Energy & Strategy
Politecnico di Milano

# Building Automation and Control Systems impact on EPC classes in Europe

**July 2024**

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eu.bac european building automation controls association

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## Executive summary

The study, developed under the auspices of **eu.bac**, provides compelling evidence that **Building Automation and Control Systems (BACS) represent the most cost-effective and ease-efficient solution for enhancing the energy efficiency of buildings**. This conclusion is particularly relevant for buildings that currently exhibit low energy performance.

Key Findings:

1. **Cost Efficiency.** The research indicates that the implementation of BACS can be achieved at a remarkably low cost, averaging below 10€ per square meter and 7,5€ per square meter for residential and non-residential buildings respectively. This cost-effectiveness is a significant advantage, especially when compared to other energy efficiency measures, which often require substantial financial investment, together with the **time efficiency** of BACS, which can be installed and become operational in a relatively short timeframe, **minimising disruptions** and allowing for **rapid improvements** in building performance.

2. **Energy Performance Improvement.** The study demonstrates that the adoption of BACS can lead to **significant improvements in a building's energy performance**. Specifically, BACS in Buildings contribute significantly to achieving Minimum Energy Performance Standards (MEPS), where appropriate Technical Building Systems are in place. Data demonstrates that where equipped, they can increase efficiency by at least one Energy Performance Certificate (EPC) class or more. In residential buildings we find improvements of 1,0 classes and in non residential buildings improvements of 1,3 classes and achieve for poorly classified buildings an **upgrade of at least one Energy Performance Certificate (EPC) class**. Finally, the achievement of highest EPC classes, like Zero Energy Buildings, results to be difficult without automation and control systems allowing a precise monitoring and management of energy consumption.

3. **"BACS multiplier effect".** Beyond energy savings, BACS also contribute to reduce operational costs, enable data driven investments and policies in the future. Health and comfort of building inhabitants can also significantly improve, and it can enable other technologies within the building, such as the integration in a Smart Grid, the adoption demand-response solutions. Considering that comfort factors such as air quality, thermal, and acoustic comfort are often considered in advanced building standards like Passivhaus, HQE, and BENG, and there are ongoing European discussions on incorporating occupant comfort into energy performance criteria, BACS systems could also be relevant to potential future efficiency class evaluation.

Given the substantial benefits and low costs associated with BACS, the deployment of these systems could have an **important impact in terms of both costs and energy consumption** on the building stock, allowing for example reaching a higher efficiency for buildings of the **public sector**. A **strategic allocation of resources** would ensure that a larger number of buildings can be upgraded to higher energy performance standards with minimal expenditure.

The European BACS sector is highly competitive, with a proven technology base and a **robust supply chain that is less dependent on extra-EU sourcing of components**. This competitive edge presents a unique opportunity for the European BACS sector to not only **enhance domestic energy efficiency** but also to **drive significant financial success through exports**. By leveraging this advantage, the **EU BACS industry can position itself as a global leader**, fostering economic growth and creating new job opportunities within the region.

Policy asks:

BACS improvements in buildings represent a low-hanging fruit that should be truly prioritised by policymakers and stakeholders. Their **cost-effectiveness, ease of implementation, and substantial impact on energy efficiency** make BACS an optimal choice for immediate action. Prioritising BACS improvements aligns with broader environmental sustainability goals and ensures a **rapid return on investment**, thereby providing a strategic and economically sound approach to enhancing building performance across Europe.

- **Incentive Programs.** Governments and regulatory bodies should consider creating incentive programs that encourage the adoption of high-level BACS solutions. Such programs could include subsidies, tax incentives, or low-interest loans to offset initial installation costs. Examples of existing incentives that include BACS are the Federal Funding for Efficient Building (BEG) in Germany[1], the Energy Savings Certificates (CEE) in France[2], and Ecobonus in Italy[3].
- **Regulatory Support.** To further promote the widespread use of BACS, regulatory frameworks like the Energy Performance of Building Directive (EPBD) should be properly transposed and implemented by national authorities to prioritise and mandate the integration of these systems in new and existing buildings, especially those with poor energy performance.
- **Awareness Campaigns.** Raising awareness about the benefits of BACS among building owners, facility managers, and the local authorities public is essential. Educational campaigns could highlight the cost effectiveness, energy efficiency improvements, and environmental benefits associated with BACS.

(1) *https://www.bafa.de/DE/Energie/Effiziente_Gebaeude/Foerderprogramm_im_Ueberblick/foerderprogramm_im_ueberblick_node.html*
(2) *https://www.service-public.fr/particuliers/vosdroits/R55191*
(3) *https://www.agenziaentrate.gov.it/portale/web/guest/superbonus-110%25*

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# Introduction

The current global energy situation is highly delicate, prompting a strong push towards improving efficiency across all sectors. Buildings, in particular, are significant contributors to energy consumption, both during their construction and throughout their operational lifespan. This has made the building sector a focal point for energy efficiency efforts and achieving efficient heating and cooling generation.

Reducing emissions from the construction phase is inherently challenging due to the materials and processes involved. However, the energy consumption of buildings during their operational life can be significantly decreased through various energy-efficient solutions. These solutions include effective thermal insulation systems, which lower the energy demand for heating and cooling, and, notably in recent years, Building Automation and Control Systems (BACS). BACS enable more efficient use of resources and heating and cooling generation, ensuring they are utilised only when absolutely necessary.

BACS hold substantial potential for energy savings. These systems integrate advanced sensors, controllers, and software to optimise the operation of heating, cooling, ventilation, and lighting systems in buildings. By automatically adjusting these systems based on real-time data and occupancy patterns, BACS can minimise energy wastage and enhance overall building performance. This leads to lower operational costs and a reduced environmental footprint.

The objective of this study is to estimate the impact that BACS can have on the Energy Performance Certificates (EPC) class distribution of buildings across Europe. Many studies already exist on the impact in terms of energy savings allowed by such systems, but no research is yet known at the time of the conduct of the study that quantitatively evaluates how such efficiency gains would translate into changes in EPC classes. The importance of energy classes for buildings is recognised and established, and such rating systems are in place in almost all states. This empowers buyers, builders and investors to have more easily usable information about the energy condition of the buildings they are interested in. By then enabling accurate comparisons between buildings of different classes, they can then serve as an incentive toward building efficiency upgrades by construction companies in order to better position their buildings in the marketplace.

This analysis will thus provide valuable insights into how the widespread adoption of BACS can transform the energy landscape of the European building stock, moving it towards greater sustainability and efficiency.

## Regulatory framework

The implementation of Building Automation and Control Systems (BACS) is crucial for improving energy efficiency and sustainability in buildings. However, widespread adoption requires strong regulations and incentives. Policies like the Energy Performance of Buildings Directive (EPBD) are essential in driving this transformation. These regulations help reduce energy consumption and carbon emissions, enhance building performance and occupant comfort, and foster market innovation and economic growth. By setting clear standards and encouraging the adoption of advanced technologies, the EPBD and similar initiatives ensure a uniform approach to energy efficiency, making it easier for stakeholders to invest in and benefit from BACS.

## EPBD Revision Overview

The Energy Performance of Buildings Directive (EPBD) [1] is a key piece of European Union legislation aimed at improving the energy efficiency of buildings within the EU. Enacted to reduce energy consumption and carbon emissions, the EPBD sets mandatory energy performance standards for both new and existing buildings. It requires member states to implement measures such as Energy Performance Certificates (EPC), regular inspections of heating and air conditioning systems, and the promotion of smart technologies like Building Automation and Control Systems (BACS). By establishing a framework for energy-efficient building practices, the EPBD supports the EU's broader climate goals and fosters a more sustainable built environment.

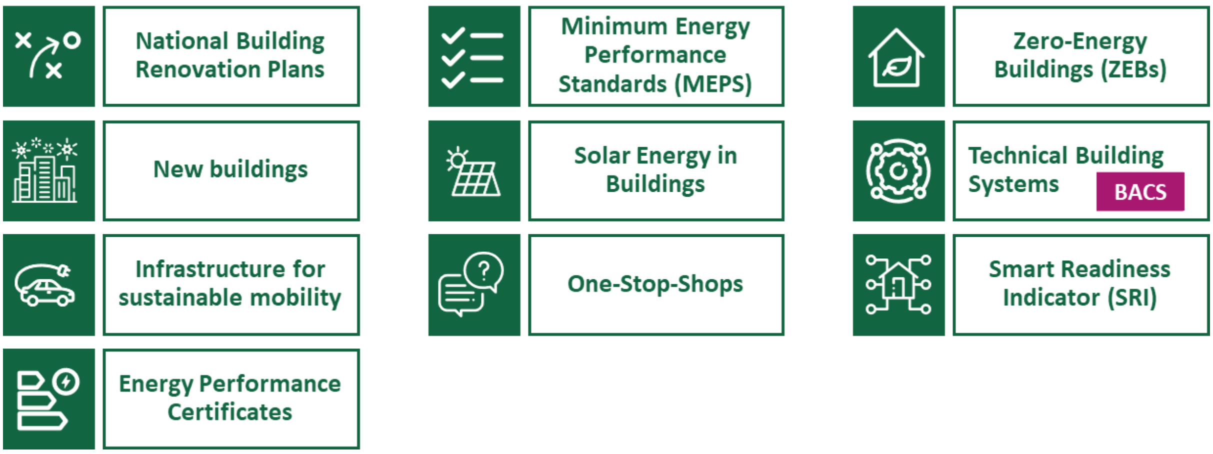



*Figure 1. EPBD key provisions*

As part of the Fit for 55 package, the EPBD Directive (Directive (EU) 2018/844) has been revised to align with the latest Green Deal targets and updates to the Energy Efficiency Directive (EED), the Renewable Energy Directive (RED), and the EU ETS system (EU ETS II for road transport and building sectors). In December 2023, the EU Parliament and the Council agreed on the final text, and the Directive entered into force on May 28$^{th}$, 2024.

The revised EPBD introduces several key provisions. National Building Renovation Plans (NBRP) replace long-term renovation strategies. These plans include each Member State's roadmap with targets for 2030 and 2040, aiming to transform existing building stock into Zero-Energy Buildings (ZEBs) by 2050. The plans detail implemented and planned policies, investment needs, and financing sources. New buildings must be ZEBs, with new public buildings complying from January 1$^{st}$, 2028, and all new buildings from January 1$^{st}$, 2030.

Minimum Energy Performance Standards (MEPS) are also to be set by each Member State. For the non-residential sector, the obligations include setting two energy performance threshold to the effect that 16% and 26% of the national non-residential building stock is above those threshold, and improving all the non-residential buildings below those thresholds from 2030 and 2033 respectively. In the residential sector, a national trajectory must reduce average primary energy use by 16% by 2030 and 20-22% by 2035, with 55% of this decrease achieved by renovating the worst-performing buildings. The revised directive introduces a new ZEB definition, requiring no on-site carbon emissions from fossil fuels and the ability to respond to external signals, adapting energy use, generation, and storage.

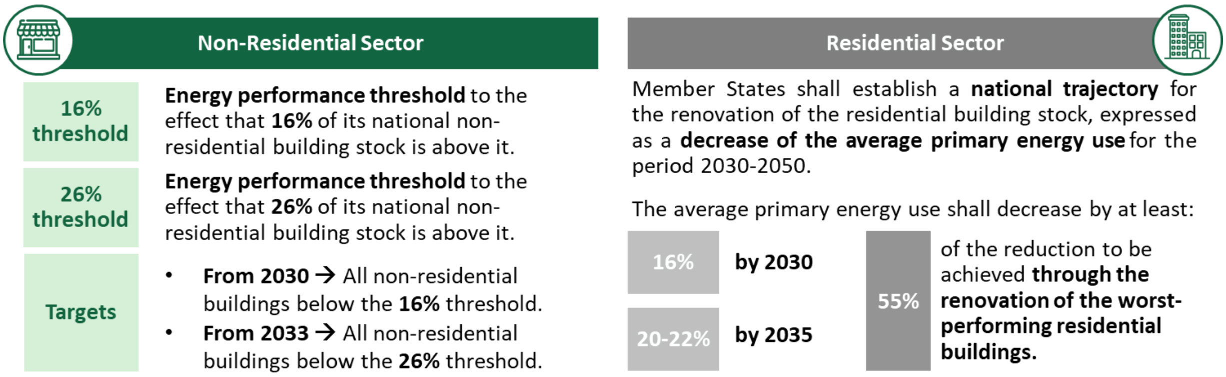



*Figure 2. MEPS requirements*

Technical Building Systems (TBS) management and improvement is also addressed in the new directive. Member States must set requirements to optimize energy use and ensure adequate indoor environmental quality standards, and BACS solutions can have a significant role in this. Non-residential ZEBs must have devices to monitor indoor air quality, mandatory during major renovations. By December 31st, 2024, non-residential buildings with systems over 290 kW must have BACS, extending to systems over 70 kW by December 31st, 2029.

Directly related to building automation systems, the EPBD introduces the Smart Readiness Indicator (SRI), a metric designed to assess and provide information about a building's level of digitalisation and automation. Based on the evaluation of TBS characteristics on seven different metrics, such as energy savings, comfort, and convenience, an SRI class is assigned to the building. The SRI will be implemented in non-residential buildings that have an effective rated output exceeding 290 kW, this will be enacted through a delegated act by the European Commission and is expected to be in place by June 30th, 2027.

Energy Performance Certificates (EPC) classes must also be established by each Member State, but with no particular common criterion, only specifying that the energy performance class of a building must be on a scale from A (Zero-Energy Buildings, ZEB) to G (worst-performing buildings). An A+ class may be defined for buildings exceeding ZEB standards, and EPCs are valid for up to 10 years.

## Focus on Technical Building Systems

Article 11 of the revised directive includes key provisions regarding the use of Technical Building Systems (TBS). Each Member State must set requirements for optimising energy use in new, replaced, and upgraded systems, including self-regulating devices for temperature regulation and hydronic balancing. When systems are retrofitted or replaced, their energy performance must be optimised, especially aiming for a complete phase-out of stand-alone fossil fuel boilers by 2040. Non-residential ZEBs must have devices to monitor and regulate indoor air quality, which are mandatory during major renovations. New residential buildings and those undergoing major renovations must have continuous electronic monitoring of system efficiency, notifying owners or managers of significant variations, and control functionalities for optimum energy generation, distribution, storage, and use, with hydronic balancing. These buildings must also have the capacity to react to external signals and adjust energy consumption. Non-residential buildings with systems over 290 kW must comply by December 31st, 2027, and those with systems over 70 kW by December 31st, 2029.

## Focus on Building Automation and Control Systems (BACS)

The EPBD also sets targets for BACS in non-residential buildings, recognising their potential to contribute to the energy efficiency of buildings. By December 31st, 2024, BACS must be installed in buildings with systems over 290 kW, and by December 31st, 2029, in buildings with systems over 70 kW. BACS must be capable of monitoring, logging, analysing, and adjusting energy use, benchmarking energy efficiency, detecting efficiency losses, and informing responsible personnel about improvement opportunities. They must also communicate with connected systems and appliances, be interoperable with various technologies, and monitor indoor environmental quality.

## Methodology

### General approach

The starting point to evaluate the impact of BACS solutions on a building's EPC class is understanding the distribution of buildings across energy classes and the energy consumption ranges associated with each class.

While obtaining such information is feasible and sometimes straightforward thanks to national reports on EPC classes, it is challenging to acquire comparable data on the distribution of energy classes across Europe. This difficulty arises not only from geographic differences in average building energy consumption, but also because each nation has considerable autonomy in determining the criteria for their energy classes. These can vary significantly; for instance, some countries might use classes from A to G, while others might include additional classes like A+ and A++, or divide them further into subclasses such as A1 to A4, or stop at class D. The assignment criteria can also differ, with some based on actual energy consumption and others on the ratio of actual to ideal energy consumption, considering all efficiency solutions [3].

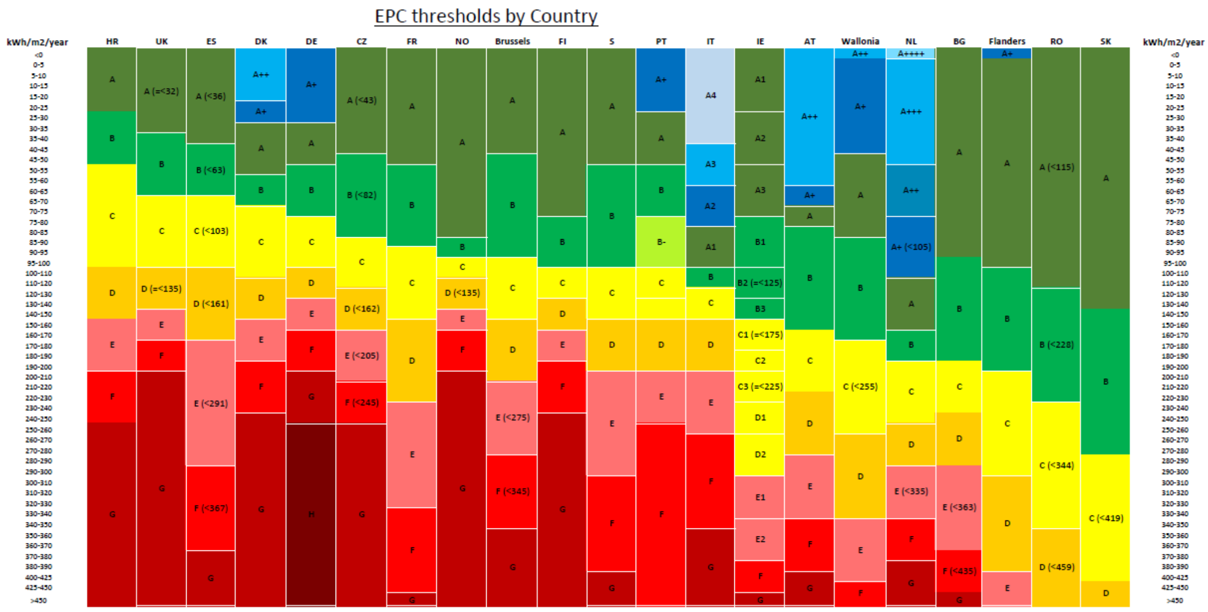



*Figure 3. EPC thresholds in energy consumption for different countries [2]*

### Data source

The data are initially collected from a first database (Tabula WebTool) [4], an exhaustive and detailed collection of energy consumption data (using Primary Energy Demand data, PED) for different building archetypes in most European countries. This information is categorised by building category and type according to the following classification:

| Non-residential sector | Residential sector |
|---|---|
| Offices | Single family – Terraced houses |
| Trade | Multifamily houses |
| Education | Apartment blocks |
| Health | |
| Hotels and restaurants | |
| Other non-residential buildings | |

For each of these buildings archetypes, a further level of detail is added, based on the construction year period:

- Before 1945
- 1945 - 1969
- 1970 - 1979
- 1980 - 1989
- 1990 - 1999
- 2000 - 2010
- Post 2010

It's important to highlight that the data in this database do not originate from statistical studies of building consumption, but from the modeling of the different building types, including factors such as average surface area and predominant heating types, in order to estimate the average energy consumption for each building type.

A second database is used however to include information such as number of different buildings, average surface, energy consumption ratios between heating, domestic hot water, cooling and others (Simon Pezzutto et al., Hotmaps Project, D2.3 WP2 Report 2018, Open Data Set for the EU28) [5]. While the building categories and construction year ranges differed between the two databases, the data were unified by making a few key assumptions. Specifically, it was assumed that similar building types in both databases had comparable energy consumption patterns, and construction year ranges were aligned by grouping them into broader periods to ensure consistency. These adjustments allowed the creation of a coherent dataset that could be analyzed uniformly across different countries and building types a few assumptions.

This led to a complete database on building types, number of buildings, average surface, PED consumption for different TBS and other main information for each of the main European countries.

## Geographical regions

As noted earlier, there are significant differences in average energy consumption across European states. For example, it is plausible that a Nordic country will have much higher heating energy needs than a Mediterranean country. Therefore, the study considered four geographic areas with comparable climates in Europe, grouping buildings into Nordic, Oceanic, Continental, and Mediterranean regions, including the following countries:

| Nordic area | Oceanic area | Continental area | Mediterranean area |
|---|---|---|---|
| Estonia | Belgium | Austria | Croatia |
| Finland | Denmark | Bulgaria | Cyprus |
| Latvia | France | Czech Republic | Greece |
| Lithuania | Germany | Hungary | Italy |
| Sweden | Ireland | Poland | Portugal |
| | Luxembourg | Romania | Spain |
| | Netherland | Slovakia | |
| | | Slovenia | |

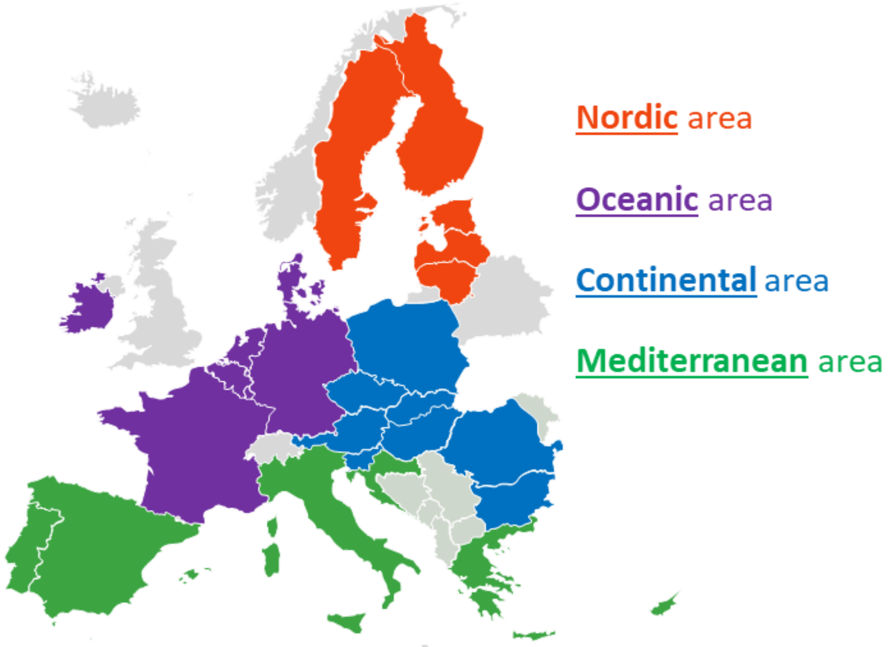



*Figure 4. Geographical regions identified for this study.*

This classification was based on climatic characteristics of European countries [6], identifying groups of countries with similar climate and socio-economic aspects. While this approach differs from the traditional geopolitical or market-based groupings that some stakeholders may be more familiar with, it allows for a more climate-sensitive evaluation, which is crucial for understanding how different building automation systems perform under varying conditions. Of the European countries, the ones with data available in the database were then considered. It is also important to note that this grouping is used for the initial phase of the study to analyze energy efficiency across comparable climatic zones. In a later phase, when the tool developed from this study is made available, stakeholders will have the flexibility to explore and extrapolate different clusters of countries or regions based on their specific interests, needs, or customary groupings. This flexibility ensures that the findings can be adapted to a broader range of applications beyond the classifications used here.

## Energy distribution calculations

Given the availability of single average values rather than energy consumption ranges for each building type, it was necessary to estimate a consumption range from an average value. Gaussian distributions were applied to the available archetypes for each geographic area, resulting in a range of energy consumption for each building type. Considering thus the number of existing buildings in each category, an energy distribution of the number of buildings in the considered geographic areas was constructed.

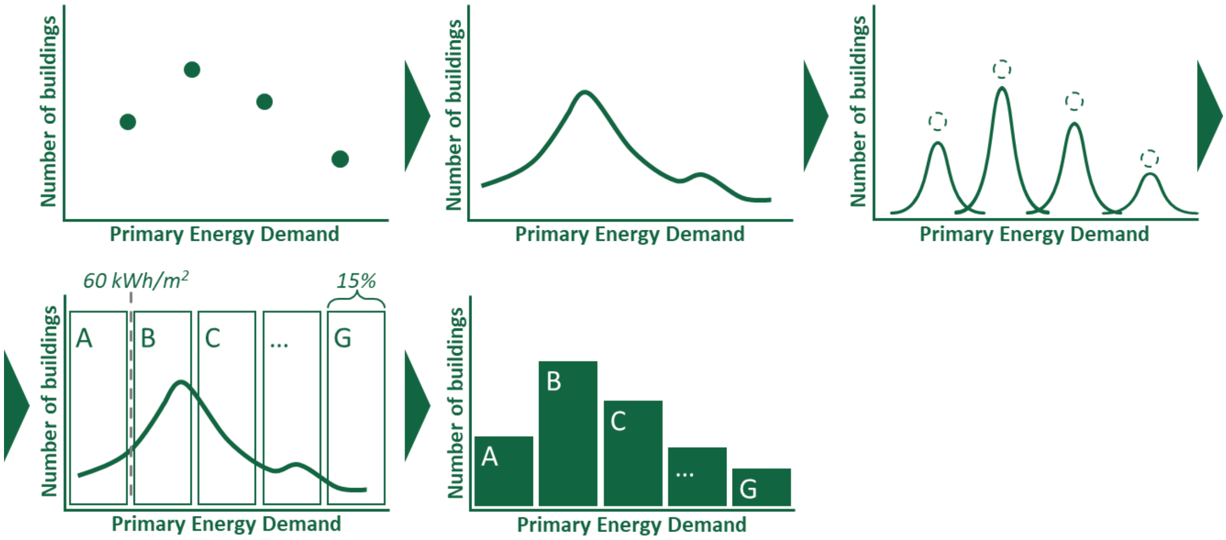



*Figure 5. Graphical representation of the methodology used for estimating the EPC classes distribution*

## Universal EPC classes definition

As mentioned before, the EPC building classes are defined with different criteria for almost each European country. The first step to identify BACS potential impact on EPC classes was thus defining common, "fictitious" EPC class criteria to be uniformly applied to the building stocks of various nations. A common classification system from class A (best energy performance) to G (worst energy performance) was chosen, with assignments based on thresholds of Primary Energy Demand (kWh/sqm). It is important to note that these classes, referred to in the report as EPC classes for simplicity, are not the actual EPC classes of the buildings but part of a hypothetical classification created solely for comparable calculations of the impact of BACS classes.

The distribution of buildings by energy needs was then divided into different EPC classes as closely aligned with potential EPBD guidelines as possible. Therefore, buildings with the worst 15% of energy consumption were assigned to class G, consistent with EPBD drafts. Class A, in the absence of specific guidelines, was defined as including all buildings with energy consumption below 60 kWh/sqm, based on analysis of the composition of higher EPC classes in various European states. The remaining classes were defined by evenly dividing the Primary Energy Demand thresholds between class A (60 kWh/sqm) and class G.

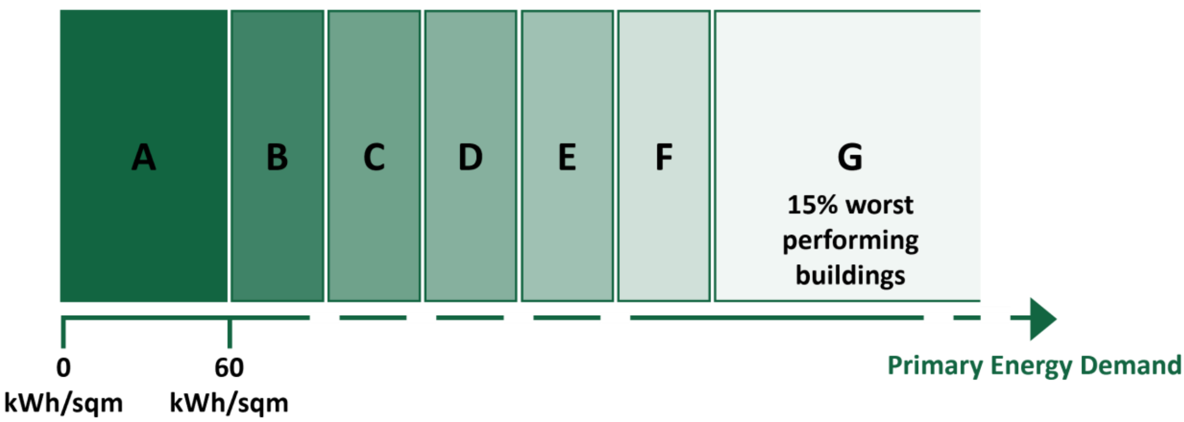



*Figure 6. Graphical representation of the EPC classes definition criteria*

## Technologies overview and BACS energy saving

Before presenting the study results, it is necessary to provide an overview of the technologies integrated into a building and how these are categorized to better understand the results and methodology applied in the analysis.

Within a building, there are integrated systems known as Technical Building Systems (TBS). These include:

- Heating
- Cooling
- Domestic Hot Water (DHW)
- Ventilation
- Lighting

Building Automation and Control Systems (BACS) typically operate in a sectoral manner on one or a few of the different TBS. It is evident that different BACS will have varying potential for efficiency and energy savings depending on the technology they act upon and the energy consumption of the relevant TBS.

It is not easy to evaluate the impact of various automation systems on buildings and to effectively consider their interoperability. To address this, two standards have been defined: UNI EN ISO 52120-1 is the most recent one [7], that integrates and updates the UNI EN ISO 15232-1 standard [8]. These standards provide a clear definition of the characteristics of building automation and control systems (BACS), such as the types of systems, potential efficiency improvements, and other relevant aspects.

The UNI EN ISO 52120-1 defines BACS standards, specifically considering how and what can be automated for each TBS and to what extent. This also implies defining different BACS classes based on the level of automation achieved across all the different TBS of the building, allowing for classification into higher or lower classes. The standard defines the possible levels of automation that can be reached for each TBS. Based on these levels of automation, different BACS classes are established, categorizing buildings according to the sophistication of their automation systems across all TBS components. This classification system is designed to rank buildings by their automation performance, rather than simply ensuring compliance with a specific regulation. These BACS classes exist in addition to the Energy Performance Certificate (EPC) classes, which primarily assess a building's overall energy efficiency. The BACS classes, by contrast, focus specifically on the effectiveness and performance of the automation systems integrated into the building.

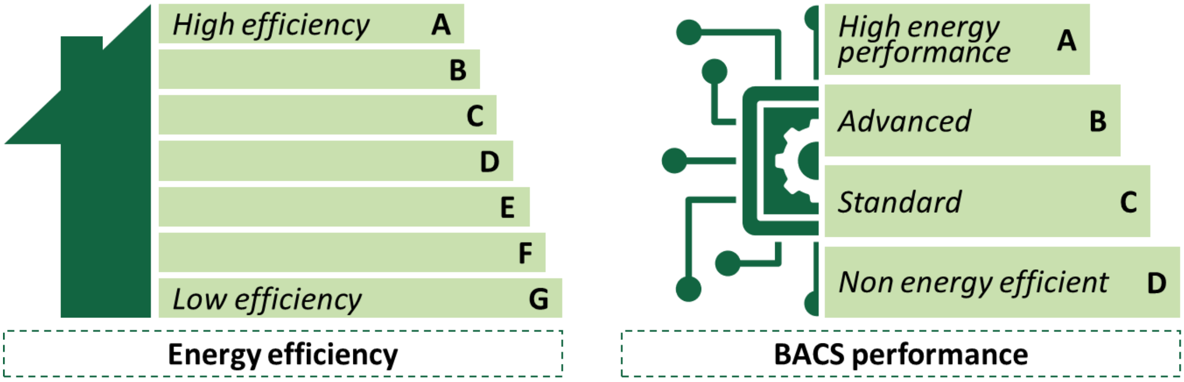



*Figure 7. Graphical representation of Building Energy Performance Classes (EPC) and BACS performance classes*

The standard provides a comprehensive framework for evaluating the impact of BACS on the energy performance of buildings. It outlines procedures for assessing how BACS contribute to energy efficiency, including criteria for system functionality, integration, and control capabilities. The standard emphasises the importance of advanced automation and control technologies in optimising energy use, improving indoor environmental quality, and enhancing overall building performance. Most importantly for this study, the UNI EN ISO 52120-1 provides precise estimates of the potential energy consumption reduction for different categories of buildings by applying various categories of BACS. Using as a reference buildings with BACS class C systems, whose energy consumption is attributed a unitary "BAC efficiency factor", the efficiency of higher class BACS systems can be determined. These BACS class A and B systems thus have efficiency factors that reflect their ability to reduce building energy consumption compared to class C systems, and will therefore have factors of less than one. For example, if a BACS class A system has a BAC efficiency factor of 0.7, this means it can reduce energy consumption by 30% compared to the reference class C system, that has by definition a BAC efficiency factor of 1.0. BACS factors are also broken down into thermal, electrical and other specific areas.

These data make it possible to extract the percentages of energy reduction possible through the implementation of such systems, providing a clear and detailed view of the benefits that can be achieved in terms of both thermal efficiency and electrification, as well as other relevant aspects. The standard thus enhances the quantitative understanding of how BACS can contribute to the overall energy efficiency of buildings, promoting effective automation and control strategies to achieve energy savings and improve building performance.

**ISO 521201-1 building types**

| Sector | Building type |
|---|---|
| Non-residential | Offices |
| | Wholesale and retail trade service |
| | Schools |
| | Hospital |
| | Hotels |
| | Restaurants |
| | Lecture hall |
| | Others (sport, storage, ind. Buildings) |
| Residential | Single family house, Apartment block, Others |

**E&S database building types**

: estimated value

| Sector | Building type | THERMAL ENERGY SAVINGS A | THERMAL ENERGY SAVINGS B |
|---|---|---|---|
| Non-residential | Offices | 54% | 47% |
| | Trade | 62% | 53% |
| | Education | 33% | 27% |
| | Health | 34% | 31% |
| | Hotels and Restaurants | 46% | 36% |
| | Others | 49% | 39% |
| Residential | Single family - Terraced houses | 26% | 20% |
| | Multifamily houses | | |
| | Apartment blocks | | |

**ASSUMPTIONS:**

**Non-residential:**
- **Direct correspondence** between ISO and E&S database for: Offices, Wholesale and retail trade service (trade), Schools (with education), Others.
- **Average values** of Hotels and Restaurants for the correspondent category of the E&S database.

**Residential:**
- **Only one aggregated value** given in the ISO, which is used for the 3 differ categories that are present in the model.

*Figure 8. Estimated thermal energy savings achievable through class A and class B BACS*

In this study, we simplified the standard approach to estimate energy savings by focusing only on the thermal components of buildings - heating and cooling - using BACS (Building Automation and Control Systems) as the basis for the calculations. According to the relevant standards, BACS Class C systems are considered the reference, but in this study, the assumption is that the buildings analyzed do not have any BACS installed and thus classify them as equivalent to BACS Class D. To explain this simplification: if we look at BACS Class A systems, which have an efficiency factor of 0.7 compared to Class D systems (with a factor of 1.3), the model shows that installing BACS Class A could reduce energy consumption by up to 46%.

However, it is important to note that this approach is a simplification. In reality, the BACS standard applies to all *Technical Building Systems* (TBS)—not just heating and cooling, but also lighting, ventilation, and other building automation aspects. In this study, we focused only on the savings from heating and cooling to provide a clearer comparison. If we were to consider the entire scope of BACS for all systems in a building, the total energy savings would be different and potentially greater, as each component—heating, cooling, lighting, and so on—would have its own contribution to the overall efficiency improvements. This simplified approach helps illustrate the potential of BACS in one key area, but does not capture the full savings that could be realized when applying BACS across all systems.

The obtained figures were rigorously compared with real-world data from case studies conducted by eu.bac members. This comparison was crucial in validating the accuracy of our methodology, ensuring that the estimated energy savings align with actual outcomes observed in practice. The consistency between the study's methodology and the case study data reinforces the reliability of the results, demonstrating that the energy savings projections are not only theoretically sound but also applicable and achievable in real-world scenarios.

BACS technologies can not only help reduce buildings' energy consumption but also enhance their Smart Readiness Indicator (SRI) score. SRI is a metric developed by the European Union to assess the intelligence of a building in terms of its automation and control capabilities, as well as its readiness for smart technologies. They aim to determine how well a building is equipped to interact with its occupants and with the energy grid, promoting energy efficiency and sustainability. SRI evaluate a building's capability to use smart technologies, many of which are part of BACS. The integration of these systems is crucial in the evaluation process. SRIs assess the functionalities of automation across various domains, such as heating, ventilation, and lighting. For example, a heating system controlled by an advanced BACS will receive a higher SRI score compared to a system without automation. Furthermore, SRIs assign scores based on the levels of automation and control provided by BACS. The more sophisticated the system, such as those with machine learning capabilities, integration with smart grids, and remote control, the higher the SRI score it will receive. BACS significantly contribute to the energy efficiency and comfort of buildings, which are fundamental criteria of SRIs. For instance, a BACS that optimises energy consumption based on building occupancy and environmental conditions will enhance the SRI score. Interoperability and integration are also key factors in the SRI evaluation. SRIs consider the ability of automation systems to integrate with other smart systems and external infrastructures like smart grids. An interoperable BACS that can communicate with other systems and optimise the use of energy resources will contribute to a higher SRI score. In summary, SRIs help identify areas for improvement and encourage the adoption of smart technologies in buildings, thus enhancing their energy efficiency, sustainability, and overall performance.

Given the upcoming mandatory application of SRIs for non-residential buildings, the role of BACS becomes even more critical. By investing in advanced automation systems, building owners can significantly improve their SRI scores, achieving higher standards of energy efficiency. As BACS integrate more sophisticated features and better interoperability, they not only help in increasing the desired SRI scores but also pave the way for smarter, more sustainable buildings.

## BACS impact on EPC classes distribution

After assessing the distribution of energy classes in different geographic areas, the objective of this study is to understand the impact that BACS can have on this distribution and on the composition of different EPC energy classes.

This study explores how Building Automation and Control Systems (BACS) can influence the energy performance of buildings, specifically looking at how they affect the distribution of buildings across different Energy Performance Certificate (EPC) classes, which rank buildings based on energy efficiency. For the analysis, it was assumed that the starting point for most buildings is BACS Class D, which represents minimal or no automation. This assumption is reasonable due to the numerous older buildings across Europe that often lack of any automation system. By assuming Class D as the baseline, the energy efficiency improvements that higher classes of BACS (like Class A or B) could bring can be better estimated.

The method works as follows:

1. **Energy Use Breakdown** → The energy each building uses for heating, cooling, and other systems (like lighting or ventilation) was initially analyzed. This energy use is known as Primary Energy Demand (PED).

2. **Applying BACS Efficiency** → The energy-saving benefits of different BACS classes were then applied to the buildings. For example, a building with more advanced automation (Class A) will save more energy than one with basic or no automation (Class D).

3. **New Energy Estimates** → Using this approach, the amount of energy each type of building would use after upgrading to a more advanced BACS was calculated.

4. **EPC Class Recalculation** → Finally, the change in the building's EPC rating thanks to the achievable saving was estimated. Buildings that save more energy would move to a higher (more efficient) EPC class.

For clarity, we kept the thresholds that define EPC classes consistent throughout the analysis. This made it easier to compare how buildings might move between classes with and without BACS system.

## BACS implementation costs

There are few recent and reliable studies available on the average costs of implementing BACS, due in particular to the continuously evolving nature and applications of these technologies. Therefore, this study utilized data from both research and bibliographic sources, as well as information gathered through surveys conducted with members of eu.bac, a significant player in the building automation systems landscape. By cross-referencing this information, the study was able to estimate approximate costs per square meter for implementing these systems in buildings. The focus of the research, as with the rest of the study, remains on thermal BACS systems for heating and cooling. The costs considered thus concern only BACS systems for these applications, leaving out other areas such as lighting and ventilation. However, it is important to note that, according to UNI EN ISO 52120-1, in order to make a building, for example, BACS class A, it is necessary to implement class A automation systems for all different TBSs (Technical Building Systems) and not only for part of them. The cost of implementing Building Automation and Control Systems (BACS) can be difficult to quantify due to the rapid evolution of these technologies and the varying levels of automation that can be applied. Recent and comprehensive studies specifically on BACS costs are scarce, so this study combines data from published research, industry reports, and surveys conducted with eu.bac members, including significant players in the BACS sector. These data points allowed for an estimation of average costs per square meter for BACS implementation in buildings.

In this study, we focus primarily on the costs of thermal BACS systems - those that control heating and cooling. Other areas of automation, such as lighting and ventilation, are not included in this estimate. However, according to the UNI EN ISO 52120-1 standard, achieving a full BACS class (e.g., Class A) requires automation across all Technical Building Systems (TBS), not just thermal systems. Therefore, the costs provided here reflect only partial automation (focused on thermal systems), and additional expenses would be necessary to implement full automation (e.g., adding lighting and ventilation controls).

For the sake of transparency, the study estimates that BACS for heating and cooling (i.e. hydronic balancing) implementation, that would be a first basic step in a renovation and would not cover all aspects of BACS, can account for roughly 10% of the total cost of achieving a full BACS class A system, which requires the integration of automation systems for all TBS of a building. For example, the estimated cost of implementing BACS systems for heating and cooling ranges from €15,000 for Class C systems to €22,000 for Class A systems, per building. These costs are based on average industry estimates provided by eu.bac members and relevant industry sources, in particular a case study within the study "Albesiano et al – BACS: energy performance and technical-economic analysis of HVAC technologies", as summarized in Table 6.6: Devices and Installation Costs of BACS Devices Used in Class A. This table includes costs for HVAC control devices, blind control devices, light and presence sensors for HVAC and blind control, and BMS and installation costs in a small building with a heating system only.

It is important to note that achieving a full Class A system in a single implementation is generally more cost-effective than upgrading incrementally over time. The initial investment may be higher, but spreading the installation over several phases typically results in higher cumulative costs due to repeated mobilization, reconfiguration, and potentially higher equipment costs over time. This is why the cost savings from a comprehensive, one-step installation should be emphasized when considering full BACS automation.

In addition, sources such as the **Siemens Building Technology Report** and industry feedback highlight that costs can vary depending on the building size, complexity, and the specific technical requirements of the automation systems. More detailed references and cost breakdowns can be found in the **CIBSE Guide to BACS Implementation Costs** and **eu.bac's 2023 Industry Survey**.

| | | Class A | Class B |
|---|---|---|---|
| Sector | Building type | [€/sqm] | [€/sqm] |
| Non-residential | Offices | 7,5 | 5,0 |
| | Trade | 7,5 | 5,0 |
| | Education | 5,5 | 3,5 |
| | Health | 5,5 | 3,5 |
| | Hotels and Restaurants | 5,5 | 3,5 |
| | Others | 7,5 | 5,0 |
| Residential | Single family - Terraced houses | 10,0 | 6,5 |
| | Multifamily houses | 7,5 | 5,0 |
| | Apartment blocks | 7,5 | 5,0 |

*Figure 9. Estimated costs for square meter for class A and class B BACS adoption for different building types*

## BACS impact on MEPS

It is crucial not only to assess the absolute impact of Building Automation and Control Systems (BACS) on building energy efficiency ratings but also to understand how these systems can support regulatory compliance, particularly in light of the recently introduced Minimum Energy Performance Standards (MEPS) under the revised Energy Performance of Buildings Directive (EPBD). The EPBD has introduced the ambitious and somewhat controversial requirement for MEPS, which mandates that buildings meet specific energy performance thresholds by set deadlines. This has intensified the need for innovative solutions that can drive buildings towards these targets.

Given this regulatory pressure, it is especially important to evaluate the role BACS can play in helping buildings achieve MEPS compliance. BACS can act as a critical tool in improving energy efficiency by optimizing the performance of heating, cooling, and other building systems, thus enabling a faster and more cost-effective trajectory toward meeting these minimum standards. The methodology for analyzing the potential impact of BACS on MEPS varies by sector due to differences in MEPS requirements for residential and non-residential buildings. In both cases, BACS could offer significant contributions, reducing the overall energy consumption of buildings and thus aiding in the achievement of these regulatory goals.

In the non residential sector, the obligations include setting two energy performance threshold to the effect that 16% and 26% of the national non-residential building stock is above those threshold, and improving all the non-residential buildings below those thresholds from 2030 and 2033 respectively. It is then possible to estimate the number of buildings to be upgraded, the total area to be upgraded based on the composition by type of the worst-performing buildings in each area, and the total investment cost required for such upgrading by considering the energy reduction achievable from BACS class A and B systems related to heating and cooling.

In the residential sector, a very specific reduction in primary energy demand is required by 2030 and 2035, with a significant part of this reduction coming from the efficiency of the worst performing buildings. Starting with the total energy consumption of each area, the required energy reduction can be estimated and, from there, the number and composition by type of buildings to be upgraded with BACS class A or B heating and cooling automation systems to achieve this reduction can be determined. The investment cost required to achieve this target using heating and cooling BACS is then also estimated.

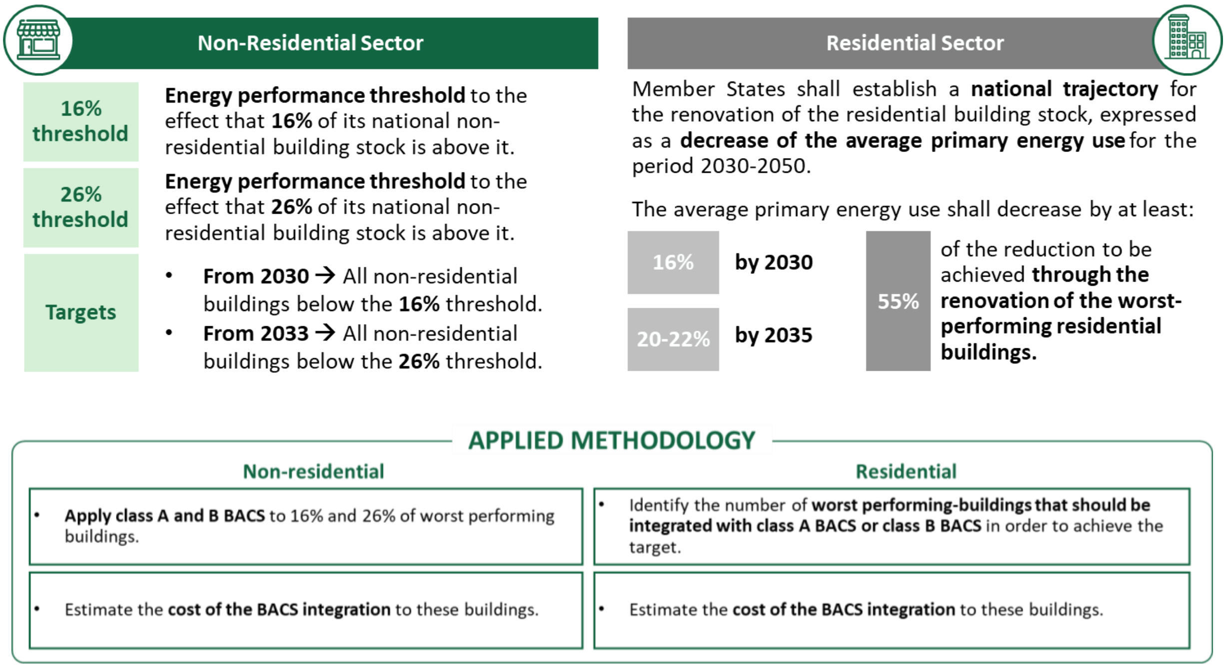



*Figure 10. Graphical representation of the Minimum Energy Performance requirements for the different building sectors, and overview of the used methodology*

# Results

Below are the results of the analysis conducted. The methodology used was previously illustrated. The three interconnected themes discussed provide a deeper understanding of the potential impact of BACS. These themes include:

- **European building stock EPC classes distribution.** This analysis focuses on the current energy consumption situation of buildings in Europe. This step is essential to understand the starting point before the introduction of BACS. The data show how buildings are distributed across different Energy Performance Certificate (EPC) classes. This allows for the identification of which classes require the most urgent interventions and where BACS could have the greatest impact.
- **BACS impact on EPC classes.** In this section, the effectiveness of BACS in improving the energy classes of buildings was estimated. Through simulations and predictive models, it was possible to determine the potential improvement in the EPC classes of existing buildings due to the implementation of BACS.
- **BACS impact on achieving MEPS targets.** The final objective was to analyze how BACS can contribute to achieving the Minimum Energy Performance Standards (MEPS) targets set by the Energy Performance of Buildings Directive (EPBD).

# European building stock EPC classes distribution

For each of the geographical regions considered, criteria for the definition of the uniform, fictitious EPC classes were applied. It's important to note that these distributions are based on an **artificial classification system** created for this study to ensure comparability across regions. This "artificial classification" was necessary to create uniform energy classes across countries with varying national EPC standards, allowing for a clearer analysis of BACS impact on energy performance.

The resulting distribution of EPC classes for non-residential buildings shows some variability across different geographic areas. Looking in detail at each region:

- In the Mediterranean region, EPC class F includes the largest number of buildings, with nearly half, 49.7%, falling into this category. The energy consumption threshold for class G is 470 kWh/sqm.
- For the Nordic region, EPC class F is also the most populated, encompassing 42.5% of buildings. The threshold for class G is set at 430 kWh/sqm, similar to the Mediterranean.
- In the Continental area, EPC class E is the most populated, including 41.0% of buildings. The energy threshold for class G is 490 kWh/sqm.
- The Oceanic region also shows EPC class E as the most populated, but it includes slightly fewer buildings, with 27% falling into this class. The energy threshold for class G in this region is 435 kWh/sqm.

While the energy class distributions share some similarities, such as the significant lack of buildings in the lower energy consumption classes, there are also notable differences. The Continental area has the highest energy threshold for class G, indicating a large number of buildings with high energy consumption. However, it also shows the highest percentage of buildings in class E, demonstrating a substantial number of higher-efficiency buildings.

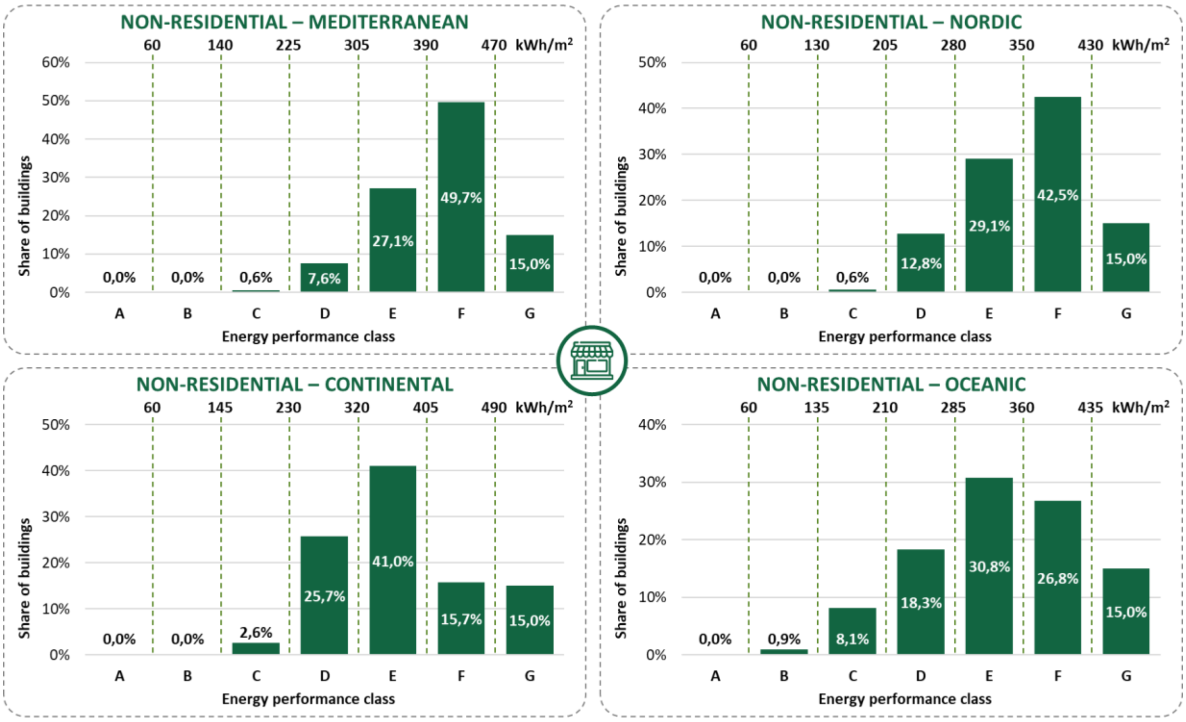



*Figure 11. EPC distributions for the non-residential sector in the different identified geographical areas.*

The resulting distribution of EPC classes for residential buildings is quite similar across different geographic areas, predominantly concentrated in the four classes indicating higher energy consumption per square meter: EPC classes D, E, F, and G. Having a detailed look at each geographic region:

- In the Mediterranean region, EPC class E has the highest number of included buildings, accounting for nearly a quarter of the total. The energy consumption threshold for EPC class G is 235 kWh/sqm.
- The Nordic region shows EPC class D as the most populated, including 22.1% of buildings. Similar to the Mediterranean, the energy threshold for class G is set at 235 kWh/sqm.
- The Continental area has a significant majority of buildings in class F, reaching 30.6% of all buildings. The energy threshold for class G in this region is 260 kWh/sqm.
- The Oceanic region, although EPC class F is also the most populated, includes slightly fewer buildings at 27%. The energy threshold for class G here is 280 kWh/sqm.

Overall, the energy class distributions are comparable across different regions, with minor differences. For instance, the Oceanic region has the highest energy threshold for class G, indicating a higher number of buildings with particularly high energy consumption. However, it also has the highest percentage of buildings with energy consumption below 60 kWh/sqm (3.0%), belonging to EPC class A. In contrast, the Continental area has an extremely low percentage of buildings in class A (0.1%), indicating few buildings with high efficiency. The Nordic region shows distributions and energy consumption patterns very similar to the Mediterranean region.

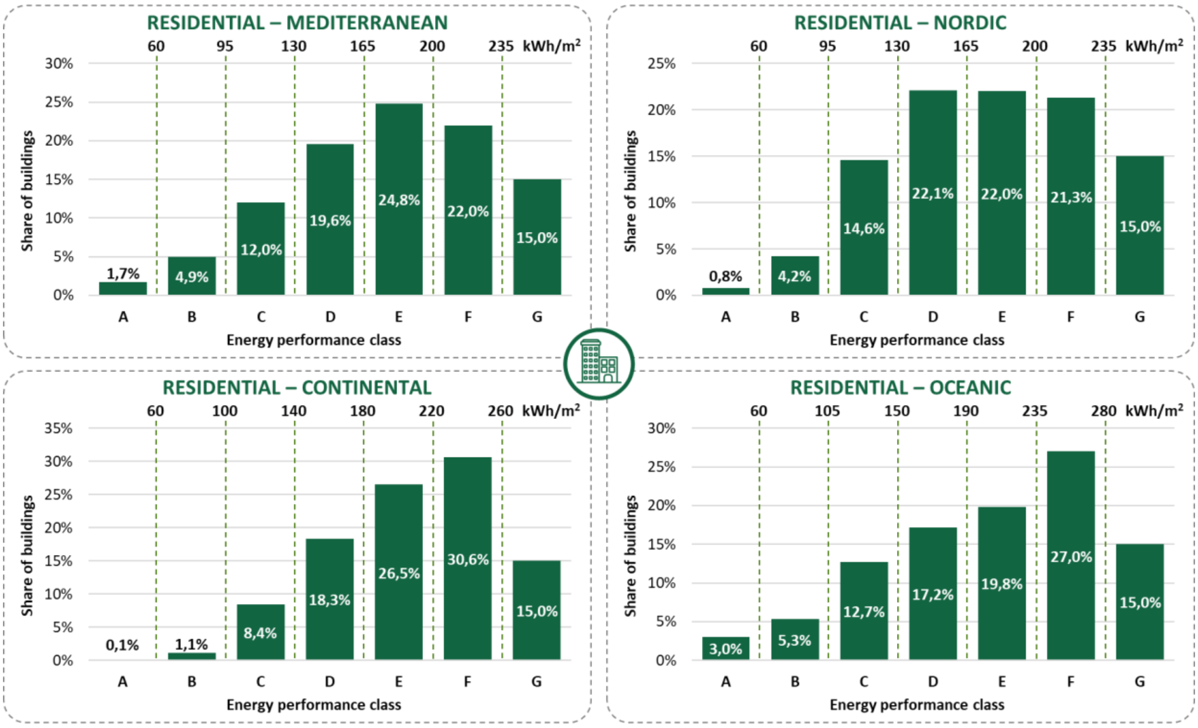



*Figure 12. EPC distributions for the residential sector in the different identified geographical areas.*

From the overall analysis, it is clear that the primary energy demand is significantly higher on average for non-residential buildings compared to residential ones. This is evident in the energy thresholds defining EPC class G and the 15% worst-performing buildings, which are often double for non-residential buildings, especially in regions like the Mediterranean. The lower energy consumption classes for the non-residential sector are predominantly empty across all geographic regions, further highlighting this disparity. This finding supports the **EPBD's ambition** to focus on improving the energy performance of non-residential buildings, which are considered as "low-hanging fruit" for increasing buildings energy efficiency. Given their higher energy demand and the potential for significant improvements with targeted interventions, non-residential buildings represent a key opportunity for achieving energy efficiency gains and meeting climate goals with relatively straightforward and impactful measures, such as the integration of BACS.

It's important to emphasize that these EPC classes are artificially created and arbitrarily defined solely to enable comparisons of energy performance distributions across different geographic areas. Nevertheless, this classification provides valuable insights into the characteristics of buildings in various regions. These defined distributions will serve as the foundation for a consistent and comparable assessment of the potential impact of BACS on EPC classes.

## BACS impact on EPC classes

It has already been discussed how BACS can reduce the energy consumption of buildings, as previously explained. Implementing these systems can significantly lower energy use, potentially allowing buildings to improve their energy performance class. Therefore, it is useful to estimate the potential EPC class improvement enabled by these systems to better understand their impact. This study examines this variation, assuming the application of heating and cooling automation systems of BACS class A and B across the entire European building stock. For a more precise evaluation, the EPC classes improvement is not only considered if the energy reduction allows a shift in EPC class, but also if it allows a movement inside the same class, considering thus classes as a continuous rather than a discrete classification. For example if the application of BACS allows a building in EPC class C to shift from an energy consumption equal to the maximum energy considered for that class, to an energy consumption equal to the middle of the energy range of that class, a shift of 0.5 EPC classes is reported.

EPC classes usually vary with the distribution of energy performance among buildings. For example, EPC class G is defined as the worst-performing 15% of buildings. If all buildings were to reduce their energy consumption, the boundaries of this class would also change. However, for simplicity in comparing results, the study considers the thresholds in Primary Energy Demand for the various classes as fixed, based on previous data. This approach allows for an evaluation of the average class improvement that the implementation of BACS can achieve.

The cost of implementing BACS class A or B systems has been estimated based on average CAPEX costs for integrating heating and cooling automation solutions per square meter, and on data regarding the average building surface for the different archetypes of buildings. This estimation is grounded in research and comparison with real case studies provided by members of eu.bac.

In the non-residential sector, the estimated class improvement ranges from 0.9 to 1.3 classes, indicating better performance compared to the residential sector. This estimate still favors the Nordic region but shows similar improvements for other areas as well.

| | | GEOGRAPHICAL REGION | | | |
|---|---|---|---|---|---|
| NON-RESIDENTIAL SECTOR | | Mediterranean | Nordic | Continental | Oceanic |
| #buildings (mln units) | | 3,2 | 0,3 | 1,3 | 4,6 |
| Class A | EPC improvement | 1,1 classes | 1,3 classes | 1,1 classes | 1,1 classes |
| | Cost* (bln€) | 5 - 7 | 0,8 - 1,2 | 3 - 7 | 20 – 25 |
| Class B | EPC improvement | 1,0 classes | 1,1 classes | 0,9 classes | 1,0 classes |
| | Cost* (bln€) | 3 - 5 | 0,5 - 1 | 2 - 4 | 13 - 18 |

*Figure 13. EPC class improvement and required costs with BACS implementation in the non-residential sector*

| RESIDENTIAL SECTOR | | GEOGRAPHICAL REGION Mediterranean | Nordic | Continental | Oceanic |
|---|---|---|---|---|---|
| #buildings (mln units) | | 26,1 | 2,5 | 16,1 | 52,4 |
| Class A | EPC improvement | 0,8 classes | 1,0 classes | 1,0 classes | 0,8 classes |
| | Cost* (bln€) | 30 - 35 | 2 - 4 | 15 - 25 | 60 – 70 |
| Class B | EPC improvement | 0,6 classes | 0,8 classes | 0,7 classes | 0,6 classes |
| | Cost* (bln€) | 20 - 25 | 1 - 3 | 10 - 15 | 40 - 50 |

*Figure 14. EPC class improvement and required costs with BACS implementation in the residential sector*

For residential buildings, it is evident that the implementation of BACS class A or B systems significantly enhances the Energy Performance Certificate (EPC) ratings of residential buildings. The estimated improvement in EPC classes varies depending on the geographic region and the type of BACS installed. The increase in EPC class due to BACS systems ranges between 0.6 and 1.0 classes, depending on the region and the specific type of BACS. This clearly demonstrates the substantial benefits these systems can bring to the European building stock, nearly achieving an improvement of a full class. The highest class improvements are observed in the Nordic and Continental regions, indicating that these areas would gain the most from the introduction of automation systems. Nevertheless, the positive impact is significant across all geographic areas, proving that the benefits are far from negligible elsewhere.

The implementation of these solutions, while having comparable CAPEX costs per square meter across regions, would require investment levels that vary greatly depending on the geographic area due to the differing numbers of buildings. For the residential sector, full implementation across geographic regions would require investments up to €134 billion for Class A systems and up to €93 billion for Class B systems. Given the smaller number of buildings in the non-residential sector, the required investments would be up to €40 billion for Class A systems and up to €28 billion for Class B systems.

It is crucial to analyze how the effectiveness of BACS varies depending on the initial energy class of a building. Applying BACS to highly efficient buildings (such as those in EPC class A or B) typically results in modest energy savings, as these buildings are often well-insulated and already equipped with advanced Technical Building Systems (TBS). In contrast, applying BACS to buildings with poor energy performance - such as those in EPC class G - yields significantly greater improvements, with the potential for enhancing the building's energy efficiency by up to 2 full EPC classes.

This significant improvement in class G buildings is largely due to their typically poor initial conditions. Class G buildings often have outdated or inefficient TBS, such as heating and cooling systems that lack modern control capabilities, and generally have minimal or no automation in place. Moreover, these buildings often suffer from inadequate insulation, which leads to excessive energy loss through walls, roofs, and windows. As a result, introducing BACS, where the necessary minimum boundary conditions are met, can optimize the use of heating, cooling, and ventilation systems, dramatically reducing energy waste and improving energy efficiency.

However, it is essential to recognize that for BACS to function effectively, certain **minimum conditions** in TBS must be met. If the TBS is too outdated or fundamentally inefficient, BACS may not deliver optimal results. For instance, the building's heating or cooling systems must be in a condition where automation can effectively control and adjust them.

| | RESIDENTIAL | | NON-RESIDENTIAL | |
|---|---|---|---|---|
| EPC CLASS | Class A BACS | Class B BACS | Class A BACS | Class B BACS |
| A | 0,1 | 0,1 | 0,2 | 0,1 |
| B | 0,4 | 0,3 | 0,3 | 0,3 |
| C | 0,6 | 0,5 | 0,6 | 0,5 |
| D | 0,8 | 0,6 | 0,8 | 0,7 |
| E | 1,0 | 0,8 | 1,2 | 1,0 |
| F | 1,2 | 0,9 | 1,6 | 1,4 |
| G | 1,9 | 1,6 | 2,0 | 1,8 |

*Figure 15. Average EPC class improvement with class A and class B BACS integration for different starting EPC classes, for residential and non-residential sectors.*

The implementation of these solutions has thus a significant impact on the energy class of a building, particularly in the non-residential sector, leading to an average improvement of about one EPC class. It is especially effective in enhancing the efficiency of high-energy consumption buildings, where the improvement is substantial, though the energy savings decrease for buildings with advanced energy classes. Assuming these high-consumption buildings are primarily older structures, BACS solutions prove particularly effective for older buildings. For these older buildings, while other efficiency solutions are possible, they are often expensive and require extensive renovations. BACS solutions, on the other hand, can be the optimal and relatively low-cost option for older buildings that are difficult to renovate and have high energy consumption.

## BACS impact on achieving MEPS targets

Considering the introduction of Minimum Energy Performance Standards (MEPS) in the EPBD regulations and, in general, the plausible introduction of increasingly stringent energy efficiency requirements for buildings, it is useful to estimate the contribution that BACS systems can make to achieving these goals, focusing specifically on heating and cooling automation systems. MEPS requirements under the EPBD differ for the residential and non-residential sectors and are therefore analysed separately in this study.

For the non-residential sector, MEPS call for setting two energy performance threshold to the effect that 16% and 26% of the national non-residential building stock is above those threshold, and improving all the non-residential buildings below those thresholds from 2030 and 2033 respectively. This study examines the impact of heating and cooling BACS adoption on these buildings and the associated cost. The focus is particularly on the worst-performing buildings, as they represent the area with the greatest potential for BACS systems application and where efficiency gains are most significant.

To achieve the goal of improving all of the building stock above the 16% threshold from 2030, about 1.5 million buildings would be involved in the geographic areas considered, covering a total area of about 570 million square meters. Estimating the costs of such adoption, and considering the investments differentiated by building type, yields a total estimate of just under €4.1 billion for the entire European region analyzed, in the case of applying BACS class A heating and cooling systems. The adoption of lower-class systems, such as BACS Class B heating and cooling systems, can still offer benefits, albeit small, at a lower cost, estimated at about 2.7 billion €.

| 16% THRESHOLD | | GEOGRAPHICAL REGION | | | |
|---|---|---|---|---|---|
| NON-RESIDENTIAL SECTOR | | Mediterranean | Nordic | Continental | Oceanic |
| #buildings (mln units) | | **3,2** | **0,3** | **1,3** | **4,6** |
| #buildings to be improved (mln units) | | 0,51 | 0,05 | 0,21 | 0,74 |
| Buildings surface to be improved (mln sqm) | | 130,6 | 21,9 | 69,8 | 350,5 |
| Class A | Cost (mln€) | 940 | 130 | 520 | 2.490 |
| Class B | Cost (mln€) | 620 | 90 | 350 | 1.650 |

*Figure 16. Study results for BACS impact on MEPS in 2030 in the non-residential sector*

In order to reach the targets set for 2033, action would be needed on nearly one million additional buildings, with a total of 2.5 million buildings to be upgraded and a total area of more than 1 billion square meters. This would entail an additional investment of €3 billion for the adoption of BACS class A heating and cooling systems in the impacted buildings, bringing the total investment to €7.2 billion. For Class B BACS systems, an additional investment of €2 billion would be required, bringing the total investment to €4.7 billion.

| 26% THRESHOLD | | GEOGRAPHICAL REGION | | | |
|---|---|---|---|---|---|
| NON-RESIDENTIAL SECTOR | | Mediterranean | Nordic | Continental | Oceanic |
| **#buildings (mln units)** | | **3,2** | **0,3** | **1,3** | **4,6** |
| **#buildings to be improved (mln units)** | | 0,83 | 0,08 | 0,34 | 1,20 |
| **Buildings surface to be improved (mln sqm)** | | 180,9 | 32,6 | 124,8 | 680,1 |
| **Class A** | **Cost (mln€)** | 1.290 | 200 | 890 | 4.740 |
| **Class B** | **Cost (mln€)** | 860 | 130 | 590 | 3.130 |

*Figure 17. Study results for BACS impact on MEPS in 2033 in the non-residential sector*

The residential sector, on the other hand, has targets structured differently, imposing a target share of the reduction in building energy consumption and an improvement of the worst-performing buildings to contribute to that reduction. The goal is to reduce building energy consumption by 16% by 2030 and 20-22% by 2035. 55% of this reduction must come from the efficiency of worst-performing buildings. This study estimates the energy reduction needed from worst-performing buildings, quantifies the buildings to be equipped with BACS heating and cooling systems of various classes to achieve this reduction, and estimates the associated costs.

To achieve the 16% reduction in energy consumption by 2030, a reduction in Primary Energy Demand (PED) for buildings of about 250 TWh would be required in the geographic areas considered, which is about 9% of the estimated PED consumption for the European area considered. This reduction is achievable by adopting heating and cooling BACS Class A systems for 25 million buildings, with estimated costs of about €34 billion. If, on the other hand, class B BACS systems were adopted, more buildings would need to be involved, as these systems are less efficient, totaling just over 33 million buildings and costing slightly less, estimated at about €29 billion.

Achieving the goals set for 2035 of greater reductions in building energy use will require additional investment and the involvement of more buildings. An additional 10 million buildings will thus be made efficient, bringing the total to about 35 million buildings in the case of adopting BACS Class A systems, or an additional 13 million buildings, for a total of 46.8 million, in the case of adopting BACS Class B heating and cooling systems. The cost of this additional adoption would be €13 billion, bringing the total to €47 billion for BACS Class A systems. In the case of BACS Class B systems, the required investment would be slightly lower, with an additional cost of about €10 billion, reaching a total of €40.5 billion.

| 16% IMPROVED | | GEOGRAPHICAL REGION | | | |
|---|---|---|---|---|---|
| RESIDENTIAL SECTOR - 2030 | | Mediterranean | Nordic | Continental | Oceanic |
| #buildings (mln units) | | **26,1** | **2,5** | **16,1** | **52,4** |
| Total PED (TWh) | | **735** | **65** | **455** | **1.600** |
| 16%*55% = 9% | | | | | |
| Required PED reduction (TWh) | | 64,7 | 5,7 | 40,0 | 140,8 |
| Class A | #buildings to be improved (mln) | 5,5 (21%) | 0,9 (37%) | 5,0 (31%) | 13,6 (26%) |
| | BACS cost (mln€) | 8.600 | 1.000 | 5.800 | 19.00 |
| Class B | #buildings to be improved (mln) | 8,1 (31%) | 1,2 (46%) | 6,4 (40%) | 17,8 (34%) |
| | BACS cost (mln€) | 7.900 | 800 | 4.900 | 15.600 |

*Figure 18. Study results for BACS impact on MEPS in 2030 in the residential sector*

| 22% IMPROVED | | GEOGRAPHICAL REGION | | | |
|---|---|---|---|---|---|
| RESIDENTIAL SECTOR - 2035 | | Mediterranean | Nordic | Continental | Oceanic |
| #buildings (mln units) | | **26,1** | **2,5** | **16,1** | **52,4** |
| Total PED (TWh) | | **735** | **65** | **455** | **1.600** |
| 22%*55% = 12% | | | | | |
| Required PED reduction (TWh) | | 88,9 | 7,8 | 55,1 | 193,3 |
| Class A | #buildings to be improved (mln) | 8,4 (32%) | 1,2 (49%) | 6,6 (41%) | 18,9 (36%) |
| | BACS cost (mln€) | 11.900 | 1.400 | 8.400 | 26.200 |
| Class B | #buildings to be improved (mln) | 11,7 (45%) | 1,6 (62%) | 8,9 (55%) | 24,6 (47%) |
| | BACS cost (mln€) | 11.000 | 1.200 | 7.000 | 21.400 |

*Figure 19. Study results for BACS impact on MEPS in 2035 in the residential sector*

## Costs comparison

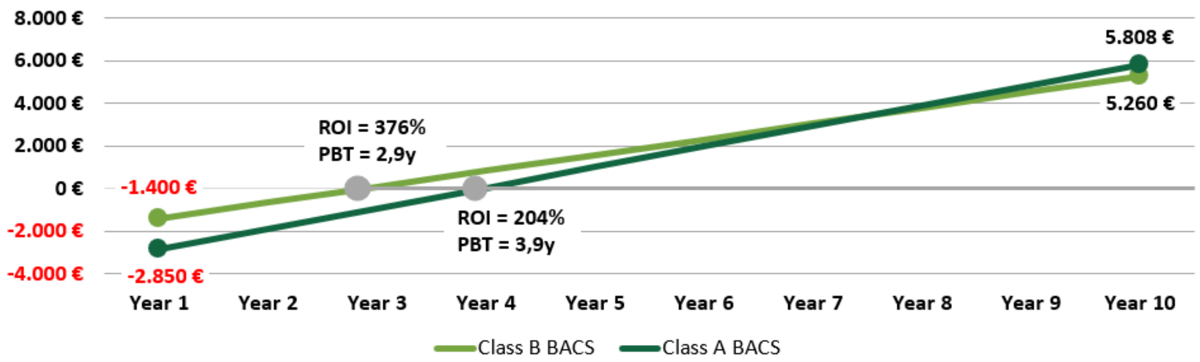
Within building efficiency solutions, it is crucial to understand the economic and performance impact of BACS solutions also with respect to other possible building efficiency solutions. Considering the implementation of common energy efficiency solutions, taking as an example an average-size apartment of 110 square meters, the required investment can be around €45 thousand, allowing energy efficiency improvements of up to 80%. These solutions include installing a thermal coat, replacing windows and doors with more efficient models, and implementing automation systems

| SYSTEM | INVESTMENT |
|---|---|
| **Thermal envelope** | 27.000 € |
| **Efficient windows** | 18.000 € |
| **Heat pump installation** | 7.000 € |
| **Condensing boiler installation** | 3.000 € |
| **Photovoltaic panels** | 3.700 € |

*Figure 20. Estimated implementation costs for alternative building efficiency solutions*

By focusing on Class A BACS systems, a potential 26% improvement in energy efficiency can be achieved at an estimated cost of about €10 per square meter with the implementation of just heating and cooling automation systems. For an average-sized apartment (about 110 square meters), this translates into an additional cost of about €1,100, a relatively small expense compared to the total investment in efficiency upgrades. This highlights the high potential for cost-effective efficiency achieved by building automation systems.

The estimated costs of €10 per square meter were obtained through literature research and feedback from practitioners. However, these costs refer only to automation systems for thermal systems, particularly heating and cooling. To achieve a full BACS class rating for the building, automation systems for other TBS like lighting and ventilation will also need to be integrated. Studies report that on average heating and cooling BACS (i.e. hydronic balancing) contribute to approximately 10% of the investment for a full BACS integration based on average industry. These costs are based on average industry estimates provided by eu.bac members and relevant industry sources, in particular a case study within the study “Albesiano et al – BACS: energy performance and technical-economic analysis of HVAC technologies”, as summarized in Table 6.6: Devices and Installation Costs of BACS Devices Used in Class A. This table includes costs for HVAC control devices, blind control devices, light and presence sensors for HVAC and blind control, and BMS and installation costs in a small building with a heating system only. The adoption of heating and cooling BACS constitutes a basic intervention in achieving a full advanced BACS solution (BACS class A), requiring a complete adoption of automation systems for all TBS of a building. This will however also lead to a further increase in energy efficiency, exceeding 26% savings and surpassing 30%, achieved with and approximate total investment, considering the previous example, of €11 thousands for a full BACS class A system implementation.




| | Adoption | | | | | | | | | End of life |
|---|---|---|---|---|---|---|---|---|---|---|
| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 |
| Class B thermal BACS | - 1.400 € | - 660 € | 80 € | 820 € | 1.560 € | 2.300 € | 3.040 € | 3.780 € | 4.520 € | 5.260 € |
| Class A thermal BACS | - 2.850 € | - 1.888 € | - 926 € | 36 € | 998 € | 1.960 € | 2.922 € | 3.884 € | 4.846 € | 5.808 € |

*Figure 21. Estimated, cumulated costs and savings for BACS class B and A systems installation*

Knowing the potential energy savings that the considered thermal BACS can provide, it is then possible to estimate the economic saving achievable, and thus the payback period of an investment in systems of different BACS classes. For a 110 square meters apartment, for example, it can be considered a 1.400 € investment in BACS class B systems and 2.850€ investment in BACS class A (including installation and other complementary costs on top of the previously mentioned 10€ per square meter). A 20% and 26% energy saving is thus possible, which can lead on average to 740€ and 962€ of yearly savings, translating into a 3-years payback period for BACS class B systems and 4-years payback period for BACS class A systems, and an economic gain of 5.260€ and 5.808€ respectively over the complete 10-years lifespan of the systems. These solutions thus present good payback times (PBT) of 2,9 and 3,9 years, with an optimal return on the investment (ROI) of 376% and 204% respectively. BACS solutions show not only a relatively low expense for the achievable energy savings, but also a positive economic impact in terms of monetary savings and short payback periods.

## Conclusions

The study highlighted how Building Automation and Control Systems (BACS) represent a **highly effective solution for reducing energy consumption in buildings**. These systems have a significant impact on improving the Energy Performance Certificate (EPC) class of buildings, with the potential to upgrade an entire class. This level of improvement reflects a **substantial enhancement in energy efficiency**, offering clear benefits for both building owners and the environment.

BACS have demonstrated their effectiveness **in both residential and non-residential sectors**. While the degree of energy reduction may vary between these sectors, the results consistently show the versatility and efficiency of these systems in a wide range of building types and contexts.

A key finding from this study is the important role BACS can play in helping buildings meet **Minimum Energy Performance Standards (MEPS)** and other regulatory requirements. By implementing BACS, buildings can achieve regulatory compliance with relatively low financial investment, making it a particularly attractive option for building owners who are aiming to align with future regulatory standards.

BACS are especially beneficial for older buildings, where energy efficiency is often poor. The integration of BACS into these buildings can lead to substantial energy savings without the need for complex structural renovations. This highlights the value of BACS in upgrading the energy performance of aging building stock across Europe.

In addition to energy savings, the study emphasized the **low initial cost and short payback period** associated with BACS implementation. This means that despite the upfront investment, BACS generate significant long-term economic benefits, making them not only an energy-efficient choice but also a **cost-effective** one. As a result, **BACS solutions should be prioritized in financial measures** designed to support the energy transition, as they offer an impactful and cost-efficient path to improving building energy performance.

Furthermore, BACS play a key role in supporting the **Smart Readiness Indicator (SRI)**, a metric introduced by the **Energy Performance of Buildings Directive (EPBD)** to assess the digitalization and automation capabilities of buildings. By prioritizing BACS, building owners can also improve their SRI scores, which will become increasingly important in the assessment of smart, energy-efficient buildings. Promoting BACS will not only help meet energy performance targets but also facilitate the smart management and adaptability of buildings in line with SRI objectives.

In addition to energy savings, BACS provide a **multiplier effect** that goes beyond energy efficiency. BACS contribute to the **health and comfort of building occupants** by optimizing indoor environments, ensuring better air quality, and maintaining ideal thermal conditions. They also enable **integration with the smart grid**, facilitating **demand response** capabilities where buildings can adjust their energy consumption based on grid conditions, thereby reducing peak demand and contributing to grid stability. BACS further contribute to **reduced operational costs** by enabling **predictive maintenance** and optimizing the performance of building systems. Moreover, the data generated by BACS supports **data-driven future investments** and policy decisions, helping building owners and policymakers identify areas for further improvement and innovation in energy management.

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