



D3.2 – Analysis of energy efficiency and links with SRI



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Executive Summary

The SRI assessment according to the methodology suggested by the European Commission will result in the identification of improvement potentials along the technical domains referring to TBS which are also reflected in the EPC or at least in the calculations the EPC is based on. Ideally, the SRI assessment results in a detailed description of the technical building systems according to technical domains and including BACS functionality levels. This would add value to the EPC because currently the technical energy model documentation produced as part of the EPC calculation process often neglects details on TBS and especially BAC. However, although it is not mandatory to consider the impact of BAC in the EPC calculation method, it is possible to do so as shown by Germany. The information provided by EN ISO 52120-1:2022 can contribute to the calculations and recommendations made in an EPC. For instance, a building with advanced automation and control systems that optimize energy usage could potentially receive a better energy efficiency rating in its EPC.

It is important to note that the EPC is based on a standardized user profile while the SRI addresses optimization of actual building use based on BAC and BACS. However, the SRI assessment is currently based on a purely qualitative procedure. In a nutshell, energy efficiency improvements based on SRI assessment are those related with the application of BAC in building operations. BAC consists of hardware and software, both of which may be subject to change during building operation. Thus, the SRI can only determine the energy efficiency potential based on the identified BAC hardware and documentation of programming. Especially programming of BAC elements can be changed at any time, and therefore, the metered overall energy consumption as well as the metered energy consumption by energy carrier and TBS (or EPB-service) are the correct energy consumption indicators to cross-check the potential determined through the qualitative SRI assessment.

The EPC database can provide valuable information as input into the SRI assessment, and the SRI assessment can generate information that should be taken into account in the recommendations section of the EPC. However, the condition is that SRI assessment report and the energy performance certificates are stored at least in the same place. The same applies to other relevant documents such as the renovation roadmap, the inspection report, and the energy audit report that can provide useful information for the SRI assessment and in turn could also benefit from the SRI assessment: It is possible that an SRI assessment is requested for a building for which no energy performance certificate or other reports are yet available. Thus, the exchange and reuse of data is needed, and the building logbook envisaged by the Commission proposal for the recast EPBD is ideal for this purpose.

The EPC database is not necessarily suitable as a building logbook to support SRI assessment because the EPC only covers data fields that are mandatory for the respective building type (residential or non-residential); that means, even if a residential building is equipped with an active cooling system, technical information would not appear in the EPC database because active cooling is not part of the calculation method for residential buildings (Austrian example). Also, inspection of HVAC TBS results in more information than contained in the EPC, and the same applies to the renovation passport, the SRI assessment, and the energy audit report according to EED. However, it is possible to extend the existing EPC database with various data fields and functions and to further develop it to the new building logbook. In this regard, it is suggested to create a basic structure with standardized data fields, with key information that can be entered according to a specific format and that can be retrieved according to a specific format (data input – assessment – report). The data contained in this basic structure should be authorized by an authority to allow for multiple uses and to avoid liability and ownership issues for experts that currently prevent them from using data collected by other experts.

This study concludes that standardization plays a key role in the realization of energy savings through building automation and control and thus in the success of SRI assessment in the area of energy efficiency.

On the one hand, this concerns the components of the automation and control systems and the programming for operation. Safe ICT operation, durability, and compatibility of the components with each other (per technical building system and the technical building systems with each other) must be ensured. Only then will the forecasts regarding whole life GWP, energy, and cost savings be realistic and safety concerns eliminated. Standardized documentation of the programming of building automation and control systems is crucial for an SRI rating that is trustworthy and reputable on the market. On the other hand, this concerns the logbook. The benefits of the building logbook will depend on whether and how data fields are standardized for data input from different sources and data export to different uses. Examples include building data models, inspection reports, energy audit reports, and renovation schedules.

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List of Acronyms and Abbreviations

Term	Description
AC	Air Conditioning
BAC	Building Automation and Control
BACS	Building Automation and Control System
BIM	Building Information Model
BRE	Building Research Establishment
BUS	Binary Unit System
CIBSE	Chartered Institution of Building Services Engineers
EED	Energy Efficiency Directive
EPB	Energy Performance of Buildings
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
GHG	Greenhouse Gas
GWP	Global Warming Potential
HVAC	Heating Ventilation Air Conditioning
ICT	Information and Communication Technology
IFC	Industry Foundation Classes
IT	Information Technology
MEPB	Methodology of Energy Performance of Building
MS	Member States
nZEB	Nearly Zero Energy Building
SBEM	Simplified Building Energy Model
SRI	Smart Readiness Indicator
SRT	Smart Ready Technologies
TBM	Technical Building Management
TBS	Technical Building Systems
XLM	Extensible Markup Language
ZEB	Zero Emission Building
ZEUS	Zentrales Energieausweis Umgebungs System

1 Introduction

1.1 Scope and objectives of the deliverable

This task aims to establish the scope of linking the Smart Readiness Indicator (SRI) with energy efficiency and to provide a relation with metrics such as energy consumption that are considered for the issuance of the Energy Performance Certificate (EPC). This way, every time an SRI assessment is offered, this will be linked to an EPC status, providing a better understanding of the two schemes and how this can be translated into improvements in the energy performance and smartness of the building. The EPC status can be represented by the collected information, the building energy model, and the EPC as issued document with the indicators and the rating. Thus, the SRI can be linked to the collection of building information (building logbook), the energy performance calculation, and the issuance of the EPC.

According to the methodology suggested by the European Commission, the SRI assesses 9 technical domains against 7 impact categories. The technical domains are heating, cooling, domestic hot water, ventilation, lighting, dynamic building envelope, electricity, electric vehicle charging, monitoring and control. The impact categories are energy efficiency, maintenance and fault prediction, comfort, convenience, health, well-being and accessibility, information to occupants, energy flexibility and storage. The assessment methodology is purely qualitative. [1]

1.2 Structure of the deliverable

This deliverable consists of the following parts:

Description of the framework

- Technical Building Systems (TBS) and Building Automation and Control Systems (BACS) in the Energy Performance of Buildings Directive (EPBD) 2010/31/EU [2], amended by Directive (EU) 2028/844 [3], and taking into account the Commission's proposal for the recast EPBD [4]
- BACS and European Standards

Analysis of the links between energy efficiency and SRI

- Analysis of the relation between SRI and energy consumption
- Identification of the scope of linking SRIs with energy efficiency

Case studies to support the analysis

- Analysis of technical procedure of data transfer regarding EPC database and building logbook (Austria, Cyprus, Greece)

The deliverable closes with a chapter on the determination of a procedure how the SRI assessment can be linked with an EPC status.

1.3 Relation to Other Tasks and Deliverables

This document builds on the results of WP2 and has been developed in coordination with the other tasks of WP3 Development of the implementation framework of easySRI:

- D3.1 – Review of the SRI methodology
- D3.3 – Technical and financial indicators for SRTs
- D3.4 – easySRI implementation pathways

It feeds mainly into the following tasks and deliverables of WP4 easySRI Services and System:

- D4.1 – easySRI calculation module
- D4.2 – easySRI additional services

It contributes mainly to the following task and deliverable of WP6 Untapping the potential of smart technologies:

- D6.1 – easySRI policy implications and national priorities report v1
- D6.3 – Business models supporting smart-ready technologies

2 Description of the framework

This chapter provides an overview of how TBS and BACS are dealt with in the EPBD and relevant European Standards. The most important paragraphs and phrases are highlighted with green colour. Conclusions are drawn for developing the procedure of linking SRI assessment with the EPC status.

2.1 TBS and BACS representation in the EPBD

The EPBD 2010/31/EU [2] amended by Directive (EU) 2018/844 [3] aims to promote the improvement of the energy performance of buildings within the European Union. One of the key elements of the EPBD is the requirement for the implementation of Nearly Zero Energy Buildings (NZEBs) by 2021 for new buildings, and by 2025 for all new buildings occupied and owned by public authorities.

With regard to the targets of Decarbonization and Zero Emission Buildings (ZEB) suggested by the proposals for the EPBD recast which are currently under negotiation, Technical Building Systems (TBS) have become more important in the context of energy efficiency in buildings.

While the properties of the building fabric are static (e.g. thermal conductivity), TBS operate at different times with different capacities depending on the demand of the respective energy service (heating, cooling, air conditioning, ventilation, lighting). The same applies to supply side TBS such as renewable energy generation systems whose operation depends on the availability of sun radiation and wind speed.

Building automation and control (BAC), which also belong to TBS, are not to be seen on the same level, but they ensure that demand-side and supply-side TBS are operated as efficiently as possible.

This is also evident from EPBD **Article 2 Definitions**.

Technical building system is defined as follows:

6. ‘technical building system’ means technical equipment for space heating, space cooling, ventilation, domestic hot water, built-in lighting, building automation and control, on-site renewable energy generation and storage, or a combination thereof, including those systems using energy from renewable sources, of a building or building unit;

Building automation and control system is defined as follows:

7. ‘building automation and control system’ means a system comprising all products, software and engineering services that can support energy efficient, economical and safe operation of technical building systems through automatic controls and by facilitating the manual management of those technical building systems;

Article 11 Technical building systems of the Commission proposal for the recast EPBD specifies the following, among others, which has some relevance for the easySRI project:

1. Member States shall, for the purpose of optimising the energy use of technical building systems, set system requirements in respect of the overall energy performance, the proper installation, and the appropriate dimensioning, adjustment and control of the technical building systems which are installed in new or existing buildings. When setting up the requirements, Member States shall take account of design conditions and typical or average operating conditions.

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

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

3. Member States shall *require zero-emission buildings to be equipped with measuring and control devices for the monitoring and regulation of indoor air quality*. In existing buildings, the installation of such devices shall be required, where technically and economically feasible, when a building undergoes a major renovation.

4. Member States shall ensure that, when a technical building system is installed, the overall energy performance of the altered part, and where relevant, of the complete altered system, is assessed. *The results shall be documented and passed on to the building owner, so that they remain available and can be used for the verification of compliance with the minimum requirements laid down pursuant to paragraph 1 and the issue of energy performance certificates.*

In the currently valid EPBD 2010/31/EU amended by Directive (EU) 2018/844, articles 8, 14 & 15 are most relevant. Selected important aspects are presented below, with reference to the fact that their content will be reflected or further developed in the recast EPBD, which is still under negotiation.

Article 8 on Technical building systems, electromobility and smart readiness indicator refers to new and existing buildings. However, it emphasizes optimising the energy use of technical building systems, to set system requirements in respect of the overall energy performance, the proper installation, and the appropriate dimensioning, adjustment and control of the technical building systems which are installed in existing buildings. For existing buildings, BACS can provide a cost-effective solution for upgrading low efficiency buildings with a poor BACS class D or C (see chapter 2.2.1), and critically their installation is far less disruptive than fabric modifications of the building envelope. In this context, and in connection with the provisions on recharging points for electric vehicles, the scheme of rating the smart readiness of buildings is introduced.

Article 14 on Inspection of heating systems and Article 15 on Inspection of air-conditioning systems contain more specific provisions for these types of TBS in relation to the inspection of the systems and the delivery of inspection reports to building owners.

More specific provisions on the energy performance calculation methodology, the energy performance certificate and the recommendations are presented in the next chapter.

2.1.1 TBS and BACS in the energy performance calculation and EPC

Article 2 Definitions in the Commission proposal for the recast EPBD states regarding the energy performance certificate (EPC):

29. **‘energy performance certificate’** means a certificate recognised by a Member State or by a legal person designated by it, which indicates the energy performance of a building or building unit, calculated according to a methodology adopted in accordance with Article 4;

37. **‘digital building logbook’** means a common repository for all relevant building data, including data related to energy performance such as energy performance certificates, renovation passports and smart readiness indicators, which facilitates informed decision making and information sharing within the construction sector, among building owners and occupants, financial institutions and public authorities;

Article 16 on Energy performance certificates specifies the following:

1. Member States shall lay down the necessary measures to establish a system of certification of the energy performance of buildings. The energy performance certificate shall include the energy performance of a building expressed by a numeric indicator of primary energy use in kWh/(m².y), and *reference values such as minimum energy performance requirements, minimum energy performance standards, nearly zero-energy building requirements and zero-emission building requirements*, in order to make it possible for owners or tenants of the building or building unit to compare and assess its energy performance.

2. By 31 December 2025 at the latest, the energy performance certificate shall comply with the template in Annex V. It shall specify the energy performance class of the building, on a closed scale using only letters from A to G. *The letter A shall correspond to zero-emission buildings as defined in Article 2, point (2) and the letter G shall correspond to the 15% worst-performing buildings in the national building stock at the time of the introduction of the scale.* Member States shall ensure that the remaining classes (B to F) have an even bandwidth distribution of energy performance indicators among the energy performance classes. Member States shall ensure a common visual identity for energy performance certificates on their territory.

3. Member States shall ensure the quality, reliability and affordability of energy performance certificates. *They shall ensure that energy performance certificates are issued by independent experts following an on-site visit.*

4. The energy performance certificate shall include recommendations for the cost-effective improvement of the energy performance and the reduction of operational greenhouse gases emissions of a building or building unit, unless the building or building unit already complies with the relevant zero-emission building standard.

The recommendations included in the energy performance certificate shall cover:

(a) measures carried out in connection with a major renovation of the building envelope or technical building system or systems; and

(b) measures for individual building elements independent of a major renovation of the building envelope or technical building system or systems.

5. The recommendations included in the energy performance certificate shall be technically feasible for the specific building and shall provide an estimate for the energy savings and the reduction of operational greenhouse gas emissions. They may provide an estimate for the range of payback periods or cost-benefits over its economic lifecycle.

[...]

7. *The energy performance certificate shall provide an indication as to where the owner or tenant can receive more detailed information, including as regards the cost-effectiveness of the recommendations made in the energy performance certificate. The evaluation of cost effectiveness shall be based on a set of standard conditions, such as the assessment of energy savings and underlying energy prices and a preliminary cost forecast. In addition, it shall contain information on the steps to be taken to implement the recommendations. Other information on related topics, such as energy audits or incentives of a financial or other nature and financing possibilities, or advice on how to increase the climate resilience of the building, may also be provided to the owner or tenant.*

[...]

11. Member States shall make simplified procedures for updating an energy performance certificate available where only individual elements are upgraded (single or standalone measures).

Member States shall make simplified procedures for updating an energy performance certificate available where measures identified in a renovation passport are put in place.

Article 17 Issue of energy performance certificates specifies the following:

[...]

7. *Member States shall ensure that all energy performance certificates issued are uploaded to the database for energy performance of building referred to in Article 19. The upload shall contain the full energy performance certificate, including all necessary data required for the calculation of the energy performance of the building.*

[...]

Article 4 Adoption of a methodology for calculating the energy performance of buildings specifies as follows:

Member States shall apply a methodology for calculating the energy performance of buildings in accordance with the common general framework set out in Annex I.

That methodology shall be adopted at national or regional level.

ANNEX I COMMON GENERAL FRAMEWORK FOR THE CALCULATION OF ENERGY PERFORMANCE OF BUILDINGS (referred to in Article 4 of the Commission proposal for the recast EPBD) specifies the following:

1. [...] *Member States shall describe their national calculation methodology based on Annex A of the key European standards on energy performance of buildings, namely EN ISO 52000-1, EN ISO 52003-1, EN ISO 52010-1, EN ISO 52016-1, and EN ISO 52018-1, EN 16798-1, EN 17423 or superseding documents. This provision shall not constitute a legal codification of those standards. [...]*

2. The energy needs and energy use for space heating, space cooling, domestic hot water, ventilation, lighting and other technical building systems shall be calculated using hourly or sub-hourly time calculation intervals in order to account for varying conditions that significantly affect the operation and performance of the system and the indoor conditions, and to optimise health, indoor air quality and comfort levels defined by Member States at national or regional level.

[...]

4. The methodology shall be laid down taking into consideration at least the following aspects:

(a) the following actual thermal characteristics of the building including its internal partitions:

- (i) thermal capacity;*
- (ii) insulation;*
- (iii) passive heating;*
- (iv) cooling elements; and*
- (v) thermal bridges;*

(b) heating installation and hot water supply, including their insulation characteristics;

(c) air-conditioning installations;

(d) natural and mechanical ventilation which may include air-tightness;

(e) built-in lighting installation (mainly in the non-residential sector);

(f) the design, positioning and orientation of the building, including outdoor climate;

(g) passive solar systems and solar protection;

(h) indoor climatic conditions, including the designed indoor climate;

(i) internal loads.

5. The positive influence of the following aspects shall be taken into account:

(b) electricity produced by cogeneration;

(c) district or block heating and cooling systems;

(d) natural lighting.

6. For the purpose of the calculation buildings should be adequately classified into the following categories:

(a) single-family houses of different types;

(b) apartment blocks;

(c) offices;

(d) educational buildings;

(e) hospitals;

(f) hotels and restaurants;

(g) sports facilities;

(h) wholesale and retail trade services buildings;

(i) other types of energy-consuming buildings

ANNEX V TEMPLATE FOR ENERGY PERFORMANCE CERTIFICATES (referred to in Article 16 of the Commission proposal for the recast EPBD) specifies the following:

1. On its front page, the energy performance certificate shall display at least the following elements:

(a) the energy performance class;

- (b) the calculated annual primary energy use in kWh/(m² year);*
- (c) the calculated annual primary energy consumption in kWh or MWh;*
- (d) the calculated annual final energy use in kWh/(m² year);*
- (e) the calculated annual final energy consumption in kWh or MWh;*
- (f) renewable energy production in kWh or MWh;*
- (g) renewable energy in % of energy use;*
- (h) operational greenhouse gas emissions (kg CO₂/(m² year));*
- (i) the greenhouse gas emission class (if applicable).*

2. In addition, the energy performance certificate may include the following indicators:

- (a) energy use, peak load, size of generator or system, main energy carrier and main type of element for each of the uses: heating, cooling, domestic hot water, ventilation and in-built lighting;*
- (b) renewable energy produced on site, main energy carrier and type of renewable energy source;*
- (c) a yes/no indication whether a calculation of the Global Warming Potential has been carried out for the building;*
- (d) the value of the life-cycle Global Warming Potential (if available);*
- (e) information on carbon removals associated to the temporary storage of carbon in or on buildings;*
- (e) a yes/no indication whether a renovation passport is available for the building;*
- (f) the average U-value for the opaque elements of the building envelope;*
- (g) the average U-value for the transparent elements of the building envelope;*
- (h) type of most common transparent element (e.g. double glazed window);*
- (i) results of the analysis on overheating risk (if available);*
- (j) the presence of fixed sensors that monitor the levels of indoor air quality;*
- (k) the presence of fixed controls that respond to the levels of indoor air quality;*
- (l) number and type of charging points for electric vehicles;*
- (m) presence, type and size of energy storage systems;*
- (n) feasibility of adapting the heating system to operate at more efficient temperature settings;*
- (o) feasibility of adapting the air-conditioning system to operate at more efficient temperature settings;*
- p) metered energy consumption;*
- q) operational fine particulate matter (PM_{2.5}) emissions.*

The energy performance certificate may include the following links with other initiatives if these apply in the relevant Member State:

- (a) a yes/no indication whether a smart readiness assessment has been carried out for the building;*
- (b) the value of the smart readiness assessment (if available);*
- (c) a yes/no indication whether a Digital Building Logbook is available for the building.*

Persons with disabilities shall have equal access to the information in energy performance Certificates.

2.1.2 Conclusions for linking SRI assessment with EPC status

It is concluded that currently and taking the Commission proposal for the recast EPBD into account, there is no obligation to include the impact of BACS into the energy performance calculation methodology. The amending Directive (EU) 2018/844 introduced the obligation for BACS installation for a certain type of non-residential buildings, but with the condition if this is technically and economically feasible.

However, there are examples of Member States providing guidance on how to consider the impact of BACS in the calculation method for heating and cooling energy consumption, such as Germany with the German Standard DIN V 18599, also based on EN ISO 52120-1:2022. [5] The German Standard DIN V 18599 provides the methodology for the German transposition of the EPBD, and the discussions on the interpretation status can be followed on a dedicated website managed by the DIN Committee on Construction. [6] More information on EN ISO 52120-1:2022 is provided in chapter 2.2. An overview about the status in Member States regarding BAC can be obtained from the Concerted Action EPBD database. [7]

It is noted that In Annex I of the agreed recast EPBD version after completion of the Trialogue, an addition appears under the mandatory elements of the EPC calculation method, namely “building automation and control systems and their capabilities to monitor, control”. [8] This version after completion of the Trialogue is not yet final, but this specific change is important for the easySRI project and must be observed.

In terms of calculation method, the request for hourly and sub-hourly calculations and the foreseen indicator on renewable energy in % of energy use makes a potential link with the SRI. These requirements aim to achieve the highest possible self-consumption of renewable energy in the building. This aligns well with the intention of the SRI in the impact criterion of Energy flexibility & Storage. Hourly and sub-hourly calculations would also provide advantages regarding the impact criterion Comfort regarding the challenge of overheating in summer, and the impact criterion Well-being & Health regarding ventilation and thus indoor air quality.

However, in practice there are some barriers regarding the calculation software that operates on hourly and sub-hourly basis, because common practice is different:

- In some countries, there is only one legally approved software, in other countries there are several approved tools available on the market.
- In some countries, there are software tools that create an energy model based on the monthly method and create the EPC based on that, in other countries there is a simple tool that relies on the input of simulation results and only creates the EPC.

Detailed information is available in the reports of the Concerted Action EPBD at <https://epbd-ca.eu/>. [9]

Changing the calculation from the monthly to the hourly based method may result in far-reaching changes that would result in increased effort for businesses and higher costs for building owners. Acceptance for this can only be achieved if the increased effort is matched by corresponding benefits, or a legal obligation exists.

Energy performance minimum requirements as displayed by the EPC are part of the building regulation and mandatory for new buildings and in some cases for renovations, as well. The requirement to achieve a specific SRI value cannot become part of the building code at this time because the SRI assessment is a purely qualitative process.

However, it could be specified, by analogy with the EPC, that the SRI assessment report needs to be handed over to the building owner or tenant if a building or building unit is sold or rented.

With regard to recommendations on how to improve energy performance that must be displayed in the EPC, recommendations identified as a result of the SRI assessment can provide useful input.

Currently, recommendations in the EPC are often generic and not tailored to the specific building. Consequently, there is the need for a new procedure on how to make this link between SRI assessment results and EPC recommendations, and probably the Renovation Passport envisaged by the recast EPBD can be a useful tool, as well.

The EPBD only provides general guidance on EPC recommendations. In practice, there are several approaches to EPC recommendations, ranging from detailed predefined lists of recommendations from which to choose to blank text boxes to be filled in by the assessor at his or her discretion. More information is available in the reports of the Concerted Action EPBD at <https://epbd-ca.eu/>. [9]

TBS systems requirements as specified by Article 11 of the Commission proposal for the recast EPBD can be a driving force to upgrade a building in terms of BACS and thus smart readiness.

The Commission proposal for the recast EPBD provides possibilities for linking SRI assessment with the EPC status, namely:

- **On-site visit** as the condition to issue an EPC: SRI assessment is also based on an on-site visit. Thus, every time an on-site visit is done in relation to an EPC assessment, the SRI catalogue could be worked through.
- **EPC database:** Depending on the functionalities of the database, recommendations to improve building energy efficiency can be present and serve as a starting point for the SRI assessment. The other way round, the SRI assessment can result in recommendations that can serve as a starting point for generating EPC recommendations.
- **Renovation Passport:** The SRI assessment can provide valuable input to consider BACS improvements in the renovation roadmap for a staged building renovation.
- **Building logbook:** This is a place where all building information is stored. Depending on the set up of the EPC database, the EPC database can be further developed to provide the functionalities of a building logbook. Then, the SRI assessment report would be stored in the same place where the EPC is stored. If data is uploaded through XML interfaces, it will be possible to relate SRI data with EPC data and extract relevant information.
- **Indicator of energy use [kWh/m².a] in the EPC:** High values could result in the standard recommendation in the EPC that the SRI assessment should be carried out to identify room for improvement in BACS regarding the impact criterion Energy efficiency.
- **Indicators of renewable energy in % of energy use in the EPC:** High values could result in the standard recommendation in the EPC that the SRI assessment should be carried out to identify room for improvement in BACS regarding the impact criterion Energy flexibility & Storage.

2.2 TBS and BACS representation in European Standards

European Energy Performance of Buildings (EPB) Standards provide guidance and specifications for designing and assessing the energy performance of buildings. Several European standards are relevant for TBS (Technical Building Systems) in the EPBD, as shown in the overview of EPB standards in the figure below. Compliance with these standards can help ensure that TBS in buildings are designed, installed, and operated in a manner that is energy-efficient, sustainable, and compliant with the requirements of the EPBD.



Figure 1. Overview of EPB standards (Source: <https://epb.center/> / 8 June 2023) [10]

Of most relevance with regard to SRI assessment is the standard EN 15232 - Energy performance of buildings - Impact of Building Automation, Controls and Building Management. EN 15232 focuses on assessing the impact of building automation, controls, and technical building management systems on the overall energy efficiency of both new and existing buildings. SRI functionalities that concern BACS and hence energy use of TBS are drawn directly from standard EN15232, and the SRI functionality steps are mostly aligned with the steps by BACS class from that standard.

The new EN ISO 52120-1:2022 "Energy performance of buildings – Contribution of building automation, controls and building management – Part 1: General framework and procedures" standard [11] substitutes the EN 15232-1:2017 "Energy performance of buildings – Impact of Building Automation, Controls and Building Management – Part 1: Module M4,5, 6, 7, 8, 9, 10". BACS classes in EN ISO 52120-1 are aligned to those in EN 15232.

The new EN ISO 52120-1 standard provides a comprehensive framework for evaluating the energy consumption of various building systems, such as heating, ventilation, air conditioning, lighting, and other technical installations. It establishes a methodology for measuring the energy efficiency improvements achieved through the implementation of advanced control strategies, automation technologies, and integrated building management systems.

The standard outlines a set of criteria and guidelines for classifying building automation and control systems based on their potential to enhance energy performance. These classifications help stakeholders, including building designers, operators, and energy managers, make informed decisions about selecting and implementing appropriate technologies to optimize energy usage while maintaining comfort and functionality.

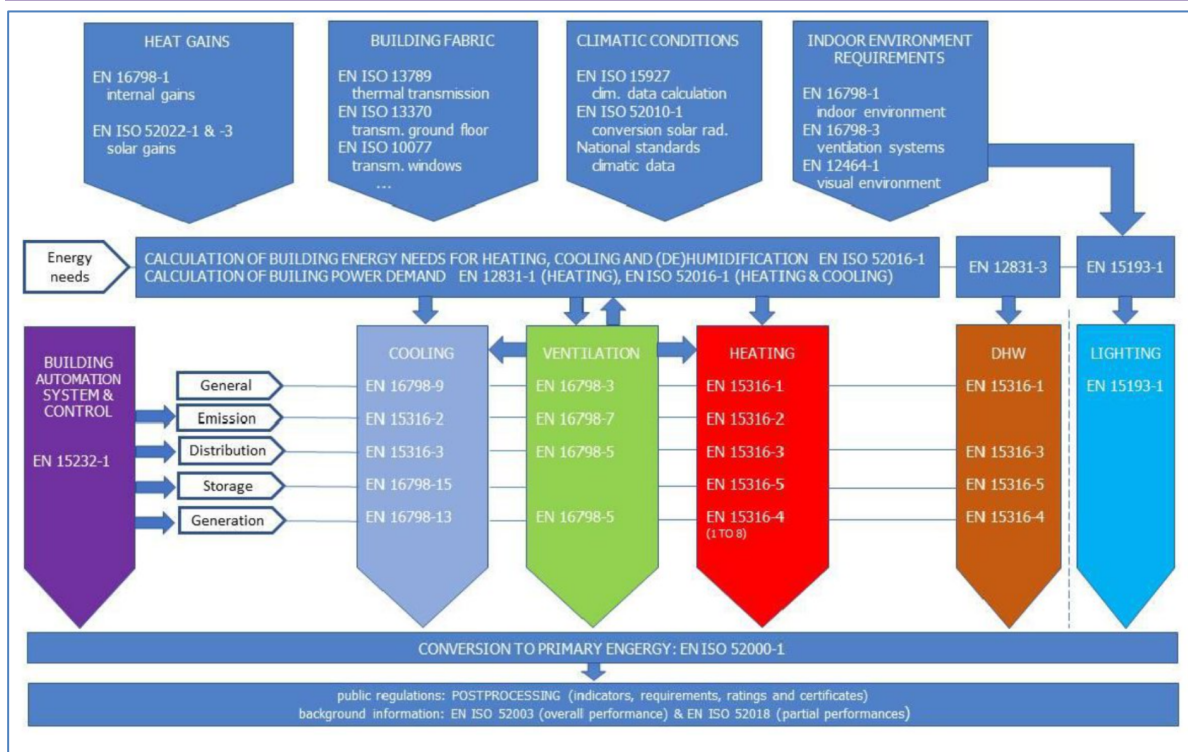


Figure 2. EPB standards and the position of the standard EN 15232 (and its successor EN ISO 52120-1:2022) on BACS (Source: <https://u-certproject.eu/proceedings/set-of-epb-standards/> 8 June 2023) [12]

2.2.1 Overview of EN ISO 52120-1:2022

EN ISO 52120-1:2022 “Energy performance of buildings – Contribution of building automation, controls and building management – Part 1: General framework and procedures” addresses the topic of building automation and control systems and their contribution to increasing the energy efficiency of buildings.

Building automation and control (BAC) provide effective control functions for any building energy system, for example, heating, ventilating, cooling, hot water and lighting appliances, that can be configured based on the actual use of a building, to avoid unnecessary energy use and GHG emissions.

EN ISO 52120-1:2022 Table 5 presents a detailed checklist to determine the BAC efficiency class of a building, as shown by means of an example in Table 1 and Table 2.

Table 1: Excerpt from EN ISO 52120-1:2022 “Table 5 — BAC and TBM functions having an impact on the energy performance of buildings”

1		Heating control
1.1		Emission control HEAT_EMIS_CTRL_DEF M3–5
		The control function is applied to the heat emitter (radiators, underfloor heating, fan-coil unit, indoor unit) at room level; for type 1, one function can control several rooms.
	0	No automatic control of the room temperature
	1	Central automatic control: there is only central automatic control acting either on the distribution or on the generation. Function is to be integrated in a system.
	2	Individual room control: by thermostatic valves or electronic controller
	3	Individual modulating room control with communication: between controllers and BACS (e.g. scheduler, room temperature setpoint)
	4	Individual modulating room control with communication and occupancy detection: between controllers and BACS; demand control/occupancy detection (this function level is usually not applied to any slow reacting heat emission systems with relevant thermal mass, e.g. floor heating, wall heating)

The relevance of functions differs depending on the building use, especially differentiating between residential and non-residential buildings. This is taken into account in EN ISO 52120-1:2022 table 6, exemplarily shown in Table 2 below.

Table 2: Excerpt (simplified) from EN ISO 52120-1:2022 “Table 6 — Function list and assignment to BAC efficiency classes”

1		Heating control	Class							
			Residential				Non-Residential			
1.1		Emission control	D	C	B	A	D	C	B	A
		The control function is applied to the heat emitter (radiators, underfloor heating, fan-coil unit, indoor unit) at room level; for type 1, one function can control several rooms.								
	0	No automatic control	X				X			
	1	Central automatic control	X				X			
	2	Individual room control	X	X			X	X		
	3	Individual modulating room control with communication	X	X	X	X	X	X	X	X
	4	Individual modulating room control with communication and occupancy detection (not applied to slow reacting heating emission systems, e.g. floor heating)	X	X	X	X	X	X	X	x

This table should be used in a way that building owners, architects or engineers put a marker in front of each of the functions in Table 6 they want to implement. They will then use the indicated boxes as a guidance to determine in which BAC class A, B, C, D the function they have specified is located.

The range of interpretation is large, depending on building design and user profile.

EN ISO 52120-1:2022 “Energy performance of buildings – Contribution of building automation, controls and building management – Part 1: General framework and procedures” presents two methods to determine the BAC contribution to the energy performance of buildings which are briefly described below.

Method 1 - Detailed calculation procedure of the BAC contribution to the energy performance of buildings (detailed method)

The output data of this method is a list of building automation and control functions and to each such function the chosen function type. This procedure is suitable for dynamic simulations and allows for quantification of impacts of functions.

Method 2 – Factor-based calculation procedure of the BAC impact on the energy performance of buildings (BAC factor method)

The BAC factor method has been established to allow a simple calculation of the impact of building automation, control and management functions on the building energy performance. The BAC efficiency factors were obtained by performing transient pre-calculations for different building types as mentioned in ISO 52003-1.

These factors represent huge thermal energy savings when moving from class D to C, and still quite significant ones when going from C to B or A. Thus, omitting BACS from EPCs can result in poor EPCs while also undervaluing the contribution that could be made by smarter control.

Examples for thermal energy (heating) are shown in the Tables 3 and 4 below. BAC efficiency factors are also available for cooling, ventilation, lighting, and domestic hot water systems. **Advanced and High performance equipment corresponding to class B and A would result in a reduction of energy consumption, while class D would result in an increase in energy consumption compared to class C representing BAC standard equipment of a building.**

Table 3. Overall BAC efficiency factors for thermal energy – Non-residential buildings (EN ISO 52120-1:2022)

Non-residential buildings	Overall BAC efficiency factors $f_{BAC,th}$			
	D	C Reference	B	A
	Non energy efficient	Standard	Advanced	High energy performance
Offices	1,51	1	0,80	0,70
Lecture hall	1,24	1	0,75	0,5 ^a
Education buildings (schools)	1,20	1	0,88	0,8
Hospital	1,31	1	0,91	0,86
Hotels	1,31	1	0,85	0,68
Restaurants	1,23	1	0,77	0,68
Wholesale and retail trade service buildings	1,56	1	0,73	0,6 ^a
Other types: - Sport facilities - Storage - Industrial buildings - Etc.		1		
^a These values highly depend on heating /cooling demand for ventilation.				

Note that overall BAC efficiency factors are not available for “Other types”.

Table 4. Overall BAC efficiency factors for thermal energy – Residential buildings (EN ISO 52120-1:2022)

Residential building types	Overall BAC efficiency factors $f_{BAC,th}$			
	D	C Reference	B	A
	Non energy efficient	Standard	Advanced	High energy performance
Single family houses	1,10	1	0,88	0,81
Apartment block				
Other residential buildings or similar residential buildings				

2.2.2 Conclusions for linking SRI assessment with EPC status

EN ISO 52120-1:2022 focuses on the impact of automation and control systems on energy consumption. It helps determine the potential benefits of implementing advanced building management systems. It also provides the methodological basis for SRI assessment.

The EPC assesses the overall energy performance of a building, taking into account various aspects such as insulation, heating, cooling, lighting, and appliances. It provides a more holistic view of a building's energy efficiency.

The information provided by EN ISO 52120-1:2022 can contribute to the calculations and recommendations made in an EPC. For instance, a building with advanced automation and control systems that optimize energy usage could receive a better energy efficiency rating in its EPC if BAC is considered in the calculation method as suggested by the German DIN V 18599. [13]

If the EPC calculation method does not consider the impact of BAC, it would be a very useful addition to link the SRI information to the EPCs so that BACS factors could be derived and used to adjust the EPC rating. This would help reduce the performance gap reported for EPCs while recognising the contribution that better controls can make.

2.3 Key HVAC TBS and their links to the SRI

In Article 2 Definitions of the EPBD, a difference is made between TBS and BACS as follows:

‘technical building system’ means technical equipment for space heating, space cooling, ventilation, domestic hot water, built-in lighting, building automation and control, on-site renewable energy generation and storage, or a combination thereof, including those systems using energy from renewable sources, of a building or building unit;

‘building automation and control system’ means a system comprising all products, software and engineering services that can support energy efficient, economical and safe operation of technical building systems through automatic controls and by facilitating the manual management of those technical building systems;

To improve understanding, a reference is made to the German terms Gebäudeautomatisierung (building automation) and Gebäudeleittechnik (building control technology) used in Germany and Austria. In summary, **building automation** encompasses all automated systems within a building that are used to control and optimize various functions. This includes the regulation of heating, ventilation, air conditioning (HVAC), lighting, security systems, blinds, and other technical facilities. Building automation aims to optimize energy consumption, improve user comfort, and reduce operating costs. **Building control technology** refers to the overarching system or software that coordinates and monitors various automated systems within a building. Building control technology enables centralized control and monitoring of all building functions through a user interface. This could be a supervisory computer or a software platform. In many cases, building control technology serves as the core of building automation, providing comprehensive control over all connected systems.

Thus, **Building Automation and Control (BAC)** always includes a software component. BAC can refer to individual TBS such as a heat pump, a biomass boiler, or a photovoltaic plant.

In this context, the term **Building Automation and Control Systems (BACS)** rather refers to a comprehensive set of systems and technologies used to automate and control various functions within a building. This would include systems such as heating, ventilation, air conditioning (HVAC), lighting, security, and other building-related functions. BACS typically involve the integration of technologies to enhance the efficiency, comfort, and security of a building. These systems often include sensors, controllers, and software platforms that allow for centralized monitoring and management of different building components.

2.3.1 Example of HVAC system and links to SRI

The example of a heat pump as described below is used to demonstrate the different levels or viewpoints.

The hardware components for building automation related to a heat pump can vary depending on specific requirements and systems. Here are some typical hardware components that may be used in a building automation solution for a heat pump system:

Sensors:

- Temperature Sensors: Measure room and outside temperatures to control heating and cooling processes.
- Pressure Sensors: Monitor pressure in different parts of the heat pump system.
- Humidity Sensors: Allow control of air humidity in the building.

Control Units:

- Microcontrollers or processors: Take control functions by interpreting data from sensors and sending commands to actuators.
- Programmable Logic Controllers (PLC): Often used for complex control processes.

Actuators:

- Valves: Regulate the flow of heating or cooling fluids.
- Pumps: Control the circulation of the heat transfer fluid through the system.
- Actuators: Regulate the position of valves in heating and cooling systems.

Communication Modules:

- Ethernet or wireless interfaces: Enable networking of building automation components.
- Modbus, BACnet, or other BUS based protocols: Frequently used for communication between different devices in building automation networks.

Control Interfaces:

- Touch panels or interfaces: Provide users with the ability to monitor and control the system.
- Programmable thermostats: Allow users to set room temperatures and operating modes.

Safety Components:

- Smoke detectors and CO2 sensors: Monitor air quality in the building.
- Emergency switches and safety valves: Ensure the safety of the heat pump system.

The precise selection of hardware depends on the specific requirements of the heat pump, the building, and the building automation concept. **It is important to ensure that the hardware components are compatible with each other and with the BAC components of other TBS, and that integrated optimisation at the building level is possible through the BUS technology or radio system technology.**

BUS stands for Binary Unit System and is a data transmission system for the standardised connection of decentralised devices, the so-called BUS participants. BUS devices are sensors and actuators. Sensors are command transmitters such as buttons, switches and motion detectors; actuators are command receivers such as relays, dimmers for lights and drives. The transmitted data is used for signalling and control and other operational functions. The BUS components are configured on a PC using special software.

In building technology, 2-wire cables are usually used for bit-serial data transmission and for feeding the electronics of the BUS participants. Power is transmitted via the conventional power installation. [14]

There are various wired and wireless BUS technologies on the market. [15]

In existing buildings, the need to renew the electrical wiring provides the opportunity to install the necessary cables for wired BUS. Existing, conventional electrical installations can be converted into radio-capable systems in which all building functions work together by using special radio system technology. There is the characteristic of changeable configurability: actuators and sensors can be reprogrammed and the assignment to each other can be changed. [16]

Without wired BUS and without radio technology, optimisation by means of BAC is restricted to the respective HVAC technical building system. For example, the BAC of a heating system would build on some of the following elements, depending on the economic and technical feasibility, especially in existing buildings: [17]

- Outdoor temperature-based control
- Control in heating installations
- Temperature sensor
- Electronic control
- Room temperature control
- Night setback
- Thermostatic valves
- Telecontrol technology
- Individual room control by radio

2.3.2 Conclusions for linking SRI assessment with EPC status

The SRI assessment takes into account the BAC functions for each HVAC TBS and for the building as a whole.

With regard to the whole building, three levels must be differentiated: [14]

- **Field level:** The technical systems are operated with sensors and actuators.
- **Automation level:** the technical building systems are controlled and regulated on the basis of the data supplied by the field level and the specifications coming from the management level.
- **Management level:** This is where cross-system and higher-level control and optimisation algorithms are implemented. A computer, redundant data storage including data backup options and an uninterruptible power supply are required.

The scope of the whole building becomes more important with the integration of renewable energy systems and storage systems, and the resulting overall optimisation of building operation.

In this regard, knowledge in the areas of electrical engineering (hardware of equipment) and ICT (software and programming) becomes more important, as well.

The German Federal Office for Information Security publishes guidelines and standards on information security, also regarding BACS. There are several challenges identified, for example: [18]

- The BACS controls the technical building systems across the board. If just one system is faulty or inadequately integrated, the functionality of the entire building management can be restricted. Components are often used in the building services installations controlled by the BACS that are no longer updated due to their age, have weak points or are no longer state of the art. This is often the result of inadequate quality in the manufacturer's development and maintenance processes or software that is insecure due to a lack of computing and storage capacity.
- The ICT connection of technical building systems to the building automation system is insecure and thus exposed to errors and attacks.
- There is no BACS commissioning protocol and no interface documentation.

Currently, the EPC is a rather cheap instrument to assess the energy performance of a building based on standardised user profiles, and standardised assumptions about the quality of control, to generate quantitative results allowing for the comparison of buildings in terms of energy performance. The SRI qualitatively assesses the smart readiness of buildings and thus indicates the potential benefits in terms of comfort, health and convenience, energy savings, and grid flexibility. The actual performance depends on the way the smart devices are used (software and programming), and this is out of scope of the SRI assessment.

If the EPC is understood as a dynamic concept that can be generated at any time from a database that also contains energy consumption data, then the common denominator of EPC and SRI is the actual final energy use and the energy use actually supplied from outside the building (not produced on site). EPC and SRI meet in these indicators, because the way the building is operated by means of BACS will have an impact on these indicators. Therefore, automation steps for each HVAC TBS and different building types should be identified that have an impact on energy consumption, for example those provided by EN ISO 52120-1:2022.

3 Analysis of the links between energy efficiency and SRI

This chapter looks at energy efficiency in different contexts and possible relations with SRI. The most important paragraphs and phrases are highlighted in a green font. In the final sub-chapter, conclusions are drawn for developing the procedure of linking SRI assessment with the EPC status.

3.1 Definitions of energy efficiency

The Energy Efficiency Directive (EED) [19] provides definitions on energy efficiency in Article 2 as follows [6]:

For the purposes of this Directive, the following definitions shall apply:

- (1) 'energy' means all forms of energy products, combustible fuels, heat, renewable energy, electricity, or any other form of energy, as defined in Article 2(d) of Regulation (EC) No 1099/2008 of the European Parliament and of the Council of 22 October 2008 on energy statistics;*
- (2) 'energy efficiency first' means energy efficiency first as defined in Article 2, point (18), of Regulation (EU) 2018/1999;*
- (3) 'energy system' means a system primarily designed to supply energy-services to satisfy the demand of end-use sectors for energy in the forms of heat, fuels, and electricity;*
- (4) 'system efficiency' means the selection of energy-efficient solutions where they also enable a cost-effective decarbonisation pathway, additional flexibility and the efficient use of resources;*
- (5) 'primary energy consumption' or 'PEC' means gross available energy, excluding international maritime bunkers, final non-energy consumption and ambient energy;*
- (6) 'final energy consumption' or 'FEC' means all energy supplied to industry, to transport, including energy consumption in international aviation, to households, to public and private services, to agriculture, to forestry, to fishing and to other end-use sectors, excluding energy consumption in international maritime bunkers, ambient energy and deliveries to the transformation sector and to the energy sector, and losses due to transmission and distribution as defined in Annex A to Regulation (EC) No 1099/2008;*
- (7) 'ambient energy' means ambient energy as defined in Article 2, point (2), of Directive (EU) 2018/2001;*
- (8) 'energy efficiency' means the ratio of output of performance, service, goods or energy, to input of energy;*
- (9) 'energy savings' means an amount of saved energy determined by measuring and/or estimating consumption before and after implementation of an energy efficiency improvement measure, whilst ensuring normalisation for external conditions that affect energy consumption;*
- (10) 'energy efficiency improvement' means an increase in energy efficiency as a result of technological, behavioural and/or economic changes;*

(11) ‘energy service’ means the physical benefit, utility or good derived from a combination of energy with energy-efficient technology or with action, which may include the operations, maintenance and control necessary to deliver the service, which is delivered on the basis of a contract and in normal circumstances has proven to result in verifiable and measurable or estimable energy efficiency improvement or primary energy savings;

Please note that the definition of primary energy consumption and final energy consumption is different from the terminology applied by the Energy Performance of Buildings Directive (EPBD), as shown in the next chapter.

With regard to SRI, the definition of energy efficiency according to EED covers all SRI impact categories. SRI impact category “energy efficiency” refers to the efficient operation of technical building systems while responding to changing conditions in relation to the external environment and demands from building occupants.

3.2 Energy efficiency in the EPBD

Energy efficiency in the context of the amended Energy Performance of Buildings Directive (EPBD) can be defined as the optimal use of energy in buildings, aiming to minimize energy consumption while ensuring the desired level of comfort and functionality. [2] [3] However, in the EPBD, energy efficiency is not explicitly defined as a standalone term. Nevertheless, the directive targets the improvement of energy performance in buildings and sets out measures to achieve energy efficiency goals through key principles such as:

- **Energy Performance Certificate (EPC):** The EPBD requires that buildings have an Energy Performance Certificate that provides information on the energy efficiency of the building. The certificate rates the energy performance of a building on a scale from A (most energy-efficient) to G (least energy-efficient).
- **Minimum requirements:** The EPBD sets out energy performance requirements for new buildings, major renovations, and existing buildings undergoing renovations. These requirements define maximum energy consumption limits, energy efficiency targets, and the use of renewable energy sources to promote energy-efficient building design and construction practices.
- **Inspections:** The EPBD requires regular energy inspections of heating and cooling systems, including boilers, air conditioning units, and ventilation systems, to assess their energy efficiency and identify potential improvements.

The Commission proposal for the recast EPBD [4] contains the following definitions with regard to energy efficiency:

[...]

8. ‘energy performance of a building’ means the calculated or metered amount of energy needed to meet the energy demand associated with a typical use of the building, which includes, inter alia, energy used for heating, cooling, ventilation, hot water and lighting;

9. ‘primary energy’ means energy from renewable and non-renewable sources which has not undergone any conversion or transformation process;

[...]

23. ‘operational greenhouse gas emissions’ means greenhouse gas emissions associated with energy consumption of the technical building systems during use and operation of the building;

24. ‘whole life-cycle greenhouse gas emissions’ means the combined greenhouse gas emissions associated with the building at all stages of its life-cycle, from the ‘cradle’ (the extraction of the raw materials that are used in the construction of the building) over the material production and processing, and the building’s operation stage, to the ‘grave’ (the deconstruction of the building and reuse, recycling, other recovery and disposal of its materials);

25. ‘Life-cycle Global Warming Potential (GWP)’ means an indicator which quantifies the global warming potential contributions of a building along its full life-cycle;

[...]

50. ‘energy performance of buildings (EPB) services’ means the services, such as heating, cooling, ventilation, domestic hot water and lighting and others for which the energy use is taken into account in the energy performance of buildings;

51. ‘energy needs’ means the energy to be delivered to, or extracted from, a conditioned space to maintain the intended space conditions during a given period of time disregarding any technical building system inefficiencies;

52. ‘energy use’ means energy input to a technical building system providing a EPB-service intended to satisfy an energy need;

53. ‘self-used’ means part of on-site or nearby produced renewable energy used by on-site technical systems for EPB services;

56. ‘delivered energy’ means energy, expressed per energy carrier, supplied to the technical building systems through the assessment boundary, to satisfy the uses taken into account or to produce the exported energy;

57. ‘exported energy’ means, expressed per energy carrier and per primary energy factor, the proportion of the renewable energy that is exported to the energy grid instead of being used on site for self-use or for other on-site uses.

[...]

The “energy performance of a building” as defined above clearly refers to the typical use of a building. In contrast, the SRI assessment targets the capability of TBS and BACS to adapt to the specific needs of the occupants and to optimize energy efficiency and other SRI impact categories at the same time. Indicators referring to “energy needs” reflect the quality of the building envelope in terms of reducing energy losses due to transmission, air leakage, and ventilation. Regarding the latter, buildings with mechanical ventilation systems with heat recovery in winter are different in comparison with buildings without mechanical ventilation systems. “Energy use” is the EPC indicator that reflects the energy needs including the efficiency of all technical building systems. **Therefore, the overall “energy use” and “energy use by TBS” are best suited to reflect the impact of smart technologies.** Other indicators relating to primary energy and greenhouse gases are less suitable, as they are calculated using factors that are based on natural science but are then determined politically. Energy cost is related to energy use. However, with regard to the recently extended Emission Trading System (ETS) that also addresses the building sector with the so-called ETS 2, **also indicators related with greenhouse gas emissions will become important from an economic point of view.** [20]

3.3 Energy efficiency and SRI

The SRI measures the readiness of a building to integrate and effectively use advanced technologies for improved energy efficiency, comfort & convenience, and grid flexibility.

Building Automation and Control Systems (BACS) play a key role in SRI. BACS refer to the systems and technologies used to monitor, control, and automate various functions within a building. BACS encompass a wide range of systems, including HVAC (heating, ventilation, and air conditioning) systems, lighting control systems, security and access control systems, fire detection and alarm systems, energy management systems, and more. BACS enable centralized control and automation of these building systems to improve operational energy efficiency, enhance occupant comfort and convenience, and contribute to a functioning electricity grid based on volatile renewable energy generation.

However, equipping a building with a higher degree of building automation does not always correlate with increase in energy efficiency. In the case of highly energy-efficient new buildings built according to the so-called low-tech architecture method [21] in climatic regions where heating energy demand dominates, the energy savings potential can be rather low compared to the potential to be realised in existing buildings. However, in such a situation, advanced BACS can be advantageous and even necessary to ensure thermal comfort, IEQ, and integration of renewables; so, the value proposition of the BACS moves beyond TBS energy savings towards ensuring stable control and healthy internal conditions. [22] [23] If energy efficiency does not only refer to operational energy use but includes also energy used to produce materials, energy required for the production of the BACS components will come to the fore (whole life greenhouse gas emissions). But these amounts are negligible, according to the Study on BACS Ecodesign [23]. Finally, the benefits of equipping buildings with higher levels of BACS functionality also depend on the usage profile (office building versus single-family house).

Basically, there is the challenge that overall energy efficiency is covered in the energy performance certificate but usually ignores TBS automation and control, and the SRI also assesses energy efficiency, but only limited to building automation and control. Studies of case studies in Austria have shown that there are cases with a very good rating in the energy performance certificate and at the same time a very poor rating of energy efficiency in the SRI due to a low level of BACS which is justifiable in the specific cases, for example, due to the low potential in improving energy efficiency and the additional expenses caused by the BACS (hardware and software, need for IT experts). This is difficult to communicate on the market and may damage the acceptance of both systems.

Another problem concerns a potential trade-off between energy flexibility and reducing energy consumption. Grid-serving behaviour in connection with the use of fluctuating renewable energy (solar and wind) can lead to buildings being cooled to lower temperatures than necessary or heated to higher temperatures than necessary if the energy is available and cannot be used otherwise. This creates a buffer for cooling or heating, so to speak. However, this energy management strategy is at the expense of energy efficiency if the energy consumption is considered in the EPC. If renewable energy is available in abundance, however, the poor performance in terms of energy efficiency should be secondary.

3.4 EPC scheme and SRI assessment

The EPC is necessary for new buildings as part of the building permit process, and for each building or building unit to be rented or sold. Building renovation does not always require a building permit, so in such cases, an EPC is not required, either. It is possible that an SRI assessment will be performed for a building that does not yet have an EPC.

SRI assessment can be performed for other reasons than energy efficiency, namely, to determine room for improvement regarding grid flexibility and health and comfort.

The following tables show the relations between the EPC scheme and the current approach of SRI assessment. This analysis serves to generate information for developing the procedure of linking the SRI assessment with the EPC status.

There are two essential aspects:

- To ensure the qualification of experts to have a certificate which is trusted on the market.
- To ensure reuse of information and to avoid multiple data collection, as this causes duplicative effort and can be a source of error.

The second issue is difficult to deal with because usually, experts do not build on other experts' work due to liability reasons. However, a similar situation exists regarding the building logbook or renovation passport, meaning that liability issues must be addressed by how local regulations are framed e.g. by removing assessor liability for usage of data from another officially recognised assessment.

Table 5. Comparison of EPC scheme and SRI assessment

Criterion of comparison	EPC scheme	SRI assessment	Recommendation
Qualified experts	Qualified experts; requirements depend on Member States. E.g. an educational background in architecture, or civil engineering (all engineering sectors) can be required which is useful for creating EPC for large/complex buildings.	Qualified experts; requirements depend on Member States. An educational background in engineering (electrical, mechanical, electronics) could be useful.	Qualified experts need training; conditions for admission must be defined. Schemes should be aligned with energy audit schemes according to EED, as is the case in some countries (for example Croatia).
Method	Different types of calculation software to produce the EPC, based on a methodological framework offering a broad range of interpretation / discretion.	Assessment method can be adjusted in many ways, but is done by each Member State.	Use the mandatory EPC indicators to link SRI assessment with EPC status (see Table 6). Use of EPC data to adapt the energy weightings per TBS.
Input data for assessment	Data collection for calculation; e.g. from architectural and TBS documentation, on-site visit.	Assessment is based on visual inspection during on-site visit and data documentation. Tools are being (have been) developed to allow data to be ported and reprocessed.	Generate SRI assessment from data collected for EPC or vice versa.
Range of interpretation	Range of interpretation is low - Quantitative method.	Range of interpretation is high - Qualitative method.	Quantitative EPC results can provide the basis for methodological subcategories to narrow the range of interpretation of the qualitative SRI assessment (Example: With a very low heating energy demand [kWh/m ² .a] for residential buildings, a high functionality level based on presence detection is less effective, as the savings potential would be minimal.)

Table 6. Relation of SRI with EPC indicators

Mandatory EPC Indicators (according to Commission proposal for recast EPBD)	Relation with SRI
Energy performance class	<p>Energy performance class > C: substantial energy saving potential can be expected.</p> <p>The lower the EPC rating and the higher the SRI energy rating, the higher the energy savings that can be expected.</p> <p>The SRI assessment can result in BAC efficiency factors according to EN ISO 52120-1:2022 that can be used to adjust the EPC calculation result.</p>
Calculated annual final energy use in kWh/(m2.a)	<p>The higher the value, the higher the energy-saving potential that can be expected.</p> <p>The SRI assessment can result in BAC efficiency factors according to EN ISO 52120-1:2022 that can be used to adjust the EPC calculation result.</p>
Calculated annual final energy consumption in kWh or MWh	<p>The higher the total amount, the higher the energy saving potential that can be expected.</p> <p>The SRI assessment can result in BAC efficiency factors according to EN ISO 52120-1:2022 that can be used to adjust the EPC calculation result.</p>
Renewable energy production in kWh or MWh	A high value in combination with a low value regarding Renewable energy in % of energy use shows the improvement potential in increasing own consumption.
Renewable energy in % of energy use	See above.

Mandatory EPC indicators are based on interim calculation results which represent indicators for energy consumption in technical domains. Indicators are available at the level of energy need, energy use, and primary energy. SRI technical domains are covered by EPC metrics except “electric vehicle charging” and “monitoring and control”, as shown in the next table.

Table 7. Relation of SRI with metrics such as energy consumption that are considered for the issuance of EPC

Metrics	Coverage	Relation with SRI technical domain
Heating energy use [kWh/m2.a] Cooling energy use [kWh/m2.a]	Transmission losses Ventilation losses Internal gains Solar gains	Heating Cooling Ventilation Dynamic building envelope
Domestic hot water energy use [kWh/m2.a]		Domestic hot water
Final energy use [kWh/m2.a] CO2-eq [kg/m2.a]	Efficiency of energy system – conversion losses	Heating Cooling Ventilation Dynamic building envelope Domestic hot water Lighting Electricity

Percentage of final energy use [kWh/a] of on-site generated renewable electricity	Self-consumption of on-site generated renewable energy	Monitoring and control addressing: Heating Cooling Ventilation Dynamic building envelope Domestic hot water Lighting Electricity
Percentage of final energy use [kWh/a] of on-site generated renewable electricity CO ₂ -eq [kg/a]	Self-consumption of on-site generated renewable energy	Electric vehicle charging Monitoring and control addressing electric vehicle charging

3.5 Inspections and SRI assessment

Inspections of heating and cooling systems according to EPBD are currently not fully suitable for improving the smartness of buildings in all member states and for all buildings: under the provisions of the EPBD MS can comply with the inspection requirements via implementation of alternative measures, such as the provision of energy advice, if they demonstrate that the proposed alternative measures can save the same amount of energy as inspections. It is also noted that the inspections may have a different legal basis than the minimum requirements and the energy performance certificate. While the contents of the energy performance certificate can be implemented through the building code (building legislation), it is possible to integrate the inspections into the legislation in the area of air pollution control. The way in which the legislation is implemented can have an impact on what type of data need to be collected as part of the inspection, and on which professions are authorised to practice and which qualification requirements exist. In the field of air pollution control, these are not necessarily those required for an SRI assessment. [24] [25]

Furthermore, according to the EPBD some types of buildings are exempt from inspections, for example, those that are under an energy performance contract, or are managed by a utility or grid operator.

An inspection report to be issued after each inspection of a heating or air-conditioning system contains the result of the inspection performed and includes recommendations for the cost-effective improvement of the energy performance of the inspected system. According to the Commission proposal for the recast EPBD, inspection should be extended to ventilation systems. With a view to SRI assessment, inspection reports can provide valuable information if BAC is checked, as well, and if reports also include recommendations on how to improve energy efficiency by means of BAC.

In summary, an SRI assessment could either substitute for a TBS inspection, or it could be complementary to one. What is viable and of interest to a MS is likely to depend on the provisions which data need to be collected during the inspection, and the nature of the professionals allowed to do the assessments.

3.6 Conclusions for linking SRI assessment with EPC status

Energy efficiency improvements based on SRI assessment

In conclusion, energy efficiency improvements based on SRI assessment are those related to application of BAC in building operation. BAC consists of hardware and software, both of which may be subject to change during building operation.

Analysis of the relation between SRI and energy consumption

Thus, the SRI can only determine the energy efficiency potential based on the identified BAC hardware and documentation of programming.

Especially programming of BAC elements can be changed at any time, and therefore, the metered overall energy consumption as well as the metered energy consumption by energy carrier and TBS (or EPB-service) are the appropriate energy consumption indicators to cross-check the potential determined through the SRI assessment. While the energy performance based on metered energy use must be normalized in the EPC, as well, actual energy consumption displayed on energy bills is used for developing specific recommendations in the renovation passport. The application of the renovation passport has been voluntary, the extent of implementation depends on the policies of the Member States. Therefore, a more generally applicable approach could be to develop a standard set of BACS related energy saving measures for different building types and uses, for example, a standard package of energy saving measures for a school in a cold climate that is used all year round and rents out rooms and facilities to other organisations during non-school hours. Based on the SRI assessment result, a selection of BACS related energy saving measures could be activated as default input to the SRI assessment report. These BACS related energy saving measures would be useful for the EPC recommendations, as well.

Identification of the scope of linking SRIs with energy efficiency

In terms of identifying the scope to which SRI is linked to energy efficiency, there are several levels to consider as described below.

- (1) **EPBD as legal basis addressing energy efficiency:** First of all, SRI data can be used to complement EPCs not taking into account the impact of BACS on energy performance, or to derive BACS factors that could retroactively be applied to improve the EPC asset methodology calculations and adjust the ratings accordingly. Furthermore, SRI assessment can generate recommendations for the EPC and for the renovation roadmap for staged renovation which is part of the renovation passport. Furthermore, it has the potential to use synergies with the inspection of HVAC TBS, and it supports the implementation of minimum requirements for technical building systems.
The SRI assessment will result in the identification of improvement potentials along the technical domains referring to TBS which are also reflected in the EPC or at least in the calculations the EPC is based on. The EPC database can provide valuable information as input into the SRI assessment, and the SRI assessment can generate information that should be taken into account in the recommendations section of the EPC. However, the condition is that SRI assessment report and the energy performance certificates are stored at least in the same place. The same applies to other relevant documents such as the renovation roadmap, the inspection report, and the energy audit report. The building logbook envisaged by the Commission proposal for the recast EPBD is ideal for this purpose.
- (2) **Legal bases addressing building energy efficiency other than the EPBD, such as the EED, the ETS 2 and the Taxonomy Regulation [26]:** Especially energy audits according to EED, but also energy efficiency obligation schemes, white certificates, and other regulations such as the accelerated renovation of all public buildings to contribute to national energy saving targets are relevant. This means that the development of the easySRI platform should also cover such potential business cases. This topic is dealt with in more detail in WP6.1.
- (3) **Voluntary and mandatory instruments addressing the as built status and operational phase of a building, with the objective of improving a building:** This includes energy audits according to EED, and the renovation passport including the renovation roadmap according to EPBD for staged renovation towards nZEB and ZEB targets. Both instruments require an on-site visit, the collection of actual energy consumption data, and the development of recommendations how to improve energy efficiency and to achieve energy savings. This has the potential to create synergies with SRI assessment.
- (4) **Realisation of the energy efficiency potential - Standardization of BAC hardware elements and documentation of programming:** The standardisation of hardware components and the standardisation of programming documentation are essential to ensure that the energy efficiency potential achievable through BAC can be realised in reality at the forecast costs. If components have to be replaced earlier because certain programming is no longer supported or communication with another BAC element is no longer possible, then both the GWP parameters and the cost parameters are incorrect. Programming is crucial for realising the energy efficiency potential, and for the SRI assessment proper documentation is advantageous.

In general, it would be useful to classify the buildings in such a way that it can be determined which buildings are candidates for an SRI assessment. This is supported by Recital (43) of the Commission proposal for recast EPBD [1] stating the following:

The smart readiness indicator should be used to measure the capacity of buildings to use information and communication technologies and electronic systems to adapt the operation of buildings to the needs of the occupants and the grid and to improve the energy efficiency and overall performance of buildings. The smart readiness indicator should raise awareness amongst building owners and occupants of the value behind building automation and electronic monitoring of technical building systems and should give confidence to occupants about the actual savings of those new enhanced-functionalities. The smart readiness indicator is particularly beneficial for large buildings with high energy demand. For other buildings, the scheme for rating the smart readiness of buildings should be optional for Member States.

For example, regarding "high energy demand", a specification would be desirable. Based on a range of values, an alarm function could be installed in the EPC database that automatically suggests an SRI assessment for certain energy consumption values. A similar mechanism could apply to the other areas of SRI assessment, namely grid flexibility and health and comfort.

4 Case studies to support the analysis

Three country-related case studies are presented. The aim is to point out those aspects that can shed light on the issue of the link between SRI and EPC. The participating countries are free to decide which aspects will be covered.

4.1 Austria

4.1.1 Availability of EPCs

The Energy Performance Certificate (EPC) is regulated at federal level regarding handing over the EPCs to owners and tenants in the course of buying or renting a building or a building unit, and regarding publicising defined indicators in real estate advertisements (federal EPC Presentation Law, 2012). [27]

All technical aspects and displaying the EPC in public buildings are regulated at the level of the federal provinces as part of the provincial building regulations. EPCs are required for new buildings and major renovations as part of the building permit procedure. Regarding major renovations, this requirement was not effective in practice. Often, renovations were planned in a way that the condition of major renovation was avoided. Thus, this requirement did not substantially contribute to increasing the number of EPCs to achieve a better coverage of the building stock. There are few exemptions from the obligation to have an EPC, namely those ones stated by the EPBD.

EPC validity is 10 years, meaning that there are different versions of EPC on the market because the underlying framework which is Guideline 6 of Austrian Institute of Construction Engineering (OIB – Österreichisches Institut für Bautechnik) has been updated in 4-years periods (2007, 2011, 2015, 2019, 2023). [28]

While the availability and quality of EPCs is good for new buildings because the EPC is part of the building permit procedure regulated by the provinces, the situation regarding the EPCs to be issued in the course of selling or renting a building or a building unit (regulated by the federal law) still needs to be improved. The obligation to hand over the EPC is hardly enforceable. Although the law provides for a penalty in case of non-compliance, a civil complaint is required for the penalty to become effective. In practice, such charges are rarely filed. There are no other effective mechanisms in Austria, such as the need to present the information to the notary for the purchase contract or to the bank for the loan.

Both, for new buildings and existing buildings there is the calculated EPC. There is no metered EPC in Austria, but it is worth noting that energy consumption and production data can be collected in addition to the EPC as part of the requirements of the social housing subsidy scheme and climate grants for non-residential public buildings.

4.1.2 Process of developing, issuing and storing an EPC

The EPC is issued for a building or a building zone. For apartments or building units, the EPC issued for the building or building zone applies. Separate EPCs are not issued for individual apartments or building units in multi-story buildings.

EPC Software

Several EPC software products are officially approved and available on the market. All of them have an interface to upload the EPC and all input data as well as interim calculation results via XML interface into the EPC database environment called ZEUS (Zentrales Energieausweis Umgebungssystem). Software products other than those officially approved must not be used.

More and more, these software products have IFC interfaces which allow for integration with a BIM environment.

The EPC software products include the creation of the energy model needed to calculate the EPC indicators, while the level of detail varies depending on the software product. Usually, energy models are based on the monthly method. There are different software modules for residential buildings, non-residential buildings, new buildings and existing buildings. Data input can be simplified, detailed, or based on external sources that are imported.

For complex non-residential buildings, separate energy simulations are carried out during building design for optimization purposes, which can also be used to generate the input data for the EPC calculation program.

For new zero-emission or positive energy buildings with extremely low heating requirements and a sophisticated energy supply system with BACS features, some of the energy models are not fully capable of accurately representing all the details.

Some of the current software versions are not able to sufficiently consider the effects of the different functional levels of BACS on the energy performance of the building. This makes it difficult to establish direct links between SRI and EPC, especially in residential buildings. For non-residential buildings, it will be easier to use the same assessment process to determine the BACS class and the SRI functionality level, so the findings from whichever assessment was done first (EPC or SRI) could be used to inform the relevant parameters for the other certification (SRI or EPC). However, currently, this will only be possible if the same person does both assessments (EPC and SRI), as experts do not build on the work of other experts due to liability reasons.

Characteristics of issuing an EPC for new buildings and for existing buildings

The EPC for new buildings is based on detailed input data and reflects the actual status of the building.

The EPC for existing buildings can be based on detailed input data or default input data and a simplified procedure, depending on the availability of data.

EPC and actual energy consumption

Non-residential buildings such as offices and educational buildings have predictable user profiles, and deviations from the standard user profile of the EPC should be minor. In these cases, simple BACS solutions such as time programs and presence detectors may be appropriate to avoid energy waste. However, optimisation of renewable energy self-consumption and consideration of other smart readiness aspects require more sophisticated BACS.

In hotels, energy consumption is linked to the comfort level, which is defined by the hotel's star classification. Guest satisfaction has a higher priority than energy performance. In hospitals, operational reliability is a top priority. Such aspects need to be considered when identifying smart readiness improvement potentials.

In residential buildings, actual energy consumption may differ significantly from EPC indicators:

- **New buildings:** Monitoring projects of residential buildings have shown that energy consumption can be much higher but also much lower than in the EPC due to the actual user behaviour that differs from the standard user profile used for the EPC calculation. This is especially true for multi-unit residential buildings, where the actual energy consumption differs depending on the use of the apartments, for example: families with young children and a high domestic hot water consumption, elderly people spending much time at home and in need of higher room temperature to feel comfortable, single households that use the apartment little due to frequent business trips, and so on.

- Existing buildings: In residential buildings with very low energy efficiency, energy indicators in the EPC can be overestimated. In reality, temperature can be lower than the standard temperature for EPC calculation, or some rooms are not heated at all, to save energy and decrease cost.

There may be a case where the energy performance certificate represents an efficient building based on the standard user profile, but in reality, energy is wasted due to user behaviour and therefore the building automation and control system enables energy savings. Actual energy consumption based on actual use is not revealed by the energy certificate, but only by energy audits and building renovation passports.

In general, it seems there is a lack of information among building owners on how much energy can be saved by the use of what type of BACS and under what conditions. It is also important to consider the total cost of ownership to avoid an increase in operating costs (due to maintenance and repair of BACS and IT services) as a result of energy savings.

EPC database environment ZEUS

The EPC database environment ZEUS is used in 6 out of 9 Austrian regions. The most advanced version is implemented in the region of Salzburg where the EPC database environment including the independent control system according to EPBD (see Figure 3 and 4) has been further developed to also cover the function of building logbook which is called “my ZEUS” building data account as shown in Figure 5.

All approved EPC software programs have an XML interface with the regional EPC databases to store input data as well as calculation results in the database. Upload is done automatically via the EPC software.

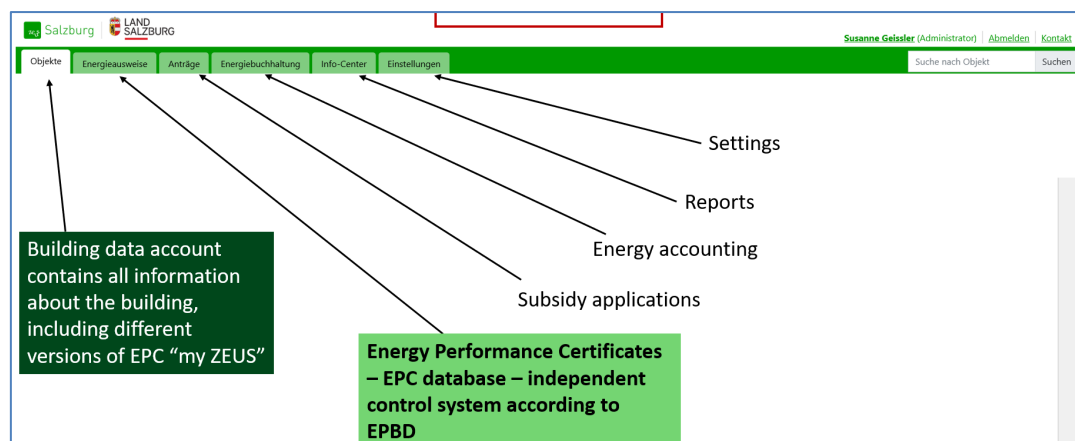


Figure 3. Test environment ZEUS (for testing and research; like the real system, but without real data)

The core of the EPC database which is the independent control system is shown in the figure below.

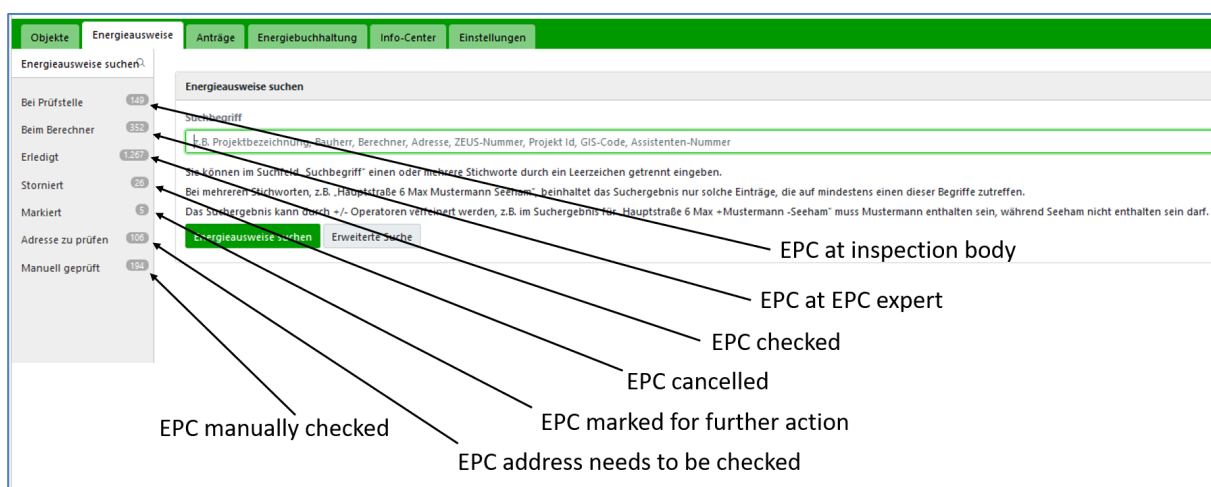


Figure 4. Energy Performance Certificates – core of the EPC database - workflow independent control system

It is important to note that the identity of the EPC is linked with the building, and not with the EPC assessor. This allows for versioning EPCs (all historical EPCs that were issued over time are available) and allocating other relevant building data to the identity. This is a prerequisite for the further development of part of the EPC database into a building logbook.

A simple database export from ZEUS without repeating elements such as information related with windows contains 356 variables from which the ones relevant for TBS can be seen in the tables below. It is noted that the EPC database export contains all EPC versions based on the EPBD 2002, 2010, and 2018, and the related transposition at national and regional levels. Data fields have changed, and data fields have been added, resulting in incomplete EPC records when compared to the latest EPC version transposing the amending Directive (EU) 2018/844.

BACS information is not yet sufficiently covered. There is information available such as heating operating mode modulating or not, heat output control, partial load control, night setback, week-end setback, and operating times, which are related with BACS functions. However, currently, there is no direct link with the BAC classes as presented in Tables 1 to 4.

In addition to the technical building systems presented below, the database contains information about ventilation systems and electricity storage systems. Information on lighting and cooling systems is only available for non-residential buildings.

Note regarding the tables below: The naming of the variables with unit in the ZEUS database and data analysis algorithm is “variable [unit]” e.g. “Bruttogrundfläche [m²]”. For better reading the naming of the variables has been changed in this document by separating the unit from the variable.

Table 8. Variables that apply to each building

Variable	English description	Data type	Unit
Typ	Construction status completed (new buildings and renovations)	category	
Uploaddatum	Upload date of EPC	datetime	
Letztgültiger EA (entspricht umgesetzten Gebäude)	Last valid EPC	boolean	
Ganzes Gebäude	Whole building	boolean	
Nutzungsprofil	Usage profile (residential, non-residential; categories within residential and non-residential)	category	
Nutzungseinheiten im Energieausweis	Number of building units in the EPC	numeric	
Baujahr	Year of construction	numeric	
Bauweise	Construction method (building constructive typology)	category	
Klimaregion	Climatic region	category	
Heizgradtage 20/12	Heating degree days	numerical	kd
Heizungstyp	Heating type space heating	category	
Energieträger	Energy carrier space heating	category	
Art der Warmwasserbereitung	Water heating centralised or decentralised	category	
Typ.2	Water heating separate or combined with space heating	category	
HWB Standortklima spezifisch	Heating energy need site climate specific	numeric	kWh/m ² a
Warmwasserwärmebedarf Standortklima spezifisch	Hot water heating energy need site climate specific	numeric	kWh/m ² a
Heizenergiebedarf Standortklima spezifisch	Heating energy use site climate specific (space heating + hot water + conversion losses; final energy indicator for heating)	numeric	kWh/m ² a
Energieaufwandszahl Heizen	Energy expenditure number heating (efficiency of the heating system; indicator for conversion loss)	numeric	

Endenergiebedarf Standortklima spezifisch	Final energy use site climate specific (heating + other uses)	numeric	kWh/m ² a
Primärenergiebedarf nicht erneuerbar Standortklima spezifisch	Primary energy use non-renewable site climate specific	numeric	kWh/m ² a
Primärenergiebedarf erneuerbar Standortklima spezifisch	Primary energy use renewable site climate specific	numeric	kWh/m ² a
Mittlerer U-Wert	Average U-value (Mean thermal transmittance of the total/opaque/transparent building envelope)	numeric	W/m ² K
Kompaktheit	Compactness	numeric	1/m
Bruttovolumen konditioniert	Gross volume conditioned (Thermally heated/cooled)	numeric	m ³
Gebäudehüllfläche	Thermal building envelope area	numeric	m ²
Bruttogrundfläche	Gross floor area	numeric	m ²

Table 9. Variables that apply to a subset of buildings

	Variable	English translation	Data type	Unit
Boiler	NWG: Kühlbedarf Standortklima spezifisch	Non-residential: Cooling need site climate specific	numeric	kWh/m ² a
	NWG: Kühlenergiebedarf Standortklima spezifisch	Non-residential: Cooling energy use site climate specific	numeric	kWh/m ² a
	Nennwärmeleistung	Nominal heat output	numeric	kW
	Wirkungsgrad Vollast	Efficiency full load	numeric	%
	Wirkungsgrad Teillast	Efficiency part load	numeric	%
	Bereitschaftsverlust	Loss of readiness	numeric	%
Heat pump	Typ.1	Type of heat pump	category	
	Betriebsart	Operating mode	category	
	Anlagentyp	Plant type	category	
	Nennleistung beim Normpunkt	Nominal power at standard point	numeric	kW
	Jahresarbeitszahl	Annual performance factor	numeric	
	Leistungszahl	Coefficient Of Performance	numeric	
Solar thermal	Kollektorentyp	Collector type	category	
	Verlustfaktor	Loss factor	numeric	
	Konversionsrate	Conversion rate	numeric	
	Hilfsenergie	Auxiliary energy	numeric	W
Photo-voltaic	Typ.4	Photovoltaic type	category	
	Kollektorfläche	Collector area	numeric	m ²
	Maximalleistung der gesamten Anlage	Maximum power of the entire plant	numeric	kW
	Wirkungsgrad	Efficiency	numeric	%
	PV-Export Standortklima zonenbezogen	PV export site climate zonal	numeric	kWh/a
	PV-Export Standortklima spezifisch	PV export site climate specific	numeric	kWh/m ² a

Building logbook

The ZEUS building logbook is represented by the building account (“my ZEUS”) as part of the EPC database environment. It is owned by the building owner who can store all relevant building data and can make this information accessible to third parties, as shown in the Figure below.

In the future, the SRI assessment could be uploaded, and automatic checks could be performed with selected EPC indicators. This would be the basis for linking the SRI assessment with the EPC status.

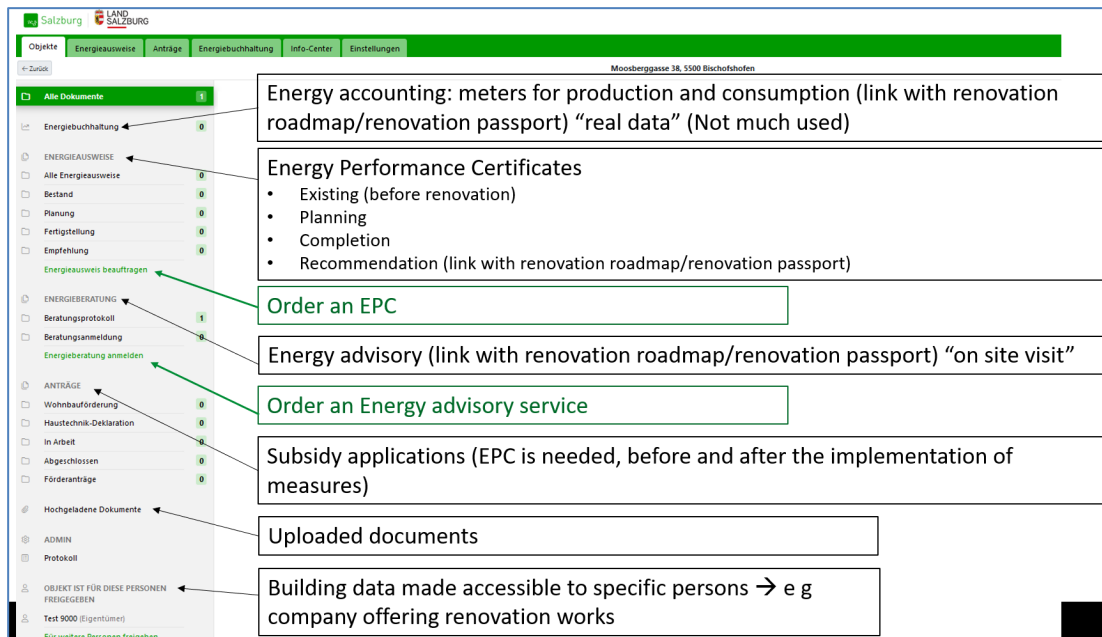


Figure 5. Current functions of the ZEUS building logbook which is represented by the building account ("my ZEUS") as part of the EPC database environment

4.1.3 Conclusions for linking SRI assessment with EPC status

Ideally, the SRI assessment results in a detailed description of the technical building systems according to technical domains and including BACS functionality levels. This would add value because currently the technical energy model documentation produced as part of the EPC calculation process usually focuses on geometry, building orientation, and building materials rather than on details of the technical building systems. Nevertheless, data fields on technical building systems are available in the EPC database, as demonstrated in the previous chapter. However, in practice, many data fields are empty because the simplified approach for calculating the EPC was used, especially for EPCs done for selling or renting a building or a building unit.

It is also important to note:

- that the EPC database only covers data fields that are mandatory for the respective building type (residential or non-residential); that means, even if a residential building is equipped with an active cooling system, technical information would not appear in the EPC database because active cooling is not part of the calculation method for residential buildings;
- that data fields have changed over time due to updates of the legal framework.

The building logbook (building account "my ZEUS") as part of the EPC database environment could have a central role in linking SRI assessment results with the EPC status. The building owner would grant access to the SRI assessor who would see the EPC versions and all other building related data stored in the building logbook database and could make use of this information.

Currently, the SRI assessment report could be uploaded into the database as a PDF file. The database could be further developed in a way that standardized SRI assessment reports can be uploaded via XML interface. Then automatic checks can be implemented that link specific information from the SRI assessment report with specific information in the EPC, for example the rating result and selected indicators.

Recommendations which are created as a result of the SRI assessment should be stored in the building logbook, to be taken into account in the next version of the EPC and for the creation of a renovation passport.

4.2 Cyprus

4.2.1 Availability of EPCs

The Energy Performance Certificate (EPC) was introduced in the Cypriot legislation by the Ministry of Energy, Commerce, and Industry in 2012 [29]. According to the regulations, the owner of the building or building unit is responsible for issuing an Energy Performance Certificate for:

- Buildings or building blocks under construction;
- Buildings or building blocks intended for sale;
- Buildings or building blocks made available for rent;
- Buildings in which the total effective surface area of more than two hundred and fifty square meters is used by a public authority and which is frequently visited by the public.

The EPC for a building includes the energy performance of the building (EPB) and reference values, such as minimum energy performance requirements for a building, to enable the owners or tenants of the building to compare and assess the energy performance. Furthermore, it provides recommendations for the optimal cost or cost-effective improvement of the EPB.

The EPCs provide an indication of how the owner or tenant can obtain more detailed information, in terms of cost-effectiveness, regarding the recommendations it contains. The cost-effectiveness assessment is based on several standard assumptions, such as the estimated energy savings, baseline energy prices, and a preliminary cost assessment. In addition, it includes information on the necessary measures to be adopted for the implementation of the recommendations.

The procedure for issuing the EPC for a building is carried out in an independent manner and issued by qualified energy auditors. The EPC for a building holds a validity period of up to ten years. The regulatory authority is responsible for maintaining a comprehensive registry of EPCs for buildings. The EPC databases are designed to enable the systematic collection of data regarding the measured or calculated energy consumption of specific buildings. This data collection includes, at a minimum, public building for which an EPC has been officially issued.

4.2.2 Process of developing, issuing and storing an EPC

The EPC is issued according to the Methodology of Energy Performance of Buildings (MEPB) defined in accordance with the Government Decree “ΚΔΠ 33/2015”. The scope of MEPB is to provide a detailed record of the procedures used to calculate the energy performance of buildings using the SBEMcy application software and the iSBEMcy interaction interface [30].

EPC Software-SBEMcy

The Energy Agency assigned Infotrend Innovations/BRE to develop a software tool for calculating the MEPB. The SBEMcy (Simplified Building Energy Model cy) is the tool used for MEPB calculations and EPC generation for both residential and non-residential buildings. The SBEMcy includes:

- the SBEM, which is the main calculation engine
- the iSBEM, the user interface based on Microsoft Access
- standard databases
- standardized format for reporting results.

According to the provisions of Cyprus legislation 142/2006, the SBEM tool is available free of charge to specialized auditors issuing Energy Performance Certificates (EPCs). The Energy Agency may accept alternative software and alternative interfaces. At this stage (December, 2023) there is an additional tool which is approved by the Energy Agency and available at cost, ECO-Engine (<https://www.modecsoft.com/site/eco-engine/>). The tool implements its calculations based on the SBEMcy calculation engine. In formulating the MEPB, CEN European standards were adopted, to the extent that they were feasible.

SBEMcy-General Overview

SBEMcy receives input values from the user and the various databases and by calculation, produces and presents the result in terms of primary energy derived from the energy used by the building and its users. SBEMcy calculates the energy requirements of each space within the building based on the activities conducted within it. Different activities may involve varying temperatures, operating periods, lighting levels, etc. Also, SBEMcy computes the energy needs for heating and cooling by achieving the energy balance, considering monthly average climatic conditions. This is combined with information about system performance to determine energy consumption. Additionally, the energy used for lighting and domestic hot water is also calculated.

SBEMcy-Data Inputs

The SBEMcy input data include:

- Geometry: physical layout of various spaces within the building.
- Space Utilization: Internal comfort conditions that need to be maintained in each activity zone (designated areas where recognized, standardized activities take place)
- Meteorological data: External weather conditions
- Building Envelope Thermal Insulation: Factors influencing heat losses from the building envelope and ventilation, including insulation levels and intentional natural ventilation
- Internal Thermal Gains: Anticipated heat gains determined by the building's use, installed equipment (including lighting and information technologies), and solar heat gains based on window area, thermal mass, geometry, and orientation.
- Efficiency of Technical Systems: Information regarding heating, cooling, lighting, and other building systems (efficiency of technical systems).

SBEMcy-Data Outputs

The SBEMcy output data include:

- Comparison of the Primary Energy of the actual building and the reference building to determine the energy category based on the relative performance of the proposed building
- Verification of compliance with specific parameters derived from the input data in the iSBEM.

The final reports are prepared in a standardized format to provide:

1. Comparison of primary energy between the actual building and the reference building
2. Confirmation of compliance for individual elements.

Intermediate results generated by the SBEM are available in electronic format for diagnostic purposes including:

1. Visualization of input data for calculations
2. Monthly representation of energy consumption for each type of end use and fuel type
3. Overall consumption of electrical and fossil fuels, along with carbon dioxide emissions.

Characteristics of issuing an EPC for new buildings and for existing buildings

EPCs for new buildings are issued through the SBEMcy software, while for existing buildings a more simplified Guide, approved by the Ministry of Energy, Commerce, and Industry is employed, in combination with the software program. The Guide provides valuable advice on the certification method and outlines the process of on-site data collection and evaluation (Figure 7) [31].

SBEMcy-Database

MEPB requires the adaptation of activity definitions for a building by selection from a set of standardized activities, which encompass both building types (29 in total) and types of spaces within a building (64 in total). The software divides the building into several zones, each potentially having different internal conditions or usage durations. This feature allows for a more detailed calculation of energy consumption, particularly in cases where a building serves multiple purposes. To ensure consistency in comparisons between similar buildings, a set of parameters for each activity space remains constant for each activity and building type, eliminating user discretion in this regard.

The parameters obtained from the databases are as follows:

- Frequency of use and related internal gains
- Defined temperatures for heating, cooling, and humidity levels
- Lighting levels
- Ventilation levels
- Gains from equipment
- Internal gains of humidity in the case of bathrooms and kitchens
- Domestic hot water usage requirements

For the above, the duration for which all the mentioned parameters are maintained at constant levels is determined, as well as defined levels when the systems are not in use.

The data are sourced from reliable references such as CIBSE recommendations and are supplemented and modified where necessary to cover activity spaces not included in these sources. These data are utilized in calculations for both, the proposed building and the reference building. The use of standardized databases is aimed at ensuring that comparisons with reference buildings and other structures are made on the basis of a standardized foundation. Therefore, primary energy and CO₂ emissions calculations should not be considered predictions for the actual use of the building.

Interface options in SBEMcy

SBEMcy requires data to be presented in a standardized format through the input interface. The iSBEM is tasked with fulfilling the role of the default interface. The input section of iSBEM acts as an interface for interaction between the user and the SBEMcy calculation. The user is guided to the appropriate databases mentioned above, and the input section is configured to correctly present the data for calculation and compliance checks. An illustrative diagram of this process is presented in Figure 6 [30].

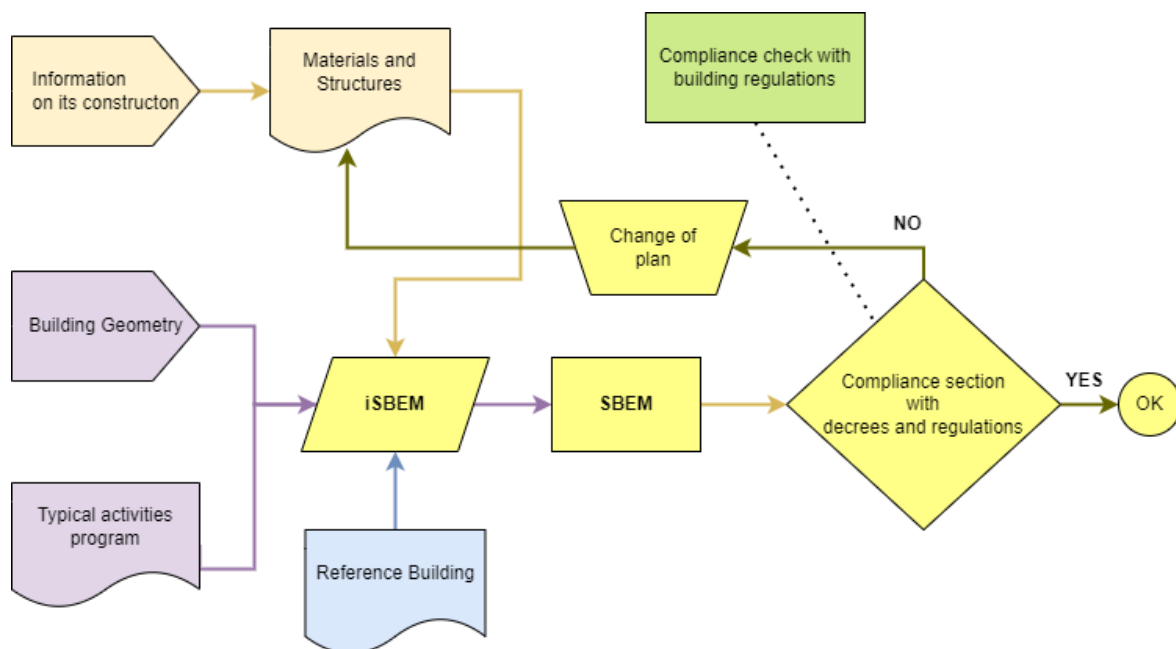


Figure 6. Inputs, calculations, and comparisons arising from the compliance check with building decrees and regulations in SBEMcy

4.2.3 Conclusions for linking SRI assessment with EPC status

In Cyprus, the Energy Performance Certificate is a crucial element in the building permit process, particularly for new constructions and those available for rent or sale. However, building renovations may not always require an EPC. SRI assessments, which go beyond energy efficiency to address grid flexibility, health, and comfort, may be performed for buildings without EPC. Linking SRI assessment with EPC status involves addressing essential aspects such as ensuring qualified experts with trusted certificates and promoting the reuse of information to prevent redundant data collection.

Integrating SRI assessment results with EPC status requires storing assessment reports and EPCs in the same location, ideally in a building logbook. While challenges exist, such as empty data fields in the EPC database, leveraging the building logbook environment could facilitate the linkage between SRI assessments and EPCs.

Efforts to link SRI assessment with EPC status in Cyprus involve considerations for expert qualifications, data consistency, and technological integration. The creation of a building logbook emerges as a key tool, providing shared space for SRI assessment reports and EPCs. The potential for standardized SRI assessment reports to be uploaded and linked with specific EPC data fields through automatic checks holds promise for enhancing the coexistence of these assessments. Recommendations from SRI assessments, stored in the building logbook, can contribute to future EPC versions and the creation of a renovation passport.

In conclusion, the integration of SRI with the EPC status in Cyprus involves overcoming challenges related to data consistency, expert collaboration, and technological solutions. Leveraging existing platforms, such as the SBEMcy by integrating a building logbook, and exploring interfaces like XML could streamline the process. A systematic approach, ensuring the secure storage and accessibility of assessment reports and certificates, is essential for achieving meaningful insights and recommendations for energy-efficient building practices.

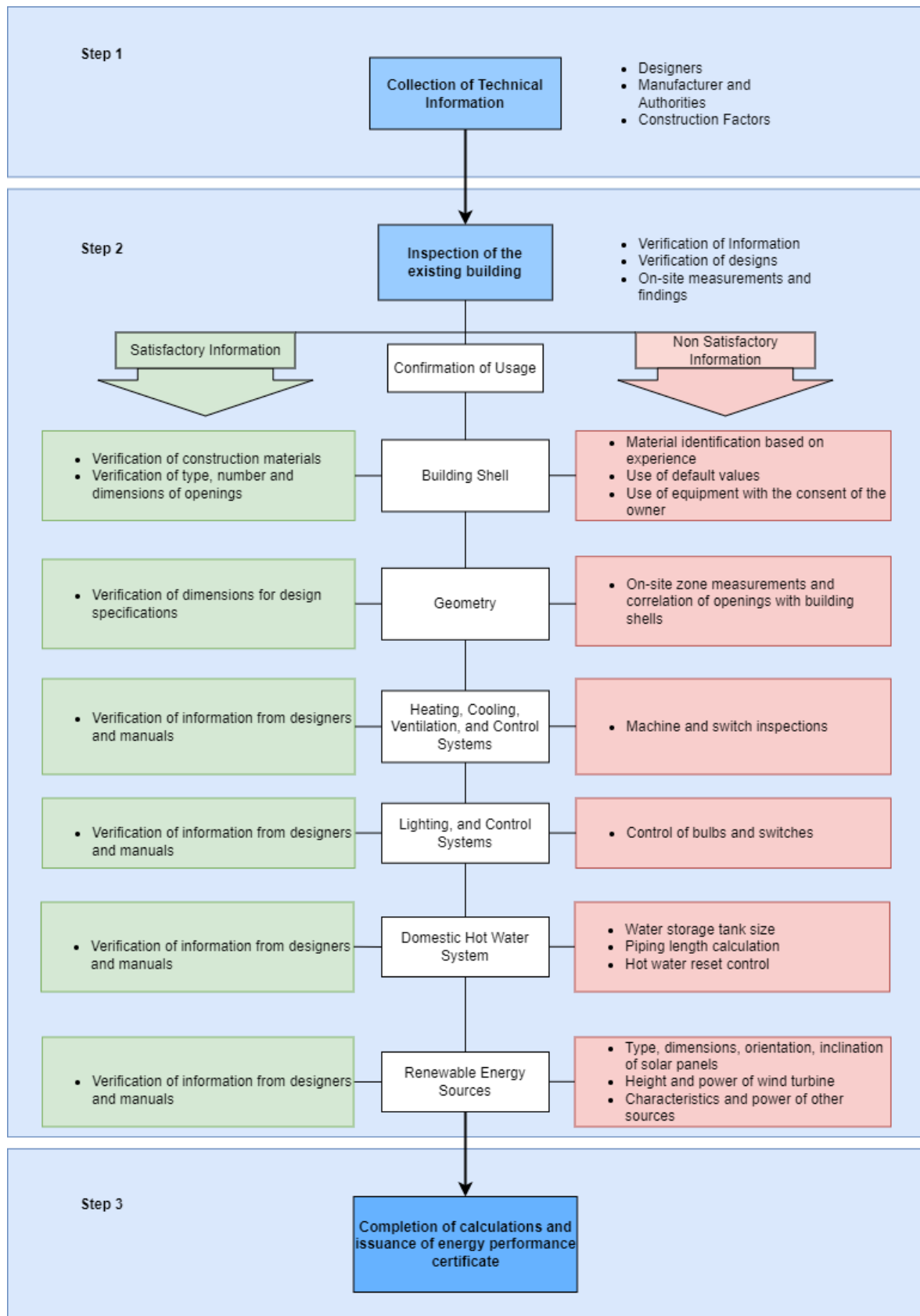


Figure 7. Diagrammatic Presentation of the Energy Performance Certification Process for Existing Buildings

4.3 Greece

4.3.1 Availability of EPCs

The Energy Performance Certificate (EPC) has been introduced in the Greek legislation in 2010 [32], and from 2011 all new buildings or building units as well as existing buildings which have undertaken a major renovation must own one for selling or renting purposes. It applies to all building types, residential and non-residential, except for some building types mentioned in the EPBD. They must be given in building owners and tenants, and energy auditors must keep records of their production. It is also obligatory by Law to state the energy class of the building in case of advertisements for selling or renting properties in real estate magazines/sites/newsletters. Additionally, in the case of renting a house or building, the owner must declare the EPC code number in the Tax Office. EPCs were greatly supported by numerous national subsidy programs for energy renovations in buildings which required the owner to issue an EPC before the energy renovation measures and a second one after the completion of the renovation process.

All public buildings are required to issue an EPC and display it in areas of the building visited by the public. This process is still ongoing, and that's why numerous national programs providing financial incentives for the energy renovation of public buildings have been launched. One of the eligibility criteria was to have an EPC before the implementation of the renovation measures.

EPC assessment methodology uses calculations following the EPB standards, and it is the same for all building typologies, new and existing ones. Energy consumption data, although they can be documented in the EPC (optional), do not take part in the calculation procedure. Actual energy consumption data are only required in some late national subsidy programs for non-residential public buildings and just for statistical purposes.

The EPCs are valid for ten years. Only in case the building undergoes a major renovation, a new certificate is issued before the end of the official period.

EPCs are issued by energy auditors who must use the official web platform (www.buildingcert.gr) to upload all required information about the building or building unit and its TBS, produce an .xml file, calculate the energy consumption, and issue the EPC in .pdf format. The web platform is a database of all issued EPCs and the registry of energy auditors (see Figure 8). It is operated by the General Directorate of the Inspectors & Auditors Body of the Ministry of Environment and Energy which is responsible for the control, maintenance and quality check of the issued EPCs. Every year, a detailed report is prepared for the yearly and total EPCs issued, covering aspects like energy classes, building use, age, geographical area, reason for issuance, etc.

Until the end of 2021 a total of 2,181,692 EPCs had been issued, of which 81.7% refer to residential buildings and 18.3% to tertiary sector buildings. The great majority of EPCs refers to buildings constructed before 2009 (99.1%). The largest percentage of EPCs (62%) covers the worse energy categories (E to H), 34.4% the categories C, D, and only 3.6% the more energy efficient categories A-B [33].

4.3.2 Process of developing, issuing and storing an EPC

EPCs are issued for a building or a building unit. In multifamily buildings an EPC can be issued for either the whole building or separate apartments. EPC calculations are carried out by the use of the official state software TEE KENAK. Several commercial software products are also used but must be officially approved by the ministry of Environment and Energy.

EPC software develops an energy model and calculates the energy consumption and the energy classification of a building or building unit following the EPB standards' requirements. It is based on a semi-steady state monthly step method and it is common for all building categories, new and existing ones. The energy auditor must input all necessary data and upload the model in the EPC web platform (www.buildingcert.gr) in order to perform the calculations. The data and results of the calculations of the energy performance and the energy rating of the buildings are submitted and exchanged through an open data structure (XML) and application programming interface (API) which are carried out in real time in the buildingcert application. The EPC is issued automatically and can be downloaded in .pdf format, and the model is stored in the EPC registry.

Figure 8. EPC's buildingcert platform

The same software (with some slight modifications from the first version) is used to calculate nZEB buildings, and the level of BACS details has not changed over the years.

Some automation controls are input requirements in the current energy software such as the existence of presence detectors, light detectors, automatic control systems for the production of hot water, but only as a tick option. Additional data regarding these systems would be beneficial for the calculations and the energy conservation potential.

SRI and additional BACS use have been introduced in the legislation by adopting amending Directive (EU) 2018/844 [34], but no adjustments have taken place in the software in order to have more data about their functionality.

Currently, BACS are taken into account by using the methodology and categories first introduced in EN 15232 standard and require specific automation and control functionalities for residential and non-residential buildings for every category (A, B, C, and D) [34]. However, no detailed information about these systems is required which could be linked with the SRI.

Moreover, user behaviour is taken into account by the use of predefined values according to the building category and not in a more detailed approach.

Every EPC is stored in the web platform of the Ministry which is controlled by the Inspectors & Auditors Body and it's the only with access to the EPCs database. Energy auditors have access only to the energy audits they have carried out. Data regarding the EPCs can be available to interested parties only after an official request and under specific terms.

4.3.3 Conclusions for linking SRI assessment with EPC status

The information stored in a building energy audit can be linked with the SRI assessment procedure and support their co-existence by contributing more details for TBS functionality options, operation, and contribution in final energy performance. To do so, a detailed description of the TBS must be provided so the SRI assessor is able to quantify the contribution of every BAC system.

Currently, the following TBS details can be determined and stored in the EPC database for a heating system:

- Heating system type
- Energy used
- Total power (kW)
- System efficiency (%)
- Period of use (months)
- Distribution network - type
- Distribution network system power (kW)
- Distribution network efficiency (%)
- Distribution network – insulation existence
- Terminal heating unit – type
- Terminal heating unit efficiency (%)

General control information collected:

- Automation and control category (4 categories), separately for Heating and Cooling purposes
- Existence of presence detectors
- Existence of light detectors
- Automatic control systems for the production of hot water (for residential buildings only)

In Greece, a well-developed scheme for energy inspection of heating systems and Air-conditioning systems is in use, which may be beneficial for linking EPC's and the SRI indicator. During the inspection of these systems, a large number of information is collected by the assessors and a detailed report is prepared which covers the following aspects:

- General info about the building
- General info about the building systems
- Technical info about the boiler/ air conditioning units
- Technical info about the distribution system
- Technical info about the heating terminal units and mechanical ventilation systems
- Measurements – calculations from maintenance sheets
- Information regarding the Control systems
- Findings regarding the current state of the system(s)
- Conclusions / Recommendations

In the Control Systems section, information regarding the automation and control systems is gathered as shown in Figure 9). These data are stored in the same database where the EPCs model is developed in the web platform buildingcert, but no connection between the two assessment procedures has been carried out yet. However, an SRI assessment can take advantage of the existing platform for inspections.

9. Characteristics of Control Systems (for each system)				
System ID: _____				
Central control - regulation system:	Timer - Compensation system - BEMS - Other: _____			
System of control - regulation of individual branches of the network:	Simple touch on/off switch	-		
	Timer	-		
	Electromechanical room thermostat	-		
	Electronic room thermostat Digital room thermostat	-		
	With external air temperature sensor With compensation and digital room sensor Other:	-		
	_____	-		
	_____	-		
Thermostat in each thermal zone	Electromechanical central room thermostat	-		
	Electronic central room thermostat Digital central room thermostat	-		
	With compensation and digital room sensor With thermostatic heads on the radiators (control per room)	-		
	With thermostats on the fan coils (control per room)	-		
	Timer	-		
	Other: _____	-		
	_____	-		
Correct thermostat position		-		
Correct thermostat setting		-		
Regulating valves in T.M.		-		
Triodes - Analogue - On/off -		-		
Operating instructions for individual control systems		-		
10. Final diagnosis				
Based on the energy efficiency of the air conditioning system:				
	Bad	Moderate	Good	Very good

Figure 9. Sample of collected information in an Inspection report

The whole SRI assessment could be developed as an extension of the current EPC web platform and all input data directly connected with the information needed for the EPC calculations.

The SRI report should be easily uploaded in the EPC database and downloaded in a .pdf format.

Recommendations from the SRI assessment should be available taking into consideration the recommendations from the EP certificate and the ones from the Inspection report of the technical systems, if available. Attention should be given in order to combine the recommendations in the best possible way, proving hierarchy and staged steps, which could be used in a digital renovation passport of buildings.

5 Procedure of linking the SRI assessment with the EPC status

The deliverable closes with a chapter on the determination of a procedure, that every time an SRI assessment is offered, this will be linked with an EPC status. This can be done through the digital building logbook if existent, or manually in the SRI assessment report by means of a respective note.

The following EPC status characteristics are possible:

- No EPC available
 - No building information on TBS available
 - Detailed building data collection on TBS (as built) available
 - Operational data collection by TBS available
 - Energy model available
- EPC available
- EPC available but no detailed data collection (EPC based on default values)

Depending on the EPC status, SRI assessment will make use of the existing information generated during energy performance certification, or contribute information for the EPC.

5.1 Basic specifications

The SRI assessment report needs to include a reference to the EPC of the assessed building. This can be done in various ways, depending on the specific situation in the Member States:

- EPC is collected from the building owner during SRI assessment
- EPC identity is retrieved from a public EPC database
- EPC is identified through access to the building logbook

It is important that the identity of the EPC is connected with the building and not with the EPC assessor. This is the precondition to follow-up with the changes in the building over time which are also reflected in the different versions of the EPC issued at a certain point in time.

5.2 EPC database and building logbook

The EPC database can provide valuable information as input into the SRI assessment, and the SRI assessment can generate information that should be taken into account in the recommendations section of the EPC. However, the condition is that SRI assessment report and the energy performance certificates are stored at least in the same place. The same applies to other relevant documents such as the renovation roadmap, the inspection report, and the energy audit report. It is also possible that an SRI assessment is requested for a building where no EPC exists.

Thus, the exchange and reuse of data is necessary, and the building logbook envisaged by the Commission proposal for the recast EPBD is ideal for this purpose.

The EPC database is not necessarily suitable as building logbook to support SRI assessment because the EPC only covers data fields that are mandatory for the respective building type (residential or non-residential); that means, even if a residential building is equipped with an active cooling system, technical information would not appear in the EPC database because active cooling is not part of the calculation method for residential buildings (Austrian example). Also, inspection of HVAC TBS results in more information than contained in the EPC, and the same applies to the renovation passport, the SRI assessment, and energy audit report according to EED. However, it is possible to extend the existing EPC database with various functions and to further develop it to the new building logbook.

Therefore, it is suggested to create a “backbone section” in the new building logbook, a basic structure with standardized data fields, with key information that can be entered according to a specific format and that can be retrieved according to a specific format (data input – assessment – report).

The data contained in this basic structure should be authorized by an authority to allow for multiple uses and to avoid liability and ownership issues for experts that currently prevent them from using data collected by other experts.

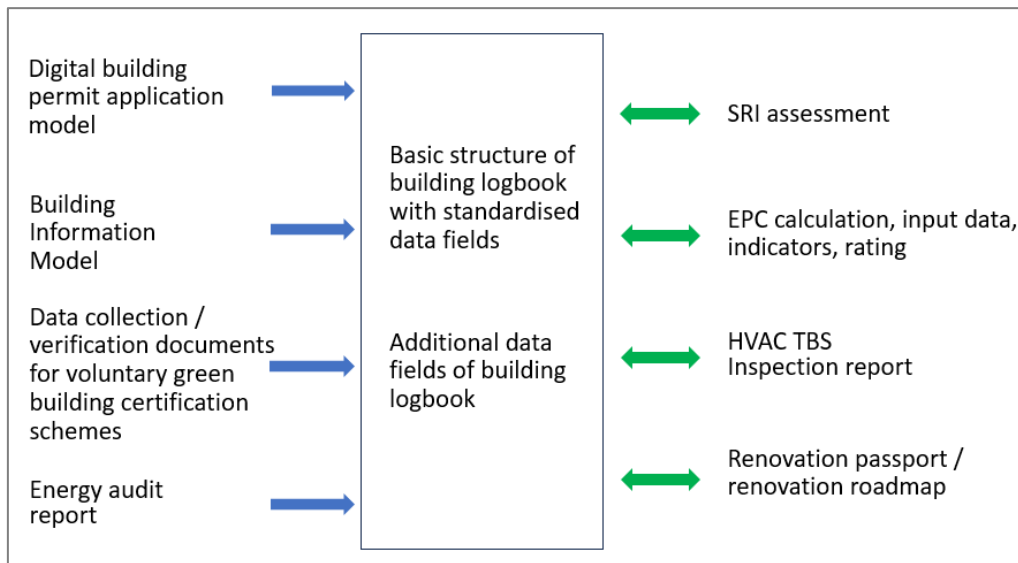


Figure 10. Concept of building logbook with standardized data fields, and data sources

5.3 Data collection, indicators and recommendations

The following tables refer to the stages of data collection, calculation of indicators and development of recommendations not only regarding EPC but also other instruments given by the EPBD, namely HVAC TBS inspection and the Renovation passport. In this context, it will be important that the checklists provided by the easySRI platform also offer the option of documenting quantitative information such as the installed capacity of systems. Related possible functions of the easySRI platform include service options (blue) where content is provided, and support options (orange), where data can be retrieved from the EPC database or building logbook or can be entered manually if the data do not exist in the EPC database or building logbook.

Information about the EPC calculation method, input data for EPC calculation, interim results, indicators, reference values and rating can be important for narrowing down easySRI platform options to those being most useful for the specific case. Furthermore, this information will be useful for integrating alert functions into the easySRI platform, for example for which buildings an SRI assessment should be recommended.

Table 10. Overview of information generated by energy performance certification and possible functions of the easySRI platform

Information generated by energy performance certification		Possible functions of easySRI platform
1.	On-site visit and data collection	
1.1	Primary data collection	Provide checklist / material according to SRI service catalogue and EN ISO 52120-1:2022, and link to building logbook
1.2	Verification of available data	
2.	EPC calculation method	
2.1	Impact of BAC considered in method: yes or no	Input of information, or retrieve necessary information from EPC database/building logbook
2.2	Hourly and sub-hourly calculations, or monthly method	
3.	Input data for EPC calculation, interim results	
3.1	BAC information available	Input of information, or retrieve necessary information from EPC database/building logbook (yes or no; and/or qualitative)
3.2	Renewable electricity plant on-site exists	
3.3	Renewable thermal energy plant on-site exists	
3.4	Space heating final energy use [kWh/m2.a]	Input of numbers, or retrieve numbers from EPC database/building logbook
3.5	Space cooling final energy use [kWh/m2.a]	
3.6	Domestic hot water final energy use [kWh/m2.a]	
3.7	Renewable electricity production [kWh/m2.a]	
3.8	Renewable thermal energy production [kWh/m2.a]	
4.	EPC	
4.1	Rating (A-G)	Retrieve from EPC database/building logbook
4.2	nZEB requirement	
4.3	ZEB requirement	
4.4	Reference value minimum energy performance requirement	
4.5	Reference value minimum energy performance standard	
4.6	Reference value nearly zero-energy building requirement	
4.7	Reference value zero-emission building requirement	
4.8	Indicator of energy use [kWh/m2.a] in the EPC	
4.9	Indicator of renewable energy in % of energy use in the EPC	
4.10	Indicator of operational greenhouse gas emissions [kg CO2/m2.year]	
4.11	Recommendations	Provide SRI technical domain related recommendations for improving SRI impact categories

Table 11. Overview of information generated by the inspection of HVAC TBS and possible functions of the easySRI platform

Information generated by the inspection of HVAC TBS		Possible functions of easySRI platform
1.	On-site visit and data collection	
1.1	Primary data collection	Provide checklist/material according to SRI service catalogue and EN ISO 52120-1:2022, and link to building logbook
1.2	Verification of available data	
2.	Inspection reports (heating, cooling, ventilation, AC)	
2.1	System requirements for TBS	Input of information, or retrieve necessary information from building logbook
2.2	Development of recommendations	Provide TBS and BACS related recommendations for improving HVAC TBS impact categories
2.3	Report to verify implementation of recommendations	Provide report for hand-over to owner/tenant

Table 12. Overview of information generated by the Renovation passport and possible functions of the easySRI platform

Information generated by the Renovation passport		Possible functions of easySRI platform
1.	On-site visit and data collection	
1.1	Primary data collection	Provide checklist/material according to SRI service catalogue and EN ISO 52120-1:2022, and link to building logbook
1.2	Verification of available data	
2.	Renovation passport	
2.1	Renovation roadmap	Provide SRI technical domain related recommendations for improving SRI impact categories

6 Conclusions

To summarize, efforts to link the SRI assessment with an EPC status include considerations regarding the qualification of experts, data consistency and technical integration. The establishment of a building logbook is proving to be an important tool that provides a common space for SRI assessment reports and EPCs. The possibility of uploading standardized SRI assessment reports and linking them to specific EPC data fields through automated processes is promising in terms of exploiting synergy potential. Recommendations from SRI assessments stored in the building logbook can contribute to future EPC versions and the creation of a renovation passport including a renovation roadmap.

Linking the SRI assessment to the energy performance of buildings has the potential to address a major shortcoming of current EPC methods, namely the so-called performance gap. This is represented by the discrepancy between the calculated energy use displayed in the EPC, and the actual energy consumption, if BACS are not taken into account in the EPC calculation method. SRI assessment is the basis for the determination of BACS factors that can be used to adjust the rating of the EPC. On the other hand, the EPC could be used to adjust the weighting factors in the SRI assessment. In addition, the SRI assessment produces improvement recommendations that can be used for the EPC recommendations and the renovation passport, leading to better BACS.

Furthermore, this study concludes that standardization plays a key role in the realization of energy savings through building automation and control, and thus in the success of SRI assessment in the area of energy efficiency.

On the one hand, this concerns the components of the automation and control systems and the programming for operation. Safe ICT operation, durability and compatibility of the components with each other (per technical building system and the technical building systems with each other) must be ensured. Only then will the forecasts regarding whole life GWP, energy and cost savings be realistic and safety concerns eliminated. Standardized documentation of the programming of building automation and control systems is crucial for an SRI rating that is trustworthy and reputable on the market.

On the other hand, this concerns the logbook. The benefits of the building logbook will depend on whether and how data fields are standardized for data input from different sources and data export to different uses. Examples include building data models, inspection reports, energy audit reports and renovation schedules.

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