D2.6 SRI Indicators for next generation EPCs v2

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DELIVERABLE D2.6
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Authors List

Leading Author				
First Name		Last Name	Beneficiary	Contact e-mail
Christiana		Panteli	CLEO	cpanteli@cleopa.de
Co-Author(s)				
#	First Name	Last Name	Beneficiary	Contact e-mail
1	Detlef	Olschewski	CLEO	dolschewski@cleopa.de
2	Afroditi	Zamanidou	IsZEB	a.zamanidou@iszeb.gr
3	Adrián	Cano Cabañero	SGS	adrian.canocabanero@sgs.com
4	Thanos	Kalamaris	HYP	t.kalamaris@hypertech.gr
5	Christos	Malavazos	HYP	c.malavazos@hypertech.gr
6	Matina	Tsiakoumi	HYP	m.tsiakoumi@hypertech.gr
7	Panagiota	Chatzipanagiotidou	CERTH	phatzip@iti.gr

Reviewers List

Reviewers			
First Name	Last Name	Beneficiary	Contact e-mail
Egle	Klumbyte	KTU	egle.klumbyte@ktu.lt
Paulius	Spudys	KTU	paulius.spudys@ktu.lt
Phoebe-Zoe	Georgali	FRC	res.gp@frederick.ac.cy
Paris	Fokaides	FRC	eng.fp@frederick.ac.cy
Pinelopi	Valiouli	IsZEB	p.valiouli@iszeb.gr

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EXECUTIVE SUMMARY

This report presents the final results of *Task 1.2 – Smart Readiness Indicators (SRI) Analysis for Energy performance certificates (EPC's)* establishing the framework and scope of SRI's integration in the dynamic EPC scheme and constitutes the second and last version of the respective deliverable. The overall goal of this report is to provide the final analysis of the SRI framework for D^2EPC as well as to present the finalized SRI calculation subcomponent of the D^2EPC platform.

Starting with a detailed overview of the current status of the SRI, following the study accomplished under the authority of the European Commission DG Energy, the SRI level of development, methodology and the related procedures needed for the issuance of SRI certification were documented. Next, a detailed analysis of the coverage of SRI systems by BIM literacy was conducted. In particular, the Industry Foundation Classes (IFC) was selected as vendor-free schema for the definition of the building systems in the BIM environment. An allocation of IFC entities with SRI functionality was conducted with the scope to identify whether the SRI class of a building can be extracted from an IFC file of a building. Based on the analysis conducted, a plugin for the integration of the SRI calculation into EPC assessment was suggested.

The analysis concluded with the following findings:

- In this current phase, the IFC schema was considered adequate for the definition of the 1st layer of SRI information. A significant number of functionality levels are not addressed in IFC4-based documents, in accordance to the assessment conducted for the alignment of the individual SRI functionalities and the IFC4 attributes. This constitutes a major drawback, which does not allow the development of a comprehensive approach for extracting the SRI indicator from an IFC document.
- For the employment of SRI indicators in the D^2EPC solution, 'minimum modelling requirements' were defined for IFC4 entities that should be defined during the development of the BIM model for the extraction of the required data for SRI assessment. This work has been reported within the D2.1 - SRI Indicators for next generation EPCs v1.

The updated version of D2.6 - SRI indicators for next generation EPCs v2 aimed to conclude the analysis of SRI integration in dEPCs by presenting the final D^2EPC SRI subcomponent based on the findings of D2.1. The tool was tested and validated by all pilots during the demonstration activities. Moreover, an update on the official status of the SRI development was conducted including the advancements occurred from onwards (M17). Relevant information from various reliable sources (such as the EU website and the official EU SRI platform) was collected. An overview of the current status of SRI was presented (as of M35), including the last SRI developments which comprised of, among others: Testing of SRI in EU countries, the development of thematic SRI working groups, Upgrades of the SRI methodology packages, Development of support material, advancements on relevant legislations, initiatives and standards etc.

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List of Acronyms and Abbreviations

Term	Description
BACS	Building automation and control systems
IFC	Industry Foundation Classes
BMS	Building management system
BIM	Building Information modelling
CEN	European Committee for Standardization
EPBD	Energy Performance of Building Directive
CHP	Combined heat and power
DSD	Demand side management
EED	Energy Efficiency Directive
EPC	Energy Performance Certificate
EPBD	Energy Performance of Buildings Directive
EU	European Union
EV	Electric Vehicle
GHG	Greenhouse gas
IAQ	Indoor air quality
ICT	Information and Communications Technology
LCA	Life Cycle Assessment
MS	Member State
SRI	Smart ready indicator
SRT	Smart ready technology
TABS	Thermal activated building systems
TBS	Technical building system
RES	Renewable energy source
API	Application Programming Interface

1 Introduction

1.1 Scope and structure of the deliverable

According to the Directive (EU) 2018/844 of the European Parliament and Council of May 2018 on the energy performance of buildings, smart readiness indicators (SRIs) will be used to measure the ability of buildings to use information and communication technologies and electronic systems, to adapt the buildings operation to the needs of the occupants and the grid as well as to improve the energy efficiency and overall performance of buildings. **Task 2.1 aims to establish the framework and scope of SRIs integration in the dynamic EPC scheme**.

1. Firstly, a **detailed overview of the current status on the SRIs definition**, in accordance with the study accomplished under the authority of the European Commission DG Energy is realized (Report of VITO, Waide Strategic Efficiency, ECOFYS and OFFIS on SRI), aiming to identify the level of development, methodology and the related procedures needed for the issuance of SRI certification (Section 2 and 3).
2. **An allocation of IFC entities with SRI functionality levels is conducted** with the scope to identify whether the SRI class of a building can be extracted from an IFC file of a building (Section 4).
3. **Based on the analysis conducted in section 4, the need for the development of a plugin** for the integration of the SRI into EPC is suggested (Section 5).
4. The **D^2EPC SRI Calculation Sub-Component** developed as part of the D^2EPC platform is presented. As a sample, the SRI calculation of Case Study 1 is included (Section 6).

1.2 Relation to Other Tasks and Deliverables

- Task 2.1 considers the findings of Task 1.3, with regard to the documentation of the current status in the market of next generation EPCs.
- The Task 2.1 considers the D^2EPC architecture developed under Task 1.4, and also provides feedback and guidelines for the development of the SRI tool in the D^2EPC platform.
- The findings of Task 2.1 were used as an input for the development of the required procedures and APIs for the BIM parser developed under Task 2.5 and Task 3.3 respectively.
- Since the aim of this task is to identify a set of SRIs which can be extracted on EPC input data, work carried out under Working Group 1, that was established during the project's duration for the development of the framework for the D^2EPC asset rating methodology, based on the EN ISO 52000:2017 standards series, was also considered.

2 The Smart Readiness Indicator (SRI) Assessment scheme

2.1 Scope and objectives of the SRI

The energy transition is steering Europe's energy consumption from fossil fuels to renewables, further highlighting the importance of efficient energy management. The aim of the European Energy Transition 2030 aims to have a clean, affordable and reliable energy system for all. More control is being transferred to the hands of consumers by decentralizing the energy system and introducing more automation. Information and communication technology (ICT) based products for monitoring and control of building energy use. The digitalization of small scale and domestic energy solutions enables the co-ordination of supply and demand in real-time giving rise to smart grids. The European Union (EU) aims to transform its overall building stock, that currently consumes 40% of the EU's final energy, to be highly energy efficient and responsive to dynamic price signals by 2050 aligned with the Paris Climate Agreement [1][2].

As the energy transition of the EU building stock aims to ensure all EU citizens have access to energy services regardless of their income, the smart readiness indicator (SRI) is expected to become an inexpensive measure promoting healthier, more comfortable, low carbon impact and low energy use buildings capable of integrating renewable energy sources (RES) [3]. Digital smart home systems optimize the use of RES installations, battery storage, heating systems and electric vehicle (EV) charging and thereby helps to integrate renewables into the power grid through data-driven energy services [4]. It is envisioned that real-time consumer data will reveal consumer patterns and improve energy management at building level, and that users will become empowered by easy to use and informative tools to better monitor and control their energy use and benefit from energy costs savings [5]. The processing of consumers' personal data requires privacy protection mechanisms and a power system enhanced by digital technology must be resilient to cyber-attacks [4]. The goal of SRI is to promote decentralized, renewable-based, consumer-focused and interconnected buildings [6].

The SRI scheme is defined in Directive (EU) 2018/844, an amendment to the Energy Performance of Buildings Directive (EPBD) 2010/31/EU [7]and the Energy Efficiency Directive (EED) 2012/27/EU [8]. Article 8 gives direct support for ICT based smart technologies calling for a voluntary European scheme for rating the smart readiness of buildings. The objectives of the SRI scheme are to evaluate the building 'smartness' by means of evaluating the extent to which a building can adapt its operation in accordance with the preferences of its occupants and the needs of the grid taking actions that improve its energy efficiency. The scope of the smart ready services assessed are aligned with those of the EPBD that are concerned with building energy performance, however, the objective of the SRI is to provide a building smartness rating. Considering, sustainability aspects such as material use and smart technologies unrelated to energy performance like security systems have been excluded from SRI domains despite their availability in building management systems (BMS). SRI development has been triggered by the recast EPBD phasing out physical routine inspections of technical building systems (TBS) and introducing building automation and control systems (BACS) in their place. In support of this, the installation of room temperature controls and building operating conditions have been regulated. Additionally, the EED requirements in Articles 9a & 10a introduce the installation of controls enabling users to respond to feedback from consumption-based billing for space heating [5]. To endorse the uptake of smart technologies the recast EPBD requires new buildings or those fitted with new heat generators to utilize self-regulating devices for temperature control in different zones or rooms of the building. These regulations outline the increasing acknowledgement of digitalization as a key to optimizing the energy performance of buildings by policy makers in the EU.

As a certification scheme, the SRI assesses building energy efficiency, interaction with the user as well as energy system reliability through energy grid interaction. It aims to trigger improvements using smart ready services and raises awareness in smarter technologies and functionalities to end users and market actors alike. As such, the SRI scheme upholds building energy performance, response to user needs and energy demand flexibility as its three key functionalities. The SRI aims to enable building users to optimize indoor comfort using dynamic and self-learning control systems. In smart buildings, cutting edge ICT solutions optimize energy efficient control of technical building systems and control energy flexibility in day-to-day operation [2]. Building response to the grid is facilitated by real-time demand side management systems such as onsite energy storage and generation, and e-mobility infrastructure. The SRI calculates the impacts of all these three functionalities, thereby providing a technology neutral overview of a building's smart readiness level.

Figure 1: Tri-partite mnemonics conveying the overall SRI rank and sub-scores.

In the SRI scheme, new innovative technologies are exploited to optimize energy performance and achieve decarbonization in buildings. Provisions of the recast EPBD building codes support the initial phases of the roll-out of built-in EV charging stations, which are a domain of the SRI methodology. Under the Directive 2014/94/EU, new and renovated non-residential buildings with an excess of 10 parking spaces within or adjacent to the building will be required to install ducting infrastructure in the form of conduits for electric cables to allow recharging points to be installed at a later stage. The ducting infrastructure also provides an opportunity for car batteries to be used as a power source [9]. On-site EV charging in buildings has the potential to significantly reduce GHG emissions and so contribute to achieving the proposed 2030 climate target of a reduction in 55% GHG emissions compared to 1990. The provisions of the recast EPBD show that the scope of the SRI is envisioned to continuously expand in terms of smart ready services, assessed domains and building types.

The SRI aims to create a market pull and push for competitive and capable smart ready technologies (SRT) and services. The SRI is envisioned to promote and incentivize investment into more intelligent buildings and building system technologies. Facility managers who utilize the SRI and are able to demonstrate energy and cost savings after implementing recommendations provided by an SRI assessment could influence investor decisions into the uptake of SRTs and long-term operation strategies such as deep energy efficiency renovations [2]. In the smart home technologies market, the SRI engages service providers such as network operators, technical building system manufacturers, engineering firms, etc. to position and package their service offers competitively on a neutral and common framework. The capabilities of smart services become more easily comparable between service providers, thereby providing a more attractive, affordable and credible market for consumers. As consumers demand smart ready services with improved functionality, manufacturers are forced to produce products with higher SRI labels ensuring the continued fast-paced evolution of the technological environment. The financial market for energy efficiency is also stimulated resulting in a boost in uptake and market growth simultaneously.

2.2 Legal Framework of SRI

The Energy performance of buildings directive (2010/31/EU) and Energy Efficiency Directive (2012/27/EU) are specifically concerned with the energy efficiency targets and are the governing legislative frameworks for the building sector. Moreover, as part of the European Green Deal, the Commission introduced the Renovation Wave strategy in October 2020 [10]. This strategy includes an action plan that outlines specific regulatory, financing, and enabling measures aimed at boosting building renovation. The objective is to increase the annual energy renovation rate of buildings by at least double by 2030 and promote deep renovation. In the context Renovation Wave strategy's goals, both the Energy Performance of Buildings Directive and other related directives underwent amendments in 2018 and 2019. The revision of the Energy Performance of Buildings Directive seeks to enhance and strengthen the regulatory framework, aligning it with the objectives of the Renovation Wave strategy and support the decarbonization goals of the European Union.

In particular, the SRI has been introduced by the EPBD revised directive (2018/844/EU) in order to reinforce the renovation and modernization of buildings with the uptake of smart building technologies that facilitate the achievement of these energy efficiency targets. The revised EPBD established the SRI as a ‘’common Union’’ scheme for rating the smart readiness of buildings. The scheme is designed to provide a standardized approach for evaluating and quantifying the level of smart readiness in buildings across the European Union. The SRI scheme was entered into force in December 2020 with provisions for a non- committal test phase by MS. The *Commission Delegated Regulation (EU) 2020/2155* established the official definition of the SRI and the common calculation methodology [11], whereas the *Commission Implementing Regulation (EU) 2020/2156* detailed the technical modalities for effective implementation of the SRI [12].

The smart readiness indicator follows a common methodology of calculating scores and deriving percentage ratings. It considers advanced building features lending to interconnectivity with intelligent devices, BMS, BACS, self-modulated devices for thermal comfort, energy storage and on-site electric vehicle charging stations. Smart readiness scores can be presented for each of the following categories which include:

- Aggregated scores of the three key functionalities (energy performance and operation, response to occupant needs and energy flexibility);
- Smart readiness impact criteria;
- Smart readiness technical domains;
- Overall aggregated SRI score for the building

The legislation lists smart-ready services that can be assessed in a building in a pre-defined smart-ready service catalogue for easier identification. The weighting of smart readiness impact criteria corresponds to pre-defined smart readiness functionalities. MSs can define the weightings applied to technical domains by defining climatic zones and accounting for possible effects of climate change.

According to the Directive, the SRI should convey to the building owner how the installed smart technologies on the property have a positive impact on the building's preparedness for climate change, energy savings, accessibility, well-being and comfort. Integration of the SRI scheme with national energy performance certification schemes is a strategy MSs can employ to enhance existing rating instruments in a complementary and cost-effective manner. The SRI scheme can be used in combination with the EPC scheme, energy audits under Directive 2012/27/EU or HVAC inspection scheme under Directive 2010/31/ EU to provide building users with a more comprehensive understanding of a building's energy performance and plan more specifically tailored energy efficiency measures. MSs are granted the option to adapt the SRI scheme to country-specific conditions through the flexibility of the rating methodology. The use of BIM and digital twins is encouraged to facilitate the calculation of smart readiness scores for existing and new buildings. MSs can opt to apply the SRI scheme to certain categories of buildings or in certain parts of their national territories on a voluntary or mandatory basis. Annually MSs will report statistics related to SRIs in their territories to enable the Commission to review the market uptake of the scheme.

Regarding the expertise required to assess the smart readiness of buildings, professional inspectors of heating, air-conditioning and ventilation systems under Directive 2010/31/EU, energy auditors under Directive 2012/27/EU or accredited EPC assessors are deemed as qualified. MSs must ensure, however, that training in ICT is included as a competence criterion. This provision allows Member States to leverage the existing expertise and qualifications of professionals who are already involved in energy performance-related activities. By setting additional requirements, such as specialized training, Member States can ensure that these experts have the necessary knowledge and skills to accurately assess and issue SRI certificates. It also helps streamline the certification process and avoid duplicative assessments by utilizing the expertise of professionals already engaged in building energy performance evaluation and auditing. The issuance of a new certificate following significant building alterations may be recommended by an expert. Self-assessment of smart readiness will be supported by open guidance and tools, such as through the framework on the Commission's website for interested stakeholders. A self-assessment will not, however, result in an official SRI certificate [11][12].

2.3 Current status of SRI development

The development of the SRI scheme commenced in 2017-2018 with a first preliminary technical study for the definition of the SRI methodology and after it, the second study, building on the outcomes of the first, commenced in 2018 until 2020. The final report of the second technical study of the European Commission services (DG ENERGY) of a smart readiness indicator [2] for buildings provides a comprehensive documentation of the development of the SRI. The report features technical aspects and the results of two support studies supervised by the European Commission, SRI implementation pathways, proposed SRI formats, assessment methods, and benefits and costs. Based on the findings of the second technical support study, the following definition was developed: “Smartness of a building refers to the ability of a building or its systems to sense, interpret, communicate and actively respond in an efficient manner to changing conditions in relation the operation of technical building systems or the external environment (including energy grids) and to demands from building occupants”.

Building on the findings of the second technical study, the European Commission DG Energy established a dedicated technical assistance service for the support and roll-out of the testing phase of the SRI. A two-year service contract has been awarded to a team consisting of VITO (Belgium), Waide Strategic Efficiency Europe (Ireland), Research to Market (R2M) Solution (France), and LIST, the Luxembourg Institute of Science and Technology. The contractual requirements include the provision of technical assistance to the European Commission services and Member States during the initial phases of testing and implementation of the SRI [13].

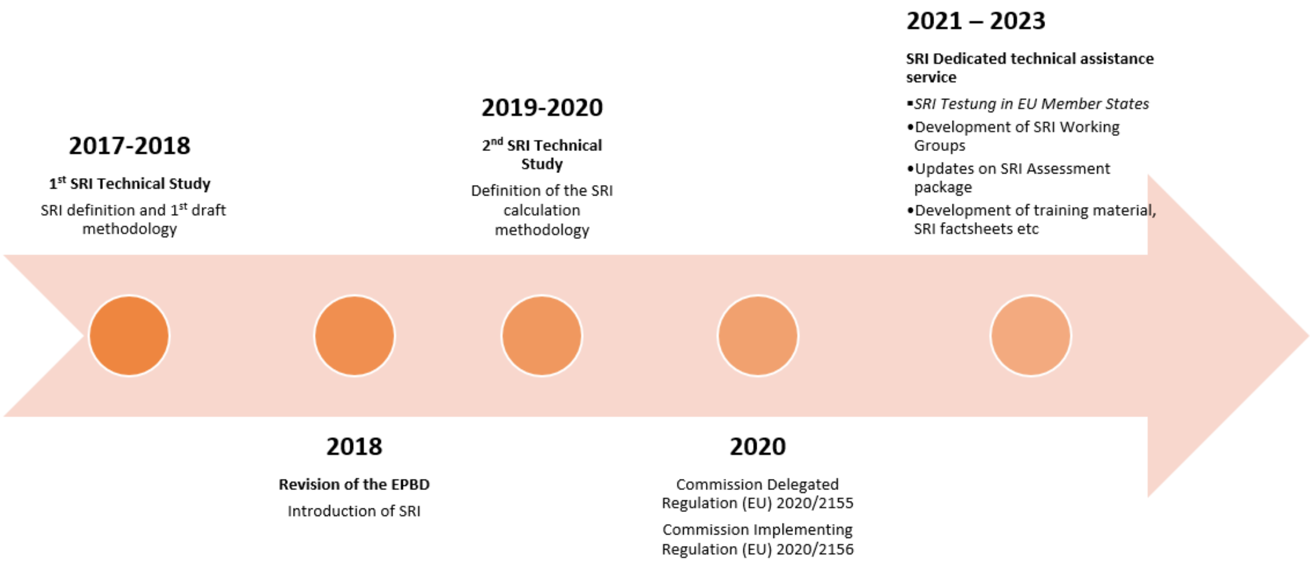


Figure 2 Historical Timeline of SRI development

As of June 2023, the following developments have taken place:

- ***SRI Testing in EU Member States***

  The SRI has been officially tested in 8 EU countries which replied positive to the call for participation in SRI testing. These countries are: Austria, Croatia, Czech Republic, Denmark, Finland, France, Slovenia and Spain. The national administration in each of the eight leading countries received assistance from one or several local technical partners and is also supported by the SRI Support Team. More MS are currently encouraged to participate in the initiative within their respective territories. Upon conclusion of the national test phases, the participating countries are required to assess the outcomes and decide on whether to implement the SRI. They must submit a report to the Commission within six months after the conclusion of the test phase, outlining the feedback received and the results of the assessment [14].

- ***Development of SRI working groups***

  In order to support and monitor the various aspects related to the SRI development, three working groups have been established to: (a) facilitate the exchange of experiences related to SRI testing, (b) address methodological aspects of the SRI (such as scoring, weighting, and service catalogues), and (c) tackle various aspects of SRI assessment and implementation. Various experts representing MSs and various organizations were pooled into the stakeholder groups following a successful respond to the call of experts in January 2022 [15]. The context of the SRI Working groups is as follows:

  - **Working Group 1** is dedicated to testing the SRI in EU MS. Its purpose is to facilitate the sharing of experiences and provide support during the testing and initial implementation of the SRI in Member States. It aims to aid evaluation and consolidate reports from Member States that are formally involved in testing the SRI.
  - **Working Group 2** focuses on the maintenance and potential expansion of the SRI methodology outlined in the delegated act on the SRI. It covers various aspects, including the process of updating the scoring, weighting, and service catalogue. The objective is to discuss and report on methodological aspects, streamline a common EU approach, and establish a process for keeping the SRI catalogues and scoring matrices up to date.
  - **Working Group 3** - SRI value proposition and supporting measures including:
    - Clarification and communication of the SRI's value proposition.
    - Support for SRI assessment.
    - Professional training and capacity building.
    - Consideration of needs for a common online assessment tool.

- Identifying SRI requirements within the Single Market.
- Exploring potential connections between the SRI and other initiatives.

As to date, the SRI support team held 3 well-attended platform plenary meetings also accessible via web-streaming and published written consultations and relevant documents regularly on a public website. During these meetings, the status of the SRI roll-out in the EU as well as the outcomes of the working groups have been presented.

- ***Development of the SRI Platform***

The official SRI platform was launched (December 2021) to promote and facilitate the testing and implementation of the SRI. The platform serves as a multi-stakeholder forum (between Member States and various stakeholders) to support and monitor the implementation of the SRI and provide recommendations for potential future enhancements of the indicator. Its main objective is to foster interaction and facilitate discussions on technical, regulatory, and implementation aspects related to the SRI. Moreover, the SRI platform includes technical and training material in order to facilitate the understanding of SRI assessment to the experts and general public [16].

- ***Update of SRI assessment package***

Since the conclusion of the 2nd technical study, the SRI assessment package has been consistently updated following the developments of the technical assistant service. The recent updates of the SRI calculation spreadsheet focused on the improvement of the accuracy and clarity of calculation methodology as well as the expansion of the usability by integrating the French and German languages (v4.4 and v4.5). In addition to the official calculation spreadsheet, a variety of digital tools have been developed to facilitate the calculation of the SRI and offer additional SRI-related services to enhance the intelligence of buildings. However, it is crucial to note that current SRI framework calculation tools cannot be utilized for official assessments, as explicitly stated in the terms and conditions. Consequently, Member States aiming to issue formal SRI certificates will need to develop their own dedicated calculation tools following the completion of the testing phase.

- ***SRI certificate design survey***

An online SRI certificate survey was released in order to support EU MS in designing their national certificate. The survey aimed to gather feedback from professionals in the building sector regarding certificate design concepts. The survey mainly concerned with the overall certificate appearance, graphic design elements as well as preferred type of information to be included in the certificate. The findings from 71 completed surveys have been carefully analysed and incorporated into the document "Provisional guidance on the implementation" [18] published by the technical assistance service and provides valuable insights and recommendations based on the survey responses. The data collected from the surveys has been processed to ensure accuracy and reliability in informing the guidance for implementing the SRI. The provisional guidance document serves as a valuable resource for stakeholders involved in the SRI implementation process.

SRI Methodological Status

Smart ready services are comprised of smart ready technologies (SRT). For the purposes of application to various aspects of a building, these SRTs are defined under technology neutral terms. Smart ready services are catalogued based on the present state-of-the-art technologies available in the market, they list the expected impacts of the services on the grid and building occupants. A simplified list of smart ready services and a detailed list were prepared as catalogue A with 27 listed services and B with 54 services. In the last SRI assessment package (v4.5), a list of 45 extra services (5 per domain) is provided for the user to customize their services in the corresponding domain. The functionality levels of a service are assessed as part of the SRI evaluation. Balancing these two approaches leverages the supporting systems in the Single Market for goods and services and produces more accurate smart readiness ratings. The SRI multi-criteria assessment of available installed smart ready services recognizes degrees of smartness and categorizes devices and services into multiple domains. The multi-criteria assessment method accounts for the different domains in which smart ready services operate and their associated impacts. Impact scores are calculated based on the effects of these services on the building users and the grid according to various impact criteria and weights designed for reaching a final SRI rating [17].

Many smart ready services are based on international technical standards and are categorised under 9 domains; heating, cooling, domestic hot water, ventilation, lighting, dynamic building envelope, electricity, EV charging and monitoring and control. At least 2 and up to 5 functionality levels are defined for each service. A higher functionality level corresponds to a smarter level of implementation of the service. Smart ready services produce impacts aggregated into three distinct functionalities according to the EPBD; Optimization of energy efficiency and overall in-use performance, adaptation to user needs and building energy flexibility. Disaggregated, the impact criteria include:

1. **Energy efficiency on-site** resulting from SRTs;
2. **Flexibility for the grid and storage** offered by smart ready services for district heating and cooling grids as well;
3. **Comfort** of the building user through conscious or unconscious perception of their indoor thermal environment;
4. **Convenience** in how easily the occupant interacts with the services in order to achieve ideal comfort levels;
5. **Wellbeing, health and accessibility** impacts on users by the services;

6. **Maintenance and fault prediction** can potentially improve building energy performance by smart ready services automatically diagnosing inefficient operation;
7. **Information to occupants** on the status of the building's operations delivered by the smart ready services.

Due to its reliance on cataloging functions and assigning scores based on the maximum achievable functionality, the *provisional guidance on the implementation of the SRI* [18] published by the technical assistance service, suggested periodic review and updates in response to technological advancements. As new and improved functionalities emerge, there is a need for documentation and adjustment of the scoring system, adjusted accordingly to account for their presence. Additionally, it highlights the necessity of evolving the current catalog of services in order to be more comprehensive, including new emerging technologies representing local/international developments. This process is thoroughly documented in the 2nd technical assistance study, but it inevitably involves striking a balance between various factors. To ensure the continuous improvement and adaptation of the methodology, it is essential to establish a structured process for its review and maintenance. At the European level, this responsibility falls under the purview of Working Group 2 of the SRI Platform. This working group is specifically tasked with the potential expansion of the SRI working methodology. While the processes described above refer to the EU generic SRI methodology, individual Member States are allowed to conduct a complementary process at their jurisdictional level. This is particularly relevant if significant adaptations or modifications have been made to the generic EU-level methodology. By conducting a complementary process at the jurisdictional level, Member States can ensure that the methodology aligns with their specific national context, priorities, and regulatory frameworks. This process allows for the customization and refinement of the methodology to address specific regional or local considerations, such as building codes, energy policies, or climate conditions.

Cybersecurity & Interoperability

According to the delegated regulation for the Smart Readiness Indicator, the SRI certificate can include information on cybersecurity, including conformity to commonly agreed standards and related risks. The provisional guidance on the implementation of the SRI suggests the European Cybersecurity Certification framework is an initiative that could assist in mitigating these risks by developing criteria applied to smart-ready technologies (SRTs) and facilitating the communication of cybersecurity status to market actors. However, the cybersecurity certification requirements and regulations are still under development, with work being carried out by ENISA. In October 2020, the Commission proposed a legislation to strengthen the cybersecurity of wireless devices and products. This legislation would impose obligations on manufacturers to enhance the cybersecurity of products sold in the EU market.

The commission recognizes that wireless communication is 80% more susceptible to cyber-attacks in comparison with wired communication, therefore many smart-ready technologies are subjected to the requirements of the initiative. Starting from the summer of 2023 onward, all wireless products that are relevant to SRTs and placed on the market will be required to meet cybersecurity standards. Another accompanying assessment is that of technical building system interoperability. In the future, interoperability could be conveyed by a metric for each technical domain, at the moment however, it remains difficult to assess the interoperability of technologies in order to develop such a metric. Alternatively, standards and communication protocols used by the devices installed in the building could be reported as an indication of the building's overall interconnectivity and interoperability capabilities. Certain schemes, like the one administered by the Smart Building Alliance in France, include specific assessments of building interoperability. In cases where credible and recognized sources provide information on building interoperability, Member States have the option to include it in the details provided on the SRI certificate. Member States that are contemplating the inclusion of explicit interoperability assessments within the SRI are advised to evaluate how such assessments have been implemented in schemes like the one operated by the Smart Building Alliance. This can serve as a reference to understand best practices and ensure effective implementation of interoperability assessments within the SRI.

Given the rapidly evolving technological advancements in smart ready services and devices, new methods regarding implementation may continuously be developed at EU level or by individual MS. Further fine-tuning of the SRI methodology would produce more objective ratings especially in cases where small residential buildings fitted with several SRTs achieve low scores because the lack of BMS, whereas larger buildings with a BMS have higher performance. Strategies for the improvement of the SRI are already in place with ongoing research into the introduction of an interoperability metric and a cyber-security label. A large uptake of the SRI roll-out would only increase the impact of the scheme on upgrading the EU building stock thereby reducing CO_2 and GHG emissions and improving building energy performance and energy cost savings.

3 Methodology of the SRI scheme

The SRI developed by the technical study of the European Commission services (DG ENERGY) is defined by the functionality levels of individual smart ready services as well as their respective impacts. The SRI score is expressed as a percentage (%) representing the ratio between the smart readiness of the building or building unit to the maximum achievable smart readiness. The calculation is based on pre-defined weighting factors, the value of which depends on climatic conditions and other relevant aspects, e.g., type of building, where applicable.

The process of calculating SRI follows this protocol:

(1) Triage process to define relevant and irrelevant smart ready services in the building or building unit

Relevant/irrelevant smart ready services are chosen and omitted/included respectively from the SRI calculation procedures in order to avoid unfair penalization of a building or building unit, e.g. cooling services that may not be relevant in Northern countries.

(2) Definition of functionality levels of building systems

The smart-ready services functionality level definition leads to the specification of the service's individual score. The building technical systems installed are assessed individually either by physical inspection or documentation depending on the followed method. The building technical systems are inspected against their functionality level as presented in the pre-defined smart ready services catalogues and depending on their domain group (i.e. heating, cooling).

(3) Calculation of smart ready domain impact scores

Each one of the services' individual impact score is derived from the specification of functionality levels. The individual impact scores are used for the calculation of an aggregated impact score for each of the 9 domains considered in the SRI methodology. Each domain score is calculated and expressed as a percentage representing the ratio of the aggregated individual services impact scores to the aggregated theoretical maximum individual impact scores.

(4) Calculation of impact score criterion

For each impact criterion (energy efficiency, flexibility for the grid and storage, comfort, convenience, health and well-being, maintenance and fault prediction, information to occupants etc.), a total impact score is calculated as a weighted sum of the domain impact scores. The weight of each domain will be influenced by its relative importance on the impact and for some impact criteria, this can differ between residential and non-residential buildings as well as between different climate zones.

(5) Smart readiness scores along the three EPBD key capabilities

A smart readiness percentage score is determined for each of the three key functionalities by weighing against impact criteria with equal weighting factors as follows:

- For ‘energy performance and operation’ the relevant impact criteria are ‘energy efficiency’ and ‘maintenance and fault prediction’;
- For ‘response to user needs’ the relevant impact criteria are ‘comfort’, ‘convenience’, ‘information to occupants’ and ‘health & well-being’;
- ‘Energy flexibility’ has only one relevant impact criterion ‘energy flexibility & storage’.

(6) Total smart readiness score for a building or building unit

The aggregated smart readiness percentage score of a building or building unit is calculated by weighing the calculated smart-readiness scores of the three key functionalities. It is possible to convert the percentage to a star rating or alphabetical score (A, B, C, etc.) and other such indicators.

(7) (Optional) Smart readiness scores for technical domains

This is an optional step that calculates the smart readiness scores of technical domains along each impact criterion.

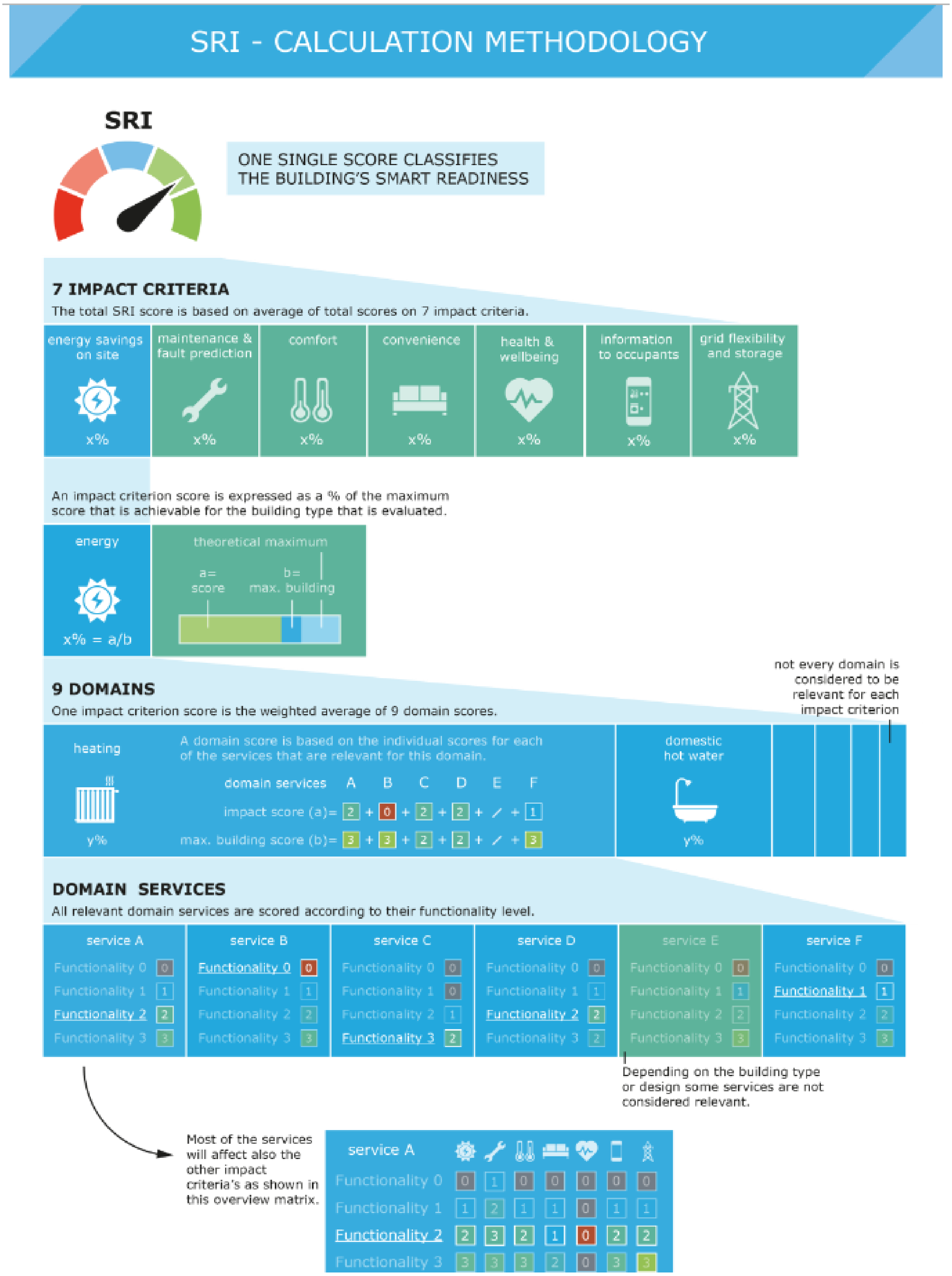


Figure 3: Overview of the SRI calculation methodology.

3.1 SRI Methods

The technical studies implemented for the establishment of the SRI methodology and supervised by DG ENERGY concluded with three different methods of SRI assessment based on the degree of complexity of the SRI definition.

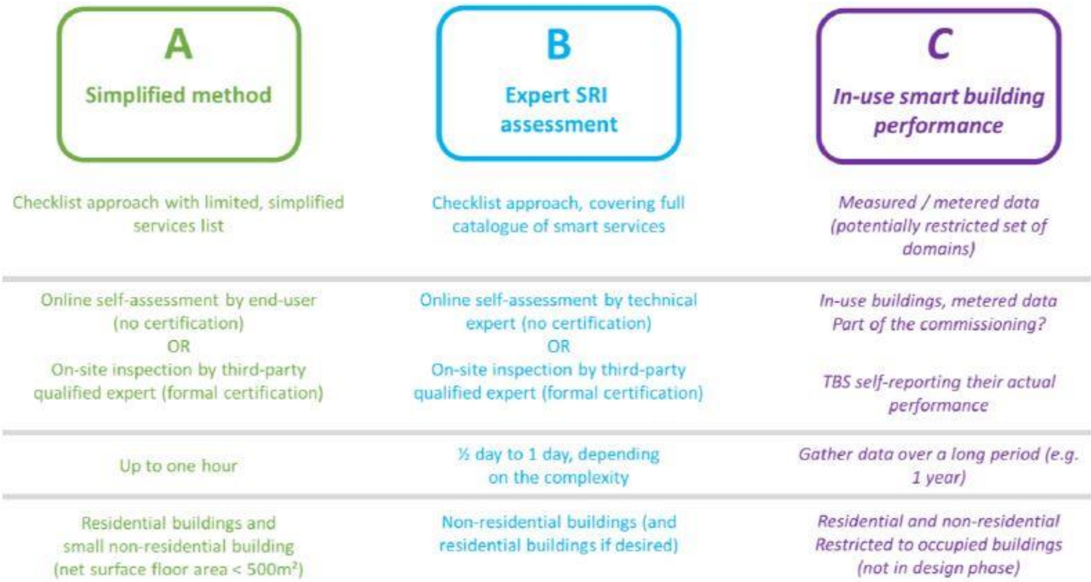


Figure 4: SRI assessment method types.

3.1.1 Method A: simplified method

Method A is the simplified approach which is designed to be applied mainly on residential buildings and small non-residential buildings. The method includes a checklist with simplified services limited to 27. Even though this method allows (online) self-assessment, a formal certification cannot be issued using this method.

According to the final technical report of DG Energy, the scope of the simplified method includes the following:

- The method should be applied based on the Simplified/limited services catalogue using a check-list approach;
- Possibility of free of charge (online) assessment to be used by users (e.g. single-family homeowners) and accessed by the public;
- The method should allow the fast assessment of the SRI; within one hour for a single-family home;
- The method should be restricted to < 500m² net usable floor area of dwellings and small non-residential buildings;

- This method targets to increase awareness of building smartness and deliver initial feedback concerning the current state of a building, e.g. in preparation for upgrades or renovations.

3.1.2 Method B: detailed method

Method B is the detailed SRI assessment designed to be applied mainly on non-residential buildings (new constructions, retrofits and existing buildings) and remains the default method of SRI Assessment. The method would allow the SRI assessment to be based on the detailed services list and it should be conducted by third-party qualified experts. According to the Article 3 of the (EU) 2020/2156 published on 4th October 2020, EU member states should decide the requirements of the qualified experts for the SRI certification. Currently, method B is the only SRI method which offers the possibility of issuing a formal certificate.

According to the final technical report of DG Energy, the scope of the detailed method includes the following:

- The method should be applied based on the detailed services catalogue using a check-list approach
- The method requires an on-site inspection by qualified/accredited experts for the recording of technical building systems and their functionalities;
- The assessment is required to be conducted by a third-party qualified expert (as defined by individual MS legislation) or by self-assessment executed by a non-independent expert, e.g. facility manager;
- assessment time is extended from ½ day to 1 day, compared to the simplified method, depending on the building size and complexity of building services;
- Applicable to larger non-residential and residential buildings (net surface floor area ≥500m²);
- Target to bring awareness to the smartness of buildings based on an official assessment which will be compared to its maximum potential smartness.

3.1.3 Method C: in-use smart building performance

Method C has been introduced by the technical studies of SRI, however, it remains a potential future evolution/possibility of the SRI assessment. This method promotes a metered/measured method approach where TBS/BACS installed at building level will be capable of self-reporting functionality levels, thereby supporting methods A and B. Eventually, Method C exceeds theoretical retrieval of building services functionalities and approaches the actual performance of in-use buildings.

The in-use performance SRI has been supported by multiple organisations during the stakeholder's consultations during SRI development. Members of topical Group C discussed potential elements related to the constitution of a data-driven SRI assessment. However, the objective of this method is different from the other methods; "Smart ready assessment" towards the assessment of actual building performance is the shift of the SRI into a quantitative indicator which will become a necessary guide to building investments and upgrades. The evolution of the SRI into a representative quantitative measure of the performance of buildings, as well as performance improvement is expected to have a positive effect on the EPBD goals.

3.2 Smart ready services domains and functionality levels

In establishing the SRI methodology, three technical studies prepared by Vito, upon the request of the European Union, were consulted [2]. These studies developed an assessment scheme for a separate, brief and detailed classification of the smartness rate of buildings. The rating scheme assesses 9 domains as follows:

1. Heating
2. Cooling
3. Domestic hot water
4. Ventilation
5. Lighting
6. Dynamic building envelope
7. Electricity
8. Electric vehicle charging
9. Monitoring and control

- **Heating and cooling systems** are assessed based on 10 individual elements, 4 of which are also evaluated in the simplified scheme. The heat emission units are rated according to the units' control. The smartness scales consider different levels of control including central, individual or even occupancy detection control, the latter being the smartest level. Heat generators' intelligence is defined according to the variance in temperature control, which may depend on the ambient temperature or on the heating load. The fluid distribution network is assessed in accordance with the use of compensation and demand-based control. The functionality levels of the heat storage assess the availability of storage vessels and the capability of heat storage control with the use of external signals. As far as the distribution pumps are concerned, their functionality levels depend on the pump speed control. Similar functionality levels are also applied for heat pump units. Other building services which are included in the heating system rating refer to the performance of thermal activated building systems (TABS), the sequencing of the performance of different heat generators and the interaction of the heating system with the grid. Reporting the performance of heating systems is similar in several domains and considers real-time and historical data logging, as well as the preventive maintenance ability of the systems. Similar services are also assessed for cooling systems. An additional element considered in cooling systems is the interlock of heating and cooling in the same thermal zone ("no interlock", "partial", "total interlock avoiding simultaneous heating and cooling");

- The assessment of **domestic hot water** is based on 5 categories. This domain is assessed according to the energy source for heating, namely the thermal boiler, electric heating with element, or heat pump and solar heating. For each of these services, the functionality levels range from on/off, to demand and grid-oriented supply. Sequencing and reporting are also considered as performance criteria;
- **Lighting systems** are rated according to the level of control they offer (on/off, dimmable, occupancy sensors) and the interaction between natural lighting and artificial lighting in a space;
- **Ventilation systems** are assessed based on 6 categories, according to air flow, air temperature, heat recovery, free cooling and indoor air quality (IAQ). The air flow control at the room level is rated according to its control functions. The air flow control ranges from on/off to automatic control. The prevention of overheating is defined according to sensors in air exhaust or multiple temperature sensors. The air temperature control at the air handling unit level is rated based on the control of the set temperature of ventilation. Free cooling using the mechanical ventilation system is assessed based on free and night cooling and H, x-directed control. Reporting information on IAQ is considered an additional important parameter for controlled ventilation systems;
- **Dynamic building envelope** domain scales its ratings according to the availability of manual or automatic control of window shading systems and the availability of interactive controls with HVAC and predictive blind control;
- **Electricity** is assessed based on 7 criteria, one of which is electricity storage where the type of stored technology energy is considered. Scheduled or automated management of locally generated electricity for self-consumption based on renewable energy availability and predicted energy needs defines optimal levels. Similarly, the combined heat and power plant (CHP) is rated against scheduled management and RES availability, providing various levels of control. The support of grid operation modes criterion defines the variance in automated management and supply. Information such as real-time feedback, historical data, performance data and values for benchmarking are reported on local electricity generation, electricity consumption and energy storage;

- Assessing **electric vehicle charging** considers charging capacity allocating functionality levels according to the percentage of parking spaces fitted with charging points. Additionally, one-way controlled charging, uncontrolled charging, EV charging information and connectivity are criteria used to assess EV charging grid balancing.
- For **monitoring and control**, assessment is based on 8 categories. The primary examined factors are the run-time management of HVAC systems and the ability to detect faults in the technical systems of buildings. Smart grid integration and interoperability with DSM, central reporting and occupancy detection are also rated.

Figure 5: SRI catalogue domains

3.3 Impact Criteria

Each service listed in the smart ready service catalogue translates to various impacts with regards to the three key functionalities described in the EPBD Recast (2018/844): the energy performance of the building, its users and the energy grid. The first technical study, which was concluded in August 2018, developed 8 impact criteria which covered the pre-defined pillars presented in the EPBD Recast (2018/844). However, the analysis conducted during the second technical study revealed a clash between “energy flexibility and storage” and “self-generation”. The second technical study concluded that “self-generation” criterion should be omitted, since its impacts are covered by the impact criterion “energy flexibility and storage” and concluded with 7 impact criteria as presented in Figure 6.

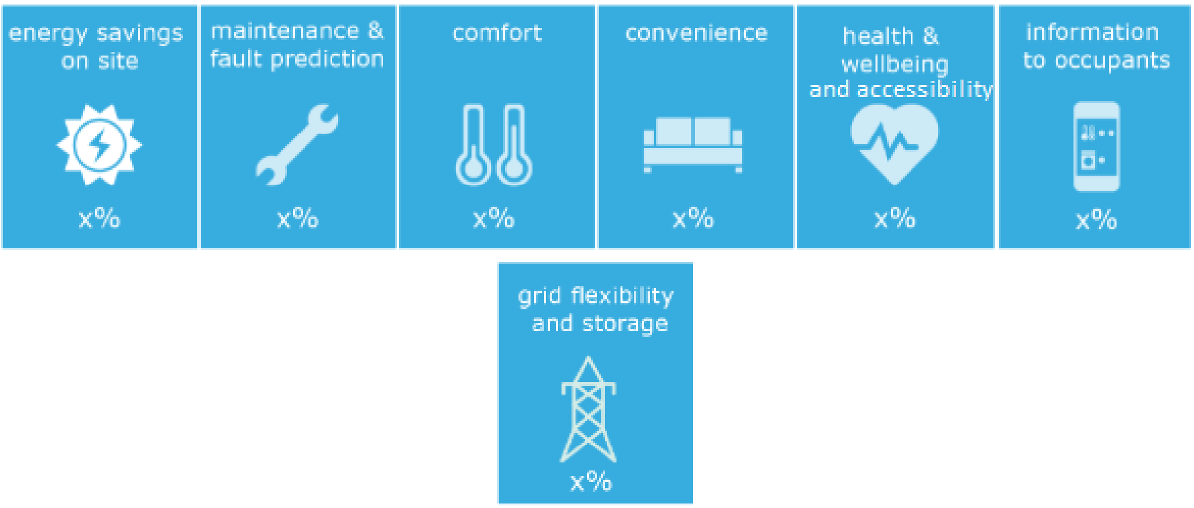


Figure 6: SRI impact criteria

Energy Efficiency

''Energy efficiency'' category includes the effects of the smart ready services on energy savings in the building. These savings do not take into consideration all sources of energy performance of building, but contributions made by SRTs and their functionality options, e.g. energy savings as a consequence of improved control of room temperature.

Energy Flexibility and Storage

''Energy Flexibility and Storage'' category is related to the bearing of smart ready services on flexibility potential of the building with regards to energy. Beyond electricity grids, this impact category also includes flexibility to interact with district heating and cooling grids.

Comfort

''Comfort'' category is related to how the smart ready services influence the comfort of the occupants/building users. The category includes conscious and unconscious perception of human comfort including the aspects of indoor comfort conditions, thermal comfort, acoustic and visual comfort.

Convenience

''Convenience'' impact category considers the effects of the smart ready services on the convenience delivered to building users, i.e. the extent to which services "make life easier" for the user, e.g. through services that require fewer or zero manual interactions.

Health, Well-being and accessibility

''Health and Well-being'' impact category relates to the effects of the smart ready services on the health and well-being of occupants/users, i.e. intelligent building control systems can improve indoor air quality compared to manual controls, hence improve occupants' health and well-being.

Maintenance and Fault Prediction

''Maintenance and Fault Prediction'' impact category relates to the bearing of the smart ready services on the improvement of maintenance and operation of TBSs. The improvement of this category may also influence the energy efficiency of the TBSs by identifying and diagnosing inefficient operation.

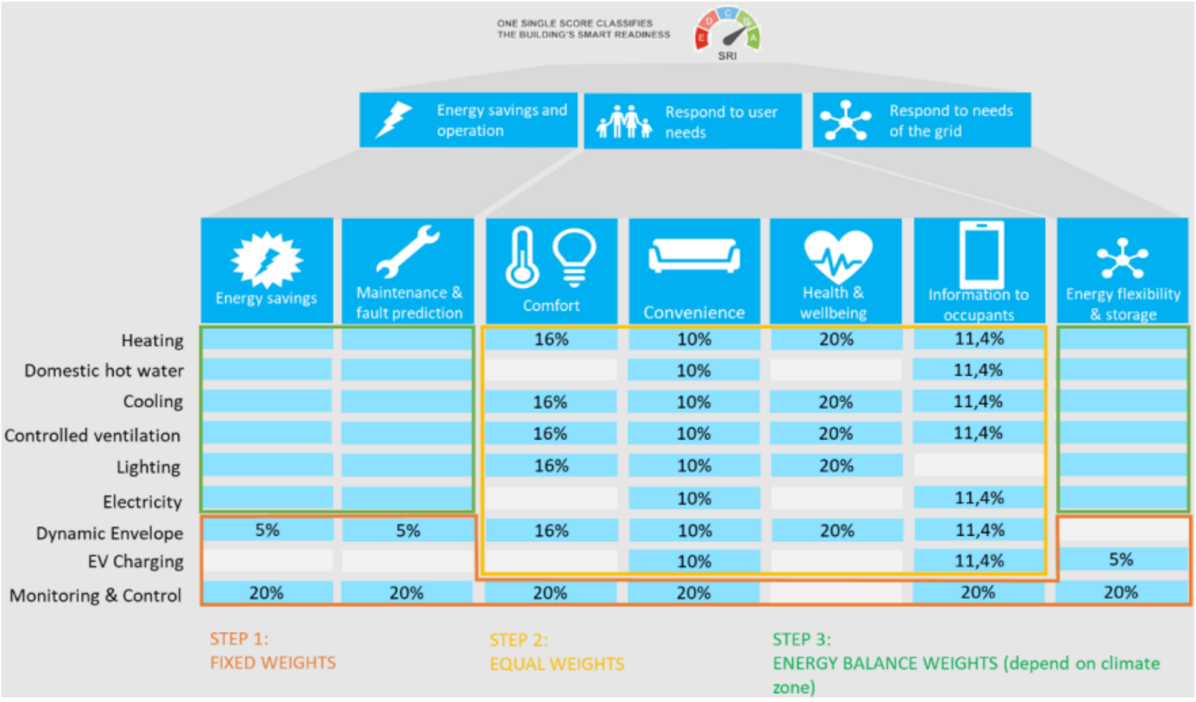
Information to Occupants

''Information to Occupants'' impact category relates to the information delivery by the smart ready services regarding building operation and building technical systems to the occupants/users.

3.4 Weighting Factors

In the multi-criteria assessment, weighting factors are applied to domains and impact criteria to indicate their relative importance in an aggregated impact score. An aggregated SRI score reflects the overall smartness level of a building; on the other hand, sub-scores distinguish scores for specific domains and impact categories. The methodology ascribes three techniques to derive the domain and service level weighting factors, i.e. equal weighting, predicted impact approach and energy balance weighting factors.

Domain weighting factors will be based primarily on an energy balance approach to ensure that regional differences are well accounted for, e.g. by applying weights from an energy balance, the heating domain's influence on scoring would increase significantly in northern Europe, whilst the relative significance of the cooling domain would increase in southern Europe. The proposed methodology has the option to input available building-specific energy balance data, e.g. extracted from an EPC calculation. Alternatively, where energy balances cannot be applied to domains, e.g. monitoring and control, and dynamic building envelope, the weighting factor is determined according to the projected impact of that domain. For individual impact criteria default weighting factors are distinguished by climate zone and the type of building to which they are applied, i.e. residential or non-residential. Equal weights for the three key smartness functionalities are allocated to balance out the different weights of individual impact criteria.



	Energy savings	Maintenance & fault prediction	Comfort	Convenience	Health & wellbeing	Information to occupants	Energy flexibility & storage
Heating			16%	10%	20%	11,4%	
Domestic hot water				10%		11,4%	
Cooling			16%	10%	20%	11,4%	
Controlled ventilation			16%	10%	20%	11,4%	
Lighting			16%	10%	20%		
Electricity				10%		11,4%	
Dynamic Envelope	5%	5%	16%	10%	20%	11,4%	
EV Charging				10%		11,4%	5%
Monitoring & Control	20%	20%	20%	20%		20%	20%

Figure 7: Overview of the weighting scheme.

Figure 7 illustrates the schedule of weights assigned to impact criteria depending on the domain. Fixed weights are defined for every impact criterion for the monitoring and control domain, shown in the figure as Step 1. Step 2 entails the allocation of calculated equal weightings to impact criteria depending on relevant domains. Finally, in Step 3 energy balance weights are assigned to the eligible impact criteria energy savings, maintenance and fault prediction, and energy flexibility and storage for the impact criteria energy efficiency; maintenance and prediction; and energy flexibility and storage using the climate zone's energy balance.

3.5 Structure of Smart Ready Services catalogues

The second technical study considered how the service catalogues for SRI calculation methods A and B could be streamlined to deliver comparable ratings across buildings and keep assessment costs low and assessment times short. The smart ready service catalogues are a part of the SRI framework and contain building services that produce impacts relative to the three key functionalities described in the EPBD recast; the energy performance of a building, building users and the energy grid.

The smart ready service catalogue for method A is structured in a way that allows an assessment to be completed in a timely manner, (within 1 hour) for a single-family residence and thus has a reduced number of 27 services. Service catalogue A uses simplified and user-friendly service definitions to facilitate self-assessment by non-expert building users. A validated SRI product database has been proposed in the future to store product functionality levels as designed by the manufacturer to reinforce the reliability of a simplified catalogue. Method B utilizes a detailed catalogue in order to allow a detailed, formal assessment of building smartness by a qualified expert. Each service catalogue defines the triage process assessors will use to assign a maximum nominal impact score based on site-specific attributes of the building that may render some of the smart services included in the catalogue inapplicable or undesirable. This reduces the maximum attainable score and ensures replicable SRI assessments with minimal human error.

In light of the rapidly evolving pace of ICT advancements and related market developments, updates to the smart ready service catalogues must be made annually to reflect the current state-of-the-art in a technology neutral manner, to match impact scores to functionalities correctly and to ensure that the catalogue lists the most appropriate services. The addition or removal of domains, services or smartness levels that adapt the SRI methodology closer to being a quantitative building performance indicator, i.e. method C, is the basis of catalogue review. Proposed changes are further examined to ensure that the disruptions they would cause to the implementation and communication of the scheme are justified. Reduced comparability between assessments adversely affects the understanding of the SRI scoring and could hinder SRT and service providers from leveraging market offers within the framework. On the other hand, insufficient updates would make the scheme unresponsive to market and technology advancements. Changes therefore require a multi-disciplinary appraisal.

The SRI service catalogues feature services that are structured within 9 domains: heating, cooling, domestic hot water, controlled ventilation, lighting, dynamic building envelope, electricity, EV charging and monitoring and control. 2 to 5 functionality levels are defined for each of the services. A higher functionality level corresponds to a “smarter” implementation of the service with greater benefits for building occupants or grid response compared to services with lower functionality levels. Quantitatively, functionality levels are not easily comparable between services because they are expressed as ordinal numbers.

4 Analysis of SRI in Industry Foundation Classes Schema (IFC)

4.1 Analysis Context

One of the main purposes of D^2EPC, is to deliver an indicator enriched certificate, including aspects beyond energy, which are related to the sustainability of building units. One of this class of indicators concerns the smart readiness indicators. On top of that, the project aims to implement all its assessment procedures within BIM environment. To this end, in order to define and describe the BIM models, D^2EPC will utilize the vendor-neutral IFC schema, developed by *Building Smart International*[1] for sharing information through various software as well as possible data through EPC asset rating, in accordance to the European EN standards series ISO 52000:2017. For the case of EPC input data, the current methodology of asset rating calculation does not include sufficient information for the extraction of SRI indicators. The asset rating in accordance to the EN52000 barely employs building automation and control related information. However, the asset BIM-based model includes more than 70% of data required for energy analysis of building [19]. D^2EPC envisions to utilize any SRI related data to issue the next generation EPCs based on IFC-based BIM models.

The current SRI methodologies as described in section 3.1, are calculated based on a ''checklist'' approach which includes the documentation of asset data concerning the operation of the building systems. This section aims to analyse the ''completeness'' of IFC4 BIM-based models to express BACS features, and the ability to share details concerning the configuration and setup of the automation dimension of a building as in the case of SRI. In order to enable the calculation of the SRI within D^2EPC

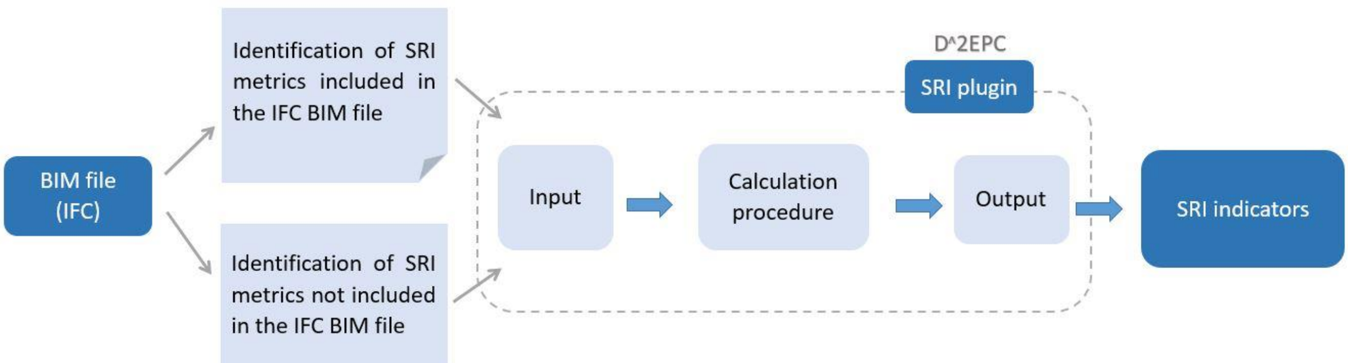


Figure 8 Analysis context diagram

[1] https://www.buildingsmart.org/

solution, the SRI input data (metrics) should be identified and evaluated against their completeness within IFC domains and entities. The methodology followed for this analysis is shown in Figure 8:

The latest version of IFC4, includes timely definitions related to the representation of building control systems where new entities have been added or expanded in the Buildings Control Domain (IfcBuildingControlDomain) to capture information on pertinent elements (sensors, controllers and actuators) using the IfcSensor, IfcController and IfcActuator entities. The concepts of building automation, control, instrumentation and alarm are defined to support ideas including types and occurrences of: actuator, alarm, controller, sensor, flow instrument, unitary control element. Components that physically perform the control action such as valves and dampers are subtypes of distribution flow elements located within the IfcHvacDomain and IfcElectricalDomain schemas. In order to assess if the new IFC4 schema (especially IfcBuildingControlDomain) adequately cover all the aspects of SRI Metrics, the various parts of BACS should be identified.

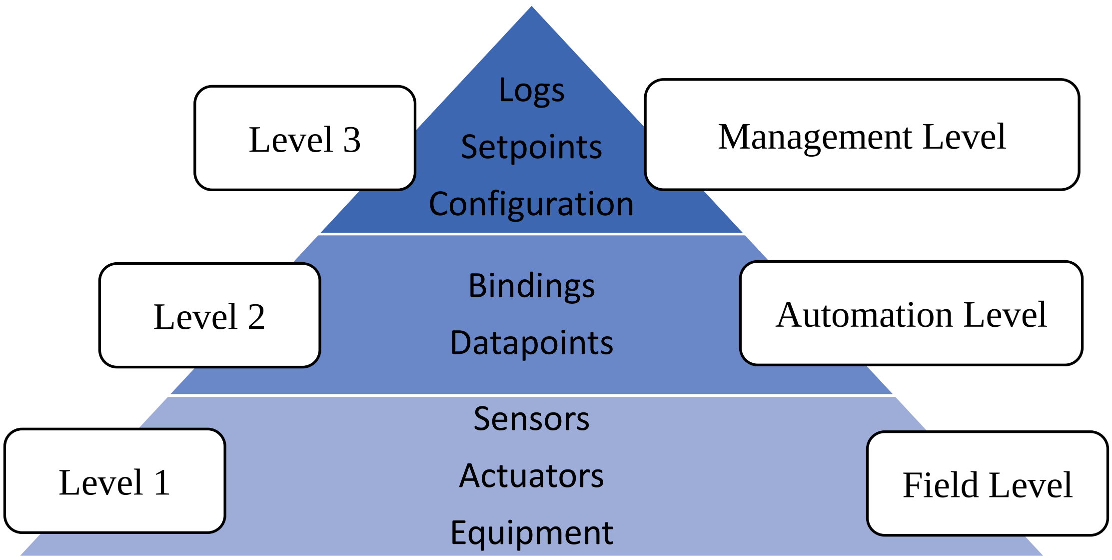


Figure 9 Staging of hierarchical levels of BACS

According to the current literature [20][21][22][23], BACS concepts can be organized according to three levels: the field level, the automation level, and the management level. The hierarchical levels of BACS are shown in Figure 9. Each level represents different information requirements and processes depending on the complexity of the BACS. IFC schema was analysed for its ''completeness'' to define SRI BACS features in accordance to the different hierarchical levels. ''Completeness'' assesses the adequacy of an information model to express the features of a specific BACS structure. In this case, a given information model covers a particular feature if it has adequate data structures or constructs in its specification to represent that feature.

The completeness of the SRI to define specific SRI functions was based on a three-level scale:

1. **Complete:** Physical objects, relationships and configurations can be expressed fully by the information model. In this case, all three Levels of BACS hierarchy can be defined.
2. **Partial:** Physical objects can be expressed, but relationships and/or specific functions of the required objects cannot be defined.
3. **Not Supported:** Physical objects, relationships and configurations cannot be defined in the IFC schema and in the information model.

4.2 SRI General Screening Information

The SRI calculation methodology initiates with some screening questions including general information such as ''assessor Information'' as well as other general building information data which enable specific calculation options depending on the building technical systems and other data. The data required for the specification of the screening questions as well as their expected source within D^2EPC solution, are presented in Table 1 - Table 8. In some cases of data extracted from the D^2EPC repository, Minimum modelling Requirements (BIM IFC) should be applied for the definition of building systems. The SRI predefined options are already specified by the SRI methodology as a drop down list. In some cases, each predefine option activates specific background calculation data, (i.e. the selection of building location related specific to the weightings and climate data per region – see Annex I)

Table 1. SRI screening - General Building Information

No	Required data	Source	SRI Predefined options	Dependence
Assessor Information				
1	Name	User specified	Free text	None
2	Organization	User specified	Free text	None
3	Contact Information	User specified	Free text	None
General Building Information				
4	Building Type	User specified	• Residential • Non-residential	None
5	Building Usage	BIM-digital twin/Repository	Residential: • Single family house • Small multi family house • Large multi family house • Other Non-Residential: • Office • Educational • Health care • Other	4
6	Location	Repository	Select country	None
7	Climatic Zone	Repository	SRI Domain weighting tables	6
8	Net floor area of the building	Repository	-	None
9	Year of construction	User specified	• < 1960 • 1960 – 1990 • 1990 – 2010 • >2010 • Not yet constructed	None
10	Building state	User specified	• Renovated • Original	None
11	Address	User specified	Free text	None
12	Preferred weightings	User specified	• Default • User-defined	None

Table 2. SRI Screening - Heating

No	Required data	Source	Minimum modelling Requirements (BIM IFC)	SRI Predefined options	Dependence
13	Presence of Heating system	Presence of at least one item of Minimum requirements for heating (repository) or *District Heating: User specified	IfcUnitaryEquipment (SPLITSYSTEM, AIRCONDITIONINGUNIT, ROOFTOPUNIT) IfcBoiler, IfcSpaceHeater (RADIATOR), IfcCoil IfcElectricAppliance (FREESTANDINGELECTRICHEATER)	• Heating system present • No Heating system present	None
14	Emission Type	Read of Minimum requirements for heating (repository) TABS (Thermaly Activated building system): User specified	**TABS**: N/A **Other hydronic systems (e.g. radiators):** IfcBoiler, IfcSpaceHeater (RADIATOR), IfcCoil **Non-hydronic systems (e.g all air):** IfcUnitaryEquipment (SPLITSYSTEM, AIRCONDITIONINGUNIT, ROOFTOPUNIT)	• TABS (Thermally Activated building system) • Other hydronic systems (e.g. radiators) • Non-hydronic systems (e.g. all air)	13
15	Production Type	Read of Minimum requirements for heating (repository)	**District Heating**: N/A **Heat Pump**: IfcUnitaryEquipment (SPLITSYSTEM) **Central Heating – Combustion**: IfcBoiler, IfcSpaceHeater (RADIATOR), IfcCoil Decentralized heating: IfcElectricAppliance (FREESTANDINGELECTRIC HEATER)	• District Hreating • Heat Pump • Central Heating – combustion • Central Heating – other • Decentralized heating (e.g. stoves)	13
16	Thermal Energy storage	User specified	N/A	• Storage Present • No storage Present	13
17	Multiple generators	User specified	N/A	• Single generator • Multiple generators	13

Table 3. SRI Screening - Domestic Hot Water

No	Required data	Source	Minimum modelling Requirements (BIM IFC)	SRI Predefined options	Dependence
18	Presence of Domestic Hot water	Presence of at least one item of Minimum modelling requirements for DHW or direct or integrated Heat pump: User specified	IfcBoiler	• DHW system present • No DHW system present	None
19	Production Type	Read of Minimum requirements for DHW (repository)	Non Electric: IfcBoiler Electric: N/A	• Non-Electric • Electric (direct or integrated Heat pump)	18
20	Storage Present	User Specified	N/A	• Storage present • Storage non present	18
21	Solar Collector	Read of Minimum requirements for DHW (repository)	IfcSolarDevice (SOLARCOLLECTOR, SOLARPANEL)	• Solar Collector present • No solar Collector present	18
22	Multiple generators	User specified	N/A	• Single generator • Multiple generators	18

Table 4. SRI Screening - Cooling

No	Required data	Source	Minimum modelling Requirements (BIM IFC)	SRI Predefined options	Dependence
23	Presence of cooling system	Presence of at least one item of Minimum modelling requirements for cooling (repository)	IfcUnitaryEquipment (AIRCONDITIONINGUNIT, SPLITSYSTEM, DEHUMIDIFIER, AIRHANDLER) IfcChiller IfcEvaporativeCooler	• Cooling system present • No cooling system present	None
24	Emission Type	Read of Minimum requirements for cooling (repository)	• **TABS (Thermally Activated**: N/A • **Other hydronic system**: IfcChiller • **Non-hydronic system**: IfcUnitaryEquipment IfcEvaporativeCooler	• TABS (Thermally Activated Building System) • Other hydronic system (e.g. radiators) • Non-hydronic system (e.g all air)	23
25	Thermal Energy storage	User Specified - calculation engine	N/A	• Thermal Energy Storage present • No Thermal Energy Storage present	23
26	Multiple generators	User specified - calculation engine	N/A	• Single generator • Multiple generators	23

Table 5. SRI Screening - Controlled Ventilation

No	Required data	Source	Minimum modelling Requirement (BIM IFC)	SRI Predefined options	Dependence
27	Presence of controlled ventilation system	Presence of at least one item of Minimum requirements for Controlled Ventilation or Controlled Natural Ventilation: User defined	IfcUnitaryEquipment (AIRHANDLER, ROOFTOPUNIT) For Controlled Natural Ventilation: N/A	• Controlled Ventilation system present • No Controlled Ventilation system present	None
28	System type	Read of Minimum requirements for controlled ventilation (repository)		• Mechanical Ventilation • Controlled Natural Ventilation	27
29	Heat Recovery	Minimum modelling requirement	IfcAirToAirHeatRecovery	• Heat Recovery • No heat Recovery	27
30	Space Heating	User specified - calculation engine	N/A	• Used for Space Heating • Not used for Space Heating	27

Table 6. SRI Screening - Dynamic Envelope

No	Required data	Source	Minimum modelling Requirement (BIM IFC)	SRI Predefined options	Dependence
31	Presence of dynamic Envelope system	Minimum modelling requirement	IfcShadingDevice	• Dynamic Envelope system present • No dynamic Envelope system present	None

Table 7. SRI Screening - ELECTRICITY: renewables & storage Screening

No	Required data	Source	Minimum modelling Requirement (BIM IFC)	SRI Predefined options	Dependence
32	Presence of Renewables	Presence of at least one item of Minimum requirements for electricity renewables & storage Other Renewable sources: User specified Other renewables: User specified in calculation engine	IfcSolarDevice (SOLARCOLLECTOR, SOLARPANEL)	• Presence of Renewables and storage • No presence of Renewables and storage	None
33	On-site renewable electricity generation	Presence of at least one item of Minimum requirements for electricity renewables & storage	IfcSolarDevice (SOLARCOLLECTOR, SOLARPANEL)	• On-site renewable	32

		Other renewables: User specified in calculation engine		electricity generation • No on-site renewable electricity generation	
34	Storage of on-site generated renewable electricity	BIM-digital twin/Repository	IfcElectricFlowStorageDevice	• Storage present • No storage present	32
35	CHP (Combined Heat and Power)	BIM-digital twin/Repository	IfcElectricGenerator (CHP)	• CHP • No CHP	32
36	Mandatory for new constructions in country of residence	User specified – calculation engine	N/A	• Yes, is mandatory • No, is not mandatory	If 32 option • No presence of Renewables and storage applies

Table 8. SRI Screening - Electric Vehicle Charging Screening

No	Required data	Source	Minimum modelling Requirement (BIM IFC)	SRI Predefined options	Dependence
36	Presence of on-site Electric Vehicle parking spots	User specified – calculation engine	N/A	• On-site parking • No on-site parking	None
37	Presence of Vehicle charging on-site parking spots	User specified – calculation engine	N/A	• EV charging present • EV charging not present	36
38	Mandatory for new constructions in the country of residence	User specified – calculation engine	N/A	• Yes, is mandatory • No, is not mandatory	If 36 option • No on-site parking

The screening questions of SRI have been analysed in terms of their coverage in the IFC4 schema. The entities covered by IFC were presented as ‘’minimum modelling requirements’’ in order to enable the triage process of the SRI. The screening SRI data not sufficiently supported by the IFC schema, should be ‘’user-specified’’ within the calculation engine. It was observed that IFC4 schema can define a wide range of mechanical systems and peripheral technical equipment.

4.2.1 Heating

Indicator Name	Description Indicator	Calculation Procedure	IFC coverage	Input Data Metric	Relation with IFC entity	Reference to IFC schema contents	Entity attribute metadata: Attribute name	Entity attribute metadata: Attribute value Datatype
Heating-1a	**Heat Emission Control**	**Level 0** No automatic control	complete	Valves/switches/ controls (0)	IfcFlowController IfcSwitchingDevice	6.2.3.12 7.4.3.41	HE-1a	Integers, [0]
		Level 1 Central automatic control (e.g. central thermostat)	complete	Central thermostat/central control unit (1)	IfcUnitaryControlElement	7.2.3.11		Integers, [1]
		Level 2 Individual room control (e.g. thermostatic valves, or electronic controller)	partial	thermostatic valves, or electronic control units (2)	IfcActuator	7.2.3.1		Integers, [2]
		Level 3 Individual room control with communication between controllers and to BACS	partial	Control element depending on heat emission type (2,3,4) controllers (3,4)	IfcFlowController IfcController	6.2.3.12 7.2.3.5		Integers, [2,3,4] Integers, [3,4]
		Level 4 Individual room control with communication and occupancy detection	partial	Temperature sensor (3,4) Occupancy sensors (4)	IfcSensorType	7.2.3.9		Integers, [3,4]
Heating-1b	**Emission control for TABS (heating mode)**	**Level 0** No automatic control	complete	Valve or other manual controls (0)	IfcFlowController IfcSwitchingDevice	6.2.3.12 7.4.3.41	HE-1b	Integers, [0]
		Level 1 Central automatic control	partial	Supply water temperature sensor (1,2,3)	IfcSensorType	7.2.3.9		Integers, [1,2,3]
		Level 2 Advanced central automatic control	partial	Outside air temperature sensor, (1,2,3)				Integers, [1,2,3]

				Room temperature sensor (2,3)				Integers, [2,3]
		Level 3 Advanced central automatic control with intermittent operation and/or room temperature feedback control	partial	Supply water valve (2,3)	IfcValve	7.5.3.63		Integers, [2,3]
Heating-1c	**Control of distribution fluid temperature (supply or return air flow or water flow)-Similar function can be applied to the control of direct electric heating networks**	**Level 0** No automatic control	complete	Default equipment (0)	IfcUnitaryEquipment	7.5.3.61	HE-1c	Integers, [0,1,2]
		Level 1 Outside temperature compensated control	partial	Outside air temperature sensor, water temperature sensor (1)	IfcSensorType	7.2.3.9		Integers, [1]
				Flow sensor (2)				Integers, [2]
		Level 2 Demand based control	partial	Flow control unit (1,2)	IfcFlowController	6.2.3.12		Integers, [1,2]
				Demand switches/controllers (1,2)	IfcController	7.2.3.5		Integers, [2]
Heating-1d	**Control of distribution pumps in networks**	**Level 0** No automatic control	complete	Default equipment (0)	IfcPumpType	7.5.3.54	HE-1d	Integers, [0,1,2,3,4]
		Level 1 On off control	Partial	Supply and return water temperature (1) Pressure sensors (4)	IfcSensorType	7.2.3.9		Integers, [1]
		Level 2 Multi-Stage control	Not supported	Pump with electronic staging device (2)	N/A	-		Integers, [2]
		Level 3 Variable speed pump control (pump unit (internal) estimations)			N/A	-		Integers, [3,4]
		Level 4 Variable speed pump control (external demand signal)	Not supported	Variable speed drive pump (3,4)	N/A	-		
Heating-1f	**Thermal Energy Storage (TES) for building heating (excluding TABS)**	**Level 0** Continuous storage operation **Level 1** Time-scheduled storage operation **Level 2** Load prediction-based storage operation	Not supported	--			HE-1f	

		Level 3 Heat storage capable of flexible control through grid signals (e.g. DSM).						
Heating-2a	**Heat generator control (all except heat pumps)**	**Level 0** Constant temperature control	complete	Outdoor temperature sensor (0)	IfcSensorType	7.2.3.9	HE-2a	Integers, [0]
		Level 1 Variable temperature control depending on outdoor temperature	Partial	Outdoor temperature sensor, flow temperature sensor, flow sensors (1, 2) *possible variant: temperature sensor included in generator (1)*				Integers, [1,2] Integers, [*1]
		Level 2 Variable temperature control depending on the load (e.g. depending on supply water temperature set point)	Partial	Communication to distribution/heat consumer (2)	N/A	-		Integers, [2]
Heating-2b	**Heat generator control (for heat pumps)**	**Level 0** On/Off-control of the heat generator	complete	Single-stage heat generator/default heat generator equipment (0)	IfcUnitaryEquipmentType	7.5.3.62	HE-2b	Integers, [0,1,2,3]
		Level 1 Multi-stage control of heat generator capacity depending on the load or demand (e.g. on/off of several compressors)	Partial	Multi-stage heat generator (1)	N/A	-		Integers, [1]
		Level 2 Variable control of heat generator capacity depending on the load or demand (e.g. hot gas bypass, inverter frequency control)	Partial	Variable-control heat generator (2,3)	N/A	-		Integers, [2,3]
		Level 3 Variable control of heat generator capacity depending	Partial	By pass valve, inverter frequency control (2,3)	IfcFlowController	6.2.3.12		Integers, [2,3]

		on the load AND external signals from grid		Communication from grid signals (3)	N/A	-		Integers, [3]
Heating-2d	**Sequencing in case of different heat generators**	**Level 0** Priorities only based on running time **Level 1** Control according to fixed priority list: e.g. based on rated energy efficiency **Level 2** Control according to dynamic priority list (based on current energy efficiency, carbon emissions and capacity of generators, e.g. solar, geothermal heat, cogeneration plant, fossil fuels) **Level 3** Control according to dynamic priority list (based on current AND predicted load, energy efficiency, carbon emissions and capacity of generators) **Level 4** Control according to dynamic priority list (based on current AND predicted load, energy efficiency, carbon emissions, capacity of generators AND external signals from grid)	**Not supported**		--		HE-2d	Integers, [0,1,2,3,4]
Heating-3	**Report information regarding HEATING system performance**	**Level 0** None **Level 1** Central or remote reporting of current performance KPIs (e.g. temperature, submetering energy usage) **Level 2** Central or remote reporting of current	**Not supported**		---		HE-3	Integers, [0,1,2,3,4]

		performance KPIs and historical data **Level 3** Central or remote reporting of performance evaluation including forecasting and/or benchmarking **Level 4** Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection				
Heating-4	**Flexibility and grid interaction**	**Level 0** No automatic control **Level 1** Scheduled operation of heating system **Level 2** Self-learning optimal control of the heating system **Level 3** Heating system capable of flexible control through grid signals (e.g. DSM) **Level 4** Optimized control of heating system based on local predictions and grid signals (e.g. through model predictive control)	**Not supported**	---	HE-4	Integers, [0,1,2,3,4]

4.2.2 Cooling

Indicator Name	Description Indicator	Calculation Procedure	IFC coverage	Input Data	Relation with IFC entity	Reference to IFC schema contents	Entity attribute metadata	
							Attribute Name	Attribute Value / Datatype
Cooling -1a	**Cooling Emission Control**	**Level 0** No automatic control	**complete**	Valve/ switch or electronic control (0)	IfcFlowController	6.2.3.12	COL-1a	Integers, [0]
		Level 1 Central automatic control	**complete**	Central control unit (1)	IfcUnitaryControlElement	7.2.3.11		Integers, [1]
		Level 2 Individual room control	**Partial**	Thermostatic valves or electronic control units (2)	IfcActuator	7.2.3.1		Integers, [2]
		Level 3 Individual room control with communication between controllers and to BACS	**Partial**	Room control units and communication, (3,4)	IfcController	7.2.3.5		Integers, [3,4]
		Level 4 Individual room control with communication and occupancy detection	**Partial**	Occupancy sensor (4)	IfcSensorType	7.2.3.9		Integers, [4]
Cooling – 1b	**Emission control for TABS (cooling mode)**	**Level 0** No automatic control	**complete**	Manual control (e.g. valve) (0)	IfcFlowController	6.2.3.12	COL-1b	Integers, [0]
		Level 1 Central automatic control	**complete**	Outside air temperature sensor, water temperature sensor (1)				Integers, [1]
		Level 2 Advanced central automatic control	**Partial**	Outside air temperature sensor, room setpoint device (2,3)	IfcSensorType	7.2.3.9		Integers, [2,3]
		Level 3 Advanced central automatic control with intermittent operation and/or room temperature feedback control	**Partial**	Room temperature sensor (3)				Integers, [3]
				Room setpoint device (2,3)	IfcUnitaryControlElement	7.2.3.11		Integers, [2,3]
				Supply water valve (2,3)	IfcValve	7.5.3.63		Integers, [2,3]

Cooling -1c	Control of distribution network chilled water temperature (supply or return)	**Level 0** Constant temperature control **Level 1** Outside temperature compensated control **Level 2** Demand based control	**complete** **Partial** **Partial**	Presence of distribution network (0) Flow temperature sensor, outside temperature sensor (1) Temperature sensor and communication (2) Control unit (1,2)	IfcDistributionElement IfcSensorType IfcUnitaryControlElement	5.4.3.8 7.2.3.9 7.2.3.11	COL-1c	Integers, [0] Integers, [1,2]
Cooling -1d	Control of distribution pumps in networks	**Level 0** No automatic control **Level 1** on/off control **Level 2** Multi-Stage control **Level 3** Variable speed pump control (pump unit (internal) estimations) **Level 4** Variable speed pump control (external demand signal)	**complete** **complete** **Partial** **Partial** **Partial**	Pump (0) Flow temperature sensor, return temperature sensor (1) Pressure sensors (3,4) Multi-speed pump(e.g. multi-stage, electrical/electronic staging equipment) (2) Variable speed pump drive (3,4)	IfcPump IfcSensorType N/A	7.5.3.53 7.2.3.9 7.5.3.53	COL-1d	Integers, [0] Integers, [1] Integers, [3,4] Integers, [2] Integers, [3,4]
Cooling -1f	Interlock: avoiding simultaneous heating and cooling in the same room	**Level 0** No interlock | **Level 1** Partial interlock (minimizing risk of simultaneous heating and cooling e.g. by sliding setpoints) **Level 2** Total interlock (control system ensures no simultaneous heating and cooling can take place)	**complete** **Not supported**	No equipment (0) Communication/connection between heating control, cooling control, and air temperature control (1,2)	No equipment --	-	COL-1f	Integers, [0] Integers, [1,2]
Cooling -1g	Control of Thermal	**Level 0** Continuous storage operation	**Not supported**	Presence of thermal energy storage passive	--		COL-1g	Integers, [0.1,2,3]

	Energy Storage (TES) operation	**Level 1** Time-scheduled storage operation **Level 2** Load prediction-based storage operation **Level 3** Cold storage capable of flexible control through grid signals (e.g. DSM)		systems in building envelopes, phase change materials (PCM) in active systems, sorption systems, and seasonal storage				
Cooling-2a	**Generator control for cooling**	**Level 0** On/off-control of cooling production **Level 1** Multi-stage control of cooling production capacity depending on the load or demand (e.g. on/off of several compressors) **Level 2** Variable control of cooling production capacity depending on the load or demand (e.g. hot gas bypass, inverter frequency control) **Level 3** Variable control of cooling production capacity depending on the load AND external signals from the grid.	**Complete** **Partial** **Partial** **Partial**	Default mode/presence of cooling generator Outdoor temperature sensor, flow temperature sensor, Multi stage equipment, demand switches/controllers (1) Communication to distribution/cooling consumer, flow sensor, demand switches/controllers, direct grid signal (2,3) External signals from grid (3)	IfcUnitaryEquipment IfcSensorType IfcController N/A	7.5.3.61 7.2.3.9 7.2.3.5 -	COL-2a	Integers, [0.1,2,3] Integers, [1,2,3] Integers, [1,2,3] Integers, [,3]
Cooling -2b	**Sequencing of different cooling generators**	**Level 0** Priorities only based on running times **Level 1** Fixed sequencing based on loads only: e.g. depending on the generator's characteristics such as absorption chiller vs. centrifugal chiller	**Not supported**	---			COL-2b	Integers, [0.1,2,3,4]

		Level 2 Dynamic priorities based on generator efficiency and characteristics (e.g. availability of free cooling) **Level 3** Load prediction based sequencing: the sequence is based on e.g. COP and available power of a device and the predicted required power Level 4 Sequencing based on dynamic priority list, including external signals from grid.				
Cooling -3	**Report information regarding cooling system performance**	**Level 0** None **Level 1** Central or remote reporting of current performance KPIs (e.g. temperatures, submetering energy usage) **Level 2** Central or remote reporting of current performance KPIs and historical data | **Level 3** Central or remote reporting of performance evaluation including forecasting and/or benchmarking |	Not supported	--	COL-3	Integers, [0.1,2,3,4]

		Level 4 Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection.				
Cooling -4	**Flexibility and grid interaction**	**Level 0** No automatic control **Level 1** Scheduled operation of cooling system **Level 2** Self-learning optimal control of cooling system **Level 3** Cooling system capable of flexible control through grid signals (e.g. DSM) **Level 4** Optimized control of cooling system based on local predictions and grid signals (e.g. through model predictive control)	**Not supported**	---	COL-4	Integers, [0.1,2,3,4]

4.2.3 Ventilation

Indicator Name	Indicator Description	Calculation Procedure	IFC coverage	Input Data	Relation with IFC entity	Reference to IFC schema contents	Entity attribute metadata	
							Attribute Name	Attribute Value Datatype
Ventilation-1a	Supply airflow at the room level	**Level 0** No ventilation system or manual control	complete	Manual operated control/no ventilation (0)	No equipment or ventilation equipment present	-	VEN-1a	Integers, [0]
		Level 1 Clock control	Partial	Existence of scheduling for the specific room/zone or functional test (1)	N/A	-		Integers, [1]
		Level 2 Occupancy detection control	Partial	Presence detection with occupancy sensor (2)	IfcSensorType	7.2.3.9		Integers, [2]
				Air quality sensors (CO2 sensors, VOC sensors) (3,4)				Integers, [3,4]
		Level 3 Central Demand Control based on air quality sensors (CO2, VOC, humidity…) **Level 4** Local Demand Control based on air quality sensors (CO2, VOC, …) with local flow from/to the zone regulated by dampers	Partial	Central demand switches/controllers (3) Demand switches/controllers, zone/room level (4)	IfcController	7.2.3.5		Integers, [3,4]
Ventilation-1c	Air flow or pressure control at the air	**Level 0** No automatic control: continuously supplies of airflow for a maximum load of all rooms	complete	Constant Air Volume system (CAV) (0)	IfcUnitaryEquipmentType	7.5.2.31	VEN-1c	Integers, [0,1]

	handler level	**Level 1** On off time control: Continuously supplies of air flow for a maximum load of all rooms during nominal occupancy time **Level 2** Multi-stage control: to reduce the auxiliary energy demand of the fan **Level 3** Automatic flow or pressure control without pressure reset: load dependent supplies of air flow for the demand of all connected rooms **Level 4** Automatic flow or pressure control with pressure reset: load-dependent supplies of air flow for the demand of all connected rooms (for variable air volume systems with VFD)	**Partial** **Partial** **Partial** **Partial**	Constant Air Volume system with scheduling/time clock (CAV) (1) Occupancy sensor (1) Ventilation system with multi-speed fan motor (2) Variable Air Volume (VAV) systems with Variable frequency drive (VFD) (4) Variable fan speed motor (3,4) Pressure sensing equipment (3,4) Demand-based sensors (temperature, air quality, occupancy, humidity etc.) (3,4) Demand/communication controller	IfcSensorType IfcFanType IfcUnitaryEquipmentType (USERDEFINED) N/A IfcSensorType IfcController	7.2.3.9 7.5.3.38 7.5.2.31 - 7.2.3.9 7.2.3.5		Integers, [1] Integers, [2] Integers, [4] Integers, [3,4] Integers, [4] Integers, [3,4] Integers, [2,3,4]
Ventilation-2c	Heat recovery control: prevention of overheating	**Level 0** Without overheating control **Level 1** Modulate or bypass heat recovery based on sensors in air exhaust **Level 2** Modulate or bypass heat recovery based on multiple room temperature	**complete** **Partial** **Partial**	Heat recovery equipment (0) Temperature Sensor for Supply Air (1,2) Multiple room temperature sensors (2) Actuators (1,2)	IfcAirToAirHeatRecovery IfcSensorType IfcActuator	7.5.3.5 7.2.3.9 7.2.3.1	VEN-2c	Integers, [0,1,2] Integers, [0,1,2] Integers, [1,2]

		sensors or predictive control		Communication controller (1,2)	IfcController	7.2.3.5		Integers, [1,2]
Ventilation-2d	Supply air temperature control at the air handling unit level	**Level 0** No automatic control	**complete**	No controls to a fixed temperature value/default ventilation equipment (0)	IfcUnitaryEquipmentType	7.5.2.31	VEN-2d	Integers, [0,1,2,3]
		Level 1 Constant setpoint: a control loop enables to control the supply air temperature, the setpoint is constant and can only be modified by a manual action	**Partial**	Room/zone temperature sensor (1)	IfcSensorType	7.2.3.9		Integers, [1,2,3]
		Level 2 Variable setpoint with outdoor temperature compensation	**Partial**	Outside air sensor (2)				
		Level 3 Variable setpoint with load dependant compensation. A control loop enables to control the supply air temperature. The setpoint is defined as a function of the loads in the room	**Partial**	Flow/air quality control, communication/connection to static heating/cooling (3) Controllers (1,2,3)	IfcController	7.2.3.5		Integers, [2,3]
Ventilation-3	Free cooling with mechanical ventilation system	**Level 0** No automatic control	**Complete**	Default ventilation system (0)	IfcUnitaryEquipmentType	7.5.2.31	VEN-3	Integers, [0]
		Level 1 Night cooling	**Partial**	Outside temperature sensor (or communication to outside air sensor) / Room/zone temperature Sensor (1,2)	IfcSensorType	7.2.3.9		Integers, [1,2]
		Level 2 Free cooling: air flows modulated during	**Partial**	Integrated economizer coil (2)	N/A	-		Integers, [2]

		all periods of time to minimize the amount of mechanical cooling **Level 3** H,x – directed control: the amount of outside air and recirculation air are modulated during all periods of time to minimize the amount of mechanical cooling. The calculation is performed on the basis of temperature and humidity.	**Partial**	Humidity sensor, humidifier/dehumidifier actuators, room/zone temperature sensor (3)	IfcSensorType	7.2.3.9		Integers, [3]
Ventilation-6	Reporting information regarding IAQ	**Level 0** None **Level 1** Air quality sensors (e.g. CO2) and real time autonomous monitoring **Level 2** Real-time monitoring & historical information of IAQ available to occupants **Level 3** Real time monitoring & historical information of IAQ available to occupants + warning on maintenance needs or occupant actions (e.g. window opening)	**Not supported**	--			VEN-6	Integers, [0,1,2,3]

4.2.4 Lighting

Indicator Name	Indicator Description	Calculation Procedure	IFC coverage	Input Data Metric	Relation with IFC entity	Reference to IFC schema contents	Entity attribute metadata Attribute name	Entity attribute metadata Attribute value Datatype
SRI-Lighting 1a	**Occupancy control for indoor lighting**	**Level 0** Manual on/off switch	**complete**	Manual on/off switch [0]	IfcFlowController (IfcSwitchingDevice)	7.4.3.41	SRI-L-1a	Integers, [0,1,3]
		Level 1 Manual on/off switch + additional sweeping extinction signal	**complete**	Manual on/off switch with sweep time control device [1]	IfcElectricTimeControl	7.4.3.23		Integers, [1,3*]
		Level 2 Automatic detection (auto on / dimmed or auto off)	**partial**	Occupancy Sensor, automatic switch [2]	IfcSensorType	7.2.3.9		Integers, [2,3]
		Level 3 Automatic detection (manual on / dimmed or auto off)	**partial**	Manual on switch, occupancy sensor or timer [3]				
SRI-Lighting 2	**Control artificial lighting power based on daylight levels**	**Level 0** Manual (central)	**complete**	Influence zone – central, room (0,1)	IfcSpatialZone	5.4.3.60	SRI-L-2	Integers, [0,1]
		Level 1 Manual (per room/zone)	**complete**	Manual lighting switch (0,1)	IfcFlowController (IfcSwitchingDevice)	7.4.3.41		Integers, [0,1]
		Level 2 Automatic switching	**complete**	Lighting sensors, occupancy sensors (2,3)	IfcSensorType	7.2.3.9		Integers, [2,3,4]
		Level 3 Automatic dimming	**complete**	Brightness/occupancy sensors, Colour Temperature Sensors, light intensity sensor (4)				
		Level 4 Scene-based light control (during time intervals, dynamic and adapted lighting scenes are set, for example, in terms of illuminance level, different correlated colour temperature (CCT) and the possibility to change the light distribution within the space according to e.g., design, human needs, visual tasks)	**partial**	Controller (keypad) (4)	IfcController	7.2.3.5		Integers, [4]

4.2.5 Domestic Hot Water

Indicator Name	Indicator Description	Calculation Procedure	IFC coverage	Input Data Metric	Relation with IFC entity	Reference to IFC schema contents	Entity attribute metadata: Attribute name	Entity attribute metadata: Attribute value Datatype
DHW-1a	Control of DHW storage charging (with direct electric heating or integrated electric heat pump)	**Level 0** Automatic control on/off **Level 1** Automatic control on/off and scheduled charging enable **Level 2** Automatic control on/off and scheduled charging enable and multi-sensor storage management **Level 3** Automatic charging control based on local availability of renewables or information from electricity grid (DR, DSM).	**complete** **partial** **partial** **partial**	Thermostat (0,1,2) Control equipment with scheduling/time-clock (1,2) built-in Multi-sensors (heat generator with integrated storage tank) (2) Solar collector (3) Controller (2,3) Electricity grid signal (3)	IfcUnitaryControlElement IfcElectricTimeControl N/A IfcSolarDevice IfcController Not supported	7.2.3.11 7.4.3.23 - 7.4.3.39 7.2.3.5 -	DHW-1a	Integers, [0,1,2] Integers, [1,2] Integers, [2] Integers, [3] Integers, [2,3] Integers, [3]
DHW-1b	Control of DHW storage charging (using hot water generation)	**Level 0** Automatic control on/off **Level 1** Automatic control on/off and scheduled charging enable **Level 2** Automatic on/off control, scheduled charging enables and demand-based supply temperature control or multi-sensor storage management **Level 3** DHW production system capable of automatic charging control based on external signals (e.g. from district heating grid)	**complete** **partial** **partial** **partial**	Thermostat Control equipment with scheduling/time-clock (1) Built-in temperature sensors (storage tank) Return water temperature sensor, Flow sensor (2) Demand controller (2) District heating grid signals (3)	IfcUnitaryControlElement IfcElectricTimeControl N/A IfcSensorType IfcController N/A	7.2.3.11 7.4.3.23 - 7.2.3.9 7.2.3.5 -	DHW-1b	Integers, [0,1,2] Integers, [1,2] Integers, [2] Integers, [2] Integers, [2] Integers, [3]
DHW-1d	Control of DHW storage	**Level 0** Manual selected control of solar energy or heat generation	**complete**	Manual switch (with preselected generator) (0)	IfcFlowController (IfcSwitchingDevice)	7.4.3.41	DHW-1d	Integers, [0]

	charging (with solar collector and supplementary heat generation)	**Level 1** Automatic control of solar storage charge (Prio.1) and supplementary storage charge **Level 2** Automatic control of solar storage charge (Prio. 1) and supplementary storage charge and demand-oriented supply or multi-sensor storage management **Level 3** Automatic control of solar storage charge (Prio.1) and supplementary storage charge, demand-oriented supply and return temperature control and multi-sensor storage management	**partial** **partial** **partial**	Supply and/or Return water temperature sensors (1,2,3) Valve (1,2,3) Historical data on water consumption (2,3) Built-in temperature sensors (storage tank) (2,3) Controller (3)	IfcSensorType IfcValve N/A N/A IfcController	7.2.3.9 7.5.3.63 - - 7.2.3.5		Integers, [1,2,3] Integers, [1,2,3] Integers, [2,3] Integers, [2*,3] Integers, [3]
DHW-2b	Sequencing in case of different DHW generators	**Level 0** Priorities only based on running time **Level 1** Control according to fixed priority list: e.g. based on rated energy efficiency **Level 2** Control according to dynamic priority list (based on current energy efficiency, carbon emissions and capacity of generators, e.g. solar, geothermal heat, cogeneration plant, fossil fuels) **Level 3** Control according to dynamic priority list (based on current AND predicted load, energy efficiency, carbon emissions and capacity of generators) **Level 4** Control according to dynamic priority list (based on current AND predicted load, energy efficiency, carbon emissions, the capacity of	**Not supported**	---				

		generators AND external signals from grid)		
DHW-3	Report information regarding domestic hot water performance	**Level 0** None **Level 1** Indication of actual values (e.g., temperatures, submetering energy usage) **Level 2** Actual values and historical data **Level 3** Performance evaluation including forecasting and/or benchmarking **Level 4** Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	**default** **Not supported**	---

4.2.6 Electricity

Indicator Name	Indicator Description	Calculation Procedure	IFC coverage	Input Data Metric	Relation with IFC entity	Reference to IFC schema contents	Entity attribute metadata	
							Attribute name	Attribute value Datatype
Electricity-2	**Reporting information regarding local electricity generation**	**Level 0** None **Level 1** Current generation data available **Level 2** Actual values and historical data **Level 3** Performance evaluation including forecasting and/or benchmarking **Level 4** Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	**Not supported**	---			ELE-2	Integers, [0,1,2,3,4]
Electricity-3	Storage of locally generated energy	**Level 0** None **Level 1** Limited: small scale storage (batteries, TES…) **Level 2** Storage which can supply self-consumption for > 3 hours **Level 3** Dynamically operated storage which can also feed back into the grid	**complete** **partial** **partial** **Not supported**	local storage available (0) On site electric battery (1) On site electric battery > 3hrs(2) Thermal storage with controller based on grid signals (3)	No equipment IfcElectricFlowStorageDevice N/A	- 7.4.3.17 -	ELE-3	Integers, [0] Integers, [1,2] Integers, [3]
Electricity-4	Optimizing self-consumption	**Level 0** None **Level 1** Short term optimization	**complete** **Not supported**	No optimization (0)	No equipment N/A	- -	ELE-4	Integers, [0] Integers, [1]

	of locally generated energy	**Level 2** Long term optimization including predicted generation and/or demand	**Not supported**	Predictive generation based on historical data (2)	N/A	-		Integers, [2]
Electricity-5	Control of combined heat and power plant (CHP)	**Level 0** CHP control based on scheduled runtime management and/or current heat energy demand	**complete**	Presence of CHP (0)	IfcElectricGenerator	7.43.19	ELE-5	Integers, [0]
		Level 1 CHP runtime control is influenced by the fluctuating availability of RES; overproduction will be fed into the grid	**Not supported**	Renewable energy sources (1,2)	IfcSolarDevice	7.4.3.39		Integers, [1,2]
		Level 2 CHP runtime control influenced by the fluctuating availability of RES and grid signals; dynamic charging and runtime control to optimise self-consumption of renewables	**Not supported**	Grid signal response (1,2)	N/A	-		Integers, [1,2]
Electricity-8	Support of microgrid operation modes	**Level 0** None	**complete**	No equipment (0)	No equipment	-	ELE-8	Integers, [0]
		Level 1 Local battery usage	**partial**	Local battery presence (1)	IfcElectricFlowStorageDevice	7.4.3.17		Integers, [1]
		Level 2 Autonomous energy consumption control	**Not supported**		N/A	-		Integers, [2]
Electricty-11	Reporting information regarding energy storage	**Level 0** None **Level 1** Current state of charge (SOC) data available **Level 2** Actual values and historical data **Level 3** Performance evaluation including forecasting and/or benchmarking **Level 4** Performance evaluation including forecasting and/or	**Not supported**	---				

		benchmarking; also including predictive management and fault detection		
electricity -12	Reporting information regarding electricity consumption	**Level 0** None **Level 1** reporting on current electricity consumption on building level **Level 2** real-time feedback or benchmarking on building level **Level 3** real-time feedback or benchmarking on appliance level **Level 4** real-time feedback or benchmarking on appliance level with automated personalized recommendations	**Not supported**	---

4.2.7 Dynamic Envelope

Indicator Name	Indicator Description	Calculation Procedure	IFC coverage	Input Data Metric	Relation with IFC entity	Reference to IFC schema contents	Entity attribute metadata Attribute name	 Attribute value Datatype
DE-1	**Window solar shading control**	**Level 0** No sun shading or only manual operation **Level 1** Motorized operation with manual control **Level 2** Motorized operation with automatic control based on sensor data **Level 3** Combined light/blind/HVAC control **Level 4** Predictive blind control (e.g., based on weather forecast)	**complete** **complete** **partial** **partial** **partial**	No sun shading (0) Manual control (0) Electrical Motor for mechanical operations(1,2,3,4) Solar sensor,brightness sensor, temperature sensor (2,3) Weather station (4) Controller (3,4)	No equipment IfcShadingDevice IfcElectricMotor IfcSensorType IfcController	- 6.1.3.36 7.4.3.21 7.2.3.9 7.2.3.5	DE-1	**Integers, [0]** **Integers, [0]** **Integers, [1,2,3]** **Integers, [2,3,4]** **Integers, [4*]** **Integers, [3,4]**
DE-2	Window open/closed control, combined with HVAC system	**Level 0** Manual operation or only fixed windows **Level 1** Open/closed detection to shut down heating or cooling systems **Level 2** Automized mechanical window opening based on room sensor data **Level 3** Centralized coordination of operable windows, e.g., to control free natural night cooling	**complete** **partial** **partial** **partial**	Manual/fixed windows operation (0) Contact sensors (1) Light sensor, temperature sensors, CO2 (2) actuators (2) Controller connecting sensors with and HVAC (1,2) Central controller connecting windows (3)	IfcWindow IfcSensorType IfcActuator IfcController	6.1.3.50 7.2.3.9 7.2.3.1 7.2.3.5	DE-2	**Integers, [0,1,2,3]** **Integers, [1]** **Integers, [2,3]** **Integers, [2,3]** **Integers, [1,2]** **Integers, [3]**
`DE-4	Reporting information regarding performance	**Level 0** No reporting **Level 1** Position of each product & fault detection **Level 2** Position of each product, fault detection & predictive maintenance	**Not supported**	---			DE-4	**Integers, [0,1,2,3,4]**

		Level 3 Position of each product, fault detection, predictive maintenance, real-time sensor data (wind, lux, temperature… **Level 4** Position of each product, fault detection, predictive maintenance, real-time & historical sensor data (wind, lux, temperature…)				

4.2.8 EV charging

Indicator Name	Indicator Description	Calculation Procedure	IFC coverage	Input Data Metric	Relation with IFC entity	Reference to IFC schema contents	Entity attribute metadata Attribute name	Entity attribute metadata Attribute value Datatype
EV-15	**EV Charging Capacity**	**Level 0** Not present **Level 1** Ducting (or simple power plug) available **Level 2** 0-9% of parking spaces have recharging points **Level 3** 10-50% of parking spaces have recharging points **Level 4** >50% of parking spaces have recharging points	Not supported	Presence and type of power plugs available (0,1) Percentage of parking spaces with charging points (2,3,4)		--	EV-15	Integers, [0,1,2,3,4]
EV-16	**EV Charging Grid Balancing**	**Level 0** Not present (uncontrolled charging) **Level 1** 1-way controlled charging (e.g., including desired departure time and grid signals for optimization) **Level 2** 2-way controlled charging (e.g., including desired departure time and grid signals for optimization)	Not supported	Presence of EV charging control (0) Unidirectional chargers (1) Bidirectional chargers with internal converters, from DC to AC (2)		--	EV-15	Integers, [0,1,2]
EV-17	**EV Charging Information and connectivity**	**Level 0** No information available **Level 1** Reporting information on EV charging status to occupant **Level 2** Reporting information on EV charging status to occupant AND automatic identification and authorization of the driver to the charging station (ISO 15118 compliant)	Default Not Supported	Availability of EV charging Information and connectivity (0) Powered charging apps (IoT platforms with advanced data analytic systems (1,2) – users can access all real time information about the charging process		--	EV-17	Integers, [0,1,2]

5 Resume of IFC-based SRI analysis

The purpose of this task was to investigate the possibility of extracting the Smart readiness indicator of a building from the data collected for an asset-based energy performance certificate. For this purpose, the metrics required to define SRI functionality levels were identified within this task, and an assessment of their availability in data required for the EPC asset rating, in accordance to the European EN standards series 52000, was conducted. It was found that the current status of data for EPC assessment does not allow the extraction of the SRI. Some screening information for the SRI may be extracted, however, this information is not sufficient to extract the SRI indicator of the building. The information which can be extracted from EPC is namely:

- Heating type, emission type
- Cooling type, emission type
- Ventilation type
- Domestic hot water system type
- Presence of renewable energy

Another approach conducted in Task 2.1 concerned the possibility of extracting the SRI from an IFC file. For this purpose, the assessment in the context of IFC files was conducted, with regard to the inclusion of the appropriate information for extracting the SRI. Based on the assessment conducted for the alignment of the individual SRI functionalities and the IFC attributes, it was revealed, that at the current stage, a significant number of functionality levels still need to be addressed in IFC based documents. This constitutes a major drawback, which does not allow the development of a comprehensive approach for extracting the SRI indicator from an IFC document. Specific information concerning BACS structure, control functions and relations —within the hierarchical level of BACs, is difficult to be defined adequately and comprehensively. It is currently a fact that complete and comprehensive BACS modelling documentation can only be offered by hardware vendors for their specific products, making the process highly dependent when it comes to modify, modelling and management of BACS systems. Ideally, this information should be able to be presented in a vendor-free way, enabling building owners/facility managers to use third-party tools or technologies. Although the open BIM exchange format IFC, already features the Building Automation domain for the definition of building automation control functions, only specific functions within the BACS can be defined. The information supported by the current BIM formats is mainly limited to the field level supporting the definition of devices and wiring relations, disregarding the logical and operational aspects, such as control loops, bindings, or configuration management. According to the analysis presented in section 4, the ''field level'' which is the lower part of the hierarchy of BACS, corresponds mostly to the ''default'' or Level 0 of the functionality levels in the SRI domains. Due to the fact that some of the field level entities are supported in IFC, the lower functionality levels of SRI can be adequately defined. However, when more complex automation and control functions are present within the ''Automation'' and ''Management'' levels (usually represented by Level 3 or Level 4 of SRI functionality levels), the definition is incomplete or even completely unsupported. The SRI functionality levels assessment in IFC schema is shown in Table 9:

Table 9 SRI functionality levels assessment in IFC schema

Domain	Complete	Partial	Not supported	Total functionalities
Lighting	6	3	0	9
EV Charging	0	0	11	11
DHW	3	9	10	22
Dynamic Envelope	3	6	10	19
Electricity	4	3	21	28
Heating	7	14	21	42
Cooling	8	10	6	24
Ventilation	4	12	7	23

As shown from the analysis from Section 4, IFC may be used for the definition of building systems required by the screening information required by the SRI. However, this information is not sufficient for the calculation of the SRI, and may be used only for activating the triage process, where services are to be included or excluded from the calculation engine. The information extraction can be realized within the BIM parser, by defining a minimum modelling requirement(s) for each screening question. The minimum modelling requirements concern IFC entities that should be defined in the BIM model during its development. The features which can be defined in IFC for the purpose of the SRI screening questions are the following:

- **Heating:** Presence of Heating system, Emission Type, Production Type
- **Domestic Hot Water (DHW):** Presence of Domestic Hot water, Production Type, Solar Collector
- **Cooling:** Presence of cooling system, Emission Type
- **Controlled Ventilation**: Presence of controlled ventilation system, System type, Heat Recovery
- **Dynamic Envelope**: Presence of dynamic Envelope system
- **Electricity: Renewables & Storage:** Presence of Renewables, On-site renewable electricity generation, Storage of on-site generated renewable electricity, CHP (Combined Heat and Power)

- **Electric Vehicle Charging**: Not supported

However, the use of IFC for automating the screening questions of the SRI still needs some user-specified inputs since not all features can be defined in the model. These features include some general building information, the presence of thermal storage, the presence of thermally activated building system, District Heating, EV charging etc.

6 D^2EPC SRI Calculation Sub-component

Following the findings of the analysis regarding the coverage of SRI functionalities by the IFC schema, the D^2EPC "SRI calculation sub-module" was developed for the calculation of SRI in the D^2EPC platform. The SRI subcomponent is a part of the Building Performance Module which offers a comprehensive calculation suite that enables the assessment of various indicators in addition to the building's smart-readiness such as indoor environment, environmental performance, and financial performance. The SRI calculation methodology implemented in the SRI tool was based on the findings of D2.1 – SRI indicators for next-generation EPCs v1 and followed the official SRI Method B to provide a more detailed representation of the building's technical infrastructure. The SRI tool was designed to operate as an online service accessible through the D^2EPC Web Platform. EPC assessors or/and users can upload building information directly into the SRI web environment, streamlining the documentation process. Given that information required for the calculation of the SRI cannot be extracted fully from existing Building Information Models (BIM), the tool can extract specific information from the BIM model in addition to manual user inputs. The SRI ''Wizard'' was developed as a guidance for the assessor through the various information required for the SRI calculation in the D^2EPC platform. This section presents the sections of the SRI "SRI calculation sub-module" and the calculation procedures for Case Study 1: nZEB Smart House in Greece.

There are four categories of information in the process flow of SRI Wizard:

1. **Assessor:** This first category includes the assessor's information and contact details.

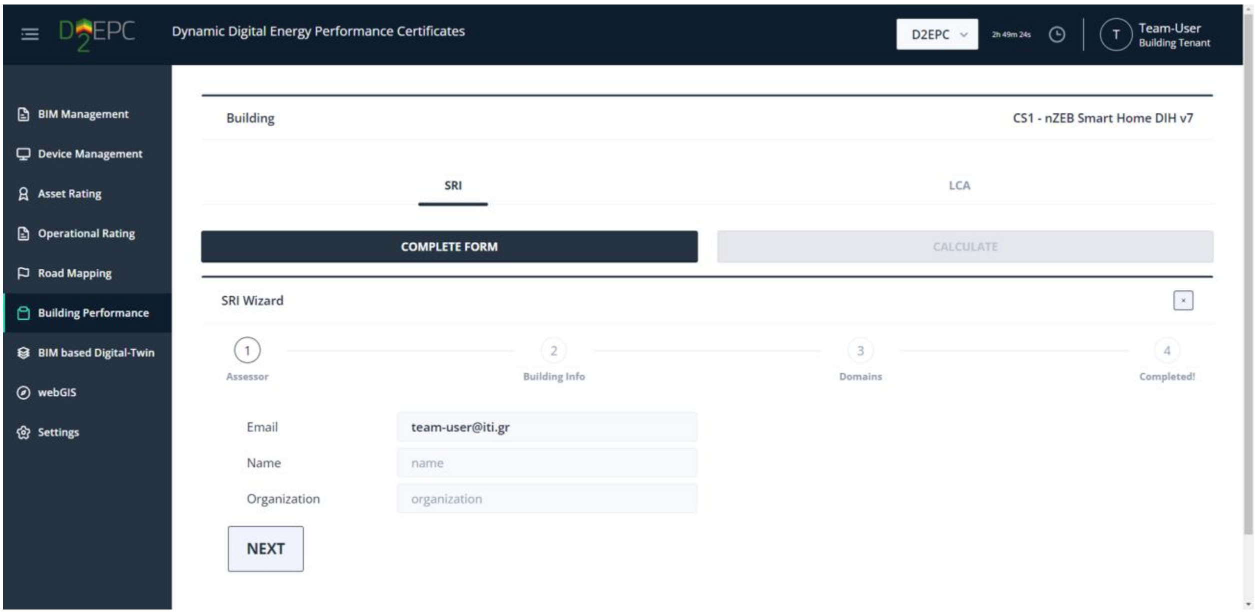


Figure 10 D^2EPC SRI Calculation subcomponent - Assessor's Information

2. **Building Info:** This category includes general building information (such as building type, use, location etc.) The majority of the inputs in this section are directly extracted from the BIM model.

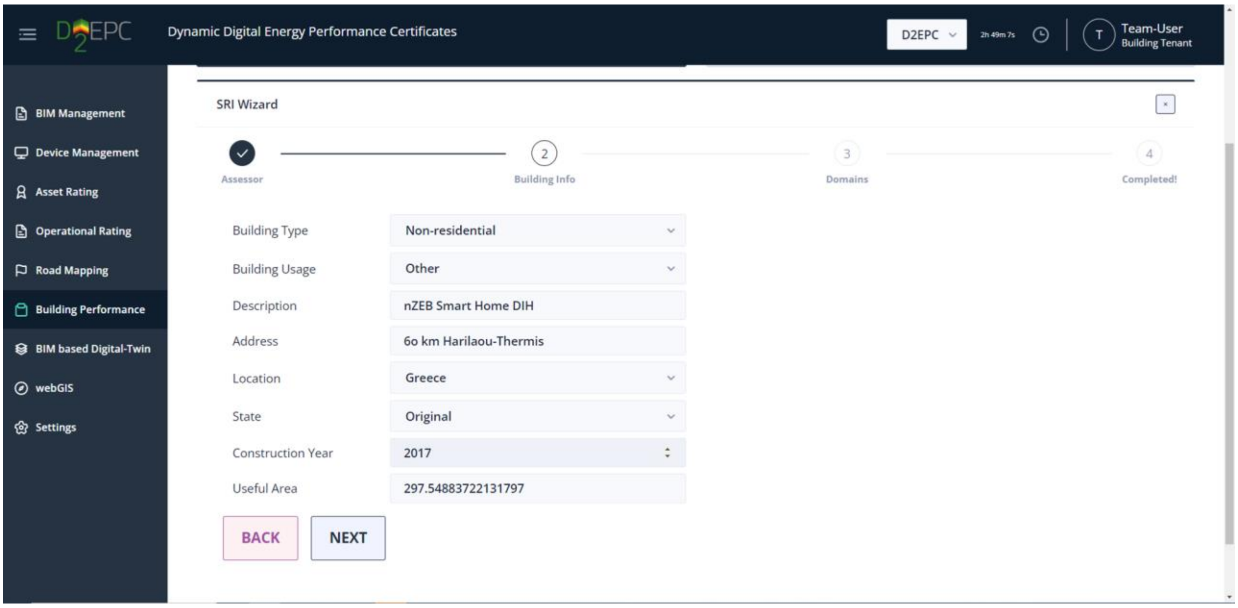


Figure 11 D^2EPC SRI Calculation subcomponent - Building Information

3. **Domains:** The assessor defines the presence of building services and assigns the functionality levels of the present services.

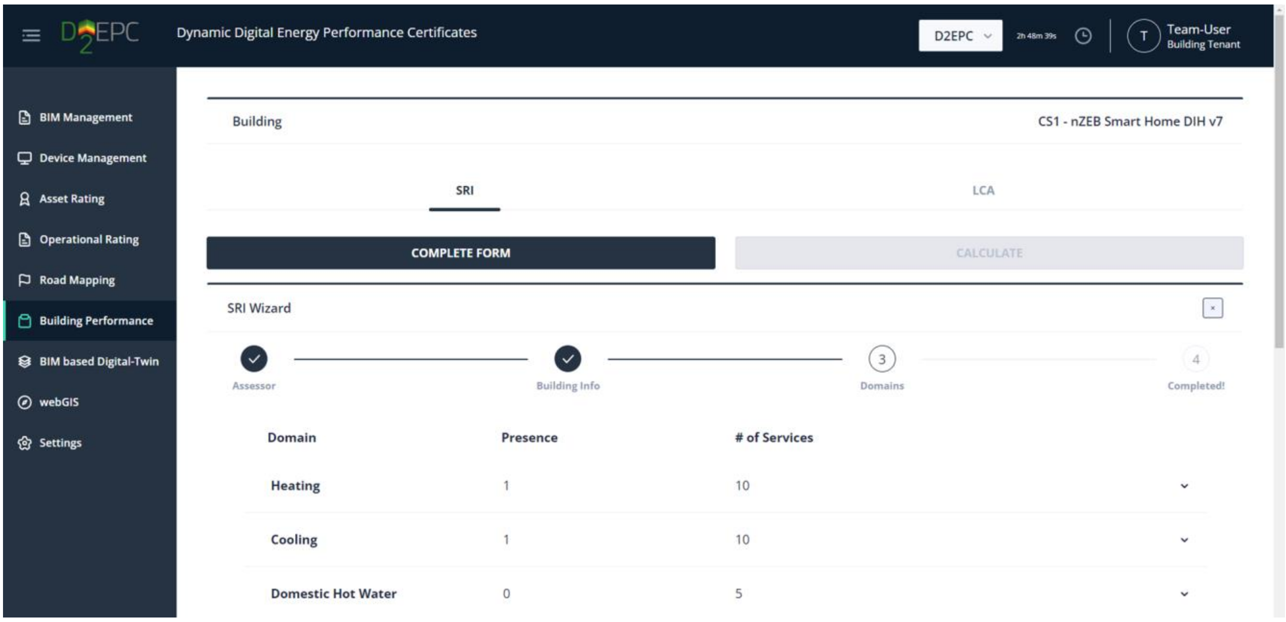


Figure 12 D^2EPC SRI Calculation subcomponent - Domains

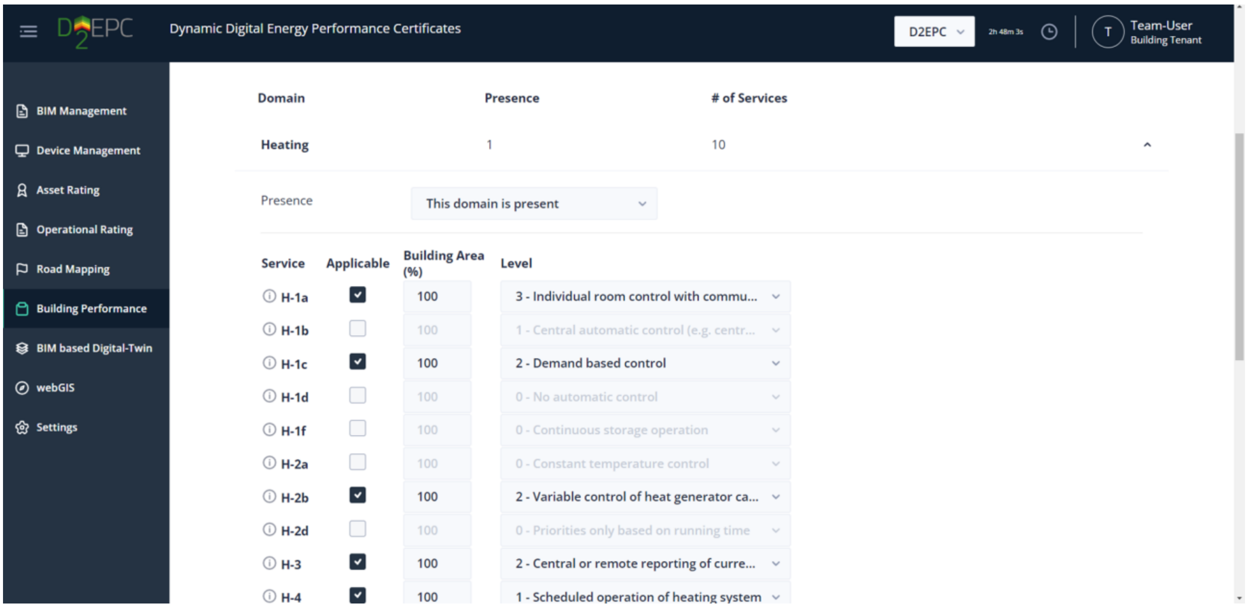


Figure 13 D^2EPC SRI Calculation subcomponent – Domains

4. **Results:** The calculation procedure is completed once the functionally levels are successfully inserted.

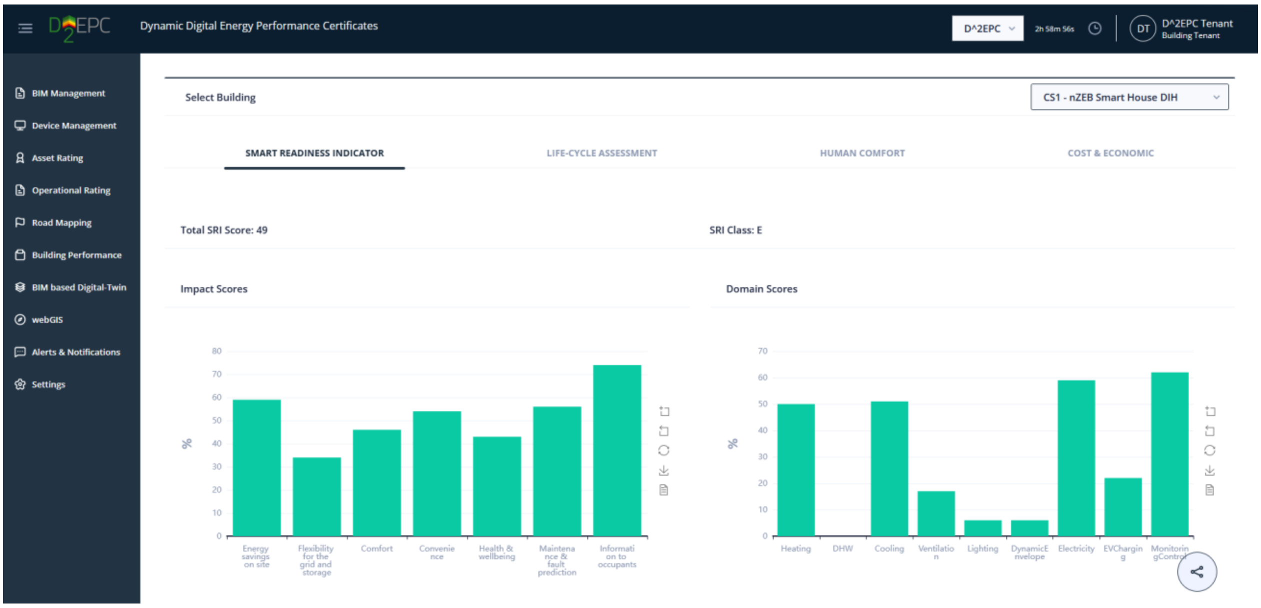


Figure 14 D^2EPC SRI Calculation subcomponent - SRI Results

The SRI results page follows user-friendly visualization techniques combining interactive graphs and detailed numerical outputs for each category. In particular, the impact and domain scores are presented graphically in the first section of the results page and the detailed and aggregated scores of the building are presented numerically right after. The SRI calculation procedure also follows a friendly approach towards the assessors, by allowing a structured way of providing the necessary information to minimise errors and enhancing time efficiency. More details on the SRI subcomponent are provided within the updated deliverable D4.5 Building Performance Module v2.

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ANNEX I: SRI Weightings per Climate region

User Defined Weightings

	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Wellbeing and health	maintenance & fault prediction	information to occupants
Heating system	11.1%	12.5%	16.7%	11.1%	0.0%	14.3%	12.5%
Domestic Hot Water	11.1%	12.5%	16.7%	11.1%	0.0%	14.3%	12.5%
Cooling system	11.1%	12.5%	16.7%	11.1%	0.0%	14.3%	12.5%
Controlled ventilation	11.1%	12.5%	16.7%	11.1%	50.0%	14.3%	12.5%
Lighting	11.1%	0.0%	16.7%	11.1%	0.0%	0.0%	0.0%
Electricity	11.1%	12.5%	0.0%	11.1%	0.0%	14.3%	12.5%
Dynamic Envelope	11.1%	12.5%	16.7%	11.1%	50.0%	14.3%	12.5%
Electric Vehicle Charging	11.1%	12.5%	0.0%	11.1%	0.0%	0.0%	12.5%
Monitoring & Control	11.1%	12.5%	0.0%	11.1%	0.0%	14.3%	12.5%
	100.0%	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*

Impact Weightings	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Wellbeing and health	maintenance & fault prediction	information to occupants	
	14.3%	14.3%	14.3%	14.3%	14.3%	14.3%	14.3%	*100.0%*

Default Weighting Factors – Residential Buildings

North Europe	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Health & Wellbeing	Maintenance & fault prediction	Information to occupants
Heating system	0.30	0.43	0.16	0.1	0.2	0.31	0.11
Domestic Hot Water	0.09	0.13	0.00	0.1	0	0.10	0.11
Cooling system	0.00	0.00	0.16	0.1	0.20	0.00	0.11
Controlled ventilation	0.19	0.00	0.16	0.1	0.20	0.20	0.11
Lighting	0.04	0.00	0.16	0.1	0.00	0.00	0.00
Electricity	0.13	0.19	0.00	0.1	0.00	0.14	0.11
Dynamic Envelope	0.05	0	0.16	0.1	0.20	0.05	0.11
Electric Vehicle Charging	0	0.05	0	0.1	0.00	0	0.11
Monitoring & Control	0.2	0.2	0.2	0.2	0.20	0.2	0.2
	1.00	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*

IMPACT WEIGHTINGS	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Health & Wellbeing	Maintenance & fault prediction	Information to occupants
	0.17	0.33	0.08	0.08	0.08	0.17	0.08

West Europe	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Health & Wellbeing	Maintenance & fault prediction	Information to occupants
Heating system	0.34	0.46	0.16	0.1	0.2	0.35	0.11
Domestic Hot Water	0.08	0.10	0.00	0.1	0	0.08	0.11
Cooling system	0.03	0.04	0.16	0.1	0.20	0.03	0.11
Controlled ventilation	0.18	0.00	0.16	0.1	0.20	0.18	0.11
Lighting	0.01	0.00	0.16	0.1	0.00	0.00	0.00
Electricity	0.11	0.15	0.00	0.1	0.00	0.11	0.11
Dynamic Envelope	0.05	0	0.16	0.1	0.20	0.05	0.11
Electric Vehicle Charging	0	0.05	0	0.1	0.00	0	0.11
Monitoring & Control	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1.00	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*

IMPACT WEIGHTINGS	**Energy savings on site**	**Flexibility for the grid and storage**	**Comfort**	**Convenience**	**Health & Wellbeing**	**Maintenance & fault prediction**	**Information to occupants**
	0.17	0.33	0.08	0.08	0.08	0.17	0.08

South Europe	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Health & Wellbeing	Maintenance & fault prediction	Information to occupants
Heating system	0.32	0.38	0.16	0.1	0.2	0.33	0.11
Domestic Hot Water	0.10	0.12	0.00	0.1	0	0.10	0.11
Cooling system	0.07	0.08	0.16	0.1	0.2	0.07	0.11
Controlled ventilation	0.09	0.00	0.16	0.1	0.20	0.10	0.11
Lighting	0.03	0.00	0.16	0.1	0.00	0.00	0.00
Electricity	0.15	0.17	0.00	0.1	0.00	0.15	0.11
Dynamic Envelope	0.05	0	0.16	0.1	0.20	0.05	0.11
Electric Vehicle Charging	0	0.05	0	0.1	0	0	0.11
Monitoring & Control	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1.00	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*

IMPACT WEIGHTINGS	**Energy savings on site**	**Flexibility for the grid and storage**	**Comfort**	**Convenience**	**Health & Wellbeing**	**Maintenance & fault prediction**	**Information to occupants**
	0.17	0.33	0.08	0.08	0.08	0.17	0.08

North-East Europe	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Health & Wellbeing	maintenance & fault prediction	information to occupants
Heating system	0.30	0.41	0.16	0.1	0.2	0.31	0.11
Domestic Hot Water	0.14	0.19	0.00	0.1	0	0.14	0.11
Cooling system	0.00	0.00	0.16	0.1	0.20	0.00	0.11
Controlled ventilation	0.19	0.00	0.16	0.1	0.20	0.19	0.11
Lighting	0.01	0.00	0.16	0.1	0.00	0.00	0.00
Electricity	0.11	0.15	0.00	0.1	0.00	0.11	0.11
Dynamic Envelope	0.05	0	0.16	0.1	0.20	0.05	0.11
Electric Vehicle Charging	0	0.05	0	0.1	0.00	0	0.11
Monitoring & Control	0.2	0.2	0.2	0.2	0.20	0.2	0.2
	1.00	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*

IMPACT WEIGHTINGS	**Energy savings on site**	**Flexibility for the grid and storage**	**Comfort**	**Convenience**	**Wellbeing and health**	**maintenance & fault prediction**	**information to occupants**
	0.17	0.33	0.08	0.08	0.08	0.17	0.08

South-East Europe	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Health & Wellbeing	Maintenance & fault prediction	Information to occupants
Heating system	0.21	0.24	0.16	0.1	0.2	0.21	0.11
Domestic Hot Water	0.06	0.07	0.00	0.1	0	0.06	0.11
Cooling system	0.15	0.17	0.16	0.1	0.20	0.15	0.11
Controlled ventilation	0.11	0.00	0.16	0.1	0.20	0.11	0.11
Lighting	0.01	0.00	0.16	0.1	0.00	0.00	0.00
Electricity	0.22	0.26	0.00	0.1	0.00	0.22	0.11
Dynamic Envelope	0.05	0	0.16	0.1	0.20	0.05	0.11
Electric Vehicle Charging	0	0.05	0	0.1	0.00	0	0.11
Monitoring & Control	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1.00	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*

IMPACT WEIGHTINGS	**Energy savings on site**	**Flexibility for the grid and storage**	**Comfort**	**Convenience**	**Health & Wellbeing**	**Maintenance & fault prediction**	**Information to occupants**
	0.17	0.33	0.08	0.08	0.08	0.17	0.08

Default Weighting Factors – Non-Residential Buildings

North Europe	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Health & Wellbeing	Maintenance & fault prediction	Information to occupants
Heating system	0.31	0.49	0.16	0.1	0.2	0.35	0.11
Domestic Hot Water	0.05	0.08	0.00	0.1	0	0.06	0.11
Cooling system	0.09	0.15	0.16	0.1	0.2	0.10	0.11
Controlled ventilation	0.20	0.00	0.16	0.1	0.20	0.22	0.11
Lighting	0.08	0.00	0.16	0.1	0.00	0.00	0.00
Electricity	0.02	0.02	0.00	0.1	0.00	0.02	0.11
Dynamic Envelope	0.05	0	0.16	0.1	0.20	0.05	0.11
Electric Vehicle Charging	0	0.05	0	0.1	0.00	0	0.11
Monitoring & Control	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1.00	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*

IMPACT WEIGHTINGS	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Health & Wellbeing	Maintenance & fault prediction	Information to occupants
	0.17	0.33	0.08	0.08	0.08	0.17	0.08

West Europe	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Health & Wellbeing	Maintenance & fault prediction	Information to occupants
Heating system	0.27	0.41	0.16	0.1	0.2	0.32	0.11
Domestic Hot Water	0.08	0.12	0.00	0.1	0	0.10	0.11
Cooling system	0.13	0.19	0.16	0.1	0.20	0.15	0.11
Controlled ventilation	0.14	0.00	0.16	0.1	0.20	0.17	0.11
Lighting	0.10	0.00	0.16	0.1	0.00	0.00	0.00
Electricity	0.02	0.03	0.00	0.1	0.00	0.02	0.11
Dynamic Envelope	0.05	0	0.16	0.1	0.20	0.05	0.11
Electric Vehicle Charging	0	0.05	0	0.1	0	0	0.11
Monitoring & Control	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1.00	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*

IMPACT WEIGHTINGS	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Health & Wellbeing	Maintenance & fault prediction	Information to occupants
	0.17	0.33	0.08	0.08	0.08	0.17	0.08

South Europe	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Health & Wellbeing	Maintenance & fault prediction	Information to occupants
Heating system	0.30	0.42	0.16	0.1	0.2	0.36	0.11
Domestic Hot Water	0.11	0.15	0.00	0.1	0	0.13	0.11
Cooling system	0.12	0.16	0.16	0.1	0.2	0.14	0.11
Controlled ventilation	0.09	0.00	0.16	0.1	0.20	0.10	0.11
Lighting	0.12	0.00	0.16	0.1	0.00	0.00	0.00
Electricity	0.02	0.02	0.00	0.1	0.00	0.02	0.11
Dynamic Envelope	0.05	0	0.16	0.1	0.20	0.05	0.11
Electric Vehicle Charging	0	0.05	0	0.1	0	0	0.11
Monitoring & Control	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1.00	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*

IMPACT WEIGHTINGS	**Energy savings on site**	**Flexibility for the grid and storage**	**Comfort**	**Convenience**	**Health & Wellbeing**	**Maintenance & fault prediction**	**Information to occupants**
	0.17	0.33	0.08	0.08	0.08	0.17	0.08

North-East Europe	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Health & Wellbeing	maintenance & fault prediction	information to occupants
Heating system	0.29	0.44	0.16	0.1	0.2	0.32	0.11
Domestic Hot Water	0.09	0.14	0.00	0.1	0	0.10	0.11
Cooling system	0.08	0.13	0.16	0.1	0.2	0.09	0.11
Controlled ventilation	0.18	0.00	0.16	0.1	0.20	0.20	0.11
Lighting	0.07	0.00	0.16	0.1	0.00	0.00	0.00
Electricity	0.02	0.04	0.00	0.1	0.00	0.03	0.11
Dynamic Envelope	0.05	0	0.16	0.1	0.20	0.05	0.11
Electric Vehicle Charging	0	0.05	0	0.1	0	0	0.11
Monitoring & Control	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1.00	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*

IMPACT WEIGHTINGS	**Energy savings on site**	**Flexibility for the grid and storage**	**Comfort**	**Convenience**	**Wellbeing and health**	**maintenance & fault prediction**	**information to occupants**
	0.17	0.33	0.08	0.08	0.08	0.17	0.08

South-East Europe	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Health & Wellbeing	Maintenance & fault prediction	Information to occupants
Heating system	0.29	0.42	0.16	0.1	0.2	0.33	0.11
Domestic Hot Water	0.12	0.17	0.00	0.1	0	0.13	0.11
Cooling system	0.07	0.11	0.16	0.1	0.2	0.08	0.11
Controlled ventilation	0.15	0.00	0.16	0.1	0.20	0.17	0.11
Lighting	0.09	0.00	0.16	0.1	0.00	0.00	0.00
Electricity	0.03	0.05	0.00	0.1	0.00	0.04	0.11
Dynamic Envelope	0.05	0	0.16	0.1	0.20	0.05	0.11
Electric Vehicle Charging	0	0.05	0	0.1	0	0	0.11
Monitoring & Control	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1.00	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*

IMPACT WEIGHTINGS	**Energy savings on site**	**Flexibility for the grid and storage**	**Comfort**	**Convenience**	**Health & Wellbeing**	**Maintenance & fault prediction**	**Information to occupants**
	0.17	0.33	0.08	0.08	0.08	0.17	0.08