may favour adoption of more conservative solutions than would otherwise be justified

- Insufficient interoperability between technical building systems (TBSs) and BACS can result in the use of more gateways than would otherwise be needed, which increases the risk of software driven system failures and adds to internal power consumption
- There is a split incentive between the interests of the project developer and the life-cycle costs of the end user which will favour underinvestment in energy-efficient BACS solutions
- The supply chain can be fragmented which results in some skill shortage issues as well as suppliers only being aware of solutions offered by their commercial partners rather than the broader set of options – this may inhibit innovation
- Commissioning and handover of the BACS to owners/facility managers can sometime be inadequate which may result in energy saving functionality not being adequately/fully operational and in the worst cases increase energy consumption.

Task 3 contains more discussion of opportunities and barriers that apply to BACS.

Opportunities

- Many technical solutions exist to increase the energy efficiency of BACS (see Task 6 for a set of reference cases, albeit this is not comprehensive). These options can be installed in new BACS installations and in many cases retrofitted in existing installations.
- The potential to increase efficiency of BACS is well known (at least by manufacturers and system integrators) and options could be offered as sales variants as well as advertised as such in private sector offers.
- At the level of the overall installed BACS product the most important information barrier would be overcome were the EN 15232 energy performance class to be reported in tenders and once the product is installed. Doing so would not just support raised awareness of the energy savings potential of BACS among procurers and users, but would also provide considerable assistance to MS regulators seeking to implement TBS/BACS performance specifications in accordance with Articles 8, 14 & 15 of the EPBD (see section 7.1.3.1).
- Also, at the level of the overall installed BACS product at least class C BACS (under EN 15232) are always cost-effective (often class A or B BACS are the cost-optimal solution), thus setting a minimum new installed BACS product energy performance requirement would eliminate the worst performing installations and save energy cost-effectively.
- At the packaged BACS product level several options exist to improve energy performance and functionality cost-effectively.
- At the packaged BACS product level opportunities exist to assist educated procurement by disclosure of energy performance and functionality in product data sheets.
- Increasing the interoperability of BACS would enhance their service life, minimise product offer lock-in, foster innovation, and reduce internal power consumption.

- Greater use of modular design, provision of spare parts and provision of information on repair would increase the service life of BACS and lower their materials footprint
- Improved standards and information disclosure could foster the uptake of BACS to support demand response.

Note, Article 15 of the Ecodesign Directive specifies criteria to be fulfilled for setting implementing measures, as follows:

a. "the product shall represent a significant volume of sales and trade, indicatively more than 200 000 units a year within the Community according to the most recently available figures": According to the Task 2 Report, BACS would be expected to be installed in 478 Mm2 of building stock floor area in 2020. Even if there is only one unit of physical hardware for every 13m2 of floor area this would account for over 34 million units of physical hardware being installed annually, which is greatly in excess of the the 200 000 threshold. Therefore, it can be assumed that a sufficiently significant volume of BACS are placed on the EU market.
b. "the product shall, considering the quantities placed on the market and/or put into service, have a significant environmental impact within the Community": according to this report more efficient BACS have the potential to reduce overall primary energy demand by up to 139 TWh in 2030 and 311 TWh in 2045 under the central case scenarios and by up to 206 TWh in 2030 and 531 TWh in 2045 under the Renovation Wave sensitivity scenarios.
c. "the product shall present significant potential for improvement in terms of its environmental impact without entailing excessive costs": satisfaction of this condition is confirmed in the Task 6 report, since many of the identified design options to reduce the environmental impact (mainly the energy consumption) are cost-effective. Depending on the Base Case, for example, Task 6 shows that the BAT level would result in total building primary energy consumption of between 7.1% and 61.9% below the Business-as-Usual (BAU) level depending on the building type considered. The BACS BAT case of EN15232 class A considered in this report results in savings in building primary energy consumption of 22.6% compared to the BAU.

7.1.3 Potential policy measures

The pros and cons of applying Ecodesign measures arise directly from the barriers and opportunities of Ecodesign measures for BACS. As already mentioned in the previous section the environmental performance of BACS is dependent on several factors driven by customer requirements. The most important is the building application and whether the BACS are an entirely new system or are being retrofit.

7.1.3.1 Policy background

A range of European policy frameworks apply to the energy performance of BACS, beginning with the measures specified in the four energy efficiency Directive/Regulations per Figure 7-1Figure 7-1.

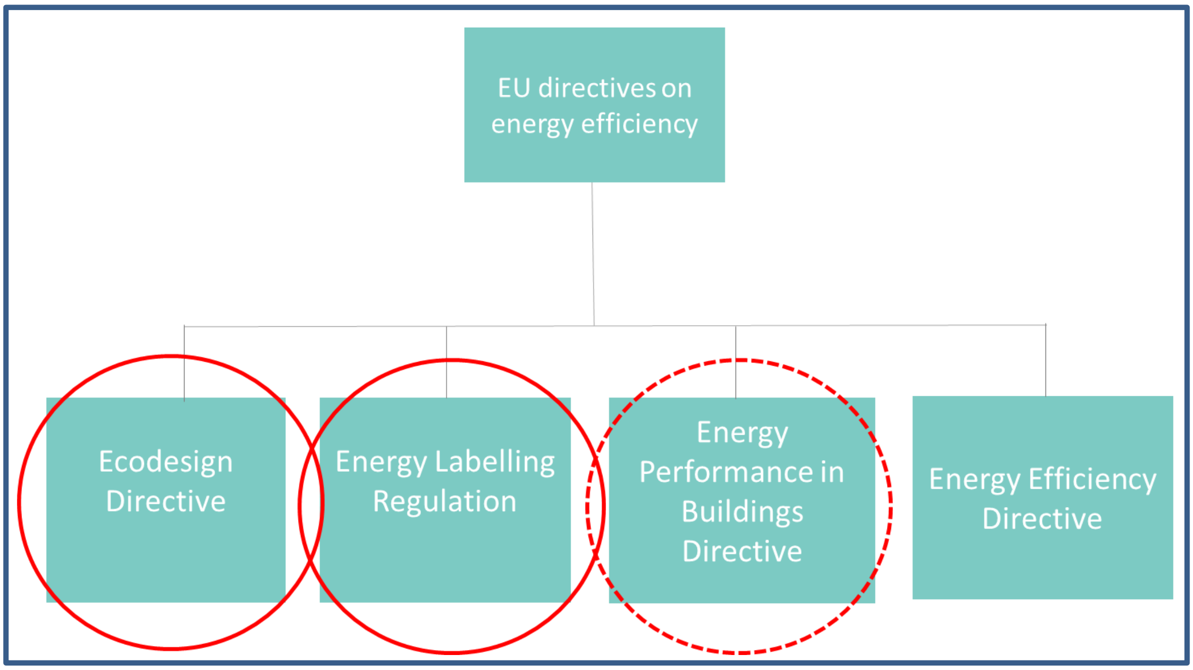

Figure 7-1: The key EU policy frameworks with implications for BACS

Currently, some of the non-energy-related environmental impacts of BACS are covered by the WEEE, RoHS and REACH Directives while some of the energy-related aspects are addressed by the EPBD. BACS as a whole are not yet subject to Ecodesign, Energy Labelling or Ecolabel requirements with the exception of some product types that have BACS functions incorporated, these are:

- space heaters, water heaters and solid fuel boilers: EU Regulations No. 811/2013, 812/2013 and 2015/1187
- local space heating products: EU Regulations No. 2015/1188, 2015/1185 and 2015/1186
- BACS are also part of the regulation 1253/2014 and 1254/2014 on ventilation units for which a review is ongoing[189] in parallel to this study
- Commission Regulation (EU) 2019/1781 for electric motors and variable speed drives
- The European regulation for circulators which are Regulation No 641/2009 amended by Regulation No 622/2012.

EU Regulations 811/2013, 812/2013 and 2015/1187 with regard to the energy labelling of space heaters, water heaters and solid fuel boilers respectively have introduced so-called package labels for the product systems they apply to, e.g. energy labelling requirements for heating systems that have to be implemented by the supplier or the dealer (in the case when the supplier only offers the components) of the system. Within these regulations the impact of controls is taken into account to the extent that they apply to the heating generator, but not fully with regard to the distribution or emission of heat where many of the largest energy savings potentials arise.

[189] https://www.ecoventilation-review.eu/

The regulations for space and water heaters are currently under review. The project websites for the associated Lot 1 and Lot 2 review studies are https://www.ecoboiler-review.eu/ and https://www.ecohotwater-review.eu/study.htm. Currently complementary work is launched, for planning and status see: https://www.ecoboiler-review.eu/study.htm. This review work is still ongoing at the time of completion of this Task and therefore please consult the respective websites.

The existing package label defines eight classes of temperature controller and attributes a saving percentage (-%) for the calculation of the space heating energy efficiency label. For example, class 1 is a mechanical on/off room thermostat that is ascribed a 1 % energy saving impact whereas class 8 is a multi-sensor room temperature control for use with modulating heaters which is ascribed a 5 % energy saving impact. The highest savings bonus attributed to any type of temperature controls is 5%.

These bonuses were developed in the course of the respective Lot 1, Lot 2 and Lot 20 preparatory studies but appear to have been developed as an aside to the main focus of both studies and may not reflect the state of the art in terms of the savings potentials. For example, EN 15232 ascribes energy savings of 9% for room control with optimum start and weather compensation for residential space heating and even more for non-residential buildings, which is significantly greater than the bonus allocated in the space heater package label regulation.

Overall, the bonuses currently presented in the Ecodesign and Energy Labelling regulations seem not to be aligned with EN 15232.

The review study for ventilation units is still ongoing, so far BACS functions are not incorporated but it is an option that can be considered and the results of this study can also be used (see Task 7).

Commission Regulation (EU) 2019/1781 defines four efficiency levels for motors (IE1-4) and requires at least efficient category IE3 from 2021.

The European regulation for circulators is Regulation No 641/2009 with an amended Regulation No 622/2012. It is currently based on the pump efficiency and does not awards credits for control functions being incorporated.

Energy performance of Buildings Directive

The measures which concern BACS within the EPBD can be summarised as:

- Mandatory requirements for installation and retrofit of Building Automation and Control Systems (BACS) in non-residential buildings (existing and new) with effective rated output of over 290 kW, by 2025 (within the amended Articles 14 and 15)
- Reinforced requirements on optimizing the performance of TBS i.a. with controls (within the amended Article 8)
- Incentives for installation of continuous electronic energy performance monitoring and effective HVAC controls in existing and new multifamily buildings (within the amended Articles 14 and 15)
- Requirements for the installation of individual room/zone temperature controls such as TRVs and individual zone controls (IZC) in new buildings and alongside the replacement of heat generators in existing buildings (within the amended Article 8)

- Non-residential and residential buildings equipped with BACS and electronic monitoring, respectively, are exempted from physical inspections of Heating and Air-Conditioning Systems (within the amended Articles 14 and 15)
- Definition of BACS according to the European Standards in the Directive (within the amended Article 2).

The following gaps existing in the EPBD specifications with regards to BACS:

- BACS are not mandatory below 290kW total installed HVAC capacity in non-residential buildings nor in residences
- Performance specification for >290kW non-res BACS is open-ended i.e. it is up to Member States to set the specifications
- Art 8 optimizing the performance of TBS i.a. with controls is also open-ended i.e. there is a lot of freedom for MS to set specifications as they see fit
- BACS system performance is not explicitly linked to EN 15232 classes and there is no requirement to use EN15232
- BACS designers/installers are not required to assess the energy performance and declare this to the service procurers
- Heating/Cooling systems <70kW not included in Art 14 and 15 inspection requirements.

It should be noted that almost all the explicit BACS measures within the EPBD were added in the revision of the Directive issued in 2018. There are many significant details which apply to these measures and their interpretation. The Commission Services have published recommendations in the Official Journal on how the new measures in the amended EPBD should be interpreted. Those relevant to BACS are reported in full in Annex A.

While the Commission Services have launched a study into Technical Building Systems within the EPBD which includes a review of current implementation which addresses BACS the provisional results are not expected to be available for some months yet and hence an overview of Member State plans with regard to BACS is not yet available.

7.1.4 Types of Ecodesign measures and product scope terminology

7.1.4.1 Type of Ecodesign measures - specific versus generic

The Ecodesign Directive provides the possibility of setting requirements according to Annex 1 and 2 of the Directive, which are:

- Generic ecodesign requirements (Annex 1) which aim for significant environmental aspects without setting limit values. Herein three parts of requirements are proposed:
    1. Generic requirements to define the relevant product parameters, for example as defined in EN 15232
    2. Generic requirements relating to the supply of information
    3. Generic requirements for the manufacturer, which might require to calculate ecological profiles against a benchmark.
- Specific ecodesign requirements (Annex 2) which typically aim to reduce consumption of a given resource such as:

1. Specific minimum energy performance requirements
2. Other specific ecological impact limits.

If specific requirements are to be set Annex 2 requires that a technical and economic analysis is conducted (as is done in Task 4 and 6), however, this is not needed for generic requirements (Annex 1). In principle all functions of EN 15232 contribute to energy savings; however, due to the constraints mentioned in the introduction to this study it was not possible to analyse each of them in detail in Task 4 and hence nor for each and every combination in Task 6. The rationale for selecting base cases and improved functionality options is explained in Task 4. When proposing specific requirements in this report the study team will look to the broader scope of BACS and thus some new detailed analysis might be required in any subsequent Impact Assessment.

7.1.4.2 Potential scope of Ecodesign policy measures – packaged versus installed products

Scoping for packaged BAC products

Hereafter when the term Packaged BAC products is used in this report it means BACS, BAC products, components or sub-assemblies when they are placed on the European market for the first time. This term packaged products is proposed because the similar term packaged solutions is used in the EPBD. Hereby BACS (EN ISO 16484-2) means Building Automation and Control Systems comprising all products and engineering services for automatic controls (including interlocks), monitoring, optimization, for operation, human intervention and management to achieve energy–efficient, economical and safe operation of building services. Controls herein also refers to processing of data and information. Packaged BAC products that are not defined in EN 15232, are excluded from the scope, for example fire alarms, intrusion detection products, etc. Within the scope are all BAC products that claim to be a BACS component as defined in EN 15232 or EN ISO 16484-2 with the aim to control Heating Ventilation and Air-Conditioning (HVAC).

This means that all three general BACS hardware levels defined in ISO 16484-2 are within the study's scope (see Task 1): the BACS hardware at the field level (sensors, actuators, etc.), Building Automation Control (BAC) hardware at the building automation level (room thermostat, etc.) and BACS at the building management level (BEMS, etc.).

For policymaking purposes it is important to note that in many cases BACS functions are already bundled in TBS components (heat pumps, gas boilers, etc.) by the manufacturer for the convenience of the installer. This is often the case for smaller TBS (heat pumps, gas boilers, etc.) and consequently they are often already subject to existing Ecodesign Regulation applied to the TBS. Consequently EC regulators will need to consider how to manage this. There would appear to be two options; of either a) amending the existing TBS-specific Ecodesign regulations to incorporate BACS-related policy measures or b) of introducing a new horizontal Ecodesign regulation.

The study team is aware that increased BACS functionality is often added by resellers, installers or energy service companies that combine packaged products from different manufacturers into a new improved packaged product. A potential negative consequence of this might be that they become de facto manufacturers with all the legal CE obligations and additional administration that this entails, as documented in the 'Blue Guide' on the implementation of EU products rules (2016/C 272/01).

According to the blue guide a manufacturer is responsible for the conformity assessment of the product and is subject to a series of obligations including traceability requirements and they must also cooperate with the competent national authorities in charge of market surveillance in the event that a product presents a risk of being non-compliant.

According to the definitions of the blue guide a manufacturer may design and manufacture the product themselves, but as an alternative, they may also have it "designed, manufactured, assembled, packed, processed or labelled" with a view to placing it on the market under their own name or trademark, and thus presenting themselves as a manufacturer. Consequently, someone who packed and/or processed BACS with new functionality and who must demonstrate conformity with any new EU regulation could become a de facto manufacturer as a result of the new EU regulation's requirements.

This means that the administrative work for this should be kept to the minimum or alternatively, the first manufacturer who brings this product on the market could avoid this by:

- documenting (in the product documentation) how class A or B compatibility and/or increased functionality can be achieved, meaning that those packaged products are still operated as intended without the need for repeating tests and producing additional documentation.
- foreseeing interoperability with other BACS and/or TBS that would allow for this without the need for repeating tests and producing additional documentation for conformity assessment needs.

It is recommended that a later impact assessment could probe this issue further if deemed necessary.

Scoping installed BACS products

Hereafter, when the term installed BACS products is used in this report it means an assembly of components after being installed and configured and put into service by the installer; from now on this second class of product will be referred to as *installed products*.

While most Ecodesign regulatory measures issued to date have applied to packaged products (under the definitions set out above) there is regulatory precedent for them to also apply to installed products. The Ecodesign Directive is one of the Harmonised Directives under the Single Market which entail the issuance of a CE marking. If a product is eligible for a CE marking under other harmonised Directives/Regulations then it is also eligible to be subject to Ecodesign regulatory measures. To the study team's knowledge a rare exception on CE-marking for installed products are lifts[190] that fall under the Lift Directive 2014/33/EU or lifting appliances that fall under the Machinery Directive (2006/42/EC), these receive a CE marking after installation (although it is noted that the types of installers in the lift industry will differ from those in the BACS/HVAC sector).

The Energy Labelling Regulation does not require CE marking and it usually applies to products placed on the market. However, there is an exception for products that are installed on site from an ensemble of sub-products and that is the case of the "package

[190] https://www.eco-lifts.eu/eco-lifts-wAssets/docs/Eco-design_Preparatory_Study_Final_Report_20191031.pdf

label” for heating and hot water products. In this case, the products themselves have individual labels enabling their placing on the market and the packaged label is an additional label - the installer is therefore responsible only for the additional package label.

When policy measures are made for installed products, Article 11 describes what can also be regulated for their components and sub-assemblies. This also means that in both policy routes the obligation for BACS manufacturers of packaged products that constitute components of BACS put into service will be needed anyway, at least for what matters with regard to providing the necessary information and compliant tools.

The reason why this distinction between packaged and installed products is very important for BACS is because most of the functionality of BACS is only achieved at the installed product level and not for packaged products. Equally, most of the potential for energy savings occurs through the configuration and functionality of the installed product, rather than the characteristics of the packaged product. Accordingly, the policy options set out in the remainder of this Task report consider both levels of BACS product and are differentiated accordingly.

A complicating factor for BACS is the sheer range of configurations that BACS may take when installed into a BACS product; however, the overall energy saving results attained is determinable through application of the calculations and energy performance classification set out in the EN15232 standard so at least conformity to this standard could be indicated through a CE marking.

Considering all this, potential Ecodesign measures include:

- specific minimum performance limits for ‘packaged products’
- specific minimum functionality requirements for packaged products
- specific energy performance limits for ‘installed products’
- specific internal power consumption limits for installed products
- specific minimum functionality requirements for installed products
- generic information requirements for packaged products
- generic information requirements for installed products
- generic requirement on the provision of a tool and compatible BACS component data to calculate energy savings from BACS.

These are now considered in turn such that for each option there is a summary of which party would be required to ensure conformity with the requirements and then a description of the policy option.

As packaged products and components are placed on the market while installed products are put into service the policy measures which apply to each can be classified in this manner. Accordingly, the Ecodesign policy proposals set out in section 7.1.5 and 7.1.6 below are structured into those that apply to products when placed on the market and into those that apply to products when put into service. Energy labelling proposals are made in section 7.1.7.

7.1.5 Prospective Ecodesign measures for products placed on the market

This section presents descriptions, rationales and pros and cons of prospective Ecodesign measures applicable to products placed on the market i.e. to packaged products and components. The first set of measures are specific Ecodesign requirements and the latter set are generic Ecodesign requirements.

7.1.5.1 Specific minimum performance limits for packaged products

Party responsible for conformity: ordinarily BACS packaged product suppliers i.e. manufacturers/importers but potentially system integrator/installers if requirements are made conditional to the intended application.

Self-regulation pathway? Potentially.

Potential product candidates

- Room temperature controllers (thermostats) and room temperature schedulers
- Air flow sensors
- TRVs
- Room humidity controllers
- Room air quality controllers.

Explicit policy proposals within this overarching category are presented in the sub-sections below.

7.1.5.1.1 Specific minimum performance limits for packaged products: Accuracy

The accuracy of **room temperature controllers and thermostats** has a significant impact on the ability of the BACS to operate HVAC systems in an energy efficient way and as such the use of low accuracy thermostats results in higher system losses. The accuracy and precision of temperature control is dependent on a number of factors, including the accuracy of temperature measurement, the precision of the final control element's (e.g. valves, dampers etc.) positioning and movement[191] and the type of controller employed, and its configuration and tuning.

EN15500-1:2017 *Energy Performance of Buildings. Control for heating, ventilating and air conditioning applications. Electronic individual zone control equipment. Modules M3-5, M4-5, M5-5* sets out an approach for the assessment of the energy impact of inaccurate room temperature control based on the calculation of temperature control accuracy (CA), which can be used to compare the relative accuracy of electronic individual zone controls (IZC), when used in conjunction with appropriately matched sensors, actuators and final control elements[192]. In principle, this approach could be generalised to cover all types of room temperature control systems and to address the control accuracy of air flow, humidity and air quality. However, stakeholders have indicated that the test procedures

[191] The positioning and movement relates to the precision of movement of an actuator that positions and moves the final control element – i.e. the value or damper etc. Sometimes the actuator is the final control element.

[192] Eu.bac operate a certification scheme which publishes data on the control accuracy of Individual Zone Controllers, Room Controllers and Programmable Room Thermostats. It has three authorised Test Laboratories in France, Germany and the UK. https://www.eubaccert.eu/#CMS

(as set out in EN15500-2:2016) would need to be reviewed because, currently, they do not clearly define the test room size or environmental conditions and hence it is difficult to ensure reproducibility between test laboratories.

As outlined in Task 4, inaccurate control of room temperature tends to result in users increasing the temperature setpoint by 1 or 2°C, particularly where resolution of the temperature display or set point adjustment mechanism is limited to 1°C intervals.

Accuracy reference cases were examined in Task 4 for base cases BC1hoBAT05 and BC1hoBAT10. The simulations found that by improving control accuracy and thereby reducing temperature setpoints by 0.5°C would reduce heating energy consumption by 5%, while by improving control accuracy and reducing temperature setpoints by 1.0°C would reduce heating energy consumption by 10%.

A priori, room temperature controllers could be required to achieve a temperature set point accuracy of <=+/- 0.5°C, and of being capable of being automatically reset to a pre-set temperature after a defined override period. To enable this set point reduction to be realised, the minimum accuracy requirements would need to be applied to sensors, controllers and final control elements, and minimum resolution specified for temperature display and set point setting.

Note, while in theory these requirements could apply to all eligible candidate packaged products placed on the market they could also be made conditional on the application for which the product is intended to be used[193]. Setting such application dependent requirements could avoid placing limits on products that might have alternative uses that are not within the scope of this study, while targeting could also help ensure cost-effectiveness; however, it may also complicate market surveillance.

In principle, measurement accuracy requirements could also be set for **air flow sensors**, however, these are integrated into larger packaged ventilation products and thus it makes more sense to address the whole performance of such products within the Ecodesign regulatory framework than the sensors they use explicitly.

In theory, introducing Ecodesign measures to increase the control accuracy of **TRV**s could also potentially be a source of cost-effective energy savings, and the market volume of TRVs is large; however, there are understood to be practical barriers to this as follows:

[193] There is precedent within Ecodesign regulations for setting application dependent requirements e.g. the Ecodesign regulations distinguish the energy performance requirements which apply to lamps depending on their intended application such that lamps which are specifically designed and marketed for use in ovens and refrigerators are exempt from requirements that the same product would be subject to if sold for use in domestic space illumination.

a) the current EU standards addressing the control accuracy of TRVs (e.g. EN 215:2019[194]) relate to mechanical TRVs and are not applicable to electronic TRVs [195] – rendering technology neutrality problematic

b) control accuracy is defined in a slightly different way in EN219:2019 compared to the definitions in EN15500-2:2016. Whilst both standards relate control accuracy to the average excess room temperature it is not clear that the two test methods would produce comparable results

c) testing infrastructure capacity for EN15500 is thought to be very limited[196].

For these reasons it is recommended that TRVs be considered within the scope of a future investigation, while the issue of technology neutral standardisation could be addressed in an intermediate standardisation review.

Similarly, there may well be a justification for the development of Ecodesign control accuracy requirements for **humidistats** and **room air quality controllers** (including for example those based on the use of integral CO_2 sensors); however, neither were investigated within this study and hence would have to be considered in future work.

7.1.5.1.2 Specific minimum performance limits for packaged products: Internal power consumption

In principle, it would be possible to set limits on the internal power consumption of packaged BACS products. However, this would require knowledge of their current internal power consumption related to their specific functionality in order to assess potential limits of internal power consumption per unit of functionality. Setting internal power consumption limits that are not related to the product function is not recommended as it might inadvertently prohibit sale of products that need more power demand to provide improved functionality. Presently, there is little public information on the internal power consumption of packaged BACS products and its relation to their functionality; in the absence of more data and proper investigation it seems premature to consider such measures. Nonetheless, they could be considered if internal power consumption data were available. A requirement to provide these data in product data sheets is considered in the section on information requirements.

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[194] It should be noted that the EU operates a CEN Keymark scheme for mechanical TRVs. https://keymark.eu/en/products/thermostatic-radiator-valves/thermostatic-radiator-valves

, based on testing to EN215: 2019 with three registered accredited test laboratories in the EU. There is also a Thermostatic Efficiency Labelling (TELL) Scheme. https://www.tell-online.eu/cms/upload/173_Energy-Labeling-Scheme-for-TRVs.pdf

[195] The test standard EN15500-1:2017 *Energy Performance of Buildings. Control for heating, ventilating and air conditioning applications. Electronic individual zone control equipment* is understood by the study team to be designed principally for electronic zone controls not electro-mechanical devices.

[196]

7.1.5.2 Specific minimum functionality requirements for packaged products

Party responsible for conformity: packaged BACS product suppliers, i.e. manufacturers/importers.

Self-regulation pathway? Potentially.

Potential product candidates [197]

- room temperature schedulers
- packaged building energy management systems[198]
- TRVs
- thermostats
- air flow controllers
- BAC controllers that can be fitted to load distributors, radiators or fan coils for heating and/or cooling
- in principle any TBS packaged product hardware including these BAC components but in particular heat pumps that claim to support smart grid applications.

Explicit policy proposals within this overarching category are presented in the sub-sections below.

7.1.5.2.1 Specific minimum functionality requirements for packaged products: Controllability of room temperature schedulers

A requirement could be set for room temperature controllers with integral set point scheduling to be capable of scheduling at least 4 temperature set point changes per day with a minimum time schedule resolution of <=15 minute intervals and to allow the use of different time schedules for each day of the week. This would increase the precision of temperature control and allow it to better be adapted to actual usage patterns, thereby saving significant amounts of energy compared to less flexible control systems.

7.1.5.2.2 Specific minimum functionality requirements for packaged products: BACS measuring and reporting of KPIs by packaged building energy management systems

Minimum functionality requirements could be imposed on packaged building energy management systems with regard to their ability to register and report key performance indicators (see also the companion requirement for installed BACS products further below). Standard EN 15232 does not give a direct list of KPIs. The KPIs chosen could align to a subset of those specified in the eu.bac BACS certification handbook (Part 4) and/or EN 16947-1:2017 on *Energy Performance of Buildings - Building Management*

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[197] Note – these would only apply to packaged BACS products that are marketed as being intended for used for building automation & control applications

[198] Packaged building energy management system refers to a building energy management controller sold as a single packaged product with the energy management software integrated within it. In practice, these are mostly used in small commercial premises to provide an all-in-one central energy management functionality. In larger buildings it is more common for energy management software (either on the premises or in the cloud) to be provided as a service and the related necessary hardware to be installed on site to collectively provide the energy management functionality.

System. Also, none of these cited sources contain KPIs for Demand Response in order to monitor the increased use of renewables, see Annex B for a proposal. Due to the lack of details included in existing standards, it is recommended to develop a transitional method for this.

For packaged Building Energy Management Systems (BEMS) as a functional minimum requirement it is proposed to require that internal power consumption should also be monitored and is capable of being reported with an open interoperable protocol.[199]

7.1.5.2.3 Specific minimum functionality requirements for packaged products: Demonstrate EN 15232 class B or A compatibility with an EU27 benchmark building

Under this notion, only packaged BACS products that are compatible with installed BACS product solutions which can attain EN15232 Class B or better would be eligible to be placed on the market. In order to avoid prohibiting the supply of retrofit products for existing class C BACS which may not always be justified in cost-effectiveness terms, i.e. for providing spare parts, and also to address cases were the packaged product could be used for purposes other than BACS, these requirements could be application dependent e.g. for new build or major renovations and/or for certain types of buildings.

Notes:

- class C is generally assumed to be the base case of BACS products brought on the market today, therefore requiring them to be upward compatible with class B/A will have a positive impact
- phasing out class D from the market might have little impact because most class D hardware are simple valves and switches that can already be retrofit with any type of automatic actuator which could convert it to anything from class C to class A (for example existing radiator valves can easily be retrofitted to attain class A BACS functionality)
- the same manual valves and switches that provide class D BACS cannot totally be phased out from the market because they have many other functions in HVAC which are not related to BACS, e.g. for purging or filling hydronic circuits during repair, etc. Nevertheless, they could be prohibited from being marketed and sold as 'BACS' hardware although they could still be purchased for other purposes.

A complicating factor is that implementation would require a means of determining whether a packaged BACS product is compatible with class B or A installed BACS products or not. In principle, such an approach would require that a manufacturer demonstrates the class B/A compatibility of their products at the functional level (EN 15232) against a benchmark building (or buildings), for example the BC8 as defined in Task 3 (i.e. via simulation or some more simplified online tool222). In practice, a transitional method which includes details of the reference buildings would need to be elaborated for this proposal to be implementable. For such a transitional method to be viable it would need to enable manufacturers to make these determinations on a standardised and verifiable

[199] Note, some manufacturers already provide this information. See section 6.3.3 of Siemens Desigo™ Room automation Engineering, mounting and installation Manual CM111043en_12 (2018-10-29) for an example of power budgets for BACS systems - including allowances for various control options and components.

basis, without undue burden. Note that this approach is also related to a proposed information requirement discussed in section 7.1.5.3.

7.1.5.2.4 Specific minimum functionality requirements for packaged products: Lifetime, material content and repair for packaged products

Rationale

Product lifetime matters for providing the return on investment of a higher functionality BACS. Another argument to consider lifetime and repair is that a single failure of BACS hardware will result in decreased functionality and lost energy savings. For example, in some cases a sensor or actuator failure can convert a class A functionality into class D functionality[200]. Packaged product failures that produce such system-level failures can also result in significant labour costs for trouble shooting and replacement. Despite the finding from Task 6 that the environmental impact of BACS hardware waste is modest, the following proposal is intended to address the issues raised above and avoid that it could become significant.

Important considerations

Based on the Task 3 data a typical economic lifetime of 15 years has been used and can serve as a reference. Task 3 also reported the following subclasses: BACS BEMS software/hardware technical lifetime, BACS mechanical field devices (actuators, valves, etc.). Given this information from the market and being aware that a field device failure can be more complex to trouble-shoot and replace, it is advised to keep this differentiation when setting policy requirements and set a higher lifetime requirement for mechanical field devices.

Requiring manufacturers to declare a minimum service life expectancy (MSLE) is not the same as requiring them to provide a lifetime warranty. A 'minimum service life expectancy' means the manufacturer has designed the product in a way that it should be able to continue operating for the specified period provided it is properly maintained. It also means that a manufacturer has a plan for supporting its continued operation through the provision of spare parts, software upgrades and security patches, or the identification of replacement components or upgrades that offer equivalent control functionality. The minimum service life expectancy could be underwritten by product liability insurance.

Requiring a minimum warranty period would oblige the manufacturer to replace failed components free or charge during that period. The manufacturer's warranty period is normally a fraction of the mean time between failure of the core components[201] but for certain packaged BAC products it could be extended beyond the usual minimum of 1 to 2 years, and manufacturers of packaged BAC products could be required to offer an extended warranty of 5-8 years in exchange for an up-front, or continuing, annual premium paid to an insurance company.

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[200] For example a variable speed pump can run at maximum power consumption after failure of a pressure sensor or a blocked 3-way way valve in a fan coil can result in an interlock between heating and cooling. Another example is a electro-mechanical switching relays that have limited life time.

[201] Otherwise the probability to replace or repair becomes too large and a service contract can become a more attractive business model.

The concept of 'spare parts' should be further elaborated and defined for practical implementation, initially we would suggest that spare parts for packaged BAC products or component are at least the following parts if they are used:

- electromechanical relays
- memory for EMS software and data logging
- connectors
- fuses
- batteries
- actuators to operate valves
- a controller module circuit when incorporated in a TBS
- .. (note, this list is not exhaustive and could be further extended).

In a later section the installed level is discussed and this is the input on which an installer can build an installed BACS product.

One of the main sources of hardware failure in BACS automation controllers are the integrated electro-mechanical switching relays that are used to directly switch on and off the mains power to plant and equipment. Newer product designs use solid state relays for switching lighting (for example), or external relay units that can more easily be replaced to control equipment that cannot be controlled by a low voltage switching signal. Generally the market is moving away from integrated relays, nonetheless policies to consider the ability to repair and replace integrated relays could be examined further.

Minimum functionality regarding the upgradability of packaged building energy management systems could be implemented via a requirement for the memory used to be upgradable and for repair for example by supporting standard protocols.

A requirement on the availability of spare parts could be introduced in line with recently adopted Ecodesign measures for other product groups e.g. a requirement for spare parts to be made available for a number of years after the last unit of the model is placed on the market.

Concepts of a policy proposal

Note that this is a relatively new and challenging policy area which would benefit from a further study and additional preparatory work.

Policy proposal for further consideration

- manufacturers, importers or their authorised representatives of packaged BAC products should be required to:
    - Option 1: Document how a minimum service life expectancy (MSLE) of all products placed on the market can be achieved. This information should be publicly available. The minimum requirement could be for example 10 years for EMS hardware & software while 15 years for other BACS devices can be achieved. Some concessions on MLSE towards 10 years could also be considered for some sensors if they can easily be replaced, e.g. if they are incorporated in lamps with a shorter lifetime. Currently there is no standardized method available for MSLE which would complicate market surveillance.

- Option 2: A possible alternative that could be developed is a simpler scoring system with a minimum threshold[202]. As a concept, this approach could take into account the following aspects with a kind of bonus-malus system that will need to be further investigated in new studies:
    1. Bonuses for using open standard multi-vendor protocols for BAC hardware at the building field level
    2. Bonus for modularity of the housing of BAC hardware at the building automation level (e.g. DIN rail)
    3. Spare parts being made available for replacement, at least: electromechanical components such as relays and valve actuators
    4. Bonuses for relays with sockets and actuators with screw fittings that can be easy replaced
    5. Availability of second source suppliers[203] could be a simple waiver for certain requirements (e.g. most of the standardized KNX BAC products[204] will benefit from that)
    6. Demonstration of the upgradability of software used in the case of BEMS
    7. Upgradability of the memory in the case of EMS
    8. Listing of software dependencies in the case of EMS.
- In the case where a packaged product require a WAN internet cloud connection, one can require to provide always an open fall-back solution that can run on a local server. This provides a fallback solution in the event that the cloud service is discontinued and/or the WAN solution becomes prone to new cybersecurity threats.
- Require packaged product suppliers to offer as an option an extended warranty of 6 years for BEMS hardware & software and 8 years after placing the last unit of the model on the market.
- Require packaged product manufacturers to replace any product that fails within the minimum service life expectancy period free of charge is also an option to consider.
- Make available to professional repairers spare parts, which:
    - starts not later than 2 years after first placing the product on the market and

[202] https://ec.europa.eu/jrc/en/publication/analysis-and-development-scoring-system-repair-and-upgrade-products

[203] A second source supplier is a company that is licensed to manufacture and sell components originally designed by another company (the first source). (John Zysman, Laura Tyson, American Industry in International Competition: Government Policies And Corporate Strategies, Cornell University Press, 1984 ISBN 0-8014-9297-1 page 160)

[204] https://www.knx.org/knx-en/for-manufacturers/

    - ends 5 years after placing the last unit of the model on the market for packaged BEMS products and software and 8 years for other packaged BAC products
    - for packaged BAC products at the field and building automation level it is allowed to bring downward compatible solutions instead of keeping replacement parts when it has with less than 8 Input/outputs
    - for packaged BAC products integrated into TBS there should also be a serial or parallel port to upgrade the BAC product with an open protocol (if not yet the default solution).
  - In the case that repairs can only be done with certified installer, publish a list of certified installers on the supplier's website.
  - Alternatively, make publicly available a list of spare parts and the procedure for ordering them during the required availability period. Also, make publicly available repair and maintenance instructions during the required availability period.
  - Provide access by qualified personnel to any software or programming tools required to (re) commission products during the required availability period.
  - Deposit copies of product hardware embedded software and source code developed by the manufacturer with an escrow service provider that should also warrant confidentially and protection of the manufacturer's IP as long as they duly fulfil their lifetime obligations. This is a back-up option to be used if the manufacturer fails to fulfil previous lifetime and repair requirements.

Positive impact expected from such a policy

An important barrier to the adoption of higher performance BAC product is a lack of confidence among building owners towards investment in more complex systems due to the risk of system failures and hidden future costs. The introduction of a minimum lifetime requirement could help to increase confidence and lower this barrier.

On the positive side, the introduction of such a minimum guaranteed service life and spare part requirement is likely to encourage manufacturers to adopt open standards and to adopt product development strategies that ensure backward compatibility of new products with old products. This would ensure that components that fail can be replaced with newer models or be sourced from alternative suppliers of products, to minimise the costs of retaining stock. The requirements to provide access to spare parts, repair and maintenance information, software and programme tools should enable users to continue to use BAC products that have been deleted from manufacturers' sales lists. The requirement to provide training should ensure that there are sufficient technicians to support older BACS systems.

Negative impact expected from such a policy

A potential negative impact is that at a time when the underlying technology of BACS is rapidly changing a minimum guaranteed service life may simply increase the cost of BAC systems without resulting in a shorter return on investment compared to the case where a better system could be retrofitted.

Manufacturers have also commented that setting such requirements would tend to increase product costs and potentially hamper innovation.

Timing

More time and development work might be needed to implement the requirement to demonstrate how a minimum MSLE can be achieved or alternatively to develop a simplified scoring system, for this measure to be sufficiently viable for implementation.

7.1.5.2.5 Specific minimum functionality requirements for packaged products: Interoperability

Rationale Interoperability is related to the product lifetime, as previously explained; provision of interoperability can support repair and upgrade and can simplify trouble shooting and avoid hidden costs later due to lack of spare parts. It can also often reduce the need for gateways and therefore lower system cost and internal power consumption.

The proposed policy (see below) would also align with the requirements in Article 14 and 15 of the EPBD wherein the BACS specified in these articles shall be capable of 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.

Moreover, in the case of the use of an internet protocol over WAN, the lifetime of an open communication protocol can be short due to continuous emerging cybersecurity threats. Indirectly related to this, but similar in effect, is planned premature obsolescence of IoT BAC devices. Therefore additional provisions can be made in BAC product policy to prevent adverse effects.

Proposal

Option 1, applicable to any new product:

Require that packaged BAC products support at least an open communication protocol between room controllers and other controllers. When a proprietary solution is provided such an open communication protocol should also be provided that can be enabled by the owner and is not excluded from being provided with the product.

The following additional requirements would apply for internet protocols that rely on WAN, for example packaged BAC products that rely on cloud services:

- An open fallback solution should be provided for a local server installed on the dedicated LAN or VLAN of the building. It should be possible at any time for the owner to enable this solution. This should also prevent planned obsolescence.

Hereby the requirements for an 'open communication protocol' are:

- being interoperable with technical building systems across different types of proprietary technologies, devices and manufacturers
- could be an EN or international standard (IETF[205]), they are considered as 'open communication protocol'

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[205] The Internet Engineering Task Force (IETF) is an open standards organization, which develops and promotes voluntary Internet standards.

- if it is neither an EN nor international standard it would also be acceptable when the standard is publicly available, free to use and deposited with the national market surveillance authority.

Option 2, applicable to existing packaged products that leave their place of manufacture or are placed on the market after the regulation comes into effect:

A requirement that today's closed proprietary protocols have to be disclosed in the public part of the product documentation. Moreover, one could require that a licence to use the protocol should always be available for anyone at a reasonable price, noting that a reasonable price is difficult to quantify.

In summary, it could be required that in the public part of the product documentation for any product a reference is either given to an existing standard protocol or it's own protocol is disclosed in such a way that anyone can interface and control the affected EN 15232 functions.

Positive impact expected from such a policy

The aim of this measure would be to help mitigate the concern and lack of trust by building owners regarding the functional lifetime of BAC products that inhibits willingness to invest in more complex systems due to system failures and hidden future costs. Such a minimum lifetime requirement could increase consumer confidence to procure more complex packaged BAC products. Also in the case of internet connected devices it should foster trust among end users of not being exposed to planned obsolescence nor the privacy or security concerns that can be associated with such services.

Negative impact expected from such a policy

It is also reported by manufacturers that there could be additional product development cost were such a requirement to be adopted. Developing and maintaining open communication protocols can be more time consuming and also the business model to generate return on investment is more complex. Often licence and/or membership fees are needed to use and/or participate in maintaining such protocols, and, therefore it should be checked that this is not unduly disadvantageous for SMEs.

Timing

Implementation should be timed to ensure there is a sufficient period for the market to adapt to respect these requirements and the proposal would benefit from further investigation and stakeholder consultation before it is potentially converted into concrete policy measures.

7.1.5.2.6 Specific minimum functionality requirements for packaged products: Minimum functionality requirements for TBS-related products with BAC functionality that claim Smart Grid capability

Rationale

A key aim of smart grids[206] is to reduce the carbon footprint of electricity by providing demand side flexibility. Although the concept of the smart grid began to be promoted and researched some 15 years ago, this has still not led to smart grid demand side flexibility being routinely integrated into today's packaged BAC products (see also Task 1) and/or into packaged TBS-related products that have in-built BAC functionality. Furthermore, no standardised set of functionality criteria have yet been formally

[206] https://www.edsoforsmartgrids.eu/

established that would enable products to demonstrate that they support Smart Grid capability (also the EN15232 standard is very generic on this topic for installed BACS). The absence of such criteria means that claims of Smart-Grid capability could be made on an inconsistent basis and without an agreed process, which will tend to undermine market confidence in the claims. Although it was not modelled in this study part of the previous Lot 33 study[207] examined the BAC functionality necessary to support smart grids - this work included appliances and also, in part, TBS-related packaged products. The proposals put forward below draw upon this work and aim to address the current gap by putting forward specific functionality requirements that packaged TBS-related products with BAC functionality would need to provide if they are to be permitted to claim that they provide Smart Grid capability. See also the recommendation to update EN 15232 to better address smart grid capability for installed BACS.

Proposal for BACS functionality requirements for heat pumps that claim to be Smart Grid ready:

Heat pumps intended for space heating which declare that they are functionally able to support Demand Response and claim to be Smart Grid ready, should at least have the following minimum BACS functionality requirements:

- 1 interrupt status (Interrupt)
- 1 normal EE mode (Normal)
- 1 boost mode (Boost)
- 1 optimum start mode (OSC)

These states should be accessible with dry contacts or free to use LAN IP.

Proposal for packaged BEMS to be declared Smart Grid ready:

As this issue has only been addressed through literature review in this study it might be premature to set specific requirements now. However, the topic could be investigated further in future work. It is also recommended to update EN 15232 to include such aspects. A detailed illustration of the type of specific functionality requirements that a draft proposal could entail is:

- Minimum interfacing requirements:
    - Central access to all room thermostats therefore: at least an RS485 interface for MODBUS, 1 USB and IP
    - Control and interface to any heat pump (see proposal for heat pumps)
    - MODBUS Sunspec interface (see ED PV proposal[208])
    - IP interface to enable interacting with the grid utility and electricity market.
- Minimum Logging requirements:

207 https://eco-smartappliances.eu/en

208 https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/contentype/product_group_documents/1581689975/20191220%20Solar%20PV%20Preparatory%20Study_Task%208_Final%20version.pdf

- Logging of all zone temperatures and set points per 15 minutes (for at least 3 zones)
- Hourly logging of the outdoor temperature
- Enabled to log occupancy per room
- Hourly logging of local energy needs for space heating and sanitary hot water (SHW)
- Hourly logging intensity of grid supplied electricity, whereby as long as there for grid electricity the hourly country carbon intensity should be used as long as EN 16325 has not been reviewed and an hourly Guaranties of Origin market has not been implemented (see recommendation on gaps in standards in Task 1)
- Hourly logging of local production and battery storage (if any)
  - if those are renewable they can be counted as 0 kgCO2eq/kWh carbon intensity
  - for batteries by a default value of 0.2 kgCO2eq/kWh should be used or the one supplied by the battery manufacturer[209].

- Minimum 5 Key Performance Indicators (KPIs) to be calculated monthly:
  - to monitor the thermal storage losses or round trip efficiency to store energy in the building
  - to estimate occupancy per room zones vs the default occupancies (see EN 15323)
  - to show the electricity needed for space heating with monthly average temperature versus display of corresponding EPC values
  - to show the displaced electrical energy needed for space heating (to be further elaborated)
  - to show primary energy for space heating obtained with hourly grid and local production data relative to the one obtained with monthly average data for the grid.

7.1.5.2.7 Specific minimum functionality requirements for packaged products: Minimum requirements for room thermostats/ room temperature controllers to be declared smart grid ready210

The idea behind this requirement is that the building mass could be used to store excess renewable energy when this is available. Therefore, for a room thermostat/temperature controller to be eligible to be declared as smart grid ready they should be able to communicate to a local BEMS to allow to temporarily adjust the set point by up to 2°C with a resolution of 0.2°C or better. This BEMS communication functionality should be based on an open interoperable standard. Moreover, the room thermostat/temperature

[209] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12399-Modernising-the-EU-s-batteries-legislation

[210] This is based on the latest research findings in smart grid related research projects, e.g. https://interconnectproject.eu/

controller should also include the cooling set points and provide alarms for interlocks between heating and cooling. When displays are used in user interfaces, they should show all set points as well as the measured temperature.

Considerations (for all Smart Grid ready declaration cases above)

Because heat pumps are important TBS (HVAC) components that use electricity for heating/cooling and have a high potential to support smart grid demand response they could be made subject to requirements for claims that they support smart grid functionality to be permitted. In principle, a similar approach could be considered for smart grid functionality claims to be permitted for refrigeration products and systems but these were not in the scope of this study.

Note that for other home appliances which are not TBS (HVAC)-related proposals are included in the Lot 33 study and therefore are not discussed further here.

Hot water storage tanks with electric heaters could also be considered, however, in most cases they can simply be converted to a smart grid application by retrofitting a smart controller and could therefore be left out of scope of the proposals made here. The minimum requirement is that at least one temperature sensor can be fitted to measure the state of charge of the tank but this is already common practice. Booster and/or anti-legionella heaters in used district heating systems can be also be converted simply and thus are left out of the previous proposals.

The proposals are soft policy requirements, meaning that they would only apply when a product is claimed to be smart grid ready (i.e. to have smart grid enabling functionality). Some of the policy proposals could be integrated into other Ecodesign product policy.

Timing and impact

Because this is a soft policy only, in principle no negative side effects would be expected and it could provide added-value for end users.

The largest challenge is likely to relate to the ability to attain an EU/EEA wide consensus on the final requirements due to the different blends of smart grid use cases currently in the pipeline (also see the discussion in Task 1). Therefore according to the principle of subsidiarity it might be preferable to implement BAC/TBS smart grid ready requirements at the regional level instead of at the EU level. The main regional/country differences are related to differences in electricity price structure (costs, levies, taxes, ..) and metering schemes (see Task 1). Therefore this option could be linked to resolving country or regional differences in electricity market design and metering before considering EU wide requirements. Both EU/EEA Smart Grid market and Smart Grid ready product requirements are interrelated and should be studied simultaneously to facilitate successful adoption. For further investigation of the final requirements it is recommended to include both electricity market experts of EU countries and BACS/TBS experts.

For BAC functionality integrated into packaged TBS-related products, such as heat pumps, this proposed policy could be combined with other Ecodesign requirements in their respective product group.

7.1.5.3 Generic BACS information requirements for packaged products

Party responsible for conformity: BACS component suppliers i.e. manufacturers/importers.

Self-regulation pathway? Potentially.

Potential product candidates [211]

- room temperature schedulers
- packaged building energy management systems[212]
- TRVs
- thermostats
- air flow sensors
- BAC actuators and controllers that can be fitted to load distributors, radiators or fan coils for heating and/or cooling
- in principle any TBS packaged product hardware including these BAC components but in particular heat pumps that claim to support smart grid applications.
- humidistats
- air quality controllers.

Explicit policy proposals within this overarching category are presented in the sub-sections below.

7.1.5.3.1 Generic BACS information requirements for packaged products: Information on accuracy

Under this notion it would be required for the control accuracy of room temperature controllers/thermostats to be declared in the product data sheet including the test standard used. In principle, the same requirement could be made for TRVs if the issue previously mentioned regarding the availability of technology neutral standards and testing infrastructure can be addressed. In principle, similar requirements could be specified for humidistats and room air quality controllers notwithstanding the caveats previously mentioned for these products which possibly renders them more appropriate for future requirements. When considering this option, one should also consider the recommendations to review/update the related standards with more methods and tools to simplify testing and to cover a better range of building applications. For thermostatic valve efficiency and EN 215 compliance and performance information requirements could be considered. An illustration of how such information is already gathered and applied is the voluntary VDMA energy labelling scheme for TRVs[213]. Note that this voluntary thermostatic valve label[214] runs up to class A, however such a valve would only be eligible

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[211] Note – these would only apply to packaged BACS products that are marketed as being intended for used for building automation & control applications

[212] Packaged building energy management system refers to a building energy management controller sold as a single packaged product with the energy management software integrated within it. In practice, these are mostly used in small commercial premises to provide an all-in-one central energy management functionality. In larger buildings it is more common for energy management software (either on the premises or in the cloud) to be provided as a service and the related necessary hardware to be installed on site to collectively provide the energy management functionality.

[213] https://www.tell-online.eu/cms/upload/173_Energy-Labeling-Scheme-for-TRVs.pdf

[214] https://www.tell-online.eu/classification/index.html

for use in an installed BACS of up to EN15232 class C. Thus, there is a case to consider reviewing this topic to try to avoid confusion for end users.

7.1.5.3.2 Generic BACS information requirements for packaged products: Compatibility with BACS systems based on their energy performance class

Under this notion it would be required for the compatibility of packaged BACS products with installed BACS product energy performance classes (A to D) under the EN15232 standard to be reported. This policy concept is analogous to the notion discussed earlier of demonstrating EN 15232 class B or A compatibility with an EU27 benchmark building and in principle if compatibility information requirements were to be introduced in the first Tier of a prospective Ecodesign regulation it would facilitate the setting of minimum compatibility requirements in a future Tier. In principle, the approach would require that a manufacturer demonstrates the energy class compatibility at the functional level (EN 15232) of their product against a benchmark building, for example as defined in Task 3. As discussed previously a transitional method including such a reference building (or buildings) would need to be elaborated for this to be applicable. For example for a sufficiently well-defined reference office building and TBS, such as BC8 in Task3, it can be assessed with an online tool such as 'Gebaude Energie Inspektor222' or a spreadsheet tool[215] from which an EN 15232 class can be attained similar to what has been done for BC8BAT1 in Task 4. Also the eu.bac certified product compliance procedures[216] could be considered as additional required information[217], even when the product itself is not compliant or certified by the instance. In any case the product information should include the function and control levels (0 to 4) of Table 5 of EN 15232-1:2017 for which the packaged BAC product case can be used. When different levels of functionality (e.g. 1 to 4) can be implemented this should be included in the product information in conjunction with documentation of how the highest level can be achieved. When providing this information the manufacturer should be aware that this is an important set of information and evidence to enable a building owner to be able to accurately calculate an EPC by taking benefit of EN 15232 or calculating the Smart Readiness Indicator[218].

7.1.5.3.3 Generic BACS information requirements for packaged products: Internal power consumption

Under this notion it would be required for internal power consumption of packaged BACS products to be reported under their lowest and maximum power states in the product design specification. In principle, it would also be possible to define standard duty cycles for some packaged BACS products that would allow average power demand across the duty cycle to be reported; however, this would probably necessitate additional research and/or standardisation development.

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215 https://hit.sbt.siemens.com/RWD/app.aspx?RC=DE&lang=de&MODULE=InfoCenter&ACTION=ShowGroup&KEY=HIT_IC_Portlet_1084213

216 https://www.eubaccert.eu/

217 https://www.tell-online.eu/classification/index.html

218 https://smartreadinessindicator.eu/

7.1.5.3.4 Generic BACS information requirements for packaged products: Interoperability

Listing of the communication protocols used for technical interoperability (see Task 1). Under this notion it would be required for the technical interoperability capabilities of packaged BACS products to be reported i.e. which standardised communication protocols[219] they can be used with. This could entail setting out all standardised communication protocols and indicating their compatibility with each plus any additional ones not in the list (to allow for innovation). Note, this is important information with a bearing on the service lifetime of the product. In the case that a proprietary communication protocol is used a clear reference to the manufacturer website should be made where all relevant information can be found.

Provision of information used for syntactical interoperability (see Task 1) - under this notion the information should be reported on data formats used for syntactical information[220]. If this is a proprietary or undisclosed data format it should be clearly listed.

Provision of information used for semantic interoperability (see Task 1) - under this notion product specific data (if any) should be reported[221], this is of particular relevance for TBS equipped with BACS. If this is a proprietary or undisclosed data format it should be clearly listed.

Note, with regard to the following text (from the section on *Specific minimum functionality requirements for packaged products: Interoperability)*

"The following additional requirements would apply for internet protocols that rely on WAN, for example packaged BAC products that rely on cloud services:

- An open fallback solution should be provided for a local server installed on the dedicated LAN or VLAN of the building. It should be possible at any time for the owner to enable this solution. This should also prevent planned obsolescence"

It is suggested that when an external server is used the product information should explain this in the product documentation.

7.1.5.3.5 Generic BACS information requirements for packaged products: Lifetime, material content and related information for installers of BACS

This proposal is related to the proposal for 'Lifetime, material content and repair for packaged products' which is extensively discussed before but it requires to report the data minimum service life expectancy (MSLE) or the simplified scoring system that is discussed in that section. Instead of requiring a minimum it could be reduced to an information requirement only, a valuable option to consider because this is a new kind of policy and would require new methods and approaches to be developed.

Additionally, information requirements on hardware repairability could follow the specifications in the new EN 45554 (see Task 1). It could be agreed to simplify this information and in the case of packaged BAC products to focus on a reduced set of

[219] For example MODBUS RCU or TCP

[220] For example: KNX, BACNET, DALI, etc.

[221] It can be for example the MODBUS holding registers for temperature set points of fan coil controllers or the meter reading registers for an electricity meter.

components with known high failure rates, for example: electromechanical relays, back-up batteries and computer memory.

If rare earth materials are used, e.g. in permanent magnet actuators or relays then it could be a requirement to disclose this in the product data sheet.

Note, there are few precedents available and as this topic does not only affect BACS but also a wider range of products it is therefore recommended to consider it for all products to which it applies in a new standard or transitional method, which also relates to the new Mandate M/543 and the ongoing standardization work done in CEN/CLC JTC10 WG3.

7.1.6 Prospective Ecodesign measures for products put into service

This section presents descriptions, rationales and pros and cons of prospective Ecodesign measures applicable to products which are put into service i.e. to installed products. The first set of measures are specific Ecodesign requirements and the latter set are generic Ecodesign requirements.

7.1.6.1 Specific BACS energy performance limits (C, B or A) for installed products

Party responsible for conformity: system integrator/installers.

Self-regulation pathway? No.

*Candidate product*s: either any installed BACS, or installed BACS products differentiated by application.

By far the largest energy savings will accrue from increasing the energy performance of installed BACS products i.e. BACS installed as a product system. Currently class C and even level D BACS (i.e. no BACS) are commonly installed. The amended EPBD makes the use of BACS mandatory for non-residential buildings above 290kW of installed HVAC capacity where technically and economically feasible but this only accounts for ~37% of non-residential building stock floor area and does not concern residences at all. Furthermore, the BACS energy class is not clearly defined so Member States are free to set specifications in a manner that may lead to suboptimal BACS even in the part of the building stock directly addressed by the EPBD requirements. Therefore, if minimum energy performance limits were to be set in line with a given EN15232 energy performance class (or classes) it could access very significant additional savings.

Possible options include setting a minimum Class C (or B) performance level; perhaps differentiated by building type e.g. class C for installed BACS in residences and small non-residential buildings, and class B for larger non-residential buildings. Note, this could also be differentiated by the magnitude of the total installed HVAC capacity e.g. class B for all building with greater than 290kW of installed HVAC capacity and class C for all other buildings.

Imposing energy/environmental performance requirements for installed BACS products is allowed under the Ecodesign Directive and has the potential to produce very large energy savings; however, market surveillance is likely to be different to the situation that applies for packaged BACS products and the obligation to conform would be placed on designers/specifiers/installers. Nonetheless, this is analogous to the situation that already applies to the installers of lifts (under the terms of the Lifts Directive) and has partial commonality with the obligations that apply to installers for the energy labelling for space and water heating.

To support conformity assessment it would be helpful were standardised tools to be made available that designers/installers could use to determine the energy performance class of their products. Some Member States, e.g. Germany, are understood to have already put such tools on line. Market surveillance would then be a matter of verifying that the design/installation complies with the conformity assessment tool, which is not a dissimilar process to verifying that an EPC has been issued correctly. On-site inspections would likely be too much work but could be done for a randomly selected set of sites. For example, this could be based on the dedicated BACS EN 15232 online tool, with a project database, which is already available in Germany[222]. This option could be appropriate for conformity assessment for larger non-residential buildings where the benefits derived from such an assessment would be expected to be cost-effective.

For residential buildings, however, conformity assessment would likely need to be simplified. Options that could be explored in more depth would include adapting Energy Performance Certificate (EPC) tools and/or limiting the scope to just the BACS concerned with space heating control and then adapting the tools used for the packaged energy label for space heating. While it is understood by the authors of this report that some Member State EPC tools already partly account for BACS in part there is no streamlined and automated data provision method. Another issue is that the cycle of issuance of EPCs may not coincide with the installation of BACS in residential buildings. The connection with the packaged energy label for space heating, thus perhaps makes more sense, especially as the amended EPBD requires room/zone controls to be installed when the heat generator is replaced, thus an integrated conformity assessment process could be envisaged to address this holistically. As potentially still some part of the residential stock has class D controls i.e. no automation, it would make sense to set the minimum threshold for existing buildings at class C which should always be cost-effective.

If this policy option is to be considered further it is recommended to examine a subset of functions for each particular class of building. Equally, the cost-benefit rationale as a function of building type and also whether a building is new build or existing, could be assessed in greater detail in a subsequent iteration of this report.

In addition, to be effective this policy measure would need to consider options to ensure proper and extensive training of designers, installers and market surveillance inspectors. Some parts of its implementation would therefore potentially benefit from support from other policy instruments than just Ecodesign e.g. from the training support articles in the EED, EPBD Renovation Wave and digital building logbooks and data for EPCs and SRI, etc.

7.1.6.2 Specific BACS internal power consumption limits for installed products

Party responsible for conformity: system integrator/installers.

Self-regulation pathway? No.

*Candidate product*s: either any installed BACS, or installed BACS products differentiated by application

In principle, it would be possible to set limits on the internal power consumption of installed BACS products. However, this would require knowledge of their current internal power consumption related to their specific functionality in order to assess potential limits of internal power consumption per unit of functionality for each specific BACS system of

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

interest. Presently, little is known about these so in the absent of more data and investigation it seems premature to consider such measures. Nonetheless, this could be reviewed in future iterations of any Ecodesign regulation especially if more data had become available in the meantime with the aid of information requirements for installed products. In principle, this would also rely on the supply of reliable internal power consumption information for packaged products which is currently often lacking, see information requirements. Hence, it is recommended to first consider the introduction of policy on the supply of information for packaged products and to then assess the option of setting limits for installed products at a later stage.

7.1.6.3 Specific BACS minimum functionality requirements for installed products

Party responsible for conformity: system integrator/installers.

Self-regulation pathway? No.

*Candidate product*s: either any installed BACS, or installed BACS differentiated by application.

Explicit policy proposals within this overarching category are presented in the sub-sections below.

7.1.6.3.1 Specific BACS minimum functionality requirements for installed products: BACS measuring and reporting of KPIs at installed product level

In an echo of the proposal for packaged BEMS, minimum functionality requirements could also be imposed on installed BACS products with regard to their ability to register and report key performance indicators. In principle, the minimum requirements could be set to be compatible with BACS class C or B under EN15232, perhaps depending on the application.

Standard EN 15232 does not give a direct list of KPI's. The KPIs chosen could align to a subset of those specified in the eu.bac BACS certification handbook (Part 4) and/or EN 16947-1:2017 on *Energy Performance of Buildings - Building Management System*. Also, none of these cited sources contain KPIs for Demand Response in order to monitor the increased use of renewables, see Annex B for a proposal. Due to the lack of details included in existing standards, it is recommended to develop a transitional method for this.

7.1.6.3.2 Specific BACS minimum functionality requirements for installed products: Lifetime for installed products

The text below puts forward a possible proposal with regard to Ecodesign requirements for BACS lifetime, the rationale behind the proposal and a set of pros (arguments in favour of the proposal) and cons (arguments against it). Note this is very similar to that proposed for packaged BACS products but the principal reason for considering similar requirements for installed products is to address the problem of the software for installed BACS not necessarily being maintained such that the functionality of the product could cease to be operable before any hardware failure occurs. In essence at installation level the configuration software information is added and the wiring is done. It is in particular the software configuration that deserves attention; as explained in Task 3 it are often software dependencies and/or security updates that may limit the lifetime.

Proposal

The following eco-design resource efficiency requirements could be introduced to ensure that installed BACS have sufficient lifetime. Installers of BACS shall be required to:

- use packaged BAC products with lifetime requirements as specified in the previous section on packaged products
- provide project documentation file(see Task 3) that also includes a list of communication protocols used
- provide a training session at commissioning on configuring the proper scheduling and set point management to follow the user needs of a building over its lifetime. This is usually the training for using the user interface[223] or BACS front end for the facility manager or building owner, allowing them, for example, to redefine comfort temperature set points
- provide to the building owner the software configuration file[224] for the installed project to allow for the needs of an upgrade or reconfiguration. This could be needed to review, for example: the screen control logic and/or lighting controls when the indoor lay out is changed, the heat generator optimal start/stop function when a new heater is installed, etc. If the installer does not want to transfer the configuration file copies of the configuration file could be deposited with an escrow service provider. These files and data should also allow for the update of information needed to support EPBD requirements or digital building logbooks to allow for a more precise Energy Performance Certificate (EPC) and Smart Readiness Indicator (SRI). It would be up to the building owner to these keep records after their receipt
- provide or update the list of BAC products or packaged BAC products used.

7.1.6.3.3 Specific BACS minimum functionality requirements for installed products Interoperability

There is a strong rationale for recommending interoperability for installed products, but it may be more advisable to require it under the EPBD than via the Ecodesign Directive. However it should be noted that Articles 14 and 15 of the revised EPBD on heating, cooling (and ventilation) systems with a combined capacity of >290 kW already require to 'allow communication to the TBS and appliances and be interoperable across different types of proprietary technologies, devices and manufacturers'. It would therefore make sense to require this also for smaller installations (<290 kW) and other technical building services than just heating and cooling.

7.1.6.4 Generic BACS information requirements for installed products

Party responsible for conformity: system integrator (designers) /installers.

Self-regulation pathway? No.

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[223] Example of a free open source version is: https://www.cometvisu.org/

[224] For example when a KNX building automation installed BACS this is the *.knxproj file, see: https://support.knx.org/hc/en-us/articles/115003360545-Import-Export#ProjectExport

Candidate products: either any installed BACS, or installed BACS differentiated by application.

Explicit policy proposals within this overarching category are set out in the following sub-sections.

7.1.6.4.1 Generic BACS information requirements for installed products: Information on energy performance

Currently, the large majority of those procuring installed BACS products do not know the energy performance of the product they are procuring because information regarding its performance is not declared, or if a claim is made it is not often supported through conformity to a common standard, such as EN15232. This is a major barrier to the adoption of energy efficient BACS. Furthermore, while the EPBD encourages Member States to set BACS energy performance requirements it is both difficult to specify and to enforce if the conformity of the installed BACS to one of the four classes within EN15232 is not declared. Therefore, were Ecodesign information requirements to be set that oblige the EN15232 energy performance class of the installed BACS product to be declared it would make BACS energy performance visible in the market and greatly facilitate the ability of Member States to set meaningful measures for BACS energy performance under the EPBD.

For this to influence BACS procurement decisions it would need to be incumbent on the BACS designers/specifiers to assess and declare the energy performance class of their design in the tenders they make to clients. For this to be confirmed as being the BACS product that is actually installed then installers would need to certify the energy performance class of the product they have installed. This latter case would operate in an analogous way to how lifts are certified as CE compliant under the Lifts Directive by their installers (although verification of conformity to this is managed by different market surveillance authorities to those that deal with Ecodesign requirements). It is also somewhat analogous to how space heating and water heater energy labels are currently issued by installers.

To support conformity assessment it would be helpful were standardised tools to be made available that designers/installers could use to determine the energy performance class of their products. In Germany, for example, such a tool is already available on line[225]. Market surveillance would then become a matter of verifying that the design/installation complies with the conformity assessment tool based on the supplied project and product data, which is not a dissimilar process to verifying that an EPC has been issued correctly. Also some national EPCs[226] already partly take BACS functions into account. Therefore it is recommended to link the project data input derived from these tools with the product information requirements proposed in this study. For example, Belgium already has a database of products which comply with the information necessary to compute an EPC. This EPBD-related product database[227] already includes some information on BACS functions for ventilation products with its own taxonomy that is used in their EPC

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

[226] https://epbd-ca.eu/wp-content/uploads/2019/06/CA-EPBD-CCT1-Technical-Elements-2018.pdf

[227] http://www.epbd.be/index.cfm?n01=data&n02=recognized_data

calculation too. E.g. for ventilation this includes whether the summer by-pass function (y/n) and automatic control function (y/n) are present.

Note, in principle this type of information requirement could also be made contingent on the application e.g. for non-residential buildings above a certain size.

In addition to the information regarding the EN15232 energy class, in theory, requirements could also be added with regard to the declaration of the internal power consumption of the installed BACS product. However, this may be better suited to future policy requirements once more work has been done to determine viability, and on the provision that the internal power consumption of packaged BACS products is already declared (see information requirements for packaged BACS products section).

7.1.6.4.2 Generic BACS information requirements for installed products: Information on demand response (DR)

In principle it would be beneficial were the DR capability of the installed BACS product to be declared. However, before this could be considered as an Ecodesign information requirement there is a need to revise the BACS standards, in particular EN 15232, to better reflect DR capability. The current provisions within EN15232 do not adequately reflect how smart grids are likely to work as many will use time of day tariffs to level out demand, rather than expecting demand side management signals from the utility company, which is a large building solution. If this issue is resolved then alignment with EN15232 DR specifications could be used in future information requirements. Note, a priori it appears that class A functionality under EN15232 is a de facto minimum requirement to be able to deliver DR and therefore in theory a revised EN15232 could introduce a new class A-DR which indicates class A capability combined with DR capability. This, suggestion also has relevance to the prospective implementation of the Smart Readiness Indicator, under the auspices of the EPBD.

7.1.6.4.3 Generic BACS information requirements for installed products: Information on interoperability and other factors

In addition to the information mentioned above, in theory, requirements could also be added with regard to the declaration of:

- interoperability i.e. which operating systems may be used against a standardised list
- commissioning, operation and maintenance characteristics were put forward as important factors (see Task 3).

The operation and maintenance manuals (O&M) for BACS are an important aspect of the deliverables presented to owners/tenants and it is proposed this documentation should contain at least the following information:

- functional description
- list of points or nodes
- data sheets for the control products.

In addition, generic information requirements could be set to require the provision of information on commissioning, which would include guidance on operation and maintenance. Note, when properly conducted, commissioning ensures that O&M documentation exists and that operators have been trained as part of any proper handover. Commissioning certification protocols, such as those provided through the

COPILOT[228] certification initiative could be used for this purpose. For buildings that use the BACNET protocol, open standard templates for project documentation are provided by STLB-BAU[229]. For BACNET, for example, the AMEV[230] recommendation and attestation was elaborated to support building owners and planners of public buildings. In general, most BACS software generates documentation and project files and it is important that the building owner should receive and properly maintain these over the lifetime of the building.

7.1.6.4.4 Generic BACS information requirements for installed products: Providing a design configuration file needed for fine tuning and further updates

See Task 3 section 3.6.9 on 'continuous commissioning of BACS', policy proposals could be sourced from this section but it is unclear whether or not this fits within the policy scope of this study.

Policy suggestions regarding O&M information and commissioning could be sourced from the methods suggested in Task 3 but may be better suited to other types of policy instruments than Ecodesign regulations, although were an information requirement implemented it could support digital building logbooks, the SRI and EPCs within the auspices of the EPBD.

7.1.7 Prospective and existing energy labelling measures

This section presents policy options with regard to energy labelling.

7.1.7.1 Updating the energy label for space heaters, water heaters and solid fuel boilers

The energy label for space heater, water heaters and solid fuel boilers i.e EU Regulations 811/2013, 812/2013 and 2015/1187 are under review in a parallel Ecodesign preparatory study[231]. It could be an option to include more BACS functions within these regulations. In fact, this is already under discussion but efforts could be made to align the approach adopted with the product information requirements proposed in this study. Herein an important aspect would be align the functions contained in EN 15232 with the updated Regulation or vice versa. For all stakeholders it is important to align this policy to avoid confusion on the market and double counting of projected energy savings. Therefore it is recommended to synchronize as much as possible these updates with the proposed BACS policy in this report.

7.1.7.2 Labelling of the BACS energy performance for installed products

Parties responsible for conformity: system integrator/installers/building owner.

Self-regulation pathway? No.

[228] https://copilot-building.com/

[229] https://www.gaeb.de/en/service/downloads/stlb-bau/

[230] https://www.amev-online.de/AMEVInhalt/Planen/Gebaeudeautomation/BACnet%202017/

[231] https://www.ecoboiler-review.eu/

Candidate products: either any installed BACS, or installed BACS differentiated by application.

As discussed in section 7.1.4.7 the EN15232 energy performance class of installed BACS products could be declared. If this happens it would also be just as viable to require the installer to issue an energy label in the same way as is done for space heating systems. Ostensibly, the same viability and market surveillance issues would apply.

Note that if the demand response specifications within EN15232 were to be amended and a DR capability to be explicitly acknowledged within its performance classifications then this could also be conveyed via an energy label.

In principle, this BACS standard EN 15232 is part of the set of EPBD set of standards and therefore the final benefits could also be taken into account in the Energy Performance Certificate (EPC) of the building and/or the new Smart Readiness Indicator[232]. Therefore this EN 15232 BACS class (A, B, C, D) including the related detailed information proposals included in this study could form part an obligatory documentation requirement to serve an EPC, SRI and/or BACS digital data specification to support commissioning. For a building it might be a more consistent policy but it requires for existing buildings that a digital renovation logbook is available[233], therefore this approach could be valuable part of the new Renovation Wave strategy. A benefit of the proposed packaged product information requirements previous discussed is that the required information for the EPC and SRI would be more easily available and the cost for such an assessment and providing the incentive to consider on upgraded BACS will be reduced. An existing building will generally undergo many TBS/BACS updates or repairs over its life and there are usually many different installers and manufacturer products involved, therefore the provision of digital commissioning data within a common data organisational structure can bring all this information together and maximize the benefits for the owner. Such a building information system would also avoid double counting benefits that could result from individual labels for parts of a TBS. The SRI has the benefit that it can take other aspects into account than purely energy savings which is also valuable building information.

Note that the establishment of digital building information systems is still a prospective concept in most cases that needs further foundational work.

When considering such a policy the roles and responsibilities of all actors involved would need to be elaborated: building owner, installers involved and packaged product suppliers.

7.1.8 Policy measures requiring additional development work

Some of the measures described above could potentially be better placed in this section if it is deemed that they are not currently viable but might be in the future.

As stated in the related discussion several of the policy measures put forward in the previous sections would require more development work to be ready to be implemented and/or demonstrate their viability. This section provides a summary list of these policy measures as an easy aide memoire.

[232] https://smartreadinessindicator.eu/

[233] https://ec.europa.eu/energy/sites/ener/files/renovation_wave_strategy_-_annex.pdf

7.1.8.1 Specific minimum performance limits for packaged products: Accuracy

Within this, it is recommended that TRVs be considered within the scope of a future investigation, while the issue of technology neutral standardisation could be addressed in an intermediate standardisation review.

Similarly, there may well be a justification for the development of Ecodesign control accuracy requirements for humidistats and room air quality controllers (including for example those based on the use of integral CO_2 sensors); however, neither were investigated within this study and hence would have to be considered in future work.

7.1.8.2 Specific minimum performance limits for packaged products: Internal power consumption

This would require data collection (potentially supported by a preceding information requirement) before it could be investigated.

7.1.8.3 Specific minimum functionality requirements for packaged products: BACS measuring and reporting of KPIs by packaged building energy management systems

Due to the lack of details included in existing standards, it is recommended to develop a transitional method for this.

7.1.8.4 Specific minimum functionality requirements for packaged products: Demonstrate EN 15232 class B or A compatibility with an EU27 benchmark building

A complicating factor is that implementation would require a means of determining whether a packaged BACS product is compatible with class B or A installed BACS products or not. In principle, such an approach would require that a manufacturer demonstrates the class B/A compatibility of their products at the functional level (EN 15232) against a benchmark building (or buildings), for example the BC8 as defined in Task 3 (i.e. via simulation or some more simplified online tool222). A transitional method including those reference buildings would need to be elaborated for this proposal to be implementable.

7.1.8.5 Specific minimum functionality requirements for packaged products: Lifetime, material content and repair for packaged products

The concept of 'spare parts' should be further elaborated and defined for practical implementation. Note that this is a relatively new and challenging policy area which would benefit from a further study and additional preparatory work.

7.1.8.6 Specific minimum functionality requirements for packaged products: Interoperability

Implementation should be timed to ensure there is sufficient time for the market to adapt to respect these requirements and the proposal will need further investigation and stakeholder consultation before it can be converted into concrete policy measures.

7.1.8.7 Specific minimum functionality requirements for packaged products: Minimum functionality requirements for TBS-related products with BAC functionality that claim Smart Grid capability

The topic could be investigated further in future work. It is also recommended to update EN 15232 to include such aspects.

7.1.8.8 Specific BACS energy performance limits (C, B or A) for installed products

If this policy option is to be considered further it is recommended to examine a subset of functions for each particular class of building. Equally, the cost-benefit rationale as a function of building type and also whether a building is new build or existing, could be assessed in greater detail in a subsequent preparatory work.

7.1.8.9 Generic BACS information requirements for packaged products: Information on accuracy

Under this notion it would be required for the control accuracy of room temperature controllers/thermostats to be declared in the product data sheet including the test standard used. In principle, a requirement information on the control accuracy of TRVs could be made if the issue previously mentioned regarding the availability of technology neutral standards and testing infrastructure can be addressed. In principle, similar requirements could be specified for humidistats and room air quality controllers notwithstanding the caveats previously mentioned for these products (i.e. possibly more appropriate for future requirements).

When considering this option, one should also consider the recommendations to review/update the related standards with more methods and tools to simplify testing and to cover a better range of building applications.

7.1.8.10 Additional potential future work

In addition to the issues raised an investigation of BACS and related packaged BAC product solutions that can help to prevent simultaneous heating and cooling would seem merited. For example, the potential for the provision of alarms within room thermostat/temperature controllers for heating and cooling interlocks.

7.2 Scenarios

Subtask 7.2 establishes scenarios according to the policy measures described in subtask 7.1. To this end, the analyses on the previous tasks have been extended to the defined scenarios in comparison with the Business-as-Usual (BAU) scenario and the different policy scenarios. Note, no explicit Best Available Technology (BAT) scenario is conducted but in this study it is in essence an improved BACS functionality, or the class A scenario (see section 7.2.1).

7.2.1 Scenarios overview

Different scenarios have been drawn up to illustrate quantitatively the impacts that can be achieved at the EU level by the year 2045 from the adoption of prospective Ecodesign policy actions when compared to the Business-as-Usual scenario. Taking into account the time needed to elaborate and implement any regulation, the regulatory provisions are assumed to enter into force in 2024 for each policy scenario.

The reference case and main technical improvement option scenarios based on the findings of Task 6 are defined as follows:

- **BAU scenario**: this scenario reflects the expected developments were there to be no new policy measures adopted beyond those that have already been adopted (e.g. under the EPBD and Ecodesign and labelling requirements for specific product types used in technical building systems)

- **Accuracy gain of 0.5˚C**: as the BAU except that the control accuracy of room temperature controllers improves by 0.5°C from the year 2024 onward
- **Accuracy gain of 1.0˚C**: as the BAU except that the control accuracy of room temperature controllers improves by 1.0°C from the year 2024 onward
- **Class C**: as the BAU except from the year 2024, all new installed BACS must attain at least an energy performance of class C
- **Class B**: as the BAU except from the year 2024, all new installed BACS must attain at least an energy performance of class B
- **Class A**: as the BAU except from the year 2024, all new installed BACS must attain at least an energy performance of class A
- **Declaration of BACS class**: as the BAU except from the year 2024, all new installed BACS must have their energy performance class declared.

7.2.1.1 Scenario assumptions

This section presents the assumptions which underpin the impact modelling applied to these scenarios. First general assumptions, which apply to all the scenarios are reported and then the scenario-specific assumptions.

7.2.1.1.1General assumptions

The total surface area of building floor area addressed by new BACS is the same in each of the scenarios considered and aligns with that reported for Table 2-4 in the Task 2 report. The floor area addressed is distinguished between new build, major renovation and retrofit cases and is subdivided between the following building types:

- Single family homes
- Multi-family housing
- Offices
- Retail buildings
- Other non-residential buildings.

The floor area addressed each year varies over time in a manner that is consistent with the evolution of the building stock floor areas projected in the EPBD Impact Assessment (see Table 2-8 in Task 2), with the exception of the part of non-residential buildings with a combined HVAC capacity of >290 kW that is fitted with class B BACS between 2021 and 2025 in line with the EPBD requirement. These assumptions are conservative and relatively robust for new build floor area (which historically has varied relatively little when smoothed over the last decade), but are probably overly conservative for the retrofit and major renovation proportions of the market. Renovation rates should increase above recent historic levels, especially in response to the Renovation Wave policy initiative, but this is addressed in a sensitivity scenario in section 7.4. Note, even under the BAU scenario retrofit rates are already assumed to increase by 2.5% per year which results in the annual magnitude of retrofit floor area increasing by 68% by 2045 compared to 2021.

BACS investment costs are assumed to align with those reported in Task 2 (Table 2-10) for class C and class A BACS and to scale linearly as a function of the difference in average BAC factor to other energy performance levels.

7.2.1.1.2 Assumptions specific to each scenario

For the BAU scenario it is assumed that BACS placed on the EU market initially have the same level of energy performance as new BACS sold in 2020; however, the energy performance of new BACS improves over time in response to the anticipated impact of Member State implementation of the measures in the revised EPBD. For these the following key assumptions are made for the BAU scenario:

- class B installed BACS are installed in the entire part of the existing non-residential building stock which has >290kW of installed HVAC capacity by 2025 (in line with the common interpretation of the revised EPBD requirements)[234]
- all new buildings have installed BACS that are at least of class C energy performance - a modest proportion are assumed to be at classes above this (in line with the data on the current market share by energy performance class[235])
- most other BACS installed under the BAU are assumed to be class C while the remaining proportion of the market does not fully attain class C
- the average efficiency of BACS in existing buildings is as reported in Annex A of the Task 2 report.

For the higher accuracy of temperature controller scenarios (i.e. **Accuracy gain of 0.5˚C** and **Accuracy gain of 1.0˚C** scenarios) the products placed on the market are assumed to have the same energy performance as in the BAU scenario except that the control accuracy of room temperature controllers improves by either 0.5°C or 1.0°C from the year 2024 onward. For these it is assumed that the relative energy savings in heating and cooling loads in all buildings fitted with higher accuracy room temperature controllers are the same as those reported in Task 4 for the BC1BAT05 and BC1BAT10 base cases respectively (section 4.3.3 Tables 43 and Table 44). In the case of the **Accuracy gain of 0.5˚C** and **Accuracy gain of 1.0˚C** scenarios the incremental costs per unit area are assumed to be the same as are reported in Task 4 and 6 for the BC1BAT05 and BC1BAT10 base cases respectively.

For the **Class C**, **Class B** and **Class A** scenarios it is assumed that everything is identical to the BAU scenario except that from 2024 onward all new installed BACS must attain a minimum performance of class C, B or A respectively.

For the **Declaration of BACS class** scenario it is assumed that the provision of information on the energy performance of BACS drives up demand for higher performance classes and reduces demand for lower performance classes. This is a compound effect with the relative rate of increase in demand (or reduction in demand) remaining constant over time (until saturation is reached). The distribution of sales by class at the start of the scenario matches that in the BAU but begins to diverge from the moment the policy comes into effect. The divergence is such that the provision of the information on the BACS energy performance class accelerates the demand to procure higher efficiency classes than would have been the case without this information, and

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234 Note, strictly speaking these requirements are “where technically and economically feasible” so it is possible that for some proportion of the buildings with >290kW of installed HVAC capacity this would not be the case; however, this is not assumed in the BAU scenario

235 See data in: *The impact of the revision of the EPBD on energy savings from the use of building automation and controls*, https://eubac.org/wp-content/uploads/2021/03/EPBD_impacts_from_building_automation_controls.pdf

equally supresses procurement of lower efficiency classes. It should be noted determining the impact of the mandatory provision of information is necessarily more speculative than the case where performance limits are imposed, nonetheless, the estimated magnitude of the effect is broadly in line with those seen for other end-uses where such information has been made available.

7.2.2 Approach

For the purpose of producing the quantified scenario impact analyses under subtask 7.2, an Excel based stock-model was developed for the BACS product group. The structure of the model is shown in Figure 7-2.

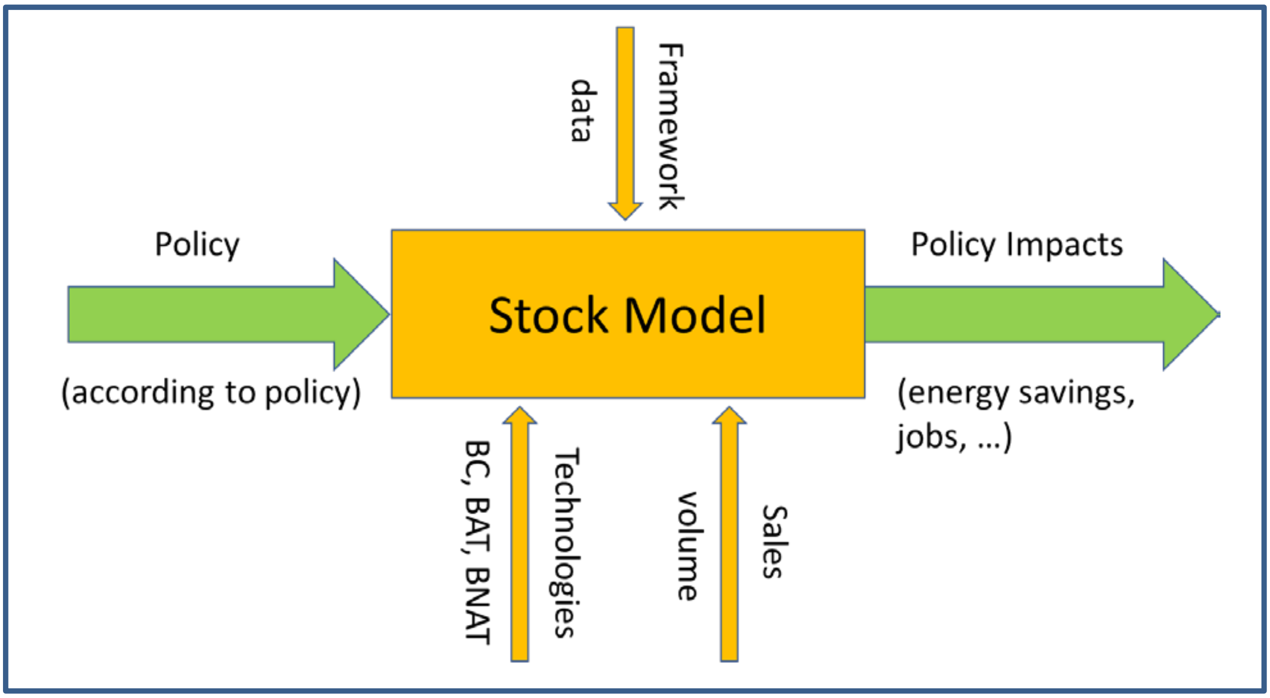

Figure 7-2: Simplified overview of the model

With:

- Technologies and policies: an overview of the main data for each Base Case according to the level of technology considered was provided in Table 7-7.
- GHG emissions factors from the consumption of electricity (Table 7-7-2): based on PRIMES[236]
- Energy prices (Table 7-7-3): based on the values used in Table 2-11 in Task 2 report and projected in line with the EPBD Impact Assessment[237]

236 reference scenario for the EU electricity mix in EU

237 Ex-ante evaluation and assessment of policy options for the EPBD, Final report for EC DG-ENER), which were also used in the Smart Readiness Indicator study (https://smartreadinessindicator.eu/)

- Employment rates per unit revenue generated (Table 7-7-4) based on the values used in the Smart Readiness Indicator study[238] (which were themselves derived from post processing information from numerous product groups in the Ecodesign Impact Accounting studies)[239]

Note, the values in Table 7-7-2 do not match to those referenced in the Task 5 report because the latter take their input from the MEErP EcoReport 2014 tool. The use of PRIMES data for the impact assessment is consistent with practice in other recent Ecodesign preparatory studies and is done to reflect the evolving knowledge about the generation fuel mix and GHG emission factors, noting that the EcoReport tool is not updated as frequently as PRIMES.

Table 7-7-2: GHG emissions related to electricity

Parameter	Scenario	Unit	2020	2025	2030	2035	2040	2045
GHG Emission	Medium	[kgCO2eq/kWh]	0.38	0.36	0.34	0.32	0.30	0.28

Table 7-7-3: Energy prices

Parameter[240]	Scenario	Unit	Value
Residential electricity price	Medium	[€cents/kWh]	20.50
Residential thermal energy price	Medium	[€cents/kWh]	6.40
Non-residential electricity price	Medium	[€cents/kWh]	11.04
Non-residential thermal energy price	Medium	[€/GJ]	8.334

Table 7-7-4: Employment created per unit revenue

Variable name and unit	Value	Source
Manufacturing jobs direct [full time equ./€billion]	20007	Based on SRI study analysis
Installation jobs direct [full time equ./€billion]	22325	Based on SRI study analysis

The model is a simplified stock model, wherein:

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238 https://smartreadinessindicator.eu/

239 https://ec.europa.eu/energy/sites/ener/files/documents/eia_ii_-_overview_report_2016_rev20170314.pdf

240 based on the values used in the Impact Assessment of the Energy Performance in Buildings Directive (ECOFYS (2016) *Ex-ante evaluation and assessment of policy options for the EPBD*, Final report for EC DG-ENER), which were also used in the Smart Readiness Indicator study (https://smartreadinessindicator.eu/)

Equation 1

$$stock_{BC_i,y} = \sum_{j=y-lifetime_i+1}^{y} sales_{BC_i,j}$$

Equation 2

$$stock_{BACS,y} = \sum_{i=1}^{7} stock_{BC_i,y}$$

Where:

- Y = year
- lifetime = lifetime of the BC
- BC = Base Case
- i = index of the BC

However, as the functional unit is the floor area addressed by BACS and policy measures would only apply to newly sold BACS it is sufficient to model the stock of BACS installed from 2021 onward by considering the surface area of building stock affected in each years sales. The floor area assumptions align with those presented in Task 2 Tables 2-2, 2-4 and 2-8 which are consistent with the assumptions used in the EPBD Impact Assessment[241] and the Smart Readiness Indicator studies[242]. The installed price of BACS per unit floor area as a function of their energy performance is aligned with the values presented in Table 2-10 for class C and A installed BACS. The installed price of BACS with other energy performance values is derived by interpolation. In the case of the two higher accuracy scenarios (see 7.2.3) the price increment for higher accuracy room temperature controllers is aligned with the values reported in Tasks 4 to 6.

Due to the reasonably long technical lifetime of the products considered (around 15 years on average and longer in a sensitivity scenario), it is important to run the model and to analyse the results over a long period. Since policy options discussed in this task will address the sales market (new products) and not the stock, the effect of such new policy options will not be perceptible from the first year the policy measure is assumed to come into effect and thus requires the scenario analysis to cover the time period of 2019-2045. Graphical results are reported across this whole time period but summary results are reported for 2040.

7.2.3 Environmental impacts

Due to the nature of the functional unit and the difficulty in characterising BACS in unit quantities which can be used to assess lifecycle impacts outside of the use phase, the environmental impacts considered in this section are confined to the use phase. Nonetheless, the findings presented in Task 6 show that in general this will dominate the overall environmental impacts of BACS.

Figure 7-3 and Table 7-7-5 show the impact the different BACS scenarios have on the final energy consumption of TBS in the part of the EU building stock that is addressed by

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241 ECOFYS (2016) *Ex-ante evaluation and assessment of policy options for the EPBD*, Final report for EC DG-ENER

242 https://smartreadinessindicator.eu/

BACS sales over the course of the scenarios i.e. from 2021 to 2045. The results show that even though the BAU already assumes significant improvement in TBS energy performance due to the transposition of the BACS related policy measures in the revised EPBD into member state building energy performance legislation, that significant additional savings can be attained by the policy scenarios considered. The class C installed BACS scenario has the lowest impact but even this (which in many regards is a backstop measure to the EPBD provisions) is projected to result in annual final energy consumption savings of 25 TWh final energy by 2040. In order of increasing magnitude the annual final energy savings due to the other policy measure scenarios in 2040 are:

- 42 TWh (Declaration of BACS class scenario)
- 66 TWh (Accuracy gain of 0.5˚C scenario)
- 108 TWh (Accuracy gain of 1.0˚C scenario)
- 181 TWh (Class B scenario)
- 267 TWh (Class A scenario).

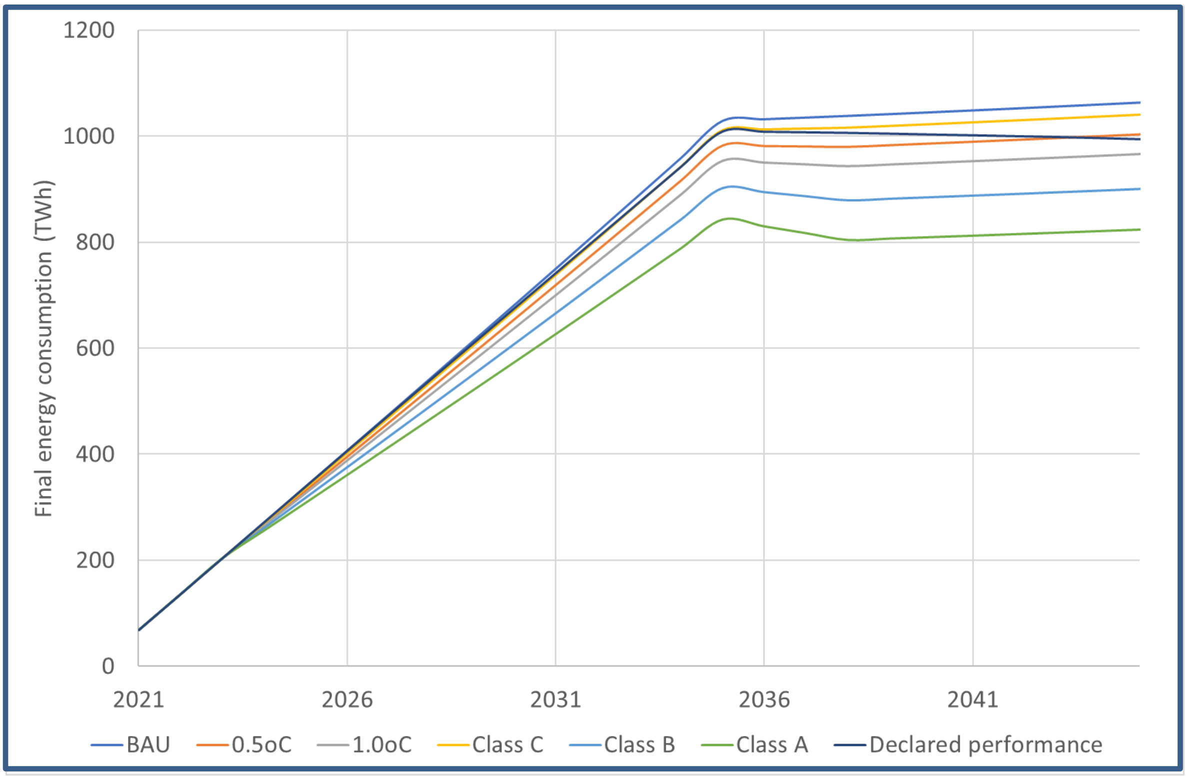

Figure 7-3: Final energy consumption for TBS operated by BACS sold from 2021 in the EU-27

Table 7-7-5: Final energy consumption in TWh/year for TBS operated by BACS sold from 2021 in the EU-27

Final energy consumption (TWh/year)						
Scenario	**2021**	**2025**	**2030**	**2035**	**2040**	**2045**
BAU	67	338	681	1029	1383	1744
0.5oC	67	331	654	982	1316	1657
1.0oC	67	326	637	953	1275	1602
Class C	67	335	670	1011	1357	1710
Class B	67	317	607	902	1202	1508
Class A	67	308	573	842	1116	1396
Declared perfoı	67	338	674	1009	1341	1668
Absolute savings compared to the BAU						
	2021	**2025**	**2030**	**2035**	**2040**	**2045**
0.5oC	0	8	27	46	66	87
1.0oC	0	12	44	76	108	141
Class C	0	3	10	18	25	33
Class B	0	21	73	126	181	236
Class A	0	31	108	187	267	348
Declared perfoı	0	0	6	20	42	75
Savings relative to the BAU						
0.5oC	0.0%	2.3%	3.9%	4.5%	4.8%	5.0%
1.0oC	0.0%	3.7%	6.4%	7.3%	7.8%	8.1%
Class C	0.0%	0.9%	1.5%	1.7%	1.8%	1.9%
Class B	0.0%	6.1%	10.8%	12.3%	13.1%	13.5%
Class A	0.0%	9.1%	15.9%	18.1%	19.3%	20.0%
Declared perfoı	0.0%	0.0%	0.9%	1.9%	3.0%	4.3%

Figure 7-4 and Table 7-7-6 present the GHG emissions from energy consumed by TBS in the buildings addressed by the BACS sold under each of the scenarios. The values increase over time due to the increasing proportion of the building stock which is addressed by BACS sold under each of these scenarios. Nonetheless, these emissions take account of the progressive decarbonisation of the energy mix expected over the period of the scenarios.

Again, the class C installed BACS scenario has the lowest impact and is projected to result in annual reductions in CO_2 emissions of 8 Mt by 2040. In order of increasing magnitude the annual savings in CO_2 emissions due to the other policy measure scenarios in 2040 are:

- 13 Mt (Declaration of BACS class scenario)
- 20 Mt (Accuracy gain of 0.5˚C scenario)
- 33 Mt (Accuracy gain of 1.0˚C scenario)
- 55 Mt (Class B scenario)
- 81 Mt (Class A scenario).

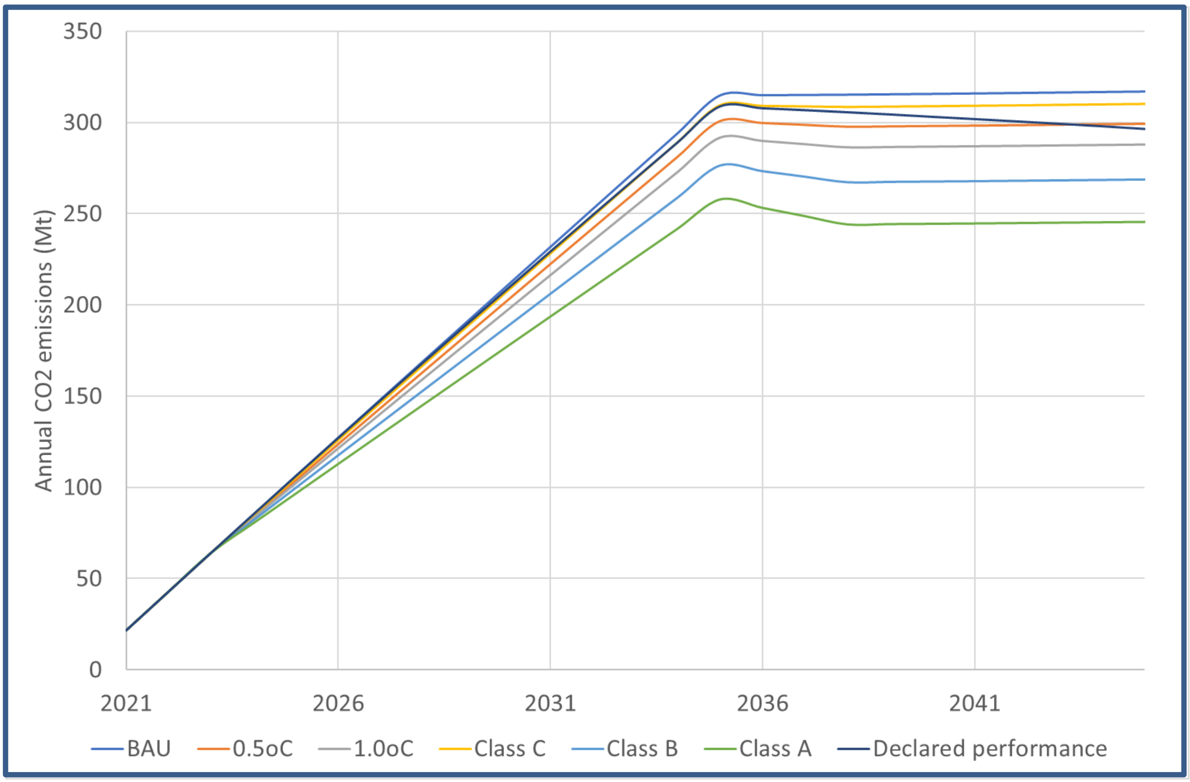

Figure 7-4: GHG emissions in Mt CO2eq/year from TBS operated by BACS sold from 2021 onward

Table 7-7-6: GHG emissions in Mt CO2eq/year from TBS operated by BACS sold from 2021 onward

CO2 emissions (Mt/year)						
Scenario	**2021**	**2025**	**2030**	**2035**	**2040**	**2045**
BAU	21	106	211	315	418	520
0.5oC	21	104	203	301	398	494
1.0oC	21	102	197	292	385	478
Class C	21	105	208	310	410	510
Class B	21	100	188	276	363	450
Class A	21	97	178	258	338	417
Declared perfo	21	106	209	309	405	498
Absolute savings compared to the BAU						
0.5oC	0	2	8	14	20	26
1.0oC	0	4	14	23	33	42
Class C	0	1	3	5	8	10
Class B	0	7	23	39	55	70
Class A	0	10	33	57	81	104
Declared perfo	0	0	2	6	13	22
Savings relative to the BAU						
0.5oC	0.0%	2.3%	3.9%	4.5%	4.8%	5.0%
1.0oC	0.0%	3.7%	6.4%	7.3%	7.8%	8.1%
Class C	0.0%	0.9%	1.5%	1.7%	1.8%	1.9%
Class B	0.0%	6.1%	10.8%	12.3%	13.1%	13.5%
Class A	0.0%	9.1%	15.9%	18.1%	19.3%	20.0%
Declared perfo	0.0%	0.0%	0.9%	1.9%	3.0%	4.3%

7.3 Impact analysis - industry and consumers

7.3.1 Impacts on consumers and investors

Figure 7-1 and Table 7-7.3-1 show the cumulative total costs incurred by the investor under the different scenarios. These include all costs except maintenance. The total cumulative costs increase over time under all scenarios as more building stock floor area is addressed by new BACS sales.

In order of increasing magnitude the relative increase in total BACS costs incurred by the investor above the BAU costs in 2040 are:

- 2.7% (Accuracy gain of 0.5˚C scenario)
- 4.5% (Class C scenario)
- 10.1% (Declared performance scenario)
- 23.6% (Accuracy gain of 1.0˚C scenario)
- 36.0% (Class B scenario)
- 89.0% (Class A scenario).

It is important to appreciate that under the BAU case these investments cover BACS for the control of TBS and related services and are providing energy saving benefits. As these BACS fail they are replaced and additional investment is incurred, which is captured in the reported values.

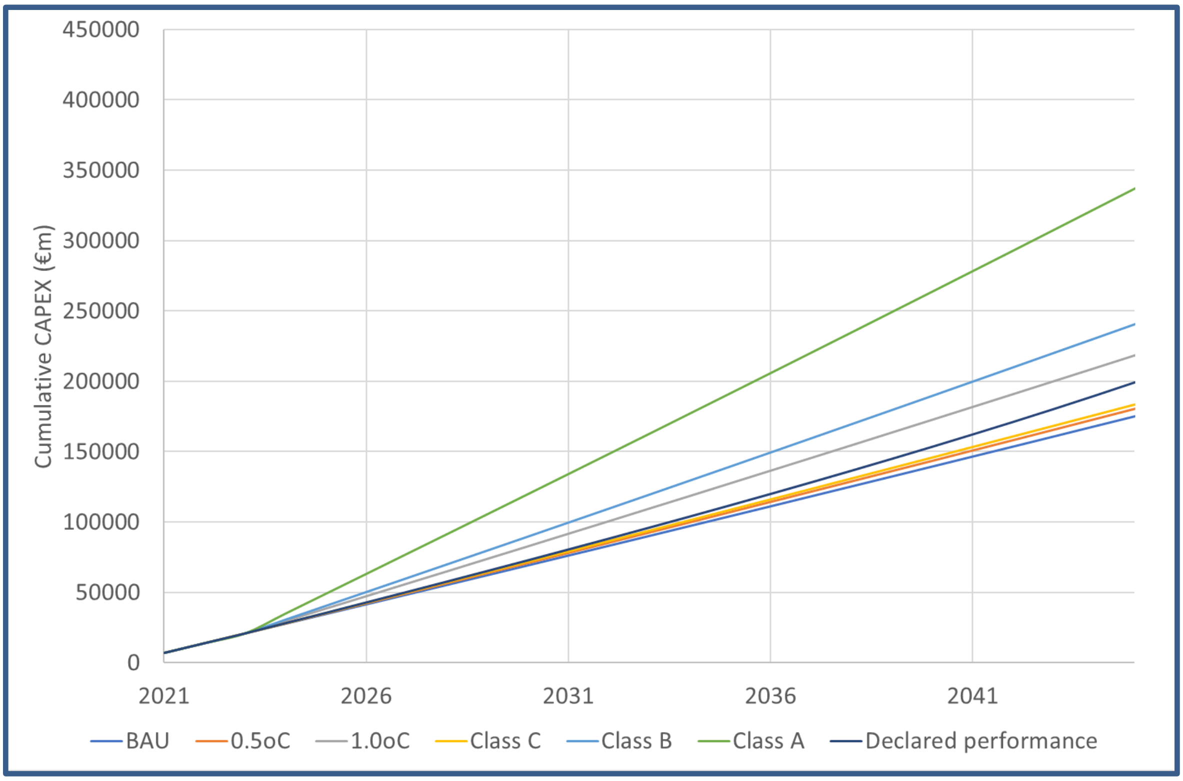

Figure 7-1: Cumulative BACS investment costs in €m (EU-27 BACS stock post 2020)

Table 7-7.3-1: Cumulative BACS investment costs in €m (EU-27 BACS stock post 2020)

Cumulative investment costs (€m)						
Scenario	**2021**	**2025**	**2030**	**2035**	**2040**	**2045**
BAU	6930	34602	69260	104237	139557	175226
0.5oC	6930	35043	70810	106908	143364	180184
1.0oC	6930	38422	82691	127390	172556	218195
Class C	6930	35329	71818	108653	145861	183448
Class B	6930	40416	89698	139462	189745	240560
Class A	6930	48992	119836	191389	263707	336806
Declared perfoı	6930	35465	72868	111944	153593	199293
Absolute incremental costs compared to the BAU (€m)						
	2021	**2025**	**2030**	**2035**	**2040**	**2045**
0.5oC	0	441	1550	2672	3808	4958
1.0oC	0	3820	13430	23154	32999	42969
Class C	0	726	2558	4416	6304	8222
Class B	0	5814	20438	35225	50189	65333
Class A	0	14389	50576	87153	124150	161580
Declared perfoı	0	863	3607	7707	14036	24066
Increase in investment costs relative to the BAU (%)						
0.5oC	0.0%	1.3%	2.2%	2.6%	2.7%	2.8%
1.0oC	0.0%	11.0%	19.4%	22.2%	23.6%	24.5%
Class C	0.0%	2.1%	3.7%	4.2%	4.5%	4.7%
Class B	0.0%	16.8%	29.5%	33.8%	36.0%	37.3%
Class A	0.0%	41.6%	73.0%	83.6%	89.0%	92.2%
Declared perfoı	0.0%	2.5%	5.2%	7.4%	10.1%	13.7%

The energy costs of TBS addressed by BACS installed from 2021 onward are presented in Figure 7-2 and Table 7-7.3-2. In order of increasing magnitude the annual savings in energy expenditure due to the other policy measure scenarios in 2040 are:

- €1950m (2.0%) (Class C scenario)
- €2718m 2.8% (Declared performance scenario)
- €4988m (5.1%) (Accuracy gain of 0.5˚C scenario)
- €8059m (8.2%) (Accuracy gain of 1.0˚C scenario)
- €12265m (12.5%) (Class B scenario)
- €17949m (18.3%) (Class A scenario).

Again the Class A and Class B cases produce the greatest and next greatest savings.

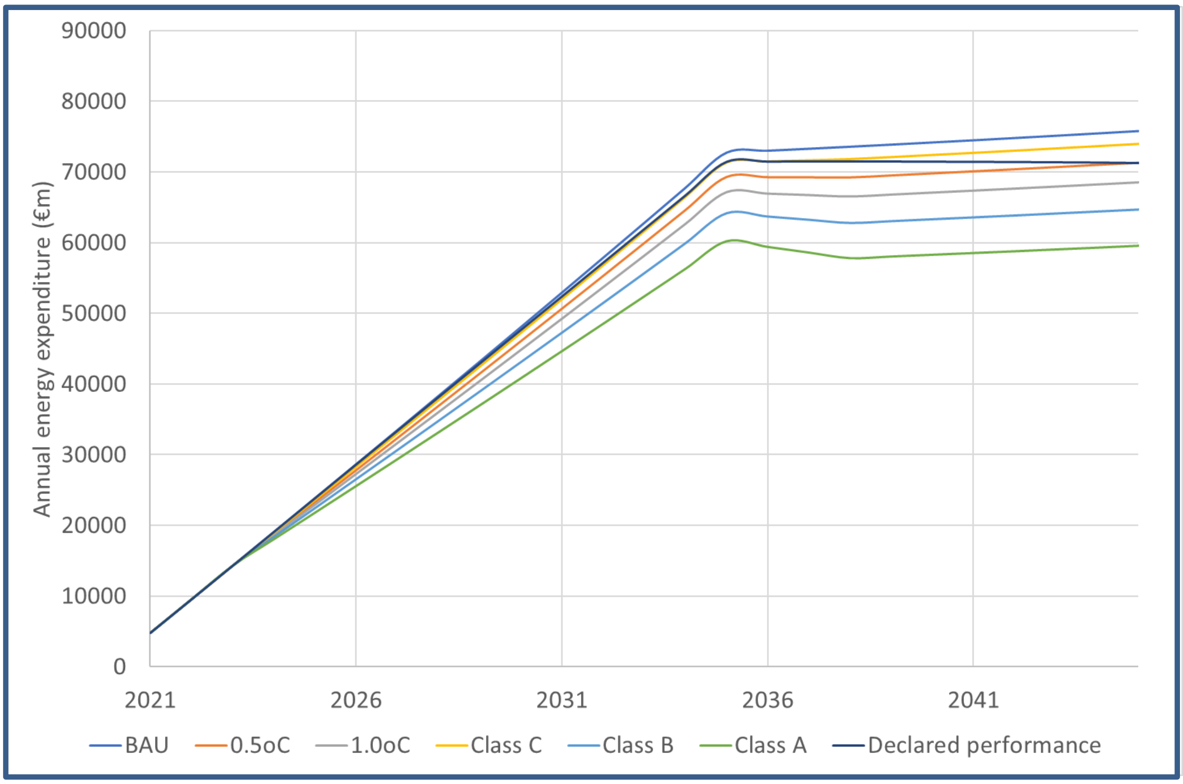

Figure 7-2: Energy costs in €m/year for EU-27 TBS addressed by BACS installed post 2020

Table 7-7.3-2: Energy costs in €m/year for EU-27 TBS addressed by BACS installed post 2020

Energy expenditure (€m/year)						
Scenario	**2021**	**2025**	**2030**	**2035**	**2040**	**2045**
BAU	4738	23816	48022	72735	97992	123811
0.5oC	4738	23247	46013	69254	93004	117280
1.0oC	4738	22896	44775	67110	89934	113263
Class C	4738	23594	47238	71375	96042	121255
Class B	4738	22415	43076	64170	85727	107764
Class A	4738	21765	40782	60199	80043	100329
Declared perfoı	4738	23810	47624	71449	95275	118898
Absolute savings compared to the BAU (€m/year)						
0.5oC	0	569	2009	3482	4988	6531
1.0oC	0	919	3247	5626	8059	10548
Class C	0	222	784	1360	1950	2555
Class B	0	1401	4946	8566	12265	16047
Class A	0	2051	7240	12536	17949	23482
Declared perfoı	0	6	398	1287	2718	4913
Savings relative to the BAU						
0.5oC	0.0%	2.4%	4.2%	4.8%	5.1%	5.3%
1.0oC	0.0%	3.9%	6.8%	7.7%	8.2%	8.5%
Class C	0.0%	0.9%	1.6%	1.9%	2.0%	2.1%
Class B	0.0%	5.9%	10.3%	11.8%	12.5%	13.0%
Class A	0.0%	8.6%	15.1%	17.2%	18.3%	19.0%
Declared perfoı	0.0%	0.0%	0.8%	1.8%	2.8%	4.0%

The average cost of BACS (i.e. investment cost paid by the investor including product and installation costs) per unit area of building floor area they are installed in is shown in
Figure 7-3.

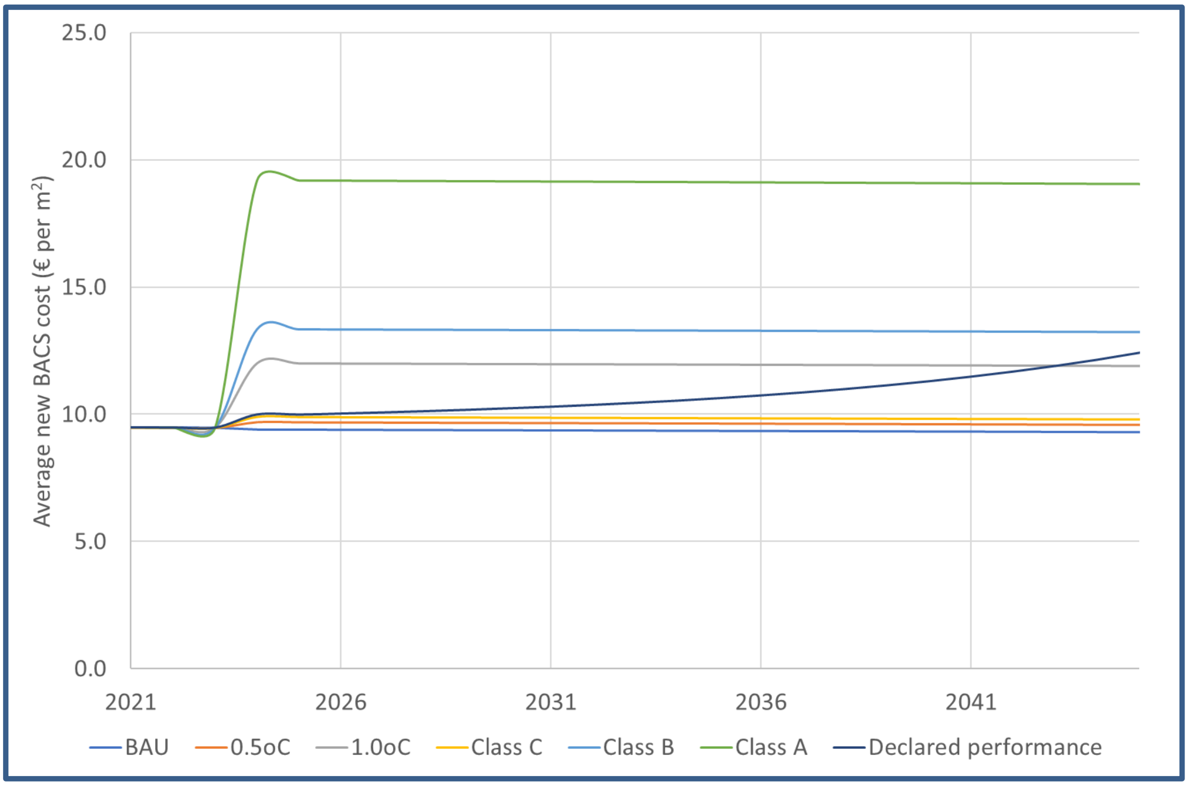

Figure 7-3: Average EU-27 BACS cost (€/m2)

7.3.2 Impacts on business

In this sub-section, the impact of the different policy scenarios on the business actors is presented.

In terms of turnover, it is assumed that:

- The turnover of the manufacturers corresponds to the ex-VAT annual product purchase costs i.e. it corresponds solely to the turnover due to the production and sale of BACS
- The turnover of the installers corresponds to the ex-VAT annual installation costs. Nevertheless, some manufacturers might also be involved in the installation business
- The turnover of the maintenance companies corresponds to the ex-VAT maintenance costs. Nevertheless, some manufacturers might be involved in the maintenance business
- The turnover of the energy companies corresponds to the ex-VAT energy costs.

The revenue of the BACS sector is based on the turnover of the BACS sector (manufacturers, installers and maintenances companies) including their margins. Figure 7-4 shows how the revenue of BACS manufacturers (for product only) is expected to vary as a function of the scenario.

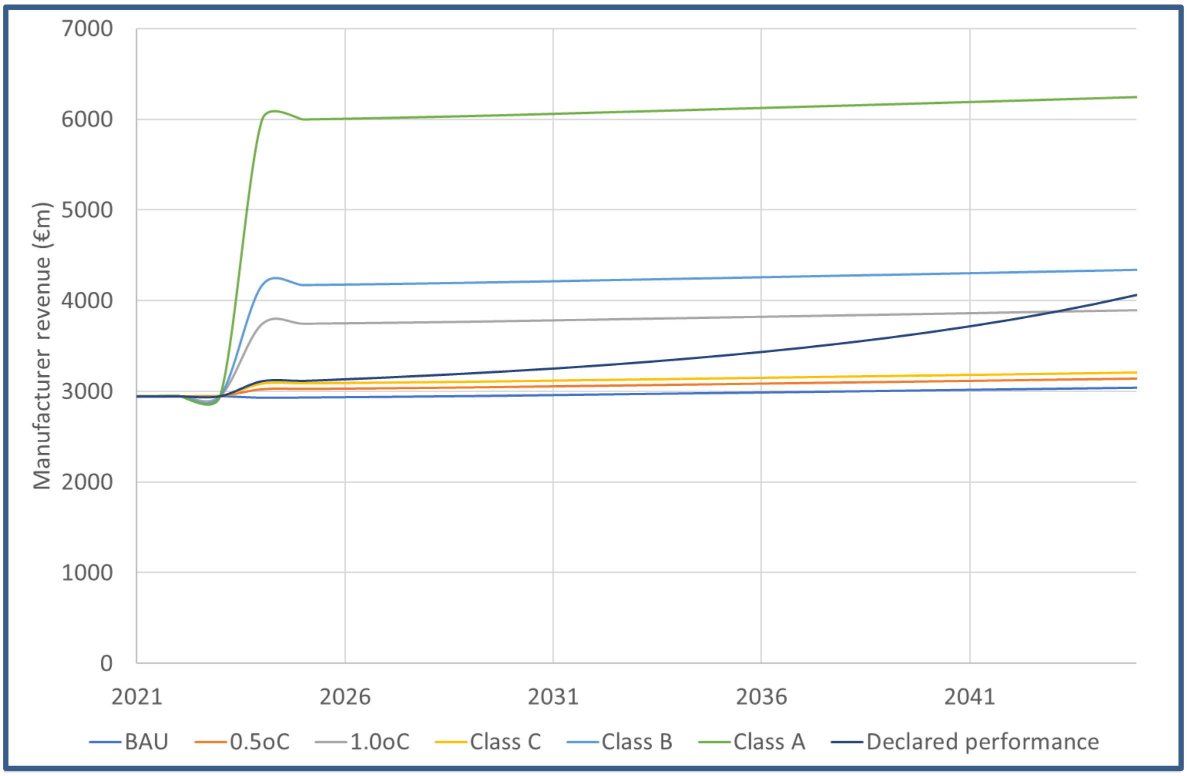

Figure 7-4: BACS manufacturer revenue (from the sale of manufactured product only)

Figure 7-5 shows how the revenue of BACS installers is expected to vary as a function of the scenario.

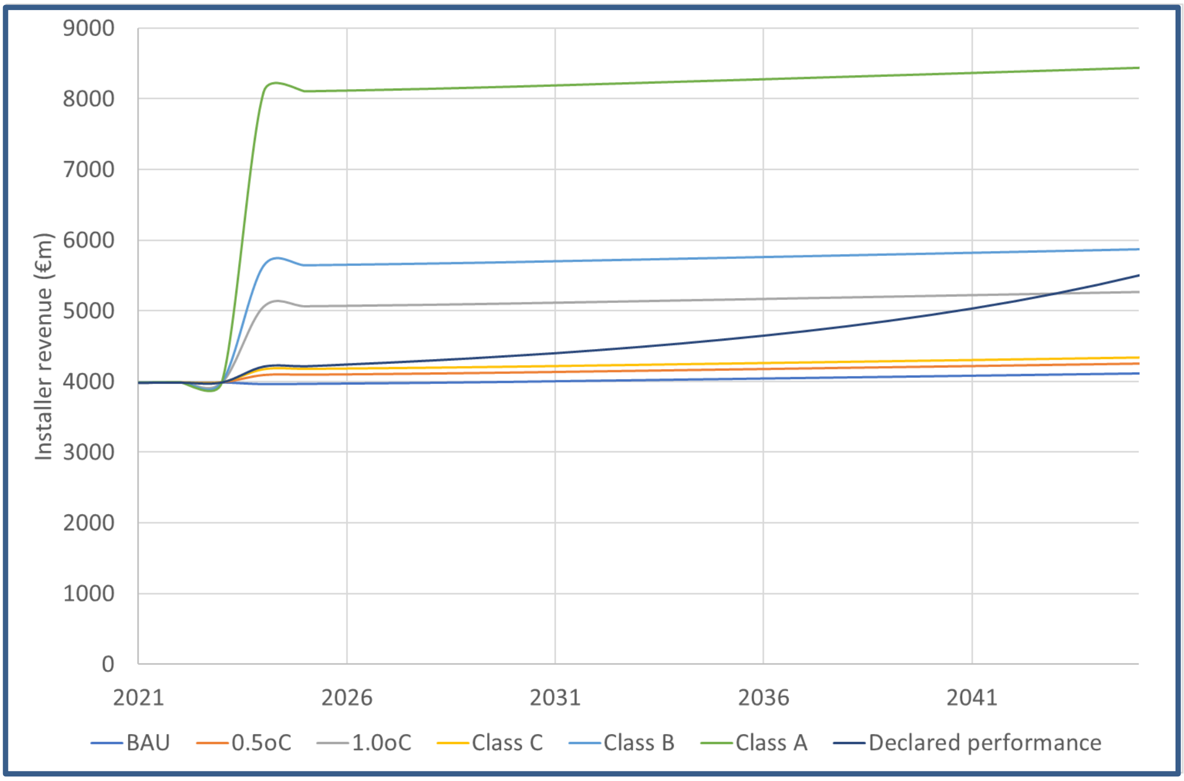

Figure 7-5: BACS installer revenue (from the installation of BACS and related services)

7.3.3 Impacts on employment

In this sub-section, the impact of the different policy scenarios on employment is presented. The number of jobs in the BACS sector are estimated from the turnover figures and the ratio of jobs / turnover (see Figure 7-6, Figure 7-7, Figure 7-8) for manufacturers, installers (and related service providers) and maintenance service providers respectively.

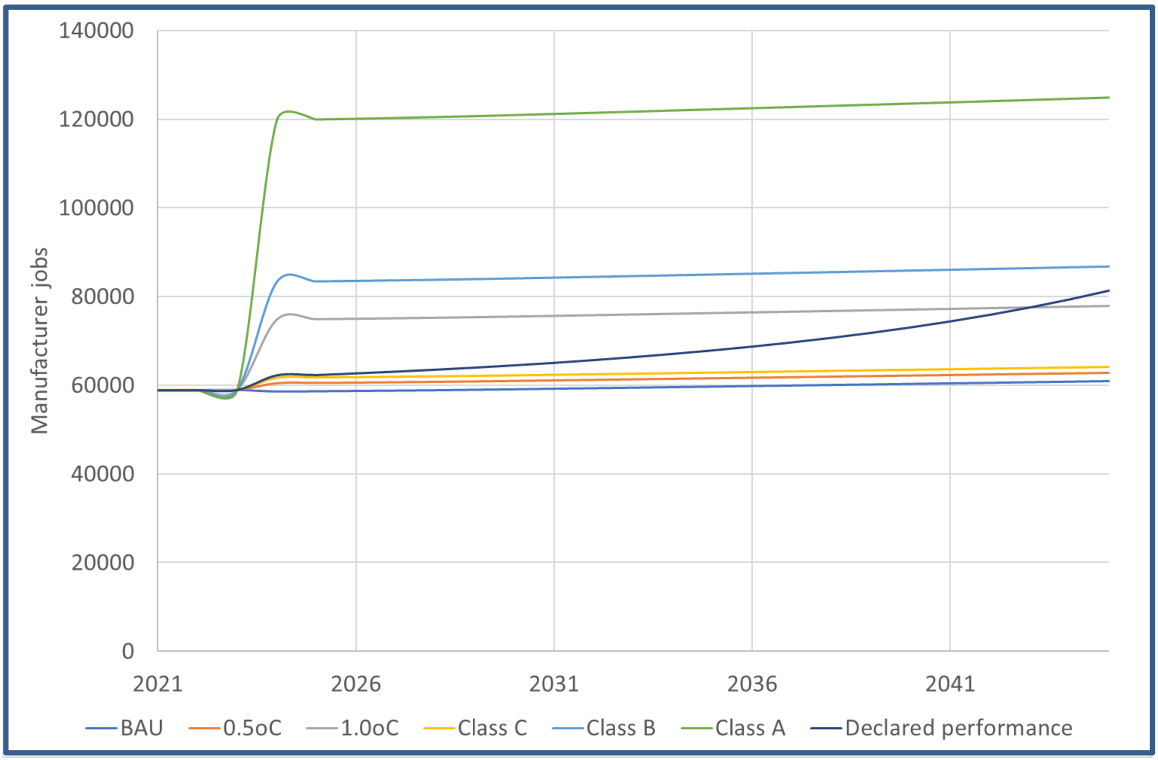

Figure 7-6: BACS manufacturer job (from the manufacture and sale of manufactured product only)

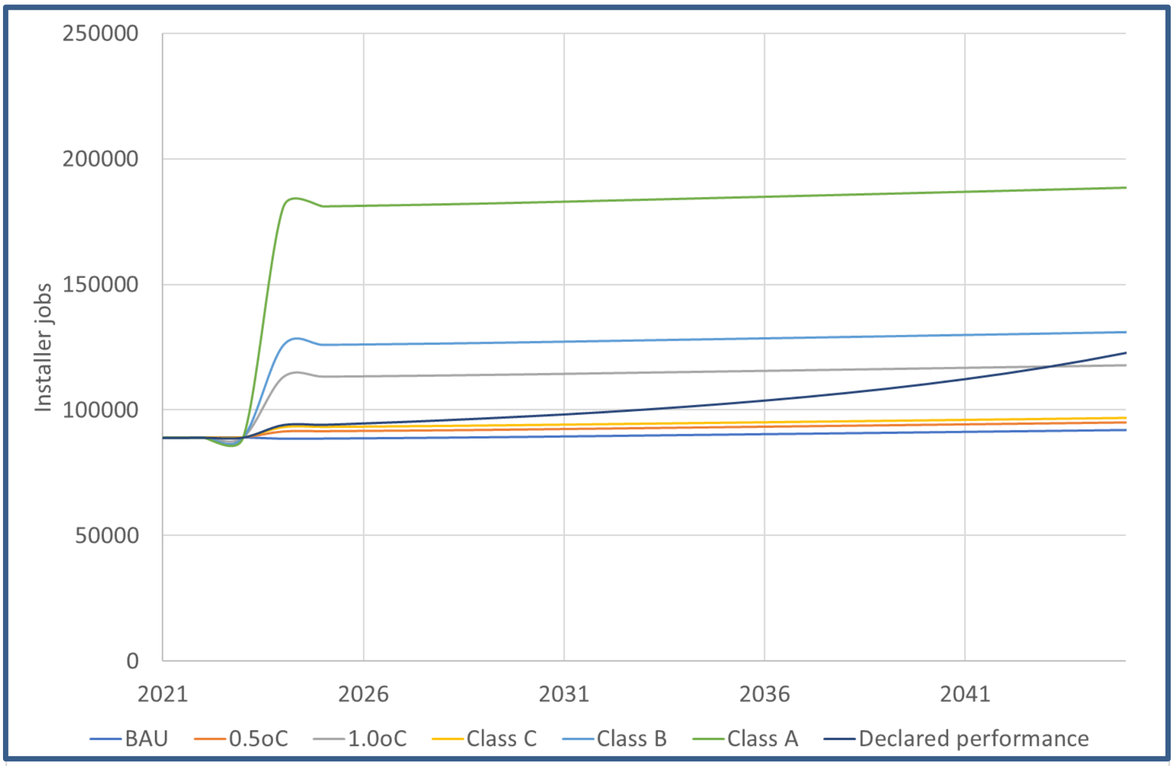

Figure 7-7: BACS installer jobs (from the installation of BACS and related services)

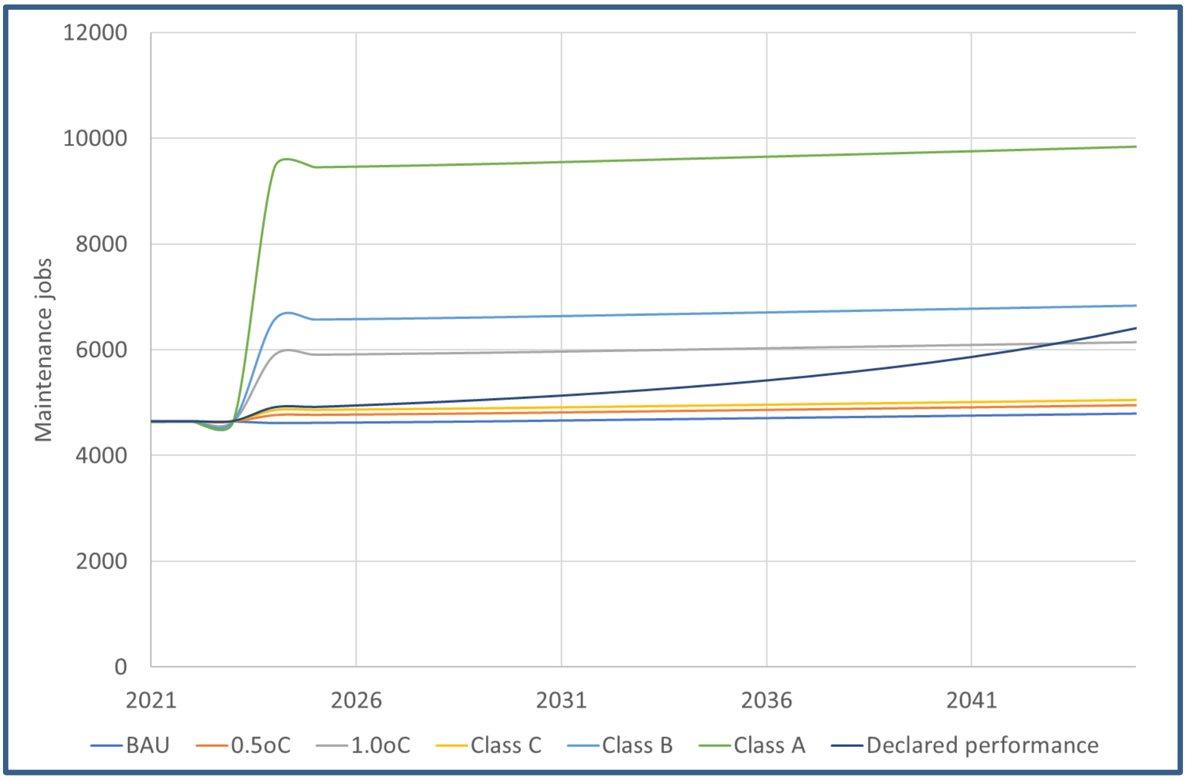

Figure 7-8: BACS maintenance jobs (from the maintenance of BACS installed from 2021 onward)

7.3.4 Overview

A summary of the main impacts of the different scenarios is presented in Table 7-7.3-3.

Table 7-7.3-3: Overview of the main environmental impacts in 2040 (stock of EU-27 BACS installed post 2021) under the central assumption case

			1	2	3	4	5	6	7
			BAU	Accuracy gain 0.5oC	Accuracy gain 1.0oC	Class C	Class B	Class A	Declaration of BACS class
ENVIRONMENT									
	Electricity	TWh/year	1045	986	949	1022	885	809	1003
	GHG	Mt CO2-eq./	316	298	287	309	267	244	303
CONSUMER									
	Expenditure (inc. energy costs)	€ bln. to 2040	213733	213121	239593	218309	253058	321985	225058
	Expenditure (ex. energy costs)	€ bln. to 2040	139557	143364	172556	145861	189745	263707	153593
	of that, purchase costs	€ bln. to 2040	57532	59102	71136	60131	78223	108713	63319
EU totals	of that, installation costs	€ bln. to 2040	77838	79962	96243	81354	105831	147082	85667
	of that, maintenance costs	€ bln. to 2040	4187	4301	5177	4376	5692	7911	4608
	Energy costs	€ bln. to 2040	74176	69757	67037	72448	63312	58278	71465
	Sales (regulated)	Floor area (MM2) in 2040	761	761	761	761	761	761	761
Product price		€ per M2 in 2040	3.96	4.09	5.06	4.17	5.64	8.11	4.80
Per product sold Installation costs		€ per M2 in 2040	5.36	5.53	6.85	5.64	7.63	10.97	6.49
Energy costs		€/year per M2 in 2040	4.98	4.69	4.50	4.87	4.25	3.91	4.80
BUSINESS									
Manufacturers		€ bln. to 2040	59312	60930	73336	61991	80642	112075	65277
	Installers	€ bln. to 2040	80245	82435	99220	83870	109104	151631	88316
EU turnover	Maintenance	€ bln. to 2040	4187	4301	5177	4376	5692	7911	4608
Energy Companies		€ bln. to 2040	60083	56503	54300	58683	51283	47205	57886
Revenue		€ bln. to 2040	203826	204168	232032	208919	246721	318823	216088
EMPLOYMENT (direct only)									
Manufacturers		Jobs in 2040	60300	62242	77127	63531	85868	123508	73081
Maintenance		Jobs in 2040	4750	4903	6075	5004	6764	9728	5756
Installers		Jobs in 2040	91035	93966	116438	95912	129635	186458	110330
Energy Companies		Jobs in 2040	96553	90800	87260	94303	82412	75859	93024
TOTAL		Jobs in 2040	252638	253062	286899	258749	304678	395553	282191

7.4 Sensitivity analysis on the main parameters

The aim of the analysis in this section is to investigate the sensitivity of the main outcomes for changes in the main calculation parameters.

The sensitivity analyses on the installed BACS service life (section 7.4.1), the potential impact of the Renovation Wave (section 7.4.2) and the electrification of space heating (section 7.4.3) are all performed at the policy scenario level.

This sensitivity analysis should also serve to compensate for weaknesses in the robustness of the reference scenarios and policy options due to uncertainties in the underlying data and assumptions.

7.4.1 Longer BACS lifetime

This scenario considers the potential impact of greater BACS lifetime, in particular as an indirect result of greater interoperability. It is assumed that instead of an average service life of 15 years in the BAU scenario that the average life is extended to 20 years. As it is assumed that BACS are installed post 2021 but fail within the scenario period are replaced by like-for-like BACS in terms of their functionality, energy performance and cost, then the main impact this scenario has is on the overall investment costs (and hence also on the cost effectiveness and employment).

The main impacts in the case of the longer lifetime scenario for the year 2040 are provided in Table 7-7.4-1.

Table 7-7.4-1: Overview of main environmental impacts in 2040 (stock of EU-27 BACS installed post 2021) under the Longer BACS lifetime sensitivity case

			1	2	3	4	5	6	7
			BAU	Accuracy gain 0.5oC	Accuracy gain 1.0oC	Class C	Class B	Class A	Declaration of BACS class
ENVIRONMENT									
	Electricity	TWh/year	1383	1316	1275	1357	1202	1116	1341
	GHG	Mt CO2-eq./	418	398	385	410	363	338	405
CONSUMER									
	Expenditure (inc. energy costs)	€ bln. to 2040	229832	228532	253745	233947	266276	332474	240913
	Expenditure (ex. energy costs)	€ bln. to 2040	131839	135529	163812	137905	180549	252431	145639
	of that,	€ bln. to 2040	54351	55872	67531	56851	74432	104065	60039
EU totals	of that, installation costs	€ bln. to 2040	73533	75591	91366	76916	100701	140793	81230
	of that, maintenance costs	€ bln. to 2040	3955	4066	4914	4137	5416	7573	4369
	Energy costs	€ bln. to 2040	97992	93004	89934	96042	85727	80043	95275
	Sales (regulated)	Floor area (MM2) in 2040	761	761	761	761	761	761	761
	Product price	€ per M2 in 2040	3.11	3.20	3.92	3.25	4.37	6.26	3.88
Per product sold	Installation costs	€ per M2 in 2040	4.20	4.33	5.31	4.40	5.91	8.47	5.25
	Energy costs	€/year per M2 in 2040	6.58	6.25	6.04	6.45	5.76	5.38	6.40
BUSINESS									
	Manufacturers	€ bln. to 2040	56032	57600	69620	58610	76734	107283	61896
	Installers	€ bln. to 2040	75808	77929	94192	79295	103816	145148	83742
EU turnover	Maintenance	€ bln. to 2040	3955	4066	4914	4137	5416	7573	4369
	Energy Companies	€ bln. to 2040	79374	75333	72846	77794	69439	64835	77172
	Revenue	€ bln. to 2040	215168	214928	241572	219836	255405	324839	227180
EMPLOYMENT (direct only)									
	Manufacturers	Jobs in 2040	47309	48746	59758	49522	66572	95344	59077
	Maintenance	Jobs in 2040	3726	3840	4707	3901	5244	7510	4653
	Installers	Jobs in 2040	71422	73591	90216	74763	100504	143941	89188
	Energy Companies	Jobs in 2040	127554	121060	117064	125015	111588	104190	124016
	TOTAL	Jobs in 2040	250011	**247236**	271745	253200	283908	350985	276934

7.4.2 Impact from the planned Renovation Wave

This scenario would examine the impact of the planned Renovation Wave[243] on the principal BACS energy performance scenarios. Under this sensitivity scenario it is assumed that BACS would be installed at the same time that heating systems are being replaced. For this it is assumed that the heating system replacement rate from Renovation Wave related policy measures rises to 4% per annum from 2026 onward.

[243] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS: A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives {SWD(2020) 550 final} https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0662&from=EN

Note, this presumes that the policy measures are extended beyond the current end period mentioned in the current Renovation Wave communications.

The main impacts in the case of the Renovation Wave scenario for the year 2040 are provided in Table 7-7.4-2.

Table 7-7.4-2: Overview of the main environmental impacts in 2040 (stock of EU-27 BACS installed post 2021) under the Renovation Wave sensitivity case

				1	2	3	4	5	6	7
				BAU	Accuracy gain 0.5oC	Accuracy gain 1.0oC	Class C	Class B	Class A	Declaration of BACS class
ENVIRONMENT										
		Electricity	TWh/year	1706	1608	1547	1667	1445	1322	1639
		GHG	Mt CO2-eq./	516	486	468	504	437	400	496
CONSUMER										
		Expenditure (inc. energy costs)	€ bln. to 2040	303697	301588	338370	310163	355594	449005	318938
		Expenditure (ex. energy costs)	€ bln. to 2040	180981	186367	227664	190475	250889	352551	200604
		of that, purchase costs	€ bln. to 2040	74609	76830	93855	78523	103429	145339	82699
EU totals		of that, installation costs	€ bln. to 2040	100942	103946	126980	106237	139933	196635	111887
		of that, maintenance costs	€ bln. to 2040	5429	5591	6830	5714	7527	10577	6018
		Energy costs	€ bln. to 2040	122716	115220	110706	119688	104706	96454	118334
		Sales (regulated)	Floor area (MM2) in 2040	1161	1161	1161	1161	1161	1161	1161
	Product price		€ per M2 in 2040	3.72	3.84	4.82	3.95	5.37	7.76	4.51
Per product sold	Installation costs		€ per M2 in 2040	5.03	5.20	6.52	5.34	7.26	10.50	6.11
	Energy costs		€/year per M2 in 2040	6.05	5.68	5.46	5.90	5.16	4.76	5.84
BUSINESS										
	Manufacturers		€ bln. to 2040	76917	79206	96757	80952	106628	149834	85257
		Installers	€ bln. to 2040	104064	107161	130907	109523	144261	202717	115347
EU turnover		Maintenance	€ bln. to 2040	5429	5591	6830	5714	7527	10577	6018
	Energy Companies		€ bln. to 2040	99400	93328	89672	96947	84812	78128	95850
	Revenue		€ bln. to 2040	285811	285287	324166	293136	343227	441256	302472
EMPLOYMENT (direct only)										
	Manufacturers		Jobs in 2040	86336	89297	111999	91629	124641	180162	104841
	Maintenance		Jobs in 2040	6800	7034	8822	7217	9818	14191	8258
	Installers		Jobs in 2040	130340	134811	169084	138332	188170	271989	158277
	Energy Companies		Jobs in 2040	159736	149979	144103	155794	136292	125552	154031
	TOTAL		Jobs in 2040	383213	381120	434007	392973	458921	591893	425408

7.4.3 Impact from high rate of electrification of heating scenario

This sensitivity scenario examines the impact of a higher rate of electrification of heating and the resulting change in heating carbon intensity on the principal BACS energy performance scenarios. Under this scenario the annual average rate of growth of electric heating is increased by 4.75% per annum compared to the BAU rate (which is aligned to the levels of electrification of heating assumed in the EPBD Impact Assessment). In general it is assumed that there will be greater use of electric heat pumps compared to resistance electric heating but still the latter continues to be used in part of the stock. Overall the annual average coefficient of performance of electric heating in its entirety is assumed to be 2.0 W/W. This is a simple and conservative assumption, as high efficiency heat pumps can have a much higher COP than this, but it is beyond the scope of this study to do an in-depth modelling of the make-up of the electric heating stock and it was thought prudent to apply conservative assumptions in the absence of such detailed modelling.

The main impacts in the case of the high electrification of heating scenario for the year 2040 are provided in Table 7-7.4-3.

Table 7-7.4-3: Overview of the main environmental impacts in 2040 (stock of EU-27 BACS installed post 2021) under the high electrification of heating sensitivity case

			1	2	3	4	5	6	7
			BAU	Accuracy gain 0.5oC	Accuracy gain 1.0oC	Class C	Class B	Class A	Declaration of BACS class
ENVIRONMENT									
	Electricity	TWh/year	1045	986	949	1022	885	809	1003
	GHG	Mt CO2-eq./	306	289	278	299	259	237	294
CONSUMER									
	Expenditure (inc. energy costs)	€ bln. to 2040	226811	225431	251429	231088	264195	332217	237551
	Expenditure (ex. energy costs)	€ bln. to 2040	139557	143364	172556	145861	189745	263707	153593
	of that, purchase costs	€ bln. to 2040	57532	59102	71136	60131	78223	108713	63319
EU totals	of that, installation costs	€ bln. to 2040	77838	79962	96243	81354	105831	147082	85667
	of that, maintenance costs	€ bln. to 2040	4187	4301	5177	4376	5692	7911	4608
	Energy costs	€ bln. to 2040	87254	82067	78873	85227	74450	68510	83958
	Sales (regulated)	Floor area (MM2) in 2040	761	761	761	761	761	761	761
	Product price	€ per M2 in 2040	3.96	4.09	5.06	4.17	5.64	8.11	4.80
Per product sold	Installation costs	€ per M2 in 2040	5.36	5.53	6.85	5.64	7.63	10.97	6.49
	Energy costs	€/year per M2 in 2040	5.86	5.51	5.30	5.72	5.00	4.60	5.64
BUSINESS									
	Manufacturers	€ bln. to 2040	59312	60930	73336	61991	80642	112075	65277
	Installers	€ bln. to 2040	80245	82435	99220	83870	109104	151631	88316
EU turnover	Maintenance	€ bln. to 2040	4187	4301	5177	4376	5692	7911	4608
	Energy Companies	€ bln. to 2040	70676	66474	63887	69034	60304	55493	68006
	Revenue	€ bln. to 2040	214419	214140	241620	219270	255742	327111	226207
EMPLOYMENT (direct only)									
	Manufacturers	Jobs in 2040	60300	62242	77127	63531	85868	123508	73081
	Maintenance	Jobs in 2040	4750	4903	6075	5004	6764	9728	5756
	Installers	Jobs in 2040	91035	93966	116438	95912	129635	186458	110330
	Energy Companies	Jobs in 2040	113576	106824	102667	110937	96909	89178	109286
	TOTAL	Jobs in 2040	269661	267935	302306	275383	319176	408872	298453

7.5 Summary

An array of potential Ecodesign policy measures have been suggested at both the packaged BACS product and installed BACS product levels. These address specific Ecodesign requirements for the product's energy performance in use and functionality (for parameters such as smart grid capabilities, key performance indicators, lifetime, material circularity and repair; and interoperability) as well as generic Ecodesign information requirements and energy labelling. Very large energy savings have been identified from policies related to these with the largest being for measures that would encourage the adoption of higher energy performance of installed BACS (minimum installed BACS limits at class A or B), but with substantial savings also from specific energy performance limits for the control accuracy of room temperature controllers. Information requirements are also likely to have a large impact, especially from the disclosure of the energy performance of installed BACS (and/or energy labelling thereof) but also significant impacts could be expected from several of the other prospective information requirements. Nor should it be forgotten how these policy options can complement the objectives of the EPBD with regard to EPCs, building digital information schemes and tools, the Smart Readiness Indicator and the Renovation Wave initiative, but also the BACS related provisions in Articles 8 and 14/15.

Another policy area BACS Ecodesign measures have the potential to enable is the greater penetration of renewable power through facilitation of Demand Response. Increasingly, the policymaking challenge is to be able to mesh aspects of current policy frameworks together to be better able to address the market barriers that are holding back the adoption of systems level savings and BACS is a good example of this type of large opportunity but technical and administrative challenge.

When considering these interactions the policymaking community may also need to pay attention to conformity assessment and market surveillance frameworks, and in particular the suitability and interactions of mechanisms currently used in the context of Ecodesign and the EPBD.

Overall the findings make very clear the advantages, in terms of energy savings, of regulating both packaged and, especially, installed BACS. Nonetheless, there remain outstanding policy level decisions and potentially related additional preparatory work that would be needed to be able to effectively implement some of the measures with the highest impact. As several stakeholders have suggested it may therefore be appropriate to conduct additional technical work to bring some of these proposals to a full state of readiness for implementation.

References for Task 7

Regulations

- Commission Regulation (EU) 811/2013, 812/2013 and 2015/1187 space heaters, water heaters and solid fuel boilers
- Commission Regulation (EU) 2015/1188, 2015/1185 and 2015/1186 local space heating products
- Commission Regulation (EU) 1253/2014 and 1254/2014 on ventilation units
- Commission Regulation (EU) 2019/1781 for electric motors and variable speed drives
- Commission Regulation (EU) 641/2009 amended by Regulation No 622/2012 for circulators
- COMMISSION REGULATION (EU) 2019/2023
- Ecodesign preparatory study for lifts: https://www.eco-lifts.eu/eco-lifts-wAssets/docs/Eco-design_Preparatory_Study_Final_Report_20191031.pdf

Other Ecodesign studies:

Ecodesign impact accounting:
https://ec.europa.eu/energy/sites/ener/files/documents/eia_ii__overview_report_2016_rev20170314.pdf

EPRS (2017) The Ecodesign Directive (2009/125/EC), European Implementation Assessment, European Parliamentary Research Service
https://www.europarl.europa.eu/RegData/etudes/STUD/2017/611015/EPRS_STU(2017)611015_EN.pdf

EPBD references:

- https://epbd-ca.eu/wp-content/uploads/2019/06/CA-EPBD-CCT1-Technical-Elements-2018.pdf
- http://www.epbd.be/index.cfm?n01=data&n02=recognized_data
- ECOFYS (2016) Ex-ante evaluation and assessment of policy options for the EPBD, Final report for EC DG-ENER
- Smart Readiness Indicator study (https://smartreadinessindicator.eu/)

Joint Research Centre references:

- https://ec.europa.eu/jrc/en/publication/analysis-and-development-scoring-system-repair-and-upgrade-products
- https://susproc.jrc.ec.europa.eu/product-bureau//product-groups/462/documents
- https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/contentype/product_group_documents/1581689975/20191220%20Solar%20PV%20Preparatory%20Study_Task%208_Final%20version.pdf

Smart grid references:

- https://interconnectproject.eu/
- https://www.edsoforsmartgrids.eu/
- https://eco-smartappliances.eu/en

Standards:

- EN15500-1:2017 Energy Performance of Buildings. Control for heating, ventilating and air conditioning applications. Electronic individual zone control equipment
- EN 15232: 2017

- EN 16947-1:2017 on Energy Performance of Buildings - Building Management System.
- eu.bac BACS certification handbook (Part 4)