



Transparent description of each national and EU technical methodology for EPB Assessment / **D2.1**

WP2 National & EU baseline contextualisation: EPB Assessments and Certification Schemes

T2.1 National procedures and instrument analysis and characterization

T2.3 EU procedures, schemes and implementing acts analysis and characterisation

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3. Executive summary

Deliverable D2.1 has been designed to create a common overview for everyone who will develop, test or use the future iEPB instruments. In keeping with the project's primary objective, the document maps today's regulatory, methodological and digital landscape from two complementary perspectives.

At European Union level it catalogues the EPB standard family, the Commission's implementing acts and the emerging "next generation" assessment methods. At national level it reconstructs the entire assessment chain in Austria, the Netherlands and Spain, examining how each country turns Annex A choices into climate zones, default schedules, primary-energy factors, software ecosystems and data flows. Chapter 6, for instance, follows the data through the Austrian, Dutch and Spanish systems step by step and shows where local decisions enhance data quality and where fragmentation still blocks interoperability.

Although the three demonstration countries share many headline indicators, they express and calculate them in subtly different way. Standardising the way results are described therefore offers a faster path to harmonisation than trying to standardise every national calculation rule. Second, the project uses the term "data model" in its strict information-science sense: it is a structured representation of the inputs and outputs of national EPB calculations, not the calculation algorithms themselves. This distinction matters because aligning inputs and outputs yields immediate benefits, such as comparability, automated quality checks, machine readability. The iEPB "schema" is an open, scalable, software-ready description of such inputs and outputs, complete with validation rules and an example computer file format.

D2.1 converts these conceptual insights into a concrete design brief: it lists the mandatory data fields already exchanged in the three countries, it flags the gaps a converged schema must bridge, and it identifies the digital interfaces that must be in place if the forthcoming web application is to interact with national EPC registries and third-party tools. By showing where high-quality data are already collected and where they are missing, the deliverable supplies policy-relevant evidence that will later feed into national recommendations and to the CEN and ISO working groups soon to prepare "software-ready" revisions of the EPB standard family.

Taken together, these elements make D2.1 both a state-of-play report and a launch pad: it establishes a common technical language for the consortium, sets measurable requirements for the iEPB schema and gives external stakeholders a transparent view of the project's EPBD implementation context and intended trajectory.



4. Introduction

4.1 Overview

The European Union's commitment to sustainability and energy efficiency in the building sector is noteworthy through the progressive adaptations of the Energy Performance of Buildings Directive (EPBD). Since its inception in 2002, the EPBD has been a cornerstone of the EU's legislative framework, aimed at reducing energy consumption in buildings and promoting the integration of renewable energy sources. This introductory chapter provides a quick analysis of the evolutionary trajectory of the EPBD, capturing its amendments and enhancements across the years 2002, 2010, 2018, and the recent 2024 recast.

Initially established in 2002, the Energy Performance of Buildings Directive (EPBD) was the first EU-wide framework aimed at promoting the improvement of energy performance in buildings. Its primary goal was to reduce energy consumption and associated greenhouse gas emissions, both critical to the EU's broader environmental and energy security strategies. A central feature introduced was the Energy Performance Certificate (EPC), designed to provide transparency regarding the energy efficiency of buildings, thereby encouraging improvements and informing potential buyers and tenants. EPCs were a pioneering step, helping raise awareness and stimulating action on energy efficiency in the real estate market. The 2002 version of the EPBD also introduced the requirement for regular inspections of boilers and air-conditioning systems, aimed at optimising their efficiency and encouraging replacement as needed. However, the scope of inspections in this initial version was somewhat limited, focusing primarily on larger heating and cooling systems.

In 2010, the EPBD underwent a major revision, strengthening the role of EPCs by making their issuance and publication mandatory whenever a building was constructed, sold, or rented. Public buildings and those frequently visited by the public were also required to display their EPCs in a prominent location. This revision transformed EPCs into more than just an informational tool, requiring them to include specific recommendations for improving energy efficiency, thereby guiding renovation efforts. Additionally, the 2010 revision introduced Nearly Zero-Energy Buildings (NZEBs), mandating that by 2021, all new buildings would need to comply with NZEB performance. These buildings were designed to have very high energy performance, with the small amount of energy they required largely coming from renewable sources produced on-site or nearby. The 2010 revision also expanded the scope of inspections. Regular inspections for heating and air-conditioning systems were now required across the EU as a key measure to reduce energy consumption, emissions, and improve the overall energy performance of buildings.

The 2018 revision built on these measures and marked a significant shift in the EPBD's focus on smart technologies and further energy savings. The concept of NZEB was reinforced, reinstating that by 2021 all new buildings meet NZEB performance. EPCs were updated, ensuring that they provided accurate information for NZEBs. A significant innovation in this version was the introduction of the Smart Readiness Indicator (SRI), designed to assess the readiness of buildings to optimize and foster



flexible energy consumption through smart technologies such as building automation and controls, smart meters, and energy storage systems. Alongside, minimum requirements for building automation and controls systems for non-residential buildings were introduced. Inspections were also further refined in the 2018 update, requiring not only inspections of heating and air-conditioning systems but also expanding these to cover ventilation systems where applicable.

The 2024 recast of the EPBD, aligned with the European Green Deal, introduced the concept of Zero Emission Buildings (ZEBs), which went beyond NZEBs by addressing not only operational energy efficiency but also the entire lifecycle emissions of buildings (from construction, operation, to decommissioning). ZEBs aim to achieve net-zero emissions, and EPCs shall be updated to capture and report on the full carbon footprint of buildings. The 2024 revision also placed a greater emphasis on digitalization within the building sector, expanding the role of the Smart Readiness Indicator (SRI) to help assess and optimize building operations. In this version, inspections shall be further enhanced. In addition to the mandatory inspections for heating, air-conditioning, and ventilation systems, the 2024 recast emphasized the importance of regularly checking the efficiency of all building systems, particularly in the context of ZEBs and smart buildings. A notable addition was the introduction of provisions to improve Indoor Environmental Quality (IEQ), recognizing the importance of promoting healthier and more comfortable and productive living and working spaces. These provisions addressed factors such as air quality, lighting, thermal comfort, and acoustics within buildings. This marked a shift towards a more holistic approach to building performance, focusing not just on energy efficiency but also on creating environments that support human health and productivity.

In summary, the evolution of the EPBD has consistently raised the ambition for energy performance in buildings across the EU. EPCs have developed from a basic transparency tool in 2002 into a comprehensive instrument that guides the renovation, decarbonization, and smart management of the building sector. The introduction of NZEBs in 2010, the expansion to ZEBs in 2024, along with the Smart Readiness Indicator (SRI) and progressively broader inspection requirements for heating, air-conditioning, and ventilation systems, ensure that buildings are at the forefront of the EU's long-term energy and climate strategies. These measures support the EU's ambition to fully decarbonize its building stock by 2050, making buildings a cornerstone of its broader sustainability goals.

This introductory chapter further delves briefly into each version of the EPBD, examining the implications of its regulatory changes and the broader impact on the EU's energy landscape, aiming to provide stakeholders with a clearer understanding of the directive's progression and its instrumental role in shaping a sustainable and energy-efficient building stock.

4.2 EPBD I (2002 original)

The original Energy Performance of Buildings Directive (EPBD), officially known as Directive 2002/91/EC, was adopted by the European Union in December 2002 and came into force in January 2003. The Energy Performance of Buildings Directive (EPBD) I (2002 original) can be found on the EUR-Lex website [1].



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This directive represented the EU's first major legislative effort aimed at improving the energy performance of buildings across member states, recognizing the significant potential for energy savings in the building sector, which accounts for approximately 40% of the EU's total energy consumption.

The EPBD I set out several key objectives and measures to increase energy efficiency in buildings:

- **Energy Performance Certification (EPCs):** It introduced the requirement for EPCs for buildings when constructed, sold, or rented out. These certificates provide information on a building's energy performance.
- **Minimum Energy Performance Requirements (MEPR):** Each EU member state was tasked with establishing its own national requirements for the energy performance of buildings, based on a common framework provided by the directive, for new buildings and for existing buildings that undergo major renovation.
- **Energy performance calculation methodology:** It mandated the creation of a methodology for calculating the integrated energy performance of buildings. This methodology would serve as the basis for the energy performance certificates and the minimum energy performance requirements.
- **Heating and cooling system inspections:** The EPBD introduced regular inspections of boilers and air conditioning systems in buildings to ensure they operate efficiently.

Through a series of stipulated articles and annexes, the directive outlines systematic approaches and measures to achieve significant improvements in energy performance:

- **Article 1 Objective:** Sets the overall objective of promoting the improvement of the energy performance of buildings within the EU.
- **Article 2 Definitions:** Defines key terms related to building energy performance, such as "building", "energy performance of a building", "energy performance certificate", and technical components like "CHP", "air-conditioning system", "boiler", "effective rated output", and "heat pump", setting a standardized framework for their application throughout the Directive.
- **Article 3 Adoption of a methodology:** Mandates the adoption of a methodology for calculating the energy performance of buildings.
- **Article 4 Setting of energy performance requirements:** Concerns setting minimum energy performance requirements for new and existing buildings.
- **Article 5 New buildings:** Focuses on the energy performance of new buildings.
- **Article 6 Existing buildings:** Addresses the energy performance of existing buildings undergoing major renovation.
- **Article 7 Energy performance certificate:** Introduces the energy performance certification of buildings.
- **Article 8 Inspection of boilers and Article 9 Inspection of air-conditioning systems:** Deal with the regular inspection of boilers and air-conditioning systems, respectively.
- **Article 10 Independent experts:** Mandates the independence of qualified and/or accredited experts for Articles 7, 8, and 9.



- **Articles 11 to 17 Various administrative provisions:** Primarily address administrative aspects related to the evaluation, information dissemination, framework adaptation, committee guidance, transposition, implementation, and enforcement of the directive.
- **Annex General framework for the calculation of energy performance of buildings (Article 3):** Provides detailed technical guidelines and specifications to support the implementation of the directive, specifically focusing on the methodology for calculating the energy performance of buildings as outlined in Article 3.

The implementation of the EPBD I marked a significant step towards reducing energy consumption and CO₂ emissions from the EU's building stock. However, the directive's impact varied across member states, depending on the stringency of pre-existing national regulations and the effectiveness of the implementation process. One of the challenges identified in the early years was the diverse range of energy performance calculation methods used across the EU, which made comparison and benchmarking difficult.

Mandate M/343, by the European Commission to the European standardization organizations, namely CEN, CENELEC, and ETSI, as part of the implementation of the Energy Performance of Buildings Directive (EPBD) I, initiated the development of a series of European Standards (ENs) to support the calculation of energy performance of buildings across EU member states. The standards developed under this mandate were intended to harmonize the way energy performance is calculated across different member states, making the results comparable and reliable. This includes methodologies for calculating integrated energy efficiency and use of renewable sources in buildings. The mandate covered aspects such as thermal performance, heating systems, air conditioning, lighting, and overall building energy requirements, which were critical for achieving the objectives of the EPBD. The development of these standards began shortly after the EPBD was adopted in 2002. The initial standards were drafted and iteratively refined over the next several years. Most of the key standards under this mandate were published between 2007 and 2010.

4.3 EPBD II (2010 recast)

The Energy Performance of Buildings Directive (EPBD), initially introduced in 2002, was updated in 2010 to further enhance the energy efficiency of buildings within the European Union. The 2010 EPBD (Directive 2010/31/EU) brought several key additions and changes compared to the original 2002 Directive. The full text of the EPBD II can be accessed via the EUR-Lex website [2].

The 2010 revision introduced the following key additions:

- **Strengthening of Energy Performance Certificates (EPCs):** More stringent requirements for the issuance and display of EPCs were introduced.
- **Introduction of Nearly Zero-Energy Buildings (NZEB):** A significant addition was the requirement for Member States to ensure that all new buildings are nearly zero-energy buildings by 2021 (public buildings by 2019).
- **Regular inspection of heating and air-conditioning systems:** Enhanced rules on the regular inspection of heating and air-conditioning systems.



- **Independent control systems:** Introduction of independent systems for the control and monitoring of the energy performance certificate issuance.
- **Cost-optimality framework:** One of the most significant additions in the 2010 revision was the introduction of the cost-optimality framework. This framework required Member States to define minimum energy performance requirements based on cost-optimal levels.

Through a series of stipulated articles and annexes, the EPBD II enhances systematic approaches and introduces new measures to achieve significant improvements in the energy performance of buildings:

- **Article 1 Subject matter:** This article outlines the directive's goal to improve the energy performance of buildings within the EU, considering climatic conditions, cost-effectiveness, and indoor climate requirements.
- **Article 2 Definitions:** Provides definitions for terms such as "building", "nearly zero-energy building", and "technical building system", ensuring clarity and uniformity in the application of the directive.
- **Article 3 Adoption of a methodology for calculating the energy performance of buildings:** Member States must adopt a common framework for calculating the integrated energy performance of buildings.
- **Article 4 Setting of minimum energy performance requirements:** Sets the requirement for Member States to ensure that buildings meet minimum energy performance requirements aimed at achieving cost-optimal levels.
- **Article 5 Calculation of cost-optimal levels of minimum energy performance requirements:** The Commission established a comparative methodology framework for calculating cost-optimal energy performance levels.
- **Article 6 New buildings:** Requires that new buildings meet the minimum energy performance requirements and considers the feasibility of high-efficiency alternative systems before construction.
- **Article 7 Existing buildings:** Ensures that buildings undergoing major renovations meet minimum energy performance requirements.
- **Article 8 Technical building systems:** Member States must set system requirements for the overall energy performance and proper installation of technical building systems.
- **Article 9 Nearly zero-energy buildings:** Sets targets for new buildings to be nearly zero-energy by 31 December 2020 and for public buildings by 31 December 2018.
- **Article 10 Financial incentives and market barriers:** Discusses measures beyond directive requirements, which promote improved energy performance in buildings.
- **Article 11 Energy performance certificates:** Establishes the need for energy performance certificates that include recommendations for cost-effective improvements.
- **Article 12 Issue of energy performance certificates:** Specifies requirements for issuing energy performance certificates for new buildings or units and when major renovations or sales occur.
- **Article 13 Display of energy performance certificates:** Requires the display of energy performance certificates in buildings occupied by public authorities and frequently visited by the public.



- **Article 14 Inspection of heating systems:** Details the inspection requirements for heating systems, including the assessment of boiler efficiency and system sizing.
- **Article 15 Inspection of air-conditioning systems:** Outlines the inspection requirements for air-conditioning systems, focusing on efficiency and appropriate sizing.
- **Article 16 Reports on the inspection of heating and air-conditioning systems:** Mandates that inspection reports include recommendations for improving system energy performance.
- **Article 17 Independent experts:** Ensures that the certification and inspection processes are carried out by qualified and accredited experts.
- **Article 18 Independent control system:** Member States must ensure that independent control systems are in place for energy performance certificates and inspection reports.
- **Articles 19 to 31 Various administrative provisions:** These articles primarily address administrative aspects related to the evaluation, information dissemination, consultation processes, technical adaptations, delegation of powers, and the committee's operation. Additionally, they cover the transposition, implementation, enforcement, and the formal addressing of the directive to Member States. Each provision ensures effective governance, compliance with the Directive's goals, and facilitates updates and adaptations to reflect technological progress and evolving regulatory needs.
- **Annex I Common general framework for the calculation of energy performance of buildings (referred to in Article 3):** Sets requirements for the methodology for calculating the energy performance of buildings, considering heating, cooling, lighting, and various building characteristics to ensure energy use is estimated accurately and transparently.
- **Annex II Independent control systems for energy performance certificates and inspection reports:** Establishes the requirement for random, statistically significant verification of energy performance certificates and inspection reports to ensure accuracy and compliance with the Directive's standards.
- **Annex III Comparative methodology framework to identify cost-optimal levels of energy performance requirements for buildings and building elements:** Provides a framework for Member States to calculate cost-optimal energy performance levels, considering various factors like use patterns, climate conditions, and economic aspects, accompanied by guidelines for implementation.
- **Annexes IV and V Repeals, transpositions, and correlation table:** Annex IV specifies the time limits for the transposition into national law and dates of application. Annex V provides a comprehensive correlation table that aligns and maps the provisions of Directive 2002/91/EC with the new Directive 2010/31/EU.

The implementation of the EPBD II represented an enhancement of the EU's efforts to reduce energy consumption and CO₂ emissions from its building sector. This revision built upon the 2002 directive, introducing stricter measures such as nearly zero-energy buildings and comprehensive energy performance certificates. The impact of the EPBD II, however, continued to vary across member states, influenced by the rigor of existing national regulations and the effectiveness of local implementation strategies. A significant challenge identified was the ongoing inconsistency in energy performance calculation methods across the EU, which complicated efforts to compare and benchmark energy efficiency effectively. This highlighted the need for more standardized



approaches to ensure uniformity and effectiveness in achieving the directive's energy reduction goals.

Mandate M/480, commissioned by the European Commission to CEN, CENELEC, and ETSI, as part of the EPBD II, triggered the further formulation of a suite of European Standards (ENs) aimed at establishing a common framework for the assessment of the energy performance of buildings across EU member states. These standards were devised to streamline the methodology for evaluating energy performance, ensuring consistency and accuracy in results. Central to this endeavour was the establishment of coordinated and interlinked standards aligned with the provisions of the EPBD II. The development of these standards commenced shortly following the adoption of the EPBD II in 2010, with initial drafts refined through iterative processes in subsequent years. Most standards under this mandate were released between 2017 and 2019, marking a pivotal phase in laying down the technical framework necessary for EU member states to effectively implement the directive by delineating clear, standardized criteria for energy performance evaluations.

While Mandate M/343 primarily established the fundamental technical criteria for energy performance calculations, Mandate M/480, as a subsequent iteration, aimed to refine and expand upon these standards. Mandate M/480 not only continued the efforts to harmonize energy performance assessment methodologies but also brought in a more holistic and level playing field approach as well as incorporated advancements in technology and understanding. Overall, Mandate M/480 represents a progression from the foundational work of Mandate M/343, reflecting an evolution in the approach towards achieving energy efficiency objectives in building design and operation across the EU, with some standards developed in collaboration with ISO resulting in EN/ISO standards (ISO 52000 family).

4.4 EPBD III (2018 amended)

The EPBD 2018 further builds upon the EPBD II and introduces several enhancements to further promote energy efficiency and sustainability in building design, construction, and operation. Unlike a full revision, the EPBD III represents a more targeted update, focusing on specific areas for improvement within the existing framework. The full text of Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings (EPBD II) and Directive 2012/27/EU on energy efficiency (Energy Efficiency Directive, EED I) can be accessed through the EUR-Lex website [3].

The key enhancements brought about by the EPBD III in comparison to the EPBD II are as follows:

- **Strengthened energy performance requirements:** The EPBD III enhances the energy performance requirements for new buildings, setting more ambitious targets for energy efficiency. This includes stricter requirements for heating, cooling, ventilation, lighting and building automation and control systems.
- **Promotion of Nearly Zero-Energy Buildings (NZEBS):** The EPBD III places a greater emphasis on promoting the concept of NZEBs.



- **Renovation strategies:** The EPBD III introduces measures to encourage the renovation of existing buildings to improve their energy performance. This includes setting targets for the renovation of public buildings and promoting the use of innovative financing mechanisms for renovation projects.
- **Smart technologies and building automation and controls:** The EPBD III encourages the use of smart technologies and building automation and control systems in buildings to optimize and make flexible energy usage and enhance comfort for occupants.
- **Enhanced inspection and monitoring:** The EPBD III emphasizes the importance of regular inspection and monitoring of building energy performance to ensure compliance with energy performance requirements.

Through a targeted set of amendments and additions, the EPBD III enhances systematic approaches and introduces new measures via the following articles:

- **Article 1 Amendments to Directive 2010/31/EU:** Updates definitions related to technical building systems, building automation, heating systems, heat generators, energy performance contracting, and micro isolated systems.
- **Article 2a Long-term renovation strategy:** Requires each Member State to establish a long-term renovation strategy for residential and non-residential buildings to achieve highly energy-efficient and decarbonized building stock by 2050. This article, previously part of the Energy Efficiency Directive (EED I), has been moved to the Energy Performance of Buildings Directive (EPBD) with the 2018 review.
- **Article 6 New buildings:** Mandates Member States to ensure new buildings meet minimum energy performance requirements and consider high-efficiency alternative systems before construction.
- **Article 8 Technical building systems, electromobility, and Smart Readiness Indicator (SRI):** Sets requirements for optimizing energy use of technical building systems, installing recharging points for electric vehicles, and developing a smart readiness indicator for buildings.
- **Article 14 Inspection of heating systems:** Establishes regular inspections for parts of heating systems in buildings with effective rated output over 70 kW to assess efficiency and sizing.
- **Article 15 Inspection of air-conditioning systems:** Mandates regular inspections of air-conditioning systems in buildings with effective rated output over 70 kW to assess efficiency and sizing.
- **Article 19 Review:** Requires the Commission to review the Directive by 2026 and assess the potential for integrated district or neighbourhood approaches in building and energy efficiency policy.
- **Article 19a Feasibility study:** Directs the Commission to conduct a feasibility study before 2020 to explore the introduction of standalone ventilation system inspections and optional building renovation passports (RPs).
- **Article 20 Information for building owners:** Requires Member States to provide information to building owners or tenants on energy performance certificates, cost-effective measures for improving energy performance, and replacing fossil fuel boilers with sustainable alternatives.



- **Article 23 Exercise of the delegation:** Specifies the conditions for the Commission to adopt delegated acts related to certain articles in the Directive.
- **Article 26 Committee procedure:** Establishes procedures for the Commission to be assisted by a committee in implementing the Directive.
- **Annex I Common general framework for the calculation of energy performance of buildings (referred to in Article 3):**
 - The energy performance assessment of buildings now incorporates calculated or actual energy usage, encompassing space heating, cooling, domestic hot water, ventilation, built-in lighting, and technical building systems. Energy performance is quantified using a numeric indicator of primary energy use per square meter per year ($\text{kWh}/(\text{m}^2\cdot\text{y})$), facilitating energy performance certification and compliance with minimum energy performance standards. Member States are mandated to outline their national calculation methodologies in alignment with overarching standards such as ISO 52000-1, 52003-1, 52010-1, 52016-1, and 52018-1, ensuring transparency and fostering innovation.
 - Energy requirements for various building functions are calculated to optimize health, indoor air quality, and comfort levels as defined by Member States at national or regional levels. Calculation of primary energy considers factors or weighting factors per energy carrier, as defined by Member States, to ensure the optimal energy performance of the building envelope.
 - Member States have the option to introduce additional numeric indicators for total, non-renewable, and renewable primary energy use, as well as greenhouse gas emissions, to further express the energy performance of buildings.
- **Annex IA Common general framework for rating the smart readiness of buildings:**
 - This new annex establishes a framework for assessing the smart readiness of buildings, focusing on their ability to adapt operation to occupants' needs and grid demands while enhancing energy efficiency and overall performance.
 - The methodology, devised by the Commission, covers features like energy savings, benchmarking, flexibility, and enhanced functionalities resulting from interconnected and intelligent devices.
 - Three key functionalities are identified: optimising energy performance, adapting operation mode to occupant needs, and offering flexibility in electricity demand.
 - The methodology may consider interoperability between systems and existing communication networks while ensuring compliance with data protection and privacy laws.
 - It aims to provide a simple, transparent, and easily understandable smart readiness indicator for consumers, owners, investors, and demand-response market participants.
- **Annex II Independent control systems for energy performance certificates and inspection reports:**
 - Competent authorities or delegated bodies must randomly select energy performance certificates for annual verification, ensuring statistically significant compliance results.



- National authorities must be able to trace the originator of added information to a database for monitoring and verification purposes.

Through these targeted set of amendments and additions, the EPBD III significantly boosts systematic approaches and introduces novel measures aimed at achieving substantial enhancements in the energy performance of buildings. These forward-looking changes, part of the broader framework of the Clean Energy for All Europeans package, resonate with the overarching objective of fostering a more sustainable built environment for future generations.

4.5 EPBD IV (2024 recast)

In October 2020, the Commission presented its 'Renovation Wave' strategy to boost energy renovation of buildings in the EU. This strategy contained an action plan with: (i) regulatory, financing, and enabling measures; and (ii) the goal of at least doubling the annual energy renovation rate of buildings by 2030. This goal required a revision of the relevant EU legal act, the Energy Performance of Buildings Directive. The revision focused on provisions that were central to boosting building renovation. The initiative underscored the twin green and digital transition under the European Green Deal, emphasizing the importance of increasing energy efficiency and expanding renewable energy use in buildings.

The roadmap for this initiative included an Inception Impact Assessment and a Public Consultation period (February – June 2021). The Commission adopted, on 15 December 2021, a Proposal for a Directive (COM(2021)802) [4], accompanied by impact assessment reports and feedback from stakeholders. The proposal was furthermore part of the Commission Work Programme 'Fit for 55' package, aiming to achieve a zero-emission building stock by 2050 and aligned with the REPowerEU plan released on 18 May 2022. On 21 October 2022, the Council adopted its General Approach [5], in response to the Proposal for a Directive of the European Parliament and of the Council on the energy performance of buildings (recast). On 14 March 2023, in Strasbourg, the Parliament adopted significant amendments, consolidated into a text [6], to the proposal for a directive of the European Parliament and of the Council on the energy performance of buildings (recast), aimed at refining and strengthening the original text.

Following these prerequisite steps the legislative process advanced to the next stage: the Trilogue negotiations. These negotiations, which took place between June and December 2023, involved representatives from the European Parliament, the Council, and the European Commission. During the Trilogue process, discussions focused on reconciling differences between the Parliament's amendments, the Council's general approach, and the Commission's initial proposal, with the aim of reaching a consensus on the final text of the directive. Following the Trilogue negotiations, the Energy Performance of Buildings Directive (EPBD) Recast saw the following progress in its journey toward implementation:

- On 12 March 2024, the European Parliament adopted the EPBD Recast.
- Subsequently, on 12 April 2024, the Council of the EU also adopted the Recast.



- With both the Parliament and the Council's approval, the EPBD Recast (Directive 2024/1275) was published on 8 May 2024 in the Official Journal of the European Union [7].
- Member States of the EU are tasked with critical responsibility by June 2026. By this date, each Member State is required to transpose and implement the provisions of the EPBD Recast into their national legislation, ensuring uniformity across the EU's diverse building landscape.

The **EPBD IV** outlines several actions aimed at enhancing the energy efficiency of buildings throughout the EU, focusing especially on the least efficient buildings. Each EU country will develop its own **National Building Renovation Plan**, with the objective of reducing primary energy consumption in residential buildings by **16% by 2030** and **20-22% by 2035**, while allowing for national flexibility. The countries can independently choose which buildings to prioritize and which strategies to adopt. At least **55%** of the reduction in residential energy use must come from renovating the buildings that currently perform the worst in terms of energy efficiency. For **commercial properties**, the revised regulations mandate incremental improvements through **minimum energy performance standards**, targeting the renovation of the least efficient **16% by 2030** and **26% by 2033**.

The EPBD IV introduces **improved Energy Performance Certificates (EPCs)**, featuring a **standardized EU template** to facilitate better information dissemination and informed financial decision-making across the bloc. Financial incentives will focus on **supporting vulnerable groups** and the **most inefficient buildings**, aiming to alleviate **energy poverty** and lower energy costs. Additional measures will be implemented to **protect tenants** from potential evictions caused by rent hikes following renovations.

This EPBD recast also incorporates **strategic planning for renovations**, supported by tools to ensure their successful execution. Member States are required to create **National Building Renovation Plans** outlining strategies for decarbonizing building stocks and addressing key challenges such as **funding** and **workforce training**. **National renovation passport schemes** will be set up to assist building owners in phased, zero-emission renovations, and **one-stop-shops** will provide comprehensive support for homeowners, SMEs, and others involved in the renovation process.

Moreover, the Directive aims to **progressively phase out fossil-fuel boilers**, banning subsidies for these boilers starting from **January 1, 2025**. It also establishes requirements for **heating systems** based on emissions, fuel types, and the usage of renewable energy. A **full phase-out of fossil-fuel boilers** is expected by **2040**.

The Directive further promotes **sustainable mobility** by requiring **pre-cabling for electric vehicle (EV) charging** and **bicycle parking** in new and renovated buildings, supporting the EU's climate goals. There will be enhanced requirements for the number of **EV charging points**, which must support **smart charging** and, where feasible, **bidirectional charging** capabilities.

The SRI becomes gradually mandatory for **large buildings** with high energy demands, while for smaller buildings, its application remains optional for Member States. The implementation of SRI is



seen as a tool to raise awareness among building owners and occupants about the benefits of **building automation**, providing greater confidence in the **energy-saving potential** of these new technologies. In addition, buildings equipped with **smart readiness** systems can contribute to **demand-side flexibility**, which is crucial for **energy system integration**, allowing buildings to respond dynamically to external signals and optimize energy consumption in real-time.

Finally, the EPBD IV mandates that all **new buildings**, both **residential** and **non-residential**, must have **zero on-site emissions from fossil fuels** by specific deadlines (**January 2028 for public buildings** and **January 2030 for others**), with certain exemptions allowed. It also stipulates that new buildings must be capable of supporting **rooftop solar installations**, making solar energy a standard feature in new constructions and requiring solar installations on existing public and commercial buildings from **2027** where viable.

- **Article 1 Subject matter:** This article explains the scope of the Directive i.e. the enhancement of energy performance in buildings and the reduction of greenhouse gas emissions, aiming for a **zero-emission building stock by 2050**. It considers **climatic and local conditions**, **indoor environmental quality**, and **cost-effectiveness**. It establishes a methodology for calculating integrated energy performance, sets **minimum energy performance requirements** for new and existing buildings, addresses **life-cycle emissions**, and incorporates **renewable energy** and **smart building technologies**.
- **Article 2 Definitions:** Provides precise definitions of key terms used throughout the directive, including "**building**," "**zero-emission building**," "**nearly zero-energy building**," and various technical terms related to building components and systems. These definitions ensure consistent interpretation and application across Member States.
- **Article 3 National building renovation plan:** Requires each Member State to establish a **National Building Renovation Plan (NBRP)** aimed at achieving a highly efficient and decarbonized building stock by **2050**. These plans must include **roadmaps**, investment strategies, and benchmarks for energy performance. Member States must submit updated plans every **five years** to the Commission, incorporating input from **public consultations** and **local and regional stakeholders**.
- **Article 4 Adoption of a methodology for calculating energy performance of buildings:** Mandates that Member States adopt a **common methodology** for calculating the energy performance of buildings, with guidance provided by the Commission. This methodology should consider building elements and ambient energy inputs, ensuring transparency and comparability across Member States.
- **Article 5 Setting of minimum energy performance requirements:** Outlines the need for **Minimum Energy Performance Requirements (MEPR)** for new and existing buildings and building elements, aiming for **cost-optimal energy performance levels**. These requirements must be regularly reviewed and updated by Member States to reflect technological advancements and regulatory changes.
- **Article 6 Calculation of cost-optimal levels of minimum energy performance requirements:** Details the **comparative methodology** for determining cost-optimal energy performance levels. Member States are required to report and revise their requirements based on **building types** and **renovation status**. If the minimum energy performance requirements



deviate by more than **15%** from the cost-optimal levels, Member States must adjust or justify the difference.

- **Article 7 New buildings:** By specific future dates, all new buildings must achieve **zero-emission performance**, with interim requirements for **nearly zero-energy buildings**. This article also introduces requirements for calculating and reporting the **life-cycle Global Warming Potential (GWP)** for new buildings, ensuring a holistic approach to carbon emissions reduction.
- **Article 8 Existing buildings:** Requires that **major renovations** of existing buildings result in energy performance improvements that meet minimum standards. It also promotes the use of **high-efficiency alternative systems** and addresses broader environmental and safety considerations during renovations.
- **Article 9 Minimum energy performance standards for non-residential buildings and trajectories for progressive renovation of the residential building stock:** Establishes **Minimum Energy Performance Standards (MEPS)** for non-residential buildings and sets trajectories for reducing energy use in residential buildings. It includes provisions for **exemptions** based on building usage, historical value, or economic feasibility.
- **Article 10 Solar energy in buildings:** Mandates that new buildings optimize their potential for **solar energy generation**, based on site conditions. It sets deadlines for installing **solar energy systems** on new and existing public and non-residential buildings, with exemptions and structural considerations outlined for specific cases.
- **Article 11 Zero-emission buildings:** Defines **Zero-Emission Buildings (ZEB)** as those that do not generate **on-site carbon emissions from fossil fuels** and can adapt their energy use based on external signals. The article specifies **maximum energy demand thresholds** and **operational greenhouse gas emissions** for new and renovated zero-emission buildings.
- **Article 12 Renovation passport:** Introduces the **Renovation Passport (RP)** scheme, providing a tailored roadmap for phased renovations towards **zero-emission** performance. This scheme, which may become mandatory, focuses on affordability and integration with **Energy Performance Certificates (EPCs)**. Renovation passports will be **digitally issued** and updated, integrating with national EPB databases and **digital building logbooks**.
- **Article 13 Technical building systems:** Sets requirements for the **optimization of energy use** in technical building systems, focusing on energy savings and improving **Indoor Environmental Quality (IEQ)**. It covers heating, cooling, and air quality control systems, particularly in non-residential zero-emission buildings.
- **Article 14 Infrastructure for sustainable mobility:** Requires the installation of **electric vehicle recharging points** and pre-cabling in new and renovated non-residential buildings with parking spaces. It also includes provisions for **bicycle parking** and allows adjustments based on local conditions, emphasizing the importance of **smart and bi-directional charging** capabilities.
- **Article 15 Smart readiness of buildings:** Proposes a **common Union scheme** for assessing the **Smart Readiness Indicator (SRI)** of buildings, focusing on adaptability to occupant needs and energy efficiency improvements. It details a timeline for the **testing and implementation** of the SRI, with a potential mandatory application for non-residential buildings.



- **Article 16 Data exchange:** Ensures that building owners, tenants, and managers have access to relevant **building system data**, promoting **interoperability** and **transparent data exchange** within the EU. It establishes guidelines for **data access**, storage, and sharing, ensuring compliance with **Union law** and **data protection regulations**.
- **Article 17 Financial incentives, skills, and market barriers:** Provides frameworks for **financing** and **support measures** to overcome market barriers and facilitate investments in building renovations. It emphasizes the importance of **skills development** and the role of **one-stop shops** in providing technical and financial support for stakeholders, particularly in energy efficiency projects.
- **Article 18 One-stop shops for energy performance of buildings:** Mandates the establishment of **One-Stop Shops (OSS)** by Member States to provide **technical assistance** for improving the energy performance of buildings. These centres will offer **streamlined advice** on technical and financial solutions, with a particular focus on **vulnerable households** and areas with aging building stocks.
- **Article 19 Energy Performance Certificates (EPCs):** Member States must set up a system for certifying the **energy performance of buildings**, including zero-emission and nearly zero-energy buildings. **EPCs** must follow a specified **template** and include a classification from **A (zero-emission) to G (worst-performing)**. These certificates must be of high quality, reliable, and **machine-readable**, issued by independent experts.
- **Article 20 Issue of energy performance certificates:** Mandates the issuance of **digital EPCs** for new buildings, major renovations, sales, and rentals. The energy performance class must be displayed in all online and offline advertisements, with **compliance monitored** through sample checks.
- **Article 21 Display of energy performance certificates:** Requires public buildings and frequently visited non-residential buildings to display their **EPCs** prominently, ensuring transparency regarding their energy performance.
- **Article 22 Databases for energy performance of buildings:** Directs Member States to establish **comprehensive databases** for managing **energy performance data**, including EPCs. These databases must comply with **data protection rules** and provide **aggregated and anonymized data** to the public.
- **Article 23 Inspections:** Sets the requirement for regular **inspections** of heating, ventilation, and air-conditioning systems with an effective rated output over **70 kW**. Inspections must assess system efficiency and provide recommendations for improving performance and reducing fossil fuel use.
- **Article 24 Reports on the inspections of heating, ventilation and air-conditioning systems:** Requires an **inspection report** after each system inspection, detailing the results and providing recommendations. The report must be provided to the building owner or tenant and uploaded to the national database.
- **Article 25 Independent experts:** Ensures that **certifications, renovation passports**, and system inspections are conducted by **independent, qualified experts**. Training and certification information must be publicly available.
- **Article 26 Certification of building professionals:** Ensures that professionals engaged in renovation work have the necessary competence and certification, with schemes made available where feasible.



- **Article 27 Independent control system:** Mandates the establishment of **independent control systems** for EPCs, renovation passports, and inspection reports. These systems must be accessible to competent authorities upon request.
- **Article 28 Review:** Calls for a review of the Directive by the Commission by **December 31, 2028**, to assess its effectiveness in achieving a **zero-emission building stock by 2050**.
- **Article 29 Information:** Requires Member States to conduct **information and awareness campaigns** to educate stakeholders about improving energy performance, with a focus on vulnerable households.
- **Article 30 Consultation:** Encourages Member States to engage stakeholders in consultations to facilitate the Directive's effective implementation.
- **Article 31 Adaptation of Annex I to technical progress:** Grants the Commission the power to adopt **delegated acts** to update the Directive in response to **technological advancements**.
- **Article 32 Exercise of the delegation:** Details the conditions under which the Commission may adopt **delegated acts**, including provisions for revocation by the Parliament or Council.
- **Article 33 Committee procedure:** Establishes a committee to assist the Commission in applying the **regulatory procedures** outlined in the Directive.
- **Article 34 Penalties:** Directs Member States to establish **penalties** for non-compliance with the Directive, emphasizing that penalties should be **effective, proportionate, and dissuasive**.
- **Article 35 Transposition:** Specifies deadlines for Member States to enact legislation to comply with the Directive and requires notification to the Commission.
- **Article 36 Repeal:** Announces the repeal of **Directive 2010/31/EU**, two years after the new Directive enters into force, while maintaining Member States' obligations regarding **transposition timelines**.
- **Article 37 Entry into force and application:** States that the Directive will enter into force on the **twentieth day** following its publication in the **Official Journal of the European Union**.
- **Article 38 Addressees:** Clarifies that the Directive is addressed to Member States, obligating them to implement its provisions.

Annex I Common general framework for the calculation of the energy performance of buildings (Article 4)

This annex establishes the **standardized methods and principles** that Member States must adopt to calculate the energy performance of buildings. It covers:

- **Thermal characteristics** (e.g., thermal capacity, insulation, air tightness).
- **Heating and cooling installation performance.**
- **Ventilation systems.**
- **Lighting.**
- **Passive heating and cooling elements.**
- **Domestic hot water supply.**
- Consideration of **climatic conditions**.
- Utilization of **renewable energy sources**.
- The calculation also includes the **life-cycle global warming potential (GWP)** of the building, factoring in emissions from the entire lifecycle (construction, use, and demolition).



Annex II Template for the national building renovation plans (Article 3)

This annex provides a template for **Member States** to submit their **NBRPs**. These plans must outline:

- **Roadmaps** for achieving a decarbonized building stock by **2050**.
- **Energy performance benchmarks** for the existing building stock.
- **Investment strategies** and estimated financing requirements.
- Targets for **energy renovation rates**, specifically for **worst-performing buildings**.
- Involvement of **local and regional stakeholders**.
- Member States are required to update and submit their renovation plans to the **European Commission** every **five years**.

Annex III Calculation of life-cycle GWP of new buildings (Article 7)

This annex details the **methodology** for calculating the **GWP** of new buildings. The calculation includes:

- **Emissions** from all stages of the building lifecycle (extraction of raw materials, production, transportation, construction, use, and decommissioning).
- Focus on **carbon footprint** reduction in both construction and operational phases.
- The inclusion of **material choices** and their long-term environmental impact.

Annex IV Common general framework for rating the smart readiness of buildings (Article 15)

This annex sets out the framework for assessing the **SRI**, which measures a building's capacity to integrate and utilize smart technologies. It includes:

- **Energy management systems** and **building automation**.
- **Interaction** with energy grids (e.g., **demand-side flexibility**).
- Adaptation to **occupants' needs** and preferences.
- **Monitoring and controlling** energy performance in real-time.
- The SRI assessment must consider the **efficiency**, **comfort**, and **flexibility** provided by smart technologies and be applied to both **new** and **existing** buildings.

Annex V Template for energy performance certificates (Article 19)

This annex provides the standardized **template for EPCs**. The template includes:

- **Energy efficiency classification**, from **A (zero-emission)** to **G (worst-performing)**.
- **Mandatory and voluntary indicators** related to building performance.
- **Recommendations** for improving energy efficiency, including cost-effective renovation actions.
- A new **A+ class** for exceptionally high-performing buildings.
- **Digital issuance** and machine-readable formats.
- The EPCs must be clear, accessible, and **easy to interpret** for building owners, tenants, and potential buyers.

Annex VI Independent control systems for energy performance certificates (Article 27)

This annex defines the procedures and requirements for setting up **independent control systems** to verify the quality and accuracy of **EPCs**. It includes:

- Regular **sample checks** of issued certificates.
- Evaluation of **certification processes**.



- Ensuring the **competence** of the certifying experts.
- These control systems must be in place to ensure that EPCs remain reliable and effective across all **Member States**.

Annex VII Comparative methodology framework to identify cost-optimal levels of energy performance requirements for buildings and building elements (Article 6)

Describes a methodology for calculating the **cost-optimal levels** of minimum energy performance requirements for buildings and building elements. It includes:

- **Cost-benefit analyses** for different energy-saving measures.
- The comparison of **initial investment costs** with **operational savings** over time.
- Adjustments based on **building type**, climate, and **renovation status**.
- Member States must use this methodology to set **energy performance requirements** that strike a balance between **cost** and **energy efficiency**.

Annex VIII Requirements for renovation passports (Article 12)

Provides the **roadmap** and guidelines for the issuance of **RPs**, which document the step-by-step actions required to achieve **zero-emission renovations**. The passport should:

- Include the building's **current energy performance**.
- Detail **planned renovations**, with timelines, cost estimates, and expected benefits.
- Include guidance on **financial assistance options** available to building owners.
- Be **digitally updated** and linked to **national EPB databases**.
- This annex ensures that renovation passports help building owners plan and execute comprehensive, phased renovations.

Annex IX Transitional provisions and repeal of directive 2010 & 2018 (Article 36)

This annex outlines the transitional provisions concerning the **repeal of Directive 2010 and 2018**, specifying that:

- The obligations under the previous Directive will continue to apply until the new Directive has been fully transposed by Member States.
- Provides a **correlation table** for mapping the provisions of the **2010 and 2018 Directive** with the new Directive, ensuring clarity in the transition process.

Annex X Correlation table (Article 36)

Outlines the **correlation table**, providing a comparison between the repealed **Directive 2010/31/EU** and the corresponding provisions of the **new Directive** to ensure continuity and legal clarity. This annex is essential for understanding how the new directive builds upon and modifies previous legislative requirements.

4.5.1 Remarks on the EPBD's evolution

The evolution of the Energy Performance of Buildings Directive (EPBD) reflects significant expansions and enhancements over time. The EPBD I (2002 original) comprised 23 recitals, 17 articles, and just one annex, focusing on the energy performance in European buildings to improve energy efficiency. The EPBD IV (2024 recast) drastically expands on its predecessor, now including



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84 recitals, 38 articles, and 10 annexes. This expansion, over three times the original in terms of recitals, more than double the articles, and ten times the annexes, indicates a robust enhancement in the scope and detail of regulations, underlining the EU's intensified commitment to reducing building energy use and promoting sustainability in the face of climate change challenges.

Building performance is recognized as a complex and continuous process, encompassing assessment, certification, and management phases. Experience has proven that simplifying this process too much can reduce it to merely an administrative burden rather than a mechanism for real improvement. The coordination and support as well as the innovation activities from projects like the “Integrated EPB Assessments. A pathway for effective EPBD implementation.” (iEPB) and the sister projects of the Next Generation EPC and SRI clusters are vital. A coordinated and coherent approach fully considering the technological advancements in building technology, software, methodologies, and processes allow for the swift and adequate assessment, certification and management of building performance, facilitating the twin green and digital energy transition.



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5. EU procedures, schemes and implementing acts analysis and characterisation

The Energy Performance of Buildings Directive (EPBD) has steadily evolved from the “first-generation” efficiency focus of 2002 to today’s holistic Zero-Emission Building paradigm endorsed in the 2024 recast. With each revision, the EU has complemented the legislative core with a growing family of implementing acts, optional Union schemes and voluntary support tools that together shape how Member States calculate, certify and disclose building performance. Chapter 5 zooms in, unpacking those instruments that are most consequential for the iEPB mission and for the quality, comparability and usability of Energy Performance Certificates (EPCs) across Europe.

The chapter is structured into three linked blocks. Section 5.1 revisits the effort to create a converged set of common-EU datasheets for the EPB standards suite, an initiative rooted in the U-CERT project. Section 5.2 dissects the Smart Readiness Indicator: its legal underpinnings, roll-out status and the added value iEPB can bring as a digital bridge between EPCs and smartness assessments. Section 5.3 introduces the ePANACEA dynamic, auto-calibrated assessment method, highlighting its potential to enrich traditional EPC workflows with measured-data feedback loops. Collectively, these analyses lay the groundwork for a harmonised, software-ready framework that can be adopted, and adapted, by national authorities, tool developers and market actors alike.

5.1 Common EU Datasheets – EPB Standard Annex A choices

The CEN/ISO set of Energy Performance of Buildings (EPB) standards are designed to provide a harmonized framework for assessing building energy performance across the European Union. These standards play a key role in supporting the implementation of the EPBD by ensuring consistency, transparency, and adaptability in national energy performance assessments. Recognizing the diverse climatic conditions, cultural practices, building traditions, and policy frameworks among Member States, these standards incorporate flexibility using National Annexes and Datasheets. This approach aligns with the EU's principle of subsidiarity [8], ensuring that decisions are made as closely as possible to the citizens and that actions at the Union level are justified only when objectives cannot be sufficiently achieved by Member States alone.

Each EPB standard includes two key annexes to facilitate this flexibility:

- Annex A (Normative): A mandatory, yet initially empty, framework template that outlines specific choices, input data, and references to other EPB standards.
- Annex B (Informative): A version of Annex A populated with a set of default choices and input data, serving as a reference point.

Member States can utilize Annex A to develop National Annexes or Datasheets, tailoring the standards to their specific contexts. A National Annex, published by a National Standards Body,



becomes an informative part of the EPB standard, while a National Datasheet, issued by national or regional authorities, serves a similar purpose within regulatory frameworks. This structured flexibility allows countries to adapt the harmonized procedures of the EPB standards to their unique climatic conditions, building practices, and policy requirements, thereby enhancing both the relevance and effectiveness of energy performance assessments. By embracing this approach, the EPB standards not only promote harmonization across the EU but also respect the autonomy of Member States, ensuring that energy performance assessments are both consistent and locally applicable.

5.1.1 The legacy of U-CERT project [9]

The U-CERT project [10], funded under Horizon 2020, directly provided support for the implementation and practical use of the EPB standards across EU Member States by:

- Developing a converged set of National Datasheets, ensuring methodological coherence while allowing national adaptations.
- Addressing barriers to adoption, including delays in national transposition of the EPB standards and inconsistencies in Energy Performance Certificate (EPC) schemes.

The set of EPB standards, developed under Mandate M/480, serves as the technical backbone of the EPBD. These standards provide a structured calculation methodology for determining building energy performance, a modular and flexible framework, allowing adaptation at the national level while maintaining EU-wide consistency, and a transparent approach that facilitates a level playing field in terms of building performance requirements and comparability of energy performance ratings and Energy Performance Certificates (EPCs).

However, the adoption of these standards across EU Member States has been uneven, mainly due to delays in national transposition due to regulatory complexity, regulatory inertia (many Member States continue to use legacy national methods), variability in EPBD transposition (different interpretations of energy performance requirements), lack of common datasets (inconsistent climate data, indoor conditions, and system efficiencies across national EPC schemes), and lack of familiarity with EPB standards among national authorities.

To address these challenges, the U-CERT project developed a converged set of National Datasheets, ensuring consistency where feasible, by harmonizing key EPB standard choices, flexibility where necessary, allowing for national adjustments based on climate, building typologies, and regulatory needs, and enhanced usability, supporting the digitalization and automation of EPB assessment.

This was accomplished by taking a bottom-up approach based on the technical expertise of the consortium and its network and stakeholder engagement, incorporating input from national authorities, standardization bodies, and market actors across 12 EU Member States: Belgium, Bulgaria, Denmark, Estonia, France, Hungary, Italy, the Netherlands, Romania, Slovenia, Spain, and Sweden.



U-CERT prioritised National Datasheets rather than National Annexes due to their flexibility and practicality. Unlike National Annexes, which require formal standardization procedures for updates, National Datasheets can be revised more easily. This makes them particularly useful for regulators and EPC scheme operators, who can integrate them directly into their workflows. Additionally, National Datasheets enable a step-by-step approach to harmonization, allowing countries to progressively align with EPB standard defaults rather than mandating full adoption from the outset.

Annex B of the EPB standards provides predefined default values and methodologies, but these were not the ideal foundation for U-CERT's approach. The primary reasons include lack of alignment with national regulations and climate-specific conditions, making them unsuitable for direct application in many countries, generic nature, which limits their ability to support a robust and context-specific national methodology, incompatibility with existing EPC schemes in several Member States, which would create barriers to practical implementation.

Instead, U-CERT took a different path by carefully curating a structured selection of Annex A choices, tailored to national needs. This approach ensured transparency in methodological deviations, providing national authorities with a framework to document and justify their choices. By doing so, U-CERT facilitated a pathway toward harmonization that respected national contexts without imposing immediate and rigid standardization requirements.

5.1.2 Converged set of datasheets for the set of EPB standards

The set of EPB standards comprises around 50 documents, each covering different aspects related to energy performance in buildings. While some standards focus on calculation procedures, others address inspection, measurement, design, certification, and indicators. However, not all calculation standards are equally relevant for practical applications, requiring a selection process.

The EPB standards are structured into modules (represent different technical domains e.g., heating, cooling, ventilation) and themes (classify the nature of the standard e.g., calculation, inspection, certification).

A selection process was applied to prioritize relevant EPB standards for practical calculations. The selection was refined in multiple steps. The initial 61 EPB standards were reduced to 53 by eliminating duplicate CEN and ISO versions. Standards covering only design, inspection, certification, or other non-calculative aspects were excluded. The selection was reduced from 53 to 37. The primary users considered were: EPB assessors and system engineers. Regulators and standard writers were excluded, reducing the selection to 25 standards. Priority was given to standards with general application over special applications or those that could be simplified without major impact. The selection was narrowed down from 25 to 16, and then further to 10 standards. The 10 EPB standards selected as the core of the converged set of datasheets are illustrated in Table 1 10 EPB standards selected as the core of the converged set of datasheets and Figure 1 10 EPB standards selected as the core of the converged set of datasheets.



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Table 1 10 EPB standards selected as the core of the converged set of datasheets

Module	Standard	Title
M1	EN ISO 52000-1	General framework and procedures for overarching EPB assessment
M1	EN ISO 52003-1	Indicators, requirements, ratings, and certificates for overall energy performance
M1	EN ISO 52010-1	External climatic conditions and conversion of climatic data for energy calculations
M1	EN 16798-1 (ISO 17772-1)	Indoor environmental parameters for design and energy assessment
M2	EN ISO 52016-1	Calculation of heating and cooling energy needs and loads
M2	EN ISO 52018-1	Indicators for EPB requirements related to thermal energy balance
M3	ISO 52032-1	Energy requirements and efficiencies of heating, cooling, and DHW distribution systems
M3	EN 15316-4-2	System energy calculation for heat pump space heating
M5+M6	EN 16798-7	Calculation methods for air flow rates and infiltration
M5+M7	EN 16798-5-1	Energy requirements for ventilation and air conditioning

Additionally, **EN ISO 52120-1** (Building Automation & Controls) is relevant.

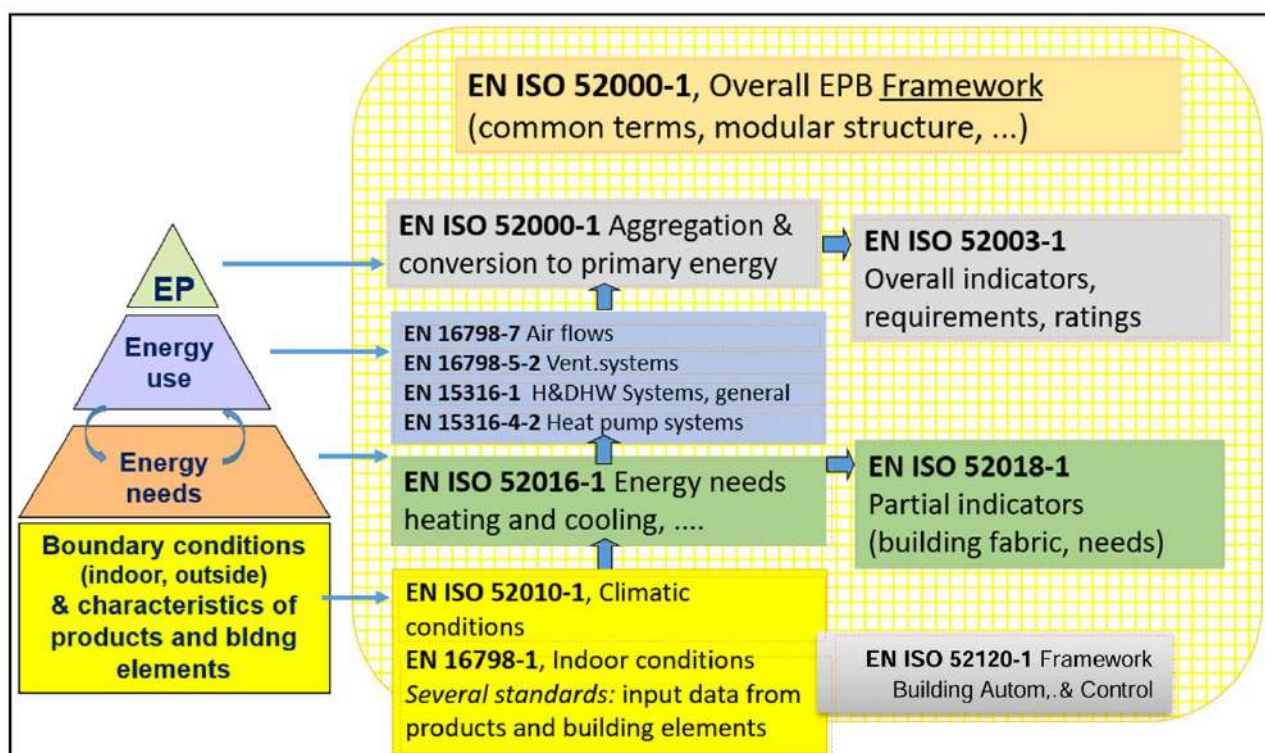


Figure 1 10 EPB standards selected as the core of the converged set of datasheets

This final selection represents the core set of EPB calculation standards for practical application in energy performance assessments. However, adjustments may be necessary depending on specific



contexts, case studies, and technological advancements. The selection methodology remains adaptable to evolving needs.

The converged set of national datasheets developed under U-CERT for the 10 core EPB standards can be found in the U-CERT deliverable D3.1 “Proposed converged set of national data sheets for the set of EPB standards” and its Annex 2 [11, 12]. These documents present a structured compilation of national datasheets (and categorized overview of choices) aligned with Annex A of the 10 core EPB standards. Rather than replacing any official standard, these datasheets serve as a harmonized reference tool to support national-level implementation while ensuring flexibility where needed. They offer a transparent, structured approach that facilitates adaptation to national and regional regulatory contexts.

For a more interactive exploration of the converged set of datasheets for the set of EPB standards, you can watch the EPB Center roadshow session on YouTube [13]. This session provides insights into how the converged datasheets support the progressive harmonization of EPC methodologies across Europe and how they can be utilized by national authorities, EPC scheme operators, and stakeholders in the building sector.

5.1.3 Upgrading the set of EPB standards for enhanced implementation of the EPBD

The EPB standards serve as a cornerstone in the implementation of the EPBD across Europe. Initially developed under the mandates M/343 and M/480, these standards have provided a harmonized framework for assessing building energy performance. However, with the EPBD IV (2024 recast) and evolving policy objectives, it has become clear that the EPB standards require a comprehensive upgrade to maintain alignment with the latest regulatory requirements and technological advancements. Stakeholder feedback has reinforced this need, pointing to areas where the standards must be enhanced for greater usability, interoperability, and digital readiness.

The current challenge lies in ensuring that the EPB standards remain fit for purpose in a rapidly changing energy landscape. The shift from Nearly Zero Energy Buildings (NZEB) to Zero Emission Buildings (ZEB), the growing focus on Indoor Environmental Quality (IEQ), and the increased importance of life-cycle greenhouse gas (GHG) assessment all demand a revision of the methodologies underpinning energy performance calculations. Moreover, the role of digital tools and automated systems in building energy management is expanding, making it imperative to transition the standards from their current “software-proof” state to a fully “software-ready” framework that allows seamless integration into regulatory and compliance systems.

- While European funding programs such as Horizon Europe and LIFE CET support innovation in this space, they do not provide the structured and coordinated approach needed for a systematic upgrade of the EPB standards. Therefore, a dedicated third EU mandate is necessary to ensure that these essential standards evolve in a way that maintains their credibility, usability, and impact across the EU and beyond.
- The latest EPBD revision has introduced significant regulatory changes that require updates to the EPB standards. The transition to ZEB and the need for more precise energy performance indicators necessitate an improved alignment between building assessment



methodologies and sustainability goals. The EPBD IV places a stronger emphasis on indoor environmental quality, reflecting growing recognition of its impact on occupant well-being. Furthermore, the interaction between buildings and energy networks, including energy storage and demand-side flexibility, must be better captured within the EPB calculation framework.

- Another key driver for this upgrade is the need for improved accessibility and usability of the standards. Currently, national implementation varies widely, partly due to the complexity and fragmentation of the existing EPB framework. To address this, efforts must focus on rationalizing terminology, harmonizing assessment boundaries, and simplifying calculation procedures. A major step in this direction is the development of an open-source EPB software kernel, which will serve as both a validation tool and a means of streamlining compliance at the national level. Such a tool would facilitate interoperability between different regulatory environments while maintaining the necessary flexibility for national adaptations.
- Beyond Europe, global relevance is another crucial aspect of the upgrade process. Many of the core EPB standards already exist as EN ISO standards, but further international harmonization is needed to ensure that the methodologies remain globally applicable. Increased collaboration with ISO standardization bodies will help position the European approach as a global benchmark, facilitating knowledge exchange and trade while supporting decarbonization efforts worldwide.

A systematic revision of the EPB standards shall be guided by four overarching goals.

- The first is to update the standards in response to the EPBD revision and stakeholder feedback. The latest directive has introduced new requirements related to carbon emissions metrics, life-cycle assessment, and smart building readiness, all of which require corresponding updates in the EPB calculation methodologies. Additionally, clearer guidelines are needed to define the interaction between energy demand, storage solutions, and grid integration.
- The second goal is to enhance the accessibility and usability of the standards. The complexity of the existing framework has led to inconsistencies in national implementation, which can be mitigated through improved structuring of the standards, better documentation, and the development of user-friendly digital tools. An open-source EPB software kernel will play a crucial role in this process by allowing regulators, assessors, and designers to validate and operationalize the methodologies with greater ease.
- A third objective is to increase the global relevance of the EPB standards. As decarbonization becomes a worldwide priority, it is essential that European methodologies align with international best practices. Strengthening ties with ISO and ensuring that EPB methodologies address diverse climate conditions and building typologies will enhance their applicability beyond the EU.
- Finally, ensuring consistency and quality assurance across the EPB standards is fundamental to their success. A Quality Assurance Group will oversee the harmonization of methodologies, ensuring that different standards align seamlessly and that national choices are clearly defined. Additionally, efforts will focus on digital integration, making the



standards not only software-compatible but fully “software-ready” to support automated compliance tools.

Achieving these goals requires a structured plan consisting of four key activities.

- The first activity is the technical upgrade of the standards to address gaps and inconsistencies in calculation methodologies. Enhancements will focus on refining assessment boundaries, integrating life-cycle GHG assessment, and improving the alignment of building automation and control functions within energy performance evaluations. The revised standards must also incorporate hourly and sub-hourly assessment capabilities to capture grid interactions and dynamic energy use patterns more accurately.
- The second activity involves the transition to fully global EN ISO standards. While most core EPB standards already exist at both the European and international levels, further efforts are needed to complete this transition and ensure that European methodologies maintain their influence in global standardization.
- The third activity focuses on making the EPB standards “software-ready.” This transition will involve structuring input parameters more systematically, defining a clear calculation workflow, and ensuring that all normative elements are expressed in a format that facilitates direct software implementation. By improving the logical calculation order and removing redundancies, the upgrade will make the standards more user-friendly and interoperable with digital compliance tools.
- A critical aspect of the upgrade is the fourth activity: the development of an open-source reference software tool. The absence of a standardized digital implementation has been a major obstacle to the widespread adoption of the EPB standards. This tool will not only provide a benchmark for validating commercial software but will also support policymakers, assessors, and designers in applying the standards more effectively.

The CEN/ISO roadmap for upgrading the EPB standards (“CEN/ISO roadmap for the set of EPB standards with regard to the key global challenges” [14]) follows a two-phase approach. The first phase, expected to last one to two years, will focus on establishing the technical and organizational framework, conducting pilot studies, and setting up quality assurance mechanisms. This phase will also involve drafting a consistent set of national (Annex B) choices to facilitate regulatory adoption. The second phase, spanning two to three years, will concentrate on detailed technical revisions, software tool development, and the full implementation of the upgraded standards.

Ultimately, the benefits of this initiative will be far-reaching. Policymakers will gain access to a robust, transparent, and harmonized methodology that simplifies the transposition of EPBD requirements. Industry stakeholders will benefit from clearer compliance pathways and a reduction in administrative complexity. Researchers and software developers will have access to open-source tools that facilitate innovation, while building owners and occupants will benefit from more accurate and reliable energy performance assessments.

Turning the roadmap into reality hinges on a clear decision: the European Commission, after consulting the Member States and the relevant CEN Technical Committees, must issue a third standardisation mandate to CEN (as it did for the first two generations of EPB standards). If for



example the mandate is granted in 2026, development can start immediately, allowing the third-generation EPB standards to be completed, adopted and delivered to all Member States by the end of 2029. Executing this upgrade timely will keep the EPB framework at the core of Europe's building-energy assessments while strengthening its role in the global push for decarbonised, climate-resilient buildings.

5.2 SRI optional common Union scheme

The Smart Readiness Indicator (SRI) is an EU-wide framework designed to assess and promote the smart capabilities of buildings in improving energy efficiency, user comfort, and integration with the energy system. It was introduced as part of the EPBD III (2018 amended) and is defined under Commission Delegated Regulation (EU) 2020/2155 [15] and Commission Implementing Regulation (EU) 2020/2156 [16].

The SRI is a voluntary scheme that aims to:

- Evaluate how smart-ready technologies (e.g., automation, control, and digitalization solutions) can enhance building energy performance and flexibility.
- Support grid-responsive and energy-efficient buildings by encouraging demand-side management.
- Improve occupant well-being by assessing factors such as indoor environmental quality, and personalized automation.
- Enable informed decision-making for building owners, tenants, and policymakers through a standardized rating methodology.

The SRI methodology assesses nine technical domains (heating, cooling, domestic hot water, ventilation, lighting, dynamic building envelope, electricity, electric vehicle charging, monitoring and control) against seven impact criteria (energy efficiency, maintenance and fault prediction, comfort, convenience, health, well-being and accessibility, information to occupants, energy flexibility and storage) [17]. Its implementation is intended to complement Energy Performance Certificates (EPCs) and other EPB assessments, reinforcing the alignment between smart technology adoption and overall building performance.

5.2.1 Status of the SRI in the EU and resources

At the time of publishing this deliverable, two main overarching sources provide a comprehensive view of the status quo of the Smart Readiness Indicator (SRI) across Europe:

- The European Commission's official SRI webpage [17]: This serves as the central reference point for all legal, technical, and methodological aspects of SRI, including its regulatory framework, assessment methodologies, and implementation tools. It also provides insights into national adoption efforts, pilot projects, and stakeholder engagement.
- The SRI Observatory [18]: Established as a dedicated knowledge hub, the SRI Observatory systematically tracks SRI-related policy developments, research, and implementation progress across Member States. It offers structured monitoring of national adoption, a



repository of research findings, and annual reports analysing key trends and challenges in SRI deployment.

The European Commission's official SRI webpage serves as the central reference for the indicator's legal and technical framework, methodology, and policy support. Key elements available include:

- **SRI rating methodology:** Outlines the SRI calculation process, which assesses building smartness based on functionalities provided by technical building systems. Highlights the three assessment levels (simplified, detailed, and expert assessment). Defines scoring criteria for each smart service and its contribution to energy performance, user interaction, and system flexibility.
- **Legal and technical framework:** Provides the official SRI regulations and related policy documents supporting national implementation. Explains the connection between SRI and the EPBD, emphasizing its role in driving smart building innovation across Member States.
- **Implementation tools:** Offers guidance documents and training materials to help national authorities, assessors, and building owners integrate the SRI into assessment procedures. Lists calculation tools to facilitate SRI assessments at different levels of complexity.
- **SRI in EU countries:** Provides an overview of SRI pilot projects and adoption efforts across Member States. Includes national implementation updates, highlighting early adopters, test phases, and ongoing policy discussions.
- **SRI Platform, events, and news:** Documents key stakeholder meetings, workshops, and policy discussions related to SRI development and implementation. Shares the latest research insights and best practices from Member States.

The SRI Observatory was established as a dedicated knowledge hub to track policy developments, research, and implementation efforts related to SRI adoption. It provides:

- **Policy implementation tracking:** Monitors the status of SRI implementation in each Member State. Publishes national-level insights on testing phases, regulatory developments, and stakeholder engagement.
- **Research repository:** Aggregates scientific studies on smart building technologies and their impact on energy efficiency. Compiles findings from EU-funded projects and independent research initiatives.
- **SRI Outlook reports:** Produces annual assessments of SRI implementation, offering a comparative analysis of Member State progress. Identifies barriers, opportunities, and policy recommendations to accelerate SRI adoption.
- **Country-specific information:** Provides detailed national profiles covering SRI testing, methodologies used, and policy incentives. Facilitates benchmarking between countries to support best-practice exchange.
- **Educational and training resources:** Offers training modules, FAQs, and expert insights to support capacity-building for assessors, policymakers, and industry stakeholders. Features case studies and practical implementation guidelines.

Together, these sources form the foundation for understanding the current state of SRI implementation, supporting policymakers, industry stakeholders, building owners and tenants, and researchers in navigating the evolving smart building landscape in Europe.



5.2.2 LIFE Clean Energy Transition projects

The LIFE Clean Energy Transition (LIFE CET) subprogramme supports projects that facilitate the implementation and market adoption of SRI and EPCs. Two primary groups of projects are relevant:

- **SMART-READY** projects (2021 call): These projects focus on enabling the adoption of SRI by Member States, supporting policy development, stakeholder engagement, and tool development. Each project launched at the end of 2022 and runs for three years.
 - **easySRI** Improving and demonstrating the potential of SRI [19]
 - **SRI2MARKET** Paving the way for the adoption of the SRI into national regulation and market [20]
 - **SRI-ENACT** Co-creating Tools and Services for Smart Readiness Indicator Uptake [21]
 - **SMART SQUARE** Smart Tools for Smart Buildings: Enhancing the intelligence of buildings in Europe [22]
- **BUILD-PERFORM** projects (2022 call): These projects help Member States improve EPCs and SRI implementation, ensuring coherence between both frameworks. Initiated in late 2023, they run for three years.
 - **iEPB** Integrated EPB Assessments. A pathway for effective EPBD implementation [23]
 - **SmarterEPC** Smarter Energy Performance Certificates; Integrating smart readiness aspects into buildings energy certification and tools for market up-take [24]
 - **tunES** Tuning EPC and SRI instruments to deliver full potential [25]

5.2.3 EPBD IV (2024 recast) provisions on the SRI and timeline

The 2024 revision of the EPBD introduces key updates to further integrate the SRI within the EU's building performance framework and enhance its practical implementation across Member States. Notable provisions include:

- While the SRI remains a voluntary scheme, Member States are encouraged to implement it more widely, particularly in non-residential buildings.
- A common framework for integration with EPCs and Digital Building Logbooks is reinforced, ensuring synergies between smart readiness and overall energy performance assessment.
- The SRI is recognized as a key instrument for promoting the deployment of smart technologies in buildings, particularly in alignment with the EU's decarbonization goals and digitalization strategy.
- It supports the implementation of Renovation Passports, guiding owners on smart technology upgrades for improving energy performance and user experience.
- The methodology is refined to better evaluate grid-interaction capabilities, considering dynamic energy pricing, flexibility services, and demand response potential.
- Member States are encouraged to integrate SRI assessment into energy audits and renovation advisory tools, facilitating better decision-making for building owners.
- The EPBD IV mandates stronger integration of smart-ready functionalities into building automation and control systems (BACS), aligning with the minimum BACS requirements for non-residential buildings.
- Digital tools will play a key role in standardizing SRI assessments, leveraging automated data collection from smart meters, IoT sensors, and energy management platforms.



The envisaged SRI rollout is prioritized for large non-residential buildings, particularly those above 1,000 m², in alignment with EPBD provisions on Building Automation and Control Systems (BACS). The initial target group includes public sector buildings, which account for approximately 10% of the EU's total building stock and represent over 800 million m² of floor area across Member States. The potential energy savings from smart automation and control systems in non-residential buildings are estimated at 15-25%, depending on usage intensity and existing energy performance. Buildings with heating or cooling systems exceeding 290 kW rated output are required to undergo regular energy performance and automation assessments, reinforcing SRI adoption in large-scale facilities.

Between 2024-2026, more EU Member States are expected to conduct national SRI testing pilots. These pilots will focus on validating SRI methodologies in real-world conditions, including integration with EPCs and Digital Building Logbooks. By 2027, results from national pilots will inform further refinements to the SRI framework, ensuring alignment with market needs and regulatory developments. By 2030, the European Commission aims for at least 50% of new and majorly renovated non-residential buildings to have an SRI assessment included as part of their EPC or energy audit.

- **2024-2025:** The updated EPBD text is adopted, and the European Commission publishes guidance on SRI integration with EPCs, BACS, and Digital Building Logbooks. Member States develop national implementation plans, including voluntary testing pilots in non-residential buildings.
- **2026-2027:** Member States progressively implement SRI within national frameworks, prioritizing large non-residential buildings. Stakeholder training and digital tools are developed to scale up SRI assessments, with cross-border knowledge-sharing initiatives to harmonize approaches.
- **2028 onward:** SRI assessments become more widely linked to EPCs, and synergies with smart metering, BACS, and energy flexibility tools are enhanced. The European Commission evaluates the impact of SRI uptake, with possible refinements to ensure effective integration with EU energy efficiency and decarbonization targets.

5.2.4 iEPB's added value contribution

The iEPB project is exploring how SRI can be effectively integrated into EPB methodologies across Europe, ensuring a seamless assessment framework that captures not only the energy efficiency of buildings but also their adaptability to smart technologies.

Traditionally, EPCs have been the cornerstone of energy performance assessment in buildings. However, their scope primarily focuses on static efficiency parameters, often overlooking the potential of smart functionalities in optimizing energy use. SRI fills this gap by evaluating a building's capacity to interact with occupants and energy grids dynamically, providing deeper insights into its operational intelligence. With national EPB methodologies varying across Member States, integrating SRI into existing building performance calculations requires a flexible, modular approach. Some countries already allow for additional indicators within their EPB frameworks, paving the way for embedding SRI-related parameters in national building performance assessment models.



To enhance this synergy, iEPB is working on:

- A converged common data model that harmonizes EPC, SRI and RP assessments, ensuring that the input and output data feed into a unified framework.
- Interoperable data exchange mechanisms, allowing for cross-referencing of EPC data with SRI parameters, and RP information, thus improving the comparability and usability of the assessments.
- Aligning SRI assessments with the CEN/ISO set of EPB standards, particularly concerning smart-ready heating, cooling, ventilation, and lighting systems.
- Developing a standalone SRI calculation engine, an open-source tool available on GitHub [26], which automates SRI assessments and ensures compatibility with EPB data structures.

A core ambition of iEPB is to establish a shared digital infrastructure that integrates multiple EPB assessment tools. This involves:

- A standardized data format, allowing seamless transfer of SRI and EPC data into national and EU-wide building performance databases.
- Automated SRI calculations, utilizing data from EPCs, smart meters, and Building Energy Management Systems (BEMS), reducing assessment costs and complexity.
- The iEPB web application plays a key role in this transformation. Designed for both professionals and end-users, this digital tool facilitates on-site data collection, enabling EPB assessors to capture all relevant parameters (including SRI) within a single building visit. Connects with public and private databases, streamlining data integration from sources such as cadastres, product manufacturers, and smart device registries.

While the potential benefits of integrating SRI into EPB assessments are clear, several challenges must be addressed, also by projects like iEPB:

- Regulatory harmonization: EPB methodologies differ significantly across EU Member States. A tailored approach is needed to ensure that SRI can be incorporated into national frameworks effectively.
- Data interoperability: Ensuring compatibility between EPC databases, smart building technologies, and SRI tools remains a technical hurdle.
- Market uptake and awareness: Building owners, professionals, and policymakers need clear incentives and user-friendly tools to fully embrace SRI.
- Policy uncertainty: Some Member States remain cautious, awaiting further guidance and best practices before integrating SRI into their regulatory frameworks.



5.3 ePANACEA Dynamic and auto-calibrated energy assessment method

5.3.1 Introducing the ePANACEA project [27]

The ePANACEA project aimed to address several challenges in the existing Energy Performance Certificate (EPC) schemes within the European Union, which had prevented them from fully meeting their initial objectives. These challenges included lack of accuracy, discrepancies between theoretical and actual energy consumption, absence of protocols for integrating smart and novel technologies, inconsistencies across EPC schemes in EU Member States, market distrust, and low user awareness regarding energy efficiency.

The project's primary objective was to develop a holistic methodology for energy performance assessment and building certification that could overcome these barriers. It envisioned ePANACEA becoming a key instrument in the European energy transition within the building sector.

To achieve this, the project created the Smart Energy Performance Assessment Platform (SEPAP), which integrated three distinct energy assessment methods:

- Smart & performance data-driven assessment: This method leveraged monitoring data to complement existing EPC schemes, focusing on normalizing and calibrating annual energy usage.
- Simplified method based on monthly calculations: Aligned with ISO 52016 standards, this approach provided a streamlined assessment using monthly data intervals.
- Advanced & automated simulation modelling (SEPAPTool): This method utilized dynamic simulation and auto-calibration of building energy models to enhance EPC accuracy and cost-effectiveness.

Among these, the SEPAPTool represented a significant advancement by integrating dynamic simulations with auto-calibration features, thereby improving the precision of energy performance assessments and reducing the gap between theoretical models and real-world energy consumption.

5.3.2 ePANACEA SEPAPTool

The global concept behind the advanced & automated simulation modelling (SEPAPTool) for EPCs was structured around the “EPC Cycle”, which is illustrated in Figure 2 “EPC cycle”. This approach implemented a sequential workflow designed to generate a calibrated model based on actual consumption patterns (i.e., the “EPC in use”) while also delivering a more accurate “Standard EPC” through correction by climate and usage factors. This methodology encompassed two perspectives for EPCs:

- Enhancing the information provided to users by incorporating their actual consumption patterns (“EPC in use”).
- Preserving administrative requirements for an objective comparison across the building stock (“Standard EPC”).



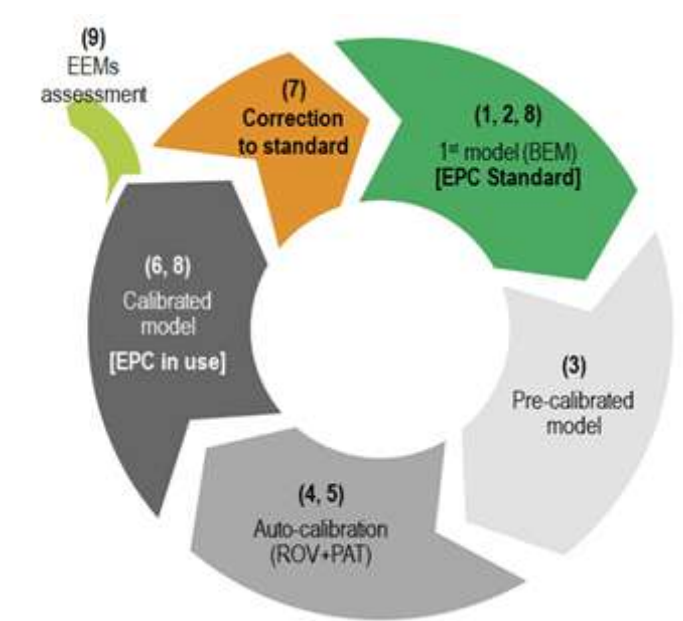


Figure 2 "EPC cycle"

The "EPC Cycle" consisted of the following key steps:

1. Data gathering: Collection of relevant data, including building documentation, utility bills, monitoring data from Building Management Systems (BMS), spot measurements, and actual weather data.
2. Development of the initial Building Energy Model (BEM): Creation of a preliminary BEM using dedicated simulation tools.
3. Adjustment to actual peak loads and operational schedules: Fine-tuning the model to reflect real-life energy usage patterns.
4. Classification of data sources: Identifying key calibration variables and defining their Range of Variation (ROV) for calibration purposes.
5. Auto-calibration: Application of parametric assessments and optimization algorithms to automatically calibrate the model based on real energy consumption data.
6. Selection of the final calibrated model: Identification of the optimal set of calibrated values for key model parameters.
7. Correction to standard conditions: Adjustments for standard reference conditions, including weather data, operational schedules, and peak loads.
8. Generation of results: Calculation of overall energy performance indicators, partial indicators, and monthly disaggregated data for each fuel type and energy service.
9. Development of Energy Efficiency Measures (EEMs): Recommendations for energy-saving actions based on the calibrated BEM.



Transparent description of each national and EU technical methodology for EPB Assessment / D2.1

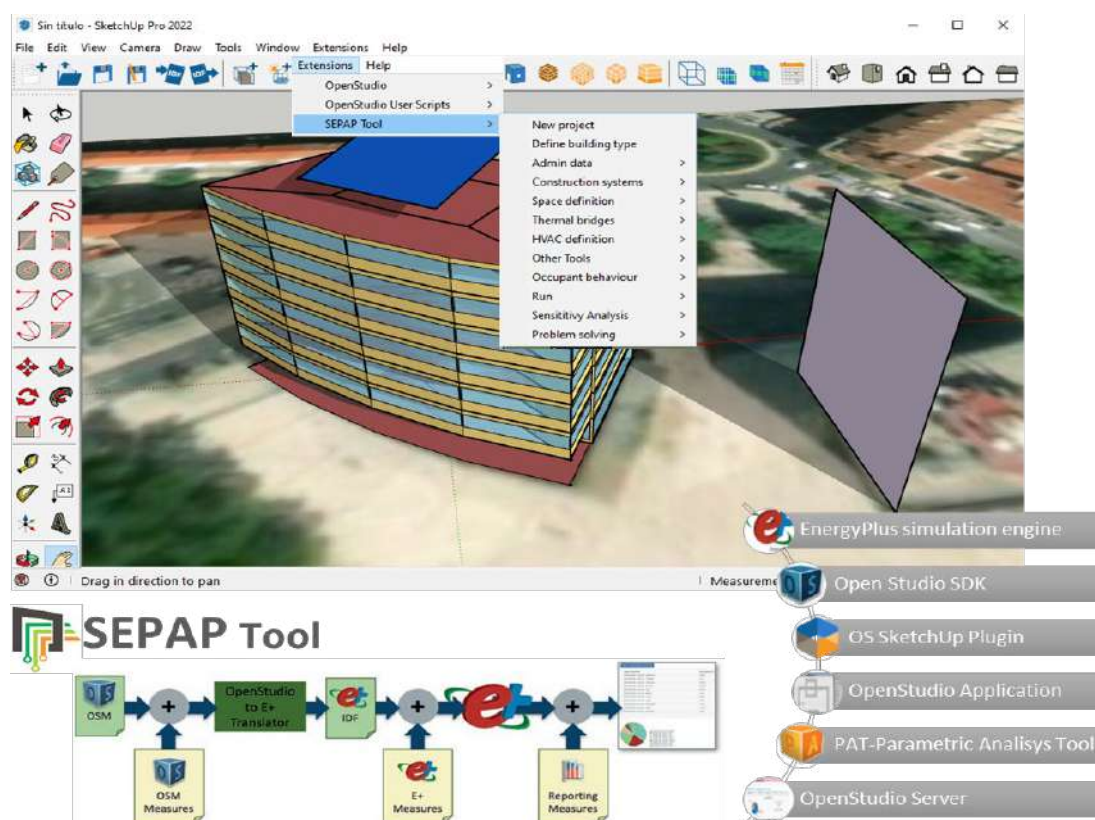


Figure 3 The workflow process

To support the “EPC Cycle” workflow, the SEPAPTool was developed as a local application based on OpenStudio®, an open-source, cross-platform suite of tools for whole-building energy modelling using the EnergyPlus simulation engine (see Figure 3 The workflow process). OpenStudio facilitates community development, customization, and private sector adoption through its graphical user interfaces and Software Development Kit (SDK). The SEPAPTool integrated several OpenStudio components, each customized to align with the objectives of the ePANACEA project, i.e. OpenStudio SketchUp Plugin, OpenStudio Application, PAT (Parametric Analysis Tool), and OpenStudio Server.

A critical component of the SEPAPTool was its plugin for SketchUp Pro 2022, which enhanced the accuracy of building energy modelling (BEM) by introducing advanced functionalities while also automating the calibration process, minimizing the technical effort required for cost-effective implementation. To facilitate automation, various "Measures" (i.e., Ruby scripts used to programmatically execute OpenStudio actions) were developed for key assessment stages, covering:

- Default construction systems: Three predefined construction sets corresponding to different insulation levels.
- Space definition: Automatic classification of spaces into thermal zones following ISO 52000-1 standards.
- HVAC system definition: Predefined templates for Domestic Hot Water (DHW), heating, cooling, and renewable energy installations.



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- Real occupant behaviour integration: Incorporation of real lighting power levels and schedules, electrical equipment usage, DHW consumption patterns, occupancy levels, and thermostat setpoints into the BEM.
- Auto-calibration process: A dedicated template was developed to automate calibration using predefined algorithm settings and ranges of variation for calibration variables. The calibration process was executed at server level via the PAT (Parametric Analysis Tool).
- Reverse or standardized correction: The calibrated model was automatically converted into a standard model, preserving the physical characteristics of the calibrated version while aligning the model with standardized national EPC parameters, such as climate data, electrical loads, usage schedules, and thermostat settings.

A detailed video tutorial demonstrating the advanced & automated simulation modelling (SEPAPTool) was made available on the ePANACEA project's YouTube channel [28]. This tutorial guided users through the entire EPC certification process, from initial BEM development to the final standardized model.

5.3.3 Import/export formats of the SEPAPTool for the iEPB common data format

This section examines the feasibility of data exchange within the various tools that constitute the SEPAPTool. The study focuses on the import and export formats provided by the OpenStudio SDK, the OpenStudio SketchUp plugin, and the Parametric Analysis Tool (PAT). The objective is to assess their potential compatibility with the iEPB common data format and explore ways to implement a structured data exchange within the iEPB framework.

OpenStudio SDK import and export capabilities

The OpenStudio SDK supports multiple data formats for importing and exporting building models, ensuring interoperability between different energy simulation platforms. The supported file formats are listed and described in Figure 4 Open Studio SDK, import and export options and Table 2 Open Studio SDK, import and export options.

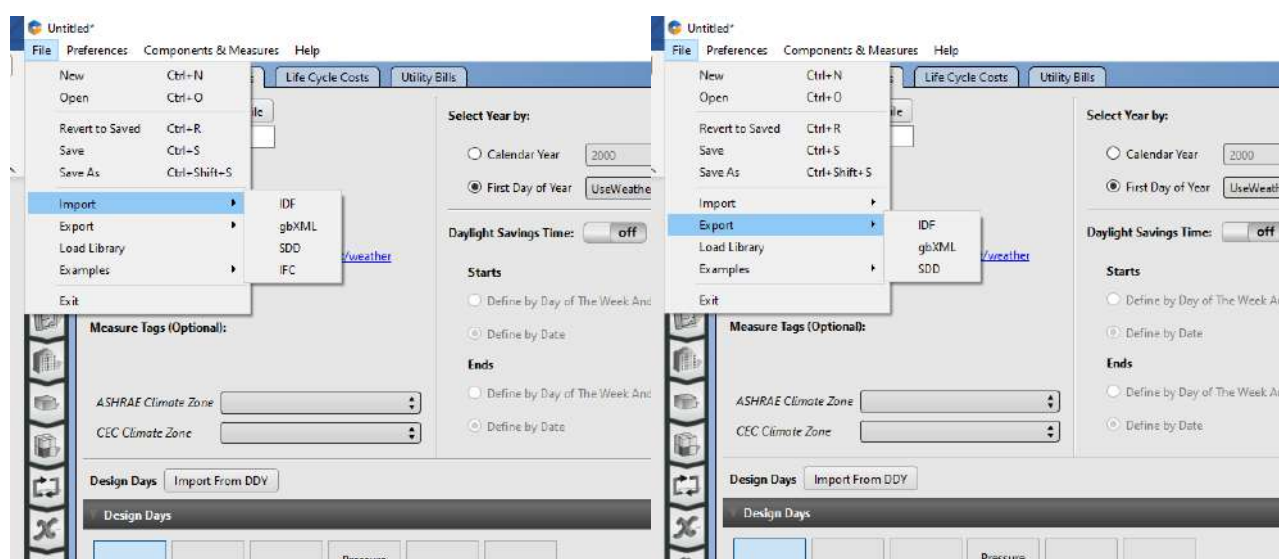


Figure 4 Open Studio SDK, import and export options



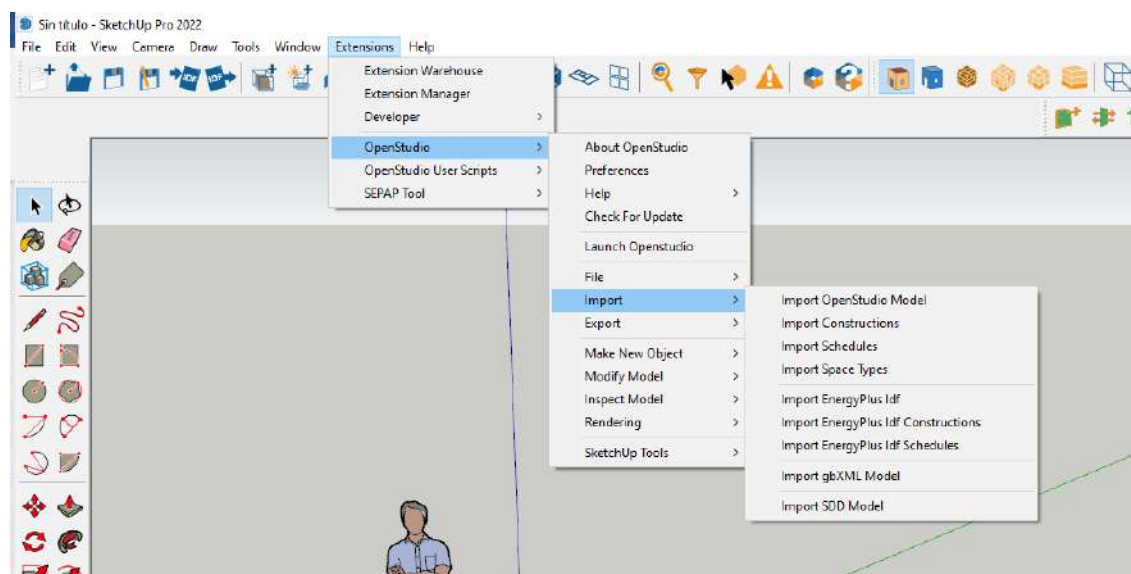
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Table 2 Open Studio SDK, import and export options

Format	Import capabilities	Export capabilities
IDF (EnergyPlus Input Data File)	Imports geometry, constructions, loads, thermal zones, and schedules	Exports full model, including HVAC systems
gbXML (Green Building XML)	Imports geometry, constructions, thermal zones, and schedules	Exports geometry, constructions, and thermal zones
SDD (Simulation Data Definition)	Imports full simulation model, including HVAC systems	Exports input format with geometry, constructions, and thermal zones
IFC (Industry Foundation Classes)	Imports geometry only	Not supported

SEPAPTool SketchUp Plugin

The SEPAPTool SketchUp plugin currently lacks direct import/export capabilities for file formats other than OSM (OpenStudio Model format). However, these functionalities could be programmed following the same principles used in the OpenStudio SketchUp plugin, which supports the same import/export options as the OpenStudio SDK. Figure 5 OS SketchUp plugin import/export options and Table 3 OS SketchUp plugin import/export options illustrates these OS SketchUp plugin import/export capabilities.



Transparent description of each national and EU technical methodology for EPB Assessment / D2.1

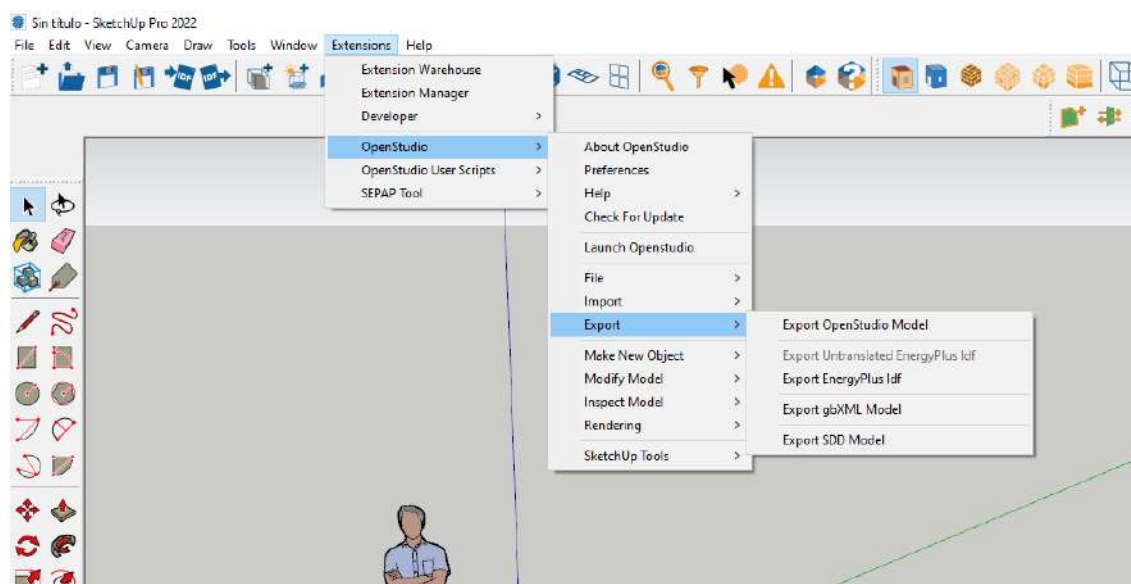


Figure 5 OS SketchUp plugin import/export options

Table 3 OS SketchUp plugin import/export options

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SDD (Simulation Data Definition)	Imports full simulation model, including HVAC systems	Exports input format with geometry, constructions, and thermal zones
IFC (Industry Foundation Classes)	Imports geometry only	Not supported

Parametric Analysis Tool (PAT)

The Parametric Analysis Tool (PAT) plays a key role in the advanced & automated simulation modelling (SEPAPTool) by automating the testing and comparison of various energy performance measures. It facilitates design optimization, model calibration, and sensitivity analysis using predefined building models. To execute simulations in PAT, two essential files are needed:

- Building model file: A .osm (OpenStudio Model) file containing the full building description, including geometry, materials, and HVAC systems.
- Climate file: A weather data file required for executing energy simulations.

To implement the advanced & automated simulation modelling (SEPAPTool) within the iEPB data format, these two files must be structured in a way that enables seamless data extraction and conversion into the iEPB common data format.



Integration with iEPB common data format

For successful integration, the SEPAPTool's import/export capabilities should be aligned with the iEPB common data model, ensuring:

- Standardized file formats for importing/exporting energy models.
- Interoperability between SEPAPTool, OpenStudio, and other EPC tools.
- Efficient data exchange between iEPB assessments and external databases.
- Automated calibration workflows linked with iEPB assessment processes.

By leveraging the existing OpenStudio SDK functionalities and enhancing the SEPAPTool SketchUp plugin, the import/export capabilities of the SEPAPTool could be expanded to facilitate seamless integration into the iEPB framework.

5.3.4 ePANACEA to iEPB

The iEPB project originally specified that the iEPB common data format would be based on either the gbXML (Green Building XML) or IFC (Industry Foundation Classes) file formats. After analysing the import and export capabilities of the SEPAPTool, it was determined that the gbXML format was the most suitable option for integrating the SEPAPTool into the iEPB common data format, given that OpenStudio currently supports both import and export of gbXML files. In addition, iEPB team examined several publications related to both formats, concluding that gbXML is more conducive to implementing new data blocks and extensions. Therefore, the advanced & automated simulation modelling (SEPAPTool) of ePANACEA is proposed for integration into the iEPB common data format using gbXML as its foundation.

To facilitate this integration, the gbXML elements used by OpenStudio for file import and export were examined through real case studies. This was carried out with the gbXML version 7.03 table of contents [29], extracted from the official website of the Green Building Council.

To fully implement the advanced & automated simulation modelling (SEPAPTool) into the iEPB common data format, the SEPAPTool will need to expand OpenStudio's import and export capabilities to include additional gbXML elements not currently supported, particularly those related to HVAC, operational schedules, and peak loads. While gbXML provides a solid foundation for data exchange, the implementation of the SEPAPTool in the iEPB common data format also requires certain additional data fields that are not currently included in gbXML, which have been identified during the assessment. To ensure full integration, these additional elements are included in the extended iEPB common data format, allowing seamless import/export compatibility with the SEPAPTool and other OpenStudio-based tools.



6. National procedures and instrument analysis and characterisation

While chapter 5 mapped the supranational “rules of the game”, chapter 6 dives into the arena where those rules are translated into practice: the national calculation methods, software ecosystems and complementary building-performance checks that shape day-to-day Energy Performance Certificate (EPC) delivery.

The bottom-up approach drew among other on laws, National Annexes, public EPC databases, and the know-how of the national iEPB partners for reconstructing the full assessment chain in the three demonstration countries (Austria, Netherlands, Spain). This granular evidence base reveals where national decisions boosts data quality and where fragmentation still hampers interoperability, insights that feed directly into the iEPB common schema and the forthcoming policy recommendations.

The chapter is organised to mirror the data flow of a typical EPC workflow. Section 6.1 analyses the National Annexes and Datasheets that transpose the EPB standards’ Annex A choices, highlighting divergences in climate zoning, default schedules and primary-energy factors. Section 6.2 examines the EPC reports, labels and database structures, contrasting disclosure practices and open-data maturity. Section 6.3 characterises the official EPC software tools, their calculation engines and input/output schemas, while Section 6.4 surveys additional national procedures that may share data fields with EPCs and thus could be bridged in the iEPB schema. Together these analyses provide the national baseline against which the project can prototype a harmonised, software-ready data model that remains sensitive to local regulatory realities.

6.1 National Annexes and Datasheets – EPB Standard A choices

The development and harmonization of National Annexes (NAs) and National Datasheets (NDs) are crucial steps toward improving the coherence, level playing field and comparability of EPB Assessments across EU Member States. Each EPB standard includes a normative Annex A, which serves as a structured template to define national or regional choices in applying the standard. Since national methodologies may vary due to climate, building traditions, and regulatory frameworks, Member States are expected to specify their national adaptations in National Annexes (NAs) or National Datasheets (NDs). National Annexes are typically prepared and published by National Standards Bodies, whereas National Datasheets are issued by national or regional authorities. These documents provide transparency in building performance calculations and ensure regulatory compliance with the EPBD.

EPBD III (2018 amended) introduced the requirement for Member States to describe their national calculation methodology following the national annexes of the overarching standards, namely:



- **EN ISO 52000-1** Energy Performance of Buildings – Overarching EPB Assessment – Part 1: General Framework and Procedures
- **EN ISO 52003-1** Energy Performance of Buildings – Indicators, Requirements, Ratings and Certificates – Part 1: General Aspects and Application to the Overall Energy Performance
- **EN ISO 52010-1** Energy Performance of Buildings – External Climatic Conditions – Part 1: Conversion of Climatic Data for Energy Calculations
- **EN ISO 52016-1** Energy Performance of Buildings – Energy Needs for Heating and Cooling, Internal Temperatures and Sensible and Latent Heat Loads – Part 1: Calculation Procedures
- **EN ISO 52018-1** Energy Performance of Buildings – Indicators for Partial EPB Requirements Related to Thermal Energy Balance and Fabric Features – Part 1: Overview of Options

EPBD IV (2024) extended this provision by requiring Member States to base their national calculation methodology on Annex A of additional key EPB standards, which now include, in addition to the previously listed standards:

- **EN ISO 52120-1** Energy Performance of Buildings – Contribution of Building Automation, Controls and Building Management – Part 1: General Framework and Procedures
- **EN 16798-1** Energy Performance of Buildings – Ventilation for Buildings – Part 1: Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings Addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics
- **EN 17423** Energy Performance of Buildings – Determination and Reporting of Primary Energy Factors (PEF) and CO₂ Emission Coefficients for Energy Delivered to and Exported from Buildings

This evolution reflects the increasing emphasis on harmonization and comparability of building energy performance assessments across EU Member States while maintaining the flexibility necessary to accommodate national and regional specificities.

6.1.1 The situation in Austria, Netherlands and Spain

National Annexes, where publicly available, were collected and analysed to gain a better understanding of the current landscape. In Spain, the National Annexes A for the EPB standards listed in Annex I of the EPBD III (2018 amended) are available and were therefore studied. In Austria, the existing national datasheet for (EN) ISO 52000-1, 52003-1, 52010-1, 52016-1, and 52018-1 was translated into English to facilitate comparison. In the Netherlands, we confirmed that the National Annexes have been completed and communicated to the European Commission; however, they are not publicly available, and despite interactions with the relevant national authorities, i.e. **Ministry of Housing and Spatial Planning (VRO) [30]** & **Netherlands Enterprise Agency (RVO) [31]**, we were unable to gain access to them.

Austria has opted to use national datasheets instead of filling in National Annexes A for the relevant EPB standards (EN) ISO 52000-1, 52003-1, 52010-1, 52016-1, and 52018-1. These datasheets are published as part of the **OIB Guideline 6 – National Accompanying Document [32, 33]**, which is publicly available on the website of the **Austrian Institute for Building Technology (OIB) [34]**. The datasheets contain Austria-specific values and choices for EPB assessments, following the structure



outlined in Annex A of the respective standards. Austria's national datasheet follows a structured methodology aligning with ISO 52000-1, providing specific references to Austrian regulations and energy performance calculations. The datasheet includes detailed references to OIB Guideline 6, which covers energy-saving requirements and climate-adaptive parameters. The document specifies the use of nationally defined climatic conditions and occupancy profiles, ensuring compliance with Austrian regulatory frameworks. The datasheet is only available in German, which may limit direct comparability for stakeholders from other EU Member States. However, as part of iEPB activities, an unofficial English translation of the Austrian national datasheets has been produced to facilitate comparison with other Member States' implementations

Spain has developed National Annexes A for ISO 52000-1, 52003-1, 52010-1, 52016-1, and 52018-1, which are publicly available on **the Ministry for the Ecological Transition and the Demographic Challenge (MITECO) website [35]** and **the Institute for the Diversification and Saving of Energy (IDAE) [36]**. These annexes outline the Spanish approach to energy performance assessments, specifying default input values, calculation methods, and compliance requirements. The annexes reference key national regulations, including Real Decreto 235/2013 (Establishing the methodology for energy performance certification) and Código Técnico de la Edificación (CTE DB-HE, Defining energy efficiency requirements). Spain has made explicit choices regarding energy indicators, climatic conditions, and zoning strategies for energy performance calculations. The annexes ensure that Spain's national methodology follows Annex I of the EPBD III (2018 amended), reinforcing transparency and alignment with EU guidelines. The documents are available in English, with detailed explanations of national adaptations.

6.1.2 Comparative analysis of national annexes & datasheets in Austria and Spain

Table 4 Comparative analysis of national annexes & datasheets in Austria and Spain

Category	Austria	Spain
1. Public availability & language	Publicly available as part of OIB Guideline 6 – National Accompanying Document on the Austrian Institute for Building Technology (OIB) website. However, only available in German. An unofficial English translation has been completed within iEPB activities for cross-country comparisons.	Publicly available as National Annexes A on the Ministry for the Ecological Transition and the Demographic Challenge (MITECO) website. Only available in Spanish, with no official or unofficial English translation.
2. Document type & implementation approach	National Datasheet (OIB Guideline 6) instead of a standard Annex A format. Austria's method follows a separate but complementary approach, ensuring flexibility through national regulatory frameworks.	National Annexes A directly implementing EPBD Annex I requirements for ISO 52000-1, 52003-1, 52010-1, 52016-1, and 52018-1. Spain follows a direct EPBD-compliant approach for EU comparability.
3. Legal basis & regulatory alignment	Governed by OIB Guideline 6 and Austrian ÖNORM standards. Compliance with EPBD III (2018	Directly aligned with EPBD Annex I. Governed by Real Decreto 235/2013 (establishing EPC methodology) and



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	amended) is indirect, as Austria maintains national discretion over methodology while referencing ISO standards.	Código Técnico de la Edificación (CTE DB-HE) (setting energy efficiency requirements). Fully integrated into national regulations.
4. Building typologies covered	Includes single-family homes, multi-family residential buildings, offices, educational buildings, hospitals, care homes, hotels, sports facilities, retail, and industrial sites. Thermal zones and building categories vary across Austrian federal states.	Includes single-family houses, apartment blocks, commercial buildings, public buildings, hotels, industrial buildings, and special use buildings. All typologies follow a unified approach across Spain.
5. Zoning & climate adaptation approach	Climate-dependent and building-use specific zoning, varying across Austrian federal states. The ÖNORM B 8110-5 standard defines climate zones and user profiles.	Nationwide standardized zoning. All buildings follow the same fixed reference conditions, with less regional adaptation.
6. Primary energy indicator calculation	Uses OIB Guideline 6 and ÖNORM H 5050 to define Austria's primary energy factor methodology. Includes regional adjustment factors based on climate and building stock variations.	Uses CTE DB-HE methodology, which establishes a nationally fixed calculation method for primary energy factors without regional differentiation.
7. Heating & cooling load calculations	Defined in ÖNORM B 8110-5 and ÖNORM B 8110-6, ensuring alignment with Austrian climate conditions. Austria adapts calculation methods based on regional building stock characteristics.	Defined according to ISO 52016-1, directly applied through the Spanish National Annexes. Uses uniform climatic reference zones.
8. Integration with Energy Performance Certification (EPC) system	Austria's national datasheet is complementary to the EPC system but is not directly embedded. Certification methodology follows OIB Guideline 6, which sets national requirements for building energy assessments.	Fully embedded into the Spanish EPC framework. Certification follows Real Decreto 235/2013, ensuring seamless integration between National Annexes and EPC requirements.
9. Compliance checks & minimum performance requirements	Set by Austrian federal states, leading to regional variations. Compliance is based on a mix of reference heating demand, share of renewable energy and total energy efficiency factor (fGEE), with different thresholds for residential and non-residential buildings.	Set at the national level through CTE DB-HE, ensuring a uniform performance threshold for all buildings. No differentiation between autonomous regions.



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10. Transparency & ease of use for stakeholders	Data transparency is limited due to the exclusive use of German and reliance on ÖNORM standards, which require specialized knowledge for interpretation. The unofficial iEPB English translation improves accessibility but is not yet officially recognized.	Highly transparent, as the National Annexes directly apply ISO standards and are available in English, increasing accessibility for non-Spanish stakeholders.
11. Calculation method selection (hourly vs monthly)	Austria's approach is a monthly calculation.	Spain follows a more standardized approach, primarily using monthly calculations with optional hourly methods for specific cases, as defined in ISO 52016-1.
12. Energy use categories considered in assessments	Covers space heating, space cooling, domestic hot water (DHW), ventilation, lighting, and auxiliary energy use, with specific national modifications aligned with Austrian standards.	Covers the same categories (heating, cooling, DHW, lighting, ventilation), but all are strictly aligned with EPBD definitions.
13. Handling of renewable energy systems	Austria defines national energy mix factors within OIB guidelines, ensuring regional adaptation of renewable energy contributions.	Spain follows ISO-defined primary energy factors, without national customization for renewables.

6.1.3 Next steps during iEPB's implementation

The iEPB project has mapped the current landscape of National Annexes (NAs) and National Datasheets (NDs) across the selected Member States, identifying key implementation practices, challenges, and areas requiring further support. Building on these findings, the next steps in iEPB's implementation will focus on facilitating broader adoption, enhancing transparency, and mapping differences between countries to ensure harmonized yet flexible national methodologies aligned with the EPB standards and EPBD provisions.

Moreover, within the framework of the project, the team aims to support and provide resources to the Austrian national authorities in publishing also an official English version, and both the Austrian and Spanish national authorities in filling in the additional EPB standards required under EPBD IV Annex I. To enhance transparency and compliance with EPBD IV Annex I, the iEPB activities will further explore engagement with Dutch national authorities to gain access to existing National Annexes, and support efforts to increase the public availability of the Dutch National Annexes, promoting transparency and facilitating comparability with other Member States, as well as provide support in filling in the additional (to the EPBD III Annex I) EPB standards required under EPBD IV Annex I.



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A key priority is also to continue the collection and analysis of National Annexes and Datasheets across additional Member States to build a more comprehensive repository, which will take place in collaboration via the ongoing activities of the sister projects of the Next Gen EPC cluster, most notably SmarterEPC [24], tunES [25] and openBEP4EU [37] projects:

- Engage with national authorities and standardization bodies to gather publicly available National Annexes and Datasheets.
- Encouraging Member States to share their methodologies and calculation choices to foster comparability and knowledge exchange.
- Providing structured summaries and comparative analyses of national approaches to facilitate understanding of different implementation pathways.

6.2 National EPC reports and labels. EPC database content mapping

The Energy Performance Certification (EPC) framework is a cornerstone of the European Union's efforts to enhance the energy efficiency of its building stock, aligning with the broader objectives set forth in the Energy Performance of Buildings Directive (EPBD). Each Member State implements EPCs through national regulations, methodologies, and administrative structures that reflect both EU directives and domestic energy policies. However, variations in procedural implementation, data management, compliance mechanisms, and integration with complementary instruments remain significant across different countries. Understanding these national building procedures is crucial for fostering harmonization and improving the accuracy and usability of EPCs at both regional and European levels.

This chapter provides a structured analysis of how EPC systems are implemented in selected Member States, focusing on procedural frameworks, compliance verification, and data integration. By exploring case studies from Austria, the Netherlands, and Spain, we aim to highlight the diverse approaches taken to address regulatory challenges and improve EPC effectiveness. These country-specific insights contribute to the overarching objectives of the iEPB project in seeking to develop an integrated assessment framework that enhances the synchrony between EPCs and complementary instruments such as the Smart Readiness Indicator (SRI) and Renovation Passports (RP).

The following sections will delve into each country's regulatory foundation, administrative infrastructure, and technical methodologies, examining the ways in which EPC data is managed, accessed, and utilized for policy development.

Through this comparative analysis, we aim to identify best practices, highlight areas for improvement, and provide recommendations for strengthening EPC frameworks across the EU. By refining and aligning these national procedures, the iEPB project will support Member States in effectively implementing the EPBD IV provisions, ensuring that EPCs remain a valuable tool for building performance assessment and sustainable energy policymaking.



6.2.1 Austria

The Energy Performance Certification (EPC) system in Austria is characterized by a well-developed regulatory framework, a methodical approach to energy performance assessment, and a robust administrative structure. Since its inception in 2006 at the national level, followed by further implementation at the regional level, the EPC framework has evolved to ensure compliance with European directives and national energy efficiency goals. The regulatory foundation of the Austrian EPC system is based on the Energieausweis-Vorlage-Gesetz 2012 [38], which establishes the legal mandate for energy certification and its application across various building typologies. Complementing this national legislation, regional regulations (for example the Styrian Building Act), provide additional governance mechanisms that align with specific local requirements of the nine Austrian provinces. The implementation of the OIB Guideline 6 [39], which serves as the methodological basis for EPC calculations, ensures consistency in assessment criteria and classification methodologies.

The Austrian EPC system benefits from a structured data management approach that incorporates both national and regional databases. The Austrian Address, Buildings, and Dwellings Register (BDR) [40] serves as the central national registry, facilitating the systematic recording and tracking of energy performance certificates. Regional databases (e.g. ZEUS [41] in Styria, Salzburg, Lower Austria, Carinthia, Burgenland and Tyrol or WUKSEA [42] in Vienna) support statistical analyses, allows quality assurance and are part of different administrative processes. This dual-layered data management structure enables authorities to monitor compliance effectively and extract meaningful insights for policy development.

The Austrian Address, Buildings, and Dwellings Register (BDR) [43], managed by Statistics Austria, was established under the Buildings and Dwellings Register Act (BGBl. I No. 9/2004 as amended). The BDR serves as a comprehensive administrative database that consolidates data from various sources, including municipalities and district authorities. It provides essential information on building stock, ownership structures, construction periods, net floor areas, and the number of dwellings, which are critical for energy performance evaluations.

Each federal province may decide whether issuers of energy performance certificates register their data directly in the central Energy Performance Certificate Database (EPCDB) or in a separate provincial database. If provincial regulations require registration in a local database, the province must also ensure that the same information is transmitted to the central EPCDB. Data entered in the Energy Performance Certificate Database (EPCDB) are automatically linked to the Address, Building and Dwelling Register (BDR). This connection supplies the unique identifiers needed to match each record to a specific building or dwelling and lets the system draw on additional BDR information. It also guarantees that certificates are issued only for real, municipality-validated buildings with legally recognised addresses.

The EPC database model follows a structured architecture, ensuring that all essential elements of energy performance assessment are systematically stored and managed. The database is organized



into multiple entities, including building characteristics, energy performance indicators, system efficiency parameters, and certificate metadata. Key attributes stored in the database include:

- General building information (location, building type, year of construction, number of floors, and conditioned floor area)
- Envelope characteristics
- Heating, cooling, and ventilation systems (types of heating systems, fuel sources, efficiency levels, and control mechanisms)
- Energy demand and consumption metrics (HWBRef, PEB, fGEE, CO₂ emissions, and energy carrier breakdowns)
- Renewable energy integration (solar thermal systems, photovoltaics, heat pumps, and district heating connection)
- Certificate issuance details (date of issuance, validity period, issuing authority, and compliance checks related to the applied OIB Guideline)

This structured approach ensures that data consistency and completeness are maintained across different entries, allowing for automated validation of EPC inputs. Furthermore, the database supports standardized queries and reporting mechanisms, enabling policymakers, researchers, and administrators to extract insights into the energy performance of Austria's building stock.

The EPCDB also incorporates a well-defined roles and rights management system, ensuring that access is granted based on user responsibilities. Federal and province authorities have distinct roles that dictate their access levels. Additionally, the EPCDB portal network allows municipalities to interact with EPC records while adhering to strict data protection guidelines.

One of the distinguishing features of the Austrian EPC system is its comprehensive set of performance indicators, which allow for an accurate and nuanced assessment of a building's energy efficiency. Among the key metrics used in the certification process are the reference heating demand (HWBRef), which quantifies the energy required to maintain standard indoor temperatures, and the final energy demand (EEB_{RK}). The primary energy demand (PEB), which is further disaggregated into renewable and non-renewable components is indicated on the first page of the EPC. The total energy efficiency factor (fGEE) provides a comparative measure of the building's final energy demand relative to a reference building from 2007, thereby allowing for an evaluation of improvements in energy efficiency over time. Additionally, carbon dioxide emissions (CO₂eq) are calculated to reflect the environmental impact of the building's energy consumption.

The certification process accounts for climatic variations, with Austria being divided into seven distinct climatic zones that influence energy demand calculations. A single province may span several climatic zones. As illustrated in Figure 6 Climatic zones in Austria (adapted from ÖNORM B8110-5:2024-03), for example, the province of Styria is divided into three distinct zones.



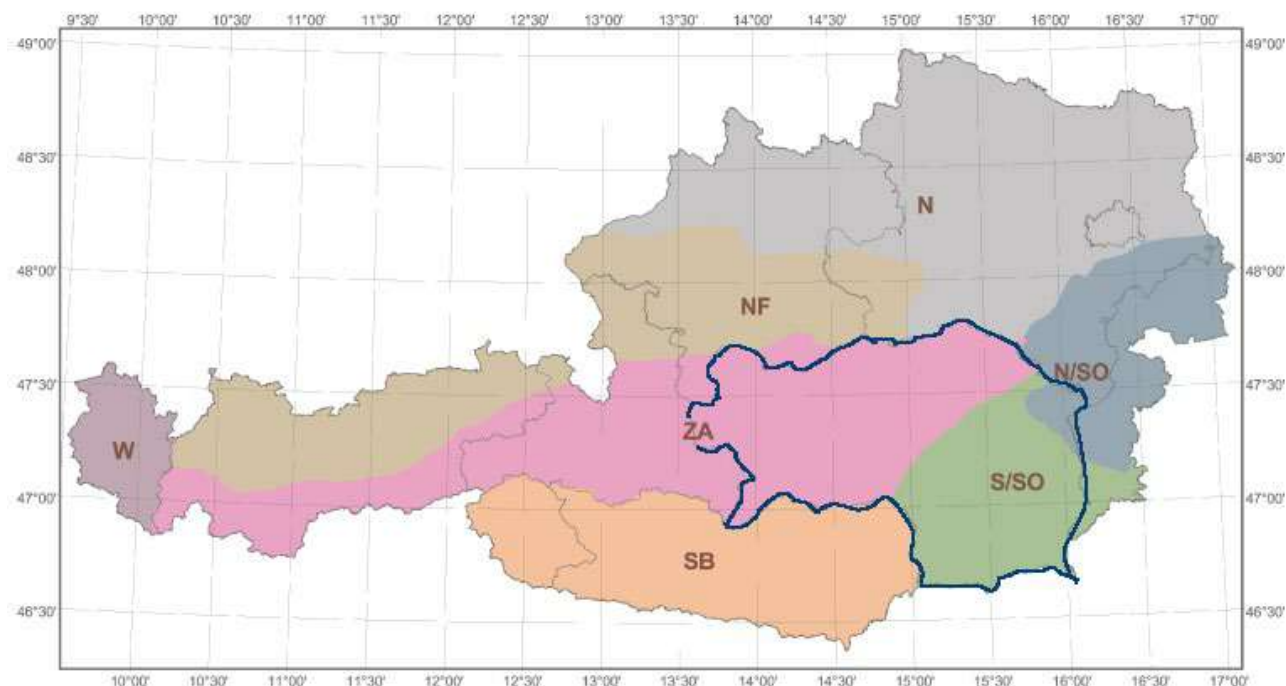


Figure 6 Climatic zones in Austria (adapted from ÖNORM B8110-5:2024-03)

These climatic zones are defined based on long-term meteorological data, ensuring that EPC assessments reflect realistic environmental conditions. The Central Institute for Meteorology and Geodynamics (ZAMG) [44], renamed to GeoSphere Austria in 2023, provides weather data used for EPC calculations, covering key parameters such as heating degree days, outdoor temperature profiles, solar radiation, and humidity levels. The differentiation between reference climate (RK) and local climate (SK) ensures that EPC calculations accurately capture site-specific variations. These datasets are used in EPC calculations to assess heating and cooling demand under standardized and local climate conditions.

In terms of energy labelling, Austria employs a classification system ranging from A++ to G, with the specific energy need for space heating (HWB_{Ref,SK}) serving as the primary determinant of a building's rating. The classification thresholds are structured as presented in Table 5 Energy classes thresholds for residential buildings in Austria.



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Table 5 Energy classes thresholds for residential buildings in Austria [32]

Energy class (Austria)	Specific energy need (HWB _{Ref,SK}) (kWh/m ² a)	Primary energy use (PEB _{BGF,SK}) (kWh/m ² a)	CO ₂ BGF, SK (kg/m ² a)	f _{GEE}
A++	≤ 10	≤ 60	≤ 8	≤ 0,55
A+	≤ 15	≤ 70	≤ 10	≤ 0,70
A	≤ 25	≤ 80	≤ 15	≤ 0,85
B	≤ 50	≤ 160	≤ 30	≤ 1,00
C	≤ 100	≤ 220	≤ 40	≤ 1,75
D	≤ 150	≤ 280	≤ 50	≤ 2,50
E	≤ 200	≤ 340	≤ 60	≤ 3,25
F	≤ 250	≤ 400	≤ 70	≤ 4,00
G	> 250	> 400	> 70	> 4,00

To enhance visually this analysis sample residential and non-residential EPCs are inserted in Figure 7 Sample residential EPC Austria and Figure 8 Sample non-residential EPC Austria to demonstrate the practical application of the classification system and the layout of certificates.

Muster Energieausweis Wohngebäude (WG) Seite 1

Muster Energieausweis Wohngebäude (WG) Seite 2

Figure 7 Sample residential EPC Austria



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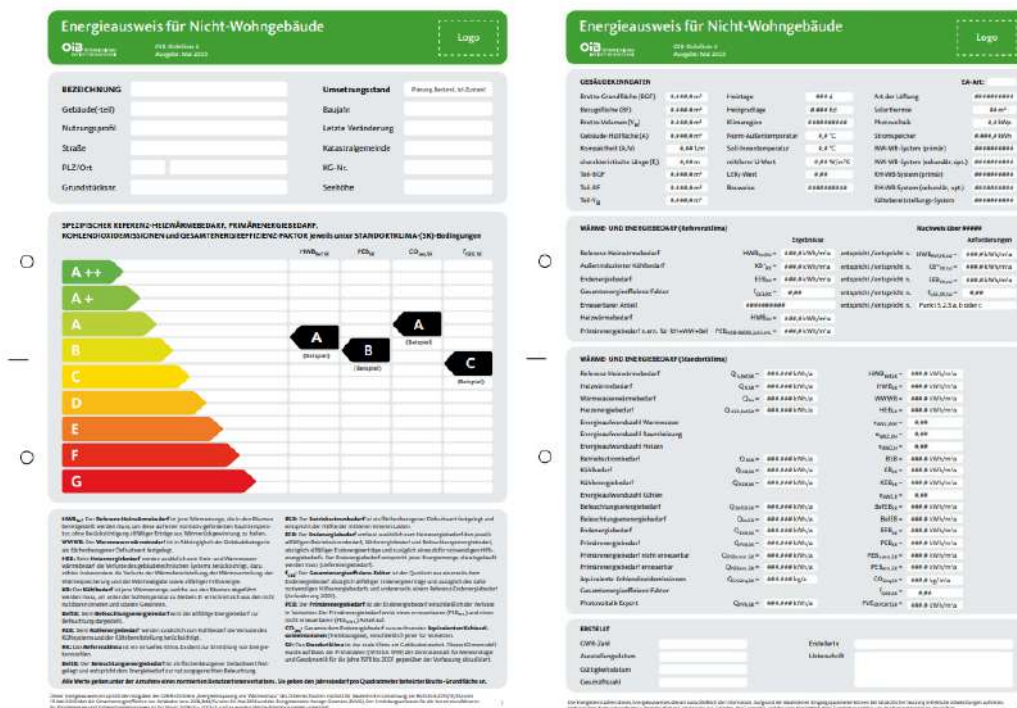


Figure 8 Sample non-residential EPC Austria

These images provide insights into the structure, layout, and specific indicators included in Austrian EPCs, helping illustrate the theoretical concepts outlined in this document.

6.2.2 Netherlands

The Energy Performance Certification (EPC) system in the Netherlands, commonly referred to as the Energielabel, is a well-structured regulatory framework designed to evaluate and communicate the energy efficiency of buildings. It plays a crucial role in promoting energy efficiency in both residential and non-residential buildings, aligning with the Energy Performance of Buildings Directive (EPBD) and national sustainability goals.

The Dutch EPC system was regulated by the Building Decree 2012 (Bouwbesluit 2012), which has been succeeded by the Building Decree for the Living Environment (Besluit bouwwerken leefomgeving, Bbl) [46]. This decree establishes comprehensive regulations ensuring that buildings meet safety, health, usability, and sustainability standards, including energy efficiency and environmental impact. The Bbl mandates that all construction and renovation projects adhere to its stipulated guidelines, regardless of whether a building permit is required. Compliance is supported by various regulatory tools in NEN standards (provide methodologies to assess conformity with Bbl regulations), recognized quality declarations (certify that specific building materials or components meet Bbl criteria), equivalent measures (allow for alternative solutions that achieve the objectives of Bbl's functional requirements), Dutch practice guidelines (NPRs, offer instructions to verify compliance with Bbl's minimum standards), and Dutch Technical Agreements (NTAs, Detail practical implementations of Bbl norms). Since January 1st, 2021, new buildings in the Netherlands must



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comply with the Nearly Energy Neutral Building (BENG) requirements (the Dutch implementation of the Nearly Zero Energy Building standard from the EPBD), which are integrated into the Bbl. These stringent standards aim to reduce energy consumption in new constructions, ensuring that occupants can efficiently manage heating, cooling, and hot water usage with minimal energy expenditure. This initiative aligns with the European Directive on the Energy Performance of Buildings, which mandates that all new structures be nearly energy neutral.

The Human Environment and Transport Inspectorate (ILT) [46] verifies compliance with EPC regulations, while the Netherlands Enterprise Agency (RVO) [47] manages the national EPC database, known as EP-Online [48].

An EPC is mandatory for all buildings at the time of sale, rental, or major renovation. Non-compliance results in fines imposed by the ILT. The introduction of the new calculation methodology (NTA 8800) in 2021 refined the assessment process, ensuring greater accuracy and harmonization with European standards.

The Netherlands employs a standardized methodology (NTA 8800:2024) for calculating energy performance, covering both residential and non-residential buildings. The latest version, NTA 8800:2024, came into effect on January 1st, 2024, introducing several key updates aimed at improving accuracy and simplifying assessment procedures. Key changes include:

- Simplified data entry: Certain input parameters have been removed or simplified. For example, data entry for heating pipes within the thermal shell is no longer required, as these pipe losses are now omitted from calculations
- New input fields: The update accommodates practical scenarios such as communal installations with hot water circulation pipes, where unknown diameters are now estimated based on the number of residential units
- Ventilation rate adjustments: A more favourable minimum ventilation rate has been introduced for small dwellings, reducing the impact of ventilation on the calculated energy performance.

These updates align the methodology more closely with real-world conditions, ensuring a more precise and practical energy performance assessment. The calculation considers factors such as insulation, ventilation, heating and cooling systems, and renewable energy integration.

To ensure compliance with the NTA 8800 methodology, there are several certified software tools for energy performance calculations for EPC:

- BouwConnect NTA 8800: A module used for energy performance calculations in a broader software solution, integrating with other legislative calculations (e.g. daylight, acoustics).
- Uniec 3: A widely used web-based tool.
- Vabi NTA 8800: A widely used desktop solution for EPC in a broader software solution.

The EPC calculations distinguish between calculated energy performance (based on standardized occupancy and climate conditions) and measured energy performance (actual energy consumption, which is not yet integrated into certification but may be in the future).



The Netherlands maintains a centralized EPC database, EP-Online, managed by the RVO. This database stores all energy performance certificates, making them publicly accessible for verification and policy monitoring. Additionally, *Gebouwenenergieprestatie.nl* [49] serves as a platform for professionals involved in energy performance assessments, providing guidelines, regulatory updates, and technical resources. The EPC system ensures electronic data exchange through an XML-based structure, allowing software tools to integrate with EP-Online accurately. The EPC data management system includes:

- Building identification details (address, construction year, cadastral data)
- Thermal envelope characteristics (insulation values, U-values, airtightness levels)
- HVAC and domestic hot water (DHW) systems (energy carriers, efficiency levels, emission factors)
- Renewable energy sources (solar PV, heat pumps, district heating integration)
- Primary energy consumption (kWh/m²·year)
- CO₂ emissions (kg/m²·year)

The Dutch EPC evaluates buildings based on several key energy performance indicators, ensuring a comprehensive assessment of energy efficiency and environmental impact.

- **Primary fossil energy consumption (kWh/m²·year):** This indicator represents the total non-renewable primary energy consumption of a building, measured per square meter per year. It accounts for energy used for heating, cooling, ventilation, domestic hot water (DHW), and lighting, adjusted for system efficiency and losses. This value determines the EPC rating from A++++ (most efficient) to G (least efficient)
- **Final energy consumption (kWh/m²·year):** The final energy demand reflects the actual energy consumed by the building before any energy conversion or losses in distribution. This includes electricity, gas, or district heating used directly for heating, cooling, ventilation, and lighting.
- **CO₂ emissions (kgCO₂/m²·year):** This indicator measures the carbon footprint of a building's energy use, reflecting the amount of CO₂ emitted per square meter per year. It is directly related to the building's energy consumption and the type of energy carriers used (e.g., fossil fuels, renewables)
- **Renewable energy contribution (%):** The EPC details the percentage of the building's energy needs met by renewable sources such as solar photovoltaic (PV), heat pumps, biomass, or district heating. A higher share of renewables results in a lower primary fossil energy consumption and a better EPC rating
- **Heating and cooling demand (kWh/m²·year):** This indicator represents the energy required to maintain indoor thermal comfort throughout the year. It considers the building's insulation, airtightness, solar gains, and ventilation losses.
- **Thermal insulation and building envelope performance:** The EPC includes values such as U-values (W/m²·K) for walls, roofs, floors, and windows, which quantify heat transfer and insulation effectiveness. Lower U-values indicate better insulation performance, reducing heating and cooling energy demand.
- **Energy efficiency of technical systems:** The EPC assesses the efficiency of heating, ventilation, and air conditioning (HVAC) systems, DHW production, and lighting systems. Seasonal efficiency values and energy recovery systems are factored into the calculations.



- Ventilation and air infiltration rates: The EPC accounts for ventilation strategies (natural, mechanical, hybrid) and the building's air permeability (n_{50} value in h^{-1}), influencing heating and cooling loads.
- TOjuli, Risk of overheating: The TOjuli indicator reflects the risk of overheating in buildings during the month of July, based on factors like solar gains, ventilation, shading, and thermal mass. It estimates how often indoor temperatures exceed comfortable levels in summer. A higher TOjuli value means greater risk of overheating. This value is required for new residential buildings, and the threshold is regulated by the Bbl.

The final energy label classification depends primarily on the primary energy consumption, while the CO₂ emissions, renewable energy share, and heating/cooling demand provide additional insights into the building's overall energy performance.

The Dutch EPC assigns buildings an energy label from A++++ to G, reflecting the building's efficiency based on primary fossil energy consumption ($\text{kWh}/\text{m}^2\cdot\text{year}$), for which the thresholds are shown in Table 6 Energy classes thresholds for residential buildings in the Netherlands.

Table 6 Energy classes thresholds for residential buildings in the Netherlands

Energy label (Netherlands)	Primary fossil energy demand ($\text{kWh}/\text{m}^2\cdot\text{year}$)
A++++	≤ 0 (energy neutral or positive)
A+++	≤ 50
A++	≤ 75
A+	≤ 105
A	≤ 160
B	≤ 190
C	≤ 250
D	≤ 290
E	≤ 335
F	≤ 380
G	> 380

The classification depends on the calculated non-renewable primary energy demand, considering factors such as energy efficiency of installations, insulation, and renewable energy generation.

The Netherlands uses official meteorological data, established in NEN-5060 [50], consisting of representative climatic data, provided by KNMI (Royal Netherlands Meteorological Institute) [51] to ensure climate conditions are accurately reflected in EPC calculations. The standardized climate files are hourly values with ambient temperature profiles, solar radiation levels, humidity levels and wind speed. In the NTA 8800 additional values are derived from the hourly values like monthly mean ambient temperature, monthly mean wind speed, and monthly mean solar radiation incidence per orientation and inclination of surfaces, calculated according to NEN-EN-ISO 52010. The EPC calculations do not include regional weather variations.



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The Dutch EPC follows a standardized format, providing clear and structured information, including, general building information (address, construction year, usage type), energy label assignment (A++++ to G), breakdown of energy consumption (heating, cooling, DHW, ventilation, lighting), and recommendations for energy efficiency improvements.

To visually illustrate these concepts, a couple of samples are included for reference (residential [52] and non-residential [53]).

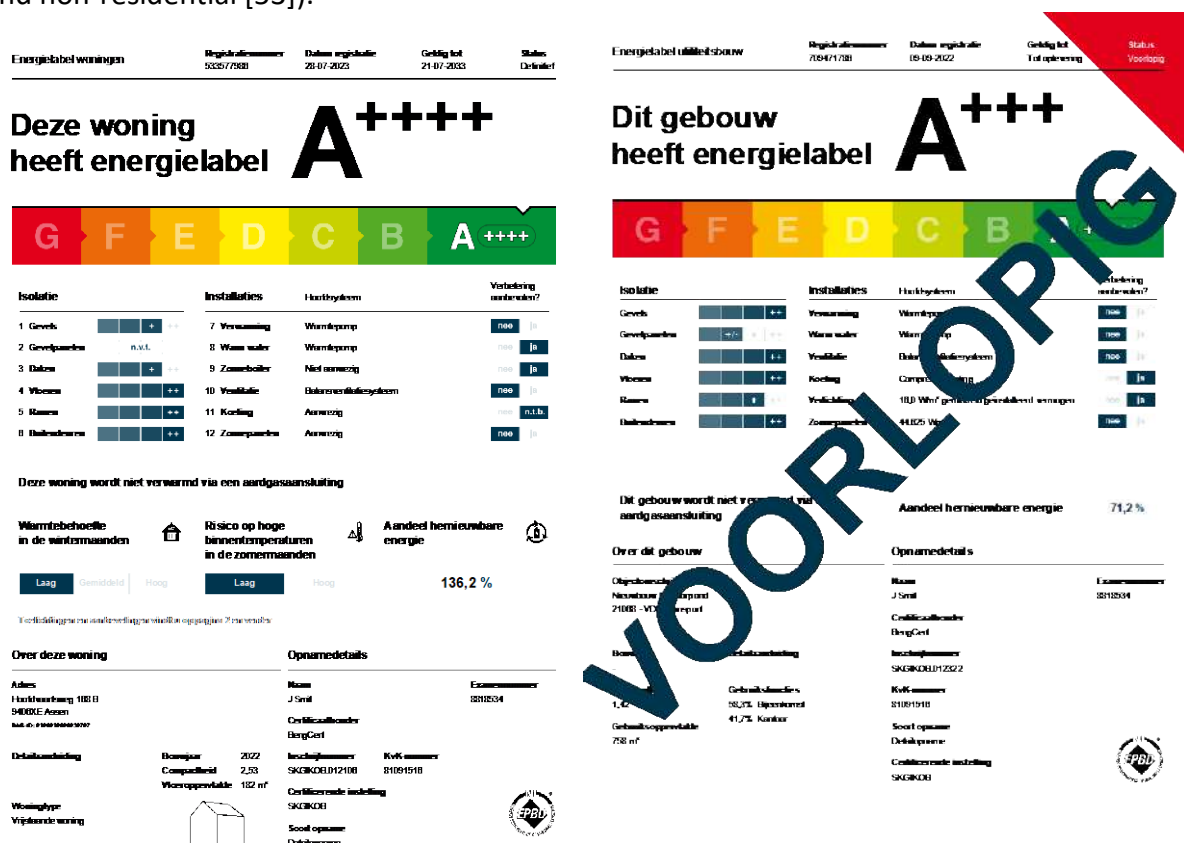


Figure 9 Sample residential (left) and non-residential (right) EPC Netherlands

6.2.3 Spain

The Energy Performance Certification (EPC) system in Spain is governed by a structured regulatory framework that has evolved in alignment with European directives and national energy policies. The first introduction of EPCs in Spain dates to 2007, following the transposition of Directive 2002/91/EC into national law. Over time, the legal basis for energy certification has been strengthened, with the Royal Decree 235/2013 and later Royal Decree 390/2021, which establishes the basic procedure for the certification of the energy performance of buildings. These decrees define the calculation methodologies, certification process, and administrative responsibilities for ensuring compliance.

The Ministry for the Ecological Transition and the Demographic Challenge (MITECO) [54], along with the Ministry of Transport, Mobility, and Urban Agenda, oversee the regulatory framework for EPCs. Certification is mandatory for both new and existing buildings in residential and non-residential



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sectors whenever they are sold or rented. The Code of Technical Building Regulations (CTE DB-HE) [55] defines the energy efficiency criteria that buildings must meet.

The EPC system operates at both national and regional levels. While Spain has introduced a National EPC Geoportal, the official EPC registries are managed regionally. Each Autonomous Community (e.g., Navarra, Madrid, Catalonia) administers its own registry, ensuring compliance with the national legislation while adapting specific requirements to local needs. The decentralized approach allows for flexibility in implementation while maintaining a centralized administrative register at the national level for statistical and policy monitoring purposes.

The Spanish EPC methodology is based on both calculated energy ratings and standardized software tools. The certification process distinguishes between dynamic and simplified methods:

- Dynamic methods (e.g., HULC, SG SAVE, CYPETHERM HE Plus) involve detailed hourly simulations and multi-zone energy calculations
- Simplified methods (e.g., CE3X, CE3, CERMA) use indirect dynamic approaches and empirical data to estimate building energy performance

The software used for EPC assessments must be officially recognized by the Spanish authorities and includes:

- HULC (Herramienta Unificada Lider-Calener): The official tool for both residential and non-residential buildings
- CE3X and CE3: Widely used for assessing existing buildings
- CYPETHERM HE Plus, CERMA, SG SAVE: Tools that have also received official approval

Spain's EPC system incorporates an XML-based reporting format [56], enabling the electronic exchange of data between certification tools and the Centralized Administrative Register of Energy Assessment Reports. The EPC system relies on regional databases for registration and quality control, with data being transferred to the National Geoportal of EPCs for national policy monitoring. The data structure of EPC databases includes key elements such as:

- Building identification details (address, cadastral reference, construction year, climatic zone)
- Thermal envelope characteristics (U-values, insulation levels, thermal bridges)
- HVAC and domestic hot water systems (energy sources, efficiency levels)
- Energy demand and performance indicators (primary energy, CO₂ emissions, energy rating class)

Spain follows a standardized EPC format, including detailed building information, energy performance indicators, and recommendations for energy efficiency improvements. The EPC model includes: building identification and certification details; Summary of energy consumption and CO₂ emissions; graphical representation of the energy label; technical details of thermal envelope and HVAC systems; proposed retrofit recommendations



The Spanish EPC system evaluates buildings based on multiple energy performance indicators, primarily:

- Heating energy demand: The annual energy required to maintain indoor thermal comfort during the heating season, measured in kWh/m²·year.
- Cooling energy demand: The annual energy necessary to maintain indoor thermal comfort during the cooling season, also in kWh/m²·year.
- Non-renewable primary energy consumption: The annual non-renewable primary energy consumption, reflecting the energy extracted from non-renewable resources to meet the building's energy needs, measured in kWh/m²·year.
- CO₂ emissions: The annual carbon dioxide emissions associated with the building's energy consumption, expressed in kgCO₂/m²·year.
- The EPC also includes a recommendation report with proposals for cost-effective or cost-optimal [57] measures to enhance the building's energy performance, considering the specific characteristics of the building.
- By providing these detailed indicators, the EPC enables building owners, potential buyers, and tenants to understand the energy efficiency of a property and identify opportunities for improvement.

Spain employs a seven-class rating system (A to G) for energy labelling as illustrated in Table 7 Energy classes thresholds for residential buildings in Spain. However, the energy classification thresholds vary depending on the climatic zone and building typology. The country is divided into 13 climatic zones, each with specific reference conditions for energy calculations. The kWh/m²·year figures shown in Table 7 are illustrative national values only, presented here to enable a straightforward comparison with the thresholds used in other EU Member States. When an Energy Performance Certificate (EPC) is issued for an actual building, the official calculation tools first assign the building to one of Spain's 13 climatic zones (A1 ... E3) and to its specific typology (single-family, multi-family, tertiary, ...). For each zone-and-type combination, the Ministry's recognised method ("Calificación de la eficiencia energética de los edificios", Annex III-IV) provides dedicated reference values. The software then scales the A to G thresholds accordingly. Thus, the precise limit that separates, say, class C from class D in zone C3 is not necessarily the same as the generic 125 / 200 kWh/m²·yr shown here.

Table 7 Energy classes thresholds for residential buildings in Spain

Energy class (Spain)	Non-renewable primary energy consumption (kWh/m ² ·year)
A	≤ 50
B	≤ 75
C	≤ 125
D	≤ 200
E	≤ 300
F	≤ 400
G	> 400



Transparent description of each national and EU technical methodology for EPB Assessment / D2.1

Spain's EPC system incorporates hourly climatic data provided by official meteorological services. The 13 climatic zones are categorized based on heating and cooling degree days, outdoor temperatures, and solar radiation levels. This classification ensures that energy assessments accurately reflect regional climate variations, influencing energy demand calculations. The official synthetic climate data files contain hourly records for ambient temperature, humidity, and solar radiation, which are integrated into the calculation methodologies of EPC software tools.

To enhance this analysis, a sample EPC valid for all considered building types is included to illustrate the practical application of these concepts in Figure 10 Sample EPC Spain. The Spanish EPC [58] includes several annexes that provide detailed technical, analytical, and regulatory information to support the energy performance certification process. These annexes are structured as follows: Annex I (Description of the building's energy characteristics), Annex II (Energy rating of the building), Annex III (Recommendations for improving energy efficiency), Annex IV (Tests, checks, and inspections conducted by the certifying technician).

CERTIFICADO DE EFICIENCIA ENERGÉTICA DE EDIFICIOS

IDENTIFICACIÓN DEL EDIFICIO O DE LA PARTE QUE SE CERTIFICA:

Nombre del edificio	
Dirección	Código Postal
Municipio	Comunidad Autónoma
Provincia	Año construcción
Zona climática	
Normativa vigente (construcción / rehabilitación)	
Referencia/s catastrales	

Tipo de edificio o parte del edificio que se certifica:

☐ Edificio de nueva construcción ☐ Edificio existente

☐ Vivienda ☐ Tercero ☐ Edificio completo ☐ Local

☐ Unifamiliar ☐ Bloque ☐ Bloque completo ☐ Vivienda individual

DATOS DEL TÉCNICO CERTIFICADOR:

Nombre y Apellidos	NIF/NIE
Razón social	NIF
Domicilio	
Municipio	Código Postal
Provincia	Comunidad Autónoma
e-mail	Teléfono
Titulación habilitante según normativa vigente	
Procedimiento reconocido de certificación energética utilizado y versión	

CALIFICACIÓN ENERGÉTICA OBTENIDA:

CONSUMO DE ENERGÍA PRIMARIA NO RENOVABLE [kWh/m²·año]	EMISIONES DE DIÓXIDO DE CARBONO [kgCO₂/m²·año]

El técnico abajo firmante declara responsablemente que ha realizado la certificación energética del edificio o de la parte que se certifica de acuerdo con el procedimiento establecido por la normativa vigente y que son ciertos los datos que figuran en el presente documento, y sus anexos.

Fecha: ____/____/____

Firma del técnico certificador: _____

Anexo I. Descripción de las características energéticas del edificio.
Anexo II. Calificación energética del edificio.
Anexo III. Recomendaciones para la mejora de la eficiencia energética.
Anexo IV. Pruebas, comprobaciones e inspecciones realizadas por el técnico certificador.

Registro del Órgano Territorial Competente: _____

Fecha (de generación del documento): XXXXXXXX
 Rol: Calentador XXXXXXXX

Página X de X

CALIFICACIÓN ENERGÉTICA DEL EDIFICIO TERMINADO ETIQUETA

DATOS DEL EDIFICIO

Normativa vigente construcción / rehabilitación	Tipo de edificio
Referencia/s catastrales	Dirección
	Municipio
	C.P.
	C. Autónoma

ESCALA DE LA CALIFICACIÓN ENERGÉTICA

	Consumo de energía kWh / m² año	Emisiones kg CO₂ / m² año
A más eficiente		
B		
C		
D		
E		
F		
G menos eficiente		

REGISTRO

 Válido hasta 31/12/2020

ESPAÑA
 Directiva 2010 / 31 / UE

Figure 10 Sample (residential and non-residential) EPC Spain

6.2.4 Comparative analysis and results

The analysis of EPC implementation in Austria, the Netherlands, and Spain reveals both commonalities and distinct national approaches that influence the effectiveness of energy performance assessments across the EU. A comparative evaluation of these systems highlights the following key takeaways:



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Transparent description of each national and EU technical methodology for EPB Assessment / D2.1

- **Regulatory frameworks and compliance mechanisms:** Austria and the Netherlands exhibit well-structured regulatory environments, with comprehensive legislative acts ensuring EPC compliance at national and regional levels. Spain has a decentralized system with autonomous community-led registries.
- **Data management and integration:** Austria has a robust, dual-layered EPC data management system that integrates national and regional databases, ensuring consistency and compliance tracking. The Netherlands operates a highly digitized EPC database (EP-Online), which allows for transparent access and automated updates, streamlining certification processes. Spain's regionalized data repositories contribute to administrative flexibility but may limit seamless nationwide data integration.
- **Calculation methodologies and energy performance indicators:** Austria follows the OIB Guideline 6 and incorporates climate-specific parameters for EPC assessments. The Netherlands applies the NTA 8800 methodology, integrating advanced calculation techniques and simplifying data entry to improve usability. Spain offers a mix of dynamic and simplified calculation methods, allowing flexibility but potentially leading to discrepancies in EPC quality across different regions.
- **Quality assurance and digitalization trends:** Austria's EPC system requires quality checks (federal administration) and data exchange to Statistik Austria. The Netherlands integrates EPC software tools with an automated compliance mechanism, reducing administrative burdens. Spain's approach emphasizes software standardization, yet enforcement consistency varies among regions.

Table 8 Comparative overview of EPC implementation provides a comparative overview of EPC implementation across Austria, the Netherlands, and Spain. It highlights key differences and similarities in regulatory frameworks, data management, compliance mechanisms, and classification approaches.

Table 8 Comparative overview of EPC implementation

Aspect	Austria	Netherlands	Spain
Regulatory framework	OIB Guideline 6, Energieausweis Law	Bbl 2024, BENG (NZEB) requirements	Royal Decree 390/2021
EPC data management	Central & regional dual-layered system	EP-Online national database	Regionalized registries with national aggregation
EPC calculation method	OIB Guideline 6, climate-specific inputs	NTA 8800, simplified inputs	Dynamic & simplified methodologies
Compliance mechanism	Federal and regional oversight	ILT inspections and fines	Regional enforcement, varying oversight
Quality assurance & data format	Automated software verification and regional authority-led verification (random samples)	Automated software verification	Regional authority-led verification



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Access and integration	XML-based with regional nodes	Automated real-time integration	Manual uploads with regional variations
User access	Tiered access for authorities & assessors	(Partly) Public access for verification	Restricted based on regional policies
Control			
Climate data usage	7 climate zones	Standardized meteorological data	13 climate zones
EPC classification	A++ to G, for dedicated indicators	A++++ to G, based on primary fossil energy demand	A to G, based on non-renewable primary energy and CO ₂ emissions adjusted by climatic zone

Energy performance classes differ significantly across Austria, the Netherlands, and Spain in terms of thresholds. The table below highlights the classification schemes used in each country. All 3 countries use a similar metric for the classifications, i.e. non-renewable primary energy (incentivizing nearly zero-energy buildings), but Austria has stricter upper-tier thresholds, promoting highly efficient buildings. Spain's classification considers climatic differences across its 13 zones, allowing for regionally adapted performance thresholds. While Austria and Spain do not specify values for the highest efficiency classes (A++++ and A+++), the Netherlands defines A++++ as energy-neutral or positive (≤ 0 kWh/m²·year).

Table 9 Cross-comparison of energy classifications for residential buildings compares the energy-class thresholds applied in Austria, the Netherlands and Spain. Because Austria does not label non-renewable primary energy, its total primary-energy figure (kWh/m²·year) is used instead. Austria imposes the tightest limits in the two “A-plus” bands. A++ is capped at ≤ 60 kWh/m²·year and A+ at ≤ 70 kWh/m²·year, while the Netherlands allows up to 75 and 100 kWh/m²·year respectively. Spain does not define these classes.

Comparing class A, Spain becomes the most demanding. Its class A ceiling of ≤ 50 kWh/m²·year is markedly lower than Austria's 80 kWh/m² year total primary energy and the Netherlands' 160 kWh/m²·year. The trend continues through the middle tiers. As efficiency decreases further, all three countries relax their thresholds, but Spain generally stays below Austria, and the Netherlands remains the least stringent. By class E the limits are ≤ 300 kWh/m²·year (Spain), ≤ 335 (Netherlands), and ≤ 340 (Austria). At the bottom of the scale all three systems now align: class G is defined as > 400 kWh/m²·year.

In short, Austria is the strictest for the ultra-efficient A++ and A+ classes, Spain leads from class A through E, and the Netherlands consistently permits the highest consumption across most categories.



Table 9 Cross-comparison of energy classifications for residential buildings

Energy class	Primary energy use (kWh/m ² ·year) Austria	Primary fossil energy demand (kWh/m ² ·year) Netherlands	Non-renewable primary energy use [59] (kWh/m ² ·year) Spain
A++++	-	≤ 0 (energy neutral or positive)	-
A+++	-	≤ 50	-
A++	≤ 60	≤ 75	-
A+	≤ 70	≤ 105	-
A	≤ 80	≤ 160	≤ 50
B	≤ 160	≤ 190	≤ 75
C	≤ 220	≤ 250	≤ 125
D	≤ 280	≤ 290	≤ 200
E	≤ 340	≤ 335	≤ 300
F	≤ 400	≤ 380	≤ 400
G	> 400	> 380	> 400

Key recommendations and future directions

- Enhancing data interoperability: Establishing a standardized EU-wide EPC data model that aligns with national databases can improve cross-border accessibility and comparability.
- Strengthening compliance and quality assurance: Encouraging Member States to adopt digital compliance tracking mechanisms, like the Netherlands' EP-Online system, would enhance EPC reliability.
- Improving methodological consistency: Promoting the use of harmonized energy performance calculation methodologies will minimize discrepancies between Member States.
- Facilitating integration: Expanding the link between EPCs, the SRI, and Renovation Passports can support the broader objectives of the EPBD IV and digital transformation in building assessments. Integrating these instruments with EPCs ensures a streamlined approach, reducing administrative burden and increasing cost-effectiveness. This holistic approach allows policymakers, building professionals, and owners to make informed decisions, accelerating deep renovation rates while leveraging existing certification infrastructures.

By adopting these measures, the EU can advance towards a more cohesive and effective EPC system, ensuring that energy performance assessments contribute meaningfully to the transition towards a decarbonized and energy-efficient built environment.



6.3 National EPC software – official calculated EPB Assessments and Certification

The implementation of EPB assessments across Austria, the Netherlands, and Spain relies on official EPC software tools that ensure compliance with national and EU-wide standards. These tools serve as the foundation for energy performance calculations, energy performance certification issuance, and renovation recommendations, in accordance with the EPBD.

The iEPB project has analysed these official EPC tools in depth for the subsequent implementation of its activities to be further detailed as needed in other deliverables, with a focus on:

- National data models (e.g., file formats, input/output structures).
- Calculation methodologies (e.g., energy needs, CO₂ emissions, primary energy factors).
- Interoperability with the iEPB common data model.
- Renovation recommendations linked to EPCs.

Furthermore, iEPB project has actively contributed its findings and input regarding these official EPC software tools to the EPC Atlas [60], of the sister project SmarterEPC. This collaboration has provided valuable insights into how EPC tools are structured, how they integrate data, and how they can be enhanced for better interoperability and usability. By sharing its analysis and knowledge, iEPB has helped support the development of EPC Atlas as a centralised knowledge base for EPC practices across Europe, facilitating improvements in EPB assessments and their alignment with national and EU policies.

This section provides an overview of the official EPC software tools used in Austria, the Netherlands, and Spain for calculated EPB assessments and certification, highlighting their role in ensuring accurate and effective energy performance assessments while supporting ongoing research and development in the field.

6.3.1 Austria

In Austria five EPC software tools are officially validated that ensure compliance with Austrian energy performance calculation methodologies. These tools are:





Figure 11 Logos of official EPC software in Austria

- **ArchiPHYSIK [61]**
 - ArchiPHYSIK contains simplified and detailed calculations for single-zone and multi-zone energy performance certificates.
 - A wide range of sound insulation requirements can be met with the integrated component and room-related calculations.
 - Evaluates the components and rooms for their summer suitability.
 - Features BIM compatibility and building physics analysis.
- **AX3000 [62]**
 - Provides energy demand calculations, heating/cooling load analysis, and EPC certification.
 - Directly integrates with CAD/BIM software for enhanced workflow efficiency.
 - Supports national EPB methodologies and EPBD renovation advisory frameworks.
- **Ecotech Gebäuderechner [63]**
 - Used for building physics calculations, EPC generation and energy performance analysis.
 - Full integration of ECOBOOK database for building materials and technical equipment data.
 - Directly integrates with BIM CAD software.
 - Calculations for cost-optimal energy efficiency improvements and financial incentive evaluations.
 - Special evaluation for the building biology certificate on holistic quality of living space and CO₂ emission.



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- **Gebäudeprofi (ETU) [64]**
 - Includes modular tools for EPC calculations, primary energy demand assessment, and CO₂ emissions tracking.
 - Large manufacturer catalogue for building materials and components as well as interfaces for the submission of energy certificates.
 - Provides renovation recommendations aligned with Austrian EPC regulations.
- **GEQ [65]**
 - Quality assurance software ensuring compliance with Austrian EPC methodologies.
 - Quick geometry capture through simple templates warns if building law limits are not complied with. In addition, many legal texts can be viewed via info buttons.
 - Enables structured data exchange with Austrian EPC databases.

6.3.2 Netherlands

The Netherlands employs several official EPC software tools that comply with Dutch EPB regulations, supporting both new and existing buildings. Additional tools are expected to enter the market.



Figure 12 Logos of official EPC software in the Netherlands

- **BouwConnect NTA 8800 [66]**
 - Dutch EPC software integrating building information modelling (BIM).
 - Supports EPB data exchange with national databases.
 - Used for compliance checks and renovation strategies.
- **Uniec 3 [67]**
 - A key EPC tool in the Netherlands, widely adopted for energy certification and compliance checks.
 - Supports building physics analysis and EPBD-related energy renovation.
 - Ensures consistency in EPC assessments by using a structured national data model.



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- **Vabi NTA 8800 [68]**

- Developed by Vitec Software Group, specialized in energy simulation.
- Desktop tool for energy performance calculation and certificate issuance, part of a broader software.
- The overall software supports more detailed thermal and energy modelling.

6.3.3 Spain

Spain has a diverse set of EPC tools, covering both new and existing buildings. The official EPC software used for certification includes:



Figure 13 Logos of official EPC software in Spain

- **Unified LIDER-CALENER Tool (HULC) [69]**

- Official Spanish EPC tool integrating energy modeling and certification.
- Used for compliance with CTE (Código Técnico de la Edificación) and EPC issuance.
- Outputs detailed renovation recommendations in line with EPBD requirements.

- **CE3 [70] & CE3X [71]**

- EPC software specialized for existing buildings in Spain.
- Used widely for energy audits and improvement recommendations.



- **CYPETHERM HE Plus [72]**
 - Module for energy performance calculation and EPC issuance, developed by CYPE Ingenieros, part of a broader advanced energy modelling software, supporting energy simulation.
 - Integrates with BIM workflows and generates energy efficiency reports.
- **SG SAVE [73]**
 - Module that provides advanced EPC verification and compliance assessment, and is part of broader software solution.
 - Ensures regulatory alignment with Spain's EPB framework.
- **TeKton3D TK-CEEP [74]**
 - Advanced energy modelling tool for Spanish EPC assessments.
 - Incorporates detailed HVAC and building envelope analysis.
- **CERMA [75]**
 - EPC software focused on residential buildings.
 - Evaluates comfort and indoor environmental quality (IEQ) alongside energy performance.

6.3.4 Comparative analysis of the EPC software ecosystems

Table 10 Comparative analysis of the EPC software ecosystems

Country	Austria	Netherlands	Spain
Scope (new & existing buildings)	Covers residential & non-residential buildings. Tools support renovation recommendations. The different tools have diverse possibilities for BIM data import.	Covers residential & non-residential buildings. Strong focus on compliance checks and integration with national databases.	Covers residential & non-residential buildings. Some tools specialize in energy audits for existing buildings, while others cover new constructions.
Building categories	Residential, commercial, institutional, and mixed-use buildings. In Austria, 13 different building categories are named in the ÖNORM.	Residential, commercial, industrial, and mixed-use buildings.	Residential, commercial, public, and historic buildings.
Calculation methodologies	National structured data models (accredited systems) ensuring consistency across EPC assessments.	National structured data model (input-output data) ensuring consistency across EPC assessments.	Energy modelling and simulation tools in compliance with the Spanish Technical Building Code (CTE).
Compliance	Follows national EPB methodologies and EPBD-aligned renovation frameworks.	Ensures compliance through a standardized national data model	Compliant with national EPB methodologies and EPBD requirements,



		and structured verification processes.	outputs detailed renovation recommendations.
Data model & interoperability	Structured input/output data formats ensuring compatibility with multiple EPC tools. BIM integration in different levels, depending on the software provider.	Standardized national EPC data model with strong EPB data exchange capabilities.	Various data models depending on tool specialization. Some BIM integration but less national database connectivity.
Renovation advisory & features	At least two renovation recommendations required. Optional renovation passport can be generated as technical annex.	Provides structured renovation recommendations aligned with Dutch EPC policies.	Specialized tools (e.g., CE3X) focus on energy audits and targeted renovation guidance.
Strengths	Database structure for EPCs, which enables a country specific overview of the current status of the building stock. Decent amount of EPCs available throughout the country.	Highly structured compliance model, robust database integration, widely adopted tools.	Comprehensive audit and simulation capabilities, specialized tools for various building types.
Limitations	Diverse software landscape can cause complexity in the reissuing of EPCs.	Limited simulation capabilities compared to Austria and Spain.	Less national database connectivity than in the Netherlands; varied methodologies among tools.

Each country has developed a distinct EPC software ecosystem tailored to its regulatory environment and building stock characteristics. Austria's software tools emphasize simulation accuracy and cost-optimal improvements, the Netherlands prioritizes database integration and compliance verification, while Spain provides a diverse range of tools catering to both audits and certification.

6.4 Additional national building procedures

Building regulations and assessment procedures vary significantly across European Member States, reflecting diverse legal frameworks, technical standards, and compliance mechanisms. While energy performance assessments under the EPBD provide a harmonized framework to evaluating buildings' energy efficiency, additional national procedures exist to ensure safety, comfort, and environmental performance. These complementary assessments, which include fire safety, acoustic certification,



and technical inspections, play a crucial role in defining the broader regulatory landscape for buildings.

This chapter provides a brief and consolidated overview of the national EPC frameworks, and the additional national building-assessment procedures identified within the scope of the iEPB project. The analysis focuses on Austria, the Netherlands, and Spain highlighting the national data models used for these assessments. These procedures, which extend beyond energy performance certification, cover critical aspects such as:

- **Structural safety and fire safety:** Including compliance with mechanical strength, fire protection regulations, and emergency evacuation requirements.
- **Safety of use, accessibility, health & well-being, and noise protection:** Addressing accessibility requirements, indoor air quality standards, noise insulation criteria, and hygiene regulations.
- **Energy efficiency & sustainability:** Covering requirements for energy performance certification, environmental impact assessments, and integration of renewable energy systems.

The mapping and characterization of these national procedures serve two key objectives. First, they enable a structured comparison of regulatory frameworks across different countries, identifying opportunities for alignment and best practice exchange. Second, they facilitate the long-term scope integration of these complementary procedures into the iEPB schema, a unified data model designed to streamline multi-criteria building assessments.

The following sections detail the regulatory frameworks in Austria, the Netherlands, and Spain, outlining the methodologies, compliance processes, and verification mechanisms associated with each country's additional national building procedures.

6.4.1 Austria

In Austria, the Österreichisches Institut für Bautechnik (OIB - Austrian Institute for Construction), establishes six Guidelines [76] covering various aspects of building safety, energy efficiency, and environmental protection. These OIB guidelines serve as the foundation for regulatory compliance and are established in regional building acts. In addition, a new guideline is under development (Guideline 7 The sustainable use of natural resources).

For this analysis, different building-related assessments have been identified and categorized according to their relevance in the Austrian regulatory framework. These assessments cover structural safety, fire protection, accessibility, environmental performance, noise protection, and sustainability, among others. The assessments are integrated into different stages of a building's lifecycle, from the planning phase, construction execution, operational phase, and eventual renovation or decommissioning.



Transparent description of each national and EU technical methodology for EPB Assessment / D2.1

To facilitate harmonization and integration with EPB methodologies, these assessments have been grouped into three main categories:

- Structural safety & fire safety
- Safety of use, accessibility, health & well-being, and noise protection
- Energy efficiency & sustainability

Each of these categories consists of specific assessments, compliance verifications, and regulatory requirements, ensuring that all aspects of building performance are addressed comprehensively.

Austria's national building procedures encompass a structured regulatory framework that integrates multiple assessments across a building's lifecycle. The 15 identified assessments highlight the complexity of national compliance mechanisms but also provide opportunities for harmonization with EPB assessment methodologies.

Structural safety & fire safety

- Structural safety assessment (OIB Guideline 1 - Mechanical strength and stability)
- Fire safety assessment (OIB Guideline 2 - Fire protection)
- Building permit application & verification process
- Construction execution verification

Planning verification & building permit application: Before the construction of a building can start, a building permit must be obtained from the respective municipal authority. This involves a detailed verification of structural integrity, fire safety, and accessibility standards. The application is reviewed through technical and legal reports issued by municipal services to ensure compliance with national and regional building codes.

Fire safety assessment: Fire protection evaluations ensure that fire safety measures, escape routes, suppression systems, and fire-resistant materials comply with the OIB Guideline 2. Fire assessments may include annual inspections and quarterly access checks by fire departments for specific buildings. Depending on the type of building, periodic fire safety inspections are required, and recommendations for fire risk mitigation may be provided.

Construction execution & final verification: During the construction phase, external controls may be conducted by accredited entities to ensure compliance with structural safety and fire protection requirements. Upon completion, functional tests of the construction elements and final verification of fire safety installations are performed before certification is issued. Fire safety verification includes inspection of compartmentation, emergency lighting, and fire prevention measures.

Safety of use, accessibility, health & well-being, and noise protection

- Safety in use & accessibility (OIB Guideline 4)
- Noise protection (OIB Guideline 5)
- Hygiene, health, and environmental protection (OIB Guideline 3)
- Occupation license & facility start-up verification



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Safety in use & accessibility: Accessibility inspections ensure compliance with national and regional accessibility laws, covering entrances, exits, circulation pathways, and vertical transport systems (elevators, ramps, etc.). These inspections are particularly relevant for public buildings and new residential and commercial developments.

Noise protection evaluation: Austrian regulations enforce acoustic performance requirements through OIB Guideline 5, which mandates noise control measures for walls, ceilings, floors, windows, and doors. Compliance with noise insulation standards is particularly required for residential and mixed-use buildings. Acoustic certification involves on-site testing by accredited laboratories.

Health & well-being evaluations: Hygiene and environmental protection assessments include indoor air quality, ventilation efficiency, and sanitation standards. Legionella prevention measures are required in large-scale water storage and HVAC systems. These requirements are addressed under OIB Guideline 3 and contribute to ensuring healthy living and working environments.

Final certification & occupancy license: Before a building can be used, a final verification ensures that technical systems (ventilation, accessibility, and safety measures) comply with national standards. The occupation license is issued by municipal authorities after all required assessments are completed.

Energy efficiency & sustainability

- Energy Performance Certificate (EPC) - OIB Guideline 6
- Thermal insulation & energy efficiency verification
- Sustainability certification & renewable energy integration

Pre-construction & design phase: Buildings must undergo energy performance assessments during the design phase, ensuring compliance with national energy efficiency standards. The energy efficiency performance is evaluated based on building envelope performance, the HVAC systems' efficiency, and the integration of renewable energy technologies.

Energy Performance Certificate (EPC) issuance: The Energy Performance Certificate (EPC) is a mandatory assessment that calculates a building's energy consumption and CO₂ emissions. It is required for all new buildings, comprehensive refurbishments and must be presented during real estate transactions for existing buildings.

Thermal insulation & renewable energy compliance: Additional evaluations ensure thermal insulation effectiveness, ventilation performance, and the integration of renewable energy technologies. Some assessments are linked to public subsidies for energy-efficient renovations and sustainable building practices.



6.4.2 Netherlands

In the Netherlands, the certification and assessment of buildings follow a structured yet nuanced approach. While new buildings are subject to detailed assessments and regulatory approvals, existing buildings undergo relatively fewer mandatory assessments over their operational lifetime. This disparity is largely influenced by cultural factors, as Dutch regulations tend to limit intrusive inspections in private homes, prioritizing occupant privacy over extensive regulatory oversight.

For this analysis, a total of 11 different building-related assessments have been identified in the Netherlands. These assessments span across structural integrity, fire safety, accessibility, noise protection, energy performance, and sustainability, and occur throughout a building's lifecycle—from the planning phase, construction execution, and operational phase to eventual renovations or decommissioning.

The Dutch regulatory framework for building assessments is governed by:

- Bbl (Building Works Decree Living Environment)
- WKB (Quality Assurance Act)
- EPBD III (Energy Performance of Buildings Directive)
- Arboret (Dutch Working Conditions Act)

These laws, which came into effect on January 1st, 2024 (except the Arboret), primarily apply to Group 1 buildings (dwellings and small offices), with Group 2 and Group 3 buildings (larger commercial and public structures) expected to gradually align with these methodologies.

To facilitate integration into EPB assessment methodologies, the national procedures have been grouped into the following three categories:

- Structural safety & fire safety
- Safety of use, accessibility, health & well-being, and noise protection
- Energy efficiency & sustainability

Structural safety & fire safety

- Structural safety verification (Bbl)
- Fire safety assessments (mandatory for utility buildings)
- Project and building permit application
- Construction work execution & final quality assurance verification

Project and building permit application: For every new construction, major adaptation, or change in building use, a building permit is required. The first-stage permit ensures compliance with urban planning, zoning, and aesthetics. The technical compliance check, including structural integrity and fire safety, is only conducted after assessment by an independent building quality assurer.

Fire safety & structural integrity assessments: Fire safety assessments verify compliance with escape routes, fire-resistant materials, and emergency protocols. Structural integrity verification occurs during both the design and construction phases, ensuring compliance with seismic and load-bearing



standards. Mandatory fire safety inspections include fire alarm systems (inspection every 3 years or annually if required), dry firefighting systems (every 5 years), fire extinguishers (inspection at least once every 1-2 years).

Construction execution & final quality assurance: Four weeks before construction starts, the building dossier is submitted to the municipality for verification. Before construction begins, the construction company must notify the municipality, confirming adherence to all regulations. During execution, proof of compliance (photos, material labels, documented construction steps) is compiled based on the Quality Assurance Plan. After construction, a building quality assurer reviews all documentation, assesses the as-built structure, and submits a final compliance notification to the municipality. Occupancy can commence two weeks after the notification, with a final permit granted by the municipality.

Safety of use, accessibility, health & well-being, and noise protection

- Safety in use & accessibility verification
- Noise protection & acoustic assessments
- Health & well-being regulations (Legionella, ventilation, indoor air quality, daylight entry)
- Elevator & building equipment inspections

Accessibility & safety in use: Buildings must comply with Dutch accessibility laws, ensuring adequate access to entrances, pathways, and circulation areas. These inspections are part of the initial permit process and final quality verification.

Noise protection evaluation: Acoustic assessments ensure compliance with national noise control laws, covering sound insulation between spaces. These evaluations rely on BIM-based building models for accurate geometric analysis.

Health & well-being evaluations: Legionella prevention measures apply to certain buildings either by legal mandate or occupant safety requirements. Ventilation and indoor air quality checks are mandatory for some buildings under EPBD III regulations. Daylight entry verification is conducted during building design and approval. The Arboret is related to this topic, however not in residential buildings. In non-residential buildings, a company must ensure a safe working environment, among others with enough daylight and lighting levels at the workstation.

Breach of these rules in offices can lead to complaints by employees to the Netherlands Labour Authority who can fine the company and force resolving the non-compliant situation.

Equipment inspections (elevators, HVAC, ventilation): Elevator inspections follow mandatory periodic checks to ensure safety. Heating, cooling, and domestic hot water systems that exceed capacity thresholds require assessments every 4-5 years under EPBD III. Reports for heating and cooling system inspections must be stored in the national database [77].



Energy efficiency & sustainability

- Energy Performance Certificate (EPC) Assessment
- Environmental performance & sustainability certifications
- Renewable energy (PV system) verification

Energy Performance Certification (EPC): A provisional EPC is required before the building permit is granted. After construction, a final EPC is issued, based on as-built energy performance. For Group 2 & 3 buildings, the final EPC must be issued within six months of occupancy.

Sustainability & environmental performance: Environmental performance assessments are mandatory for offices >100m² and new residential buildings. Data overlaps with EPC calculations but is not yet fully integrated into a common database. Compliance is measured through the Milieuprestatie Gebouwen (MPG) tool.

Renewable energy systems & PV assessments: PV system registration is required to enable grid feed-in compatibility. Some software providers have developed modules that extract BIM-based building information to streamline energy performance calculations. Mandatory inspections apply to installations with more than 50 solar panels.

6.4.3 Spain

In Spain, building certification and assessment procedures are comprehensive and well-defined, with a strong regulatory framework governing both new constructions and existing buildings. The Technical Building Code (Código Técnico de la Edificación - CTE) serves as the core regulatory standard, ensuring compliance with the Building Regulations Act (Ley de Ordenación de la Edificación - LOE).

For this analysis, a total of 18 different building-related assessments have been identified in Spain. These assessments span across structural integrity, fire safety, accessibility, noise protection, energy performance, and sustainability, covering both the construction phase and ongoing operational assessments.

The Spanish regulatory framework is primarily governed by:

- Código Técnico de la Edificación (CTE - Technical Building Code)
- Ley de Ordenación de la Edificación (LOE - Building Regulations Act)
- Certificado de Eficiencia Energética (CEE - Energy Efficiency Certificate)
- Regional and municipal building permits & licenses

These assessments are structured across different building stages, from initial design and permitting, through construction, to post-completion and operational verification.

To facilitate integration with EPB assessment methodologies, the Spanish national procedures are categorized into:

- Structural safety & fire safety



- Safety of use, accessibility, health & well-being, and noise protection
- Energy efficiency & sustainability

Structural safety & fire safety

- Structural safety assessment (CTE)
- Fire safety compliance (CTE & Municipal Regulations)
- Building permit approval process
- Construction execution verification

Project and building permit application: All new buildings, major renovations, and changes in building use require a building permit. Besides energy efficiency, the Technical Building Code (CTE) also mandates compliance with structural stability, fire protection, accessibility, and habitability requirements, health & well-being and noise protection. The project must be reviewed and endorsed by a professional association to verify formal correctness and professional qualifications. Certain public housing projects may be subject to additional public administration project supervision.

Insurance for residential buildings: Developers must obtain mandatory insurance covering structural failures (10 years) and habitability defects (3 years). Insurance providers may require project validation from a Technical Control Organisation (Organismo de Control Técnico - OCT).

Fire safety & structural integrity verification: Fire safety assessments ensure compliance with evacuation plans, fire-resistant materials, and suppression systems. They also include periodic fire alarm and suppression system maintenance. Structural safety checks verify that load-bearing elements meet seismic and stability standards.

Construction execution & final verification: The municipality may conduct inspections during construction to verify compliance with permit requirements. For buildings with a high energy rating (CEE A, B, C, or D), an independent quality control entity must conduct additional onsite inspections and testing. Once construction is complete, functional tests of structural components and fire safety systems are in certain cases conducted by accredited laboratories.

Safety of use, accessibility, health & well-being, and noise protection

- Safety in use & accessibility requirements (Royal Decree 1/2013 on disability rights)
- Noise protection & acoustic certification (Law 37/2003 on noise pollution)
- Health & well-being assessments (Royal Decree 3/2023 on water quality and legionella prevention)
- First occupation license & building logbook requirements

Accessibility & safety in use: Accessibility compliance ensures that buildings provide barrier-free access, particularly in public, commercial and multi-family residential buildings. Specific design requirements for stairs, ramps, elevators, and handrails are regulated.



Noise protection & acoustic certification: Onsite acoustic measurements must be performed in certain municipalities, particularly for facades, partition walls, and floors. Soundproofing tests are conducted by accredited laboratories, and results are included in the final building dossier.

Health & well-being evaluations: Certain buildings (e.g., hotels, hospitals, commercial buildings) require indoor air quality and ventilation compliance checks. Legionella prevention measures are mandatory for buildings with large-scale water storage or HVAC systems.

First occupation license & building logbook: Before residential buildings can be occupied, the developer must obtain a First Occupation License from the municipality. This requires submitting a responsible declaration confirming compliance with building regulations and habitability standards. A building logbook must be created for multi-family residential buildings, containing technical, legal, and maintenance information.

Energy efficiency & sustainability

- Energy Performance Certificate (Certificado de Eficiencia Energética - CEE)
- Building energy performance testing (air permeability, insulation, etc.)
- Verification of renewable energy & technical installations

Energy Performance Certification (EPC/CEE): A provisional Energy Performance Certificate (CEE) is required before construction begins. A final EPC is issued after completion, based on measured energy performance of the actual building.

Building energy performance testing: In certain new buildings, air permeability tests are conducted to assess thermal insulation efficiency. Functional testing of thermal, electrical, and ventilation systems is required before final approval.

Renewable energy & facilities verification: For solar panels, HVAC systems, and gas installations, installation companies must issue certificates of compliance. These certificates confirm that systems are installed according to design specifications and function correctly.

6.4.4 Comparative analysis and results

The comparative analysis of additional national building procedures in Austria, the Netherlands, and Spain highlights significant regulatory differences in how structural safety, fire protection, accessibility, noise control, energy performance, and sustainability are assessed. These differences are shaped by each country's legislative history, enforcement mechanisms, and administrative structures.

Despite these variations, common assessment categories emerge, providing a basis for comparison and harmonization with EPB methodologies. These include:

- Structural safety & fire Safety
- Safety of use, accessibility, health & well-being, and noise protection
- Energy efficiency & sustainability



Structural safety and fire safety

Austria follows a centralized regulatory approach through the Österreichisches Institut für Bautechnik (OIB), which provides six overarching guidelines established in regional building acts. Structural safety and fire safety are integral parts of the building permit application process, and compliance is ensured through multi-stage verification during construction execution. In addition, a new guideline is under development (Guideline 7 The sustainable use of natural resources).

The Netherlands operates under the Building Works Decree Living Environment (Bbl) and Quality Assurance Act (WKB), emphasizing independent verification by third-party quality assurers. Fire safety assessments are mandatory for utility buildings and involve periodic inspections.

Spain enforces structural and fire safety requirements through the Código Técnico de la Edificación (CTE) and municipal regulations, incorporating stricter insurance requirements for residential buildings to cover structural failures and habitability defects.

While all three countries mandate fire safety and structural integrity assessments, the Netherlands relies more on independent quality assurers, whereas Austria and Spain enforce compliance through governmental verification processes.

Safety of use, accessibility, health & well-being, and noise protection

Austria integrates accessibility and noise protection into OIB Guidelines 3, 4, and 5, ensuring barrier-free design and environmental quality controls. Noise protection is a key requirement for residential and mixed-use buildings for certain building types.

The Netherlands enforces accessibility through Bbl, focusing primarily on new buildings. Noise control is integrated into BIM-based regulatory compliance models, minimizing the need for intrusive on-site inspections.

Spain follows Royal Decree 1/2013, which mandates accessibility in public and multi-family buildings, and Law 37/2003, which requires acoustic assessments in designated municipalities. Compliance is verified through accredited testing laboratories.

Spain and Austria enforce stricter noise protection regulations, whereas the Netherlands relies on digital modelling tools to ensure compliance. Accessibility requirements are most rigorously applied in Spain.

Energy efficiency and sustainability

Austria mandates like the Netherlands and Spain Energy Performance Certificates (EPCs). The EPC is integrating parameters about the building envelope and the technical building systems. Further, it indicates the shares of renewable energy. The upload of the EPC on a regional or centralised database is necessary to receive the building permit.



The Netherlands requires provisional EPCs before issuing building permits, with final certification conducted within six months post-construction. Environmental performance is assessed through the Milieuprestatie Gebouwen (MPG) tool.

Spain mandates Certificado de Eficiencia Energética (CEE), ensuring energy performance compliance at both the design and post-construction stages. Additional performance testing includes air permeability assessments and renewable energy compliance checks.

The Netherlands and Spain implement two-stage EPC certification (pre-construction and post-construction). In Austria the situation is similar and the process is differentiated between the EPC of new buildings and renovation.

Recommendations for harmonization

Based on the comparative analysis, several harmonization opportunities with EPB methodologies emerge:

- While Spain requires extensive acoustic and environmental testing and Austria has its specific regulations depending on the building type, the Netherlands' BIM-based compliance model could improve efficiency.
- Encouraging Spain and Austria to integrate independent quality assurers into their building verification processes could streamline compliance checks.

The analysis highlights significant national differences in building assessment procedures, regulatory structures, and certification methodologies. While Austria follows a highly structured and centralized regulatory framework, the Netherlands adopts a decentralized approach emphasizing independent verification. Spain enforces stricter accessibility and environmental requirements, ensuring compliance through extensive testing protocols.

By leveraging the EPB framework as a harmonization tool, opportunities exist to create a more integrated European approach to building safety, energy efficiency, and sustainability while maintaining national flexibility.



7. Conclusions

Deliverable D2.1 gives a transparent, verifiable picture of how EPB assessments are presently carried out and documented, first at EU level and then, in depth, in Austria, the Netherlands and Spain. The document begins by tracing the “rules of the game”: the EPB standard family, the draft provisions of the EPBD recast and associated EU funded initiatives such as the ePANACEA method. This EU baseline establishes why harmonisation is now framed not only around a single pan-European calculation engine but also around a shared, machine-readable way of describing results.

The full assessment chain in each demonstration country is reconstructed, starting with the choices each one makes in the Annex A tables of the core EPB standards. The analysis shows, for instance, how Austria and Spain refine those annexes to reflect seven and thirteen climate zones respectively, while the Netherlands opts for a single national climate file. These contrasts become visible again in the EPC labels: Austria’s A++ threshold is set at $\leq 60 \text{ kWh/m}^2$ year of total primary energy, Spain’s class A reaches $\leq 50 \text{ kWh/m}^2$ year of non-renewable primary energy, and the Netherlands reserves an A++++ class for energy-neutral buildings. Beyond thresholds, the deliverable documents the differing digital ecosystems that surround those EPCs. Austria’s dual national-regional database structure enables authorities to monitor compliance effectively and extract meaningful insights for policy development. The Netherlands operates a fully automated compliance loop through EP-Online. Spain still relies on regional uploads that limit nationwide data reuse. By juxtaposing database structures, software input/output files and quality-assurance regimes, D2.1 lays the groundwork for pinpointing where data are comparable and where they are not. These findings fed straight into the functional brief of the iEPB schema, whose scope is to accommodate both highly digitised and still-fragmented contexts while keeping a single semantic core.

A further contribution is the technical scoping of advanced modelling workflows. The deliverable examines how the ePANACEA SEPAPTool exchanges gbXML, IFC and other formats through the OpenStudio SDK, and it lists the extra HVAC and scheduling fields that remain to be mapped if such dynamic, auto-calibrated models are to read and write the iEPB common file seamlessly. This exercise proves that the iEPB schema can host both conventional steady-state EPC inputs and outputs and richer time-series data without creating silos.

Taken together, these strands of evidence turn what might be considered a high-level survey into a technical baseline that the rest of the project and EPBD stakeholders can rely on. By cataloguing the concrete data items now exchanged in three member states, D2.1 frames an actionable roadmap for iEPB activities and for any sister initiative that aims at pan-European interoperability.

Looking ahead, the term data model must be pinned down in plain language and linked explicitly to inputs and outputs, not algorithms, so that practitioners stop confusing “EPC calculation” with “EPC file”. A cross-matrix of EN ISO symbols should be compiled and published, because the moment a quantity is missing from one national EPC, its absence usually signals a deeper methodological difference that will eventually need joint resolution. Addressing these aspects will further cement the clarity and practical value of the work already achieved in this deliverable.



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Transparent description of each national and EU technical methodology for EPB Assessment / D2.1

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