TIMEPAC

Towards Innovative Methods
for Energy Performance Assessment and Certification of Buildings

Deliverable 2.4

Procedures and services for the integration of the SRI and environmental sustainability indicators in existing EPC tools

Transversal Deployment Scenario 4

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Executive Summary

Deliverable 2.4 “Procedures and services for the integration of Smart Readiness Indicator (SRI) and environmental sustainability indicators in existing EPC tools” relates to the work performed in Task 2.4 of the TIMEPAC project “Towards Innovative Methods for Energy Performance Assessment and Certification”. Task 2.4 is part of WP2 “Transversal Deployment Scenarios”, which is aimed at investigating, implementing and delivering advanced and innovative methods and procedures to generate the enhanced energy performance certificate (EPC). This deliverable reports the work carried out in TDS4 “Integration of SRI and sustainability indicators in EPC“, with the main focus on determining the dependency of the information requirements between the SRI, the sustainability indicators and the energy performance calculation; an evaluation of the potential extraction of additional energy and flexibility improvement measures based on the SRI and sustainability indicators; and the identification of common data-collection methods to evaluate the response of target audiences (EPC experts, energy auditors, building owners, building managers and ESCOs). Once again, it has been confirmed that reliability and relevance of the data are of highest importance when calculating the SRI and selected sustainability indicators.

To promote the use of the SRI and sustainability indicators, the TIMEPAC Code of Conduct for Smart Readiness and Sustainability Rating has been created. It represents a set of guidelines, values and principles that are considered fundamental for the successful, professional and transparent calculation of the SRI and selected sustainability indicators. The Code of Conduct is generated based on experiences gained through the implementation of the TDS4 in six countries participating in TIMEPAC. In an international comparison, the results of the TDS4 are reviewed and several common and transnational challenges have been identified. These include the complexity of use, problems with the subjectivity of the auditor and potential problems with the price for the final users. Our experiences confirmed that to make the SRI and the sustainability rating useful, specific and tailored recommendations for performance improvements must be provided to the final user. This means that to be cost-effective, the SRI and the sustainability rating should be combined with energy auditing and energy-performance assessments.

The conducted field work revealed that the competences of the SRI and the sustainability auditors should encompass a diverse range of technical and soft skills, derived from various disciplines. It is clear that a background in mechanical, electrical or civil engineering provides a strong foundation for the SRI and the sustainability auditors. However, a proper combination of technical knowledge, soft skills, and continuous learning is what makes the SRI and the sustainability auditor truly effective in this role. The identified competences will be addressed during the envisioned training activities that are dedicated to the SRI (Training Scenario (TS) 2 and TS6).

From the service provider’s point of view, the SRI and Re-Commissioning (Re-Co) activities can be combined, and this combination has the potential to become an attractive business for engineering or energy service providers. Even though they might give rise to some additional costs, Re-Co services can be carried out successfully and be a cost-effective part of the SRI and the EPC generation process, because they will generate additional benefits for the owners and the building’s users. A cooperation with ESCOs can help in identifying and implementing energy and flexibility solutions based on the SRI findings, and they might operate on performance-based contracts, ensuring real energy and flexibility savings.

The outputs of the analysis carried out in this task will also be used in all the verification scenarios (WP3) to demonstrate the potential of energy-efficiency and flexibility measures that could be identified during the SRI and sustainability rating and tailored to specific use cases and behaviours. Additionally, the outputs of Task 2.4 will be used in four training scenarios (WP4), TS 2 – EPC data collection, validation and exploitation, TS 3 – Advanced methods and tools for the holistic energy renovation of buildings, TS 5 – Evaluation and verification of energy-saving opportunities based on EPC and TS 6 – Operational optimising of a building’s energy performance based on activities during EPC generation.

1 Introduction

1.1 Purpose and target group

According to the European Commission, today's building sector is the largest consumer of energy in the EU. It is responsible for 40 percent of energy consumption and 36 percent of greenhouse-gas emissions. Furthermore, approximately 75 percent of the EU's building stock is energy inefficient. In response, the European Union intervenes through political actions aimed at major renovations and energy requalification. These proposed policy actions include the European Green Deal, the Renovation Wave, and the proposed revision of the Energy Performance of Buildings Directive (EPBD), all aimed at achieving the political and environmental targets set for 2050.

In this perspective, the Energy Performance Certificate (EPC) represents an essential document when identifying which buildings that need to be upgraded, the interventions that need to be performed, and the best methodology to be applied. The project "Towards Innovative Methods for Energy Performance Assessment and Certification of Buildings" (TIMEPAC) aims to identify any failings in the current energy-performance certificates and to improve the current energy-certification processes from a single, static certification to more holistic and dynamic approaches.

The aim of WP2 "Transversal Deployment Scenarios" (TDSs) is to deploy and deliver new methods to implement enhanced EPC schemes, which will then be implemented in the Verification Scenarios to be carried out in WP3. Different partner profiles — certification bodies, software developers and research groups — have been involved in the deployment of these methods, which embrace the technical, scientific, operational, legislative and standardization levels.

WP2 includes five TDSs:

- TDS1 – Generating enhanced EPCs with BIM data,
- TDS2 – Enhancing EPC schemes through operational data integration,
- TDS3 – Creating Building Renovation Passports from data repositories,
- TDS4 – Integration of Smart Readiness Indicator (SRI) and sustainability indicators in the EPC,
- TDS5 – Large-scale statistical analyses of EPC databases.

This deliverable reports the work carried out in TDS4 "Integration of Smart Readiness Indicator and sustainability indicators in EPC", the objectives of which are:

- to determine the dependency of information requirements between the SRI, the sustainability indicators and the energy performance calculation,
- to prepare a framework for the SRI's integration into the EPC, depending on the level of effort and the impact of the rating process,
- to assess the possible extent of the sustainability indicators' integration into the existing EPC schemes,
- to evaluate the potential for the extraction of additional energy and flexibility improvement measures based on the SRI and the sustainability indicators,
- to test the framework and to propose common data-collection methods to evaluate the response of target audiences (EPC experts, energy auditors, building owners, building managers and ESCOs).

The main outcomes of this task are the Report on the technical specification of TDS 4 - Procedures and services for the integration of the SRI and environmental sustainability indicators in existing EPC tools, including guidelines for effective SRI and sustainability auditing, and the TIMEPAC Code of Conduct for Smart Readiness and Sustainability Rating with a focus on providing tailored energy-efficiency and flexibility-improvement measures, including the integration of renewable energy sources and considering the additional workload, the availability and the quality of the data.

For the extraction of the energy-efficiency and flexibility-improvement measures, two scenarios will be considered:

- The building has not been renovated and the energy audit has not been conducted recently; therefore, energy audit must be conducted.
- The building has undergone a major energy renovation, but the focus was on the pure energy efficiency and not on the smartness and flexibility; the energy audit has been conducted and the building's documentation (the as-built documentation) is also available.

1.2 Deliverable structure

The deliverable is organized into seven main sections. Section 1 serves as the introduction, covering the purpose of TDS4 (1.1), the deliverable structure (1.2), the contribution of the TIMEPAC partners (1.3), and the relationships with other project activities (1.4). Section 2 presents the TIMEPAC vision and motivation for the SRI and the sustainability auditing. Section 3 discusses the recent developments and methodology for calculating the SRI and selected sustainability indicators, considering the EPBD recast and existing guidelines. Also, in Section 3 the methodology applied for TDS4 is described. In Section 4, a calculation of the SRI and the sustainability indicators for selected buildings in the partners' countries is presented. Section 5 provides a description of the identified challenges and the international comparison. Section 6 presents the main findings and guidelines for effective SRI and sustainability auditing. Section 7 presents the conclusions and future challenges drawn from the findings and outcomes of TDS4. Finally, Annex A1 contains the TIMEPAC Code of Conduct for Smart Readiness and the Sustainability Rating and Annex A2 provides the SRI and sustainability: case studies.

1.3 Contribution of partners

The JSI was the task leader and the main developer for TDS 4, with contributions from the TIMEPAC consortium. The calculations for the SRI and the sustainability indicators were conducted by SERA (Austria), EIHP (Croatia), CEA and CUT (Cyprus), EDILCLIMA (Italy), GOLEA and JSI (Slovenia) and ICAEN and CYPE (Spain). The remaining consortium members provided the necessary data, such as drawings, audit reports, BIM and BEM models and operational data. The JSI was responsible for compiling the deliverable and creating the Code of Conduct for an effective SRI and sustainability auditing.

1.4 Relationships with other project activities

Task 2.4 aims to explore the main barriers and opportunities for the integration of sustainability and the SRI in existing EPC schemes, considering efforts for data collection (e.g., none, small) and the impact of calculations of the indicators (e.g., partial, overall). The main objective is to propose a solution that integrates the SRI and the selected sustainability indicators with existing EPC mechanisms in each country. This will be tested on residential and public buildings. A preliminary assessment of the sustainability indicators from the Level(s) framework revealed that several of them have the potential to add value to the enhanced EPC we are envisioning in TIMEPAC, in particular the use stage energy performance, the time outside the thermal comfort range, the lifecycle costs and the lifecycle global warming potential. A schematic representation of TDS 4 is given in Figure 1.

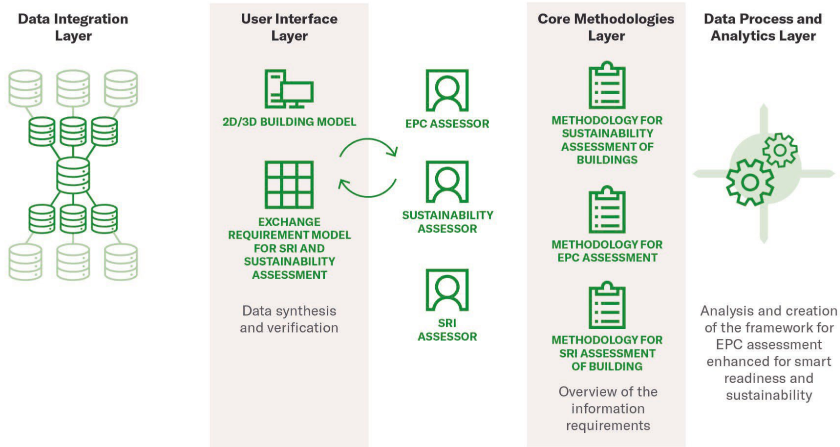

Figure 1. Schematic representation of TDS 4

The work in this task builds on the analysis carried out in Task 1.1 “EPC generation” and Task 1.5 “EPC workflow applicable at the European level”. Also, Task 2.4 has connections to other tasks in WP2, as follows:

- Generating enhanced EPCs with BIM data (Task 2.1). This task is not directly related to Task 2.4, but it was essential input for the creations of BEMs in Task 2.2. BIM tools provide a comprehensive, digital representation of the physical and functional characteristics of a building. They enable better coordination among all the stakeholders, reducing errors and miscommunications that could lead to wasteful practices.
- Enhancing EPC schemes through operational data integration (Task 2.2). BEMs that are created for the selected buildings in the framework of Task 2.2 are used to calculate selected sustainability indicators and to determine the energy performance of a building before and after the implementation of the proposed energy-efficiency and flexibility measures. The measures that are analysed in Task 2.2 are subsequently used to create the optimal scenario for the major renovation of the selected buildings in Task 2.3 (Renovation Passports).
- Creating Renovation Passports (RPs) from data repositories (Task 2.3). Measures that are used for the creation of the initial version of the RP are re-examined in the framework of Task 2.4 and enriched with the smart and flexibility components. These measures are used to calculate the SRI and selected sustainability indicators before and after the major energy renovation of the selected buildings. Before providing any recommendation, the SRI and the sustainability auditor always consider all the aspects of the building's energy use, including heating, cooling, lighting, and equipment.
- Large-scale statistical analysis of EPC databases (Task 2.5). This task is not directly related to Task 2.4, but it was very important for understanding the accuracy and relevance of the data collected during the SRI and the sustainability-rating process.

The outputs of the analysis carried out in this task will also be used in all the verification scenarios (WP3) to demonstrate the potential of the energy-efficiency and flexibility measures that are identified during the SRI and the sustainability rating and tailored to specific use cases and behaviours. Additionally, the outputs of Task 2.4 will be used in four training scenarios (WP4), TS 2 – EPC data collection, validation and exploitation, TS 3 – Advanced methods and tools for holistic energy renovation of buildings, TS 5 – Evaluation and verification of energy-saving opportunities based on EPC and TS 6 – Operational optimising of a building’s energy performance based on activities during EPC generation.

2 TIMEPAC vision and motivation

The TIMEPAC project is centred around a new holistic approach to Energy Performance Certification that covers every stage of the certification process, including generation, storage, analysis and exploitation. According to the survey conducted in the framework of Task 1.1 "EPC generation", current EPCs are incapable of providing the end-user with simplified and reliable information about the energy performance of a building. One of the goals of the TIMEPAC project is to examine the EPC practices and tools in six of the participating TIMEPAC countries (Austria, Croatia, Cyprus, Italy, Slovenia, and Spain) and propose effective measures to enhance the EPCs in a holistic and cost-effective manner, supported by a new set of different and dynamic data and tools.

TIMEPAC anticipates that new indicators, in combination with real consumption data, will allow a more accurate reflection of a building's energy efficiency as they consider the actual usage patterns, unlike static or older data which might be based on assumptions or outdated usage patterns. Also, dynamic data can optimize the energy usage of a building more effectively. For instance, it can be used to identify patterns and peak periods of energy consumption, thus facilitating more efficient energy use. This is especially important for identifying potential energy-flexibility measures.

There is a global shift towards more stringent energy-efficiency standards and regulations for buildings. Modern approaches like Building Information Modelling (BIM) and Building Energy Modelling (BEM) can play a crucial role in creating tailored and implementation-oriented EPCs. BIM/BEM models help generate accurate building simulations, providing more detailed information about a building’s energy performance. To ensure compliance, it is important to use the most accurate data and modelling techniques. The energy performance of buildings can change over time due to several factors, such as aging of the infrastructure, changes in occupancy patterns, and advances in technology. BIM/BEM can assess the impact of different energy-efficiency measures, identify the best opportunities for energy savings, and even predict future energy consumption based on different scenarios. Additionally, these tools are essential for calculating the sustainability indicators associated with different renovation options, which is critical for selecting an appropriate comprehensive energy-renovation scenario. Thus, using the most recent and relevant data and tools will have crucial role in keeping the EPCs up to date and relevant.

An improved accuracy in EPCs makes them more appealing for building owners, occupants, and energy professionals (ESCOs, facility and energy managers, auditors, designers). For example, a more accurate EPC can help building owners target their investments in improvements that will have the highest impact on energy efficiency, thus maximizing the return on investment.

In the framework of TDS4, the combination of the Smart Readiness Indicator (SRI) and the use of modern modelling techniques for creating sustainability indicators will be examined. The applicability of the SRI and the sustainability indicators will be assessed through a broad set of well-targeted and realistic cases, featuring various locations, building types and climatic conditions. It is expected that all these activities will result in the identification of tailored and building-specific energy-efficiency and flexibility measures. This represents a significant step forward in the accuracy and usefulness of these certificates. In TDS4, TIMEPAC's vision and motivation are to examine the following two improvement points and challenges related to the enhancement of EPCs and the implementation of a continuous flow of data through the four stages of the EPC cycle (i.e., generation, storage, analysis, and exploitation):

- Data integration from various sources for more effective EPCs by considering the building as a whole;
- EPC enhancement with a Smart Readiness Indicator and sustainability indicators to accelerate the creation of reliable, smart and sustainable renovation plans.

TIMEPAC’s consortium members are fully aware that enhancing the EPC in terms of using operational data brings the EPC-generation process much closer to an energy audit, which can be costly for the final user. On the other hand, if the energy audit is already conducted, it represents a valuable source of information for the EPC certifier. Real operational data and findings from the energy audit are essential for the calibration of energy models and make them a very useful tool for predicting future energy consumption. In the context of generating and enhancing EPCs with the implementation of a continuous workflow, the main challenge is how to incorporate all these positive elements of the identified approaches without making the EPC-generation process too complex and costly for the final users. All this brings us to the critical point for the future development of the EPC. i.e., the interoperability between different databases (e.g., cadastre database, geographical database, EPC database, thermal energy plant register, statistical database, operational data and utility database). Current practices, where building-related data are used only for single/dedicated purposes, are unsustainable and cannot result in an enhanced EPC. It is crucial to enable the interoperability between existing databases, previously developed models (like BIM or BEM), and past energy-audit reports. This information should be accessible to building professionals (such as energy and facility managers, energy performance certifiers, designers, etc.) in a way that allows the new EPC to build upon previous data. This approach is the only way to achieve cost-effectiveness for the client. Understanding past performance is vital for identifying tailored and building-specific measures to improve both energy efficiency and flexibility. This approach is in line with the current EPBD-recast proposal and the recognised need to create the Digital Building Logbook (DLB) that aggregates all the relevant data about a building and ensures that authorised people can access accurate information relating to a particular building (European Commission, 2023a). The Digital Building Logbook is depicted in Figure 2.

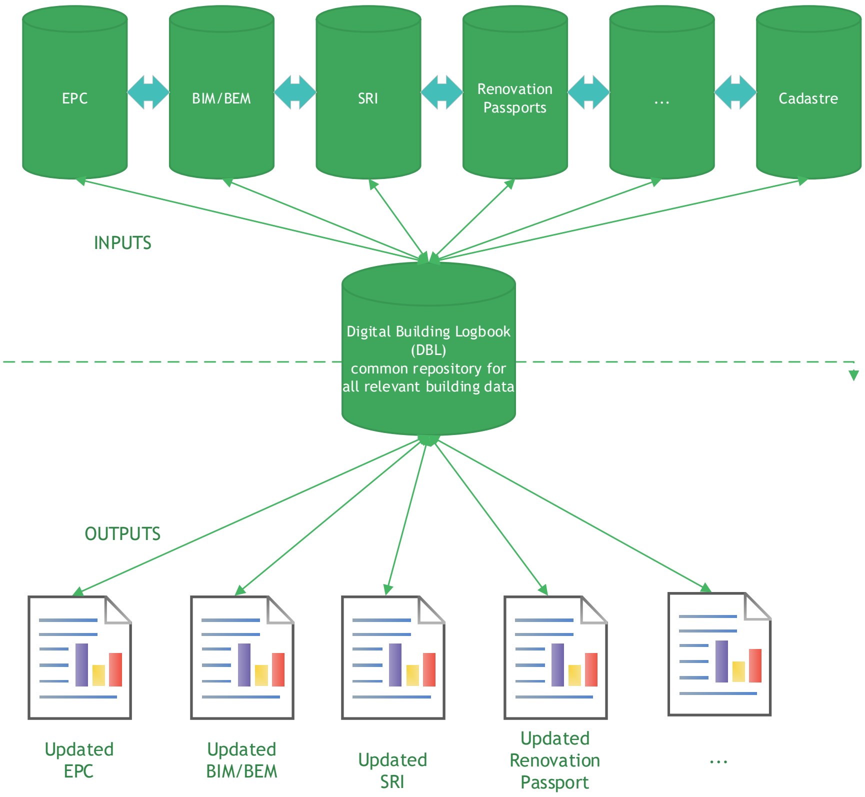

Figure 2. Digital Building Logbook as a central element of the future interoperability between different databases and envisaged dataflow

To promote the use of the SRI and sustainability indicators, the TIMEPAC Code of Conduct for Smart Readiness and Sustainability Rating has been created (see Annex A1:TIMEPAC Code of Conduct for Smart Readiness and Sustainability Rating). It represents a set of guidelines, values and principles that are considered fundamental for the successful, professional, and transparent calculation of the SRI and selected sustainability indicators. The Code of Conduct is generated based on experiences gained through the implementation of TDS4 in six countries participating in TIMEPAC .

3 Recent developments

3.1 Smart Readiness Indicator and its purpose

Energy and resource efficiency in combination with renewable energy sources represent the backbone of future sustainable development in any sector. In this context, the reduction of energy consumption in buildings in combination with the widespread integration of renewable energy sources (RES) in urban areas are vital elements in the long-term transition towards a low-carbon society. The EU has identified buildings as being the most promising target for improving energy efficiency and has quantified a significant energy-saving potential associated with infrastructure and equipment investments. The framework for EU energy and climate policy foresees Europe's energy system becoming decentralised, decarbonised and community led. Also, there is an increasing demand for energy-efficient solutions and intelligent systems in buildings that cannot only enhance comfort and convenience, but also reduce energy consumption and the environmental impact. Although theory often cites the so-called universally applicable solutions, practical experiences confirm that it is not possible to expect the successful implementation of the initially defined energy-community creation plans without the proper decision-support indicators. The ambitious plans for increasing the share of RES and improving energy efficiency in buildings require continuous improvement in policy and research for new and efficient implementation approaches and instruments. Improvements in building efficiency, regarding energy and other resources, require a systematic approach that goes beyond the current common practice of energy-consumption monitoring and optimization.

One innovative solution that has emerged in this context is the Smart Readiness Indicator (SRI). The SRI was introduced by the European Union in 2018 while amending the Energy Performance of Buildings Directive (EPBD) (European Parliament, 2018) and its subsequent regulations (Delegated Regulation 2020/2155 (European Commission, 2020a) and Implementing Regulation 2020/2156 (European Commission, 2020b)), triggering an optional implementation phase by the EU countries. Therefore, the EU countries might decide to implement the SRI on their territory for all buildings or only for certain categories of buildings.

It is important to underline that under the amended EPBD, the European Commission was mandated to develop a common framework for the SRI. Following this, a series of studies were carried out to develop the concept of the SRI and create a methodology for its calculation. At the moment the SRI is optional and a voluntary EU scheme that will be used to assess the technological readiness of buildings to interact with their occupants, to interact with connected energy grids and to operate more efficiently. The concept of the SRI and proposed seven impact criteria are illustrated in Figure 3.

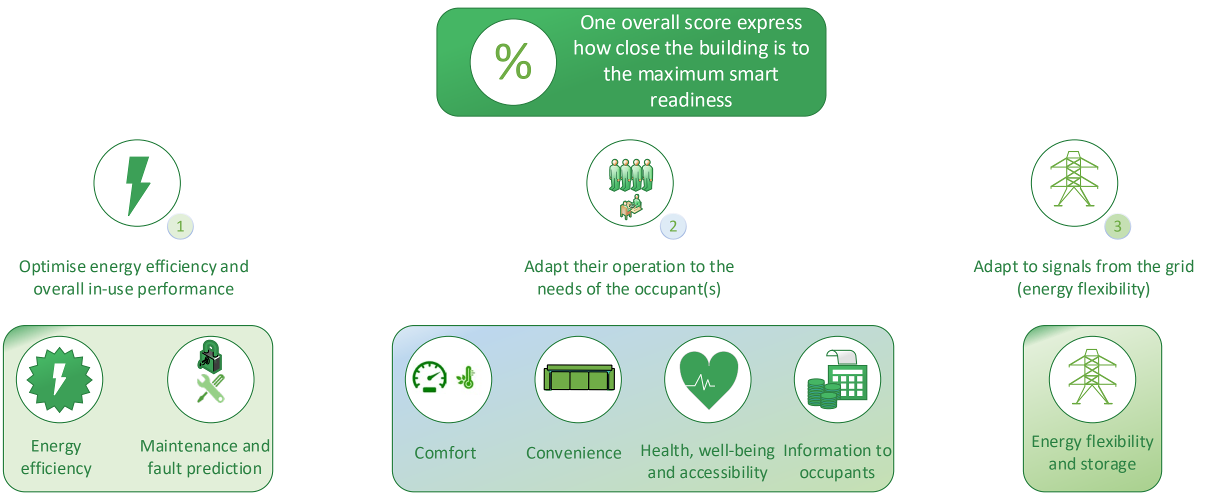

Figure 3. Concept of the SRI and seven selected impact criteria (European Commission, 2022)

Several EU countries (Austria, Croatia, Czech Republic, Denmark, Finland, France, Slovenia, and Spain) interested in the SRI scheme began by launching a non-committal test phase (European Commission, 2023b). However, they had to inform the European Commission prior to implementing the SRI test phase on their territory. Feedback from national test phases will make it possible to adjust the implementation modalities of the scheme. There are no specific guidelines from the European Commission for the SRI's implementation according to Implementing Regulation 2020/2156 (European Commission, 2020b). This means that the national governing bodies of each Member State have the freedom to modify the SRI tool for their own test phase.

The SRI aims to assess the capacity of buildings to adapt their operation to the needs of the occupant, to optimize the energy efficiency, and to support the overall energy grid by responding to market signals. The SRI is seen as a critical measure to enable the 'smartening' of buildings, as it addresses how well a building can adapt its functioning based on the user's needs and external factors. The SRI aims to measure the capacity of buildings to use information and communications technology (ICT) and electronic systems to adapt their operation and energy consumption to the needs of the occupant and the grid. It reflects the degree to which the building's energy usage can be controlled, monitored, and predicted to optimize both energy efficiency and comfort levels, decrease carbon emissions and contribute to grid stability. In doing so, the SRI promotes the transition to a cleaner, more sustainable, and technology-driven future.

The purpose of the SRI is multi-dimensional. Firstly, it is designed to measure a building's readiness to connect and interact with its occupants and the grid. This is vital for energy efficiency and comfort. Buildings that score high on the SRI can adapt their energy use based on occupancy patterns, weather conditions, and energy-price signals, among other things. This makes them not only more energy efficient, but also more comfortable and convenient for the occupants.

Secondly, the SRI aims to promote the deployment of smart technologies and digital infrastructures in buildings. It does so by providing a benchmark against which buildings can assess their readiness for smart technologies, incentivising building owners and managers to invest in smart and digital solutions. This, in turn, can stimulate the market for smart building technologies and services, thus driving innovation and creating jobs.

Furthermore, the SRI can become an important tool for the transition to a more energy-efficient and sustainable built environment. It encourages a shift from traditional, one-dimensional, consumption-based energy buildings (consumers) towards more flexible, demand-response buildings that produce energy and consider the intermittent nature of renewable energy sources (prosumers).

The SRI also plays a crucial role in empowering consumers, providing them with clear and understandable information about a building's smart readiness. This can inform purchasing or renting decisions and encourage consumers to choose more energy-efficient and comfortable homes or offices. Over time, this could drive a market transformation towards smarter and more energy-efficient buildings.

In practice, the SRI involves a technical assessment of several aspects of a building, including its installed building-automation-and-control technologies, energy-management capabilities, and readiness to manage and optimize its consumption and generation of renewable energy. The SRI is a comprehensive indicator, considering a wide range of factors and providing a holistic picture of a building's smart readiness. A key part of the methodology for the calculation of the SRI is data collection. Accurate data is needed for a range of variables, including the building's technical systems, its use and occupancy, the external conditions it faces, and the control systems in place. This information is crucial for accurately calculating the SRI. Data can be in through several ways, including site visits, energy audits, energy performance certification, interviews with owners, occupants, energy or building managers, and automated data collection systems such as smart meters or building-energy-management systems.

In the framework of the TIMEPAC project, two assessment methods are employed: a simplified assessment method and a detailed assessment method. Detailed descriptions of both methods are given in (Verbeke et. al, 2020) and so will not be repeated in this report. Also, the general framework for the contribution of building automation, controls and building management on the energy performance of buildings is given in European Standard EN 15232-1 Energy Performance of Buildings Part 1: Impact of Building Automation, Controls and Building Management, and so it will not be repeated in this report (CEN, 2022c). The SRI service catalogue is mainly a BACS checklist that was derived from this standard.

The simplified method (Method A) uses a reduced set of services, which requires less effort and expertise to conduct the assessment. In the final stage of TDS4, the detailed method (Method B) will be used to compare the smart readiness of similar building types in the participating countries. In this process a use-case approach that focuses on the following end-users will be used:

- Demand-Side-Management-aware facility manager,
- Cost-conscious facility manager,
- Sustainability-supporting owner,
- Informed tenant,
- Informed ESCO,
- Informed utility.

A use-case approach is a methodology used to capture the potential benefits of a tested tool from the end-user's perspective. The end-users are the group of potential users or beneficiaries of the SRI. In this phase, assessors will need to act as end-users and perform the SRI calculation, while keeping in mind the main needs of adopted end-user's role. All the comments that are entered into the SRI calculation spreadsheet will be used to extract potential energy-efficiency and flexibility measures. The structure of the adopted use-case approach for all the addressed end-users is presented the Table 1.

Table 1. Structure of the adopted use-case approach

End-user	Demand-Side-Management-aware facility manager
End-user expectations/needs	An DSM-aware facility manager who works with a large state-owned building needs to objectively evaluate the building's flexibility potential and identify interesting DSM projects. The manager would like to propose tailor-made energy efficiency projects with a special emphasis on energy flexibility.
Results of SRI rating process	A reliable list of potential DSM projects that can be implemented through energy-performance contracting or a similar funding scheme.
Comments made by SRI evaluator	The selection criteria for potential DSM projects should be clearly defined, including factors such as energy efficiency, cost savings and user comfort. In addition, independent and context-sensitive variables, such as occupancy, scheduling, and weather conditions, should be identified. The key inputs required for the report, which will contain the list of potential projects to be implemented in the selected building, should include a detailed analysis of the building's energy consumption and usage patterns.
End-user	Cost-conscious facility manager
End-user expectations/needs	A cost-conscious facility manager who manages several state-owned buildings belonging to the education sector needs to identify potential energy-efficiency measures. The manager also needs to know the kind of preventive and predictive maintenance of the systems at the building level that can be combined with re-commissioning activities.
Results of SRI rating process	A reliable list of potential energy-efficiency measures that can be implemented and a proposal for the preventive and predictive maintenance actions that can be combined with the re-commissioning activities.

Comments made by SRI evaluator	The selection criteria for potential energy-efficiency measures should be clearly defined, including factors such as cost savings and user comfort. In addition, a list of re-commissioning activities that can be combined with the preventive and predictive maintenance should be provided.
End-user	Sustainability-supporting owner
End-user expectations/needs	A sustainability-supporting owner wants to become aware of energy- and comfort-improvement opportunities for his/her property so that he/she can implement the most effective measures to reduce energy consumption and related costs, and at the same time improve user comfort for the building's occupants.
Results of SRI rating process	Definition of priorities for possible energy-renovation activities to enhance the energy efficiency and indoor air quality.
Comments made by SRI evaluator	Clear definition of the potential energy-efficiency measures and their impact on the quality of the indoor air. Also, the provided information must inform the end-user about the energy and environmental footprint of his/her property, the level of comfort and the sustainability aspects of the proposed energy-efficiency measures.
End-user	Informed tenant
End-user expectations/needs	An informed tenant who works in a state-owned building belonging to the education sector wants to improve user comfort at his/her working place.
Results of SRI rating process	A reliable list of potential projects that can improve user comfort but also improve the energy performance of the building.
Comments made by SRI evaluator	The selection criteria for potential projects that can improve user comfort should be clearly defined, including factors such as expected energy consumption and improved level of comfort. The end-user needs reliable and transparent information about energy and the environmental footprint as well as the associated level of comfort in the building.
End-user	Informed ESCO
End-user expectations/needs	An informed ESCO who cooperates with several large, state-owned buildings needs to identify interesting energy-efficiency and flexibility projects in the selected buildings to propose a list of potential projects interesting for third-party financing.
Results of SRI rating process	A reliable list of potential energy-efficiency and energy-flexibility projects that can be implemented through energy-performance contracting or a similar funding scheme.
Comments made by SRI evaluator	The selection criteria for potential energy-efficiency and energy-flexibility projects should be clearly defined, including factors such as energy efficiency, cost savings and user comfort. An additional metering infrastructure should be proposed to enable monitoring and verification of the identified energy savings or flexibility improvement (guaranteeing energy performance and flexibility).
End-user	Informed utility
End-user expectations/needs	An informed utility wants to identify interesting renewable-energy and flexibility projects in the selected buildings to propose a list of potential projects to improve the quality and reliability of the supply and to improve the flexibility response of the addressed buildings.

Results of SRI rating process	A reliable list of potential projects that can be implemented through reliability/flexibility performance contracting or a similar funding scheme.
Comments made by SRI evaluator	The selection criteria for potential renewable energy and flexibility projects should be clearly defined, including factors such as improved reliability, power quality, and cost savings. Additional metering infrastructure should be proposed in order to enable monitoring and verification of impacts (guaranteeing performance).

The selected use-case approach was discussed in a series of preliminary dialogs with representatives of Slovenian ESCOs and building managers. During these conversations, it was confirmed that comments and notes from assessors are crucial for properly understanding the SRI rating. Furthermore, it was acknowledged that the SRI can facilitate the alignment of common interests between ESCOs and building owners in exploiting urban areas for energy production from RES and supporting e-mobility.

3.2 Level(s) framework and sustainability indicators

3.2.1 Methodology description

Level(s) is the common EU framework for the core sustainability indicators of buildings. Throughout this briefing, the main aspects of the performance addressed by Level(s), as well as the types of buildings and professionals it is aimed at, are described.

Level(s) is designed to enable professionals who play a role in the planning, design, financing and execution of building projects to make a clear contribution to broader environmental improvements at the European level. It aims to establish a common language of sustainability for buildings by defining core indicators for the sustainability of office and residential buildings. In the scope of the TIMEPAC project, the partners will have to identify which indicators and at what level can be transposed to their respective countries and integrated in the EPC.

The Level(s) framework provides a set of indicators and common metrics for measuring the sustainability performance of buildings over their lifecycle, assessing the following aspects:

- environmental performance,
- health and comfort,
- lifecycle cost and value,
- potential risks to future performance.

The Level(s) common framework is based on 6 macro-objectives, which describe the strategic priorities for the contribution of buildings to EU and Member State policy objectives in areas such as energy, material use and waste, water and indoor-air quality. An overview of the macro objectives is shown in Figure 4.

Level(s) can help building professionals in their work to improve the existing building stock by future-proofing it against climate change through renovation. To this end, Level(s) makes it possible to take the whole-life carbon impact of both embodied and operational emissions into consideration when thinking about renovation. Meeting clients' immediate needs, while also ensuring that properties can be adapted as demands change, is essential to extending the lifespan of buildings and Level(s) creates opportunities to address this imperative in the design process too.

A further advantage is that Level(s) is a tool that can help to bring different kinds of professionals together to collaborate and to assess the options for improving sustainability, while learning how different decisions impact on the performance of a building.

Macro-objective	Indicator	Unit of measurement
1: Greenhouse gas and air pollutant emissions along a building's life cycle	1.1 Use stage energy performance	kilowatt hours per square metre per year (kWh/m^2 /yr)
	1.2 Life cycle Global Warming Potential	kg CO_2 equivalents per square metre per year (kg CO_2 eq./m^2/yr
2. Resource efficient and circular material life cycles	2.1 Bill of quantities, materials and lifespans	Unit quantities, mass and years
	2.2 Construction & demolition waste and materials	kg of waste and materials per m^2 total useful floor area
	2.3 Design for adaptability and renovation	Adaptability score
	2.4 Design for deconstruction, reuse and recycling	Deconstruction score
3. Efficient use of water resources	3.1 Use stage water consumption	m^3/yr of water per occupant
4. Healthy and comfortable spaces	4.1 Indoor air quality	Parameters for ventilation, CO2 and humidity Target list of pollutants: TVOC, formaldehyde, CMR VOC, LCI ratio, mould, benzene, particulates, radon
	4.2 Time outside of thermal comfort range	% of the time out of range during the heating and cooling seasons
	4.3 Lighting and visual comfort	Level 1 checklist
	4.4 Acoustics and protection against noise	Level 1 checklist
5. Adaptation and resilience to climate change	5.1 Protection of occupier health and thermal comfort	Projected % time out of range in the years 2030 and 2050 (see also indicator 4.2)
	5.2 Increased risk of extreme weather events	Level 1 checklist (under development)
	5.3 Increased risk of flood events	Level 1 checklist (under development)
6. Optimised life cycle cost and value	6.1 Life cycle costs	Euros per square metre per year (€/m2/yr)
	6.2 Value creation and risk exposure	Level 1 checklist

Figure 4. Macro-objectives of the Level(s) common framework (Dodd et. al, 2017)

The common framework is organised into three levels. The levels provide a choice as to how advanced the project's reporting on sustainability will be. The three levels represent the following stages in the execution of a building project:

- **Level 1.** The conceptual design for the building project - the simplest level as it entails early-stage qualitative assessments of the basis for the conceptual design and reporting on the concepts that have or are intended to be applied.
- **Level 2.** The detailed design and construction performance of the building - an intermediate level as it entails a quantitative assessment of the designed performance and monitoring of the construction according to standardised units and methods.
- **Level 3.** The as-built and in-use performance of how the building performs after completion and handover to the client - the most advanced level as it entails the monitoring and surveying of activity both on the construction site and of the completed building and its first occupants.

The basic idea is that the levels represent a professional journey from the initial concept through design, construction and then, after handover, to the reality of the completed building. Progression through the levels also represents an increase in the accuracy and reliability of the reporting – the higher the level, the closer the reported results will be to providing data that reflects the performance of the building as-built and in-use.

The approach

The first step for the TIMEPAC partners in their respective countries is to establish a **TIMEPAC TDS 4 calculation plan**:

1. TDS 4 will address certain indicators under macro-objectives 1 (Greenhouse gas and air pollutant for a building's lifecycle), 4 (Healthy and comfortable spaces) and 6 (Optimised lifecycle cost and value).
2. In order to assess performance, the indicators used are:
   a. Use-stage energy performance (mandatory)
   b. Lifecycle Global Warming Potential (voluntary)
   c. Time outside of thermal comfort range (mandatory)
   d. Lifecycle costs (mandatory)
3. Partner(s) in their respective countries have to establish to which 'level' the project performance will be assessed.
4. Partner(s) in their respective countries have to plan which resources will be needed to assess performance and when in the project's lifecycle.

3.2.2 Integration of Level(s) indicators in the EPC

3.2.2.1 Indicator 1.1 Use-stage energy performance

Primary energy use is the required metric for reporting on the energy performance of buildings across the EU. The energy performance of a building, expressed in primary energy, is used for both compliance with the minimum energy-performance requirements and for the Energy Performance Certificates (EPCs), which can be based on either the design or the as-built input data.

Broadly speaking, for buildings constructed before 2010, use-stage primary-energy demand will account for the most significant lifecycle impacts. For newer buildings, the production stage and other use stages related to material use, such as replacement and refurbishment, assume greater importance. This is because proportionately they use less energy in the use stage and the materials used for their construction are more energy intensive. In this case, the use stage is potentially responsible for as little as 30% of lifecycle energy use, depending on the building type, form and specification.

In addition, reporting on this indicator can provide useful insights into the building's total emissions of air pollutants to the ambient air. Whereas an overall reduction in the primary energy consumption will generally have a positive effect on air quality, a fuel switch can also lead to an increase in the emissions of specific ambient air pollutants.

Methodology framework for indicator calculation and assessment reporting can be found at the web portal containing Level(s) documentation (European Commission, 2021).

General guidance: The partners are asked to extract results from an energy-performance calculation from TDS 2 and report it as they see fit – at either level 2 or level 3 (Table 2).

Table 2. Three levels representing the execution of a building project

Level 1. Conceptual design	Level 2.Detailed design and construction	Level 3. As-built and in-use
Qualitative assessments and reporting on the concepts This level is for those users who would like to: - Understand the energy needs associated with the type of building they are working on. - Know where they can focus attention to reduce the total primary-energy use associated with the building's delivered energy needs during the use stage.	An intermediate level, quantitative assessment This level is for those users who are at the stage of needing to calculate the energy needs and primary-energy use of a building for the purpose of design comparisons, building permitting or tendering.	Monitoring and surveying of activity This level is for those users who would like to: - Collect metered data to understand the energy needs associated with the building. - Carry out testing of the building in use to identify any performance issues with the building fabric and technical services. This could include an energy meter that measures real-time energy consumption.

Reporting at Level 2

This level is for those users who are at the stage of needing to calculate the delivered energy and primary-energy consumption of a building for the purpose of design comparisons, building permitting or tendering (Table 3).

Table 3. Template for reporting the results of a delivered energy-use assessment at level 2 for the selected building

Building service	Energy need	System eff.	Energy carrier	Delivered energy per energy carrier	Non-renewable primary energy		Renewable primary energy		Total primary energy	
	kWh/a.	Decimal	Text	kWh/a.	Factor	kWh/a.	Factor	kWh/a.	Factor	kWh/a.
Heating										
Cooling										
Ventilation										
Hot water										
Lighting										
Exported renewable energy										
Overall										

For the purposes of comparison, EPBD services in Level(s) reporting should be considered as: heating, cooling, ventilation (including any humidification and dehumidification), hot water and lighting (Table 4).

Table 4. Template for reporting the results of an energy-performance assessment at level 2 for the selected building

	kWh/m²/a
L2.1 EPBD services[1] non-renewable primary energy self-used[2] (mandatory)	
L2.2 EPBD services[1] renewable primary energy self-used[2] (optional)	
L2.3 EPBD services[1] total primary energy self-used[2] (optional)	L2.1 + L2.2
L2.4 Exported renewable primary energy (mandatory)	
L2.5 EPBD services[1] non-renewable primary energy balance[3] (mandatory)	L2.1 – L2.4
L2.6 Non-EPBD services non-renewable primary energy self-used[2] (optional)	
L2.7 Non-EPBD services renewable primary energy self-used[2] (optional)	
L2.8 Non-EPBD services[1] total primary energy self-used[2] (optional)	L2.6 + L2.7
L2.9 Total primary energy self-used [2] (optional	L2.3 + L2.8
L2.10 Total primary energy balance[2] (optional)	L2.9 – L2.4

1. For the purposes of comparison, EPBD services in Level(s) reporting should be considered as: heating, cooling, ventilation (including any humidification and dehumidification), hot water and lighting.

2. Self-used means energy delivered to the building as part of the building operation. This includes all energy delivered from all sources, including onsite sources for EPBD services, such as PV panels and solar thermal installations and ignores any excess of renewable energy from onsite sources that is exported.

3. Primary energy "balance" means the subtracting any exported renewable primary energy from the total "self-used" energy.

Reporting at Level 3

This level is for those users who would like to:

- Collect metered data to understand the energy use associated with the building they are working on,
- Carry out testing of the building in use to identify any performance issues with the building's fabric and the building's technical systems.

Table 5 and 6 are the reporting templates.

Table 5. Template for reporting the results of a delivered energy-use assessment at level 3 for the selected building

Building service	Energy carrier		Delivered energy per energy carrier	Non-renewable primary energy		Renewable primary energy	Total primary energy	
	Text	kWh/a.	Factor	kWh/a.	Factor	kWh/a.	Factor	kWh/a.
Heating								
Cooling								
Ventilation								

Hot water								
Lighting								
Exported renewable energy								
Overall								

Table 6. Template for reporting the results of an energy-performance assessment at level 3 for the selected building

	kWh/m^2/a.
L3.1 EPBD services[1] non-renewable primary energy self-used[2] (mandatory)	
L3.2 EPBD services[1] renewable primary energy self-used[2] (optional)	
L3.3 EPBD services[1] total primary energy self-used[2] (optional)	L3.1 + L3.2
L3.4 Exported renewable primary energy (mandatory)	
L3.5 EPBD services[1] non-renewable primary energy balance[3] (mandatory)	L3.1 – L3.4
L3.6 Non-EPBD services non-renewable primary energy self-used[2] (optional)	
L3.7 Non-EPBD services renewable primary energy self-used[2] (optional)	
L3.8 Non-EPBD services[1] total primary energy self-used[2] (optional)	L3.6 + L3.7
L3.9 Total primary energy self-used[2] (optional)	L3.3 + L3.8
L3.10 Total primary energy balance[2] (optional)	L3.9 – L3.4

1. For the purposes of comparison, EPBD services in Level(s) reporting should be considered as: heating, cooling, ventilation (including any humidification and dehumidification), hot water and lighting.
2. Self-used means energy delivered to the building as part of the building operation. This includes all energy delivered from all sources, including onsite sources for EPBD services, such as PV panels and solar thermal installations and ignores any excess of renewable energy from onsite sources that is exported.
3. Primary energy "balance" means the subtracting any exported renewable primary energy from the total "self-used" energy.

3.2.2.2 Indicator 1.2 Lifecycle Global Warming Potential

This indicator aims to quantify the Global Warming Potential (GWP) contributions of a building over its lifecycle from the 'cradle' (the extraction of the raw materials that are used in the construction of the building) through to the 'grave' (the deconstruction of the building and how to deal with its building materials, i.e., recovery, reuse, recycling and disposal).

Carbon emissions embodied in building materials are brought together with direct and indirect carbon emissions from the use-stage performance (e.g., energy consumption and water consumption) in this indicator. Cradle to grave thinking allows for building design solutions that seek the optimum balance between embodied carbon and use-stage carbon emissions. In particular, with embodied carbon, it is important to recognise that buildings are a material bank, being a repository for carbon-intensive resources over many decades, and so it is important to explore designs that facilitate the future reuse and recycling at the end of the building life.

The system boundary is 'cradle to grave' as defined by EN 15978:2011 (CEN, 2012), i.e., from the production of building materials to the end of the building's useful life and the subsequent demolition and recovery of the building materials. It is defined in terms of lifecycle stages, which are in turn split into modules as defined by EN 15978:

- The product stage (A1-5)
- The use stage (B1-6)
- End-of-life stage (C1-4)
- Benefits and loads beyond the system boundary (D)

General guidance: The partners are asked to **try** to extract results from a software simulation if their model is sufficient in terms of filled-out data and the extent of relevant BIM libraries – either at level 2 or level 3.

Instructions for Level 2

Methodology framework for the indicator calculation and assessment reporting can be found at the web portal containing Level(s) documentation (European Commission, 2021).

Check subchapter "L2.2. Step-by-step instructions" for detailed steps of the calculation, which can be done with an LCA tool or BIM software with the relevant material libraries.

Table 7 is the reporting template.

Table 7. Template for reporting results of assessment 1.2 at level 2/3 for the selected building

	Unit	Product (A1-3)	Construction process (A4-5)	Use stage (B1-7)	End of life (C1-4)	Benefits and loads beyond the system boundary (D)
(1) GWP - fossil	kg CO_2 eq					
(2) GWP - biogenic	kg CO_2 eq					
GWP - (1) + (2)	kg CO_2 eq					
(3) GWP - Land use and land use change	kg CO_2 eq					
GWP - (1) + (2) + (3)	kg CO_2 eq					

Instructions for Level 3

The same procedure and instructions as defined in Level 2 can be equally applied to the building assessment after its construction or renovation. The only difference would be that the design data are supported by the certainty of the materials procured and the technical building systems installed instead of being based on a design only.

3.2.2.3 Indicator 4.2 Time outside of thermal comfort range

The control of thermal comfort, and in particular the solar gains in summer, is an important factor in all buildings. This is because, even in Northern European locations, uncontrolled gains from solar radiation can lead to uncomfortable conditions that might in turn require additional cooling energy.

While the main focus of this indicator is on thermal comfort in summer, the ability of residents to keep homes warm in winter is also an important factor. A large proportion of the EU's housing stock cannot provide adequate levels of thermal comfort because of the combination of a lack of insulation, poor-quality windows, cold bridging through the building fabric, high levels of air infiltration and inadequate or poorly maintained heating systems. This can lead to inadequate heating, which can put more vulnerable residents at risk from seasonal illnesses.

Calculation method and reference standards

The calculation of the reported performance must be based on a dynamic energy simulation and in accordance with the method described in Annex A.2 of EN 16798-1 (CEN, 2019). An overheating assessment that forms part of the National Calculation Method will be accepted if it is based on a dynamic simulation method. If a more advanced calculation method is used, it must be compliant with the ISO 52000-1 series (ISO, 2017b).

If there is the intention to carry out a post-occupancy evaluation of satisfaction/dissatisfaction with the thermal environment, the Predicted Percentage Dissatisfied (PPD) must be estimated based on ISO 7730 (ISO, 2005) (for mechanically cooled buildings) or the acceptable summer indoor temperature range (for buildings without mechanical cooling). The estimate PPD can then be compared with the results from an occupier survey.

General guidance: The partners are asked to extract results from TDS 2 – either at level 2 or at level 3.

Instructions for Level 2

This level is for those users who are at the stage of having to assess the energy requirements of a building and wish to make a quantitative assessment of the indoor thermal conditions according to the Category II temperature ranges stipulated in EN 16978-1 (or national equivalent).

Table 8 and 9 are the reporting templates.

Table 8. Template of supporting information for the reporting of indicator 4.2 of an assessment at level 2 for the selected building

Level 2 reporting item	Information to provide
Calculation method	Specify the Member State and the specific method used
	The specific dynamic method used if it is not a national calculation method
Post-occupancy survey	Indicate whether the design-stage thermal comfort category will be calculated for a later comparison

Table 9. Template for project assessment results for the reporting of indicator 4.2 of an assessment at level 2 for the selected building

	Heating season	Cooling season
Operating temperature range (°C)	Lower/upper limits	Lower/upper limits
Time out of range (%) - without mechanical heating/cooling	Proportion of time	Proportion of time
Time out of range (%) - with mechanical heating/cooling	Proportion of time	Proportion of time

Instructions for Level 3

This level is for those users who would like to:

- Collect monitoring data on the thermal conditions in a building to compare the performance with design simulations,
- Carry out a post-occupancy survey of occupants to determine the level of dissatisfaction with the thermal comfort conditions and compare the results with the design estimates.

Table 10 is the reporting template.

Table 10. Template for project assessment results for the reporting of indicator 4.2 of an assessment at level 3 for the selected building

	Heating season	Cooling season
Operating temperature range (°C)	Lower/upper limits	Lower/upper limits
Time out of range (%) - without mechanical heating/cooling	Proportion of time	Proportion of time
Time out of range (%) - with mechanical heating/cooling	Proportion of time	Proportion of time

3.2.2.4 Indicator 6.1 Lifecycle costs

Lifecycle Costing is a technique that “enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors, both in terms of initial capital costs and future operating and asset replacement costs”. It is particularly relevant to achieving an improved environmental performance because higher initial capital costs may be required to achieve lower lifecycle running costs.

By estimating lifecycle costs, important information can be provided to investors, asset managers and occupiers. The latter includes homeowners, who may wish to understand the costs associated with maintaining and running a home for the duration of a full mortgage term, and residents' organisations responsible for the communal costs of maintaining apartment blocks.

A lifecycle cost perspective encourages clients and designers to consider the relationship between upfront capital costs and use-stage costs. They can also provide a more informed basis for understanding the future performance, value and liabilities associated with a building.

Calculation method and reference standards

The reference standards for calculating the lifecycle costs of each lifecycle stage are EN 15459 (CEN, 2017), ISO 15686- 5 (ISO, 2017a) and EN 16627 (CEN, 2015). The reference standard ISO 15686-8 (ISO, 2008) provides a methodology for calculating and estimating the design life of elements and components. Development of a lifecycle cost plan for a building will require the collection of a range of cost data, which can vary in quality according to its source and age.

General guidance: The partners are asked to extract results from TDS 2 – either at level 2 or at level 3.

Instructions for Level 2

This Level is for those who intend to calculate the lifecycle costs of their building project (Table 11). It provides instructions on:

- How to use the Level(s) building description.
- How to select software tools and databases.
- The basic parts of the calculation and the calculation steps according to the Cost Optimal method, EN 15459 (CEN, 2017) and standard ISO 15686-5 (ISO, 2017a).

- Information and assumptions additional to the Cost Optimal method and the ISO 15686-5 standard to make a calculation, including default parameters that will be used and data gap filling.

Table 11. Template for project-assessment results for reporting of indicator 6.1 at level 2 for the selected building

Type of cost	Normalised cost by lifecycle stage (€/m^2/a.)		
	A Product and construction stages	B Use stage	C End-of-life stage
Initial costs	Construction	Refurbishment and adaptation	Deconstruction and demolition
Annual costs	-	Energy Water Maintenance, repair and replacement	-
Periodic costs	-	Maintenance, repair and replacement	-
Global costs by lifecycle stage	Sum of A	Sum of B	Sum of C

Instructions for Level 3

This Level is for those who intend to revise the lifecycle costs of their building project based on the as-built initial costs and any associated revisions in the projected annual and periodic costs. It can also be used to report on the lifecycle costs for a completed building.

Reporting table is the same as for Level 2.

3.3 Data-collection process and limitations

Data reliability and relevance are of highest importance for the calculation of the SRI, selected sustainability indicators, and an energy performance assessment. The calculation of the SRI and sustainability indicators involves data collection from various aspects of a building's design, operation and usage. During the data-collection process the SRI and sustainability auditor must extract useful data from the drawings, daily log sheets, predefined readings from various Supervisory Control and Data Acquisition systems (SCADA), and from the interview with the energy and/or facility managers, building occupants and owner.

Specific data-handling routines must be followed to ensure data accuracy. An experienced auditor is always making cross checks and compares related data (for example, data from drawings with the actual situation, checking accuracy of reading and recording, etc.). The main steps of the data-collection process are presented in Figure 5.

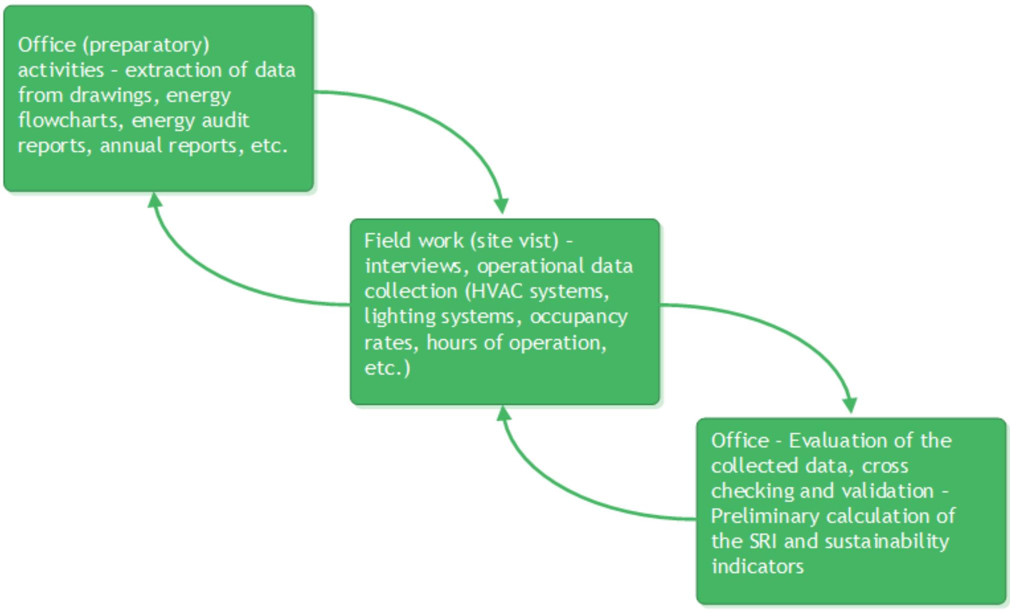

Figure 5. Main steps in the data-collection process for the calculation of the SRI and sustainability indicators

The data-collection process starts in the office with an in-depth analysis of the available data, like drawings, existing inspection reports, energy audit, etc. before the actual site visit. The main purpose of this step is to empower the SRI and the sustainability auditor with basic knowledge about the building that is being audited. The next step is a site visit, which typically starts with an interview with the energy and/or facility manager and/or owner. During the site visit the auditor has to check all the data extracted from drawings and previous reports, such as its age, size, construction materials, insulation levels, and gather other missing data about the building, such as HVAC systems, lighting systems, types of appliances used, occupancy rates, hours of operation, and how different spaces within the building are used. This is a crucial step as it sets the base for further calculations and analyses. In order to be able to propose sound energy-efficiency and flexibility-improvement measures, the auditor should collect data on energy consumption, typically from utility bills or smart-meter readings. This includes electricity, gas, and any other forms of energy used in the building. Information about any smart systems and controls installed in the building must also be collected. This includes smart thermostats, smart lighting systems, energy-management systems, and any other technology that contributes to the building's smart readiness. This data is crucial for calculating the SRI, as the indicator is intended to measure a building's capacity to use new technologies and systems for managing its energy use more efficiently and flexibly. For sustainability indicators, data on the environmental impact of the building is needed.

Data related to indoor environmental quality, such as temperature, humidity and illuminance levels, as well as data on occupant satisfaction and comfort, should be collected. These data points contribute to the calculation of sustainability indicators and, in some cases, the SRI. The majority of this data can often be collected from the building's energy-management system or various SCADA systems, if they are present.

Once the necessary information about the building and its operation has been collected, these data can be used to calculate the SRI and the sustainability indicators. For the calculation of the SRI, a standard SRI-assessment package comprising a calculation sheet should be used. The SRI-assessment package is available free of charge and it can be provided upon request by filling out a form available at the EUSurvey serviceweb site (SRI, 2023). Calculations of sustainability indicators typically involve applying certain models or algorithms that have been developed for this purpose, like BIM/BEM.

However, data collection for the SRI and sustainability indicators is subject to several limitations. The accuracy of the SRI and the sustainability indicators is highly dependent on the availability and quality of the data. If accurate and detailed data are not available, the calculations might not accurately reflect the building's actual performance. This is especially a problem for older buildings, where certain information may be missing or outdated. The data-collection process can be time-consuming and costly, especially for larger buildings or complexes, for an inexperienced or unprepared auditor. This can be a barrier to routine calculations of the SRI and the sustainability indicators. Also, buildings with complex systems or unusual features might require more detailed data and more complex calculations, which once again can make the process more time-consuming and result in a more expensive final product. The process of collecting data and calculating the SRI and the sustainability indicators typically requires a certain level of expertise in areas like building science, energy management and data analysis. This can limit the ability of poorly trained people when it comes to calculating these indicators themselves. Also, SRI is a relatively new concept and since there is lack of standardisation and operational practice, subjectivity and the preferences of an auditor can significantly influence the final results, which can make it difficult to compare results across different buildings or regions.

3.3.1 SRI and sustainability auditing

The SRI and sustainability auditing, if conducted in a systematic and comprehensive manner, have the potential to identify energy efficiency and flexibility measures that can improve the overall performance of a building. The SRI and sustainability audit is carried out through a sequence of activities aimed at determining current energy performance, the level of smartness and sustainability, and identifying opportunities to improve performance and reduce costs. For the SRI and sustainability auditing, the TIMEPAC partners decided to follow the recommendations of EN 16247 – 1 (CEN, 2022a) and EN 16247 – 2 (CEN, 2022b). An overview of this process in given in Figure **6**.

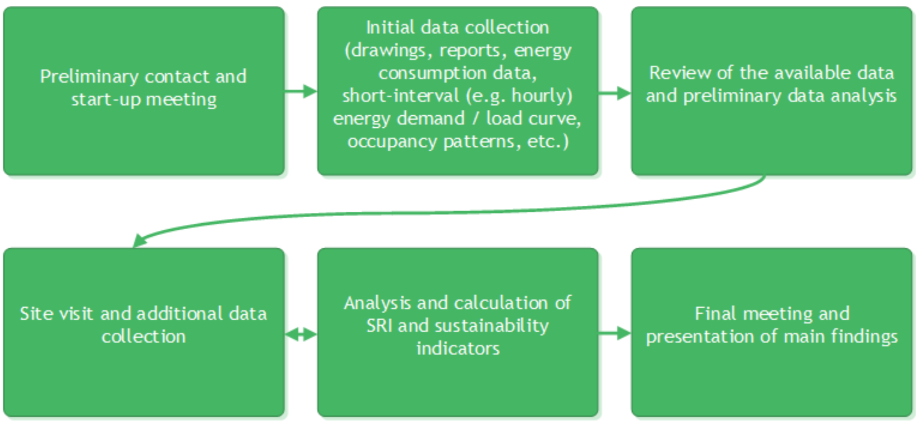

Figure 6. Main elements of the SRI and sustainability auditing based on EN 16247 – 1 (CEN, 2022a) and EN 16247 – 2 (CEN, 2022b)

In the case that during the analysis and the calculation of the SRI and sustainability indicators crucial data are found to be missing, it might be necessary to repeat or supplement some of the activities. The SRI and sustainability auditing require accurate and comprehensive data to produce reliable results and recommendations. During the review of the available data and a preliminary data analysis, the SRI and sustainability auditor must go through the data that was collected during the preliminary phase and identify which data are missing and determine how these data will be collected during the site visit. In the case that a lack of crucial data is identified during the analysis and calculation process, a plan for data collection should be created, and this may involve revisiting the building site, reviewing the building documentation and interviewing the building operators or occupants. To prevent similar issues in the future, data-collection tools or procedures must be constantly updated. It is important to note that while it can be time-consuming and potentially costly to collect missing data after a site visit, it is often more costly in the long run to make decisions based on incomplete or inaccurate data. Ensuring that the SRI and sustainability rating is as accurate and complete as possible can help to ensure that the building's energy efficiency, smartness, flexibility and sustainability performance are accurately assessed and that the most effective improvement measures are identified and presented to the owner/decision maker.

3.4 Links between TIMEPAC and sister projects

TIMEPAC partners actively communicate with representatives from various institutions gathered within the NextGenEPC cluster. TIMEPAC joined the NextGenEPC cluster with the aim of identifying common areas of research and targeting stakeholders to share knowledge, experience, and actively disseminate the project’s results. Additionally, cooperation with the NextGenEPC cluster provides valuable networking opportunities with other professionals in the field, fostering potential collaborations or partnerships. We all share the same goal: producing more accurate and useful Energy Performance Certificates (EPCs) that can help improve the energy efficiency and flexibility of buildings, thereby contributing to environmental sustainability.

Table 12 provides a list of projects participating in the NextGenEPC cluster that have a connection with the SRI or sustainability indicators and are of particular interest for TDS4.

Table 12. Next-generation Energy-Performance Certificates H2020 cluster and relation with TDS4 (SRI and sustainability indicators)

Funding Scheme	Topic(s)	Project name	Relation with TDS4
CSA*, 2019	H2020_LC-SC3-EE-5-2019	QualDeEPC	X (SRI)
		U-CERT	X (SRI and sustainability)
		X-tendo	X (SRI and sustainability)
IA, 2020	H2020_LC-SC3-EE-5-2019	D^2EPC	X (SRI and sustainability)
		EDYCE	
		ePANACEA	X (SRI)
		EPC RECAST	

Funding Scheme	Topic(s)	Project name	Relation with TDS4
CSA, 2021	LC-SC3-B4E-4-2020	crossCert	
		EUB SuperHub	X (SRI and sustainability)
		iBRoad2EPC	
IA, 2021	LC-SC3-B4E-3-2020	COLLECTiEF	X (SRI and sustainability)
CSA, 2021	LC-SC3-B4E-11-2020	SER	
* CSA = Coordination and Support Actions; IA = Innovation Actions			

QualDeEPC - Enhanced Energy Performance Certification with deep renovation (1/9/2019-31/8/2022)

This project does not deal directly with the SRI or sustainability indicators, but in its *D5.3 Guidebook for improved EPCs presenting the project's proposal for an enhanced and converging EPC assessment and certification scheme* recognises the need to include an SRI in the training content (QualDeEPC, 2023). This recommendation was considered during the creation of the TIMEPAC Training Programme and specific training activities are dedicated to the SRI.

U-CERT - Towards a new generation of user-centred Energy Performance Assessment and Certification; facilitated and empowered by the EPB Center (1/9/2019-28/2/2023)

The project encourages the development and application of holistic, user-centred innovative solutions, including the SRI and selected sustainability indicators like Indoor Environmental Quality (IEQ). It is recognised that energy flexibility is an issue raised by the SRI, but it is currently not addressed in any EPC. The U-CERT project proposes that the starting point for flexibility indicators can be so-called delivered and exported energy-duration curves with hourly data from the energy carrier, which have the potential to describe the effect of the building on distribution grids (U-CERT, 2020). This approach will also be tested during the exercises in Training Scenario (TS) 2 and TS6. Data relating to the electricity consumption of the selected buildings will be obtained from the GOLEA energy-management system.

X-tendo - eXTENDing the energy performance assessment and certification schemes via a mOdular approach (1/9/2019-31/8/2022)

The X-tendo project recognises that the simplified method appears best suited to the first stage of the implementation of the SRI, as it does not require extensive additional training and costs (X-tendo, 2022). A similar approach is also applied in the TIMEPAC project, and all buildings are assessed using both methods, firstly with the simplified method (Method A) and then with a more detailed method (Method B).

D2EPC - Dynamic Digital Energy Performance Certificates (1/9/2020-31/8/2023)

This project focuses on the evaluation of the applicability of a new set of indicators covering different aspects, including smartness (SRI) and sustainability (energy and environmental performance, health and comfort, lifecycle cost and value, etc.) to improve EPC schemes. D^2EPC recognises that the current status of data for an EPC assessment does not allow the extraction of the SRI and that site visits are essential. A similar assessment was conducted concerning the possibility of extracting the SRI from an IFC file. However, it was once again concluded that at the current stage, a significant number of the functionality levels necessary for the SRI are not addressed in the IFC-based documents (D^2EPC, 2022). Based on this recommendation, in the TIMEPAC project, a site visit is a compulsory activity for the calculation of the SRI and selected sustainability indicators. Data extracted from BIM/BEM will be used for the calculation of selected sustainability indicators.

ePANACEA - Smart European Energy Performance Assessment & Certification (1/6/2020-31/5/2023)

The project recognises that the SRI can act as a promoter of innovative smart-building technologies and that it is possible to integrate the SRI into new building assessments (ePANACEA, 2021). In the TIMEPAC project, the SRI and sustainability indicators are calculated before and after the implementation of the “smart-renovation scenario”, with the aim to clearly present the benefits of smart technologies. The main idea behind the smart-renovation scenario is to underline the benefits of the SRI and sustainability indicators and their potential regarding raising an awareness of advanced technologies for increased efficiency and flexibility beyond those generic measures proposed in current EPCs.

EUB SuperHub - European Building Sustainability performance and energy certification Hub (1/6/2021-31/5/2024)

EUB SuperHub aims to develop a certification scheme and tools designed to create a demand-driven market by addressing the needs of multiple stakeholder groups with an online hub (a one-stop shop) platform that uses harmonized criteria. The project partners believe that the harmonized criteria will enable holistic assessments of buildings and districts based on the EPC, Level(s), and SRI indicators (EUB SuperHub, 2023). The EUB SuperHub project also recognises several elements that could have the potential to raise the impact of the next-generation of EPCs on the real-estate market and proposes that EPCs should be less technical, easier to read, and display more practical information for consumers. They could include additional data on EPCs like potential annual energy savings, financial (annual cost savings), environmental (reduction of carbon footprint), social benefits, and health benefits using appropriate KPIs (EUB SuperHub, 2022). TDS4 also recognises these elements as valuable, especially when raising awareness of building smartness and sustainability aspects among experts, non-experts and the building’s occupants. The EUB SuperHub platform is not ready yet, but the TIMEPAC project will follow the activities of the EUB SuperHub project and, if possible, will include its main findings in the foreseen training activities (TS2).

COLLECTiEF - Collective Intelligence for Energy Flexibility (1/6/2021-31/5/2025)

This project aims to upgrade existing pilot buildings with at least one level of smartness according to SRI scoring methods, independently from the starting smart-readiness level. The COLLECTiEF project provides the methodology and the Key Performance Indicator (KPI) to assess the impacts on the smart readiness of buildings, the methodology and the sensors to measure and assess impacts on IEQ, identifying a set of relevant parameters able to provide optimal information about the health and comfort of the occupants, and the methodology and the KPIs identified to assess energy flexibility (COLLECTiEF, 2022). The recommendations and findings of the COLLECTiEF project are integrated into the TIMEPAC Code of Conduct for Smart Readiness and Sustainability Rating, where it is clearly stated that the SRI and sustainability auditor supports the long-term use of energy-management systems. Also, the Monitoring and Verification (M&V) approach of the COLLECTiEF project will be presented and discussed during the exercises in TS2 and TS6.

Based on all the recommendations from the above-mentioned projects, TDS4 will propose a common flow of activities to use synergies and reuse building data in the evaluation of the SRI, sustainability, EPC, energy audit, and any other assessments. The pros and cons of this approach will be weighed in the WP3 Verification Scenario against market acceptance and user-friendliness, costs and benefits, and the readiness and training of EPC/SRI assessors.

4 Calculation of the SRI and sustainability indicators for selected buildings

4.1 Brief overview of the selected buildings

In the scope of the TDS4, 36 different buildings were analysed. In Croatia, Cyprus, Italy and Spain, 5 different buildings were selected for a detailed testing and analysis. In Austria 6 and in Slovenia 10 buildings were selected for a detailed testing of the SRI sustainability rating. The selection includes buildings with different uses, sizes, energy performance, spatial and constructive characteristics, aiming to cover the diverse possibilities of the building stock. Twenty-eight out of the 36 analysed buildings were identified as non-residential buildings. The majority of them, 19 out of 28, belong to the education sector (3 in Austria, Croatia, Cyprus, Italy, 6 in Slovenia and 1 in Spain). Eight buildings were classified as residential. Among the 36 analysed buildings, 8 have been categorized as large buildings (conditioned floor area ≥ 3000 m^2), 12 as medium-sized buildings (1000 m^2 < conditioned floor area < 3000 m^2), and 16 as small buildings (conditioned floor area ≤ 1000 m^2). In the case of Cyprus and Slovenia, all the analysed buildings belong to the tertiary (non-residential) sector (Figure 7).

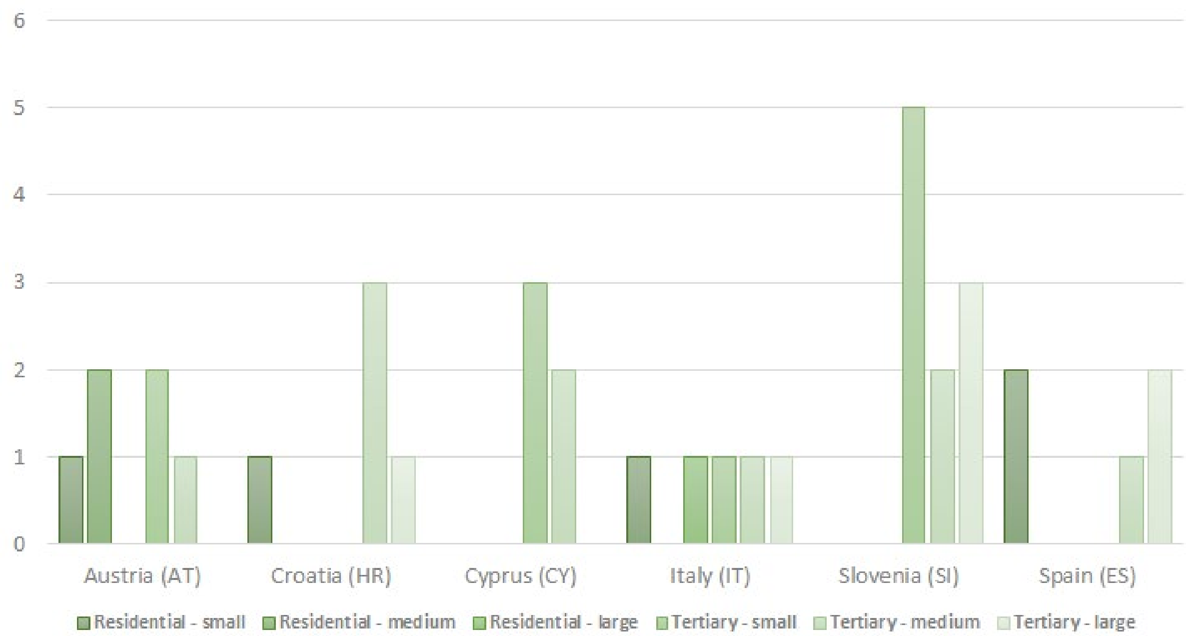

Figure 7. Brief overview of the selected buildings

All the selected locations provided a real testing environment with the full support of owners and maintenance staff and open access to all requested data necessary for the SRI and sustainability rating. According to Eisenhardt and Graebner (2007), this represents an opportunity with unusual research access.

4.2 Austria

Table 13 shows the buildings that were selected for the analysis in the current task. These buildings were analysed with SRI Excel tool version 4.5 with default method A and default method B.

Table 13. Overview of analysed Austrian buildings

TIMEPAC Code	Building type	Status
AT-01	Multi-unit residential building	New construction
AT-04	Multi-unit residential building	Existing, after major renovation
AT-06	Educational building	Existing, after renovation
AT-07	Dormitory (residential/educational)	Existing, after renovation
AT-08	Educational building	Existing, after major renovation
AT-09	Multi-unit residential building	Existing, before renovation

AT-01 is a multi-unit residential building that is part of a settlement that was developed in a close cooperation between the municipality and a private construction and real-estate company. The mobility concept does not include an E-charging infrastructure as this was to be dealt with at the municipality level (urban plan/zoning, in German "Bebauungsplan"). The core of the heating system is a biomass-pellet plant with an exhaust-gas recovery. The pellet system covers up to 92 % of the heat demand. For peak demand, an efficient gas-condensing boiler is installed. There is only one central heat-distribution system with a central pumping station in a specially constructed heating building. The residential units in all the buildings are heated without system separation by means of underfloor heating. Each room is equipped with a thermal, individual room-control system. Domestic hot water is heated in the individual living-room stations by means of plate heat exchangers in a hygienic flow-through process in the individual living-room stations. The energy service provider takes over the maintenance and servicing of the heat supply and ensures the contractually guaranteed availability of the supply. The energy service provider also bills the residents directly for the heating costs. Regarding the photovoltaic system, a model was developed to provide the electricity generated during the day directly to the residents by means of a dynamic billing model. Only the surplus electricity is fed into the grid. The project was thus the first major model project for the new SOLAR TOP offer of Salzburg AG (grid operator) to the dynamic billing of communal systems. The PV system is operated by the grid operator on behalf of the owners according to the conditions specified in a contract.

AT-04 is part of a complex of buildings that were all renovated at once and with a very low heating-energy demand. The heating-energy demand is so low that the buildings share a common micro-heating grid, which also supplies the domestic hot water. There is a central hot-water storage for all the buildings. Heat comes from waste water and waste air via heat pumps, while the remaining heat demand is covered by a small biomass boiler. The space on the roofs is used for a photovoltaic system, which powers the heat pumps. The energy-supply system is operated by an Energy Service Company that is interested in doing it the most energy-efficient way. A monitoring-and-control system for optimization is in place. Grid flexibility was not a topic during the development of the concept. This would need discussions between the building owner/facility manager, the ESCO, and the electricity company.

AT-06 was renovated, and as a consequence, transmission losses through the building envelope were massively reduced. The user profile is an educational building (kindergarten), which means that there are substantial internal gains that reduce the heating-energy demand even more. Due to the well-insulated airtight building envelope, a mechanical ventilation system with heat recovery and summer bypass was installed to ensure good air quality. The remaining heating demand was very low, and therefore it was decided to maintain the electric heating system. Regarding the PV and self-consumption, the level of self-consumption is already high. The technical building systems run on a time-controlled basis, which is sufficient due to the regular and clearly defined user profile. Monitoring after commissioning has led to improvements in the time control schedules.

AT-07 is the dormitory of a private school with an independent energy-supply system (electricity and heat). It belongs to the fire brigade and is part of a campus supplied by an independent and self-sufficient energy system based on a combined heat-and-power plant fuelled by liquid gas. It was renovated due to the age of the building. For this purpose, the curtain-type reinforced concrete façade was demolished and provided with a new, composite thermal insulation system with an integrated photovoltaic façade. The windows were also replaced by new, plastic–aluminium constructions. Energy consumption was further reduced by targeted energy monitoring and consumption optimization, including self-consumption from the PV system installed not only in the dormitory but throughout the campus, without any loss of performance or restrictions on use.

AT-08 is a small, community centre and seminar building in a rural municipality; it was completely renovated and partly rebuilt. The user profile is partly unpredictable because the building is used for community activities on a regular basis, such as choir rehearsals, but it is also sometimes rented to third parties. The renovation concept was to create a building with a high storage mass and an extremely energy-efficient building envelope, which reacts slowly to thermal changes and is robust in operation, i.e., the effort for operation is very low in terms of maintenance and repair. The number of different technical building systems was deliberately reduced as much as possible. Ventilation is through windows in the open roof space, which are opened with motors and let hot air out through the chimney effect. In addition, windows and a large door on the ground floor can be manually opened for ventilation. The cooling-energy demand can be managed by means of opening windows and through the large volume: the average room height is 4.5 m. Solar gains are very low; only internal gains have to be managed. No active cooling system is needed. The building is connected to a biomass district-heating system that is operated by a cooperative, and the building owner is a member of this cooperative. There are other buildings on the property that use a solar thermal plant. If all these buildings and systems were analysed together, different optimization potentials would be identified, especially in connection with the free-standing PV plant on the property that is 30 years old and will need replacing soon.

AT-09 is a multi-unit residential building where apartments are owned by different individuals (co-ownership, condominium). The building was renovated many years ago. The oil boiler was replaced by a district heating connection and the façade was repaired: a thin layer of insulation was partially applied. Partial measures were also carried out on the electrics. Over time, the owners have replaced windows on their own initiative. There have been changes of use, e.g., a shop was abandoned and converted into a flat. No improvements have yet been made to the roof; repair work is also expected here. The roof would be suitable for a PV system, considering potential shadows cast by objects in the vicinity. There are several condominiums of the same type in this location which are all managed by the same facility-management company. Extending the scope from the building to the neighbourhood opens up new perspectives in terms of possible solutions for improvement.

A sustainability assessment was conducted for building AT-07, which is the dormitory of a school. It is similar to residential use, but by definition the energy model for the EPC is calculated according to the rules valid for the respective type of non-residential building and is thus more detailed.

For the analysis, the provided guideline was used; however, it was adjusted, as described in table 14.

Table 14. Methods used for AT-07

Used approach	Level 2	Level 3
Indicator 1.1 Use stage energy performance	yes	--
Indicator 1.2 Lifecycle Global Warming Potential	yes	--
Indicator 4.2 Time outside of thermal comfort range	--	--
Indicator 6.1 Lifecycle costs	yes	--

Primary energy use reporting at Level 2 (indicator 1.1 use stage energy performance) is based on the energy model developed for the EPC. Primary energy factors are taken from OIB Guideline 6 (2019), which prescribes the factors to be used. Specific factors are not available but could be applied, for example, if the electricity is delivered by a Renewable Energy Community (according to the Renewable Energy Directive) where specific conditions are known. The table presenting the results is adjusted compared with the original version provided for the analysis to consider the joint preparation of domestic hot water and space heating, which can be found very often in Austria. In future, due to the highly efficient building envelopes of new buildings, large savings potentials are identified in the area of domestic hot-water supply and in decoupling it from space heating, at least during the warm period where no space heating is needed.
In the EPC calculated with the approved EPC software ETU Hottgenroth, the primary energy numbers are not available per energy service, but only as a total of the delivered energy, which also includes “electricity for other uses” as a default value.

The **quantification of the Global Warming Potential (GWP)** (indicator 1.2 Lifecycle Global Warming Potential) is done as required by the Klimaaktiv declaration. Klimaaktiv is the official voluntary green-building assessment scheme of the Austrian government and builds on the EPC, extending the scope towards additional indicators such as GWP and lifecycle cost assessment. It includes a lifecycle assessment (LCA) with the calculation of the GWP of the building envelope of the respective zone the EPC refers to. In this case, the EPC refers to the first and second floors, while the ground floor is occupied by a different type of non-residential use and would need a separate EPC. Thus, the basement is not considered in the GWP calculation presented below. The embodied GWP of technical building systems is not yet required on a regular basis and thus not available.

For the Klimaaktiv declaration, usually the LCA-Tool eco2soft is used, which is a service of baubook GmbH. This company provides and maintains the building products and material database called “baubook” containing all the relevant information according to an LCA methodology. The Baubook database (material library) is also connected with the EPC software calculation programmes, and the GWP of the thermally relevant structure is automatically calculated. However, as thermally irrelevant structures are not necessarily considered in the EPC (such as the floors between heating spaces), additional calculations might be needed if the full picture regarding the GWP of building materials relevant for the respecting building zone is to be provided.

It is hardly realistic to introduce a different method of GWP calculation connected with the EPC, because Klimaaktiv was introduced more than 20 years ago, it is widespread and became part of the housing-subsidy schemes of the provinces. However, currently, further developments of eco2soft in the direction of the BIM and a calculation with Gabi-based data are in preparation.[1] Such efforts would need to be combined with a possible further development of methodological GWP calculation approaches as part of Klimaaktiv.

Regarding a **lifecycle cost assessment**, there are two approaches in use which are in line with the given standards: a full lifecycle cost assessment, and an energy-related lifecycle cost assessment. In

[1] https://www.baubook.info/en/tools/eco2soft-life-cycle-assessment-of-buildings?set_language=en (30.06.2023)

connection with the EPC, the energy related lifecycle cost assessment is made for comparing renovation options, mainly to inform about the investor-user dilemma (high investment cost results in reduced energy costs over time). There is a software module called "Energieberater" that can be combined with the EPC calculation software. It contains standard values that can be replaced by specific values, and it calculates and compares renovation options automatically.

A full lifecycle cost calculation is usually made during the design phase for large projects where the client specifies the system boundaries, the data and calculation method to be used, and to receive comparable results for the decision making, which option to choose to proceed with.

4.2.1 Outcomes of the SRI and sustainability assessment for selected buildings

The following tables (Table 15 and Table 16) show the results of the assessments made according to default method A and default method B.

Table 15. Outcomes of the SRI assessment for selected buildings in Austria - default method A

TIMEPAC Code	Building usage	Data from	SRI score	Key functionality 1 score - building	Key functionality 2 score - user	Key functionality 3 score - grid
AT-01	Residential	EPCs, technical reports, site visits, interviews	33%	25%	28%	47%
AT-04	Residential		36%	40%	33%	33%
AT-06	Educational		13%	13%	25%	0%
AT-07	Dormitory (residential/ educational)		36%	41%	36%	31%
AT-08	Educational		7%	11%	10%	0%
AT-09	Residential		20%	11%	15%	34%

Table 16. Outcomes of the SRI assessment for selected buildings in Austria - default method B

TIMEPAC Code	Building usage	Data from	SRI score	Key functionality 1 score - building	Key functionality 2 score - user	Key functionality 3 score - grid
AT-01	Residential	EPCs, technical reports, site visits, interviews	21%	30%	23%	10%
AT-04	Residential		26%	33%	30%	15%
AT-06	Educational		13%	17%	23%	0
AT-07	Dormitory (residential/ educational)		30%	35%	29%	25%
AT-08	Educational		7%	10%	10%	0
AT-09	Residential		13%	18%	21%	0

The results of analysis of sustainability indicators for building AT-07 are presented below: first, Indicator 1.1 Use stage energy performance, second, Indicator 1.2 Lifecycle Global Warming Potential, and third, Indicator 6.1 Lifecycle costs (Table 17 and 18).

Areas: gross floor area: 773 m^2, conditioned floor area: 618 m^2. The conditioned floor area corresponds with the useful floor area used for normalising the Level(s) indicators.

Table 17. Delivered energy use assessment at level 2 for building AT-07

Building service	Energy need	System eff.	Energy carrier	Delivered energy per energy carrier	Non-renewable primary energy		Renewable primary energy		Total primary energy	
	kWh/a.	Decimal	Text	kWh/a.	Factor	kWh/a.	Factor	kWh/a.	Factor	kWh/a.
Heating	23,295	CHP plant	Natural gas	39,210	1.10	43,131	0.00	0.00	1.10	43,131
Hot water	19,468									
Cooling	14,801	No active cooling system		0						
Ventilation	Natural ventilation windows			0						
Lighting	9,770	Grid supply	Electricity	9,770	1.02		0.61		1.63	15,925
Exported renewable energy	n/a	n/a								
Overall	67,334			48,980		43,131				59,056

Table 18. Energy-performance assessment at level 2: results for building AT-07

Services	$kWh/m^2/a.$
L2.1 EPBD services non-renewable primary energy self-used (mandatory)	96
L2.2 EPBD services renewable primary energy self-used (optional)	0
L2.3 EPBD services total primary energy self-used (optional)	96
L2.4 Exported renewable primary energy (mandatory)	0
L2.5 EPBD services non-renewable primary energy balance (mandatory)	96
L2.6 Non-EPBD services non-renewable primary energy self-used (optional)	--
L2.7 Non-EPBD services renewable primary energy self-used (optional)	--
L2.8 Non-EPBD services total primary energy self-used (optional)	--
L2.9 Total primary energy self-used (optional	--
L2.10 Total primary energy balance (optional)	--

In terms of the Lifecycle Global Warming Potential, the table 19 shows the results for the building structure of the relevant EPC zone, excluding the embodied GWP for technical building systems, and excluding the GWP for building use. The GWP is calculated for a period of 100 years (the building's lifetime) and includes the repair and exchange cycles of the building components according to the lifetime catalogue.

Table 19. Reporting the results of assessment 1.2 at level 2 for building AT-07: GWP of materials

	Unit	Total of covered stages	Product (A1-3)	Construction process (A4-5)	Use stage (B1-7)	End of life (C1-4)	Benefits and loads beyond the system boundary (D)
			Covered : A1-3	Not covered	Covered : B1-4	Not covered	no
(1) GWP - fossil	kg CO_2 eq						
(2) GWP - biogenic	kg CO_2 eq						
GWP - (1) + (2)	kg CO_2 eq	217,213 kg 351 kg/m^2					
(3) GWP - Land use and land use change	kg CO_2 eq						
GWP - (1) + (2) + (3)	kg CO_2 eq						

In terms of the total CO_{2eq} from energy building use, the calculation results are presented in the tables 20 and 21. Energy-carrier-specific CO_{2eq} factors are taken from OIB Guideline 6 (2023), which is the official document for EPBD transposition in Austria (https://www.oib.or.at/sites/default/files/oib-rl_6_ausgabe_mai_2023.pdf). Two ways are presented to show the large difference in results, which depends on the choice of emission factor.

Table 20. Reporting the results of assessment 1.2 at level 2 for building AT-07: GWP of energy services - emission factor 1

Energy service	kWh/a	Energy carrier specific CO_{2eq} factor		CO_{2eq}
Heating	39,210	Heat from highly efficient CHP	0.067 kg/kWh	2,627.07 kg/a
Lighting	9,770	Electricity delivery average	0.156 kg/kWh	1,524.12 kg/a
Total	48,980			4,151.19 kg/a
				6.72 kg/m²a
			100 years	672 kg/m²

Table 21. Reporting the results of assessment 1.2 at level 2 for building AT-07: GWP of energy services - emission factor 2

Energy service	kWh/a	Energy carrier specific CO_{2eq} factor		CO_{2eq}
Heating	39,210	Heat from non-renewable district heating	0.193 kg/kWh	7,567.53 kg/a
Lighting	9,770	Electricity delivery average	0.156 kg/kWh	1,524.12 kg/a
Total	48,980			9,091.65 kg/a
				14.71 kg/m²a
			100 years	1,471 kg/m²

Table 22 shows the results for the lifecycle cost calculation made for B use stage with the objective to compare renovation options in terms of lifecycle costs. Consideration period: thermal insulation 30 years, building services 30 years. All the factors' default values were used as offered by the calculation programme (ETU Hottgenroth energy advisory module for developing renovation concepts, additional module in combination with EPC calculation).

Table 22. Assessment results for reporting indicator 6.1 at level 2 (Use stage) building AT-07

	Status before renovation	Renovation concept (envelope, heating, lighting, PV)	Insulation of building envelope (windows, walls)
Investment costs in €/a m²	0	5,251	3,991
Consumption and maintenance costs for building services in €/a	26,218	8,042	20,216
Income from PV power feed-in in €/a m²	0	-329	0
Reserve for maintenance of value in €/a m²	5,504	253	1,513

	Status before renovation	Renovation concept (envelope, heating, lighting, PV)	Insulation of building envelope (windows, walls)
CO_2 follow-up costs in €/a (100 €/tCO_2)	4,802	1656	3,424
Annual cost (30 years)	36,524	14,873	29,144
Annual cost in €/m²	59	24	47

4.2.2 Extraction of energy and flexibility measures and integration of the SRI and sustainability indicators in EPC

Legal document and Independent Control System: The EPC is a legal document that has to comply with the energy performance's minimum requirements and other aspects prescribed by law. The Independent Control System according to EPBD Article 18 plays an important role in securing the quality of the EPC as a policy instrument. This is essential to build confidence in the EPC and to achieve the intended impact on the market, which is the conversion of the building stock to nearly zero-energy buildings and eventually zero-emission buildings. From this perspective, the integration of the SRI into the EPC seems impossible, as it is unclear how the currently qualitative approach should be dealt with during quality-control and legal checks. A similar argument can be made for the lifecycle cost assessment, the results of which are difficult to verify because of the freedom the methodology gives the user. Thus, integration of the SRI and sustainability indicators in the EPC would rather be interpreted as creating an informative annex to the legally binding document.

Technical building systems: In Austria, the EPC has focused on the energy efficiency of the building envelope, which is absolutely justified due to the predominance of the cold season and the heating-energy demand. However, with the increasing efficiency of the building envelope, especially in new buildings due to legal requirements, technical building services have become more important to achieve further efficiency gains and greenhouse-gas savings. In the current versions of the officially approved EPC calculation programmes, technical building systems and BACS are considered, but a greater level of detail would be desirable to better reflect the reality. A better documentation for the technical building systems is needed, which is currently mainly available from technical documentation, reports, on-site visits and interviews with the facility management and the building owner. There was an expectation that SRI could create some synergies here, as all technical building systems are addressed in the sense of the EBPD. However, it became apparent that very innovative approaches applied in highly energy-efficient buildings and at the neighbourhood level are hardly covered by the service catalogue. In summary, it is nearly impossible to create at least a qualitative documentation of the energy-supply system by selecting options from the service catalogue. Rather, we would have to define verification documents that contain quantitative and precise information and serve as evidence for the selection of certain options in the service catalogue.

Examples of areas not well covered by the current service catalogue and the definition of functionality levels:

- Storage of Domestic Hot Water (DHW): Buildings with very low transmission and ventilation losses through the envelope have a very low space-heating energy demand and a high savings potential in the area of domestic hot water. Efficiency strategies are to decentralize DHW production to reduce losses through pipes and the energy consumption for pumps, and to decouple DHW from space heating in summer. Furthermore, there is strict hygiene legislation to prevent problems with legionella, which must be considered.
- Domestic Hot Water: DHW supply together with space heating (micro-heating grid): the available options do not reflect the characteristics of the DHW supply in use in such buildings.

- Information to occupants and facility manager: It is clear why the facility manager would be interested in performance KPIs of the heating system, but it is not evident why occupants of a multi-unit residential building would be interested in such an indicator.
- An educational building (kindergarten) has a clear user profile (presence, occupancy, and temperature requirements), and there are services where a higher functionality level does not bring any advantage, e.g., H-04; or V-1a: occupancy detection would hardly result in any improvements, because there is a fixed presence schedule, and time programmes are sufficient.

4.2.3 Main gaps and recommendations

Gaps identified and recommendations are presented as input into the discussion below.

Comments regarding the SRI methodology

In the SRI assessment tool, there are services that affect the maximum score, even if the service is not applicable in the building. This feature of the methodology is not clear and needs more explanation. Depending on the thermal performance of the building envelope and the user profile, functionality levels and their scoring would need adaptations.

Method A is recommended for residential buildings, but some relevant features are deactivated compared with method B, although they can be relevant:

- mechanical ventilation (necessary for well-insulated buildings);
- some features related with PV generation, e.g., optimized self-consumption (relevant for buildings equipped with PV).

Observations regarding Method B:

- Cooling affects the maximum score, even if cooling is not mandatory for residential buildings and not needed because the building manages comfort without cooling;
- There are other features that affect the score but are an overkill for use in residential buildings (e.g., occupancy detection);
- It seems that the method assumes that the building runs only on electricity; some features do not fit well with district heating like the heat supply for space heating and domestic hot water.

In general, some measures and functionalities resulting in a high score are not easily applicable everywhere. For example, outside blinds are good for avoiding overheating, but pose a problem in windy regions like Vienna, when they go up due to wind but should be down due to sun. It can be much more efficient and convenient to use structural shading.

Regarding renovations, other types of information would be relevant in addition to the checklist the service catalogue represents, for example: is there space available for storage systems; when was the electrical system done and will need refurbishment?

SRI and identification of improvement potential

Analysis shows that a low SRI does not necessarily mean that the improvement potential in terms of energy efficiency and user comfort, convenience and health is high. The assessment of building AT-08 results in a low SRI, but this does not reflect the improvement potential in terms of energy efficiency, because higher flexibility would not make sense due to the way the renovation of the building was designed and the building is operated. However, in terms of grid flexibility, the scope of the assessment at the building level is too narrow; in the case of AT-08 all the buildings located on the property including the district heating system should be analysed together, to reveal the true potential of grid flexibility.

The SRI for building AT-07 does not reflect the potential for improvement, either. However, the reason is different: this building is not allowed to offer grid flexibility services due to the safety regulations that must be complied with. The situation would be similar to hospitals and other critical infrastructure. Therefore, any future application of the SRI would need to be specified for certain building uses and allow for exemptions. In general, it should be noted that very energy-efficient buildings in the same neighbourhood can be served by a micro-grid that provide heating and cooling based on a single-energy centre professionally operated by an ESCO. Some statements in the SRI assessment, e.g., about pumps, therefore refer to the whole system and not to the individual building under assessment.

Definition of Smartness

The SRI service catalogue in its current form is mainly a BACS checklist that was derived from European Standard EN 15232-1 Energy Performance of Buildings Part 1: Impact of Building Automation, Controls and Building Management. "Smartness" is limited to the equipment with building automation and control systems and neglects the concept of "smart" low-tech building. In the residential sector, especially, BACSs need to be simple and robust. User research has shown that only a small group of occupants is interested in smart technologies. Often, default settings remain unchanged and many functionalities unused. A housing association has explicitly changed its strategy from "smart" in terms of BACS functionality levels to "smart" in terms of a low-tech design concept. Problems were the short lifetime of components which were not used properly and a dependence on IT experts from facility management. In addition, the focus of the political discussion is on affordable housing, and additional costs are difficult to argue for, especially if savings cannot be proven.

Cost of Smartness

In general, this is the key question for building owners and investors, how much investment cost is needed to achieve the next functionality level, and how many savings can be generated from this investment. Currently, insufficient information is available to answer this request.

Definition of target groups

There is a need to better define who is the target group of which SRI aspect, who can influence which aspects, who pays, and who benefits. It seems that the scope of the individual building is not always the best choice to achieve overall optimisation. There is an interface with municipal development plans and neighbourhood development, for example, regarding the e-charging infrastructure, but also photovoltaic systems. Grid operators are interested in flexibility services, but need quantitative information about the potential of the building.

Sustainability indicators

Regarding sustainability indicators, one challenge is data availability, especially for the operational phase. It is recommended that the number of the metering point of the smart meter should be included in the EPC. Assessors should be given access to the data based on their professional license. For multi-unit residential buildings where EPCs at the apartment level do not exist, but the EPC is only issued for the entire building, root meters for each energy carrier in the entire building should be made mandatory and appear on the EPC. This will raise awareness about smart meters and their functions and will make access to consumption data much easier.

A lifecycle cost assessment (LCCA) is important to achieve an overall optimising in terms of investment cost, operational cost, and disposal cost. However, the consideration of disposal costs in dynamic methods has almost no effect on the calculation because, due to discounting, costs will be lower in the future. Furthermore, results are dominated by the assumed lifetime of components, but the lifetime depends on product quality, maintenance, and repair. Other important aspects are interest rate and inflation. Depending on the purpose of including the lifecycle cost indicator, supporting material is needed: a catalogue of components lifetime and how to use it (e.g., the technical life is not the same as the economic life in terms of tax depreciation; how to consider product quality and quality of maintenance); default values for interest rate and inflation; and other standardised input data. Such calculation results can inform the owner about the tendency of the economic impact of an investment in comparison with another one, and can be used for support programmes. However, if realistic information should be provided, specific products and maintenance and repair cycles must be considered as well as the real development of economic factors, which requires a dynamic approach in terms of regular updating of the LCCA, probably as part of the facility-management services.

4.3 Croatia

The SRI (Smart Readiness Indicator) calculation was performed for five buildings with different usage patterns. The data used for the calculation was derived from energy audits and interviews conducted with the building owners. Methods A and B with default domain weightings, along with tool variants 4.5 and 4.4, were utilized to assess the smart readiness of each building. Both methods considered various factors such as energy efficiency, connectivity, and the use of smart technologies to enhance the building's performance. By employing this approach, a comprehensive evaluation was conducted to determine the smart readiness of the buildings and identify areas for potential improvement. Table 23 shows the buildings that were selected for the analysis in this task.

Table 23. Overview of analysed Croatian buildings

TIMEPAC Code	Building type	Status
HR-01	Office building	Existing, after renovation
HR-02	Educational building - kindergarten	Existing
HR-03	Educational building - library	Existing
HR-04	Residential building – single family house	Existing
HR-05	Educational building – primary school	Existing

For HR-01, the building has all the domains present, and they have been evaluated. The main issues identified in the heating system include the absence of occupancy detection and variable-speed pump control, which affect its efficiency. Similarly, in the DHW (Domestic Hot Water) production, there is a lack of integration with renewable energy sources (RESs) and no provision for demand-based supply, leading to inefficiencies. The cooling system also faces challenges with the absence of occupancy detection and variable-speed pump control, impacting its performance. The ventilation system lacks advanced air-quality sensors and load-dependent compensation, hampering its effectiveness. Furthermore, the lighting system lacks central control, and the window shading controls are manual. There is no on-site electricity generation, and information regarding electricity consumption is not shared. The EV (EV) charging infrastructure is rudimentary and lacks optimization capabilities. Additionally, monitoring-and-control systems are deficient in fault predictions and demand forecasting. Overall, there is a lack of information available to occupants and facility managers regarding the building's systems. Furthermore, the low grid flexibility observed is primarily due to the limitations imposed by current legal restrictions, which offer minimal opportunities for monetizing flexibility through investment and savings.

For HR-02, the building has most of the domains present, and they have been evaluated. The main issues identified in the heating system include the absence of room temperature control, occupancy detection, variable-speed pump control, and a central monitoring-and-control system. In the DHW (Domestic Hot Water) production, there is no integration with renewable energy sources (RESs) and no provision for demand-based supply, with no centralized system in place. The cooling system is addressed through local split systems. Unfortunately, there is no ventilation system installed. In terms of lighting, there is no central control, dimming capability, or occupancy detection. Window shading controls are manual. The building does not have on-site electricity generation, and information regarding electricity consumption is not shared. Photovoltaic (PV) systems are not feasible due to legal restrictions. Moreover, there is no EV charging infrastructure available. Monitoring-and-control systems are almost non-existent, leading to a lack of information for occupants and facility managers. The building lacks grid flexibility, primarily due to the limitations imposed by current legal restrictions, which make it nearly impossible to monetize flexibility through investments and savings.

For HR-03, the building has most of the domains present, and they have been evaluated. The main issues identified in the heating system include the absence of room temperature control, occupancy detection, variable-speed pump control, and a central monitoring-and-control system. In the DHW (Domestic Hot Water) production, there is no integration with renewable energy sources (RESs) and no provision for demand-based supply, with no centralized system in place. The cooling system lacks occupancy detection, sequencing capabilities, and reporting features. There is no ventilation system installed. In terms of lighting, there is no central control, dimming capability or occupancy detection. Window shading controls are manual. The building does not have on-site electricity generation, and information regarding electricity consumption is not shared. Photovoltaic (PV) systems are not feasible due to legal restrictions, particularly for cultural heritage buildings. Moreover, there is no EV charging infrastructure available. Monitoring-and-control systems are almost non-existent, leading to a lack of information for occupants and facility managers. The building lacks grid flexibility, primarily due to the ratio between investment and savings, coupled with current legal restrictions that severely limit the possibilities of monetizing flexibility.

For HR-04, the building has most of the domains present, and they have been evaluated. The main issues identified in the heating system include the absence of room temperature control, occupancy detection and a central monitoring-and-control system. In the DHW (Domestic Hot Water) production, there is no provision for demand-based supply, and a centralized monitoring system is lacking. The cooling system lacks occupancy detection and reporting capabilities. There is no ventilation system installed. In terms of lighting, there is no central control or dimming functionality. Window-shading controls are manual. The building does not have on-site electricity generation, and information regarding electricity consumption is not shared. However, photovoltaic (PV) systems are a viable option. Additionally, there is no EV charging infrastructure available. Monitoring-and-control systems are rudimentary, leading to a lack of information for occupants. The building lacks grid flexibility primarily due to the ratio between investment and savings, compounded by current legal restrictions that limit the possibilities of monetizing flexibility.

For HR-05, the building has most of the domains present, and they have been evaluated. The main issues identified in the heating system include the absence of occupancy detection and a central monitoring-and-control system. In the DHW (Domestic Hot Water) production, there is no integration with renewable energy sources (RESs) and no provision for demand-based supply, with no centralized system in place. The cooling system is addressed through local split systems. The ventilation system is present in a few rooms but has rudimentary controls. Regarding the lighting system, there is no central control, dimming capability, or occupancy detection. Window shading controls are manual. The building does not have on-site electricity generation, and information regarding electricity consumption is not shared. Unfortunately, photovoltaic (PV) systems are not a viable option due to legal restrictions. Moreover, there is no EV charging infrastructure available. Monitoring-and-control systems are almost non-existent, leading to a lack of information for occupants and the facility manager. The building's grid flexibility is limited primarily due to the ratio between investment and savings, compounded by current legal restrictions that severely restrict the ability to monetize flexibility.

A sustainability assessment was conducted for building HR-01 because the most relevant documentation was available, including an energy audit, EPC (Energy Performance Certificate), monthly building energy model (BEM), hourly BEM, measurements, historical data on consumption and temperatures, BIM (Building Information Modelling) and design. An overview of the method used is provided in Table 24.

Table 24. Methods used for HR-01

Used approach	Level 2	Level 3
Indicator 1.1 Use-stage energy performance	-	yes
Indicator 1.2 Lifecycle Global Warming Potential		
Indicator 4.2 Time outside of thermal comfort range	yes	yes
Indicator 6.1 Lifecycle costs	-	yes, significant assumptions

4.3.1 Outcomes of SRI and sustainability assessment for selected buildings

The SRI (Smart Readiness Indicator) calculation results are presented in Table 25 and Table 26. The SRI scores are relatively low, with the scores being largely influenced by the year of construction or the most recent reconstruction. The key functionality 3, which relates to grid integration, has the lowest scores primarily due to legal restrictions and the absence of a market for flexibility. These factors greatly limit the building's ability to adapt and contribute to a more flexible grid system.

Table 25. Outcomes of SRI assessment for selected buildings in Croatia – default method A

TIMEPAC Code	Building usage	Data from	SRI score	Key functionality 1 score - building	Key functionality 2 score - user	Key functionality 3 score - grid
HR-01	Office	Energy audit reports, BEM, site visits, interviews	24%	15%	20%	38%
HR-02	Kindergarten		8%	7%	18%	0%
HR-03	Library		10%	8%	14%	7%
HR-04	Single-family house		11%	8%	18%	7%
HR-05	Primary school		19%	20%	19%	18%

Table 26. Outcomes of SRI assessment for selected buildings in Croatia – default method B

TIMEPAC Code	Building usage	Data from	SRI score	Key functionality 1 score - building	Key functionality 2 score - user	Key functionality 3 score - grid
HR-01	Office	Energy audit reports, BEM, site visits, interviews	30%	34%	37%	18%
HR-02	Kindergarten		9%	9%	13%	5%
HR-03	Library		7%	8%	9%	2%
HR-04	Single-family house		8%	8%	11%	4%
HR-05	Primary school		17%	21%	18%	11%

The SRI calculation methodology is straightforward and can be implemented efficiently. Most of the required data for the calculation are already collected as part of the energy-audit process, provided it has been conducted correctly. This means that a significant portion of the necessary information is readily available, simplifying the SRI calculation. However, for certain services or aspects, additional interviews or surveys might be required to gather specific data and ensure a comprehensive assessment. By combining the data from energy audits and supplementary interviews, a thorough SRI calculation can be conducted to evaluate the smart readiness of the building.

For sustainability indicators the results are shown below. Indicator 1.1 was calculated for level 3 using data from the BEM, the energy audit and the real energy consumption. The use-stage energy-performance indicator represents standard value that is commonly used when conducting energy auditing and an EPC assessment. Results are shown in Table 27, Table 28, Table 29 and Table 30.

Table 27. Delivered energy assessment for HR-01 - existing situation before energy renovation

Building service	Energy carrier	Delivered energy per energy carrier	Non-renewable primary energy		Renewable primary energy		Total primary energy	
		kWh/a.	Factor	kWh/a.	Factor	kWh/a.	Factor	kWh/a.
Heating	Heat	96,600	1.471	142,099	0.010	966	1.481	143,065
Heating	Electricity	19,400	1.181	22,911	0.433	8,400	1.614	31,312
Cooling	Electricity	29,150	1.181	34,426	0.433	12,622	1.614	47,048
Ventilation	Electricity	450	1.181	531	0.433	195	1.614	726
Hot water	Heat	37,400	1.471	55,015	0.010	374	1.481	55,389
Hot water	Electricity	490	1.181	579	0.433	212	1.614	791
Lighting	Electricity	40,850	1.181	48,244	0.433	17,688	1.614	65,932
Exported renewable energy	-	0	-	0	-	0	-	0
Overall		224,340	-	303,806	-	40,457	-	344,263

Table 28. Energy-performance assessment at level 3 results for building HR-01

Services	kWh/m^2/a.
L3.1 EPBD services non-renewable primary energy self-used	147.41
L3.2 EPBD services renewable primary energy self-used	19.63
L3.3 EPBD services total primary energy self-used	167.04
L3.4 Exported renewable primary energy	0.00
L3.5 EPBD services non-renewable primary energy balance	147.41
L3.6 Non-EPBD services non-renewable primary energy self-used	38.68
L3.7 Non-EPBD services renewable primary energy self-used (optional)	14.18
L3.8 Non-EPBD services total primary energy self-used (optional)	52.86
L3.9 Total primary energy self-used (optional)	219.90
L3.10 Total primary energy balance (optional)	219.90

Indicator 1.2 was not calculated. Although a significant amount of data is known about the building, and various available documentation can be used, the Lifecycle Global Warming Potential indicator also depends on databases of individual materials, activities and similar factors. Since the databases were neither available nor complete, it was not possible to even make a quality assumption. The calculation methodology is extremely complex, and significant steps are needed in the future, both in the development of the and in the development of the software tools, to simplify the calculation of the indicator.

Indicator 4.2, the time spent outside the thermal comfort range, can be easily calculated either from the hourly Building Energy Model (BEM) or from temperature measurements within the building. In TDS2, thermal comfort was calculated based on simulation data, resulting in a discomfort level of 0% for HR-01. Furthermore, the average indoor temperature of the building was cross-checked using historical data, and no time outside the comfort range was observed.

Table 29. Project-assessment results for reporting of indicator 4.2 of an assessment at level 3 for building HR-01

	Heating season	Cooling season
Operating temperature range (˚C)	18 - 24	22 - 28
Time out of range (%) - with mechanical heating/cooling	0	0

Indicator 6.1 Lifecycle costs was calculated from data available in TDS2 (economic validation of energy-efficiency measures) and rough estimates for unknown data (construction, destruction etc.), especially that the building was constructed 50 years ago and had one major renovation already. In conclusion, the methodology described in the annex was only loosely followed.

Table 30. Project-assessment results for reporting of indicator 6.1 at level 3 for building HR-01

Type of cost	Normalised cost by lifecycle stage (€/m^2/a.)		
	Product and construction stages	Use stage	End-of-life stage
Initial costs	40	0.01	5.00
Annual costs - energy and water	-	13.02	13.02
Annual costs - maintenance	-	2.91	3.72
Periodic costs	-	2.43	-
Global costs by lifecycle stage	40	18.37	21.74

4.3.2 Extraction of energy and flexibility measures and integration of the SRI and sustainability indicators in an EPC

An SRI (Smart Readiness Indicator) and an EPC (Energy Performance Certificate) can be easily integrated, as a significant portion of the data collected during an energy audit can be utilized for the SRI's calculation. In a way, the SRI and EPC complement each other, with the EPC defining the quality of the building and its technical systems, while the SRI focuses on the quality of the control systems. This integration allows for a comprehensive evaluation of the building's energy efficiency and smart readiness. By deriving possible energy-efficiency measures from both the EPC and SRI assessments, a cohesive improvement scenario can be developed. The emphasis is placed on all aspects, including efficiency, flexibility and comfort, to create a holistic and well-rounded process. It is essential for future buildings to be not only energy efficient, but also integrated with renewable energy sources, smart with grid communication capabilities, and designed to provide high levels of comfort. Table 31 showcases possible improvements and their corresponding influence on the SRI scores for the analysed buildings, further illustrating the potential for enhancing their smart readiness.

Table 31. Extracted energy and flexibility measures for buildings in Croatia and new SRI scores

TIMEPAC Code	Building usage	SRI score	Key impact	Energy and flexibility measures	New SRI score
HR-01	Office	30%	Flexible-grid office building	Installation of new building-monitoring-and-control system with demand/response functionalities and feedback to the occupants Installation of PV and battery system with advanced grid interaction Installation of new control elements and sensors for heating, cooling and ventilation system Installation of new speed-variable pumps Installation of new LED-lighting system with occupancy detection and central control Installation of new EV-charging station with advanced control systems and all system reports	76%
HR-02	Kindergarten	9%	Smart-energy kindergarten	Installation of control elements and sensors for heating system Installation of new variable-speed pumps Installation of new LED-lightning system with dimming control	41%
HR-03	Library	7%	Energy-information library	Installation of control elements and sensors for heating system Installation of remote energy meters Installation of central monitoring system and info monitor for occupants	42%
HR-04	Single-family house	8%	Smart home	Installation of PV (5 kW) Installation of control elements and sensors for heating and cooling systems Installation of new LED-lightning system with dimming control	37%

HR-05	Primary school	17%	Smart light-and-heat school	Linking control elements and sensors for heating system Installation of sensors in LED-lighting system.	31%

Also, based on the proposed "smart-renovation scenario" sustainability indicators for building HR-01 are calculated again and the results are given in Table 32, Table 33, Table 34 and Table 35.

Table 32. Delivered energy assessment for HR-01 –after energy renovation

Building service	Energy carrier	Delivered energy per energy carrier	Non-renewable primary energy		Renewable primary energy		Total primary energy	
		kWh/a.	Factor	kWh/a.	Factor	kWh/a.	Factor	kWh/a.
Heating	Heat	88,872	1	130,731	0	889	1	131,619
Heating	Electricity	6,290	1	7,429	0	2,724	2	10,153
Cooling	Electricity	9,452	1	11,162	0	4,093	2	15,255
Ventilation	Electricity	146	1	172	0	63	2	235
Hot water	Heat	34,408	1	50,614	0	344	1	50,958
Hot water	Electricity	159	1	188	0	69	2	256
Lighting	Electricity	13,245	1	15,643	0	5,735	2	21,378
Exported renewable energy	Electricity	7,339			0	0	0	0
Overall		152,572	-	215,939	-	13,916	-	229,855

Table 33. Energy-performance assessment at level 3 results for building HR-01 - after energy renovation

Services	kWh/m²/a.
L3.1 EPBD services non-renewable primary energy self-used	104.77
L3.2 EPBD services renewable primary energy self-used	6.75
L3.3 EPBD services total primary energy self-used	111.53
L3.4 Exported renewable primary energy	3.56
L3.5 EPBD services non-renewable primary energy balance	101.21
L3.6 Non-EPBD services non-renewable primary energy self-used	38.68
L3.7 Non-EPBD services renewable primary energy self-used (optional)	14.18
L3.8 Non-EPBD services total primary energy self-used (optional)	52.86
L3.9 Total primary energy self-used (optional)	164.39
L3.10 Total primary energy balance (optional)	160.82

Table 34. Project-assessment results for reporting of indicator 4.2 of an assessment at level 3 for building HR-01 – after energy renovation

	Heating season	Cooling season
Operating temperature range (°C)	18 - 24	22 - 28
Time out of range (%) - with mechanical heating/cooling	0	0

Table 35. Project-assessment results for reporting of indicator 6.1 at level 3 for building HR-01 – after energy renovation

Type of cost	Normalised cost by lifecycle stage (€/m²/a.)		
	Product and construction stages	Use stage	End-of-life stage
Initial costs	75	0.02	7.00
Annual costs - energy and water	-	8.85	13.02
Annual costs - maintenance	-	3.00	3.72
Periodic costs	-	2.50	-
Global costs by lifecycle stage	75	14.37	23.74

It should be noted that the proposed improvements are significant and might not be economically viable in the current context. While the identified measures and enhancements aim to improve the building's performance and smart readiness, the costs associated with implementing these changes can pose challenges from a financial perspective. The high investment requirements need to be carefully considered, taking into account the return on investment and feasibility within the existing economic framework. A cost-benefit analysis and long-term planning are crucial to evaluate the potential economic viability and determine the most appropriate course of action. It is essential to strike a balance between the desired improvements and the financial feasibility to ensure a sustainable and realistic approach in the future.

When considering the integration of sustainability indicators in Energy Performance Certificates (EPCs), the feasibility depends on the specific indicator in question. Indicator 1.1, which relates to primary energy calculations, is the easiest to integrate and is already included in the EPC process in certain countries like Croatia. On the other hand, Indicator 1.2, which involves BIM (Building Information Modelling) and construction libraries, can be calculated if such resources are available, but its added value in the EPC is questionable. For Indicator 4.2, which measures the time spent outside the thermal comfort range, integration is possible if the EPC shifts from a monthly calculation model to an hourly one. Lastly, Indicator 6.1, which pertains to lifecycle costs, can be calculated if the BIM and comprehensive cost libraries are accessible. However, it should be noted that this indicator requires regular updates on a yearly basis, as costs are subject to constant changes. Implementing this indicator effectively would involve the development of specialized tools and an online storage system to ensure accurate and up-to-date cost information.

4.3.3 Main gaps and recommendations

The integration of Energy Performance Certificates (EPCs), a Smart Readiness Indicator (SRI), and sustainability indicators is feasible and can provide a more comprehensive understanding of a building's performance, leading to better-informed improvement strategies. However, a major challenge lies in the integration of different tools and methodologies utilized for these assessments. Establishing a common methodology is possible by employing complete Building Information

Modelling (BIM) that can be transformed into a Building Energy Model (BEM). To facilitate specific calculations for sustainability indicators, additional databases are necessary. The SRI calculation should be integrated with the BEM, and EPC generation should also be linked to the BEM. The main gaps in this process are currently the lack of an integrated or compatible tools, the availability of the required databases, and the high cost associated with obtaining an EPC. It is recommended to integrate the SRI and EPC processes, with the possibility of incorporating certain sustainability indicators as well. This integration should not significantly increase the overall cost, ensuring a more cost-effective and streamlined approach to assessing a building’s performance.

4.4 Cyprus

The five buildings for our study were selected carefully to provide a comprehensive overview of the energy performance and sustainability challenges in Cyprus. Among these, we focused on three primary schools, representing Cyprus's predominant school type. These schools exemplify the challenges faced by educational institutions in the region. Additionally, we included two office spaces strategically chosen to mirror the common scenario of older office buildings found in city centres, often undergoing minor renovations. By encompassing these diverse building types, our selection allows us to explore tailored solutions that address the unique demands and characteristics of each, offering valuable insights into enhancing energy efficiency, indoor environmental quality, and overall sustainability. Table 36 shows the buildings that were selected for the analysis in this task.

Table 36. Overview of analysed buildings in Cyprus

TIMEPAC Code	Building type	Status
CY-01	Primary school Aglatzia	Existing, not renovated
CY-02	Primary school Lakatamia	Existing, not renovation
CY-03	CEA offices Building 1	Existing, after renovation
CY-04	CEA offices Building 2	Existing, after renovation
CY-05	Primary school Larnaca - Leivadia	Existing, not renovated

For Cyprus, the study focused on five buildings: two office spaces and three schools. The office spaces were situated in the city centre. The schools represented primary-education levels, across the island. The selected buildings varied in terms of age, construction materials, and energy-consumption profiles, providing a comprehensive representation of the building stock in Cyprus.

For office spaces (CY-03 and CY-04) we have access to hourly energy consumption data, allowing for detailed monitoring and analysis of energy-usage patterns. Additionally, both buildings have an automatic air purifier that continuously monitors air quality to ensure a healthy indoor environment.

However, one notable finding is that most features in the office spaces have minimum automated functions, typically limited to simple on/off controls. For instance, air-ventilation and air-conditioning systems (both for cooling and heating) have basic automation capabilities. This indicates the potential for further optimizing building performance through advanced automation and energy-management solutions.

The assessment also identified opportunities for implementing energy-saving measures, such as upgrading lighting systems to advanced sensors and dimming controls and integrating smart HVAC controls to adjust temperature settings based on occupancy and environmental conditions dynamically. These measures can enhance energy efficiency, comfort and indoor air quality, while reducing overall energy consumption.

Furthermore, it should be noted that the office buildings have installed solar panels to produce renewable energy, and from the interviews, it was revealed that electric charging will be added in the near future to enhance sustainability performance.

For the three schools assessed (CY-01, CY-02, CY-05) there are some differences in the Smart Readiness. For CY-05, the SRI and sustainability assessment outcomes for Leivadia Primary school indicate commendably lower energy consumption and corresponding CO_2 emissions than other Cypriot public schools. These lower consumptions can be attributed to several factors. The school's compact building design significantly reduces heat-transfer losses, particularly from the buildings' envelope and distribution systems. Moreover, insulated roofing and replacing iron-framed windows contribute to more suitable internal conditions, reducing energy consumption for thermal comfort. Additionally, the reduced usage of the school premises compared to other school buildings further justifies the lower energy consumption.

Both indoor and outdoor lighting systems are operated with basic on/off functions, lacking advanced automation. Although the outdoor lighting system is rarely used due to the school's predominantly daytime activities, the indoor lighting system would benefit from the implementation of advanced sensors and controls to optimize energy usage based on occupancy and natural lighting conditions.

Regarding ventilation, the school operates fans for 3 to 4 hours per day, considering each classroom’s orientation and daily occupation schedule. This practice shows a level of consideration for energy efficiency and thermal comfort. However, there might be potential for further optimization by introducing more dynamic ventilation strategies, such as demand-controlled ventilation, to match airflow rates with occupancy and indoor air-quality needs more precisely.

Notably, active cooling is not provided in any of the main classrooms, aligning with the school's design standards. This design choice demonstrates a commitment to passive-cooling solutions, which could be enhanced by optimizing the building-envelope design and implementing shading strategies to reduce heat gain.

To assess the buildings using Level(s) indicators, CY-03 was considered, as the most data were available, including an energy audit, EPC and BIM data. The current condition of the building was considered when evaluating indicator 1.1 (energy performance during the use stage) and indicator 4.2 (instances of being outside the thermal comfort range). The renovation status was considered for evaluating indicator 6.1 (lifecycle costs). An overview of the methods used is provided in Table 37.

Table 37. Methods used for CY-04

Used approach	Level 2	Level 3
Indicator 1.1 Use-stage energy performance	yes	--
Indicator 1.2 Lifecycle Global Warming Potential	--	--
Indicator 4.2 Time outside of thermal comfort range	yes	--
Indicator 6.1 Lifecycle costs	yes	--

4.4.1 Outcomes of the SRI and sustainability assessment for selected buildings

The SRI calculation results for our buildings are presented in Table 38 (default method B). The obtained SRI scores indicate relatively low levels, mainly influenced by the overall smart readiness status of buildings in Cyprus. Notably, Key functionality 3, which pertains to grid integration, demonstrates the lowest scores primarily due to legal restrictions and the absence of a market for flexibility. These significant factors greatly hinder the buildings' potential to adapt and actively contribute to a more flexible and dynamic grid system.

The SRI scores and associated functionalities reflect the current state of these buildings concerning their smart readiness and energy performance. It is important to note that these scores result from a data-collection process, drawing from multiple sources, including EPCs, energy audits, energy-consumption data, on-site visits, and in-depth interviews with stakeholders. Additionally, advanced Building Information Modelling and Building Energy Modelling (BIM/BEM) were employed to enhance the accuracy of the assessments.

The subsequent four tables (Table 39, Table 40, Table 41 and Table 42) are dedicated specifically to Building CY-03, a renovated office space located in the city centre. These tables provide detailed insights into the building's energy performance and renovation potential. Table 39 outlines the delivered energy assessment for CY-03 in its existing state before any energy-renovation measures.

Table 40 presents the energy-performance assessment at level 2 results for the same building in its pre-renovation condition. Indicator 4.2, the time spent outside the thermal comfort range, was calculated from the hourly BEM model, see Table 41. Lastly, Table 42 summarises the project-assessment results, providing a normalised cost by use stage.

Table 38. Outcomes of SRI assessment for selected buildings in Cyprus - default method B

TIMEPAC Code	Building usage	Data from	SRI score	Key functionality 1 score - building	Key functionality 2 score - user	Key functionality 3 score - grid
CY-01	Primary school Aglatzia	EPC, energy audit, energy consumption data, site visit and interviews, BIM/BEM	4%	5%	6%	0%
CY-02	Primary school Lakatamia		4%	5%	7%	0%
CY-03	CEA offices Building 1		20%	19%	40%	0%
CY-04	CEA offices Building 2		13%	8%	33%	0%
CY-05	Primary school Leivadia		4%	5%	6%	0%

Table 39. Delivered energy assessment for CY-03- existing situation before energy renovation

Building service	Energy carrier	Delivered energy per energy carrier	Non-renewable primary energy		Renewable primary energy		Total primary energy	
		kWh/a.	Factor	kWh/a.	Factor	kWh/a.	Factor	kWh/a.
Heating	Electricity	6,798.9	2.7	18,357.03	0	0	2.7	18,357.03
Cooling	Electricity	10,198.35	2.7	27,535.54	0	0	2.7	27,535.54
Ventilation	Electricity	906.52	2.7	2,447.60	0	0	2.7	2,447.60
Hot water	Electricity	679.89	2.7	1,835.70	0	0	2.7	1,835.70
Lighting	Electricity	4,079.34	2.7	11,014.22	0	0	2.7	11,014.22
Exported renewable energy	-	0	-	0	-	0	-	0
Overall		22,663	2.7	61,190.10	-	0	-	61,190.10

Table 40. Energy-performance assessment at level 2 results for building CY-03 – existing situation before energy renovation

Services	kWh/m^2/a.
L3.1 EPBD services non-renewable primary energy self-used	416
L3.2 EPBD services renewable primary energy self-used	0
L3.3 EPBD services total primary energy self-used	416
L3.4 Exported renewable primary energy	0
L3.5 EPBD services non-renewable primary energy balance	416
L3.6 Non-EPBD services non-renewable primary energy self-used	n/a
L3.7 Non-EPBD services renewable primary energy self-used (optional)	n/a
L3.8 Non-EPBD services total primary energy self-used (optional)	n/a
L3.9 Total primary energy self-used (optional)	n/a
L3.10 Total primary energy balance (optional)	n/a

Table 41. Project-assessment results for reporting indicator 4.2 of an assessment at level 2 for building CY-03 – existing situation before energy renovation

	Heating season	Cooling season
Operating temperature range (°C)	19 - 21	23 - 25
Time out of range (%) - with mechanical heating/cooling	0	0

Table 42. Project-assessment results for reporting of indicator 6.1 at level 2 for building CY-03 – existing situation before energy renovation

Type of cost	Normalised cost by lifecycle stage (€/m^2/a.)		
	Product and construction stages	Use stage	End-of-life stage
Initial costs	-	-	-
Annual costs - energy and water	-	2.89	-
Annual costs - maintenance	-	47.16	-
Periodic costs	-	0	-
Global costs by lifecycle stage	-	50.05	-

4.4.2 Extraction of energy and flexibility measures and integration of the SRI and sustainability indicators in EPC

The assessment identified key energy and flexibility measures for each building. These include installing smart meters and energy-management systems, upgrading lighting fixtures to LED, implementing renewable energy systems, and optimizing HVAC controls. Integrating the SRI and sustainability indicators in existing EPC tools enabled a comprehensive evaluation of the buildings' performance, allowing for targeted energy-saving strategies and sustainability improvements. The schools could benefit from optimized ventilation systems, daylight utilization, and better insulation to improve energy efficiency and indoor environmental quality. The assessment also demonstrated the feasibility of integrating the SRI and sustainability indicators into existing EPC tools, empowering building managers to access valuable data for decision-making and implementing tailored energy-efficiency measures (Table 43).

Table 43. Extracted energy and flexibility measures for buildings in Cyprus and new SRI scores

TIMEPAC Code	Building usage	SRI score	Key impact	Energy and flexibility measures	New SRI score
CY-01	Primary school Aglatzia	4%	Introduction/Improvement of automated features focused on air-quality and lighting	HVAC interaction control Feedback reporting information for energy use Automated window control Automated artificial lighting control Air-flow and air-temperature control	44%
CY-02	Primary school Lakatamia	4%	Introduction/Improvement of automated features focused on air-quality and lighting	HVAC interaction control Feedback reporting information for energy use Automated window control Automated artificial lighting control Air-flow and air-temperature control Simple plug EV charge	44%
CY-03	CEA offices Building 1	20%	Upgrade of the lighting systems General improvement of the BACS systems Smart EV charging station Upgrade of the building envelope (insulation) and adding dynamic and smart features Improved user feedback	High functionality features - high-cost solution	49%
CY-04	CEA offices Building 2	13%	Smart EV charging Built envelope smart features - shading systems / night cooling Improved user feedback	Low-functionality features/ lower-cost interventions and updates	29%

TIMEPAC Code	Building usage	SRI score	Key impact	Energy and flexibility measures	New SRI score
CY-05	Primary school Leivadia	4%	Improvement of automated features focused on air-quality and lighting (highest functionality level of the same features in other schools)	HVAC interaction control Feedback reporting for energy use Automated window control Automated artificial lighting control Air-flow and air-temperature control EV charge	68%

For the three schools in Cyprus, and public schools in the region in general, it has become evident that there is a pressing need for substantial improvements. These observations were validated through comprehensive interviews conducted during the assessment process. The primary concerns voiced by school stakeholders included air-quality issues, with occupants often experiencing a 'stuffy' atmosphere. Additionally, a significant challenge arises from the substantial energy consumption required to heat and cool classrooms during extreme temperatures, indicating insufficient insulation. As recommended in the table above, the integration of smart measures holds the potential to address these critical issues effectively. By implementing advanced control systems, energy-efficient solutions, and enhanced monitoring, we can contribute to creating healthier and more comfortable learning environments, while reducing the energy demand of these facilities.

In the assessment of schools CY-01 and CY-02, a deliberate choice was made to select features and functionality levels with a lower budget in mind. This approach was taken to ensure that the proposed enhancements were feasible and practical for schools operating within constrained budgets. By opting for lower functionality levels, we aimed to demonstrate how even modest investments can yield tangible improvements in the SRI scores and buildings' performance. In contrast, in the case of CY-05, we intentionally selected high functionalities to showcase the potential impact of more substantial budget allocations. This choice highlights how the same set of features, when implemented with greater resources, can significantly enhance the SRI score and contribute differently to building readiness and smart capabilities. These strategic selections serve as valuable examples of tailoring SRI improvements to budget constraints, while also showcasing the transformative potential of increased investment in building upgrades.

For assessing the office buildings CY-03 and CY-04, two distinct scenarios were intentionally crafted to showcase the flexibility and adaptability of enhanced EPCs. In the case of CY-03, an approach was taken to incorporate high-level functionality features, resulting in a higher-cost solution. This scenario exemplifies the potential of integrating advanced technologies and smart systems to maximize building readiness and capabilities, albeit at a higher cost. Conversely, for CY-04, a scenario was chosen that employed more features but at a low-to-medium functionality level. This choice was deliberate, emphasizing a lower-cost and more accessible solution that can be implemented relatively easily. The aim of presenting these two scenarios is to demonstrate how tailored enhancements can align with varying budget constraints, offering a spectrum of possibilities for optimizing building operations using enhanced EPCs.

4.4.3 Main gaps and recommendations

Despite the positive outcomes, some challenges were encountered during the assessment process. One main gap identified was the lack of historical data on certain buildings, which limited the depth of the analysis. Additionally, the building managers' familiarity with the SRI and sustainability indicators varied, indicating the need for awareness and training initiatives. To address these gaps, it is recommended to collaborate with building managers, energy consultants, and relevant authorities to establish a central database for building-performance data. Training programs and workshops should be organized to familiarize stakeholders with the SRI and sustainability concepts and encourage their active involvement in optimizing building operations. Furthermore, ongoing monitoring and data collection are recommended to track the effectiveness of implemented measures and inform future energy-efficiency strategies.

4.5 Italy

Table 44 shows the buildings selected for the analysis in the current task. These buildings were analysed with SRI Excel tool version 4.5, applying default method A and default method B.

IT-15 was selected to conduct the assessment through Level(s) indicators.

Table 44. Overview of analysed Italian buildings

TIMEPAC Code	Building category	Status
IT-09	Multi-unit residential	New construction
IT-11	Multi-unit residential	Existing, after renovation
IT-12	Educational	Existing
IT-13	Educational	Existing
IT-15	Educational	Existing

IT-09 is a complex consisting of two multi-residential buildings located in Borgomanero, Novara, in the northern part of Italy. The buildings have three and four above-ground floors, respectively, with a total net floor area of 340 and 480 m^2.

These buildings were constructed around ten years ago with the intention of meeting passive-house standards, resulting in a high-performance opaque envelope. The average *U*-value for the vertical opaque portion is notable, even by current Italian standards, with specific values of 0.17 W/(m^2K) for the opaque part and 0.98 W/(m^2K) for the transparent part. Both buildings are equipped with a central air-conditioning system that provides both space heating and cooling. The heating system utilizes a heat pump with an inertial tank for heat generation. The heat exchange with the external environment is facilitated by geothermal wells. Additionally, a methane gas boiler is installed as a backup to support the heat pump. Radiant panels serve as heat-emission systems.

For domestic hot water, a dedicated heat pump is employed. It supplies a storage boiler, and heat exchange with the external environment is also achieved through the use of geothermal wells.

Each individual building unit features a centralized mechanical ventilation system, incorporating a filtration system to ensure high-quality air in the living areas. The system operates as "primary air," facilitating thermally treated air renewal. There are two air-handling units (AHUs), one for each building. The AHUs employ heat-exchange coils for thermal treatment. Specifically, the AHUs have hydronic pre-treatment coils supplied by the geothermal wells, followed by hydronic treatment coils connected to the centralized generation system.

Regarding renewable energy sources, as previously mentioned, the generation systems utilize heat exchange with the ground through geothermal wells. Additionally, solar panels are installed to supplement hot-water production, while photovoltaic panels generate energy for the operation of the heat pumps, fans and auxiliary equipment.

The entire building is also equipped with a central building energy-management system, allowing the energy manager to change the settings of the heating-and -cooling system at the building level and to change the indoor air-quality-parameter settings at the building-unit level.

IT-11 is a multi-unit residential building located in Novara, in the northern part of Italy. It consists of 6 stories and an unheated attic with a conditioned floor area of 3,500 m^2. The building consists of a load-bearing structure with reinforced concrete pillars and cavity walls filled with 5 cm of thermal insulation, bringing a *U*-value of around 0.50 W/(m^2K).The doors and windows are generally double glazed with *U*-values of around 3 W/(m^2K). The building originally had centralized condensing boilers for space heating and domestic hot-water production.

The entire building was constructed in the 1990s and in 2021 the technical building system for space heating and domestic hot-water production was renovated. The original centralized generator was substituted with a heat pump integrated with a condensing boiler for producing both space heating and domestic hot water. Moreover, a 7.6-kW PV system was installed on the rooftop.

IT-12 is a single-story nursery school owned by the municipality of Borgofranco d'Ivrea, in the northern part of Italy. The building was constructed in the 1980s with a load-bearing structure of reinforced concrete pillars, vertical panels made of prefabricated reinforced concrete, with internal insulation made of polystyrene. The vertical opaque envelope has an average *U*-value of 0.75 W/(m^2K), while the transparent envelope consists of the original windows mostly made of single glazing and an aluminium frame with an average *U*-value of 5.00 W/(m^2K).

The school is connected to a single external central heating system located outside the building. The generator for space heating consists of a boiler, installed in 1993. The heat emitters consist of radiators without thermostatic valves in all the heated rooms. The production of domestic hot water is centralized and combined with the aforementioned heating system through a boiler located in the central heating facility.

IT-13 is a school complex located in Chieri in the northern part of Italy, built in the 1970s and consisting of four buildings of different shapes connected by internal corridors. The building consists of a load-bearing structure with reinforced concrete pillars, cavity walls with alternating brick masonry and precast concrete elements. The average *U*-value of the vertical opaque envelope is 1.40 W/(m^2K). The windows and doors are original and made of single glazing and aluminium frames with an average *U*-value of 4.48 W/(m^2K).

The heating system of the building is connected to the urban district-heating network through a plate heat exchanger. The distribution system utilizes radiators without thermostatic valves. Hot water is produced by electric and methane boilers installed in specific rooms within the building.

IT-15 is a school complex located in Venaria, close to Torino, and it consists of two volumes, both single-story, constructed in different periods. The original portion of the building was constructed in 1997, while the expansion volume was added in 2010 to increase the available space and accommodate a larger number of occupants. Both sections of the school have a load-bearing structure with reinforced concrete pillars and external infill walls, partially insulated with cavity brickwork. The vertical opaque envelope of the older part has a thermal transmittance of 0.59 W/(m^2K), while the more recent one has a thermal transmittance of 0.33 W/(m^2K).

The windows and doors of the building are from different time periods. In the 1997 building, they consist partly of wooden frames and double-glazed units with an average *U*-value of 3.00 W/(m^2K), while in the 2010 expansion, they feature PVC frames with thermal breaks and varying thicknesses of double-glazed units (*U*-values varying from around 3 to 4 W/(m^2K).

The school is connected to a single external central heating system located outside the building. The heating system includes three natural gas condensing boilers to provide space heating. The heat emitters are radiators without thermostatic valves.

The production of domestic hot water is centralized and combined with the aforementioned heating system. Additionally, there is a solar thermal system installed on the roof of the building. A 1500-liter storage tank is present in the central heating facility to serve the production of domestic hot water.

Description of the assessment procedures

To conduct the smart-readiness assessment of the selected buildings, the first step was to find a qualified "building expert". For IT-09, a meeting was arranged with the building's designer, and a site visit was conducted to the central heating-and-cooling plant, as well as the building unit. The same process was carried out for IT-11.

For IT-12, IT-13, and IT-15, a site visit had already been conducted, and an energy audit was generated for an Energy Performance Contract tender. Therefore, specific information needed for the SRI analysis was derived from those documents.

To assess the buildings using Level(s) indicators, IT-15 was considered. The current condition of the building was considered when evaluating indicator 1.1 (energy performance during the use stage) and indicator 4.2 (instances of being outside the thermal comfort range). The renovation status was considered for evaluating indicator 6.1 (lifecycle costs). The level 2 assessment is provided for all indicators, as shown in Table 45.

Table 45. Methods used for IT-15

Used approach	Level 2	Level 3
Indicator 1.1 Use-stage energy performance	yes	
Indicator 1.2 Lifecycle Global Warming Potential	--	
Indicator 4.2 Time outside of thermal comfort range	yes	
Indicator 6.1 Lifecycle costs	yes	

Primary energy use reporting at Level 2 (indicator 1.1 Use-stage energy performance) was carried out based on the energy model developed for the TDS2 evaluation. The simple hourly method according to EN ISO 52016-1:2017 was considered for the assessment of the thermal energy needs for heating and cooling, while UNI/TS 11300, an Italian technical standard, was used for the calculation of the primary energy.

Primary energy factors were taken from the Italian Decree of the Ministry of Economic Development of 26 June 2015.

The energy model carried out for the evaluation of this indicator is based on a tailored mode (Tailored energy performance assessment – TEPA), considering the real use of the building (real occupancy profile as well as real operating time of the technical building systems), with standard climatic conditions, according to the procedure described in D2.2.

The energy model was created using the Edilclima certified tool, EC700.

Regarding **thermal comfort** (indicator 4.2 Time outside of thermal comfort range), the evaluation was conducted based on the energy model developed for the TDS2 evaluation, on a TEPA mode, with the same consideration as for indicator 1.1. According to the procedures specified in EN ISO 16798-1 and -CEN/TR 16798-2 in line with the TDS2 procedures, the following steps were carried out:

- Selection of a representative space of the building
- Calculation of the running mean outdoor-air temperature
- Definition of the operating comfort range
- Calculation of the percentage of hours outside comfort range for both the periods with and without mechanical heating and cooling

Regarding the **lifecycle costs** (indicator 6.1 Lifecycle costs), the energy-related costs assessment was conducted. The costs of the renovation options were considered, in line with TDS2 procedures (Economic evaluation of the energy-efficiency measures – ECM) and with results in D2.3 were the same renovation options were included for the building renovation passport. The building energy model was conducted with the same consideration as for the former indicators, considering the same calculation mode and assumptions.

4.5.1 Outcomes of the SRI and sustainability assessment for selected buildings

Results of the smart-readiness assessment for the 5 Italian buildings are presented below, in Table 46 through default method A, in Table 47 through default method B.

Table 46. Outcomes of SRI assessment for selected buildings in Italy - default method A

TIMEPAC Code	Building category	Data sources	SRI score	Key functionality 1 score - building	Key functionality 2 score - user	Key functionality 3 score - grid
IT-09	Residential	Energy audit reports, site visits, interviews	41%	45%	52%	27%
IT-11	Residential		38%	43%	39%	32%
IT-12	Educational		12%	6%	8%	22%
IT-13	Educational		9%	0%	2%	24%
IT-15	Educational		18%	12%	19%	22%

Table 47. Outcomes of SRI assessment for selected buildings in Italy - default method B

TIMEPAC Code	Building category	Data sources	SRI score	Key functionality 1 score - building	Key functionality 2 score - user	Key functionality 3 score - grid
IT-09	Residential	Energy audit reports, site visits, interviews	35%	47%	50%	10%
IT-11	Residential		26%	36%	27%	14%
IT-12	Educational		4%	7%	6%	0%
IT-13	Educational		4%	8%	4%	0%
IT-15	Educational		8%	14%	10%	0%

The results of the analysis of the sustainability indicators are presented below: in Table 49 indicator 1.1 Use-stage energy performance, in Table 50 indicator 4.2 Time outside of thermal comfort range.

Table 48. Delivered energy use assessment at level 2 for building IT-15 - situation before energy renovation

Building service	Energy need	System eff.	Energy carrier	Delivered energy per energy carrier	Non-renewable primary energy		Renewable primary energy		Total primary energy	
	kWh/a.	%	Text	kWh/a.	Factor	kWh/a.	Factor	kWh/a.	Factor	kWh/a.
Heating	252,125	89.6	Natural gas	315,439	1.05	331,210	0	0	1.05	331,210
Hot water	10,930	86.6	Natural gas	15,260	1.05	16,023	0	0	1.05	16,023
Cooling	6,944	No active cooling system								
Ventilation	No mechanical ventilation									
Lighting	58,861		Electricity	58,861	1.95	114,780	0.47	27.665	2.42	142,444
Exported renewable energy	n/a	n/a								
Overall	328,860			389,559		462,013		27.665		489,678

Table 49. Energy-performance assessment at level 2: results for building IT-15 – situation before energy renovation

Services	$kWh/m^2/a$.
L2.1 EPBD services non-renewable primary energy self-used (mandatory)	278.88
L2.2 EPBD services renewable primary energy self-used (optional)	17.21
L2.3 EPBD services total primary energy self-used (optional)	296.09
L2.4 Exported renewable primary energy (mandatory)	0.00
L2.5 EPBD services non-renewable primary energy balance (mandatory)	278.88
L2.6 Non-EPBD services non-renewable primary energy self-used (optional)	--
L2.7 Non-EPBD services renewable primary energy self-used (optional)	--
L2.8 Non-EPBD services total primary energy self-used (optional)	--
L2.9 Total primary energy self-used (optional	--
L2.10 Total primary energy balance (optional)	--

Table 50 presents the results for the thermal comfort analysis. The temperature ranges were derived from Table 5 of EN 16798-1. In the calibration process carried out for TDS2 and reported in D2.2, the set point was decreased to 19°C. For this reason, the temperature comfort was not met during most hours.

Table 50. Assessment results for reporting of indicator 4.2 of an assessment at level 2 for building IT-15 – situation before energy renovation

	Heating season	Cooling season
Operating temperature range (°C)	19.5/24.5	-
Time out of range (%) - without mechanical heating/cooling	0	-
Time out of range (%) - with mechanical heating/cooling	0	-

4.5.2 Extraction of energy and flexibility measures and integration of the SRI and sustainability indicators in EPC

In this section, renovation scenarios are presented for three educational buildings (IT-12, IT-13, and IT-15) that require renovation. These scenarios were also proposed in the building renovation passport (TDS3) as implemented in D2.3 as well as in the TDS2 as implemented in D2.2. The same scenarios are now presented in this report along with the corresponding SRI scores. Additionally, other renovation measures are proposed to enhance certain aspects based on the baseline evaluation of the SRI (see Table 51). IT-09 was not considered in TDS2 and TDS3. The smart-renovation scenario proposed in this report includes the installation of EV-charging stations, the installation of a battery for storing the electricity produced through the PV system and the enhancement of the building energy system for maximizing the self-consumption of RES and introducing the demand/response functionalities for some TBS. Also, the automatic lighting-control system is introduced. These smart renovations increase the SRI from 35% to 54%.
Neither IT-11 was considered for TDS2 and TDS3 calculations. The smart-renovation scenario proposed in this report includes the installation of EV-charging stations, the installation of a PV system, installation of a battery system for the PV, installation of an energy-management system with demand/response functionalities and the automatic lighting-control system. These smart renovations increase the SRI from 26% to 39%.

For IT-12, the proposed renovation also included in TDS2 and TDS3 involves replacing the natural gas boiler with two air-to-water heat pumps, the installation of a PV system on the roof and the installation of thermos-valves for controlling the heating emission system at room level. In this scenario, the installation of a building management system is also considered. The impact on the SRI score is high, ranging from 4% to 30%. To further improve the SRI score, other renovation options are considered, which include the distribution pump's control enhancement, the installation of a battery system for the PV, information to occupants about PV production and maximization of self-consumption, automatic lighting-control system, installation of energy-management system with demand/response functionalities, installation of EV-charging station. After implementing these additional measures, the SRI score rises to 47%.

For IT-13, the proposed renovation also included in TDS2 and TDS3 involves replacing the control system for the emission system of space heating and the installation of an automatic lighting control system. Also, the installation of a building-management system is considered. This change significantly impacts on the SRI score, ranging from 4% to 25% . Other recommendations to enhance the SRI score include the distribution pump's control enhancement, the installation of a PV system, the installation of a battery system for the PV, information to occupants about PV production and the maximization of self-consumption, installation of energy-management system with demand/response functionalities and the installation of an EV-charging station. After implementing these recommendations, the SRI score improves to 35%.

For IT-15, the proposed renovation, also included in TDS2 and TDS3, involves replacing the natural gas boiler with two air-to-water heat pumps. In this scenario, the installation of a building management system is also considered. This change impacts on the SRI, ranging from 8% to 25%. Other feasible measures include the installation of a PV system, the installation of a battery system for the PV, information to occupants about PV production and the maximization of self-consumption, automatic lighting-control system, installation of energy-management system with demand/response functionalities, installation of an EV-charging station. After implementing these recommendations, the SRI improves to 44%.

Overall, these renovation scenarios and measures are designed to improve the buildings' smart readiness, increase energy efficiency, and provide better comfort and functionality for the occupants.

Table 51. Extracted energy and flexibility measures for buildings in Italy and new SRI scores

TIMEPAC Code	Building usage	SRI score (method B)	Renovation according to TDS2 and TDS3	New SRI score	Other energy and flexibility measures	New SRI score
IT-09	Residential	35%	-	-	EV-charging station Installation of battery system and maximization of self-consumption Enhancing the control system allowing demand/response functionalities Automatic lighting-control system	54%
IT-11	Residential	26%	-	-	EV-charging station Installation of PV system	39%

TIMEPAC Code	Building usage	SRI score (method B)	Renovation according to TDS2 and TDS3	New SRI score	Other energy and flexibility measures	New SRI score
					Installation of a battery system for PV and maximization of self-consumption Installation of energy-management system with demand/response functionalities Automatic lighting-control system	
IT-12	Educational	4%	Individual room control Substitution of the existing heat generator with two heat pumps Installation of PV system Installation of energy-management system with feedback to the occupants and fault-detection functionalities	30%	Renovation according to TDS2 and TDS3 Enhancement of distribution pump control Installation of a battery system for PV Information to occupants about PV production and maximization of self-consumption Automatic lighting-control system Upgrade of energy-management system with demand/response functionalities Installation of EV-charging station	47%
IT-13	Educational	4%	Individual room control Installation of energy-management system with feedback to the occupants and fault-detection functionalities Automatic lighting control system	25%	Renovation according to TDS2 and TDS3 Enhancement of distribution pump control Installation of PV system Installation of a battery system for PV Information to occupants about PV production and maximization of self-consumption Upgrade of energy-management system with demand/response functionalities Installation of EV-charging station	35%
IT-15	Educational	8%	Substitution of the existing heat	25%	Renovation according to TDS2 and TDS3	44%

TIMEPAC Code	Building usage	SRI score (method B)	Renovation according to TDS2 and TDS3	New SRI score	Other energy and flexibility measures	New SRI score
			generator with two heat pumps Installation of energy-management system with feedback to the occupants and fault-detection functionalities		Installation of PV system Installation of a battery system for PV Information to occupants about PV production and maximization of self-consumption Automatic lighting-control system Installation of energy-management system with demand/response functionalities Installation of EV-charging station	

Also, based on the renovation according to TDS2 and TDS3 and “smart renovation scenario” sustainability indicators for building IT-15 are calculated once again and results are given in Table 52, Table 53, Table 54, Table 55 and Table 56.

Table 52. Energy-performance assessment at level 2: results for building IT-15 (renovation according to TDS2 and TDS3)

Services	kWh/m^2/a.
L2.1 EPBD services non-renewable primary energy self-used (mandatory)	235.10
L2.2 EPBD services renewable primary energy self-used (optional)	61.68
L2.3 EPBD services total primary energy self-used (optional)	296.77
L2.4 Exported renewable primary energy (mandatory)	0
L2.5 EPBD services non-renewable primary energy balance (mandatory)	235.10
L2.6 Non-EPBD services non-renewable primary energy self-used (optional)	--
L2.7 Non-EPBD services renewable primary energy self-used (optional)	--
L2.8 Non-EPBD services total primary energy self-used (optional)	--
L2.9 Total primary energy self-use (optional	--
L2.10 Total primary energy balance (optional)	--

Table 53. Energy-performance assessment at level 2: results for building IT-15 (smart renovation scenario)

Services	kWh/m²/a.
L2.1 EPBD services non-renewable primary energy self-used (mandatory)	185.50
L2.2 EPBD services renewable primary energy self-used (optional)	71.60
L2.3 EPBD services total primary energy self-used (optional)	257.10
L2.4 Exported renewable primary energy (mandatory)	0.18
L2.5 EPBD services non-renewable primary energy balance (mandatory)	185.32
L2.6 Non-EPBD services non-renewable primary energy self-used (optional)	--
L2.7 Non-EPBD services renewable primary energy self-used (optional)	--
L2.8 Non-EPBD services total primary energy self-used (optional)	--
L2.9 Total primary energy self-used (optional	--
L2.10 Total primary energy balance (optional)	--

Table 54 presents the results for the thermal comfort analysis. The temperature ranges were derived from Table 5 of EN 16798-1. The calculation was performed only during the occupied hours that, for building IT-15, coincide with the hours of mechanical heating. For this reason, the number of hours without mechanical heating, and therefore the time out of range, for the heating season is equal to zero. The increase in the time out of range from the baseline to the renovation scenarios is attributable to the higher capacity of the building to meet the required set point that, in this specific case, is out of the comfort range.

Table 54. Assessment results for reporting of indicator 4.2 of an assessment at level 2 for building IT-15 (renovation according to TDS2 and TDS3/smart renovation scenario)

	Heating season	Cooling season
Operating temperature range (°C)	19.5/24.5	-
Time out of range (%) - without mechanical heating/cooling	0	-
Time out of range (%) - with mechanical heating/cooling	0	-

Table 55 and Table 56 present the results for the lifecycle cost calculation for B use stage with the objective to compare renovation options in terms of lifecycle costs. Consideration period: thermal insulation 30 years, building services 30 years.

Table 55. Assessment results for reporting of indicator 6.1 at level 2 for building IT-15 (renovation according to TDS2 and TDS3)

Type of cost	Normalised cost by lifecycle stage (€/m^2/a.)		
	Product and construction stages	Use stage	End-of-life stage
Initial costs	-	-	-
Annual costs	-	29.06	-
Periodic costs	-	10.27	-
Global costs by lifecycle stage	-	39.33	-

Table 56. Assessment results for reporting of indicator 6.1 at level 2 for building IT-15 (renovation according to TDS2 and TDS3 + smart renovation scenario)

Type of cost	Normalised cost by lifecycle stage (€/m^2/a.)		
	Product and construction stages	Use stage	End-of-life stage
Initial costs	-	-	-
Annual costs	-	22.93	-
Periodic costs	-	12.64	-
Global costs by lifecycle stage	-	35.57	-

4.5.3 Main gaps and recommendations

Consideration for integrating the SRI and EPC

Currently, the EPC in Italy does not include indications regarding a building's smartness. Therefore, there is a need to integrate the SRI into the EPC. However, certain issues need to be addressed in order to better combine the EPC and SRI indicators.

Firstly, it is important to align the evaluation of the SRI and the Building & Automation Control Systems (BACS) according to EN ISO 52120-1 (CEN, 2022c). In Italy, the installation of BACS is mandatory and regulated by the Decree of the Ministry of Economic Development of 26 June 2015, which sets minimum requirements for non-residential buildings, both new and undergoing major renovation. As per the decree, the evaluation of the BACS level, based on EN ISO 52120-1 (CEN, 2022c), should be provided when submitting the technical report for building permission.

Another issue to be addressed is linking the smart readiness evaluation with the energy-performance assessment through the EPC. This means that when energy and flexibility measures are suggested for a specific building, and they affect the SRI scores, the impact, especially in terms of energy efficiency, should also be clearly demonstrated through the energy label.

The current calculation method used for EPC purposes in Italy is based on the UNI/TS 11300 technical specifications, which employ a quasi-steady-state method on a monthly basis. This method includes simplified procedures for accounting for the control of space heating-and-cooling systems, mainly through an evaluation of the pre-calculated efficiency of the control system. Consequently, it becomes challenging to adequately assess the impact of the automation and smart control of technical building systems.

Currently, Italy is undergoing a revision of the calculation procedure, and it has not yet been determined whether to continue with the monthly method or switch to an hourly simulation.

Naturally, adopting the hourly energy-assessment method would offer a more detailed procedure to account for the energy impact of the BACS.

Moreover, during the adoption phase, it is crucial to clarify the specific domains to be evaluated through the SRI for each building category, especially if an alignment with the EPC is desired. For instance, in Italy, the EPC for residential buildings does not include a calculation of the lighting system. Therefore, any suggestions or improvements related to this domain would not have an impact on the EPC score. To ensure consistency and avoid discrepancies between the SRI and EPC assessments, it is essential to define and communicate the exact domains and systems that will be evaluated in each evaluation framework.

Comments regarding the SRI methodology

Regarding the SRI assessment tool, it seems there is a need for clearer explanations about certain aspects. For example, services that might not be applicable in a building should not affect the maximum score. Further elaboration on this issue is required to avoid confusion and ensure accurate scoring.

The comparison between method A and B is also raising concerns as the simplified methodology (method A) is resulting in higher scores than the more detailed one (method B). This contradicts the common expectation that simplified methods tend to be more conservative and favour security. A detailed explanation of the scoring criteria and the reasons for these discrepancies should be provided to address this issue.

The domain "information to occupants" is posing challenges as different interpretations by different technicians can lead to inconsistent results. Providing specific examples or guidelines to assess this domain more consistently would be beneficial for achieving more homogeneous results.

Concerning the "key functionality 3 score - grid," there seem to be discrepancies between method A and B, particularly regarding code H-1c, which is related to controlling heat-production facilities or heat control on the demand side. These discrepancies are found in IT-12, IT-13 and IT-14 where, if we look at method B, the score is 0%, while looking to method A, the score reaches 24%.

Definition of target groups

To ensure the accuracy and reliability of the SRI assessment, involving qualified building experts is essential. The technicians responsible for conducting the SRI calculation should have the appropriate expertise and knowledge of buildings' technical systems, energy efficiency, and smart technologies. Non-technicians might not possess the necessary competencies to answer the questions accurately and meaningfully.

Nevertheless, during the data-collection and elaboration process, doubts and challenges arise, especially when dealing with aspects such as information supplied to occupants and procedural complexities. Therefore, specific training and courses are necessary to address the uncertainties and avoid generic errors in the implementation of the procedure. Providing appropriate training and guidelines for the technicians involved in the SRI assessment can significantly improve the consistency and reliability of the results.

Sustainability indicators

Calculating the sustainability indicators for the entire lifecycle of a building presents challenges due to the need for comprehensive data, from cradle to disposal. A Lifecycle Assessment (LCA) is a complex and data-intensive process that requires access to reliable and up-to-date information on various aspects of a building's lifecycle, including raw-material extraction, manufacturing, construction, operation, maintenance, and end-of-life scenarios.

One of the main difficulties faced by professionals is the availability and accessibility of data for an LCA evaluation. Gathering data for each phase of a building's lifecycle can be time consuming and resource intensive. Moreover, the accuracy and reliability of the data are crucial to obtaining meaningful results and making informed decisions.

4.6 Slovenia

Calculating the SRI for ten buildings in Slovenia using Methods A and B was a comprehensive process that assessed the buildings' technological features, energy performance and flexibility aspects. By evaluating these key factors, we tried to determine the readiness of the buildings for smart applications and identify areas for improvement. This information is crucial for policymakers, building owners/users, and other relevant stakeholders (energy and facility managers, utilities and ESCOs) in making informed decisions regarding sustainable development, energy-efficiency measures, and the implementation of smart technologies. The table 57 shows the buildings that were selected for the analysis in the current task.

Table 57. Overview of analysed Slovenian buildings

TIMEPAC Code	Building type	Status
SI-01	Educational building - primary school	Existing, not-renovated
SI-02	Health centre	Existing, after renovation
SI-03	Offices	Existing, after renovation
SI-04	Offices	Existing, not-renovated
SI-05	Educational building - primary and secondary school	Existing, not-renovated
SI-06	Educational building - primary school	Existing, after renovation
SI-07	Educational building - kindergarten	Existing, not-renovated
SI-08	Educational building - primary school	Existing, not-renovated
SI-09	Cultural centre	Existing, after renovation
SI-10	Educational building - primary school	Existing, after renovation

In the Slovenian case all ten assessed buildings are non-residential buildings (educational, health and office) with different usage patterns. The calculated SRIs serve as a valuable tool to drive the transformation of buildings towards a smarter and more sustainable future. Smart-ready buildings integrate advanced technologies to optimize energy consumption, improve occupants' comfort and reduce environmental impact.

Methods A and B are two recommended approaches for calculating the SRI. The first step in calculating the SRIs using Methods A and B is to collect the relevant data on the selected ten buildings in Slovenia. This includes information about the building's size, construction characteristics, energy consumption, and technological infrastructure. During the site visit and in communication with the energy and facility managers, the smart features present in each building were identified. These can include intelligent energy-management systems, automation and control systems, renewable energy integration, smart lighting, HVAC systems, and sensor networks. In all the assessed buildings the energy performance was also evaluated. The analysis considered factors such as energy-consumption patterns, implemented energy-efficiency measures and the utilization of renewable energy sources.

Valuable sources of information were the energy-audit reports, the EPCs, the energy-consumption data and simulation models that were developed in the framework of the TIMEPAC project. In the final step, the flexibility of a building's system was analysed and official Excel tool version 4.5 containing Methods A and B with default domain weightings was utilized to assess the smart readiness of each building.

The Building SI-01 belongs to the educational sector and lacks cooling, ventilation, a dynamic building envelope and EV charging domains. All other domains are present and they have been evaluated. The building has not undergone renovation, and the installed systems are outdated and energy inefficient. New LED lighting has been installed only in the hallways, while the rest of the building still uses energy-inefficient lighting. An energy-accounting system has been implemented to monitor energy consumption, but no additional energy-consumption measurements are available apart from the official ones.

Regarding the building's smart systems, it has been identified that the existing heating system relies on fossil fuels and lacks occupancy-detection sensors and variable-speed pump control, which affects its efficiency. The same issues apply to the domestic hot water (DHW). There is also a lack of integration with renewable energy sources (RESs) and no provision for demand-based supply. Additionally, the lighting system lacks central control, and window shading controls are not present. On-site renewable-electricity generation is absent, and information regarding electricity consumption is not shared. Overall, occupants and facility managers have limited information available regarding the building's systems. Grid flexibility does not exist, primarily due to current legal restrictions, offering minimal opportunities for monetizing flexibility through investment and savings.

It is evident that the Building SI-01 requires major energy renovation, and the main heating systems need to be replaced. As part of the renovation roadmap, it is proposed that the first energy-efficiency measure should be the installation of a modern energy-management system with demand/response functionalities and feedback to the occupants. The subsequent steps would involve the renovation of the lighting system, implementation of advanced control systems, installation of a PV system, and a complete reconstruction of the HVAC system. This reconstruction would include the implementation of a new heat pump for heating and cooling, new VSD pumps, and advanced control of the heating and cooling systems.

The Building SI-02 belongs to the health sector and almost all domains are present (EV charging is missing), and they have been evaluated. The building underwent comprehensive energy renovation in 2019. A modern energy-management system is installed, but it lacks demand/response functionalities and feedback to the occupants. The main issues identified in the HVAC system include the absence of occupancy detection which affect its efficiency. Similarly, in the DHW production, there is a lack of integration with RES and no provision for demand-based supply, leading to inefficiencies. Furthermore, the lighting system lacks central control, and the window shading controls are manual. There is no on-site electricity generation, and information regarding electricity consumption is not shared.

It is clear that the Building SI-02 requires additional upgrade of its energy systems which will enable additional energy and cost savings. As part of the renovation roadmap, it is proposed that the first energy-efficiency measure should be the upgrade of the existing energy-management system with demand/response functionalities and feedback to the occupants. The subsequent steps would involve the renovation of the lighting system, implementation of advanced control systems, installation of a PV system, and the installation of a battery system for the peak-load management, emergency power supply and optimising of the PV production.

The Building SI-03 is an office building and almost all domains are present (ventilation, dynamic building envelope and EV charging are missing), and they have been evaluated. The building underwent comprehensive energy renovation in 2013. A modern energy-management system is installed but it lacks demand/response functionalities and feedback to the occupants. The main issues identified in the HVAC system include the absence of occupancy detection, which affects its efficiency. Similarly, in the DHW production, there is a lack of integration with RESs and no provision for demand-based supply, leading to inefficiencies. Furthermore, the lighting system lacks central control, and the window shading controls do not exist. There is no on-site electricity generation, and information regarding electricity consumption is not shared with occupants.

The Building SI-03 requires an additional upgrade of its energy systems, which will enable additional energy and cost savings. As part of the renovation roadmap, it is proposed that the first energy-efficiency measure should be an upgrade of the existing energy-management system with demand/response functionalities and feedback to the occupants. The subsequent steps would involve the renovation of the lighting system, implementation of advanced control systems, reconstruction of the existing HVAC system, which will include advanced CO_2-based ventilation with occupancy detection, installation of a PV system, and the installation of a battery system for the peak-load management, emergency power supply and optimising of the PV production.

Building SI-04 is an office and lacks cooling, ventilation, a dynamic building envelope, EV charging and monitoring and control domains. All other domains are present and they have been evaluated. The building has not undergone renovation, and the installed systems are outdated and energy inefficient. Monitoring-and-control systems are not present, leading to a lack of information for the occupants and facility managers. No additional energy-consumption measurements are available apart from the official ones.

Regarding the building's smart systems, it has been identified that the existing heating system lacks occupancy-detection sensors and variable-speed pump control, which affects its efficiency. The same issues apply to the DHW production. There is also a lack of integration with RESs and no provision for demand-based supply. Additionally, the lighting system lacks central control, and window-shading controls are not present. On-site renewable electricity generation is absent, and information regarding electricity consumption is not shared. Occupants and facility managers have limited information available regarding the building systems.

It is clear that Building SI-04 requires major energy renovation, and the main systems need to be replaced. As part of the renovation roadmap, it is proposed that the first energy-efficiency measure should be the installation of a modern energy-management system with demand/response functionalities and feedback to the occupants. The subsequent steps would involve the renovation of the lighting system, implementation of advanced control systems, a complete reconstruction of the HVAC system, installation of a PV system and the installation of a battery system for the peak-load management, emergency power supply and optimising of the PV production.

Building SI-05 is under cultural heritage protection and belongs to the educational sector. It lacks cooling, ventilation, a dynamic building envelope, EV charging, and monitoring and control domains. All other domains are present and have been evaluated. The building has not undergone renovation, and the installed systems are outdated and energy inefficient. Monitoring-and-control systems are not present, leading to a lack of information for occupants and facility managers. No additional energy-consumption measurements are available apart from the official ones.

Regarding the building's smart systems, it has been identified that the existing heating system relies on fossil fuels and lacks occupancy-detection sensors and variable-speed pump control, which affects its efficiency. The same issues apply to the DHW production. There is also a lack of integration with RESs and no provision for demand-based supply. Additionally, the lighting system is outdated and lacks central control, and window-shading controls are not present. On-site renewable electricity generation is absent, and information regarding electricity consumption is not shared. Overall, occupants and facility managers have very limited information available regarding the building systems.

Building SI-05 requires major energy renovation, and the main systems need to be replaced. As part of the renovation roadmap, it is proposed that the first energy-efficiency measure should be the installation of a modern energy-management system with demand/response functionalities and feedback to the occupants. The subsequent steps would involve the renovation of the lighting system, implementation of advanced control systems, installation of a PV system, installation of a battery system for the peak-load management, emergency power supply and optimising of the PV production and a complete reconstruction of the HVAC system. This reconstruction would include the implementation of a new heat pump for heating and cooling, new VSD pumps, and advanced control of the heating and cooling systems.

Building SI-06 belongs to the educational sector and lacks cooling, ventilation, a dynamic building envelope and EV charging domains. All other domains are present and they have been evaluated. The building has not undergone comprehensive energy renovation but it has a renovated boiler room. A new wood-pellet-based boiler has been installed. The distribution system has also been renovated with built-in frequency-controlled circulation pumps. The heating system is controlled based on external temperature regulation. Heat and electricity consumption measurements are conducted in the building and are integrated with the energy-management system. Additionally, measurements of microclimate in one room and outdoor temperatures have been carried out. The lighting is old and outdated.

Regarding the building's smart systems, it has been identified that the existing heating system lacks occupancy-detection sensors which affects its efficiency. The same issues apply to the DHW production. There is also a lack of integration with RES for electricity generation and no provision for demand-based supply. Additionally, the lighting system is inefficient and lacks central control, and window shading controls are not present. On-site renewable electricity generation is absent, and information regarding electricity consumption is not shared. Overall, occupants and facility managers have limited information available regarding the building systems.

The Building SI-06 requires major energy renovation, and the main systems need to be replaced. As part of the renovation roadmap, it is proposed that the first energy-efficiency measure should be the upgrade of the energy-management system with demand/response functionalities and feedback to the occupants. The subsequent steps would involve the renovation of the lighting system, implementation of advanced control systems, upgrade of the HVAC (installation of ventilation system) and advanced control, installation of a PV system, and installation of the battery system for the peak-load management, emergency power supply and optimising of the PV production.

The Building SI-07 also belongs to the educational sector and lacks cooling, ventilation, dynamic building envelope and EV charging domains. All other domains are present and they have been evaluated. The building has not undergone renovation, and the installed systems are outdated and energy inefficient. An energy accounting system has been implemented to monitor energy consumption, but no additional energy-consumption measurements are available apart from the official ones.

Regarding the building's smart systems, it has been identified that the existing heating system relies on fossil fuels (natural gas) and lacks occupancy-detection sensors and variable-speed pump control, which affects its efficiency. The same issues apply to the DHW production. There is also a lack of integration with RESs and no provision for demand-based supply. Additionally, the lighting system is outdated and lacks central control, and window-shading controls are not present. On-site renewable-electricity generation is absent, and information regarding electricity consumption is not shared. Overall, occupants and facility managers have limited information available regarding the building's systems.

Building SI-07 requires major energy renovation, and the main systems need to be replaced. As part of the renovation roadmap, it is proposed that the first energy-efficiency measure should be the installation of a modern energy-management system with demand/response functionalities and feedback to the occupants. The subsequent steps would involve the renovation of the lighting system, implementation of advanced control systems, installation of a PV system, installation of a smart EV-charging station, and a complete reconstruction of the HVAC system. This reconstruction would include the implementation of a new heat pump for heating and cooling, new VSD pumps, and advanced control of the heating, ventilation and cooling systems.

Building SI-08 belongs to the educational sector and almost all domains are present (only EV charging is missing), and they have been evaluated. The building underwent comprehensive energy renovation in 2022. Unfortunately, an energy-management system is not installed. There is no on-site electricity generation, and information regarding electricity consumption is not shared.

Building SI-08 requires an additional upgrade of its energy systems, which will enable additional energy and cost savings. As part of the renovation roadmap, it is proposed that the first energy-efficiency measure should be the installation of a modern energy-management system with demand/response functionalities and feedback to the occupants. The subsequent steps would involve the installation of a PV system, and the installation of a battery system for the peak-load management, emergency power supply and optimising of the PV production.

Building SI-09 belongs to the cultural heritage sector and almost all domains are present (only a dynamic building envelope is missing), and they have been evaluated. The building underwent comprehensive energy renovation in 2018. Unfortunately, only a very basic energy-management system is installed, and it needs to be upgraded. There is no on-site electricity generation, and information regarding electricity consumption is not shared.

Building SI-09 requires an additional upgrade of its energy systems, which will enable additional energy and cost savings. As part of the renovation roadmap, it is proposed that the first energy-efficiency measure should be the upgrade of the existing energy-management system with demand/response functionalities and feedback to the occupants. The subsequent steps would involve the installation of a PV system followed by the installation of a battery system for the peak-load management, emergency power supply and optimising of the PV production, advanced control of the ventilation system and an upgrade of the existing EV-charging station.

Building SI-10 belongs to the educational sector and almost all domains are present (only a dynamic building envelope and the EV charging are missing), and they have been evaluated. The building underwent comprehensive energy renovation in 2022. Unfortunately, only a very basic energy-management system is installed, and it needs to be upgraded. Also, there is no advanced control of the lighting system. There is no on-site electricity generation, and information regarding electricity consumption is not shared.

Building SI-10 requires an additional upgrade to its energy systems, which will enable additional energy and cost savings. As part of the renovation roadmap, it is proposed that the first energy-efficiency measure should be the upgrade of the existing energy-management system with demand/response functionalities and feedback to the occupants. The subsequent steps would involve the installation of an advanced control system for the lighting, installation of a PV system followed by the installation of the battery system for the peak-load management, emergency power supply and optimising of the PV production and installation of the smart EV-charging station.

A sustainability assessment was conducted for building SI-02 because the most relevant documentation was available, including an energy audit, EPC (Energy Performance Certificate), Building Energy Model (BEM), measurements, historical data on consumption and temperatures, BIM (Building Information Modelling) as well as design-project documentation. An overview of the method used is provided in Table 58.

For indicator 1.2 (lifecycle global warming potential) several possible scenarios of energy renovation have been analysed and compared to the actual, executed energy-renovation measures. In this case it is possible to observe the effect of using more sustainable materials.

Table 58. Methods used for SI-02

Used approach	Level 2	Level 3
Indicator 1.1 Use-stage energy performance	-	yes
Indicator 1.2 Lifecycle Global Warming Potential	-	yes
Indicator 4.2 Time outside of thermal comfort range	yes	yes
Indicator 6.1 Lifecycle costs	-	yes

4.6.1 Outcomes of the SRI and sustainability assessment for selected buildings

The SRI calculation results for all ten Slovenian buildings are presented in Table 59 and Table 60. The SRI scores are relatively low, being heavily influenced by the year of construction or the most recent reconstruction. The key functionality 3, which relates to grid integration, has the lowest scores, primarily due to relatively low presence of energy generation and storage assets and the low awareness about positive elements of a market for flexibility. These factors greatly limit the building's ability to adapt and contribute to a more flexible grid system.

Table 59. Outcomes of the SRI assessment for selected buildings in Slovenia – default Method A

TIMEPAC Code	Building usage	Data sources	SRI score	Key functionality 1 score - building	Key functionality 2 score - user	Key functionality 3 score - grid
SI-01	Elementary School	EPCs, energy audit, energy-consumption data, site visits, interviews, BIM/BEM	14%	12%	25%	0%
SI-02	Health centre		15%	17%	20%	0%
SI-03	Offices		23%	18%	39%	19%
SI-04	Offices		17%	10%	42%	0%
SI-05	Elementary and secondary school - building is under cultural heritage protection		2%	1%	6%	0%
SI-06	Elementary School		36%	27%	47%	33%
SI-07	Kindergarten		30%	15%	44%	30%
SI-08	Elementary school		27%	22%	32%	27%
SI-09	Cultural Centre		31%	31%	39%	22%
SI-10	Elementary school		35%	30%	45%	31%

Table 60. Outcomes of the SRI assessment for selected buildings in Slovenia – default Method B

TIMEPAC Code	Building usage	Data sources	SRI score	Key functionality 1 score - building	Key functionality 2 score - user	Key functionality 3 score - grid
SI-01	Elementary School	EPCs, energy audit, energy-consumption data, site visits, interviews, BIM/BEM	10%	12%	14%	0%
SI-02	Health centre		18%	21%	21%	4%
SI-03	Offices		16%	17%	19%	8%
SI-04	Offices		12%	10%	29%	0%
SI-05	Elementary and secondary school - building is under cultural heritage protection		5%	7%	9%	0%
SI-06	Elementary School		17%	25%	18%	8%
SI-07	Kindergarten		13%	18%	16%	5%
SI-08	Elementary school		20%	23%	27%	9%
SI-09	Cultural Centre		22%	27%	31%	8%
SI-10	Elementary school		24%	26%	34%	12%

The main purpose of the SRI auditing is to convince the building owner/users to invest money in making their building smarter and, at the same time, improve the energy and environmental performance. In this context, the planning and preparation of data collection is a crucial phase of the SRI auditing. In our case, the majority of the data for the SRI calculation was successfully extracted from the available energy audits, the existing EPC, and the available BEM/BIM. Missing data were collected during the site visit and interviews with the on-site personnel. The collected data were also used to verify existing energy-management practices.

During the data collection process, it was observed that the available data are separately captured and kept at various business units operating in the addressed buildings according to their functional needs. Various business units are collecting essentially the same data on their own, usually by different means, which can lead to inevitable inconsistencies. Such practices increase the cost of data gathering and processing, and create more problems when the data are analysed by external experts.

The site visit was carefully planned and used for the evaluation of the current energy and environmental performance. Its purpose was to establish the existing position regarding smart energy services already available in the addressed building, set directions and targets for smartness and performance improvement based on owner's/occupant's preferences, establish the baseline for progress evaluation, and prepare a comprehensive list of measures to improve the smartness, flexibility and energy performance of the addressed building.

For the sustainability indicators the results are shown below. Indicator 1.1 was calculated for level 3 using data from the BEM, energy audit and real energy consumption. The use-stage energy-performance indicator represents a standard value that is commonly used when conducting energy auditing and EPC assessment. The results are shown in Table 61, Table 62, Table 63, Table 64 and Table 65.

Table 61. Delivered energy assessment for SI-02 – existing situation before energy renovation

Building service	Energy carrier	Delivered energy per energy carrier	Non-renewable primary energy		Renewable primary energy		Total primary energy	
		kWh/a.	Factor	kWh/a.	Factor	kWh/a.	Factor	kWh/a.
Heating	District heating	230,316	0.8	184,253	0.4	92,126	1.2	276,379
Cooling	Electricity	51,597	1.5	77,396	1.0	51,597	2.5	128,993
Ventilation	Electricity	105,621	1.5	158,432	1.0	105,621	2.5	264,053
Hot water	District heating	49,194	0.8	39,355	0.4	19,678	1.2	59,033
Lighting	Electricity	107,772	1.5	161,657	1.0	107,772	2.5	269,429
Exported renewable energy	-	0	-	0	-	0	-	0
Overall		544,500	-	621,093	-	376,794	-	997,887

Table 62. Energy-performance assessment at level 3 results for building SI-02 – existing situation before energy renovation

Services	kWh/m^2/a.
L3.1 EPBD services non-renewable primary energy self-used	171.1
L3.2 EPBD services renewable primary energy self-used	103.8
L3.3 EPBD services total primary energy self-used	274.9
L3.4 Exported renewable primary energy	0.0
L3.5 EPBD services non-renewable primary energy balance	171.1
L3.6 Non-EPBD services non-renewable primary energy self-used	16.5

Services	kWh/m²/a.
L3.7 Non-EPBD services renewable primary energy self-used (optional)	11.0
L3.8 Non-EPBD services total primary energy self-used (optional)	27.5
L3.9 Total primary energy self-used (optional)	302.4
L3.10 Total primary energy balance (optional)	302.4

A lifecycle GWP (indicator 1.2) was calculated for the status before and after energy renovation, whereas 4 different renovation scenarios were observed, i.e., the actual implemented one and three additional scenarios. This was to compare the impact of using different materials for energy-renovation measures, although the overall energy balance remains the same.

As one of the essential results of the European standardization process, LCA standards now provide clear rules for the preparation of an LCA that reflects the entire lifecycle of buildings and their construction products within a modular approach. This comprises the production phase (A1-3); the use phase (B1-7); and includes both guidance on the handling of end-of-life (EOL) impacts in phase C1-4 and the treatment of recycling potentials in phase D. In particular, the standards require separating the calculated impacts represented in phases C and D, which, before this regulation, were most often summed up as a single value, leading to inconsistent and opaque LCA results.

Reporting on the results of the assessment of indicator 1.2 GWP covers the following sub-indicators:

- The "GWP-fossil" indicator considers greenhouse-gas emissions resulting from the use of fossil fuels or substances.
- The "GWP-biogenic" indicator considers the amount of CO_2 absorbed from the atmosphere during biomass growth, as well as biogenic emissions into the air during oxidation or decomposition biomass (e.g., combustion). It is considered according to the principle of 'biogenic carbon neutrality' approaches in accordance with the SIST EN 16449 methodology.
- The indicator "GWP - land use and land use change" takes CO_2 emissions into account that are the result of changed land use.

Table 63. Results of an assessment 1.2 at level 3 for building SI-02 – existing situation before energy renovation

	Unit	Before ER
		C/B + porous concrete
(1) GWP – fossil	kg CO_2 eq /m²	1,450
(2) GWP – biogenic	kg CO_2 eq /m²	0
GWP – (1) + (2)	kg CO eq /m²	1,450
(3) GWP – Land use and land-use change	kg CO_2 eq /m²	N/A
GWP – (1) + (2) + (3)	kg CO_2 eq /m²	N/A

* C/B – load-bearing structure from concrete and bricks

Indicator 4.2, the time spent outside the thermal comfort range, can be calculated either from the hourly Building Energy Model (BEM) or from temperature measurements within the building. In TDS2, thermal comfort was calculated based on simulation data, resulting in a discomfort level of 0% for SI-02 (Table 64). Furthermore, the average indoor temperature of the building was cross-checked using historical data, and no time outside the comfort range was observed.

Table 64. Project-assessment results for reporting of indicator 4.2 of an assessment at level 3 for building SI-02 – existing situation before energy renovation

	Heating season	Cooling season
Operating temperature range (°C)	18 - 24	22 - 28
Time out of range (%) - with mechanical heating/cooling	0	0

Indicator 6.1 Lifecycle costs were calculated from data available in TDS2 (economic validation of energy-efficiency measures) and rough estimates for unknown data (construction, destruction etc.), especially those for the building that was constructed 43 years ago and in 2019 had its first major renovation (Table 65).

Table 65. Project-assessment results for reporting of indicator 6.1 at level 3 for building SI-02 – existing situation before energy renovation

Type of cost	Normalised cost by lifecycle stage (€/m²/a.)		
	A Product and construction stages	B Use stage Before renovation	C End-of-life stage
Initial costs	-	-	-
Annual costs	-	2.1	-
Energy costs	-	23.3	
Periodic costs	-	-	-
Global costs by lifecycle stage	-	25.4	-

4.6.2 Extraction of energy and flexibility measures and integration of the SRI and sustainability indicators in EPC

Collecting data for a calculation of the SRI and sustainability indicators can be integrated with the EPC generation. The process begins by collecting all the necessary data about the building. This includes structural information, energy usage, and existing technologies, as well as data about how the building is used and occupied. Some of these data can be obtained from buildings' energy-management systems or smart meters, while other data might need to be collected through inspections or interviews with occupants.

To connect the calculation of the SRI and the sustainability indicators with the EPC generation process an energy-performance certifier should assess the current status of the building's smart readiness, energy efficiency, and sustainability. This involves identifying and assessing the current energy systems, technologies, and strategies in place. For example, the building might have an automated lighting system that reduces energy use, or a demand-response capability that helps to flexibly adapt to the grid's needs. Once the current status has been assessed, the next step is to identify opportunities for improvement. This could involve upgrading outdated systems, installing new, smart technologies, or changing the operational strategies to increase the efficiency. These opportunities are generally the energy and flexibility measures that can be taken to improve the building's SRI and overall energy performance.

The EPC certifier should make these observations in form of written comments in the SRI Excel tool. To integrate the SRI and sustainability indicators into the EPC, these comments should be translated into measures that should be incorporated into the overall energy-performance assessment. This could involve a quantitative integration, where the measures are included in the calculation of the building's energy-performance rating, or a qualitative integration, where the measures are described in the EPC report to provide a more comprehensive picture of the building's energy performance. Finally, after the EPC has been issued, the identified measures should be implemented and their impacts monitored over time. This monitoring is crucial for verifying the effectiveness of the measures and for continuously improving the building's energy performance.

The table 66 showcases possible improvements, the so-called “smart-renovation scenario” and their corresponding influence on the SRI scores for the analysed buildings, further illustrating the potential for enhancing their smart readiness. The proposed measures are in line with main findings from the TDS3 and Renovation Passport.

Table 66. Extracted energy and flexibility measures for buildings in Slovenia and new SRI scores

TIMEPAC Code	Building usage	SRI score	Key impact	Energy and flexibility measures	New SRI score
SI-01	Elementary School	18%	Smart school building	Installation of the modern energy-management system with demand/response functionalities and feedback to the occupants Renovation of lighting system and advanced control systems Installation of PV system Reconstruction of the HVAC system – implementation of new heat pump for heating and cooling, new VSD pumps and advanced control of heating and cooling systems	49%
SI-02	Health centre	18%	Smart, renewable and flexible health centre	Upgrade of the installed energy-management system with demand/response functionalities and feedback to the occupants Installation of PV system Renovation of lighting system and advanced control systems Installation of the battery system for the peak-load management, emergency power supply and optimising of the PV production	51%
SI-03	Offices	23%	Smart and flexible municipality building	Upgrade of the installed energy-management system with demand/response functionalities and feedback to the occupants Installation of PV system	51%

TIMEPAC Code	Building usage	SRI score	Key impact	Energy and flexibility measures	New SRI score
				Renovation of lighting system and advanced control systems Advanced control of ventilation, heating and cooling systems Installation of the battery system for the peak-load management, emergency power supply and optimising of the PV production	
SI-04	Offices	12%	Smart and flexible offices	Installation of the modern energy-management system with demand/response functionalities and feedback to the occupants Renovation of lighting system and advanced control systems Installation of PV system Complete reconstruction of the HVAC system Installation of the battery system for the peak-load management, emergency power supply and optimising of the PV production	58%
SI-05	Elementary and secondary school - building is under cultural heritage protection	5%	Smart, flexible and sustainability aware school	Installation of the modern energy-management system with demand/response functionalities and feedback to the occupants Renovation of lighting system and advanced control systems Installation of PV system Comprehensive reconstruction of the HVAC system and advanced control of heating, cooling and ventilation system Installation of the battery system for the peak-load management, emergency power supply and optimising of the PV production	61%
SI-06	Elementary School	25%	Smart and flexibility aware school	Upgrade of the installed energy-management system with demand/response functionalities and feedback to the occupants	52%

TIMEPAC Code	Building usage	SRI score	Key impact	Energy and flexibility measures	New SRI score
				Installation of PV system Renovation of lighting system and advanced control systems Upgrade of the HVAC (installation of ventilation system) and advanced control Installation of the battery system for the peak-load management, emergency power supply and optimising of the PV production Installation of the smart EV-charging station	
SI-07	Kindergarten	13%	Smart and renewable kindergarten	Installation of the modern energy-management system with demand/response functionalities and feedback to the occupants Renovation of lighting system and advanced control systems Installation of PV system Reconstruction of the HVAC system – implementation of new heat pump for heating and cooling, new VSD pumps and advanced control of heating, ventilation and cooling systems Installation of the smart EV-charging station	63%
SI-08	Elementary school	20%	Smart, flexible and renewable school	Installation of the modern energy-management system with demand/response functionalities and feedback to the occupants Installation of PV system Installation of the battery system for the peak-load management, emergency power supply and optimising of the PV production	43%
SI-09	Cultural Centre	22%	Smart cultural building	Upgrade of the installed energy-management system with demand/response functionalities and feedback to the occupants	44%

TIMEPAC Code	Building usage	SRI score	Key impact	Energy and flexibility measures	New SRI score
				Advanced control of ventilation system Installation of PV system Installation of the battery system for the peak-load management, emergency power supply and optimising of the PV production Upgrade of the smart EV-charging station	
SI-10	Elementary school	24%	Smart, flexible and comfort school	Upgrade of the installed energy-management system with demand/response functionalities and feedback to the occupants Installation of PV system Advanced control system for lighting Installation of the battery system for the peak-load management, emergency power supply and optimising of the PV production Installation of the smart EV-charging station	46%

Also, based on the proposed “smart-renovation scenario” sustainability indicators for building SI-02 are calculated again and the results are presented in Table 67, Table 68, Table 69, Table 70, Table 71 and Table 72.

Table 67. Delivered energy assessment for SI-02 – after energy renovation

Building service	Energy carrier	Delivered energy per energy carrier	Non-renewable primary energy		Renewable primary energy		Total primary energy	
		kWh/a.	Factor	kWh/a.	Factor	kWh/a.	Factor	kWh/a.
Heating	Heat	212,370	0.8	169,896	0.4	84,948	1.2	254,843
Cooling	Electricity	6,361	1.5	9,542	1.0	6,361	2.5	15,903
Ventilation	Electricity	13,022	1.5	19,533	1.0	13,022	2.5	32,554
Hot water	Heat	45,360	0.8	36,288	0.4	18,144	1.2	54,433
Lighting	Electricity	13,287	1.5	19,930	1.0	13,287	2.5	33,217
Exported renewable energy	-	0	-	0	-	0	-	0
Overall		290,400	-	255,189	-	135,762	-	390,951

Table 68. Energy-performance assessment at level 3 results for building SI-02 – after energy renovation

Services	kWh/m^2/a.
L3.1 EPBD services non-renewable primary energy self-used	70.3
L3.2 EPBD services renewable primary energy self-used	37.4
L3.3 EPBD services total primary energy self-used	107.7
L3.4 Exported renewable primary energy	0.0
L3.5 EPBD services non-renewable primary energy balance	70.3
L3.6 Non-EPBD services non-renewable primary energy self-used	16.5
L3.7 Non-EPBD services renewable primary energy self-used (optional)	11.0
L3.8 Non-EPBD services total primary energy self-used (optional)	27.5
L3.9 Total primary energy self-used (optional)	135.2
L3.10 Total primary energy balance (optional)	135.2

Table 69. Results of an assessment 1.2 at level 3 for building SI-02 for status after energy renovation for all phases (A-D)

	Unit	After energy renovation			
		C/B + EPS	C/B + mineral wool	C/B + porous concrete	C/B + cellular glass
(1) GWP – fossil	kg CO_2 eq /m^2	1,850	2,415	2,650	3,150
(2) GWP – biogenic	kg CO_2 eq /m^2	0	2,875	0	0
GWP – (1) + (2)	kg CO_2 eq /m^2	1,850	5,290	2,650	3,150
(3) GWP – Land use and land use change	kg CO_2 eq /m^2	N/A	N/A	N/A	N/A
GWP – (1) + (2) + (3)	kg CO_2 eq /m^2	N/A	N/A	N/A	N/A

C/B – load bearing structure from concrete and bricks
ER – energy renovation
EPS - expanded polystyrene

The results show that all analysed scenarios for the energy renovation of the selected building SI-02 achieve positive substitution factors for their construction on basis of the current LCA standards (EN 15978 2012; 15804:2014) (Figure 8). The construction elements of the analysed buildings are the foundation, external walls, internal walls, ceiling, roof and balcony when present. The relevant building type is defined by the load-bearing structure. Further elements included in the buildings as finishing components comprise doors, windows, stairs, flooring, roofing, façade, and technical building equipment.

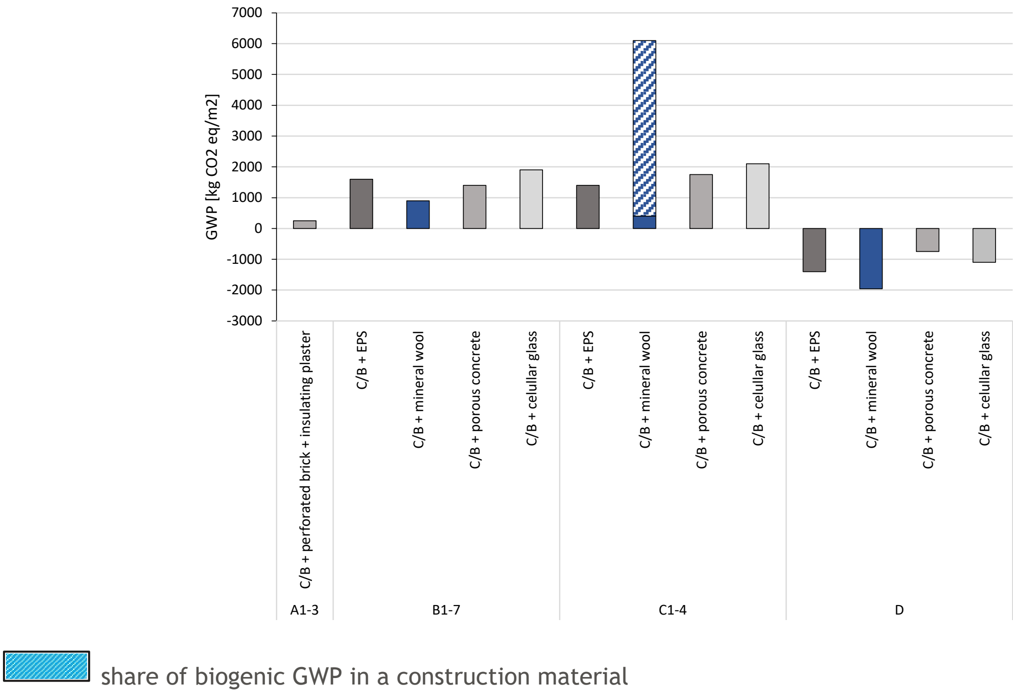

Figure 8. LCA results (indicator GWP) for selected building SI-02 divided into different lifecycle stages A, B, C, and D

Rucinska[2] et al. (2020) defined a GWP benchmark for office buildings in relation to the total Global Warming Potential normalised to the usable floor area. The calculated mean and median values for the 11 buildings were 5001 and 4.965 $kgCO_2eq/m^2$ TLT, respectively. Based on those outcomes, a GWP value of 5.000 kg CO_2eq/m^2 in TLT = 60 years was selected as a reference mean value for defining the GWP benchmark of office buildings in Poland. Finally, building classes were calculated according to the methodology defined by the European standard EN ISO 52003-1 [38], which sets the requirements and is used as a rating method to assess the energy performance of buildings. The defined building rating labels are presented in Table 70.

The benchmarks from Rucinska are set for phases A-C only. According to this, building's SI-02 GWP is 3.250 of kg $CO_2eq/m2$, which reaches label C.

Table 70. Building rating labels for GWP

Building class	GWP [kg CO_2 eq /m^2]
A	≤ 1800
B	≤ 2500
C	≤ 3500
D	≤ 5000
E	≤ 7100
F	≤ 10,000
G	≤ 14,100

[2] Rucinska, J., Komerska, A., Kwiatkowski, J. 2020. Preliminary Study on the GWP Benchmark of Office Buildings in Poland Using the LCA Approach. Energies 13(13), 3298; https://doi.org/10.3390/en13133298

Table 71. Project-assessment results for reporting of indicator 4.2 of an assessment at level 3 for building SI-02 – after energy renovation

	Heating season	Cooling season
Operating temperature range (°C)	18 - 24	22 - 28
Time out of range (%) - with mechanical heating/cooling	0	0

Table 72. Project-assessment results for reporting of indicator 6.1 at level 3 for building SI-02 – after energy renovation

Type of cost	Normalised cost by lifecycle stage (€/m^2/a.)		
	A Product and construction stages	B Use stage After renovation	C End-of-life stage
Initial costs	-	15.9	-
Annual costs	-	6.7	-
Periodic costs	-	1.2	-
Global costs by lifecycle stage	-	23.8	-

It should be noted that the required investments for the proposed improvements are significant. Performed research work clearly indicates that calculation of SRI and sustainability indicators can be combined with the EPC generation. SRI and sustainability indicators serve as a data source for the energy performance certifier and have a potential to provide a more comprehensive understanding of a building's energy, flexibility and smart performance, leading to better-informed improvement strategies. However, a major challenge lies in the integration of different tools and methodologies utilized for these assessments. Research work conducted in the framework of the TIMEPAC project clearly revealed that for the effective calculation of sustainability indicators is necessary to employ BIM and BEM.

The main gaps in this process are lack of an integrated or compatible tool, the availability of required databases, and the high cost associated with obtaining an EPC based on BIM/BEM. However, for comprehensive renovation of larger non-residential buildings we recommend combination of the SRI and EPC processes, with the possibility of incorporating certain sustainability indicators as well. This integration should not significantly increase the overall cost, ensuring a more cost-effective and streamlined approach to assessing current and future building energy performance. In this context, EPC could benefit from customised recommendations that are tailored to the specific building and its unique characteristics and needs.

4.6.3 Main gaps and recommendations

During the data collection and calculation of SRI and sustainability indicators for selected buildings in Slovenia the following obstacles, barriers and challenges have been identified:

- Unawareness of opportunities related to the flexibility, maintenance and indoor air quality,
- Motivating on-site personnel including owner to actively participate in SRI and sustainability related activities – actual SRI values are low and demotivating for the owner/occupants,
- High cost of smartness,
- Subjectivity in evaluation of existing systems – SRI is extracted from European Standard EN 15232-1 (CEN, 2022c) and it is mainly focused on BACS functionalities which can be easily misinterpreted or overestimated.

- Concept of sustainability is not very clear to the main stakeholders and they do not see added value in a complicated calculation,
- Sustainability and smartens is perceived as the first step towards implementation of very comprehensive energy-efficiency measures and are always connected with very high implementation costs,
- There is a need for increased energy efficiency and flexibility related educational activities with on-site demonstration.

Data collection

The SRI relies on detailed information about the building and its systems. Unfortunately, this data may not always be readily available or accurate. The accuracy and relevance of the data collected during the SRI and sustainability rating process directly impact the reliability of the analysis. If the data is inaccurate or irrelevant, the resulting recommendations or conclusions may not be valid or effective. Accurate and reliable data provides a clear understanding of the current situation, which is necessary for the development of effective strategies and measures to improve energy efficiency, flexibility of energy services and overall smartness of the building. Stakeholders are more likely to trust and act upon the recommendations if they are based on solid data. Accurate data allows effective benchmarking against similar buildings which is vitally important for facility and energy managers. Inaccurate data could also lead to sub-optimal investment decisions and financial losses. In this context site visit is essential and collected data and main findings should be objectively presented to the owner/occupants.

Value of the SRI

One of the main issues is understanding what exactly the SRI measures and how to implement it. The SRI score is not just percentage of smartness. The SRI and sustainability auditor should always try to explain his/her findings with the emphasis on the potential energy efficiency and flexibility improvement measures. While the methodology for calculating the SRI is relatively clear, it can still be complex due to the variety of factors it considers. This complexity can be a barrier to implementation, particularly for smaller buildings or organizations with limited resources. We are fully aware that the SRI is relatively new concept but it has to be emphasized that the information on SRI alone is not solving the problem and the intention of the TIMEPAC project and this TDS is to propose an appropriate approach on how to correctly interpret SRI value. For the proper management of smartness and flexibility in buildings and to enable support for the implementation of innovative energy efficiency and flexibility measures, it is necessary to introduce the Smart Performance Coefficient (SPC) which is the ratio of actual SRI (SRI_{act}) to benchmark SRI (SRI_{bench}) for the selected building type (so called actual SPC or SPC_{act}) as shown by Eq. 1 or ratio of predicted SRI (SRI_{pred}) after implementation of the virtual smart renovation scenario and actual SRI as shown by Eq. 2.

$$SPC_{act} = SRI_{act} / SRI_{bench} \quad (1)$$

$$SPC_{imp} = SRI_{pred} / SRI_{act} \quad (2)$$

Benchmark values are specific values extracted from the SRI database for each defined building type. When the actual SRI is close to the benchmark, SPC has a value of 1.0 which is an indication that the energy systems within the building are running as expected according to the selected building type. On the other hand, when the actual SRI_{act} is higher than benchmark, SPC has a value higher than 1.0 which is an indication that the energy systems within the building already have some degree of smartness. In case of SPC_{imp}, values higher than 1.0 are indicating that there is a potential for improvement which must be further investigated and objectively presented to the building owner and occupants. The purpose of the SPC is to enable proper interpretation of the SRI value and to present that information to the building owner/occupant in a simple and straightforward way. During the initial period of SRI implementation this approach will require continuous updates of the benchmark values since there is no operational definition what is expected benchmark value for the selected building type.

Need for training

The SRI methodology includes certain qualitative elements, such as assessing how well occupants understand and can use the smart technology in their building. These subjective factors can be influenced by the individual auditor's judgement, potentially leading to inconsistency in SRI scores. Objective calculation of SRI and sustainability indicators requires significant knowledge and technical skills which means that more extensive implementation will require more in-depth training and practical exercises. The subjectivity of the auditor and the influence on the final SRI results can lead to variation in the scores between different buildings. Clear guidelines and training can help to mitigate this, but it will always be a factor to some degree. To ensure accuracy and consistency, auditors should be well-trained and experienced, and the same auditor should ideally assess all similar buildings in a portfolio. This is very important for the energy or facility managers that managing larger portfolio of similar buildings. Regular audits and reassessments can also help to ensure the ongoing accuracy of the SRI. There's a need for further research and refinement to reduce the subjectivity involved in SRI calculations and ensure the system is robust, transparent, and useful to all stakeholders. Also, the use of smart technologies is adding complexity to the operation of a building. It is clear that additional training will be required for occupants and maintenance staff to use and manage these systems effectively. Without any doubt it can be concluded that training for auditors and other stakeholders (owners, occupants, etc.) is critical to ensuring the effective use of the SRI.

Concerns regarding implementation of smart technologies

It is clear that smart technologies have a potential to significantly increase a building's energy efficiency. In a combination with advanced energy-management systems, they allow real-time monitoring and control of various systems such as heating, lighting, and cooling. This can result in significant savings of energy and consequently on energy costs and lower environmental impact. Also, smart technologies often increase the comfort and convenience for occupants. Automated lighting and temperature controls, flexibility services, and advanced predictive maintenance features all contribute to a more comfortable and convenient living or working environment. However, the initial cost of implementing smart technologies can be very high. This includes the cost of the technology itself, as well as installation and integration with existing systems. Also, smart technologies evolve quickly, and what is cutting-edge today may be obsolete in just a few years. Objective SRI and sustainability auditor must inform building owner and occupants that they may need to be prepared for the costs of upgrading their systems to stay current. Implementing smart technology can increase the value of a building but also, due to the complexity and new systems, it increases the maintenance costs. Based on the Slovenian experiences, it is not clear are prospective tenants or buyers willing to pay more for the benefits that such technology provides. We have also noticed that some of the owners and occupants are concerned about pure dependence on technology. With smart technology controlling various aspects of a building, there is increased dependence on these systems. If they fail or malfunction, it could have a significant impact on the building's operations and the comfort of its occupants.

Target groups/main stakeholders

Based on the limited Slovenian experiences, the SRI and sustainability indicators can be a very useful for anyone involved in the management, operation, or auditing of buildings. The SRI and sustainability indicators provide a clear and standardized measure of a building's readiness for smart technologies and sustainability, which can help various stakeholders to make more informed decisions and improve the performance of the buildings they work with, facilitating the transition towards smarter, more energy-efficient buildings. Through the implementation of the TDS4 in Slovenia the following stakeholder groups were recognised:

- Building owners,
- Occupants,
- Energy and facility managers,
- Energy auditors and energy performance certifiers,

- Energy Service Companies (ESCOs),
- Energy utilities,
- Local and regional authorities (municipalities, cities and regions),
- Policy developers/regulators.

Building Owners: SRI and sustainability indicators can provide buildings owners with a clear indication of their building's readiness for smart technologies and overall sustainability. By understanding their current status, owners can prioritize improvements, potentially increase the value of their property, and potentially reduce operational costs through energy savings.

Occupants: Occupants can benefit from the improved comfort, safety, and potentially reduced energy costs resulting from the smart readiness of a building. The SRI and sustainability indicators can also help occupants make more informed decisions when choosing a rental property or purchasing a building.

Energy and facility managers: Energy managers can utilize the SRI and sustainability indicators to identify and prioritize areas where energy efficiency can be improved through the use of smart and sustainable technologies. They can use the SRI and sustainability to track improvements over time and demonstrate the benefits of investments in smart and sustainable technologies to building owners or other stakeholders. For facility managers, the SRI and sustainability indicators can provide a clear indication of a building's readiness for new technologies, which can aid in their management of the facility.

Energy auditors and energy performance certifiers: The SRI and sustainability indicators help energy auditors and energy performance certifiers to assess the smart readiness and sustainability of a building, which complements their main task of identifying energy-saving opportunities. By using the SRI and sustainability indicators, energy auditors and energy performance certifiers can broaden their scope and provide more comprehensive suggestions for improving a building's overall energy performance.

ESCOs: The SRI and sustainability indicators can help ESCOs identify potential opportunities for implementing energy-efficiency measures in a building. This can help them to prioritize their efforts and develop effective solutions for their clients.

Energy utilities: Energy utilities can use the SRI to help identify buildings that are well-suited to demand response programs or other initiatives that require smart technologies. Based on data from SRI database, energy utilities could develop targeted activities to encourage building owners/occupants to participate in various demand response programs. This can improve the efficiency of the energy grid and reduce costs.

Local and regional authorities (municipalities, cities and regions): For local and regional authorities, the SRI and sustainable indicators can provide an information of how well the buildings within their jurisdiction are prepared for the transition to a smarter, more sustainable energy grid. It can help guide policy decisions and inform urban planning efforts.

Policy developers/regulators: At a broader level, policy developers can use the SRI and sustainability indicators to guide the development of building codes and standards, and to track progress towards energy and climate goals. The SRI and sustainability indicators can provide valuable data to inform policy decisions and help identify areas where further support or regulation may be needed.

Value of the sustainability indicators

Based on the assessment results, it is clear that the use phase has an important contribution to the buildings environmental impact (Indicator 1.1) and financial costs (Indicator 6.1). Likely the importance for the environmental impact is mainly caused by the energy use for heating, while for the financial cost, cleaning and maintenance are important. Further, the construction phase as well has a big influence on the costs and impacts. Lastly, it has to be recognised that multiple aspects considering future adaptability of the building to changing user needs are implemented in the building design. However, based on these results, it is not possible to highlight the importance of the different building elements and to get insights about opportunities to improve the sustainability of the building.

The testing of the Level(s) in the scope of TDS 4 revealed that for many of the indicators detailed lifecycle inventory data is needed which cannot be directly retrieved from the architectural plans or documents. A complete assessment of all the indicators on a Levels 1-3 requires a lot of time. The reporting itself is not time consuming. To reduce the time efforts, it is recommended to establish or improve the links with national tools (e.g. current link with EPB-software for indicator 1.1). Default values are seen as a second way to reduce time efforts.

As a team of actors are typically involved in the design of buildings, it became clear that the data and knowledge required for Level(s) is spread over these different actors. For example, the EPB-document for indicator 1.1 was drafted by the collaborating engineer firm, while the LCA and cost analysis are mainly performed by an academic institution. In order to work efficiently, it might be recommended that various actors are responsible for parts of the Level(s) reporting. Although this is probably more time efficient, a good overall coordination will then be required to ensure that the same assumptions are taken for the multiple calculations required. Linking as much as possible with available tools and interfaces (e.g. BIM-model) could enhance uniformity across different assessments and actors.

The testing revealed that most of the indicators are linked to assessment methods that require data structuring that is different than in architectural practice to date. This is for example the case for the LCA study (Indicator 1.2): even if a BIM model is available, this model may provide information about the general composition of building elements and their amounts but information on sub-element composition is lacking, such as for example the kg of brick per m^2 wall or the kg of cement mortar per m^2 wall. Default element compositions and related amount of materials could help practitioners. Further alignment between different tools could moreover improve this information flow.

The objective of the Level(s) assessment is to provide a common reference point for the performance assessment of buildings across Europe. The assessment moreover provides general insights in the various environmental impacts, energy use and costs their design is causing. However, it does not allow to evaluate the ‘sustainability’ level of their project as reference values are not available to compare with and detailed hotspot analysis is not possible. In order to increase the added value of the assessment for practitioners it is recommended to integrate such reference values (benchmarks) or more detailed reporting in future.

4.7 Spain

The SRI calculation was carried out on a total of five buildings, each characterized by distinct usage patterns. Among these buildings, three were relatively new constructions, while the remaining two were older structures. To gather the necessary data for the calculation, a comprehensive approach was employed, involving on-site visits and interviews with either building owners or energy managers, depending on the specific case. To assess the SRI of each building, Method B with default domain weightings and tool variant 4.5 was used. This method considers factors such as energy efficiency, connectivity, and the utilization of smart technologies to enhance building performance. By employing this approach, a comprehensive evaluation was carried out to determine the smart readiness of the buildings and identify potential areas for improvement. Additionally, Method A was utilized in all buildings to compare both methodologies across different building uses.

Table 73 shows the buildings which were selected for the analysis in the current task. These buildings were analysed with SRI Excel tool version 4.5 with default method A and default method B.

Table 73. Overview of analysed Spanish buildings

TIMEPAC Code	Building type	Status
ES-01	Educational building	New construction
ES-02	Offices	New construction
ES-03	Nursing home	New construction
ES-04	Residential building	Existing, partially refurbished
ES-05	Small residential building	Existing

ES-01 has all the domains present (except the EV charging), and they have been evaluated. The buildings use the Building Management System (BMS) which is used to monitor and manage the heating and cooling services in the building and the mechanical ventilation through the $C0_2$ detection. Heating and cooling are served by an aerothermal system. PV is present for RES generation. The main issues identified in this building revolve around its static building envelope, lacking a dynamic system that could adapt to changing conditions. Currently, the building relies on passive elements, such as vertical slats, which are fixed and non-adjustable. Additionally, the interior shutters lack automatic control, further limiting their functionality.

The ES-02 building incorporates all evaluated domains except for DHW, which is not included due to its office nature. The building utilizes a Building Management System (BMS) to effectively monitor and manage its mechanical, electrical, and electromechanical services. Additionally, it features PV technology for renewable energy generation and implements a monetized EV charging system. Similar to the previous building, the main concern lies with the dynamic building envelope. Unfortunately, the fixed slats cannot be controlled, resulting in limited flexibility. The heating and cooling systems are regulated based on CO_2 levels rather than occupancy control. Moreover, there is currently no Thermal Energy Storage (TES) system in place. While the lighting system is centrally controlled in common areas, it lacks control in individual offices.

The ES-03 building encompasses a wide range of domains, except for EV charging, which has been thoroughly evaluated. The building employs the Building Management System (BMS) to monitor and oversee heating and cooling services, mechanical ventilation, and window openings in correlation with the HVAC system. For heating and cooling, an aerothermal system is utilized, while photovoltaic (PV) panels generate renewable energy. However, several key issues have been identified in this building. Firstly, the absence of a dynamic building envelope is a concern, as it relies on passive vertical slats that cannot be adjusted. Additionally, the interior shutters lack automatic control.

ES-04 building together with the ES-05 has the lowest number of the domains present since it was wanted to study different types of building constructions. The present domains, however, have been evaluated. The main issues identified in the heating system (natural gas) include the absence of occupancy detection and the control of the heating system done by the users. The same happens with the cooling system, which is controlled by the users by switching on/off the split units. In DHW (Domestic Hot Water) production, there is no integration with renewable energy sources (RES). The ventilation system is present in a few rooms but has rudimentary controls, for instance: the only ventilation system is the manual opening of the windows. Regarding the lighting system, there is no central control, dimming capability, or occupancy detection. Window shading controls are manual (manual roller blinds). The building does not have on-site electricity generation, and information regarding electricity consumption is not shared. Monitoring-and-control systems are almost non-existent, leading to a lack of information for occupants.

The ES-05 is the Spanish oldest building from the study (constructed in 1933). This building has the lowest of the domains present since is the oldest building of the study and the only one not refurbished. The present domains, however, have been evaluated. The main issues identified in the heating system (natural gas) lacks of occupancy detection and relies on user control. Similarly, the cooling system depends on user-controlled split units for operation. In terms of Domestic Hot Water (DHW) production, there is no integration with renewable energy sources (RES). The ventilation system is limited to a few rooms with basic controls, such as manual window opening. The lighting system lacks centralized control, dimming capabilities, and occupancy detection. Window shading controls are manual, utilizing roller blinds. The building lacks on-site electricity generation and does not provide information on electricity consumption. Furthermore, there is no available infrastructure for EV charging. Monitoring-and-control systems are nearly non-existent, resulting in a lack of information for occupants.

A sustainability assessment was conducted for building ES-03, taking advantage of the most pertinent documentation, including the Energy Performance Certificate (EPC), monthly building energy models (BEM), historical consumption and temperature data, and Building Information Modelling (BIM). Furthermore, this building was constructed in 2021. For a comprehensive understanding of the assessment method employed, please refer to Table **74**. For the analysis, the provided guideline was used, however, in an adjusted manner, as described below.

Table 74. Methods used for ES-03

Used approach	Level 2	Level 3
Indicator 1.1 Use stage energy performance	--	yes
Indicator 1.2 Lifecycle Global Warming Potential	--	yes, significant assumptions
Indicator 4.2 Time outside of thermal comfort range	--	yes
Indicator 6.1 Lifecycle costs	-	yes, significant assumptions

4.7.1 Outcomes of SRI and sustainability assessment for selected buildings

The Smart Readiness Indicator (SRI) calculation results are displayed in the tables 75 and 76, showcasing a wide range of scores. These scores vary significantly due to the inclusion of diverse buildings for study, with their year of construction or recent reconstruction having a substantial impact. Notably, Key Functionality 3, which pertains to grid integration, exhibits the lowest scores primarily due to legal restrictions and the absence of a flexible market. Consequently, these factors greatly hinder the buildings' capacity to adapt and contribute to a more flexible grid system.

Table 75. Outcomes of SRI assessment for selected buildings in Spain – default Method A

TIMEPAC Code	Building usage	Data from	SRI score	Key functionality 1 score - building	Key functionality 2 score - user	Key functionality 3 score - grid
ES-01	Educational building	Site visit, interview with the building manager	61%	76%	65%	42%
ES-02	Office	Site visit, interview with the building manager and certifiers	58%	62%	71%	39%
ES-03	Nursing home	Site visit, interview with the building manager and the energy certifiers	70%	72%	88%	49%
ES-04	Multifamily house	Site visit, interview with the owners	15%	11%	35%	0%
ES-05	Small multifamily house	Site visit, interview with the owners	14%	10%	34%	0%

Table 76. Outcomes of SRI assessment for selected buildings in Spain – default Method B

TIMEPAC Code	Building usage	Data from	SRI score	Key functionality 1 score - building	Key functionality 2 score - user	Key functionality 3 score - grid
ES-01	Educational building	Site visit, interview with the building manager	54%	73%	62%	27%
ES-02	Office	Site visit, interview with the building manager and certifiers	53%	66%	71%	21%

TIMEPAC Code	Building usage	Data from	SRI score	Key functionality 1 score - building	Key functionality 2 score - user	Key functionality 3 score - grid
ES-03	Nursing home	Site visit, interview with the building manager and the energy certifiers	53%	65%	68%	26%
ES-04	Multifamily house	Site visit, interview with the owners	10%	9%	22%	0%
ES-05	Small multifamily house	Site visit, interview with the owners	10%	8%	22%	0%

For sustainability indicators results are shown below. Indicator 1.1 was calculated for level 3 using data from the energy performance calculation from TDS2 and the calibrated model. The factors used in the Table 77 shown below are the standards values from the document "Factores de emisión de $C0_2$ y coeficientes de paso a energía primaria de diferentes fuentes de energía final consumidas en el sector de edificios en España" from the Spanish joint resolution of the Ministry of Industry, Energy, and Tourism, and the Ministry of Development (Table 78).

Table 77. Delivered energy assessment at level 3 for ES-03 - existing situation before energy renovation

Building service	Energy carrier	Delivered energy per energy carrier	Non-renewable primary energy		Renewable primary energy		Total primary energy	
		kWh/a.	Factor	kWh/a.	Factor	kWh/a.	Factor	kWh/a.
Heating	Electricity	11,681	1.954	22,825	0.414	4,836	2.368	27,661
Cooling	Electricity	25,046	1.954	48,940	0.414	10,369	2.368	59,309
Ventilation	Electricity	25,203	1.954	49,247	0.414	10,434	2.368	59,682
Hot water	Electricity	44,294	1.954	86,550	0.414	18,338	2.368	10,4887
Lighting	Electricity	56,089	1.954	109,599	0.414	23,221	2.368	132,820
Exported renewable energy	-	0	-	0	-	0	-	0
Overall		162,313	1.954	317,161	0.414	67,198	2.368	384,359

Table 78. Energy-performance assessment at level 3: results for building ES-03 – existing situation before energy renovation

Services	$kWh/m^2/a.$
L3.1 EPBD services non-renewable primary energy self-used	88.67
L3.2 EPBD services renewable primary energy self-used	18.79
L3.3 EPBD services total primary energy self-used	107.45
L3.4 Exported renewable primary energy	0.00
L3.5 EPBD services non-renewable primary energy balance	107.45

In terms of the Lifecycle Global Warming Potential (indicator 1.2), the table below shows the results for the building's structure of the relevant EPC zone, excluding the embodied GWP for technical building systems, and excluding the GWP for building use (Table 79). The GWP is calculated with the CYPE software tool that allows a calculation of the total $kgCO_2eq$ GWP for the A1–A5 stage. The system boundaries as defined by EN 15978 determine which unit processes are included in the LCA study. The system-building is divided into process units, encompassing all the elements, materials, and components that constitute the building and are affected by flows of matter and energy during their life phases. In this study, the system boundary comprises the manufacturing and construction of the entire building. Finally, this calculation encompasses the A1-A3 Product Stage and the A4-A5 Construction-Process Stages in accordance with the standards UNE.

Table 79. Reporting the results of assessment 1.2 at level 2 for building ES-03 – existing situation before energy renovation

	Unit	Total of covered stages	Product (A1-A3)	Construction process (A4)	Construction process (A5)	Use stage (B1-B7)	End of life (C1-C4)	Benefits and loads beyond the system boundary (D)
			Covered	Covered	Covered	Not covered	Not covered	no
Total GWP	kg CO_2 eq	820,741.67	799,342.03	16,062.78	5,336.86			

In terms of total CO_2 eq from the building's use (total delivered energy consumption according to the EPC), the following calculation results are presented:

- 229.44 kg CO_2 eq/m^2

Indicator 4.2, the time spent outside the thermal comfort range, can be easily calculated either from the hourly Building Energy Model (BEM) or from temperature measurements within the building (Table 80). In TDS2, the thermal comfort was calculated based on simulation data, resulting in a discomfort level of 23% for ES-03 in the heating season without mechanical ventilation. Furthermore, the average indoor temperature of the building was cross-checked using historical data, and no time outside the comfort range was observed during the cooling season.

Table 80. Project-assessment results for reporting indicator 4.2 of an assessment at level 3 for building ES-03 – existing situation before energy renovation

	Heating season	Cooling season
Operating temperature range (°C)	19 - 21	20 - 27
Time out of range (%) - without mechanical heating/cooling	23%	0

Indicator 6.1 Lifecycle costs was calculated from data available in TDS2 - economic validation of energy-efficiency measures (Table 81).

Table 81. Project-assessment results for reporting of indicator 6.1 at level 3 for building ES-03 – situation before energy renovation

Type of cost	Normalised cost by lifecycle stage (€/m^2/a.)		
	Product and construction stages	Use stage	End-of-life stage
Initial costs	39.63	-	18.83
Annual costs - energy	-	18.80	-
Annual costs - maintenance	-	1.17	-
Periodic costs	-	-	6.08
Global costs by lifecycle stage	39.63	19.97	24.91

4.7.2 Extraction of energy and flexibility measures and integration of the SRI and sustainability indicators in EPC

Table 82 provides an overview of potential improvements and their respective impact on the SRI scores of the analysed buildings. This further demonstrates the potential for enhancing their smart readiness.

Table 82. Extracted energy and flexibility measures for buildings in Spain and new SRI scores

TIMEPAC Code	Building usage	SRI score	Key impact	Energy and flexibility measures	New SRI score
ES-01	Educational building	54%	Smart school with grid interaction	PV and battery system with advanced grid interaction Control elements and sensors for dynamic building envelope	59%
ES-02	Office	53%	Smart dynamic building envelope	Control elements and sensors for dynamic building envelope Adding batteries to existing PV	57%
ES-03	Nursing home	53%	Smart-energy nursing home	PV and battery system with advanced grid interaction (100 kW) Control elements and sensors for dynamic building envelope New LED lighting system with dimming control	69%

TIMEPAC Code	Building usage	SRI score	Key impact	Energy and flexibility measures	New SRI score
ES-04	Multi-family house	10%	Smart residential building	PV and battery system (5 kW) with advanced grid interaction Replacement of the combined generator for heating, DHW and cooling with high-efficiency technologies, control elements and sensors for heating and cooling systems, Smart mechanical ventilation system Installation of EV charging	36%
ES-05	Small Multi-family house	10%	Smart small building	PV and battery system (3 kW) with advanced grid interaction Replacement of the combined generator for heating, DHW and cooling with high efficiency technologies control elements and sensors for heating and cooling systems, Smart mechanical ventilation system Installation of EV charging	35%

After applying the improvement measures related to the SRI, we conducted an analysis of Building ES-03 using the selected sustainability indicators. The specific measures implemented were as follows:

- PV and battery system with advanced grid interaction (100 kW pic.)
- Control elements and sensors for dynamic building envelope
- New LED lighting system with dimming control

Indicator 1.1 was calculated again for level 3 (Table 83). It was assumed and calculated using the software CYPE that the PV panels provided 100% of the electricity in this new scenario, since the PV panels are considered with batteries for energy storage. This means that in building ES-03, all the PV-produced electricity is self-consumed with no exported renewable energy (Table 84).

Table 83. Delivered energy assessment at level 3 for ES-03 – situation after energy renovation

Building service	Energy carrier	Delivered energy per energy carrier	Non-renewable primary energy		Renewable primary energy		Total primary energy	
		kWh/a.	Factor	kWh/a.	Factor	kWh/a.	Factor	kWh/a.
Heating	Electricity	10,513	--	0	1	10,513	1	10,513
Cooling	Electricity	22,542	--	0	1	22,542	1	22,542
Ventilation	Electricity	22,683	--	0	1	22,683	1	22,683
Hot water	Electricity	39,864	--	0	1	39,864	1	39,864

Lighting	Electricity	50,480	--	0	1	50,480	1	50,480
Exported renewable energy	-	-	-	0	-	0	-	0
Overall		146,082				146,082		146,082

Table 84. Energy-performance assessment at level 3: results for building ES-03 – situation after energy renovation

Services	$kWh/m^2/a$.
L3.1 EPBD services non-renewable primary energy self-used	0
L3.2 EPBD services renewable primary energy self-used	40.84
L3.3 EPBD services total primary energy self-used	40.84
L3.4 Exported renewable primary energy	0
L3.5 EPBD services non-renewable primary energy balance	0

In terms of Lifecycle Global Warming Potential (indicator 1.2), this analysis was not conducted. As the CYPE software only calculates the construction process for phases A1-A5, it becomes redundant to recalculate with additional elements (installation of PV), as this would inevitably escalate the GWP (Global Warming Potential). The key focus in this scenario should be on studying the use stage, where a noticeable reduction can be achieved, particularly in overall GWP, by installing photovoltaic panels. In this case, it is crucial to acknowledge this limitation. When considering stages A1-A5, they might not appear favourable in terms of GWP. However, when we comprehensively analyse them in conjunction with the use stages B1-B7, the results begin to align logically, as the building's consumption aspect is considered.

Indicator 4.2, the time spent outside the thermal comfort range, was calculated. In TDS2, thermal comfort was calculated based on simulation data, resulting in a discomfort level of 0% for ES-03 in the heating and cooling season without mechanical ventilation (Table 85). Furthermore, the average indoor temperature of the building was cross-checked using historical data, and no time outside the comfort range was observed during the cooling season.

Table 85. Project-assessment results for reporting indicator 4.2 of an assessment at level 3 for building ES-03 – situation after energy renovation

	Heating season	Cooling season
Operating temperature range (°C)	19 - 21	20 - 27
Time out of range (%) - without mechanical heating/cooling	0%	0%

Indicator 6.1 Lifecycle costs were calculated from data available in TDS2 - economic validation of energy-efficiency measures (Table 86).

Table 86. Project-assessment results for reporting of indicator 6.1 at level 3 for building ES-03 – situation after energy renovation

Type of cost	Normalised cost by lifecycle stage (€/m²/a.)		
	Product and construction stages	Use stage	End-of-life stage
Initial costs	39.63	0.21	21.62
Annual costs - energy	-	3.70	-
Annual costs - maintenance	-	2.17	-
Periodic costs	-	-	8.87
Global costs by lifecycle stage	39.63	6.08	27.7

It is important to consider that the EPC, the SRI indicator and the Level(s) indicator could be interrelated in the 'Digital Building Logbook'. As defined in the Amendments adopted by the European Parliament on 14 March 2023 on the proposal for a directive of the European Parliament and of the Council on the energy performance of buildings (recast) (COM(2021)0802 – C9-0469/2021 – 2021/0426(COD)) the 'Digital Building Logbook' means a common repository for all the relevant building data, including data related to energy performance such as energy-performance certificates, renovation passports and smart-readiness indicators, as well as on the lifecycle GWP and indoor environmental quality, which facilitates informed decision making and information sharing within the construction sector, among building owners and occupants, financial institutions and public authorities.

The following points are crucial to achieve this good interrelation of the documents relating to a building:

- Consistency of information:

The EPC, the SRI and the Level(s) from the same building, sharing common aspects, must be correlated to prevent information inconsistencies. For instance, both the EPC and SRI play a crucial role in evaluating the condition of a building's facilities. Simultaneously, the EPC and Level(s) assess the building's energy consumption, with the former focusing on its operational phase and the latter examining greenhouse-gas emissions throughout the building's lifecycle, encompassing design, construction, use and demolition.

- Economy:

To comply with the requirements of the SRI and Level(s) documents, evaluating additional building parameters necessitates investing time in training and dedicating more effort to the design process, resulting in increased project costs. Therefore, having the same person handle multiple document developments becomes crucial to containing the project’s costs.

- Information management:

When moving from the scale of a building to the scale of the city or country, it is essential that the Digital Building Logbook can be managed jointly. It is important to highlight that all this information is managed by one (or several) public entities. In this way, it will be possible to guarantee the maintenance and security of the data, as well as ensure that they can be consulted by everyone, i.e., that they are open data.

In the future, it will be necessary to define which entities or public bodies will be able to manage this Digital Building Logbook, which will relate to the EPC, SRI, Level(s), Renovation Passport, the Technical Inspection of the Building, etc. This situation will need to be defined, in the public powers distributed at the state, regional and local levels, by sector (housing, tertiary) and by subject (cadastre, energy, as well as other environmental aspects of Level(s) such as water, resilience, emissions, etc.). Moreover, there will be the option for a single body that manages all these complex data, and ensures the quality, or different bodies, each specialized in its own subject, ensuring that the data are interrelated electronically.

4.7.3 Main gaps and recommendations

There are multiple challenges, and here are some recommendations:

- Coherence, interrelation and quality of information:
  a) It is advantageous to have software that enables the execution of the EPC, SRI, Level(s), and Renovation Passport, with shared input data encompassing geometry, construction details of the envelope, thermal and renewable installations, and occupation schedules. Utilizing such software not only streamlines the process and lowers costs, but also enhances document quality by preventing errors and conflicting information.
  b) The SRI assesses a building's potential for improvement based on its management and control facilities. To enhance the interplay between the SRI and EPC, a more effective approach would involve integrating the proposed improvement measures from the SRI into the EPC and then quantifying the resulting energy savings.
  c) To facilitate meaningful comparisons of lifecycle assessments (LCAs) and the indicator GWP for various buildings, it is crucial to establish standardized, publicly accessible databases at the EU level. This will enable comprehensive evaluations of different buildings' environmental impacts, promoting effective comparisons on both national and EU scales.
  d) When calculating the level indicators, particularly indicator 1.2 (GWP), focusing solely on the A1-A5 stages does not provide meaningful insights if our goal is to implement more sustainable practices in the building. This is because introducing new services or facilities will inevitably lead to a worse environmental impact. To establish a relevant comparison, it becomes essential to mandate the inclusion of a building’s consumption data at a European level when evaluating environmental impacts. Without this standardized approach, there would be no baseline for comparison, rendering the assessments less effective.
  e) In Spain, there is pending approval for an update to the regulations that would establish a specific and mandatory training requirement for conducting EPCs. This training will not only enhance the quality of the EPCs but also ensure their effectiveness.
- Economy:
  a. In Spain, there are two types of tool for building design: simplified and general. Simplified tools define the geometry of enclosures based on the surface, while general tools enable three-dimensional building design. It is recommended that simplified tools be exclusively used for small buildings or specific sections (e.g., a single floor within a block). Conversely, for larger buildings, it is imperative to utilize three-dimensional tools for precise definitions. This approach effectively minimizes errors in the geometrical representation and ensures accurate building design. Moreover, the time invested in training and utilizing the tool would correspond to the complexity of the building.
  b. In regards to the application of the SRI indicator and the Level(s) indicators, they are relevant for both new buildings and renovations. However, for small existing buildings that lack intelligent equipment, the information obtained through the SRI indicator is not particularly relevant. On the other hand, tertiary buildings often feature intricate facilities, making the application of the SRI indicator very valuable in such cases.

5 Identified challenges and international comparison

In this chapter, the main findings and challenges that are identified in all partner countries are presented together with some considerations regarding the effectiveness of the SRI and sustainability rating in the countries.

5.1 Data availability

The analysis of the data sources for all the assessed buildings, as presented in Figure 9, shows different available sources from country to country. In all the assessed buildings, site visits and interviews with identified stakeholders were a very important step in the data-collection process as well as the SRI and sustainability rating. This is also in line with the current proposal of strengthened provisions on the EPC's generation requirements, articles 16-19 and annexes V and VI, where it is clearly stated that the EPC is to be provided following an on-site visit (European Commission, 2023a). It is interesting that only in the Austrian case were the technical and inspection reports available. Regarding the actual energy-consumption data, it is was used as the data source only in the cases of Slovenia and Cyprus.

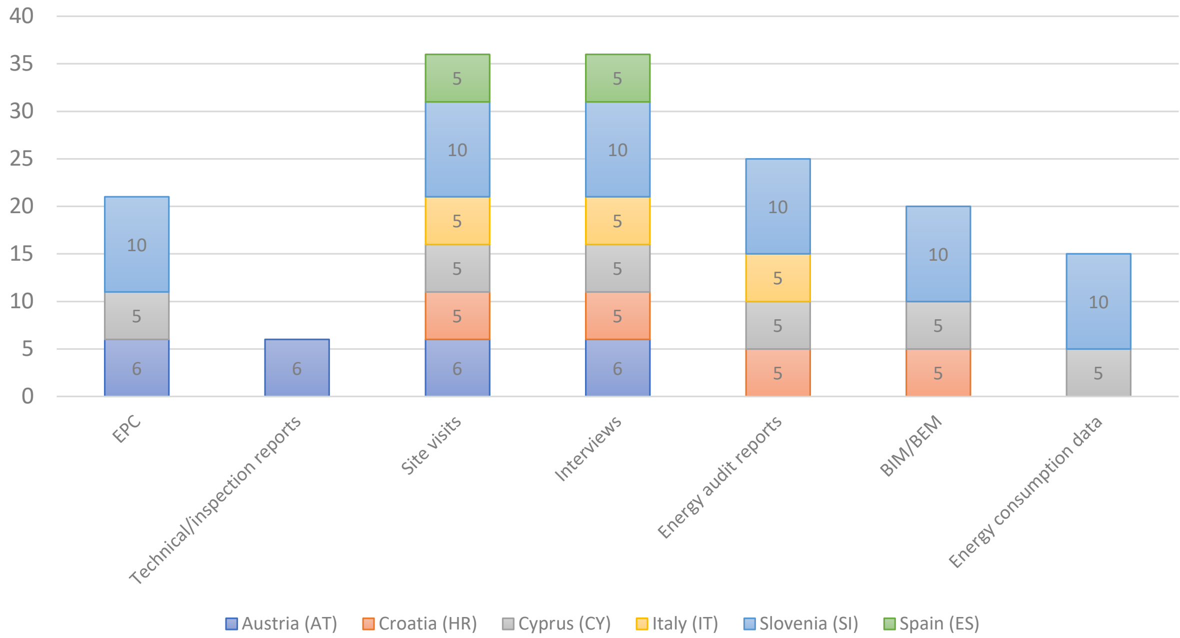

Figure 9. Data sources for SRI and sustainability rating in TDS4

5.2 Country specifics

This section presents the outcomes and comparisons of the SRI rating results across all the participating countries. The primary aim of this analysis was to detail the total scores both before and after the application of the smart renovation scenarios in various implementation environments or countries. Additionally, it offers results about the different impact categories, such as energy efficiency, energy flexibility and storage, comfort, convenience, health, well-being and accessibility, maintenance and fault prediction, as well as information dissemination to occupants. The analysis also covers domain scores encompassing heating, domestic hot water, cooling, ventilation, lighting, the dynamic building envelope, electricity, EV charging, as well as monitoring and control. Furthermore, it elucidates the outcomes of different key functionalities, namely the building, the user and the grid.

Figure 10 shows the total SRI score before and after the implementation of selected energy-efficiency and flexibility measures. It is evident that these selected measures hold the potential to markedly enhance the SRI score. However, for a more comprehensive understanding of the implementation context in different countries, a detailed examination of the impact and domain scores is necessary.

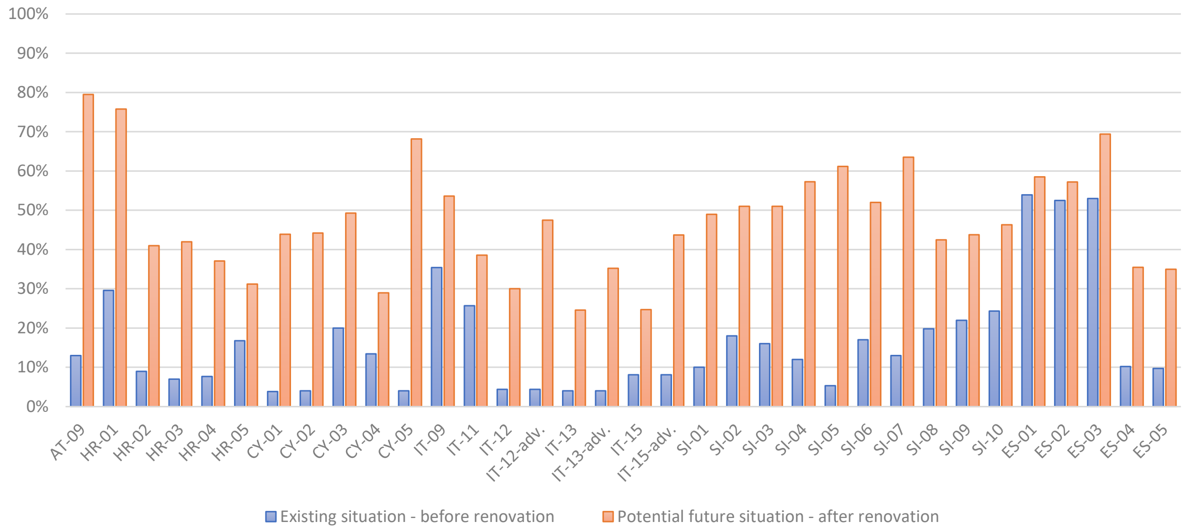

Figure 10. Total SRI score before and after renovation

The impact scores for energy efficiency before and after a renovation are presented in Figure 11 and Figure 12. The results confirm that energy efficiency has always been, and continues to be, of paramount importance for all the selected buildings. Given that several of these buildings had already undergone renovations, the impact scores for the existing situations are reasonably good. However, a closer examination of the data reveals that the renovations were primarily influenced by the preferences of individual stakeholders, owners, and energy managers. Surprisingly, not many of the installed systems qualify as "smart."

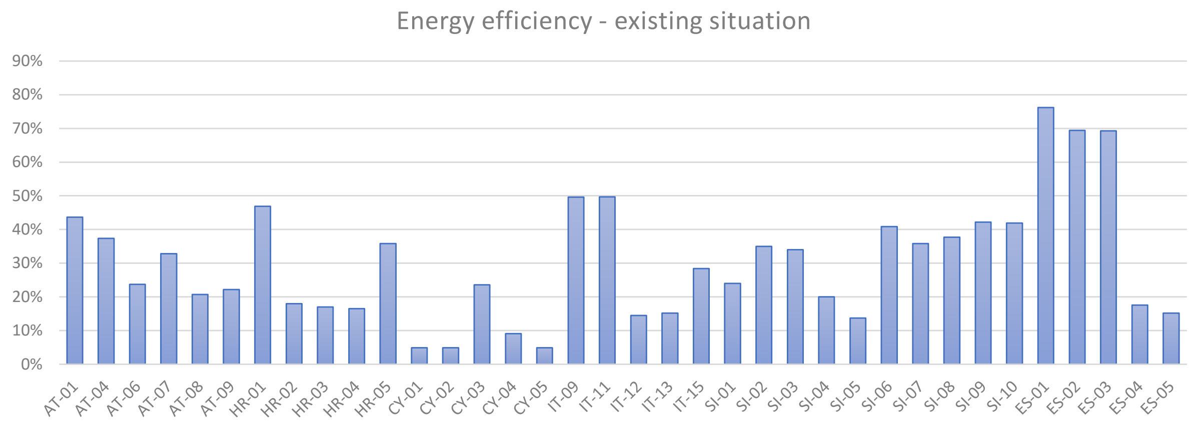

Figure 11. Impact score - energy efficiency, existing situation

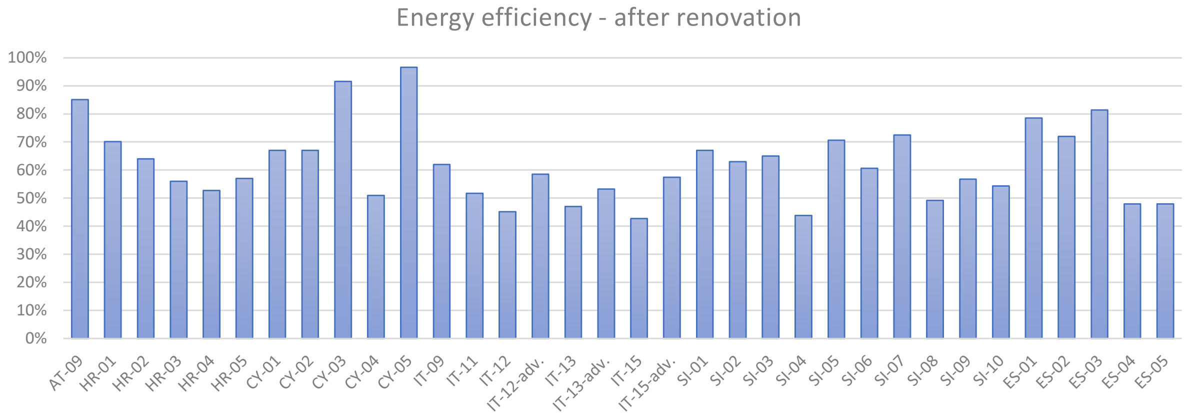

Figure 12. Impact score - energy efficiency, after renovation

Figure 13 and Figure 14 reveal the situation concerning energy flexibility and storage both before and after renovation. An evaluation of the existing situation indicates that, even in instances of new constructions or major energy renovations, energy flexibility and storage were not primary concerns for the owners or energy managers. This is mainly because such technologies are relatively expensive, and there are no well-functioning markets for flexibility services in the countries in question. This highlights an additional barrier to the broader application of services related to flexibility and storage, which is tied to the development of the market for demand-response services.

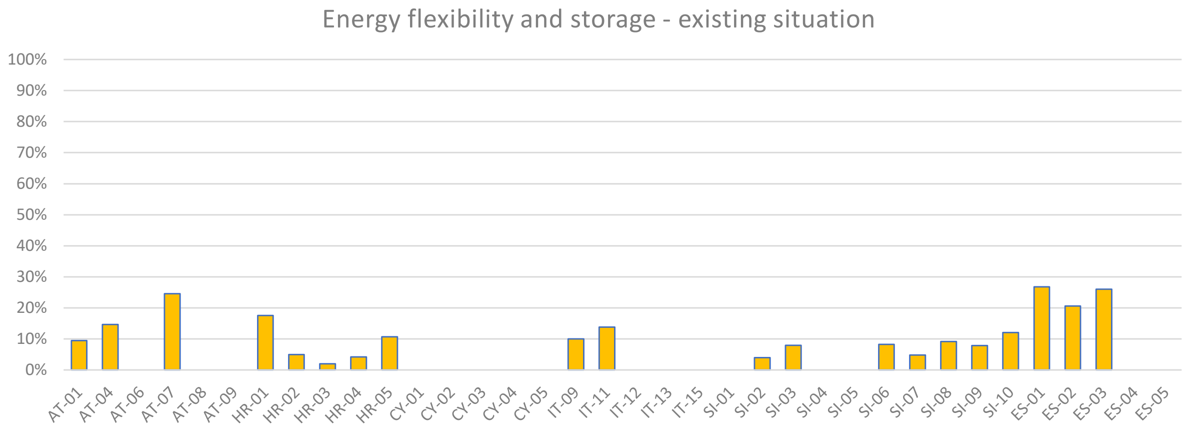

Figure 13. Impact score - energy flexibility and storage, existing situation

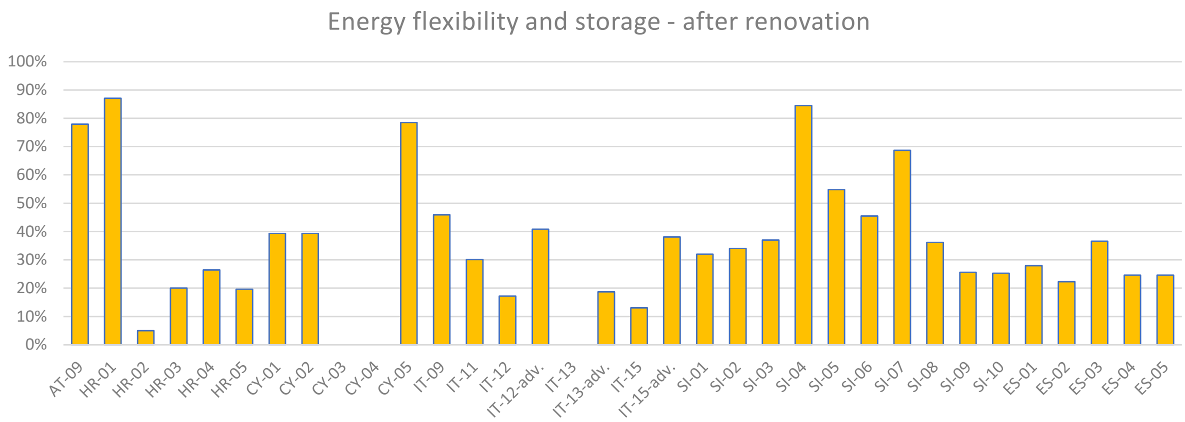

Figure 14. Impact score - energy flexibility and storage, after renovation

Comfort, convenience, health, well-being and accessibility are perceived as very important elements of the building environment both before and after energy renovation, as shown in Figure 15 through Figure 20. All the addressed stakeholders were very interested in implementing various measures to enhance these impact scores.

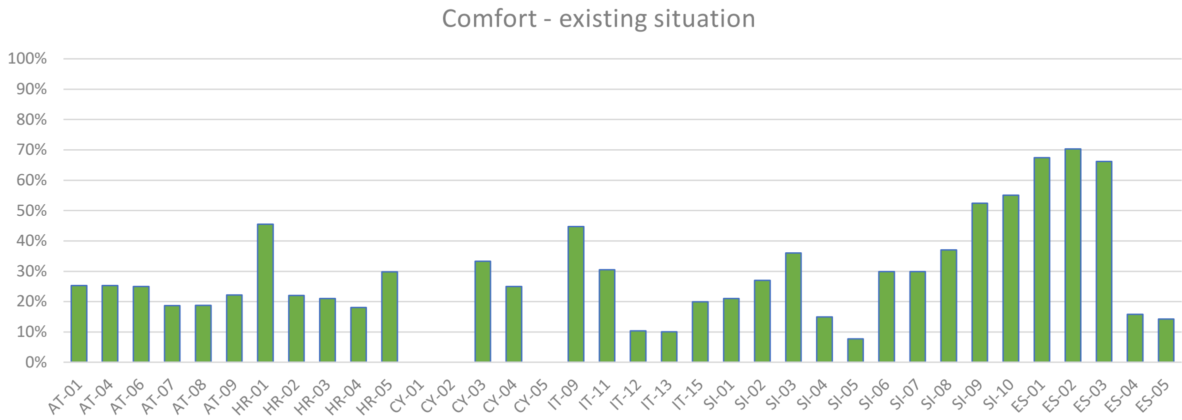

Figure 15. Impact score - comfort, existing situation

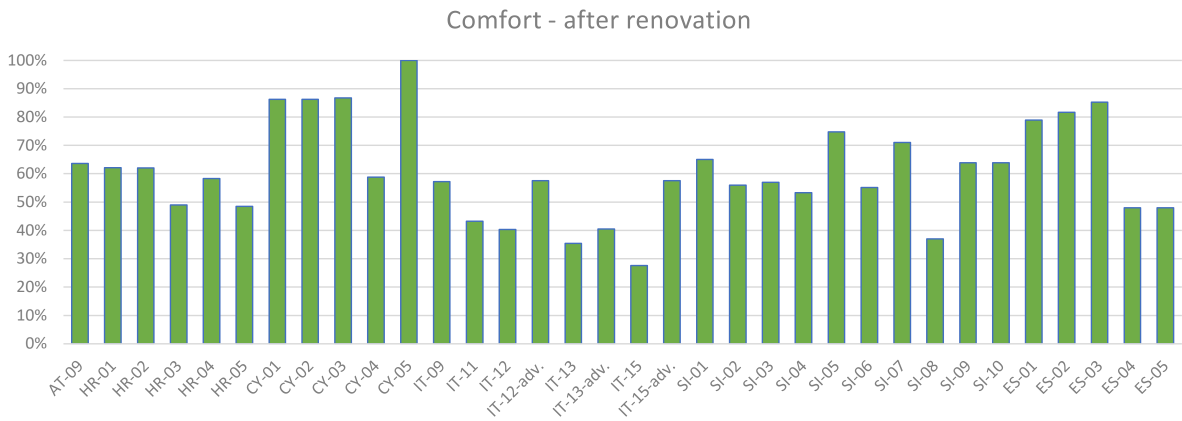

Figure 16. Impact score - comfort, after renovation

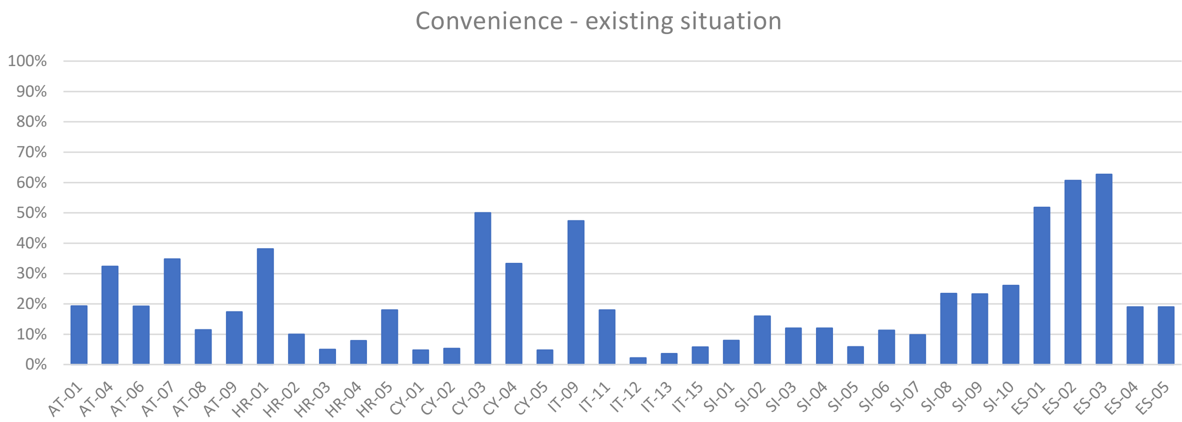

Figure 17. Impact score - convenience, existing situation

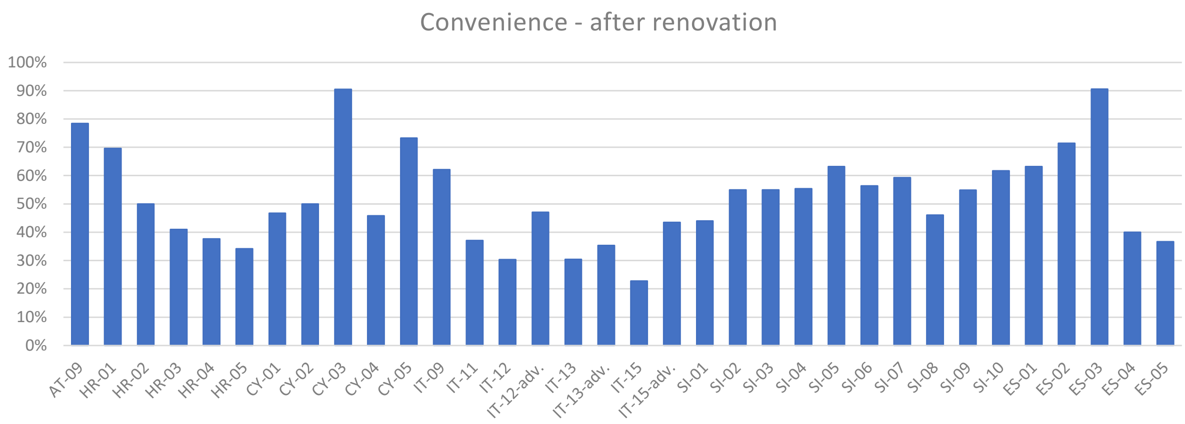

Figure 18. Impact score - convenience, after renovation

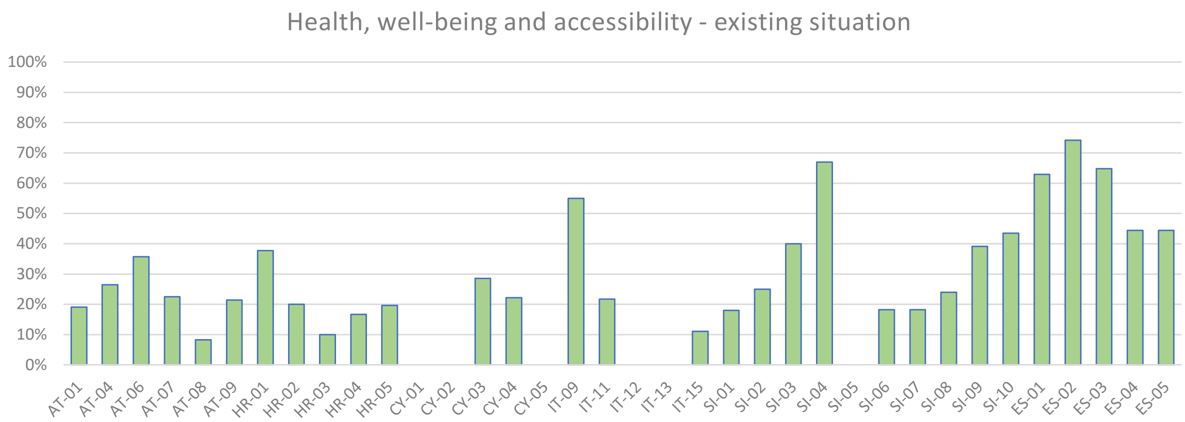

Figure 19. Impact score - health, well-being and accessibility, existing situation

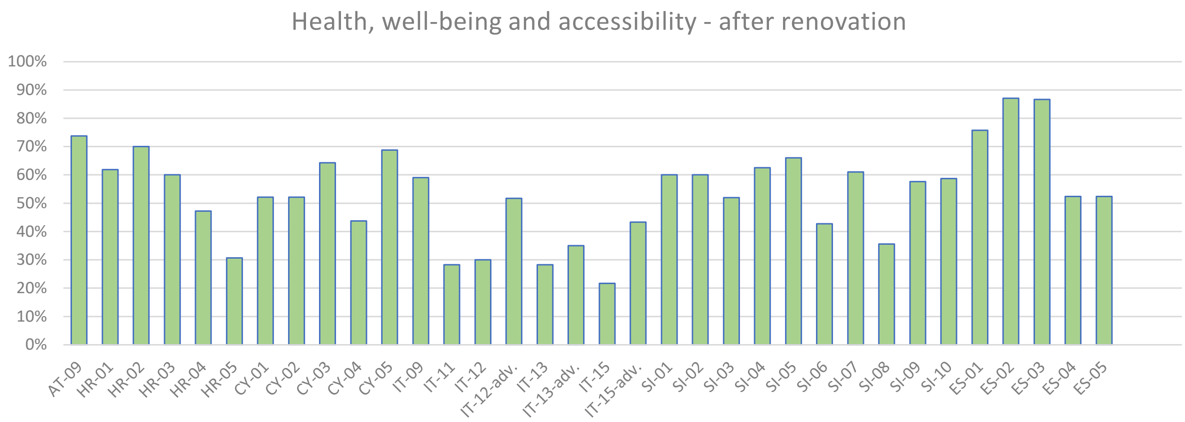

Figure 20. Impact score - health, well-being and accessibility, after renovation

The results of the evaluation of maintenance and fault-prediction functionalities are presented in Figure 21 and Figure 22. The current situation is marked by relatively modest functionalities related to maintenance and fault prediction. However, stakeholders expressed interest in enhancing these functionalities. They have also indicated that facility management should be an additional domain within the SRI rating tool.

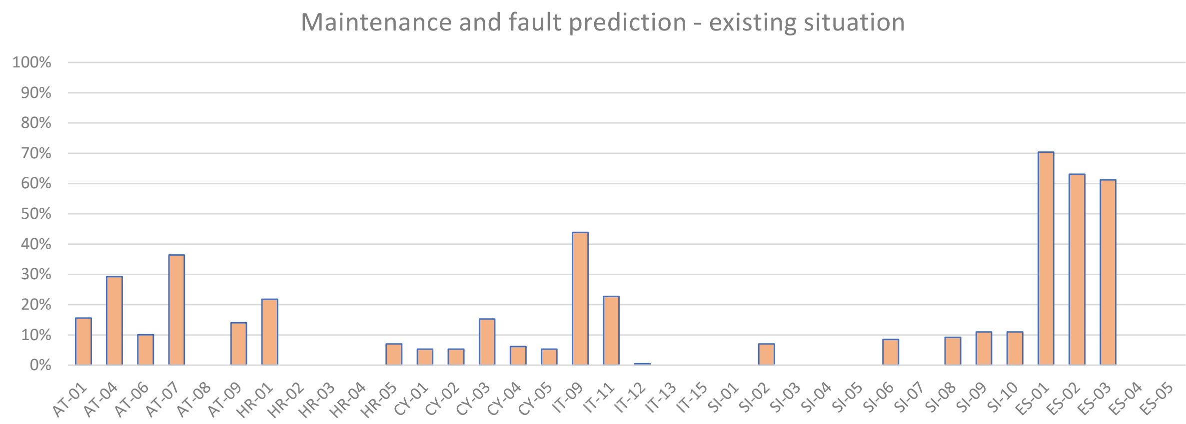

Figure 21. Impact score - maintenance and fault prediction, existing situation

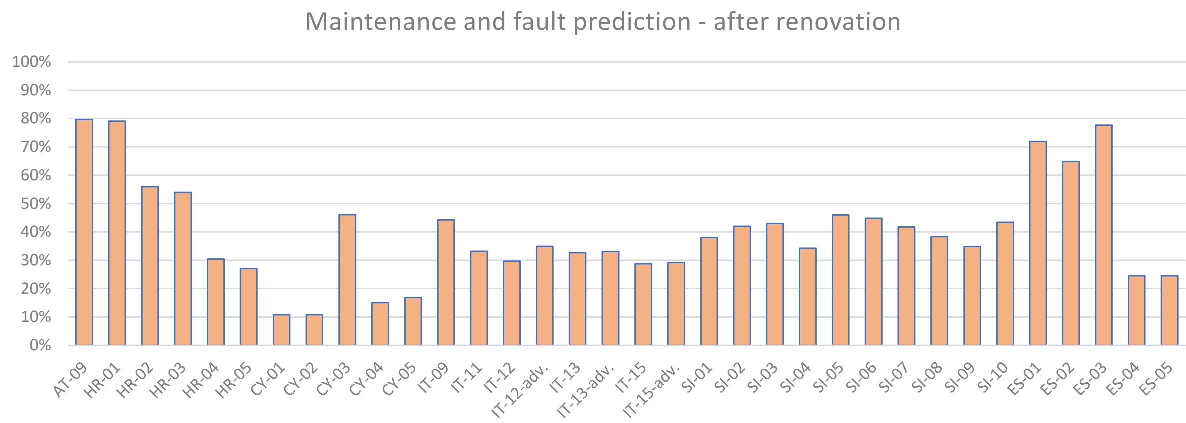

Figure 22. Impact score - maintenance and fault prediction, after renovation

Well-informed occupants are viewed as key stakeholders in making informed decisions about energy efficiency. However, the results shown in Figure 23 and Figure 24 indicate that this functionality in nearly all the addressed buildings could be improved.

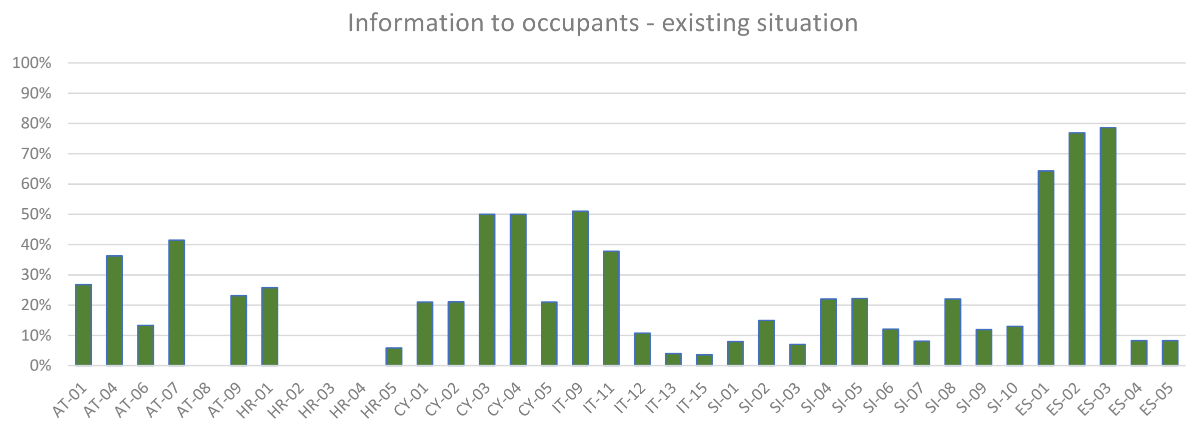

Figure 23. Impact score - information to occupants, existing situation

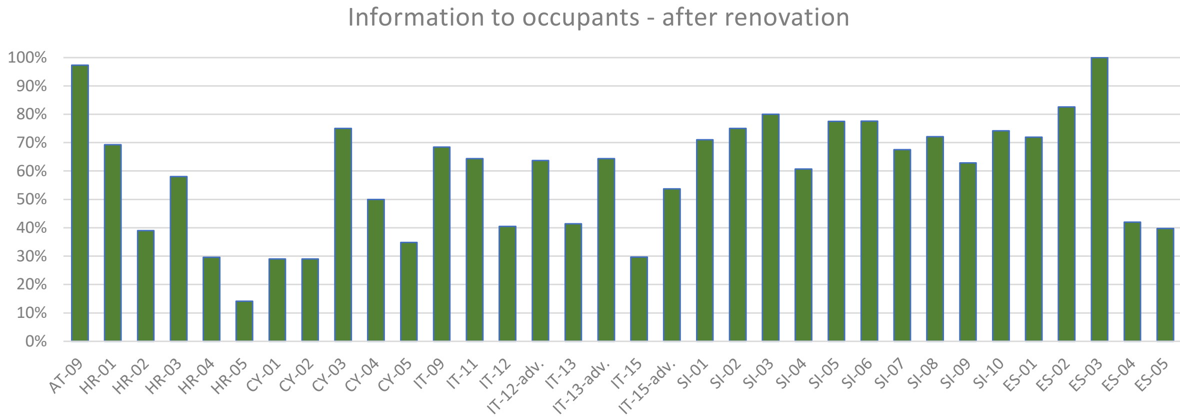

Figure 24. Impact score - information to occupants, after renovation

Figure 25 and Figure 26 present domain scores for heating. An evaluation of the current situation indicates that there is potential for making the heating domain more automated and smarter.

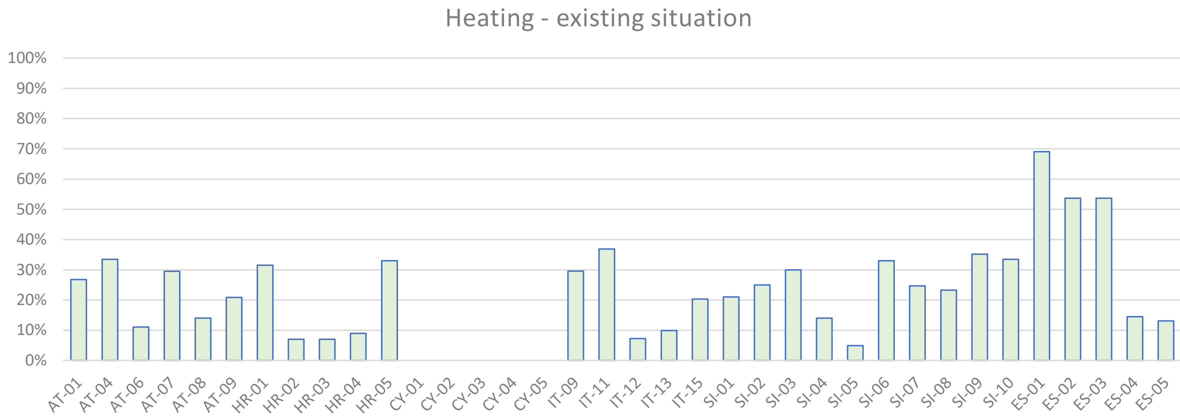

Figure 25. Domain score - heating, existing situation

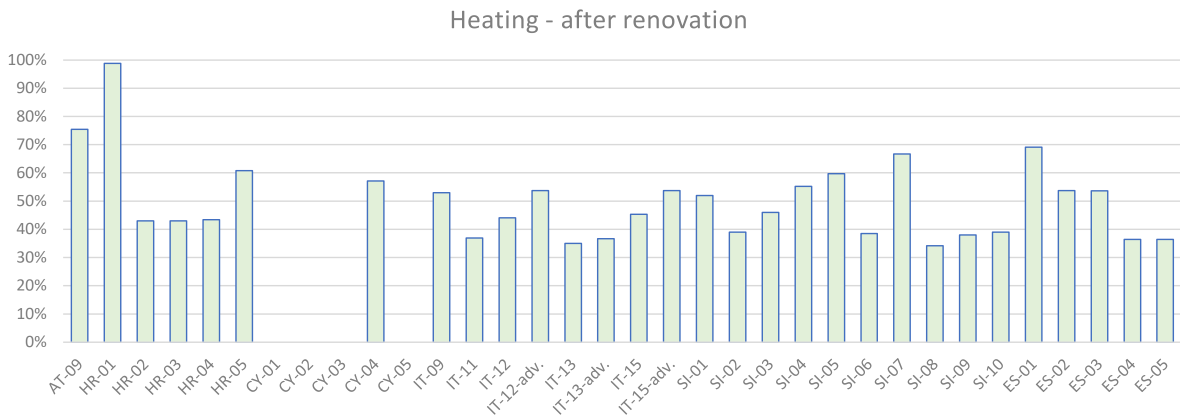

Figure 26. Domain score - heating, after renovation

Domain scores for domestic hot-water preparation are given in Figure 27 and Figure 28. Evaluations of the existing situation revealed that the main stakeholders (owners and energy managers) are not always aware of the benefits of having smart, domestic hot-water preparation. During site visits we were informed that existing water heaters are reliable and require low maintenance. Stakeholders stressed that adding smart components might introduce points of failure and increase the need for maintenance.

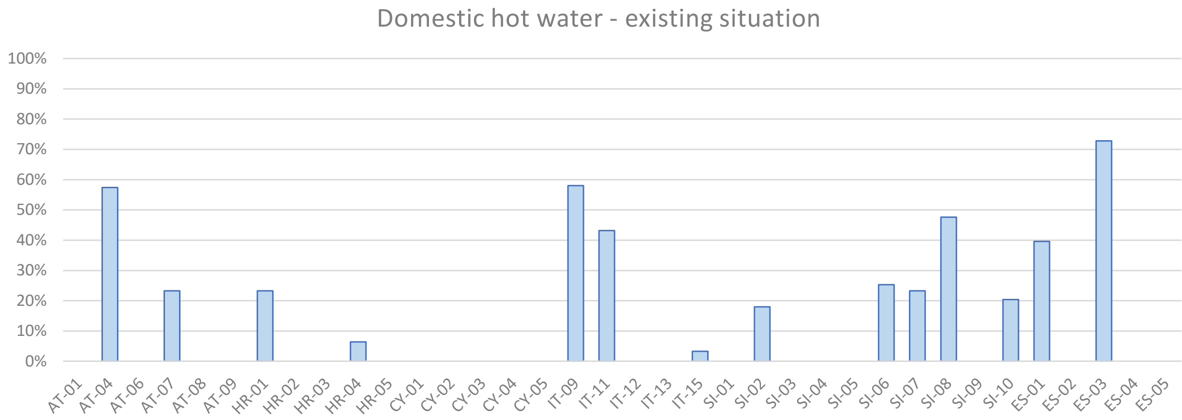

Figure 27. Domain score - domestic hot water, existing situation

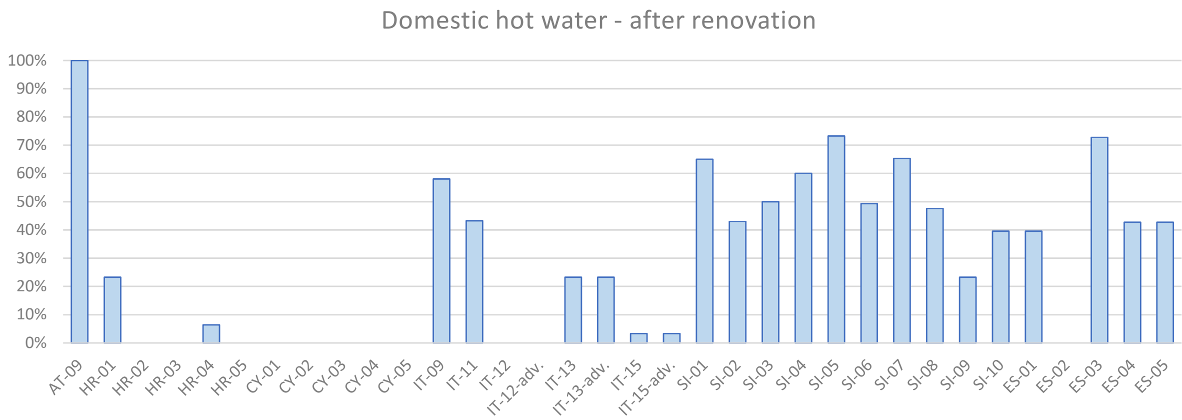

Figure 28. Domain score - domestic hot water, after renovation

Domain scores for cooling are given in Figure 29 and Figure 30. An improvement potential has been identified, and the main stakeholders have expressed interest in implementing smart components in their cooling systems. They are also aware of new, smart technologies, such as IoT devices and sensors, that can be integrated into their cooling systems. However, they emphasized that the majority of cooling systems operate for a relatively small number of hours in the year.

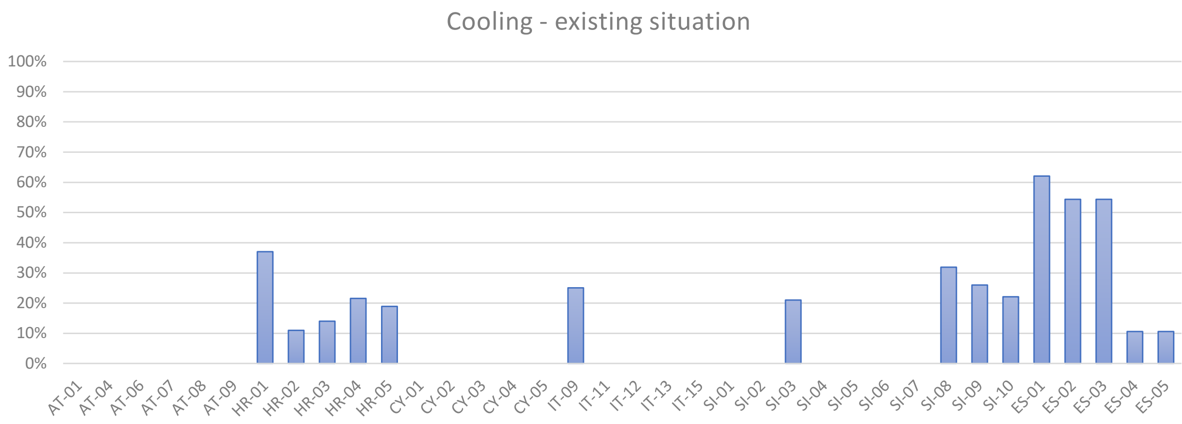

Figure 29. Domain score - cooling, existing situation

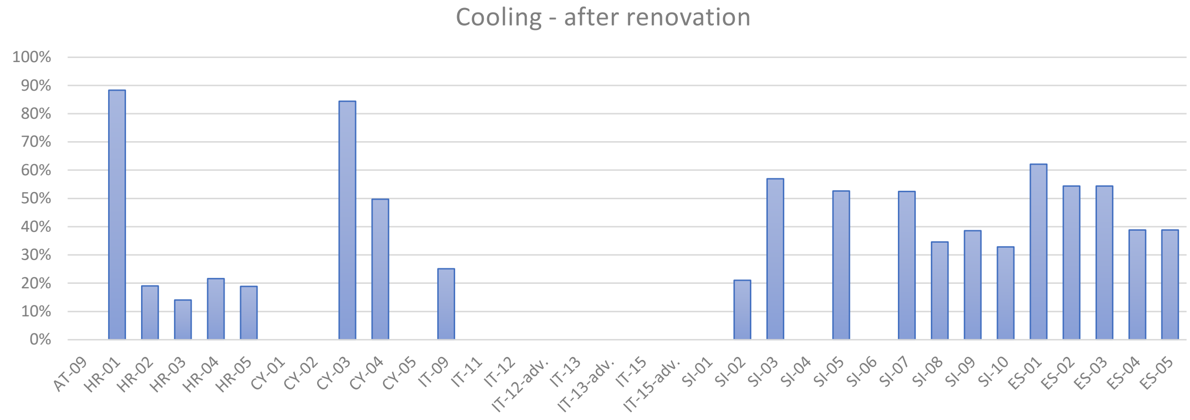

Figure 30. Domain score - cooling, after renovation

The domain scores for ventilation and lighting are given in Figure 31, Figure 32, Figure 33 and Figure 34. The main stakeholders are well aware that improving the ventilation and lighting domains of the SRI not only enhances the efficiency and functionality of buildings but also contributes to the well-being of their occupants and the environment. This finding is also in line with the impact scores for comfort, convenience, health, well-being and accessibility. Many stakeholders stressed that an appropriate and smart ventilation system must be an element in any major energy-renovation project and it must ensure a continuous supply of fresh air, removing pollutants and providing a healthier indoor environment. Modern and smart lighting systems can adjust lighting based on natural daylight availability and control ventilation based on occupancy and air quality, ensuring that energy is used only when necessary. Stakeholders also expect that by optimizing the ventilation and lighting through smart systems, operational costs related to energy consumption can be reduced. However, they were afraid that the smartness of these systems could increase maintenance costs.

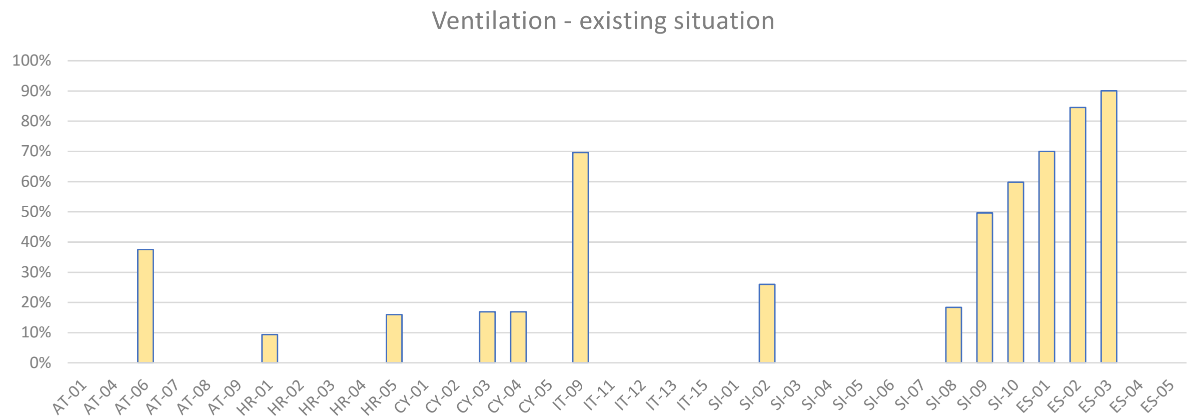

Figure 31. Domain score - ventilation, existing situation

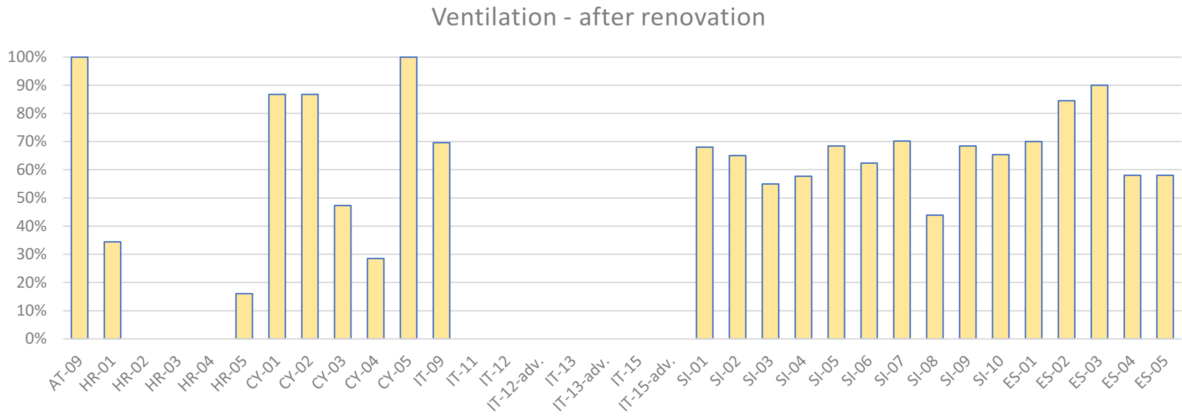

Figure 32. Domain score - ventilation, after renovation

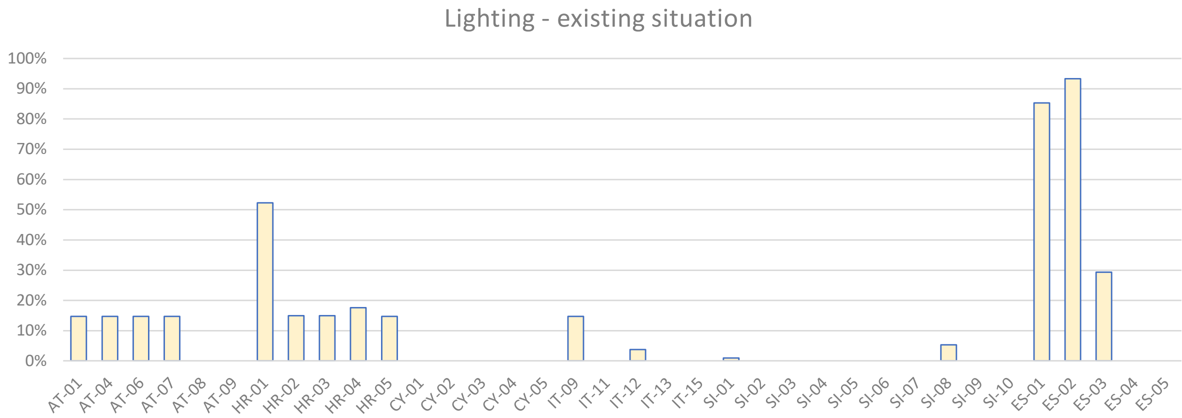

Figure 33. Domain score - lighting, existing situation

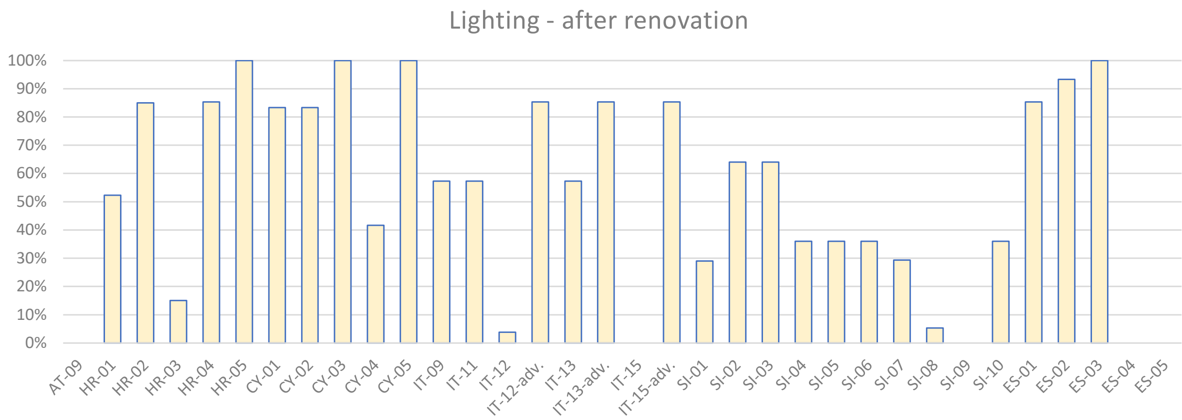

Figure 34. Domain score - lighting, after renovation

The domain scores for a dynamic building envelope are given in Figure 35 and Figure 36. It is clear that this domain is not of great interest to many stakeholders. From the expert's point of view, it is clear that dynamic building envelopes offer potential advantages; however, a combination of technical, economic, regulatory, and market factors can make them less attractive to some the SRI stakeholders. Many building owners were afraid of large implementation costs, especially when comparing them with potential energy savings or other benefits. The same applies to maintenance costs, because dynamic components, especially those with moving parts or electronic systems, might require more regular maintenance than static building components, leading to concerns about long-term operational costs.

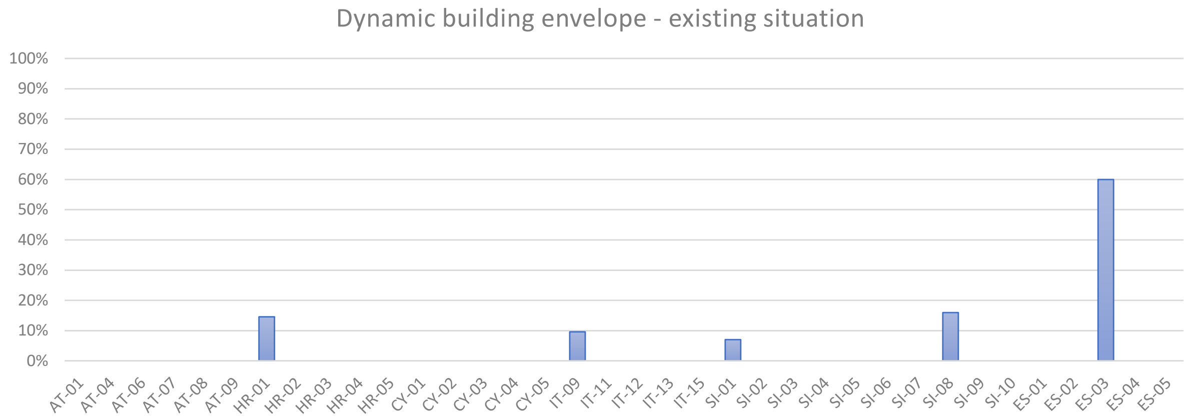

Figure 35. Domain score - dynamic building envelope, existing situation

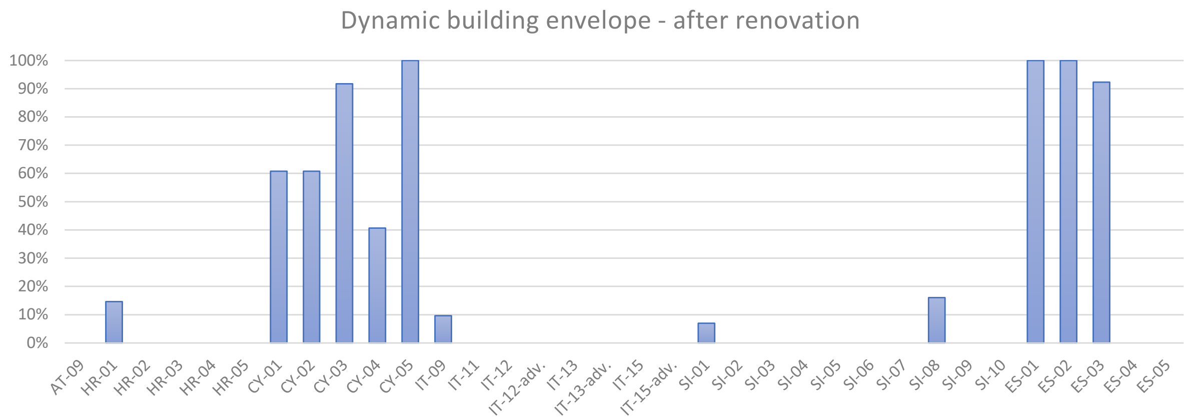

Figure 36. Domain score - dynamic building envelope, existing situation

Domain scores for electricity are given in Figure 37 and Figure 38. The evaluation reveals potential for improvement. The proposed improvement measures were well balanced and the main stakeholders recognised the potential for cooperation with ESCOs and electricity utilities.

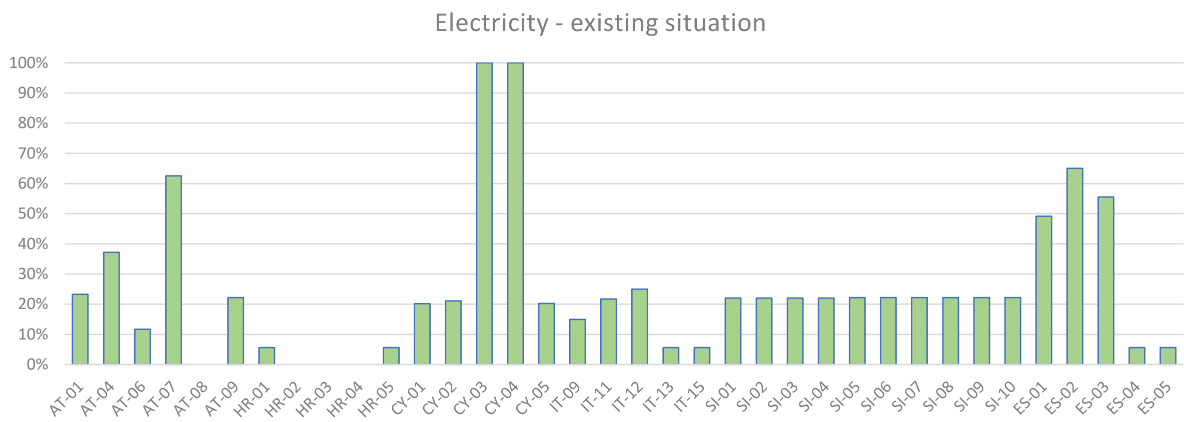

Figure 37. Domain score - electricity, existing situation

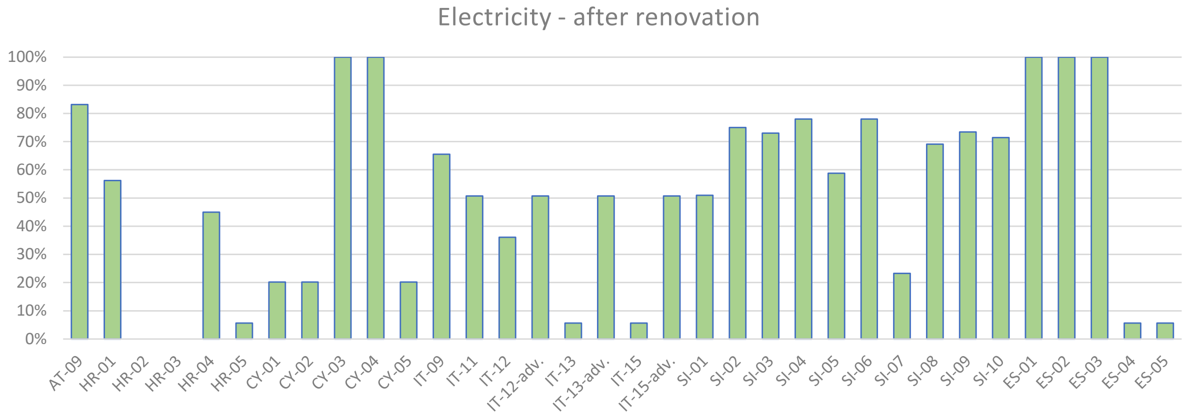

Figure 38. Domain score - electricity, after renovation

Electric vehicle charging is the domain that was present in relatively small number of the buildings. The domain scores are given in Figure 39 and Figure 40. An evaluation of the existing situation reveals that simple charging solutions have a negative influence on the overall smartness of the building. This is due to the fact that simple charging solutions might increase the energy demand of the building, especially during peak-usage times. It is clear that simple EV charging solutions provide the basic functionality for charging EVs, but they lack the adaptability, efficiency and the integration capabilities of smarter solutions, which can negatively influence the overall smartness of a building. However, due to the selected building types, not many stakeholders were interested in the implementation of any EV-charging stations.

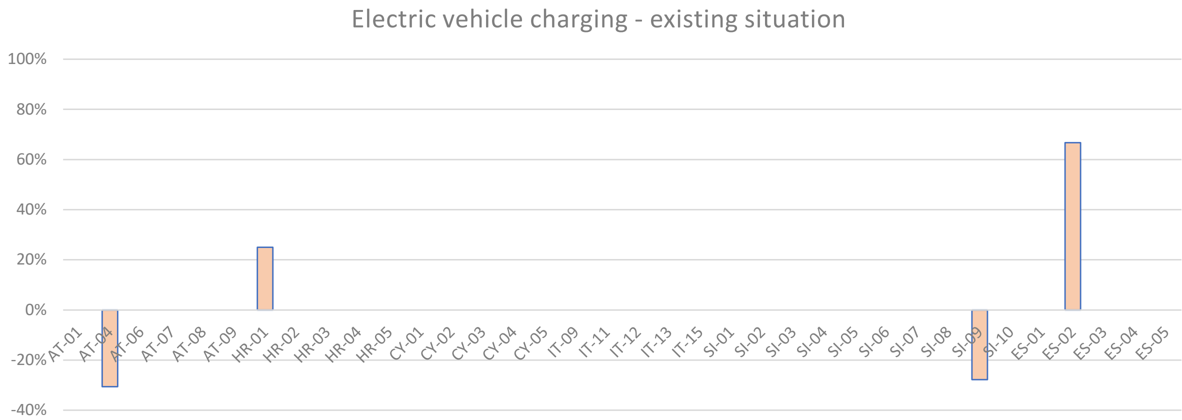

Figure 39. Domain score - EV charging, existing situation

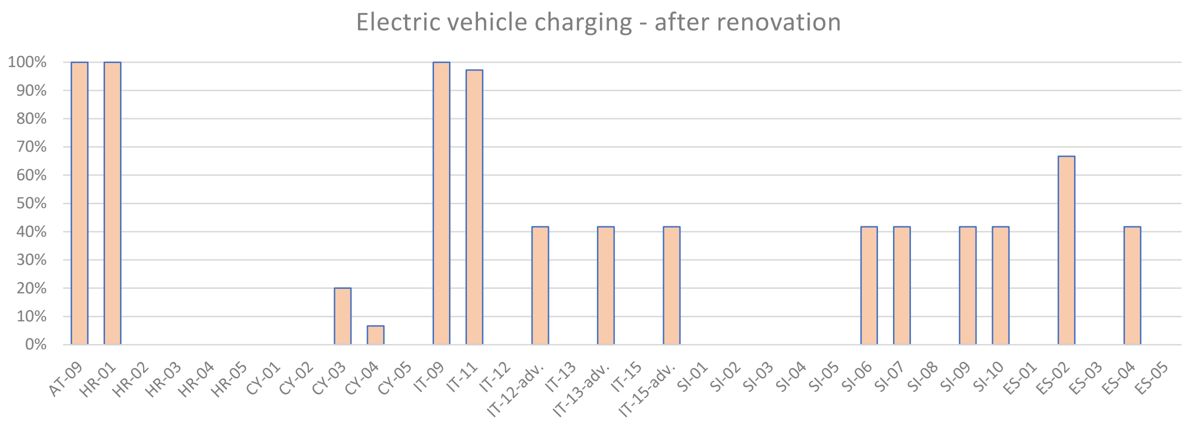

Figure 40. Domain score - EV charging, after renovation

Monitoring and control was recognised as an important domain in many modern buildings. The results of the evaluation are given in Figure 41 and Figure 42. The main stakeholders are interested in measures that improve the score of this domain because they believe that smart monitoring-and-control systems can collect vast amounts of data, helping them to understand usage patterns, predict maintenance needs, and optimize the overall operation of a building's technical systems.

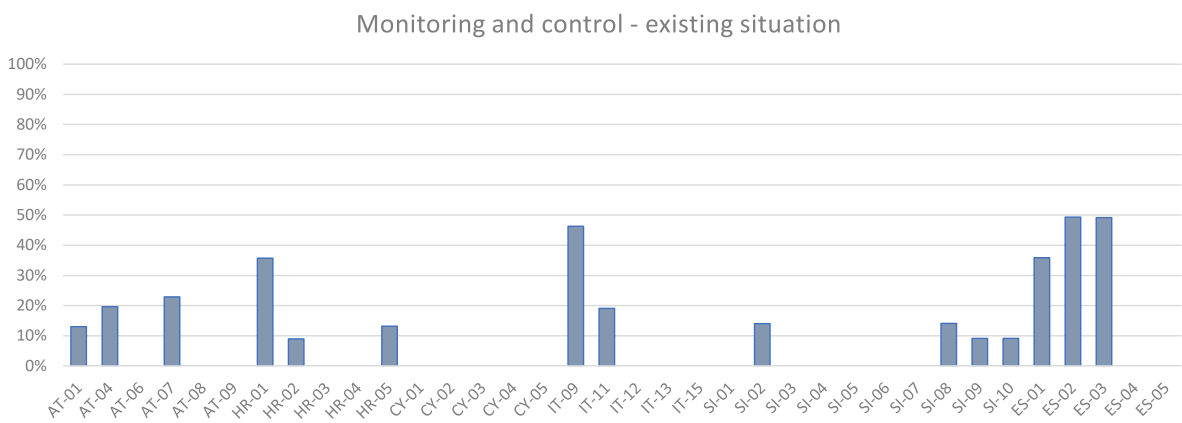

Figure 41. Domain score - monitoring and control, existing situation

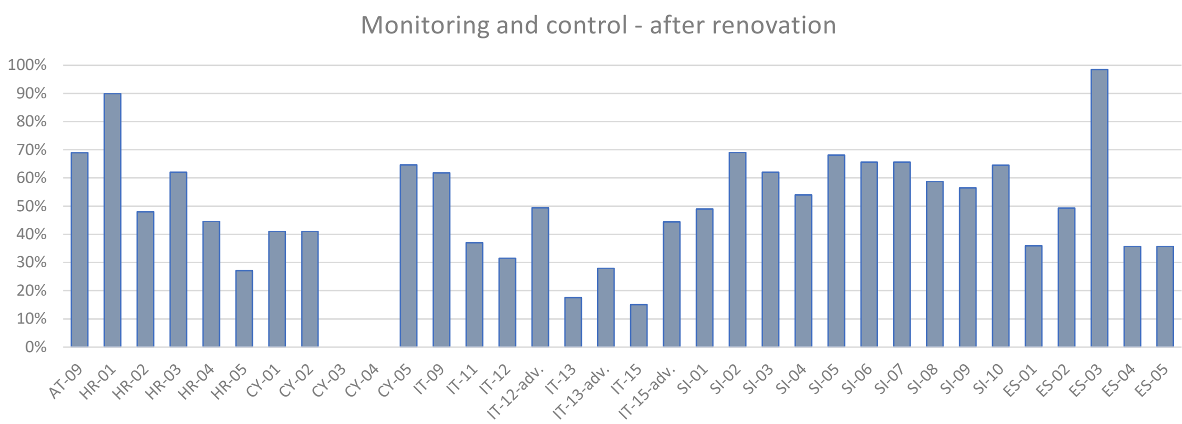

Figure 42. Domain score - monitoring and control, after renovation

The results for all three key functionalities, i.e., the building, the user and the grid, are given in Figure 43, Figure 44, Figure 45, Figure 46, Figure 47 and Figure 48. They also represent a summary of the main findings for the impact and domain scores. Once again it can be recognised that the key functionality related to the grid receives relatively lower scores because smart grid technologies are relatively expensive, and there are no well-functioning markets for flexibility services in the countries in question.

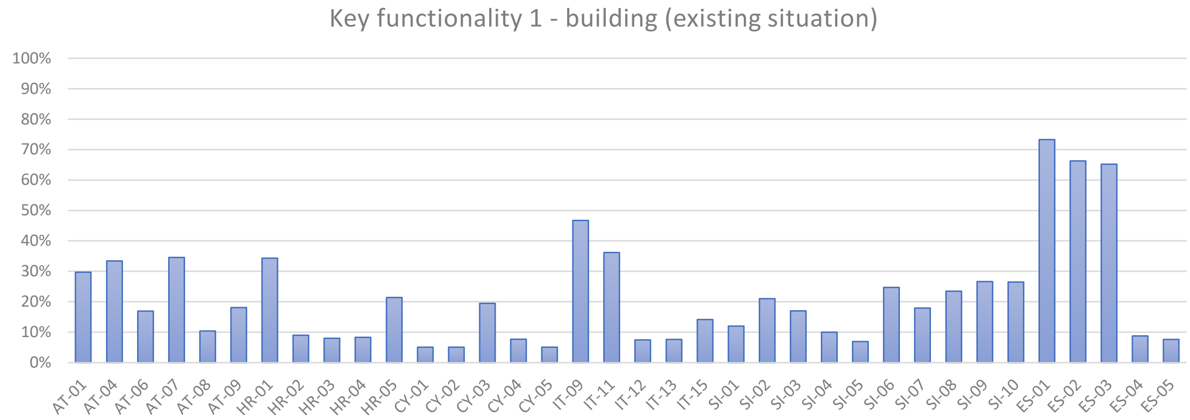

Figure 43. Key functionality 1 - building, existing situation

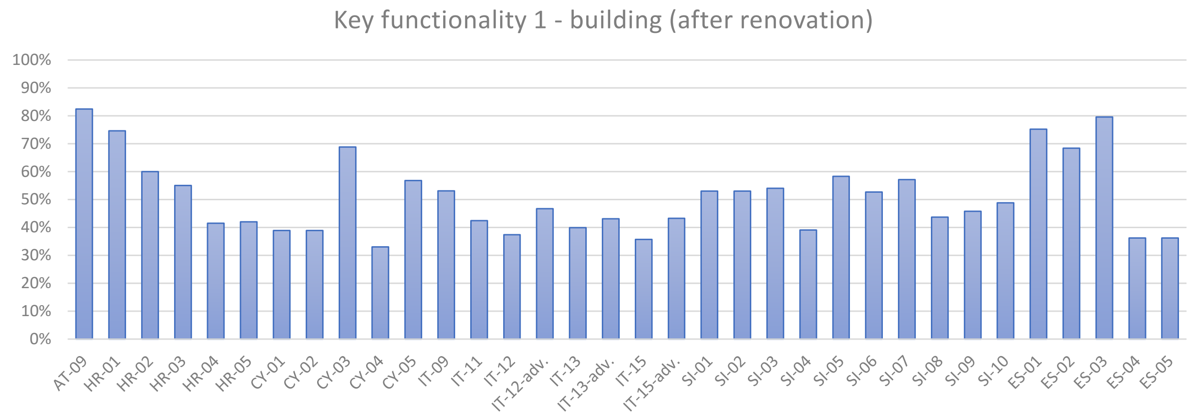

Figure 44. Key functionality 1 - building, after renovation

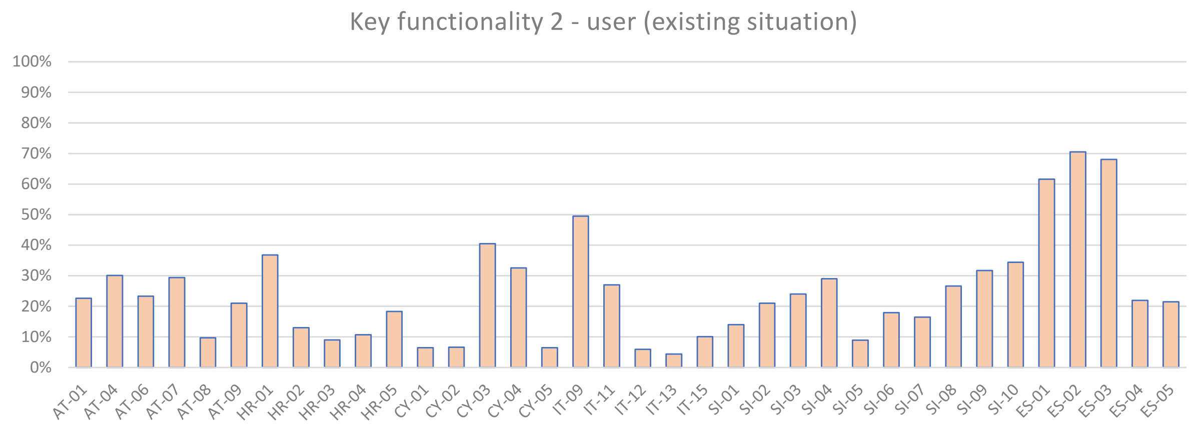

Figure 45. Key functionality 2 - user, existing situation

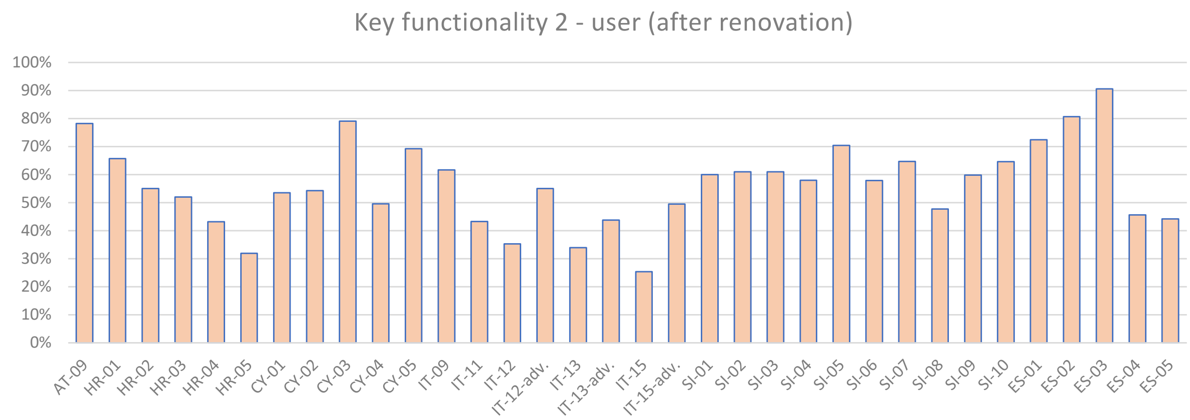

Figure 46. Key functionality 2 - user, after renovation

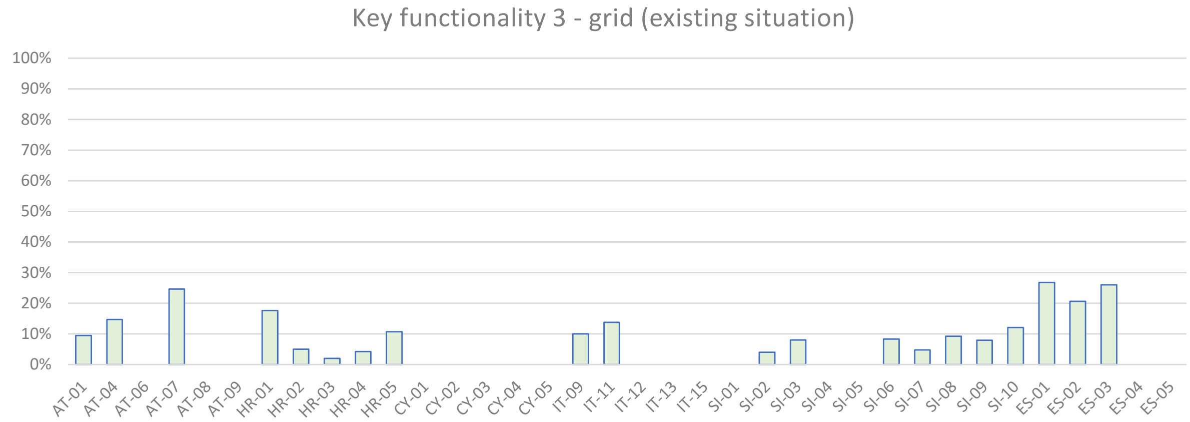

Figure 47. Key functionality 3 - grid, existing situation

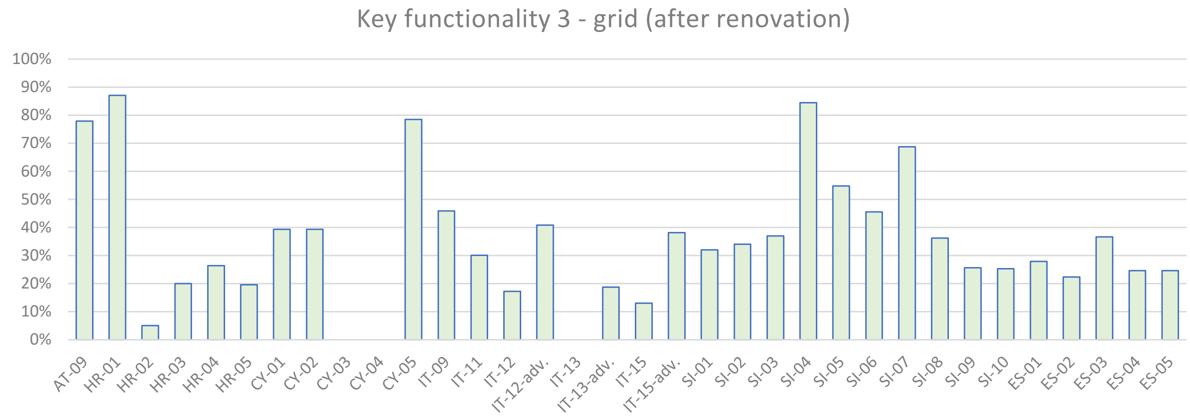

Figure 48. Key functionality 3 - grid, after renovation

5.3 Main challenges and replicability potential

This section presents the outcomes of the use-case approach based on the results of the SRI rating in all the participating countries. In this context the use case is a method used to capture potential energy-efficiency and flexibility measures from data collected during the process of the SRI rating. Like it is defined in Table 1, each end-user has a different perspective and expectations from the SRI rating. Based on the SRI rating, Table 87 summarises all the identified energy-efficiency and flexibility measures in different countries and relates them to the specific end-user. A single energy-efficiency and flexibility measure can benefit multiple end-users. For instance, the potential installation of a battery-storage system is of interest to three distinct end-users: the DSM-aware facility manager, the informed ESCO, and the informed utility.

Table 87. Outcomes of the use-case approach based on results of SRI rating

End-user	Outcomes of the use-case approach based on results of SRI rating
DSM-aware facility manager	• Installation of new or upgrade of existing energy-management or a building's monitoring-and-control system with demand/response functionalities and feedback to the occupants • Enhancing the control system allowing demand/response functionalities • Installation of PV and battery system with advanced grid interaction and maximising of self-consumption • Installation of battery system and maximising of self-consumption • Installation of battery system for peak-load management, emergency power supply and optimising of the PV production • Installation of battery system to existing PV • Installation of new EV-charging station with advanced control systems and all system reports • Upgrade of existing EV-charging station with smart functionalities
Cost-conscious facility manager	• Renovation and insulation of roof • Renovation of façade, including windows and mechanical ventilation with heat recovery • Automated window control • Reduction of water supply and return temperature of the heating system • Lowering temperature of heat-delivery system (panel heating) • Separation of space heating and domestic hot-water production • Enabling individual room control with optimising function (heating and cooling) • Installation of new control elements and sensors for heating, cooling and ventilation system • Installation of new variable-speed pumps • Installation of new LED lightning system with occupancy detection and central control • Installation of new LED lightning system with dimming control • Substitution of existing heat generator with heat pumps or other system based on RESs • Enhancement of distribution pump control • Installation of energy-management system with fault-detection functionalities • Comprehensive reconstruction of the HVAC system – implementation of new heat pump for heating and cooling, new VSD pumps and advanced control of heating-and-cooling systems • Installation of new and smart HVAC system with advanced control systems • Replacement of the combined generator for heating, DHW and cooling with high efficiency RESs-based technologies including advanced control elements and sensors
Sustainability supporting owner	• Renovation and insulation of roof • Renovation of façade, including windows and mechanical ventilation with heat recovery

End-user	Outcomes of the use-case approach based on results of SRI rating
	• Automated window control • Reduction of water supply and return temperature of the heating system • Lowering temperature of heat-delivery system (panel heating) • Separation of space heating and domestic hot-water production • Enabling individual room control with optimising function (heating and cooling) • Installation of the rooftop PV system • Installation of PV and battery system with advanced grid interaction • Installation of new control elements and sensors for heating, cooling and ventilation system • Installation of new variable-speed pumps • Installation of new LED lightning system with occupancy detection and central control • Installation of new LED lightning system with dimming control • Installation of new EV-charging station with advanced control systems and all system reports • Upgrade of existing EV-charging station with smart functionalities • Installation of energy-management system with demand/response functionalities • Installation of energy-management system with feedback to the occupants and fault-detection functionalities • Comprehensive reconstruction of the HVAC system – implementation of new heat pump for heating and cooling, new VSD pumps and advanced control of heating and cooling systems • Substitution of the existing heat generator with heat pumps or other system based on RESs • Installation of new and smart HVAC system with advanced control systems • Replacement of the combined generator for heating, DHW and cooling with high-efficiency RESs-based technologies including advanced control elements and sensors
Informed tenant	• Automated window control • Enabling individual room control with optimising function (heating and cooling) • Installation of new control elements and sensors for heating, cooling and ventilation system • Installation of new LED lightning system with occupancy detection and central control • Installation of new LED lightning system with dimming control • Installation of new or upgrade of existing energy-management or building monitoring-and-control system with demand/response functionalities and feedback to the occupants • Installation of remote energy meters • Installation of central monitoring system and info monitor for occupants • Installation of new EV-charging station with advanced control systems and all system reports • Installation of a battery system for PV and maximization of self-consumption • Information to occupants about PV production and maximising self-consumption

End-user	Outcomes of the use-case approach based on results of SRI rating
Informed ESCO	• Renovation and insulation of roof • Renovation of façade including windows and mechanical ventilation with heat recovery • Automated window control • Reduction of water-supply and return temperature of the heating system • Lowering temperature of heat-delivery system (panel heating) • Separation of space heating and domestic hot-water production • Enabling individual room control with optimising function (heating and cooling) • Installation of new control elements and sensors for heating, cooling and ventilation system • Installation of new variable-speed pumps • Installation of new LED lightning system with occupancy detection and central control • Installation of new LED lightning system with dimming control • Substitution of the existing heat generator with heat pumps or other system based on RESs • Enhancement of distribution pump control • Installation of new or upgrade of existing energy management or building monitoring-and-control system with demand/response functionalities • Comprehensive reconstruction of the HVAC system – implementation of new heat pump for heating and cooling, new VSD pumps and advanced control of heating and cooling systems • Installation of new and smart HVAC system with advanced control systems • Replacement of the combined generator for heating, DHW and cooling with high efficiency RES-based technologies including advanced control elements and sensors • Installation of PV and battery systems with advanced grid interaction and maximizing of self-consumption • Installation of battery system and maximizing of self-consumption • Installation of the battery system for the peak-load management, emergency power supply and optimising of the PV production • Installation of battery system to existing PV • Installation of new EV-charging station with advanced control systems and all system reports • Upgrade of existing EV-charging station with smart functionalities
Informed utility	• Installation of PV and battery system with advanced grid interaction and maximizing of self-consumption • Installation of battery system and maximizing of self-consumption • Installation of the battery system for the peak-load management, emergency power supply and optimising of the PV production • Installation of battery system to existing PV • Installation of new EV-charging station with advanced control systems and all system reports • Upgrade of existing EV-charging station with smart functionalities • Enhancing the control system allowing demand/response functionalities • Installation of new or upgrade of existing energy-management or building monitoring-and-control system with demand/response functionalities and feedback to the occupants

For each identified energy-efficiency and flexibility measure the SRI auditor should provide an indicative estimation of the energy and economic benefits. For example, in one of the addressed buildings the potential for the installation of the rooftop PV plant was identified. The first simulation was made with SolarEdge Designer,[3] which is a free web-based, solar-design software tool that helps solar professionals in initial estimations of the PV generation capacity at the selected location. Based on the size of the addressed roof, the total installed power is estimated at 34.4 kW_p. Based on the collected electricity consumption over a 15-minutes interval, the SRI auditor should be able to calculate the total Self Sufficiency Rate (SSR) and the Self Consumption Rate (SCR). The SSR indicates the proportion of electricity demand that is covered by the self-generated electricity from the PV system. The SCR is an indication of how much of the electricity generated by a domestic PV system is consumed locally. An example of the economic analysis is given in Table 88. The introduction of new indictors like Net Present Value or Internal Rate of Return was also analysed in the framework of TDS2 and it will be validated through VS2, VS3 and VS4. Initial results are indicating the potential for using an expanded range of information, including indicators from the economic domain in the future exploitation of EPC-related data. In cases when all the necessary data is available, a well-trained SRI and sustainability auditor will not need more than four additional hours for this type of analysis. The potential of using metered data for various calculations has also been recognised in strengthened provisions on EPCs generation requirements, articles 16-19 and annexes V and VI (European Commission, 2023a).

Table 88. Example of the economic analysis for the installation of the PV system - installed power of 34.4 kW

Installed power	34.4 kW
Unified/Single Tariff (including price of energy and grid fee)	160 €/MWh
Investment	1,300 €/kW
Economic lifetime	30 years
Required return on equity	4%
Fixed annual maintenance costs	9 €/kW
Fixed annual insurance costs	9 €/kW
Design, connection and commissioning	3,000 €
Total costs of the PV system (investment)	47,720 €
Expected electricity generation	35.95 MWh/year
Value of the generated electricity (SCR = 100%)	5,751.68 €/year
Operation, maintenance and insurance costs	619.20 €/year
Total savings (SCR = 100%)	5,132.48 €/year
Value of the generated electricity (SCR = 84%)	4,832.07 €/year
Operation, maintenance and insurance costs	619.20 €/year
Total savings (SCR = 84%)	4,212.87 €/year
Simple payback period (SCR = 100%)	9.3 years
Net present value (SCR = 100%)	27,075.84 €
Simple payback period (SCR = 84%)	11.3 years
Net present value (SCR = 84%)	11,684.46 €

[3] SolarEdge Designer is available at: https://www.solaredge.com/en/products/software-tools/designer

In the context of the future utilisation of the SRI, the main challenge is how to incorporate positive elements of the SRI rating process without making the generation process too complex and costly for the final users. Lessons learned during the implementation of TDS4 clearly confirmed that to make the SRI rating useful, specific and tailored recommendations for performance improvements must be provided to the final user. This means that to be cost-effective, the SRI and sustainability rating should be combined with energy auditing and energy-performance assessments. However, in the case of residential buildings some shortcuts can be made. An outline of the approach for improving the overall effectiveness of the SRI rating in buildings is given in Figure 49.

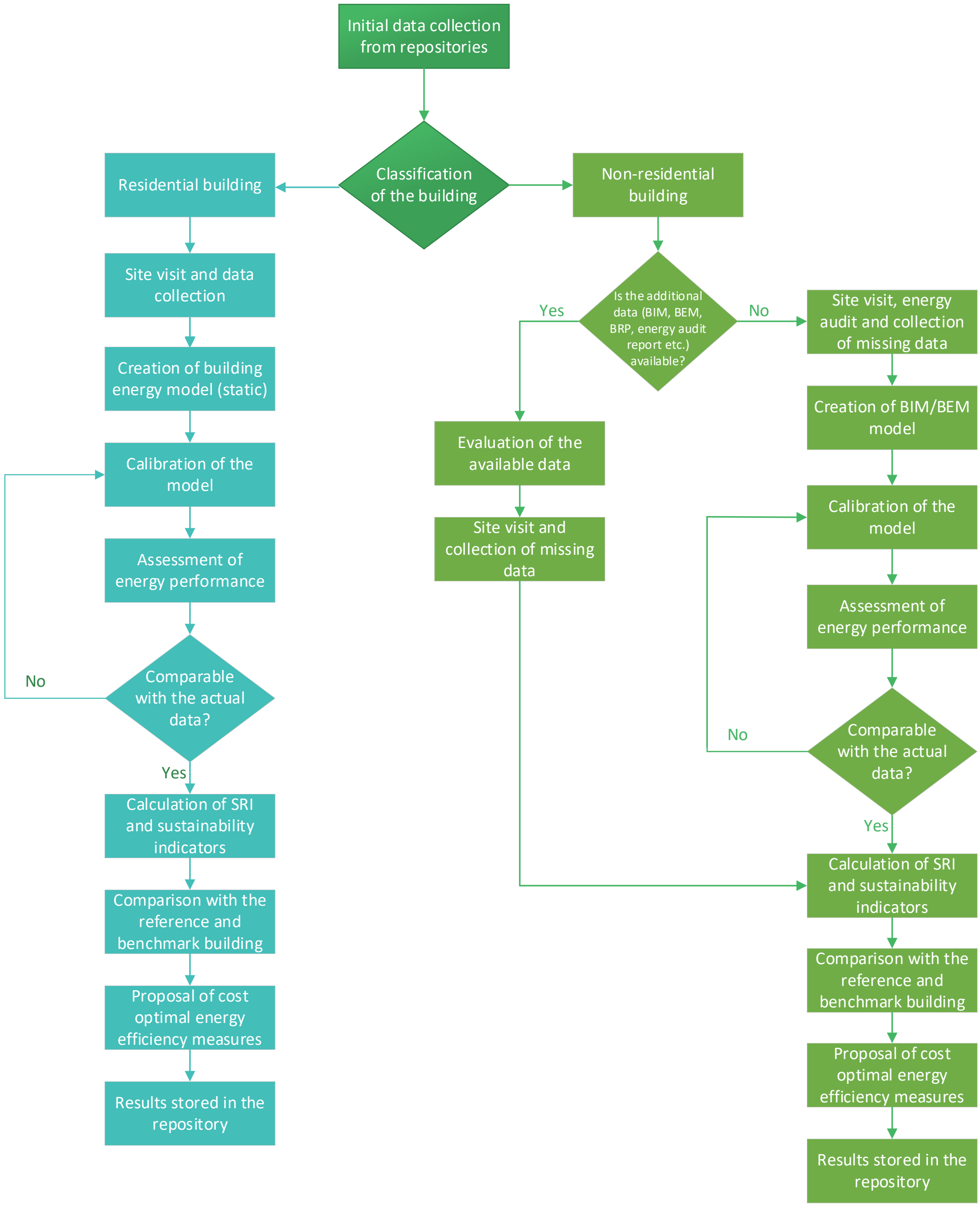

Figure 49. TIMEPAC approach to improving overall efficiency of the SRI rating

The results of the SRI rating will not be useful for different end-users if they are not stored in repositories that enable different advanced functionalities. Based on recommendations from Deliverable 1.2 Comprehensive analysis of data storage in the participating countries, the following requirements for the future SRI repositories were identified:

- Supporting advanced data-analytics functionalities aimed at enhancing the information associated with the input data;
- Dedicated pre-processing routines aimed at cleaning, filtering or integrating the raw data provided by end-users;
- Interconnectivity and interoperability among specific repositories (EPC, BIM/BEM, etc.);
- Need for end-users to freely query, visualize and interact with the SRI data they have access to;
- Specific functionalities able to present in a clear and effective way the information extracted from sets of data;
- Specific functionalities aimed at presenting data or service results in an effective and attractive form;
- Feature preventing the system from executing any unauthorized operation towards data and system components.

Regarding the sustainability rating, the international comparison confirmed the usefulness and potential of the Level(s) indicators. The objective of the Level(s) assessment is to provide a common reference point for the performance assessment of buildings across Europe, and by calculating certain indicators before and after the energy renovation, the TIMEPAC partners created new information that enables stakeholders to make more important decisions. In the scope of TDS4 – the selected indicators were (1) energy performance, (2) GWP, (3) thermal comfort and (4) LCC.

The testing of the Level(s) in the scope of TDS 4 revealed in all countries that for many of the indicators, detailed lifecycle inventory data are needed, which cannot be directly retrieved from the architectural plans or documents. A complete assessment of all the indicators on Levels 1-3 requires a lot of time. The reporting itself is not time consuming. To reduce the time efforts, it is recommended to establish or improve the links with national tools (e.g., a current link with EPB-software for indicator 1.1). Default values are seen as a second way to reduce time efforts.

The testing also revealed that most of the indicators are linked to assessment methods that require data structuring that is different than in architectural practice to date. For example, this is the case for the LCA study (Indicator 1.2): even if a BIM is available, this model may provide information about the general composition of building elements and their amounts, but information on sub-element composition is lacking, such as for example the kg of brick per m² wall or the kg of cement mortar per m² wall. Default element compositions and related amounts of materials could help practitioners. Further alignment between different tools could moreover improve this information flow. Furthermore, such a calculation can be done by sustainability experts to understand the process of the calculations. BIM tools indeed make it possible to make GWP calculations, but it is only a support tool. The expert must be the one who leads the process of calculations and not vice versa. The indicator was calculated by Austria and Slovenia only, which indicates the need for properly trained personnel.

To sum up, BIM technology provides a new means of predicting, managing and monitoring the environmental impacts of a project's construction and development phases through a "one-stop-shop". BIM is helpful for environmental sustainability monitoring and management over a building's full lifecycle. Furthermore, BIM presents the opportunity from the information embedded in a building project to expand its scope within sustainability. BIM allows sustainability to become a key component of the design, construction and delivery of a building and enables the corresponding decisions that affect its environmental performance to avoid costly redesign or engineering waste. But to do that, trainings and experiences are needed. All the partner countries have done such an exercise, but only with further trainings of AEC (Architecture, Engineering and Construction) experts, will such a transfer of knowledge be possible, since those are the ones who are going to use such analyses in practice and present the possibilities to the investor.

6 Guidelines for effective SRI and sustainability auditing

This chapter provides guidelines for effective SRI and sustainability auditing, including the specification of the necessary competences of the SRI and sustainability auditors, an overview of the workflow and quality assurance, and tips for identifying energy and flexibility potentials. Some elements that are necessary for the effective SRI and sustainability auditing are already outlined in the section dealing with the methodology. An overview of the SRI and sustainability-rating process is given in Figure 50.

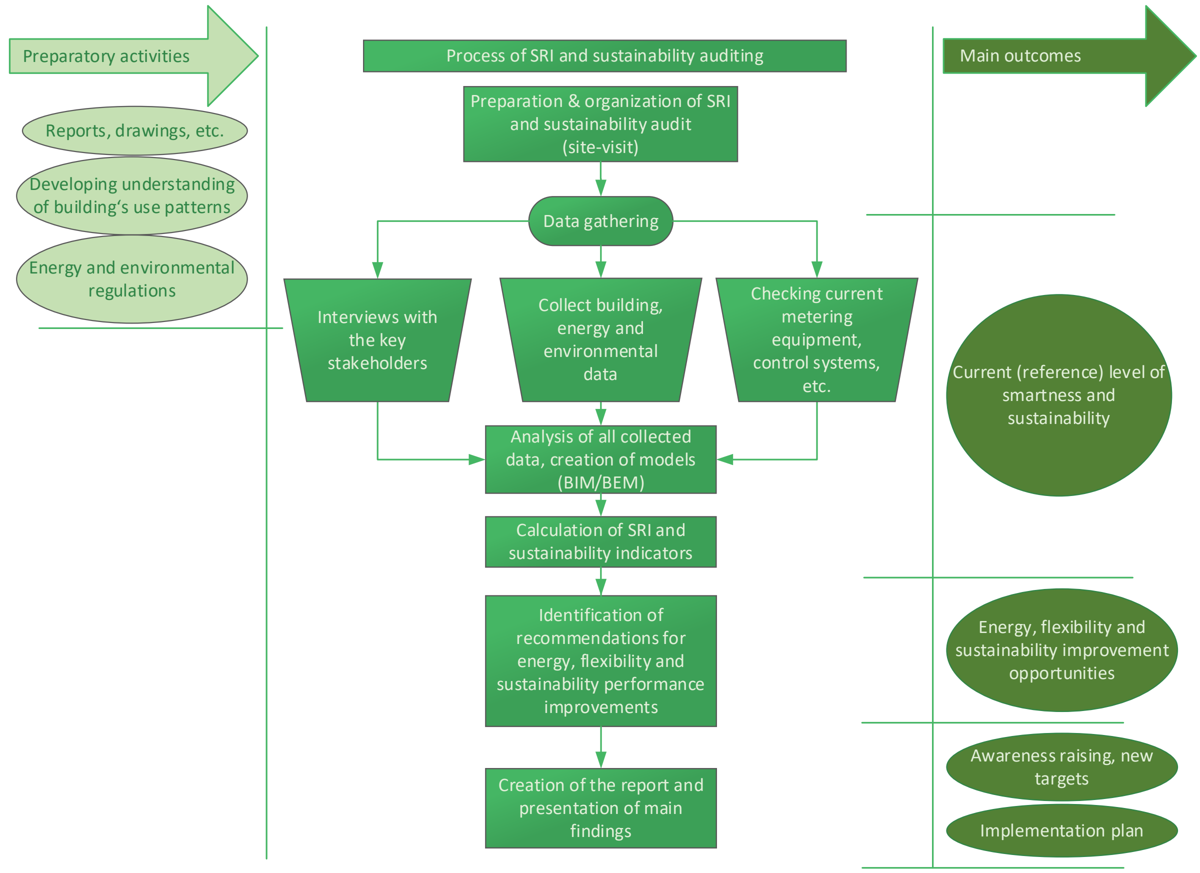

Figure 50. Overview of the SRI and sustainability-rating process

The main findings from this chapter are summarised in the TIMEPAC Code of Conduct for Smart Readiness and Sustainability Rating (annex A1).

6.1 Competences of SRI and sustainability auditors

Energy efficiency is a very multidisciplinary field, and no single discipline offers a guaranteed approach to reach the full potential of savings or sustainability improvements. The competences of the SRI and sustainability auditors should encompass a diverse range of technical and soft skills, derived from various disciplines. Given the multidisciplinary nature of smart readiness and sustainability, these auditors often need a broad base of knowledge and expertise. However, the first sept towards effective SRI and sustainability auditing is a clear understanding and open communication between the owner or representative of the building that is being audited and the SRI and sustainability auditor. The SRI and sustainability auditor should have good communication skills because open communication maximizes understanding, creates confidence and minimizes risks. This includes moderation and presentation skills.

Based on the experiences derived from the implementation of the TDS4, the following key competences of SRI and sustainability auditors have been identified:

- A technical and engineering background is necessary for effective SRI and sustainability auditing. The auditor should be capable of analysing energy consumption within buildings, with the focus on identifying current inefficiencies and proposing measures to ensure maximum efficiency and sustainability. Mechanical engineering is essential for understanding HVAC (Heating, Ventilation, and Air Conditioning) systems, the thermal properties of buildings, and energy-efficiency methods. Electrical engineering is necessary for evaluating a building's electrical systems, smart grid connections, and potentials for renewable-energy integrations such as PV systems. Civil engineering is necessary to understand the building envelope, structural components, and materials that can influence energy performance and sustainability.
- The auditor should also have a solid knowledge of environmental sciences and being able to provide insights into the environmental impacts of buildings, lifecycle assessments, and sustainable-resource management.
- The auditor should be capable of using various energy-performance assessment tools and software used for energy modelling, SRI evaluations, and sustainability assessments.
- Creating an effective data-collection plan for the data-collecting activities within the scope of the SRI and sustainability auditing is very important. The auditor should be able to analyse complex data sets, often derived from energy-management systems, SCADA or other monitoring tools. The auditor should be able to verify and validate all the data and assessment results and to draw conclusions.
- The auditor should have a clear understanding of the benefits and positive impacts of smart devices and systems on the overall energy consumption in buildings. This includes renewable-energy systems and their integration within building systems.
- Soft skills are very important for effective SRI and sustainability auditing. Engaging with a building's occupants, owners, and other stakeholders requires good interpersonal abilities. The auditor should have the ability to convey complex technical information in a clear and understandable manner to non-experts. He/she also should be able to identify open issues and come up with feasible solutions. The auditor should clearly recognize the value of multidisciplinary collaboration and being able to work with experts from diverse fields like mechanical, electrical and civil engineering, architecture, urban planning, IT, etc.
- The fields of smart buildings and sustainability are continuously evolving. Staying updated with the latest technologies, methods, and research is vital. Familiarity with local, national, and international standards for a building's energy efficiency, sustainability, and smart readiness is very important. Also, the auditor should have a solid understanding of building codes, regulations, and certifications relevant to energy and sustainability.
- The auditor should have a clear understanding of the financial implications of identified recommendations, so that the solutions proposed are both sustainable and economically viable.

A background in mechanical or electrical or civil engineering provides a strong foundation for the SRI and sustainability auditors, it is the combination of technical knowledge, soft skills and continuous learning that makes him/her truly effective in this role. Identified competences will be addressed during the envisioned training activities that are dedicated to SRI (TS2 and TS6). Also, since the energy technologies and state-of-the-art techniques are changing very rapidly, extra efforts will be planned for the training-material updates and the further development of the content of the TIMEPAC Academy after the project's lifetime.

6.2 Overview of the workflow and quality assurance

Assessing a building's smart readiness and its sustainability requires a comprehensive, methodical approach. Auditors must be properly trained and up to date with the latest standards and technologies. They must be familiar with data-collection techniques and capable of using the software and tools that are standard in the industry for modelling, analysis, and evaluation (energy management, SCADA, BIM/BEM, etc.). The SRI and sustainability-rating process must be robust, reliable, and it should provide genuine value to building owners and stakeholders.

Sustainability and smart readiness are not one-time evaluations. The SRI and sustainability auditor supports the long-term use of energy-management systems. These energy-management systems help to monitor, control, and optimize energy usage and power flows, resulting in significant cost savings over time. Effective SRI and sustainability auditing requires a lot of data to be collected in a systematic manner, which is a prerequisite for the auditor to propose effective measures not only for conserving energy but also making buildings adaptive and responsive to the users' needs and the grid's demands. To become effective, data gathering should be coordinated, and in this context a thorough preparation is essential. Before a site visit, the SRI and sustainability auditor should be familiarized with the building's documentation, previous audits, drawings, and available operational data. Based on a preliminary analysis of the available data, the auditor should prepare a detailed checklist for the missing SRI and sustainability parameters that should be collected during the site visit.

Interviews and meetings with building occupants, facility managers, and owners are essential to understand their perspectives, concerns, and requirements. Their feedback can provide insights into user satisfaction, which is a crucial aspect of smart readiness and sustainability.

Site visit must be properly planned, and the SRI and sustainability auditor should visually inspect the condition of the equipment, systems, and living/working spaces. During the site visit, the auditor should check installed smart technologies, their operational settings, and user interfaces. After the site visit the auditor should analyse the collected data on energy-use patterns, control systems, occupancy patterns, HVAC operations, the performance of renewable-energy systems, indoor environmental quality, etc. In this process, auditor should utilize energy-management systems and other data-logging tools like SCADA to get real-time data for accurate analysis. Use BIM to understand the structural and architectural aspects of the building is also very useful. BEM are used to determine the building's energy performance and for the calculation of the sustainability indicators. Results are compared with established benchmarks or standards for the SRI and sustainability.

Calculation of the SRI and sustainability indicators should be basis for the identification of the performance-improvement opportunities. The first step in this process is the identification of the limitations of installed systems in terms of smart operations and sustainability. The SRI and sustainability rating does not only focus on energy, but also on adaptability, user comfort, and the building's potential to respond to the grid's demands.

Before the final meeting and presentation of the main findings, always discuss your main recommendations with the building's owners, occupants, facility and energy managers. Always encourage discussion about an assessment's results to catch potential errors and offer alternative viewpoints. Clearly communicate the methodologies and tools used during the assessment to stakeholders. The final list of recommendations should be balanced, including the proposal of new and advanced, smart solutions, clear explanations of retrofitting opportunities, and optimization strategies for existing systems. After the presentation of the main findings, the auditor should compile a detailed report outlining the findings, analysis, recommendations, and potential benefits. To improve the quality of its services, the auditor should create a system where stakeholders can provide feedback on the assessment process and findings. For the auditor it is very important to utilize the feedback to continuously improve the assessment process and improve the competitiveness of its services. The auditor should keep detailed records of every step in the process, from preliminary the assessment to the final recommendations. This not only ensures transparency, but also provides a reference for future assessments or disputes.

To enable a systematic reduction of energy consumption, an improvement of flexibility and sustainability, training activities should be proposed to the building's owner, occupants, energy and facility managers. Also, it is essential to propose monitoring of the energy consumption and encourage feedback after implementing the changes. This will help in refining future audits and understanding the actual impact of all the implementations.

6.3 Tips for identifying energy efficiency and flexibility potential

By understanding the value of the SRI and its implications, energy and facility managers, owners, and occupants and other stakeholders like ESCOs and utilities can identify numerous measures to improve energy efficiency and flexibility, thus maximizing the benefits of their smart building technologies. The SRI auditor must always use data analytics from installed smart systems and available metering devices to analyse occupants' behaviour patterns. Energy efficiency and flexibility measures should always be tailored to the actual energy usage and according to when and how spaces within the building are used. Do not forget the golden rule of energy efficiency: WHEN YOU DON'T NEED IT, TURN IT OFF!

The most crucial step is for the SRI auditor to provide comprehensive comments on the assessed systems and components. For instance, when evaluating the potential for installing a roof-top PV plant for local electricity generation, the auditor should consider the orientation of the roof, potential shading issues, and grid-connection possibilities. Within the SRI report's comments, the auditor should detail the possible size of the PV plant, its distance from the current transformer station, and, if 15-minute interval electricity consumption data is available, provide a basic simulation of future electricity generation. This should also cover self-consumption and potential benefits from optimizing with local storage.

A helpful tip for analysing operational performance and identifying the flexibility potential can come from the use of a load-duration diagram. The load duration diagram can be constructed from a load diagram so that cumulative durations of any particular load over the observed period are plotted in sequence together (Figure 51).

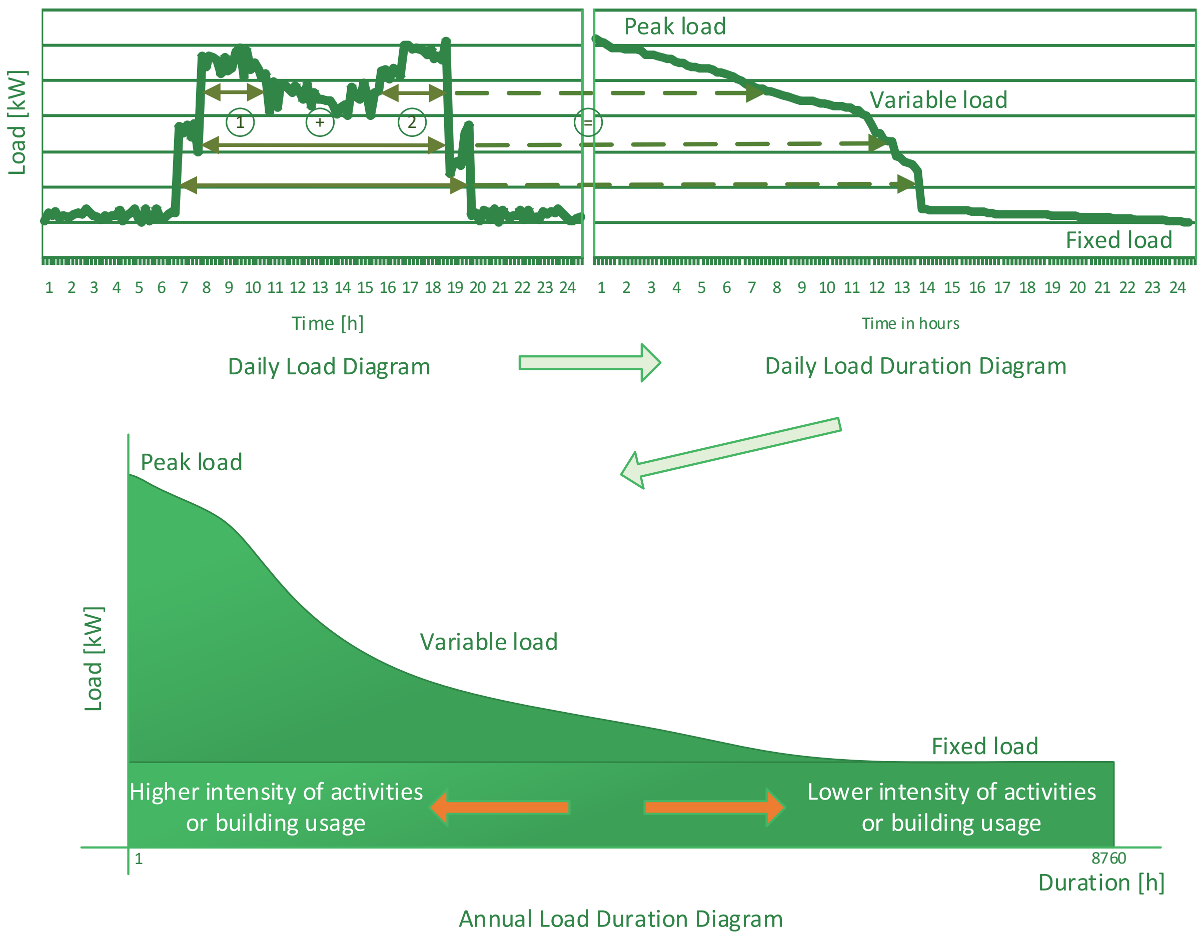

Figure 51. Creation of a Load Duration Diagram

The load-duration diagram indicates not only the peak load but also the duration of peak loads over the observed time interval, which is important for a consideration of demand-control strategies. It also provides an insight into the variable and fixed demands, which provide a basis for determining operational performance and potentials for improvements. By correctly identifying and managing controllable loads, demand can be shifted to off-peak hours when energy is cheaper and more abundant. This not only leads to cost savings, but also improves the overall efficiency of the grid. Additionally, the proper identification of controllable and uncontrollable loads is crucial for better planning, control and interaction with the grid. In periods of high demand, being able to reduce controllable loads can prevent overloading and ensure grid stability. If controllable loads can be properly managed, they can be matched to times when renewable-energy production is high, reducing reliance on non-renewable energy sources. For consumers/prosumers, managing controllable loads effectively can result in significant cost savings.

Proper interpretation of the SRI scores is crucial for identifying the energy-efficiency and flexibility potentials. High SRI scores generally mean the building has substantial smart-technology integration. However, there might be a gap between the available technology and its effective utilization for energy efficiency and grid flexibility. Auditors should be aware that even buildings with advanced smart systems might not be utilizing them to their full potential. During the SRI audit the auditors must identify the most important systems (for example HVAC, lighting, server rooms, etc.) and check whether they are properly calibrated, configured and operated. Also, high SRI scores might indicate a building's potential to integrate with RESs. However, this can also be misleading, and auditors should identify realistic opportunities to connect to local solar or another renewable-energy generation asset (for example biomass for heating or heat pumps for heating/cooling). This not only saves energy but also offers flexibility potential in terms of energy storage and demand response. Buildings with heat pumps or other bigger, controllable electric loads are likely primed for demand-response initiatives. Large electrical loads can adjust their energy use in real-time based on grid signals, thereby aiding grid stability and benefiting from cost savings. Also, never forget to analyse the building's capacity to shift heating or cooling loads to times when energy demand is low, thus reducing peak load and energy costs. In this context the auditor should always explore opportunities for battery or heat storage, allowing the building to store locally generated renewable energy during off-peak times and use it during peak times.

A low SRI score could indicate that the building lacks the technology, systems, or practices that facilitate smart operation. This can also be an indication of untapped potential and should be systematically investigated. For buildings with a lower SRI score, the auditor should identify potential upgrades to smart devices or systems that can improve both energy efficiency and flexibility. This can include smart thermostats, automated lighting, or energy-efficient HVAC systems with variable-frequency drives. At present, the VSD application represents the greatest potential for reducing electrical energy consumption by replacing the traditional regulation of pressure and fluids flows by throttling, by adjusting the vanes and blades of pumps and fans and by by-passing lines, etc. However, although the technology is often in place, energy and facility managers or occupants are not aware of its full potential. Providing training or awareness programmes can help in tapping into the energy and flexibility potentials that smart technologies offer.

SRI auditing should always be combined with the Retro-commissioning or Re-Commissioning (Re-Co) activities. Re-CO is a methodical process of testing an existing building’s energy-intensive systems like HVAC and any other equipment to make sure they are still functioning according to the original design intent or to adjust and correct any deviation from the original design(California Commissioning Collaborative, 2006). It focuses on improving the overall performance of a building by investigating and improving how systems operate together. In the context of SRI auditing, Re-Co activities can be considered as part of an SRI audit where the main emphasis is on the identification of low-cost, energy-efficiency measures that can be easily implemented. In this process data from existing meters and systems that continuously monitor the building's energy performance should be utilised. The inspection of the on-site metering system is a direct connection between Re-Co and SRI auditing. On-site metering is important because it provides first-hand information about energy performance. Both the Re-Co expert and the SRI auditor need to check the following issues:

- How is the energy consumption metered and monitored?
- How is the operation of the equipment/processes controlled and who is responsible for defining operational parameters of the main equipment?
- How is the existing metering equipment accurate and reliable?

From the service providers point of view, it should be noted that the SRI and Re-Co activities can be combined, and this combination has the potential to become an attractive business for engineering or energy-service providers. Key factors are teamwork with maintenance personnel, a good selection of buildings and a focus on effective low-cost measures. Even though they might give rise to some additional costs, Re-Co services can be carried out successfully and be a cost-effective part of the SRI and EPC generation process because they will generate additional extra benefits for the owners and building users. Cooperation with ESCOs and utilities can help in identifying and implementing energy and flexibility solutions based on SRI findings, and they might operate on performance-based contracts, ensuring actual energy and flexibility savings.

7 Conclusion and future challenges

It is clear that the SRI is a relatively new concept, and that additional testing and adaptations of the proposed methodology will be necessary before it can prove its full potential. From its design, the most valuable aspect of the tool is the fact that it provides a common and reference language for the whole of Europe, which enables experts and policy makers to compare progress in the smart readiness of the European building stock. The activities within TDS4 confirmed that the SRI has the potential to become an important policy instrument that supports the transformation of the building sector towards more energy-efficient and user-centric models. By assessing a building's readiness for smart technologies, promoting the deployment of digital infrastructures, empowering consumers, and supporting the transition to demand-response energy models, the SRI serves a critical role in shaping a more sustainable, efficient, and comfortable built environment for the future. As the importance of energy efficiency and smart buildings continues to grow, the SRI will undoubtedly become an increasingly valuable tool in shaping the buildings of the future. Our research work also revealed that it is beneficial to use simulation tools and software to model the building's energy consumption and the impact of different smart technologies and strategies on the SRI.

However, several barriers have also been identified, which might affect its smooth development. These include its complexity of use, problems with the subjectivity of the auditor and potential problems with the price for the final users. Our experiences clearly confirmed that in order to make the SRI rating useful, specific and tailored recommendations for performance improvements must be provided to the final user. This means that in order to be cost-effective, the SRI and sustainability rating should be combined with energy auditing and energy-performance assessments. Also, it would be beneficial to additionally research the benefits of including facility management as an additional domain in the calculation of the SRI. Facility management encompasses various activities that are essential for optimizing a building's performance, such as maintenance, energy management, and building automation. Incorporating these activities into the SRI calculation can provide a more comprehensive assessment of a building's ability to use ICT and electronic systems to optimize its operation and interaction with the grid. Also, including facility management in the SRI calculation encourages a more holistic approach to a building's operation and management. It acknowledges that the smart readiness of a building is not just about the technology and systems in place, but also about how these are managed and maintained over time. An assessment of the facility-management practices can be combined with Re-CO activities and can help to identify opportunities for improving the operational efficiency, such as through predictive maintenance, optimized energy consumption, and intelligent building automation resulting in improved occupant comfort and well-being, and overall sustainability.

Special attention must be given to the proper explanation of the SRI score. The SRI score is not just a percentage of smartness. The SRI and sustainability auditor should always try to explain his/her findings with the emphasis on the potential energy-efficiency and flexibility-improvement measures. In order to tackle this issue, we proposed the introduction of the Smart Performance Coefficient (SPC), which is the ratio of actual SRI to the benchmark SRI for the selected building type or the ratio of the predicted SRI after the implementation of the virtual smart renovation scenario and the actual SRI. The purpose of the SPC is to enable a proper interpretation of the SRI value and to present that information to the building owner/occupant in a simple and straightforward way. During the initial period of the SRI's implementation, this approach will require continuous updates of the benchmark values since there is no operational definition for what is the expected benchmark value for the selected building type. Also, it is essential to properly address the high cost of smartness and develop a set of measures to promote and inform the public about benefits of smart and flexible technologies. This is the only way to achieve an appropriate level of smartness in buildings and adapting to climate change.

The next open issue is the calculation of the SRI for mixed-use buildings (i.e., buildings that have multiple uses such as residential, commercial, and retail) because this can be problematic for several reasons. The current methodology does not recognise this issue, but it is very challenging to apply a one-size-fits-all approach to the calculation of the SRI for this kind of building. From the professional perspective it is clear that different types of spaces (e.g., residential, commercial, retail) have different requirements in terms of energy consumption, comfort and building services, and must be treated separately. Mixed-use buildings have different occupancy patterns for different types of spaces. For example, commercial spaces might be occupied during the day, while residential spaces may be occupied at night. This can affect the building's energy consumption and the effectiveness of common smart technologies. Mixed-use buildings often have more complex building systems and services compared to single-use buildings. This can make it more challenging to assess and optimize the building's smart readiness. The most challenging practical issue is connected with the conflicting interests and priorities of different occupants and stakeholders in a mixed-use building. For example, commercial tenants might prioritize energy savings, while residential tenants might prioritize comfort. A possible solution could be to calculate the SRI separately for each type of space (e.g., residential, commercial, retail) and then aggregate the results into a single SRI score using a weighted-average approach. The weights could be based on the relative importance of each type of space in terms of floor area, energy consumption, or other relevant criteria. However, the appropriateness of this approach should be tested in a lager sample of mixed-use buildings.

Also, our research work revealed limited applicability of the SRI for the residential buildings, particularly from an owner's perspective. Owners of residential buildings emphasise that implementing smart technologies and systems in a single or multi-residential building can be costly and complex, and the benefits might not always justify the investment. While larger non-residential buildings could see significant cost savings and efficiency improvements from smart technologies, the benefits might be less pronounced for individual homes. Our field work in T2.4 and conducted surveys in the framework of WP1 - Context Analysis to Support EPC Workflow (T1.1 EPC generation) and WP5 - Communication, Dissemination and Exploitation (T5.7. Exploitation) revealed that many residential owners are not fully aware of the concept of the Smart Readiness Indicator or its potential benefits. Even if they are aware, they may not have the technical knowledge or expertise to accurately assess their home's smart readiness or to implement the necessary improvements. Also, our research work in the framework of T2.4 revealed that unlike non-residential buildings, which might have more flexibility to implement significant changes to their building systems and operations, residential buildings might have more limitations in terms of what changes they can make to their homes, particularly if they live in older buildings or have limited financial resources. Our experiences revealed that owners of the residential buildings do not perceive the benefits of smart technologies and the SRI as being significant enough to warrant the investment. However, it is important to note that while there are challenges and limitations to the applicability of the SRI for residential buildings, it is not inherently unsuitable for residential use. The SRI concept is under development and special attention should be given to the identified open issues. From the expert point of view, the SRI has the potential to be successfully applied in residential buildings too, particularly if it is being calculated before planning significant renovations or in cases when the owners are particularly interested in optimizing their home's energy efficiency and comfort. Also, it is important to involve all the relevant stakeholders in the process of upgrading the SRI methodology for residential buildings, such as residential buildings' owners, facility managers, and tenants, to ensure that their interests and priorities are considered in the calculation of the SRI. Ultimately, the methodology used for calculating the SRI for residential buildings should be flexible and adaptable to the specific characteristics and requirements of the building and its occupants.

Since the buildings are a major source of energy consumption, the European Commission has created Level(s), a framework that provides a common language for assessing and reporting the sustainability of buildings in order to assist the building sector on the journey to net zero, from design to end of life for a range of stakeholders including sustainability professionals, asset designers, owners and investors, as well as policymakers and public authorities. The work done in T2.4 showed that although the Level(s) framework is relatively new, the core indicators are not. Many of them can be calculated in the scope of the standard analyses that are already being done in the scope of energy-renovation design. TDS4 covered 4 indicators, whereas only the GWP indicator was new and required additional exploitation of the BIM tools available to the partners. Such calculations of different Level(s) indicators enable the investor and the design team to make better-informed decisions from the point of view of investments, energy efficiency, environment, health, etc.

The sustainability indicators within each macro-objective link a building's performance to key European initiatives on the circular economy, energy, material use and waste, indoor air quality and resilience to climate change. The lifecycle Global Warming Potential (GWP) of new buildings is one of the major ones included under the first Level(s) objective, which seeks to minimise a building's whole-life carbon output. Acting on the GWP of new buildings is vital for reducing embodied carbon emissions. Given the construction industry accounts for 50 % of Europe's raw-material extraction, implementing sustainability performance measures in this area will contribute to reducing CO_2 emissions. This shows the analysis in the scope of T2.4, where the GWP was calculated with the aid of the BIM environment.

Typically, a team of different experts is involved in the building's design, so it is clear that the data and knowledge required for Level(s) are spread over these different actors. For example, the EPB-document for indicator 1.1 was drafted by the collaborating engineer firm, while the LCA and cost analysis are mainly performed by an academic institution. To work efficiently, it might be best if various actors are responsible for parts of the Level(s) reporting. Although this is probably more time efficient, a good overall coordination will then be required to ensure that the same assumptions are taken for the multiple calculations required. Linking as much as possible with available tools and interfaces (e.g., BIM model) could enhance uniformity across different assessments and actors.

T2.4 revealed that most of the indicators are linked to assessment methods that require data structuring that is different from that in architectural practice to date. This is, for example, the case for the LCA study (Indicator 1.2): even if a BIM model is available, this model could provide information about the general composition of building elements and their amounts, but information on sub-element composition is lacking, such as, for example, the kg of brick per m^2 of wall or the kg of cement mortar per m^2 of wall. Default element compositions and related amounts of materials could help practitioners. Further alignment between different tools could moreover improve this information flow.

Based on the assessment results, it is clear that the use phase has an important contribution to the buildings' environmental impact (Indicator 1.1) and financial costs (Indicator 6.1). The importance of the environmental impact is mainly related to the energy use for heating, while for the financial cost, cleaning and maintenance are also important. Furthermore, the construction phase as well has a large influence on the costs and impacts. Lastly, it must be recognised that multiple aspects considering future adaptability of the building to changing user needs are implemented in the building design. However, based on these results, it is not possible to highlight the importance of the different building elements and to obtain insights about opportunities to improve the sustainability of the building.

The testing of the Level(s) in the scope of TDS 4 revealed that for many of the indicators a detailed lifecycle inventory of data is needed, which cannot be directly retrieved from the architectural plans or documents. A complete assessment of all the indicators on Levels 1-3 requires a lot of time. The reporting itself is not time consuming. To reduce the time efforts, it is recommended to establish or improve the links with national tools (e.g., the current link with EPB-software for indicator 1.1). Default values are seen as a second way to reduce time-related efforts.

The objective of the Level(s) assessment is to provide a common reference point for the performance assessment of buildings across Europe. The assessment moreover provides general insights into the various environmental impacts, energy use and costs that their design is causing. However, it does not allow us to evaluate the 'sustainability' level of their project as reference values are not available to compare with and a detailed hotspot analysis is not possible. In order to increase the added value of the assessment for practitioners, it is recommended to integrate such reference values (benchmarks) or more detailed reporting in the future.

To conclude the sustainability aspect of TDS4, Level(s) helps to design buildings that can be renovated easily in the future or modified as users' needs change. This extends their lifespan and is especially critical in limiting whole-life carbon emissions. For example, when replacing an old building with a new one, it can take several decades for the reduced in-use energy consumption of a the new building to compensate for the carbon emitted during its construction.

Designers and architects can refer to several of the Level(s) macro-objectives and indicators when working on a renovation project, in order to limit the environmental impact of the intervention, to maximise the sustainability performance improvements and to prolong the lifespan of the building.

As a conclusion, once again it must be emphasised that the effectiveness of the SRI and the sustainability rating relies on competent technicians who require additional training on the assessment of a building's energy performance and the creation of sound recommendations for the reduction of energy consumption.

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Annex A1 – TIMEPAC Code of Conduct for Smart Readiness and Sustainability Rating

Background and introduction

Towards **I**nnovative **M**ethods for **E**nergy **P**erformance **A**ssessment and **C**ertification of Buildings (TIMEPAC) is a *Coordination and Support Actions* (CSA) Horizon 2020 project. Europe's building stock covers some 25 billion square metres of floor space, of which 75% is residential. Therefore, retrofitting plays a major role in achieving the energy and climate targets set for 2050. The ongoing revision of the EU Energy Performance of Buildings Directive (EPBD) is therefore crucial for tackling climate change and energy poverty. This is TIMEPAC's starting point – turning goals into action by transforming the entire Energy-Performance Certification (EPC) process.

As valued as the EPC is, some doubt exists as to whether it reflects real building conditions. There is clearly a trade-off between the cost of issuing a detailed and tailored EPC and the willingness of customers to pay for it. Current EPCs are cheap, but they are not investment-grade documents and follow a static approach. TIMEPAC aims to improve existing energy-certification processes and move from single, static certification to more holistic and dynamic approaches. As a result, Energy-Performance Certificates will be enriched with retrofitting solutions and experts can be better trained to make our homes fit for the future.

The TIMEPAC Code of Conduct for Smart Readiness and Sustainability Rating is a voluntary initiative managed by the TIMEPAC consortium. It is a set of guidelines, values and principles that are considered fundamental for the successful, professional and transparent calculation of the Smart Readiness Indicator (SRI) and selected sustainability indicators in European countries. The aim is to inform and stimulate the SRI and sustainability auditors to objectively evaluate the existing situation in the assessed building and propose effective measures to reduce energy consumption in a cost-effective manner, without hampering the building itself or any function of technical building systems. Also, the TIMEPAC consortium hopes that the Code of Conduct for Smart Readiness and Sustainability Rating will stimulate other European stakeholders to discuss and agree to voluntary actions that will improve the energy efficiency, smartness, sustainability and flexibility of European buildings following common conditions such as the climate and energy-market regulations.

Additionally, the TIMEPAC Code of Conduct for Smart Readiness and Sustainability Rating can be considered as a quality indicator for clients (building owner, facility managers, building users, etc.) on what they should expect and require from the SRI and sustainability auditors in order to achieve expected benefits.

According to the European Commission's Delegated Regulation (EU) 2020/2155 of 14 October 2020 supplementing Directive (EU) 2010/31/EU of the European Parliament and of the Council by establishing an optional common European Union scheme for rating the smart readiness of buildings, Smart Readiness Indicators "means an indicator that informs on the rating of smart readiness of a building or building unit in line with Article 8(10) of Directive 2010/31/EU."

The Level(s) is the common EU framework of core sustainability indicators for buildings, and it is designed to enable professionals that play a role in the planning, design, financing and execution of building projects to make a clear contribution to broader environmental improvements at the European level. It aims to establish a common language of sustainability for buildings by defining core indicators for the sustainability of office and residential buildings. In the scope of the TIMEPAC project the following sustainability indicators with the potential to effectively enrich existing EPCs are selected from the Level(s) framework:

a. Use-stage energy performance
b. Lifecycle Global Warming Potential
c. Time outside of thermal comfort range
d. Lifecycle costs

Ethics and values

The TIMEPAC Code of Conduct for the Smart Readiness and Sustainability Rating reflects ethics and values shared among the TIMEPAC partners, which make the entire process of Smart Readiness and Sustainability Rating more effective, professional and transparent, with the aim to deliver sustainable energy savings in buildings. The TIMEPAC consortium is committed to promoting the highest level of professionalism and integrity and to foster trust and mutual respect among the SRI and sustainability auditors, clients as well as the public. These values illustrate the effective, professional and transparent approach to managing the Smart Readiness and Sustainability Rating in terms of:

Efficiency	• Energy savings • Economic efficiency • Indoor environmental quality • Sustainability in time
Flexibility	• Power saving • Power quality • Economic efficiency • Sustainable balance supply and demand • Renewable-energy generation
Sustainability	• Long - term thinking • Health-and-safety concerns • Respect for the environment • Intergenerational equity and intragenerational equity • Resilience • Innovation
Transparency	• Objectivity • Expertise • Integrity • Cooperation and participation • Openness • Clarity and fairness • Clear, regular and honest communication

Implementation principles

The TIMEPAC Code of Conduct for the Smart Readiness and Sustainability Rating consists of a set of twelve guiding implementation principles that are essential for the effective and trustworthy smart readiness and sustainability rating. The implementation principles are designed to inform the SRI and sustainability auditors about the required standards of professional conduct and practice that they are required to observe and to inform the client of the standard of conduct and practice they can expect of a SRI and sustainability auditor.

1. **Site visit is essential for the effective and transparent SRI and sustainability rating.** It is crucial to physically inspect the building to understand its design, layout, construction, and materials. These factors greatly influence the building's energy consumption, flexibility potential and overall smartness. A site visit allows the SRI and sustainability auditor to see first-hand how the building is used. During the site visit the SRI and sustainability auditor collects all necessary data. The site visit should also be used to check how the systems work and check operation schedules, lighting usage, heating, ventilation and air-conditioning

(HVAC) settings, and other factors that could affect energy usage, the SRI and the sustainability rating. A site visit helps to validate information provided by the building's management or obtained from energy and facility management. Use the opportunity to talk with building occupants about their activities, expectations, perceptions, and any issues they have noticed related to building usage.

2. **Avoid conflicts of interest and never try to sell products or services.**
   The SRI and sustainability auditor will not participate in professional activities involving a conflict of interest. Honesty is the key ingredient for the success and always disclose to the client all potentially questionable associations and relationships in advance to any stakeholder, product or service providers that could potentially affect your work and professional integrity. If you are giving energy and flexibility advice, always aim at an economically efficient combination of sustainable energy efficiency and flexibility improvement measures in a transparent way.
3. **Respect the privacy and confidentiality of the client's information.**
   The SRI and sustainability auditor will not disclose any confidential information obtained during the rating process concerning the business affairs or technical processes of any present or former client or employer without consent. Confidential information is defined here as names, addresses, phone numbers, financial data, personal details, vulnerabilities, defects, measurements, diagrams, blueprints, photographs, recordings, electronic versions, and other descriptions or representations that only the employers or clients have a right and a need to know about and disseminate.
4. **The SRI and sustainability auditor supports the application of innovative tools such as Building Energy Models (BEMs) and Building Information Modelling (BIM).**
   BEMs are essential for predicting a building's energy use, providing valuable insights for improving efficiency and potentially reducing costs. An auditor with knowledge of BEMs can better evaluate a building's sustainability performance and offer suggestions for improvement. BIM tools provide a comprehensive, digital representation of the physical and functional characteristics of a building. They enable better coordination among all stakeholders, reducing errors and miscommunications that could lead to wasteful practices. Investors are increasingly looking for investments that are both financially profitable and socially responsible. Auditors that use BEM and BIM to optimize energy performance are likely to propose more sustainable solutions for comprehensive renovations. An auditor who understands these tools appealing to such investments. This reinforces the importance of sustainable and efficient building practices in the construction and real-estate businesses.
5. **The SRI and sustainability auditor supports long – term use of energy-management systems.**
   Energy-management systems help to monitor, control, and optimize energy usage and power flows, resulting in significant cost savings over time. These savings contribute to the financial performance of an building. The reduced energy consumption achieved by using energy-management systems leads to a decrease in greenhouse-gas emissions and other forms of pollution. Modern energy-management systems support demand-side management operations. Also, energy-management systems contribute to the sustainability of a business by minimizing resource depletion. This is a key consideration for the SRI and sustainability auditors, who aim to promote and invest in businesses that are environmentally responsible and sustainable in the long term. Energy-management systems can help organizations comply with local and international energy-efficiency standards and regulations. The SRI and sustainability auditors would support these systems as they help organizations to verify achieved energy savings, maintain compliance and avoid potential fines or penalties. The SRI and sustainability auditor must stay up to date on the latest technologies, strategies, and best practices in energy management.
6. **A key element of efficient demand-side management (DSM) is the proper identification of controllable and uncontrollable loads.**

By correctly identifying and managing controllable loads, demand can be shifted to off-peak hours when energy is cheaper and more abundant. This not only leads to cost savings, but also improves the overall efficiency of the grid. Additionally, proper identification of controllable and uncontrollable loads is crucial for better planning, control and interaction with the grid. In periods of high demand, being able to reduce controllable loads can prevent overloading and ensure grid stability. If controllable loads can be properly managed, they can be matched to times when renewable energy production is high, reducing reliance on non-renewable energy sources. For consumers/prosumers, managing controllable loads effectively can result in significant cost savings. By reducing peak demand and overall energy consumption, DSM contributes to climate-change mitigation efforts. Overall, the proper identification of controllable and uncontrollable loads is a foundational step in implementing effective demand-side management strategies and must be properly addressed during the SRI and sustainability rating.

7. **Recommendations should be tailored to the specific building and its unique characteristics and needs.**
   Before providing any recommendation, the SRI and sustainability auditor must consider all aspects of the building's energy use, including heating, cooling, lighting and equipment. Document your observations and comments because this can be used for extracting energy-efficiency and flexibility-improvement measures. The SRI and sustainability auditor must always consider environmental impacts and strive to enhance sustainability. Recommendations should be economically and technically feasible for the client to implement.
8. **Always be transparent about the methods and assumptions used during the SRI and sustainability rating.**
   The SRI and sustainability auditor should be transparent about methods, explaining the rating process, and sharing his/her findings openly with stakeholders. Transparency helps build trust among all stakeholders including building owners, investors, tenants, and regulatory bodies. If stakeholders understand the process and assumptions used in the rating, they are more likely to trust and accept the results. Clear communication about the methods and assumptions used makes the rating process and results more understandable. This allows stakeholders to make more informed decisions based on the rating. If the methods and assumptions used are clearly documented and communicated, it allows for the results to be reproduced and verified by others. This enhances the reliability and credibility of the rating. Clear communication about the methods and assumptions used supports the fairness and objectivity of the rating. It shows that the process is systematic and unbiased, rather than arbitrary. Transparency also demonstrates that the process complies with relevant regulations and standards. It also supports accountability by making it clear how decisions and ratings were reached.
9. **The SRI and sustainability rating should be unbiased and objective, focused on providing accurate and reliable information.**
   To make informed decisions about energy-efficiency investments or improvements, stakeholders need accurate and reliable information. Biases or subjectivity could distort the results, leading to misleading conclusions or decisions. The smart readiness and sustainability rating should be unbiased and objective to ensure it provides accurate and reliable information. Investors and financiers often rely on these ratings to assess the sustainability and future performance of their investments. An unbiased and accurate rating system gives them confidence in their decision-making. For the rating system to maintain its credibility and continue to be used and respected, it must be seen as objective and unbiased. Otherwise, it could be discredited or disregarded.
10. **Always try to understand operational practices about how the building is used and operated, including occupancy, operating hours, and behaviour of occupants.**

Each building and its occupants are unique. By understanding operational practices, the SRI and sustainability auditors can provide recommendations tailored to specific use cases and behaviours, which are more likely to be implemented and effective. The behaviour of occupants and their interaction with building systems can greatly affect comfort and productivity. A good understanding of these factors can help improve these aspects while maintaining or improving energy efficiency.

11. **The SRI and sustainability auditor must ensure that all collected data are accurate, reliable and relevant.**
    The accuracy and relevance of the data collected during the SRI and sustainability-rating process directly impact the reliability of the analysis. If the data are inaccurate or irrelevant, the resulting recommendations or conclusions might not be valid or effective. Accurate and reliable data enable informed decision-making. It provides a clear understanding of the current situation, which allows for the development of effective strategies and measures to improve energy efficiency. The credibility of the SRI and sustainability rating relies heavily on the accuracy and reliability of the data. Stakeholders are more likely to trust and act upon the recommendations if they are based on solid data. Accurate data allow for effective benchmarking against similar buildings, which is vitally important for facility and energy managers. Inaccurate data could also lead to sub-optimal investment decisions and financial losses.
12. **Before submitting an official report always discuss your findings with the client.**
    The SRI and sustainability indicators are not just percentages and numbers. The SRI and sustainability auditor should always try to explain his/her findings with the emphasis on the potential energy-efficiency and flexibility-improvement measures. This means open dialogue and feedback, which can lead to the implementation of the proposed improvements. Openness in the smart-readiness and sustainability-rating process ensures the results are reliable, understandable, verifiable and fair. It enhances the credibility of the process and supports decision-making by all stakeholders.

Definitions and glossary

See TIMEPAC glossary.

Annex A2 – SRI and sustainability – case studies

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Case Study

Smart Readiness Indicator (SRI) and Sustainability - Austria

Building

Building type: Residential

Location: Lower Austria

Surface area: 3077 m^2

Construction year: 1969

Specificities: It is a multi-unit residential building where apartments are owned by different individuals (co-ownership, condominium). The roof would be suitable for a PV system, considering potential shadows cast by objects in the vicinity. There are several condominiums of the same type in this location which are all managed by the same facility management company.

Technical characteristics

The building was renovated many years ago. The oil boiler was replaced by a district heating connection and the façade was repaired; a thin layer of insulation was partially applied. Partial measures were also carried out on the electrics. Over time, the owners have replaced windows on their own initiative. There have been changes of use, e.g. a shop was abandoned and converted into a flat. No improvements have yet been made to the roof. Extending the scope from the building to the neighbourhood opens up new perspectives in terms of possible solutions for improvement.

Outcomes of smart readiness and sustainability rating - existing situation

Total energy consumption (final energy)	Heating energy consumption	Primary energy consumption (total)
282 kWh/m²/ann.	254 kWh/m²/ann.	453 kWh/m²/ann.

Overall score

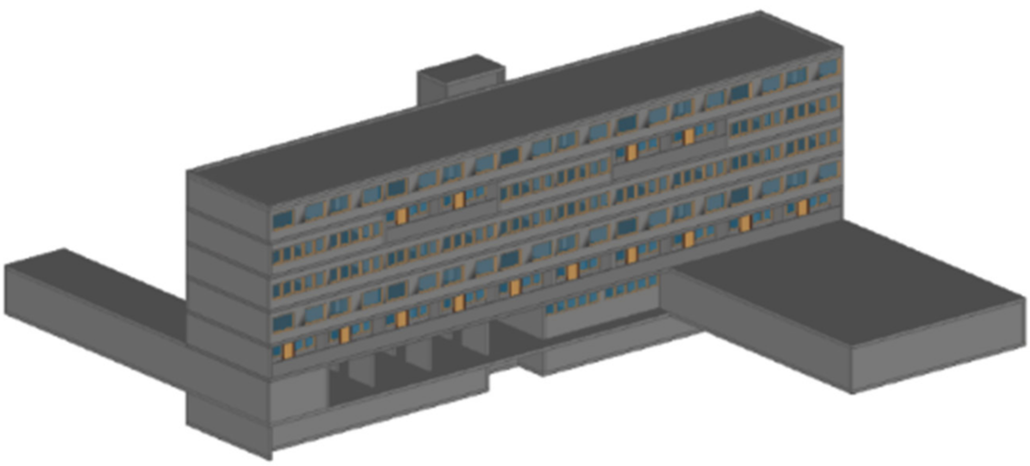
13%

Score per impact criteria

Energy efficiency: 22%
Energy flexibility and storage: 0%
Comfort: 22%
Covenience: 17%
Health, well-being and accesibility: 21%
Maintenance and fault prediction: 14%
Information to occupants: 23%

Technical domains

Heating: 21%
Domestic hot water: 0%
Cooling: 0%
Ventilation: 26%
Lighting: 0%
Dynamic building envelope: 0%
Electricity: 22%
Electric vehicle charging: 0%
Monitoring and control: 0%



Improvement potential measures

- Renovation and insulation of roof
- Installation of PV system on the roof
- North and south façade: Prefabricated Curtain wall, e.g. “GAP façade”, including windows and mechanical ventilation with heat recovery
- West and east façade: GAP façade with integrated PV panels in the upper third of the façade
- Reduction of water supply and return temperature of the heating system
- Low-temperature heat delivery system (panel heating)
- Individual room control with optimisation function
- Separation of space heating and domestic hot water production

Outcomes of smart readiness and sustainability rating - implementation of identified improvement measures

Total energy consumption (final energy)	Heating energy consumption	Primary energy consumption (total)
63 kWh/m²/ann.	37 kWh/m²/ann.	103 kWh/m²/ann.

Overall score

79%

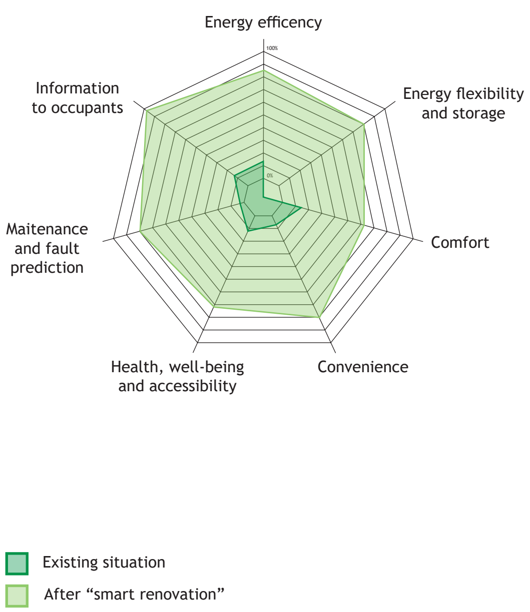
Score per impact criteria

Energy efficiency: 85%
Energy flexibility and storage: 78%
Comfort: 64%
Covenience: 78%
Health, well-being and accesibility: 74%
Maintenance and fault prediction: 80%
Information to occupants: 97%

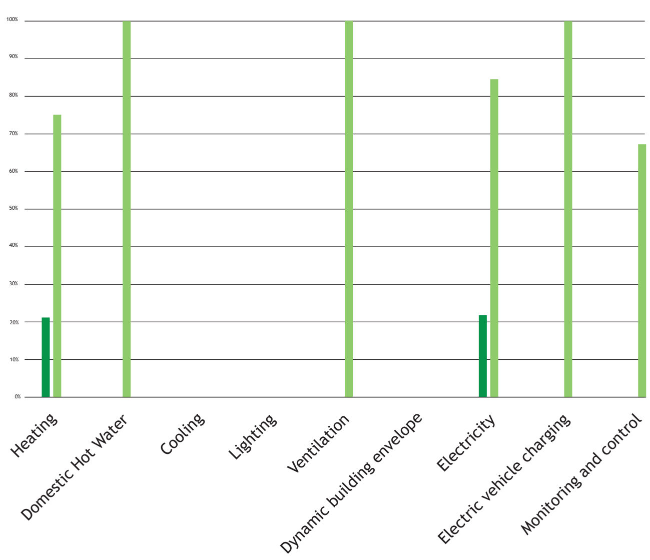
Technical domains

Heating: 75%
Domestic hot water: 100%
Cooling: 0%
Ventilation: 100%
Lighting: 0%
Dynamic building envelope: 0%
Electricity: 83%
Electric vehicle charging: 100%
Monitoring and control: 69%

SRI IMPACT SCORES



SRI DOMAIN SCORES



References

Material based on the document structure:
European Union (March 2023). *SRI case study n°1-NEOBUILD.* https://energy.ec.europa.eu/system/files/2023-03/SRI%20case%20study%20n%C2%B01-NEOBUILD_0.pdf

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Case Study

Smart Readiness Indicator (SRI)
and Sustainability - Croatia

Building

Building type: Non-residential

Location: North-West Croatia

Surface area: 2060 m^2

Construction year: 1975

Specificities: It is an office building and all the domains present. The building was refurbished in 2000. It is connected to local district heating network. It also has central cooling system with heat pump and ice bank.

Technical characteristics

The main issues identified in the heating system include the absence of occupancy detection and variable speed pump control, which affect its efficiency. Similarly, in the DHW production, there is a lack of integration with RES and no provision for demand-based supply, leading to inefficiencies. The cooling system also faces challenges with the absence of occupancy detection and variable speed pump control, impacting its performance. The ventilation system lacks advanced air quality sensors and load-dependent compensation, hampering its effectiveness. Furthermore, the lighting system lacks central control, and the window shading controls are manual. There is no on-site electricity generation, and information regarding electricity consumption is not shared. The EV charging infrastructure is rudimentary and lacks optimization capabilities. Additionally, monitoring and control systems are deficient in fault predictions and demand forecasting.

Outcomes of smart readiness and sustainability rating - existing situation

EPBD services total primary energy self-used 167.0 kWh/m²/ann.	Global costs by life cycle stage (use stage) 18.4 EUR/m²/ann.	Operative temperature range 18-24 °C Time out of range - with mechanical heating 0%

Overall score

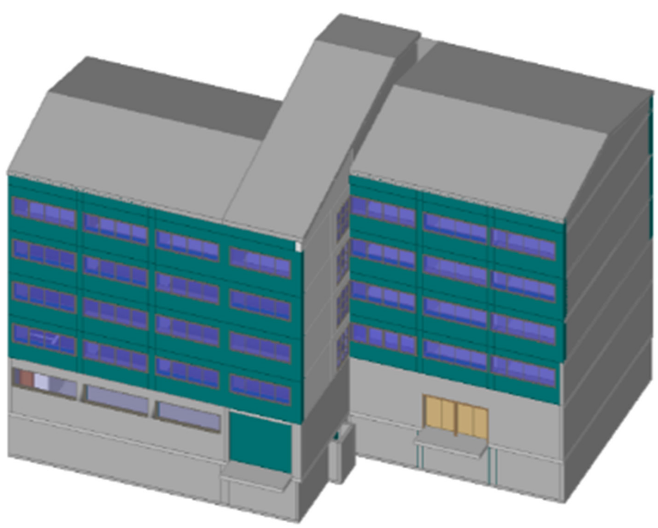
30%

Score per impact criteria

Energy efficiency: 47%
Energy flexibility and storage: 18%
Comfort: 45%
Covenience: 38%
Health, well-being and accesibility: 38%
Maintenance and fault prediction: 22%
Information to occupants: 26%

Technical domains

Heating: 32%
Domestic hot water: 23%
Cooling: 37%
Ventilation: 9%
Lighting: 52%
Dynamic building envelope: 15%
Electricity: 6%
Electric vehicle charging: 25%
Monitoring and control: 36%



Improvement potential measures

- Installation of new building monitoring and control system with demand/response functionalities and feedback to occupants
- PV and battery system with advanced grid interaction

Outcomes of smart readiness and sustainability rating - implementation of identified improvement measures

EPBD services total primary energy self-used	Global costs by life cycle stage (use stage)	Operative temperature range 18-24 °C
111.5 kWh/m²/ann.	14.4 EUR/m²/ann.	Time out of range - with mechanical heating 0%

Overall score

76%

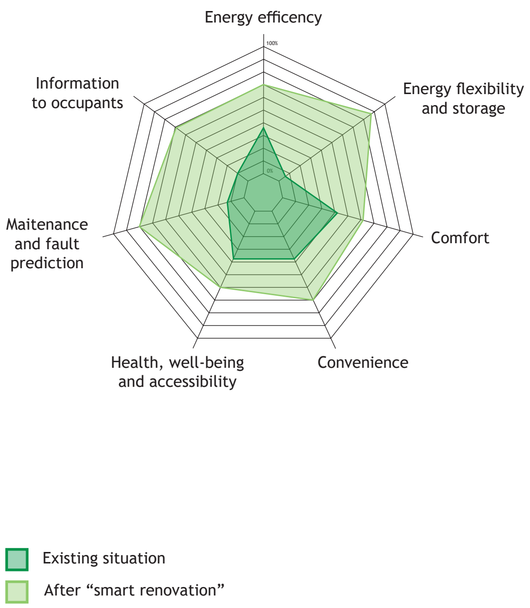
Score per impact criteria

Energy efficiency: 70%
Energy flexibility and storage: 87%
Comfort: 62%
Covenience: 70%
Health, well-being and accesibility: 62%
Maintenance and fault prediction: 79%
Information to occupants: 69%

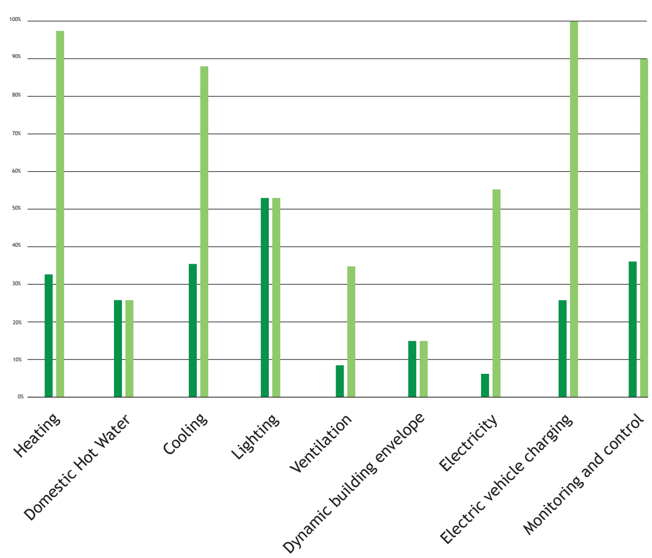
Technical domains

Heating: 99%
Domestic hot water: 23%
Cooling: 88%
Ventilation: 34%
Lighting: 52%
Dynamic building envelope: 15%
Electricity: 56%
Electric vehicle charging: 100%
Monitoring and control: 90%

SRI IMPACT SCORES



SRI DOMAIN SCORES



References

Material based on the document structure:
European Union (March 2023). *SRI case study n°1-NEOBUILD.* https://energy.ec.europa.eu/system/files/2023-03/SRI%20case%20study%20n%C2%B01-NEOBUILD_0.pdf

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Case Study

Smart Readiness Indicator (SRI) and Sustainability - Cyprus

Building

Building type: Non-residential

Location: Cyprus

Surface area: 173 m^2

Construction year: 1953

Specificities: The building is used for office purposes. Occupants have access to hourly energy consumption data, enabling them to monito r and analyse energy usage patterns in detail. Additionally, the building is equipped with an automatic air purifier that continuously monitors air quality, ensuring a healthy indoor environment.

Technical characteristics

Appliances installed in the assessed office building have only basic automated functions, typically limited to simple on/off controls. The assessment revealed several opportunities for implementing energy efficiency measures. These include upgrading lighting systems with advanced sensors and dimming controls, as well as integrating smart HVAC controls that dynamically adjust temperature settings based on occupancy and environmental conditions.

Outcomes of smart readiness and sustainability rating - existing situation

Total energy consumption

131 kWh/m^2/ann.

Operative temperature range 19-21 °C

Time out of range - with mechanical heating

0%

Operative temperature range 23-25 °C

Time out of range - with mechanical cooling

0%

Total SRI score

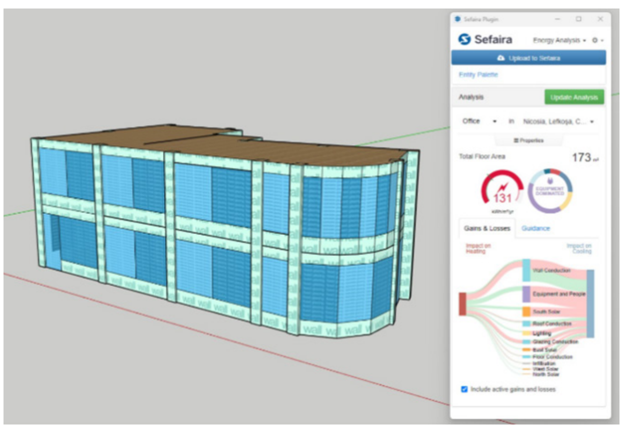
20%

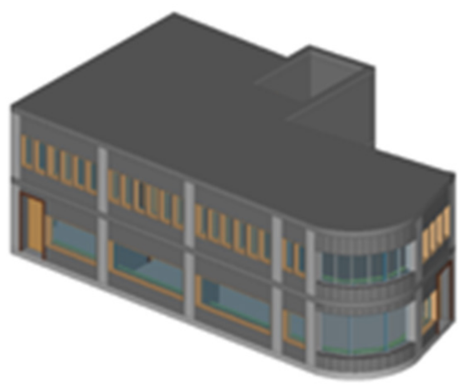
Score per impact criteria

Energy efficiency: 24%
Energy flexibility and storage: 0%
Comfort: 33%
Covenience: 50%
Health, well-being and accesibility: 29%
Maintenance and fault prediction: 15%
Information to occupants: 50%

Technical domains

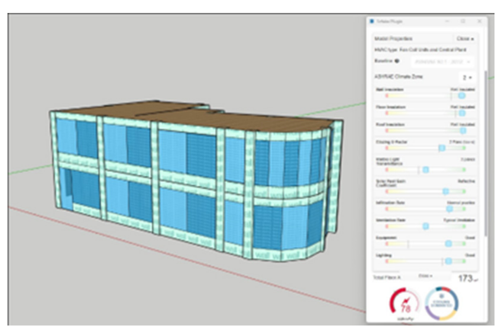
Heating: 0%
Domestic hot water: 0%
Cooling: 0%
Ventilation: 17%
Lighting: 0%
Dynamic building envelope: 0%
Electricity: 100%
Electric vehicle charging: 0%
Monitoring and control: 0%





Improvement potential measures

- Improvement potential measures
- Upgrade of the lighting systems
- General improvement of the BACS systems
- Smart EV charging station
- Upgrade of the building envelope (insulation) and adding dynamic and smart features
- Improved user feedback reporting



Outcomes of smart readiness and sustainability rating - implementation of identified improvement measures

Total energy consumption 78 kWh/m²/ann.	Operative temperature range 19-21 °C Time out of range - with mechanical heating 0%	Operative temperature range 23-25 °C Time out of range - with mechanical cooling 0%

Total SRI score

49%

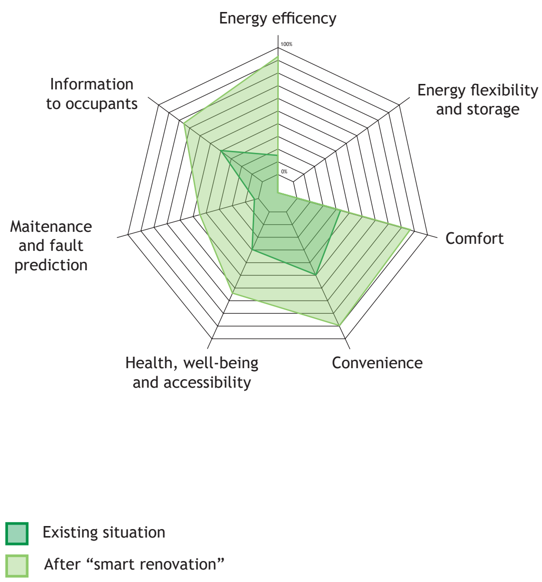
Score per impact criteria

Energy efficiency: 92%
Energy flexibility and storage: 0%
Comfort: 87%
Covenience: 90%
Health, well-being and accesibility: 64%
Maintenance and fault prediction: 46%
Information to occupants: 75%

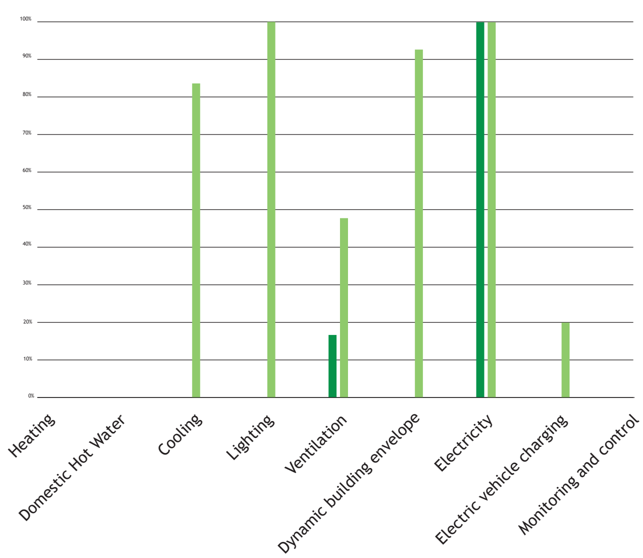
Technical domains

Heating: 0%
Domestic hot water: 0%
Cooling: 84%
Ventilation: 47%
Lighting: 100%
Dynamic building envelope: 92%
Electricity: 100%
Electric vehicle charging: 20%
Monitoring and control: 0%

SRI IMPACT SCORES



SRI DOMAIN SCORES



References

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Case Study

Smart Readiness Indicator (SRI) and Sustainability - Italy

Building

Building type: Non-residential

Location: Piemonte region

Surface area: 1674

Construction year: 1997 (the first part) and 2010 (the second part)

Specificities: It is a school complex consisting of two volumes, both single-story, built in two different periods. The expansion volume was added to increase the available space.

Technical characteristics

Both sections of the school have a load-bearing structure with reinforced concrete pillars and external infill walls, partially insulated with cavity brickwork. The vertical opaque envelope has a thermal transmittance between 0.59 and 0.33 W/(m^2K) respectively for the old and new parts. The transparent components of the building differ from time period both for frame materials, from wood to PVC with thermal breaks, and thermal transmittance, from 3 to 3÷4 W/(m^2K) respectively in the old and new parts. The facility for heat generation, both for heating and DHW, consists of three natural gas condensing boilers and a solar thermal system installed on the building's roof. The heat emitters are radiators without thermostatic valves.

Outcomes of smart readiness and sustainability rating - existing situation

EPBD services non-renewable primary energy self-used	EPBD services renewable primary energy self-used	Operative temperature range 19.5-24.5 °C Time out of range - with mechanical heating
278.9 kWh/m²/ann.	17.2 kWh/m²/ann.	0%

Overall score

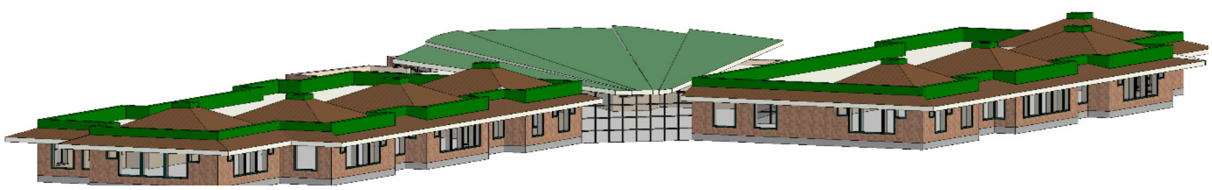
8%

Score per impact criteria

Energy efficiency: 28%
Energy flexibility and storage: 0%
Comfort: 20%
Covenience: 6%
Health, well-being and accesibility: 11%
Maintenance and fault prediction: 0%
Information to occupants: 4%

Technical domains

Heating: 20%
Domestic hot water: 3%
Cooling: 0%
Ventilation: 0%
Lighting: 0%
Dynamic building envelope: 0%
Electricity: 6%
Electric vehicle charging: 0%
Monitoring and control: 0%



Improvement potential measures

- Substitution of the natural gas fired boiler with two heat pumps
- Installation of energy management system with feedback to occupants, fault detection functionalities and with demand response functionalities
- Installation of PV system
- Installation of a battery system for PV
- Information to occupants of PV production and maximization of self-consumption
- Automatic lighting control system
- Installation of EV charging station

Outcomes of smart readiness and sustainability rating - implementation of identified improvement measures

EPBD services non-renewable primary energy self-used	EPBD services renewable primary energy self-used	Operative temperature range 19.5-24.5 °C Time out of range - with mechanical heating
185.5 kWh/m²/ann.	71.6 kWh/m²/ann.	0%

Overall score

44%

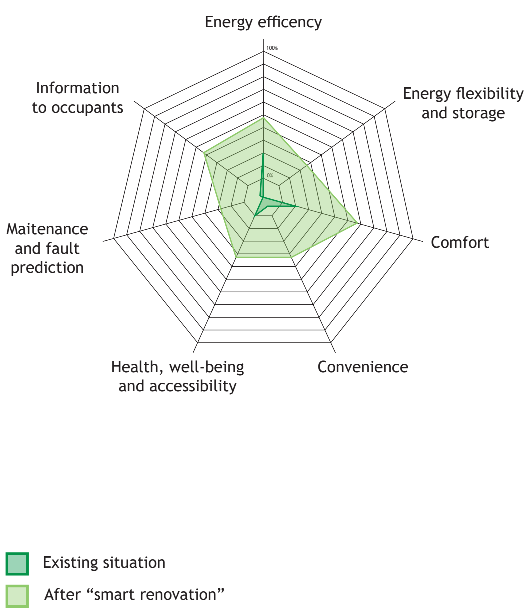
Score per impact criteria

Energy efficiency: 57%
Maitenance and fault prediction: 38%
Comfort: 57%
Covenience: 43%
Health, well-being and accesibility: 43%
Information to occupants: 29%
Energy flexibility and storage: 54%

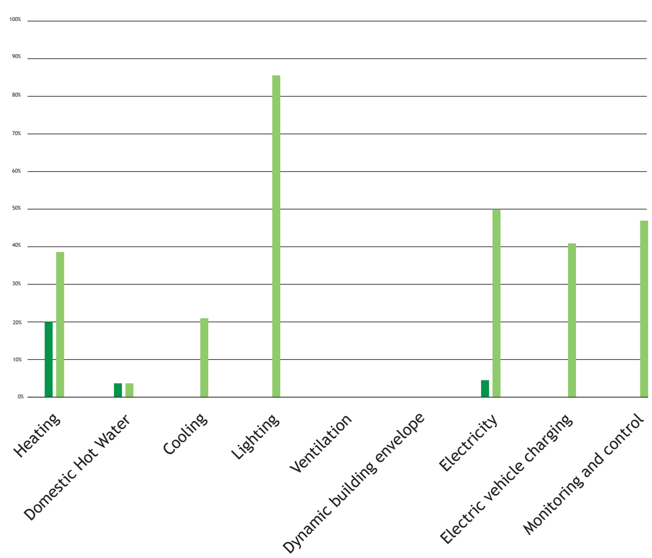
Technical domains

Heating: 54%
Domestic hot water: 3%
Cooling: 0%
Ventilation: 0%
Lighting: 85%
Dynamic building envelope: 0%
Electricity: 51%
Electric vehicle charging: 42%
Monitoring and control: 44%

SRI IMPACT SCORES



SRI DOMAIN SCORES



References

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Case Study

Smart Readiness Indicator (SRI) and Sustainability - Slovenia

Building

Building type: Non-residential

Location: Western Slovenia

Surface area: 3630 m^2

Construction year: 1980

Specificities: The building belongs to the health sector and almost all domains are present (electric vehicle charging is missing). The building underwent comprehensive energy renovation in 2019. Building is connected to local district heating network.

Technical characteristics

Modern energy management system is installed but it lacks demand/response functionalities and feedback to occupants. The main issues identified in the HVAC system include the absence of occupancy detection which affect its efficiency. Similarly, in the DHW production, there is a lack of integration with RES and no provision for demand-based supply, leading to inefficiencies. Furthermore, the lighting system lacks central control, and the window shading controls are manual. There is no on-site electricity generation, and information regarding electricity consumption is not shared.

Outcomes of smart readiness and sustainability rating - existing situation

EPBD services total primary energy self-used	Global costs by life cycle stage (use stage)	Operative temperature range 18-24 °C
247.9 kWh/m²/ann.	25.4 EUR/m²/ann.	Time out of range - with mechanical heating 0%

Overall score

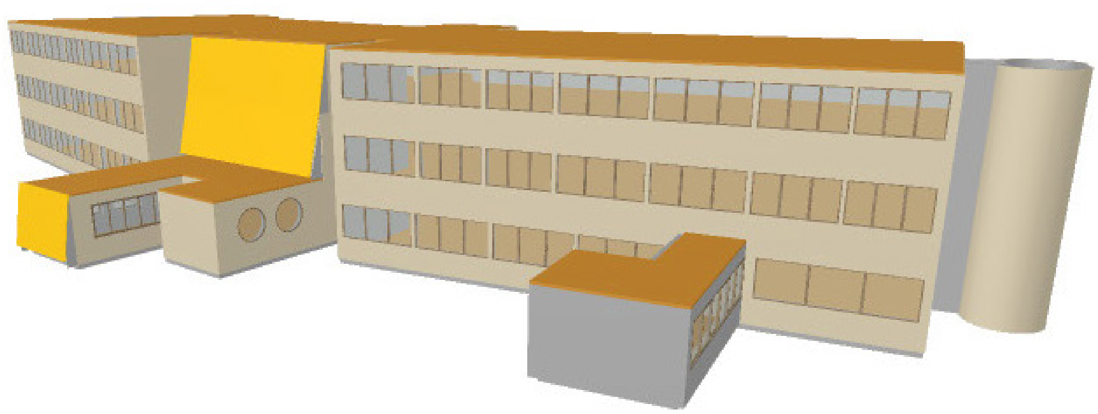
18%

Score per impact criteria

Energy efficiency: 35%
Maitenance and fault prediction: 7%
Comfort: 27%
Covenience: 16%
Health, well-being and accesibility: 25%
Information to occupants: 15%
Energy flexibility and storage: 4%

Technical domains

Heating: 25%
Cooling: 0%
Domestic hot water: 18%
Ventilation: 26%
Lighting: 0%
Dynamic building envelope: 0%
Electricity: 22%
Electric vehicle charging: 0%
Monitoring and control: 14%



Improvement potential measures

- Upgrade of the installed energy management system with demand/ response functionalities and feedback to occupants
- Installation of PV system for local electricty generation
- Renovation of lighting system and advanced control systems
- Installation of the battery system for the peak load management, emergency supply and optimisation of the PV electricity generation

Outcomes of smart readiness and sustainability rating - implementation of identified improvement measures

EPBD services total primary energy self-used	Global costs by life cycle stage (use stage)	Operative temperature range 18-24 °C
107.7 kWh/m²/ann.	23.8 EUR/m²/ann.	Time out of range - with mechanical heating 0%

Overall score

51%

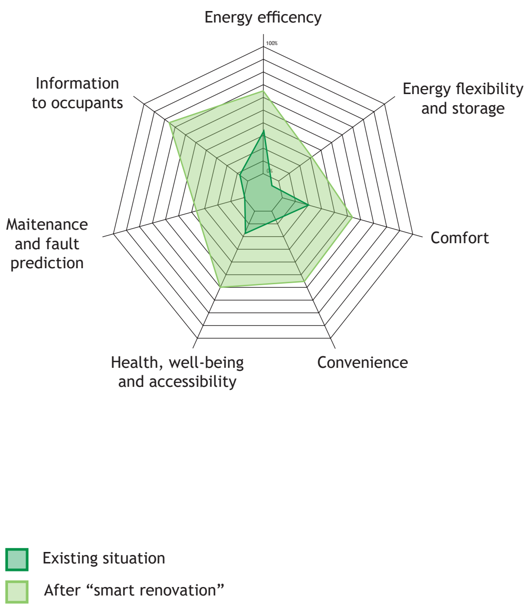
Score per impact criteria

Energy efficiency: 63%
Maitenance and fault prediction: 42%
Comfort: 56%
Covenience: 55%
Health, well-being and accesibility: 60%
Information to occupants: 75%
Energy flexibility and storage: 34%

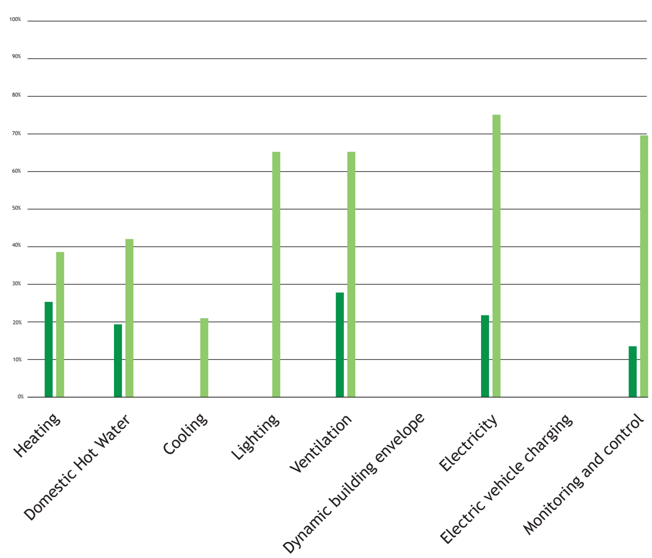
Technical domains

Heating: 39%
Cooling: 21%
Domestic hot water: 43%
Ventilation: 65%
Lighting: 64%
Dynamic building envelope: 0%
Electricity: 75%
Electric vehicle charging: 0%
Monitoring and control: 69%

SRI IMPACT SCORES



SRI DOMAIN SCORES



References

Material based on the document structure:
European Union (March 2023). *SRI case study n°1-NEOBUILD.* https://energy.ec.europa.eu/system/files/2023-03/SRI%20case%20study%20n%C2%B01-NEOBUILD_0.pdf

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TIMEPAC

Towards Innovative Methods
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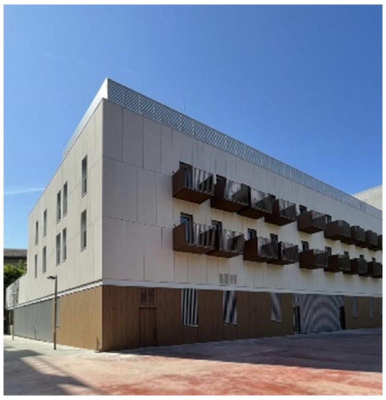
Case Study

Smart Readiness Indicator (SRI) and Sustainability - Spain

Building



Building type: Non-residential

Location: Catalonia

Surface area: 6000 m^2

Construction year: New construction

Specificities: It is a nursery home and almost all the domains are present except electric vehicle charging.

Technical characteristics

The building employs the Building Management System to monitor and oversee heating and cooling services, mechanical ventilation, and window openings in correlation with the HVAC system. For heating and cooling, an aerothermal system is utilized, while photovoltaic panels generate renewable energy. However, several key issues have been identified in this building. Firstly, the absence of a dynamic building envelope is a concern, as it relies on passive vertical slats that cannot be adjusted. Additionally, the interior shutters lack automatic control.

Outcomes of smart readiness and sustainability rating - existing situation

EPBD services non-renewable primary energy self-used	Global costs by life cycle stage (use stage)	Operative temperature range 19-21 °C Time out of range - without mechanical heating
107.5 kWh/m²/ann.	20.0 EUR/m²/ann.	23%

Overall score

53%

Score per impact criteria

Energy efficiency: 69%
Energy flexibility and storage: 26%
Comfort: 66%
Covenience: 63%
Health, well-being and accesibility: 65%
Maintenance and fault prediction: 61%
Information to occupants: 79%

Technical domains

Heating: 54%
Domestic hot water: 73%
Cooling: 54%
Ventilation: 90%
Lighting: 29%
Dynamic building envelope: 60%
Electricity: 56%
Electric vehicle charging: 0%
Monitoring and control: 49%

Improvement potential measures

- PV and battery system with advanced grid interaction (100 kW)
- Control elements and sensors for dynamic building envelope
- New LED lighting system with dimming control

Outcomes of smart readiness and sustainability rating - implementation of identified improvement measures

EPBD services non-renewable primary energy self-used	Global costs by life cycle stage (use stage)	Operative temperature range 19-21 °C
40.8 kWh/m²/ann.	6.1 EUR/m²/ann.	Time out of range - without mechanical heating: 0%

Overall score

69%

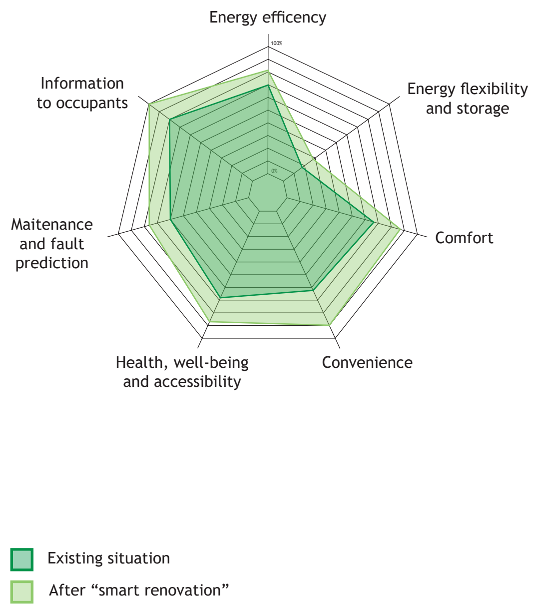
Score per impact criteria

Energy efficiency: 81%
Energy flexibility and storage: 37%
Comfort: 85%
Covenience: 91%
Health, well-being and accesibility: 87%
Maintenance and fault prediction: 78%
Information to occupants: 100%

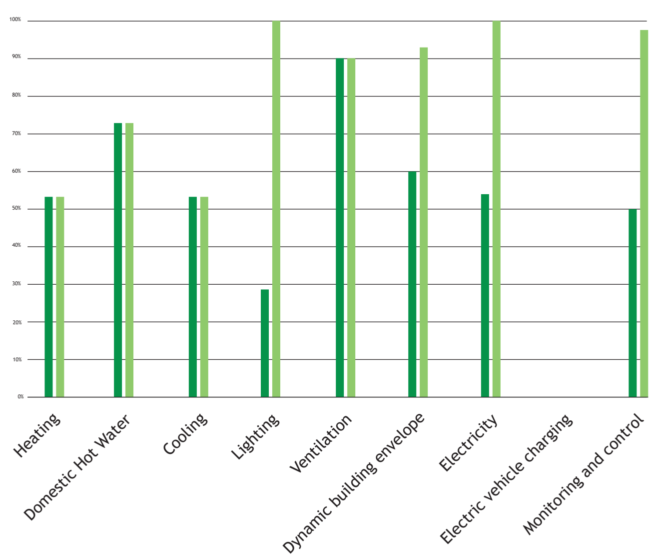
Technical domains

Heating: 54%
Domestic hot water: 73%
Cooling: 54%
Ventilation: 90%
Lighting: 100%
Dynamic building envelope: 92%
Electricity: 100%
Electric vehicle charging: 0%
Monitoring and control: 98%

SRI IMPACT SCORES



SRI DOMAIN SCORES



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