Prescient building Operation utilizing Real Time data for Energy Dynamic Optimization

WP2 – Streamlining data collection processes

D2.3 – Updated EPIQR platform

Version 1.0

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PRELUDE CONSORTIUM PARTNERS

	Participant organisation name	*Country*
1	*AALBORG UNIVERSITET*	*DK*
2	*TAMPEREEN KORKEAKOULUSAATIO SR*	*FI*
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21	*INNOVACION Y CONSULTING TECNOLOGICOSL*	*ES*

EXECUTIVE SUMMARY

In the current context, the renovation of a given building cannot only be based on the refurbishment of the building's architectural elements but must also be an opportunity to rethink the issues related to the type of heating or cooling systems, the measurement of comfort and consumption parameters as well as the in-situ production and self-consumption of renewable energy.

The EPIQR method, a result of a previous European project, which has been used to diagnose thousands of buildings over the last decades, has been upgraded in the framework of the PRELUDE project to extend its scope to include these new objectives. On this occasion, the transition from desktop software to a web application was made, to facilitate and extend its use.

In parallel, this task involved investigating the possibility of establishing connections between the EPIQR method and the Smart readiness indicator (SRI) (e.g. the common EU scheme for rating the smart readiness of buildings).

This report starts with a description of the existing EPIQR diagnostic method (structure, coding process, etc.). It then presents the outline of the new web application and describes the list of new technologies that have been implemented in the database. The Swiss case study was used as the main basis for the description of smart actions, and the costs associated with the corresponding works were collected on the basis of recent renovation operations in Switzerland.

The second part of the paper focuses on the evaluation of the SRI assessment and the potential connection with the EPIQR method. The smart readiness comparison of two case studies, located in Poland and in Austria, was done and helped to derive an opinion regarding the assessment of the SRI through the EPIQR method. In particular, the document concludes that at this stage the integration within the EPIQR method is premature as it is not fully adapted to all climatic conditions encountered in Europe. In addition, it was considered that steps should be taken to minimise the element of subjectivity in the evaluator's decisions, in order to reduce the risk of discrepancies in the results from the final assessment.

However, both analyses are complementary in the process of reducing the impact of a building on its environment and increasing its occupant's comfort. This complementarity should be studied in the future steps of the project. Finally, and similarly to the SRI evaluation, the EPIQR costs should also be adapted and validated for the overall European localisations of PRELUDE.

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ABBREVIATIONS

BCC Building Construction Cost Code
BS Built Area
EGID Swiss building indicator
EPIQR Energy Performance, Indoor environmental Quality and Retrofit
EPBD Energy Performance of Buildings Directive
EPFL Swiss Federal Institute of Technology Lausanne
ERS Energy Reference Surface
FSO Swiss Federal Statistical Office
SRI Smart Readiness Indicator
VAT Value Added Tax

1 Introduction

The cost and financial aspect of refurbishments are often the main obstacle to renovating buildings . The "Energy Performance, Indoor environmental Quality and Retrofit" or EPIQR platform was developed to help private or public entities, owners of one or more buildings, in their decision-making scheme, by comparing different renovation scenarios with their corresponding costs.

In addition to the existing costs in the EPIQR software, namely those linked to the diagnosis of architectural (interior and exterior) and technical elements, a non-exhaustive list of expenses needed to make a building smarter are included in the EPIQR web-app. This task of the PRELUDE project actively contributes to the development of the third renovation strategy set by the European Union through the "Energy Performance of Buildings Directive", known as the modernization of all buildings with smart technologies. To do so and to follow up on the intrinsic method of EPIQR, real costs of several smart technologies' implementation in different building's renovation in Europe were collected, studied and integrated. In parallel, the assessment of the "Smart Readiness Indicator" or SRI within the new EPIQR web-app was addressed.

The first chapters concern the overall EPIQR description, starting from its method definition including the diagnosis' structure, elements and costs, to continue with the new EPIQR outline and its innovative functions. Following the new EPIQR presentation, the procedure of updating the database with costs related to smart technologies and its upscaling and verification phases are described in the following two chapters. The SRI assessment study and the utility of its integration in the EPIQR web-app are presented in the last chapter.

2 DESCRIPTION OF THE EPIQR METHOD

2.1 Introduction

EPIQR was born out of a European project on the diagnostic method of a building. It was carried out within the framework of the European program JOULE, between 1996 et 1998, and with the support of the Swiss Federal Office of Education and Science, on the basis of the MERIP method (Wikipédia, 2020), and has made it possible to develop a software with multiple functions:

- To evaluate the state of deterioration of the building from a complete and rapid diagnosis which constitutes the starting point of any rehabilitation operation.
- To establish works proposals that consider not only the rehabilitation of the building but also the improvement of its energy performance through the thermal quality of the envelope and the modernization of the technical installations as well as the improvement of the interior quality of the housing.
- To estimate the costs corresponding to these works.
- To estimate the probable evolution of the degradation of the components if none of the works were carried out as well as the evolution of the cost of the rehabilitation which would result from it.

In 2009, the EPFL in collaboration with the Swiss companies ESTIA SA and EPIQR Rénovation developed EPIQR+, a version allowing the assessment of all types of building uses (unlike EPIQR, which is only intended for residential buildings) (Wikipédia, 2021).

EPIQR+, or the most recent version of EPIQR, is therefore a technical-financial planning tool for the renovation of all types of buildings and allows the client to determine the options to be taken between various possible intervention scenarios. Before completing the diagnosis and in order to collect the data necessary for its evaluation, a complete and systematic tour of the building according to an itinerary that reviews all its components and identifies problems, is at the minimum necessary and is an integral part of the MERIP method.

The EPIQR diagnosis method is addressed to any person or organization involved in the renovation of buildings or managing a real-estate property, especially architects and engineers, homeowners' associations, housing cooperatives, real estate agencies or experts' offices and it is widely used in Germany, Switzerland and France where it has been used to diagnose thousands of buildings.

2.2 Structure of the building

Elements: In order to establish the diagnosis of the physical and functional state of deterioration as well as the estimate of the cost of the restoration work, the building is broken down into elements. These elements correspond to groups of components or chains of components, ensuring the same unit of function, for example, the element "Exterior walls".

Types: To apply the method to the entire stock of constructed buildings, types have been defined for certain elements. These are types of execution which can depend on the age, the construction system of the building or the element considered.

For example, the element "Exterior walls" has the following 12 types:

- Plaster,
- Masonry,
- Exposed concrete,
- Ventilated façade,

- Prefabricated concrete elements,
- Stone and imitation veneer,
- Wood or metal cladding,
- Wooden windows, Aluminium windows,
- Curtain wall,
- Light facade between a framework,
- Industrial hall doors.

In some cases, the types can be combined with a percentage assigned to each one of them, representing its overall share of the building.

Then, to have a global vision of the diagnosis, several elements are grouped together to create Macro-elements. For example, the Macro-element "Facades" groups the following elements:

- Exterior walls (including windows),
- Facade decorative element,
- Occultations and solar protections,
- Exterior doors,
- Basement windows,
- Thermal insulation of walls,
- Facade scaffolding.

2.3 Coding principle

To assess the degree of degradation of each element, 4 degradation codes are used:

- State "0": Good condition of the element,
- State "1": Slight deterioration,
- State "2": Advanced deterioration,
- State "3": End of life of the element.

These codes represent the state of physical or functional degradation of each element.

The work to bring the diagnosed elements back to a current standard is associated with 4 distinct codes:

- Code "0": There is no work to be undertaken on the element considered,
- Code "1": Revisions or light refurbishment work is to be expected,
- Code "2": Major repairs or partial replacement are necessary,
- Code "3": Complete replacement of the elements is prescribed.

Improvement options can also be selected, if a modification of the current standard is wanted, whether it concerns the architectural elements, the envelope or the technical installations. As examples, a selection of an improvement option is necessary to transform a plaster façade to a ventilated one or to replace a gas boiler by a wood pellet one.

The priority of intervention on the elements is assessed according to three levels:

- Priority "I": Urgent work to be done within five years,
- Priority "II": Work to be undertaken in the medium term, between five and ten years,
- Priority "III": Maintenance work or costs that can be deferred to the longer term.

The correspondence between the actual condition of an element, the degradation code and the degree of urgency of intervention is the responsibility of the expert carrying out the diagnosis (Epiqr-Rénovation, s.d.).

To summarize the two previous paragraphs, macro-elements are representing different parts of a building: the external architectural elements of a building ("Façades or "Roofs and floors"), the internal ones (with a differentiation between the main and secondary use rooms for example or the circulations) and the technical installations. Their number or selection depends on the client's needs as well as on the building use. These macro-elements are divided into elements themselves consisting of several types. For each selected type (of an element being part of a macro-element being part of the building), there is a cost corresponding to the desired intervention level or to a potential improvement option. The Table 1 below summarizes this EPIQR building structure for the macro-element "Facades" specifically.

Table 1: Summary of the EPIQR building structure for the macro-element "Facades"

Macro-element(s)	Elements	Types
Facades	Exterior walls	Plaster
		Masonry
		Exposed concrete
		Ventilated facade
		Prefabricated concrete elements
		Stone and imitation veneer
		Wood or metal cladding
		Wooden windows
		Aluminium windows
		Curtain wall
		Light façade between a framework
		Industrial hall doors
	Exterior doors	Generic
		Manual wooden or metal doors
		Manual glass doors
		Garage doors
		Automatic doors
		Automatic swing doors

	Occultations and solar protections	Wood or metal shutters
		PVC shutters
		Roller shutters
		Exterior slat blinds
		Exterior fabric blinds
		Internal solar protections
	Façade decorative element	19th century building
		20th century building
	Basement windows	Cellar windows
		Windows with skylight
	Thermal insulation of walls	Absence of thermal insulation
		Existing peripheral insulation
		Lightweight facade
		Internal thermal insulation
		Double wall with air space or insulation
	Façade scaffolding	Façade scaffolding and site facilities

Other elements can also be integrated if present in the building or on its parcel such as “Balconies and loggias” or “Outdoor facilities”.

2.4 Costs and dimensional coefficients

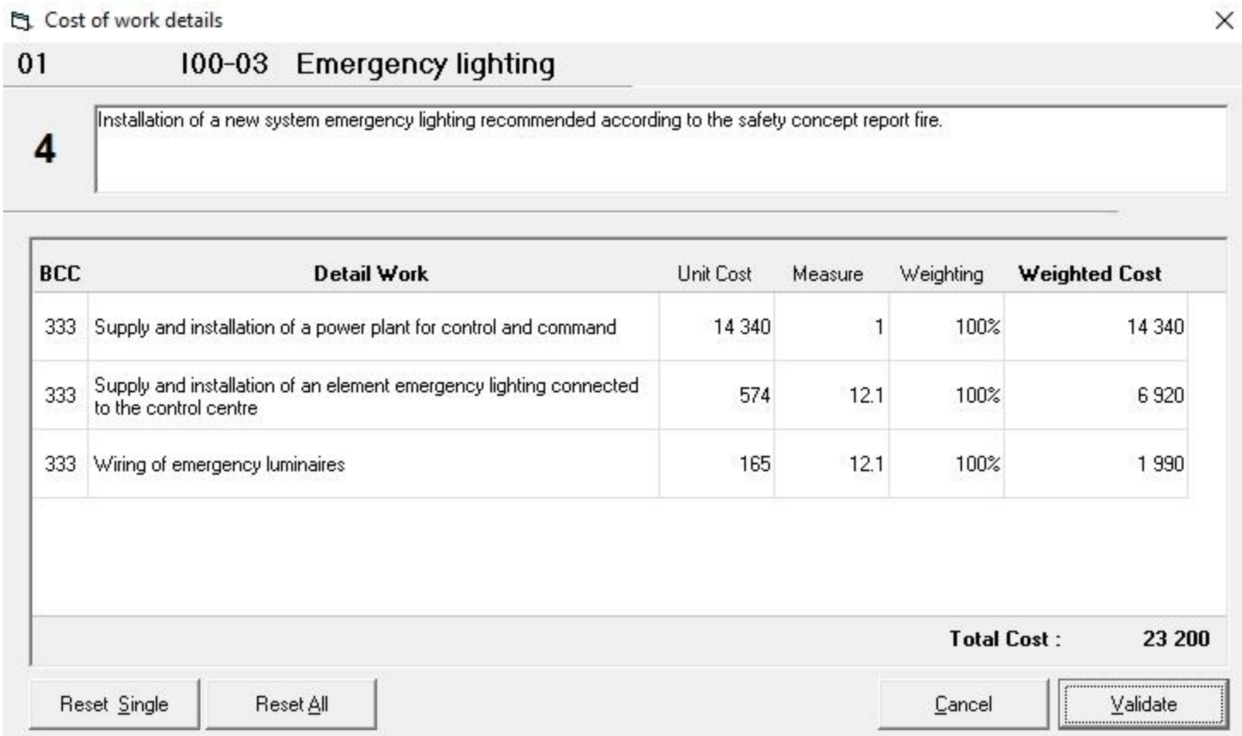
In the EPIQR method, every element type is affected with a degradation state, linked to an intervention level or improvement related cost. Each cost is broken down into several smaller costs, corresponding for each one of them to a component of a nomenclature named Building Construction Cost Code (BCC), allowing to structure in a clear way all the costs generated by a construction project, from its conception to its realization. Every BCC element cost corresponding to a specific work is linked to one quantity survey that was measured or counted in a real building, also named the baseline building, and derived from the total expenses for that work.

For each building use or affectation, a different baseline building, corresponding always to an existing site, was used. The relation between one specific value measured in the baseline building and its corresponding amount in the diagnosed building depends on a dimensional coefficient, that has to be entered in the application by the expert performing the diagnosis.

As an example, in the macro-element "Electricity", there is the type "Centralized power supply" being part of the element "Emergency lighting". The intervention code "4" of this specific type, corresponding to the installation of a new emergency lighting system, has a total cost which is divided into three different parts with their respective costs:

- Supply and installation of a control and command centre,
- Supply and installation of an emergency lighting element connected to the central,
- Wiring of emergency lights.

The interface showing these elements is presented in the Figure 1 below:



BCC	Detail Work	Unit Cost	Measure	Weighting	Weighted Cost
333	Supply and installation of a power plant for control and command	14 340	1	100%	14 340
333	Supply and installation of an element emergency lighting connected to the control centre	574	12.1	100%	6 920
333	Wiring of emergency luminaires	165	12.1	100%	1 990

Figure 1: Different costs of the intervention 4 for "Centralized power supply" type

Each one of these works is linked to a quantity survey and a dimensional coefficient allowing to calculate the corresponding theoretical quantity for the studied building and its derived cost. For the second and third works, costs are based on the measurement "Number of emergency lights" in the baseline building and the dimensional coefficient "Floor area", permitting to calculate the number of emergency lights for the diagnosed building according to its floor area. For the first work, the cost is considered as a fixed price for one building, not depending on any quantity survey or dimensional coefficient.

For the residential baseline building, based in the canton of Vaud in Switzerland, 95 quantity surveys were measured for the architectural elements, respectively 65 for the technical ones, and are part of the EPIQR database. To link these standard values with their theoretical amounts in the studied building, 11 dimensional coefficients are needed and presented as follows:

- 1: Energy reference surface (ERS) (the sum of all floors area of floors and basements that are included in the thermal envelope and whose use requires heating or air conditioning),
- 2: Number of elevator shaft modules,
- 3: Number of dwellings,
- 4: Wall surface against the exterior,
- 5: Windows area,
- 6: Built-up area (BS) (area of land occupied by the building or parts of the building),
- 7: Surface of the landscaped surroundings,
- 8: Floor area,
- 9: Living area,
- 10: Secondary surface (developable floor area that is not included in the energy reference surface),
- 11: Main clearance surface.

Moreover, costs can be updated based on multiple parameters that are also considered as inputs to the diagnosis:

- Percentage allocated to fees,
- Percentage allocated to miscellaneous and contingencies,
- Percentage allocated to VAT,
- Percentage allocated to construction price index,
- Percentage allocated to the complexity of the intervention linked to the access to the site,
- Percentage allocated to the complexity of the intervention linked to working conditions (size of the building and whether or not it is occupied during the work),
- Percentage allocated to the complexity of the intervention linked to the building size (usable surface).

With all its specificities described above, the EPIQR method offers, through the Scenario module, a summary of the entire analysis allowing the expert to generate renovation scenarios according to the client's needs. It is possible to select different renovation actions and generate a financial evaluation of the corresponding work in a short to long-term vision for the investments planning.

3 EPIQR WEB-APP

The increasing need of having access to informatic tools and data as well as the willingness to get closer to the state of the art in terms of interactive interface were the driving forces behind the transition from a software platform to a web application for the EPIQR method. In summary, the following major improvements can be noted:

- Web access,
- Easier navigation in the tool, especially with the merging of the diagnosis and scenarios tabs allowing to directly code the desired interventions in parallel with their respective costs,
- More efficient reporting with a full report directly generated,
- Better design facilitating interactions with the user.

Information defining a building project and its related various contact persons have also been updated. Hence, new useful data can be added such as the construction date of the building, its EGID number, its rating or protection level in the architectural census and even the visit date and a picture of the whole building. This second visualization shows this specific information, where to add them and the page design referring to it:

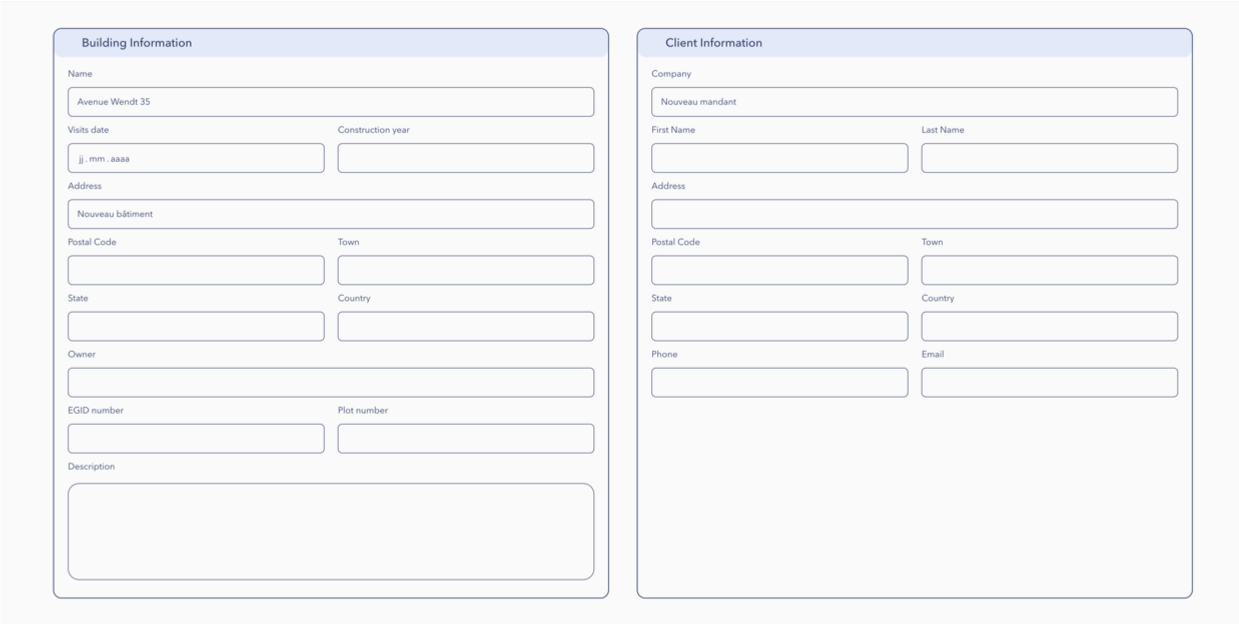


Figure 2: Screenshot of the building information page in the EPIQR web-app

In the web-app and to fit with the vast majority of web applications or website use, the login tab has been added in the top right corner of the screen. In addition, the various tabs representing the different stages of the diagnosis have been transferred from the top of the screen to the left of it. This way, reading all the information can be done more naturally, from the left to the right. Also, to be user-friendly, this web-app limits as much as possible the number of clicks or tabs selections needed to enter a parameter or information. To follow up on the example depicted in Figure 2, one more selection was necessary in the old software version to reach this information page. The screenshot in Figure 3 illustrates the previous design of this same page:

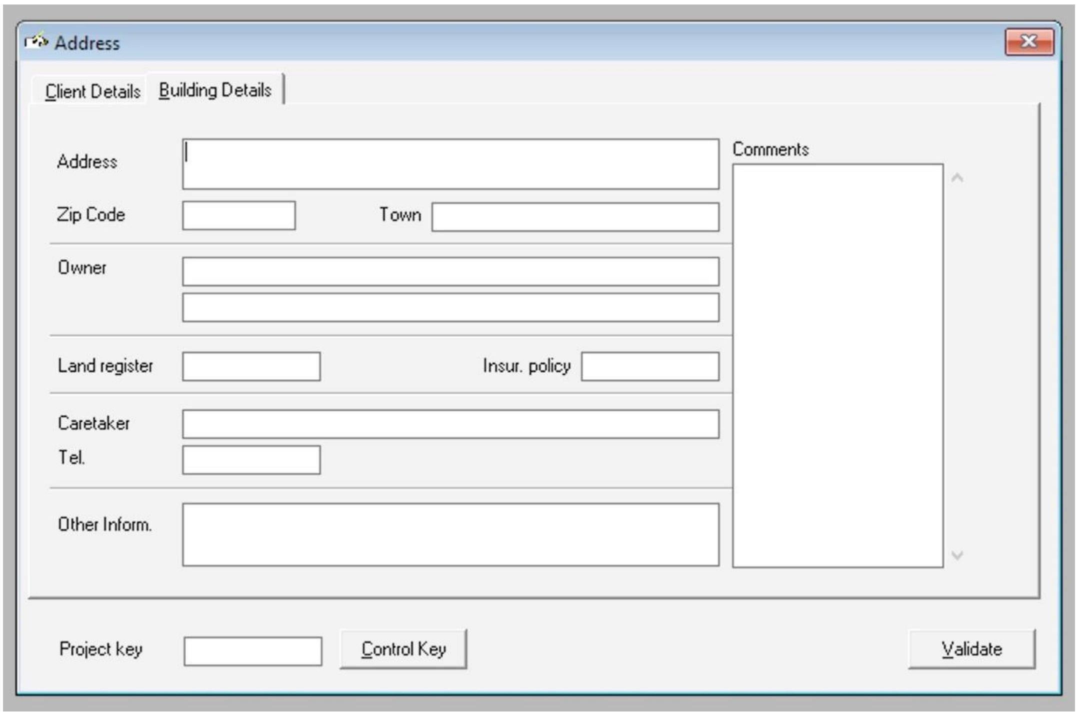


Figure 3: Visualization of the building information's page in the EPIQR software

The user-friendliness of this application does not stop at the design improvements mentioned previously, but enables among other things, a greater speed of use. Indeed, the web version also helps with the core function of the application, i.e. to provide assistance to the expert making the diagnosis, by improving the global architecture of the application. There is now one tab on the left for the building information inputs, another one underneath to enter all the dimensional coefficients and the final two are for creating different renovation scenarios and publishing their results according to the level of information required. The tabs number has been divided by two and the fundamentals data, renovation works and their corresponding costs, can now be assessed together on the same page. After completing the baseline scenario or the first renovation scenario, it is possible to make a second scenario by copying the baseline one and applying some changes directly on the intervention works, their corresponding costs and their priorities. The modified values are made visible by placing coloured icons in front of the referring line. The results, in the form of a pdf report with some possible graphical visualizations are separated from the scenarios creation or "Evaluation" tab. Several levels of results can now be chosen, ranging from simple to full reports. Figure 4 below reflects an example of the visual rendering of the evaluation tab, with three different scenarios being coded:

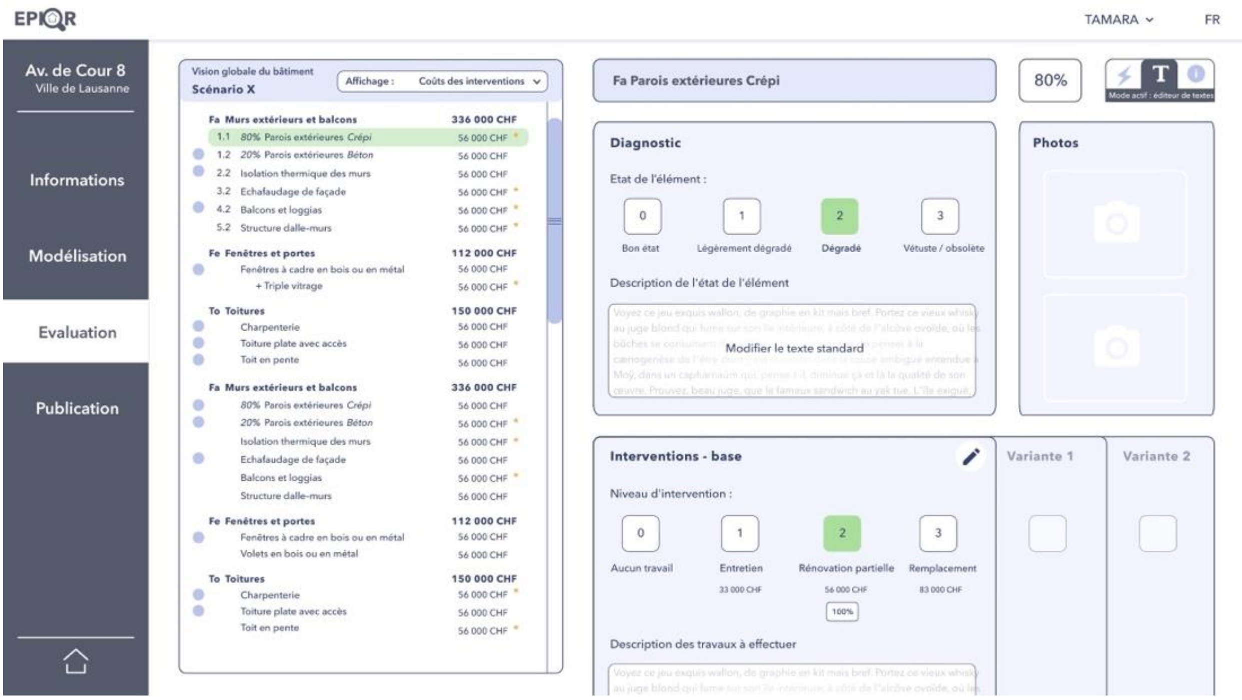


Figure 4: Example of the visual rendering of the "Evaluation" tab

As in the software, some texts can be added to describe in more detail the state of the element type and the work to be carried out. Similarly, pictures can also be integrated in the "Evaluation" tab to help the expert and their client understand to which building part the diagnosis is referring to.

Note that this rendering being part of the mock-up, is currently in French. The web-application is, for the time being, in French and English. Translation into other languages could be done later, in the following phases of PRELUDE. Also, the web version of EPIQR is first targeting housing buildings diagnostics. The addition of the remaining building uses present in the software, such as administrative or industrial ones, will be studied afterwards.

To summarize, the EPIQR web-app is based on the existing method but presents a new design and features helping the expert to diagnose the building more easily and quickly and generates results that should be clearer for the clients. It will be available at the following URL from mid-December 2022: https://epistimmo.ch/. Note that this version will still be in beta until the official release, this implies that the backup of the data will not be guaranteed.

4 UPDATED COST DATABASE

4.1 Methodology

Before collecting data, in particular data regarding the monitoring plan of PRELUDE demo-sites, the first step of this task was to figure out which type of information should be considered as useful. Here, "useful" means both consistent with the desire to promote smart technologies for building modernization and consistent with the functionality offered by the EPIQR method, which has not changed between the software version and the web version.

The EPIQR method allows the generation of renovation costs, defined as a one-time investment considering either labor and/or material costs. Other types of costs, linked to an annual or recurring payment over the building life, such as small maintenance costs, are not taken into account. Thus, only one-time costs can be added to the current database. The monthly financial gains of using electricity produced by a photovoltaic installation, instead of extracting it from the grid, is an example of smart-technology cost that is outside the EPIQR's scope.

Regarding the aforementioned second selection criteria, e.g. the use of smart technologies in reducing carbon emissions and improving energy savings in building stock, only elements associated with a corresponding and reliable cost were chosen as pertinent. Indeed, the main goal of the EPIQRmethod is to estimate the costs of proposed renovation works, so the availability of the cost data of any smart technology is the fundamental prerequisite in deciding whether or not it is going to be added to the database. As expected, the number of data collected, each defined by a new type of technology and its corresponding cost, increases the reliability of the financial element. Thus, to fit with the EPIQR data granularity, only significant costs linked to a smart-technology or equipment installed with sufficient frequency or in other words already on the market are considered.

Then comes the data collecting phase. Based on the monitoring plans of the demo-sites defined in the previous PRELUDE WP2 tasks, a number of costs have been gathered. For the Danish buildings, only the equipment purchasing prices were available, excluding installation costs, as the related sensors and meters were mostly installed in the buildings before the PRELUDE project. Moreover, the majority were referring to building management system, including sensors and peripheral equipment for storing and sharing data and some energy meters. So far, only one source from the demo-sites has provided information related to renewable energy production, storage or distribution equipment, regarding a photovoltaic panel installation with a battery. Hence, to improve the data disparity and their reliability, costs from other European projects or sources previously validated by the office's experience, have been considered as input data for the new technologies in the EPIQR method. The renovation of these building's being for the most part situated in Switzerland, the Swiss cost update factor already in use had to be taken into account and the total cost of each smart technology has been dissected to fit with the EPIQR method structure.

Further work will consist in collecting the remaining costs related to the monitoring plans for PRELUDE's demo-sites , to first verify the already implemented smart-technology costs in the EPIQR database and then confirm the cost-conversion factors between Swiss and other European country currencies at a certain period.

4.2 New elements

In terms of the market in Switzerland, there were in 2020 more than seven thousand buildings equipped with lithium-ion batteries (OFEN, s.d.), a few thousand with energy optimization contracts and only a few hundred with self-consumption communities. Renewable heat production systems such as heat pumps are already well established with 300,000 items inventoried at the end of this same year (BKW, 2021). Replacing former manual valves and rebalancing the hydraulic system of a building are improvements that have been made for many years, similarly to the implementation of a global technical management. In September 2020 in Switzerland, the number of charging stations for electric vehicles was roughly equal to 5,000 (TCS, 2020), making the usefulness of all the technologies mentioned in building energy efficiency an already validated criterion.

The concept of cost-conversion factors mentioned in the methodology makes it possible, by introducing a construction price index (see paragraph 2.4 Costs and dimensional coefficients), to update the diagnosis costs in relation to a price reference defined for a given period and location. For the actual EPIQR method, the reference price corresponds to value 100 and is based on October 1998 Swiss construction cost. To diagnose a building renovation today in Switzerland and more especially in the Lake Geneva region, the FSO construction price index of 154 as to be introduced, corresponding to the April 2022 data released (OFS, 2022).

Based on this index and on the available smart equipment costs for actual Swiss projects, the following table was derived:

Table 2: Smart technology elements and costs updates according to the EPIQR method structure

Macro-element	Element	Type	Denomination	Work	Work unit	Cost	DC*	DC unit
Heating	Heat production	Oil or gas boiler	Abandonment of fossil fuels: installation of an air-water heat pump (+27% on the cost related to the power to be taken into account for a water-water heat pump)	Dismantling of the existing installation, removal of the base (fixed price based on one day with a worker and a helper)	U	1386	Unitary	1
				New air-water heat pump (+27% for a water-water heat pump)	kW	1294	ERS energy reference surface	m^2
Heating	Heat production	Oil or gas boiler	Abandonment of fossil fuels: creation of a substation and connection to district heating	Dismantling of the existing installation, removal of the base (fixed price based on one day with a worker and a helper)	U	1386	Unitary	1
				Installation of a new substation	kW	246	ERS energy reference surface	m^2
				Connection of the substation to the district heating network	kW	195	ERS energy reference surface	m^2
Heating	Heat production	Oil or gas boiler	Abandonment of fossil fuels: installation of a wood heating system (wood chips or pellets)	Dismantling of the existing installation, removal of the base (fixed price based on one day with a worker and a helper)	U	1386	Unitary	1
				New wood chip boiler	kW	1146	ERS energy reference surface	m^2
Heating	Heat production	Oil or gas boiler	Partial abandonment of fossil fuels with 30% of DHW production produced with a heat pump (if replacing the boiler in parallel, take into account 85% of the costs related to the total power)	Installation of a heat pump to produce part of the domestic hot water	kW	194	ERS energy reference surface	m^2

Heating	Domestic hot water	Central boiler with heat exchanger	Installation of a heat pump with heat recovery to produce part of the domestic hot water	Installation of a heat pump with heat recovery to produce part of the domestic hot water	kW	194	ERS energy reference surface	m^2
Heating	Heat distribution	Apparent heat distribution	Change of circulation pumps or addition of hydro ejectors	Change of circulation pumps or addition of hydro ejectors	U	3506	Unitary	1
Heating	Heat emitters	Radiators - Housing	Hydraulic balancing	Hydraulic balancing with calorimetry per room	U	12857	Unitary	1
Heating	Heat emitters	Radiators - Housing	Supply and installation of thermostatic valves, purging of the network	Supply and installation of thermostatic valves, purging of the network	U	125	ERS energy reference surface	m^2
Heating	Heat emitters	Radiators - Housing	Remove radiators and replace heating elements, fittings and valves. Filling and bleeding.	Remove radiators and replace heating elements, fittings and valves. Filling and bleeding	U	1257	ERS energy reference surface	m^2
Heating	Control for heating	Control	Implementation of an energy optimization contract with sensors	Implementation of an energy optimization contract with sensors	U	3896	Unitary	1
Heating	Control for heating	Control	Implementation of an energy optimization contract without sensors	Implementation of an energy optimization contract without sensors	U	1364	Unitary	1
Heating	Control for heating	Control	Installation of energy meters	Installation of energy meters	U	2922	Unitary	1
Heating	Control for heating	Control	Implementation of a technical management of the building	Implementation of a technical management of the building	U	22727	Unitary	1
Electricity	Light fixtures	Light fixtures	Installation of presence detectors in the common areas	Installation of presence detectors in the common areas	U	1591	Unitary	1
Electricity	Photovoltaic panels	Photovoltaic solar panels	Establishment of a group of self-consumption	Establishment of a group of self-consumption	U	714	Number of dwellings	U
Electricity	Photovoltaic panels	Photovoltaic solar panels	Addition of storage elements (battery or inertia wheel)	Addition of storage elements (battery or inertia wheel)	U	77	BS Built-up area	m^2
Electricity	Photovoltaic panels	Photovoltaic solar panels	Installation of charging stations for electric vehicles	Installation of charging stations for electric vehicles	U	1623	Number of dwellings	U

*Dimensional coefficient

The mentioned costs refer to the baseline value 1.00 for October 1998 Swiss costs. They originate from actual renovation costs to which the 1.54 April 2022 ratio was applied. Furthermore, to make these standard works correspond to a specific renovation project, the three-dimensional coefficients brought up (the energy reference surface, the number of dwellings and the built-up area) would have to be calculated and entered in the EPIQR platform. Note that “Unitary” refers to the entire building and not to a specific part of it. This way, the actual renovation costs will be derived from the baseline costs, the list of works and their link with the dimensional coefficients based on the baseline building quantity surveys.

As an example, the use of the interface (and EPIQR method) step by step to enter the last data of the Table 2 in a diagnostic, related to a photovoltaic installation and its connected charging stations, is explained and depicted below. Since the new design is currently being developed, the old interface is shown instead:

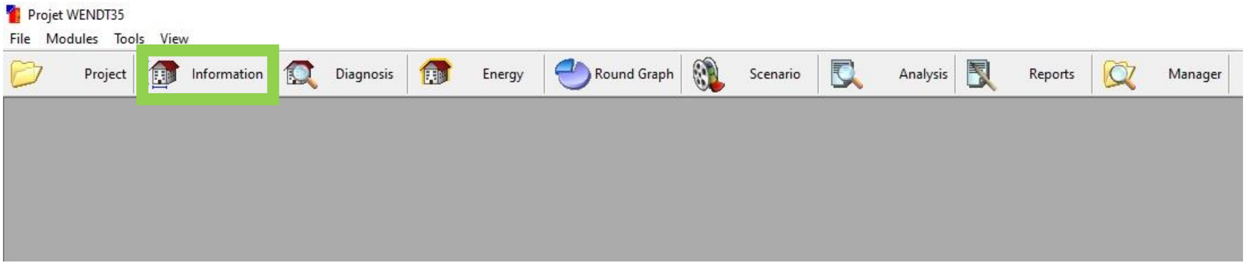


Figure 5: STEP 1 – Selection of the “Information” tab

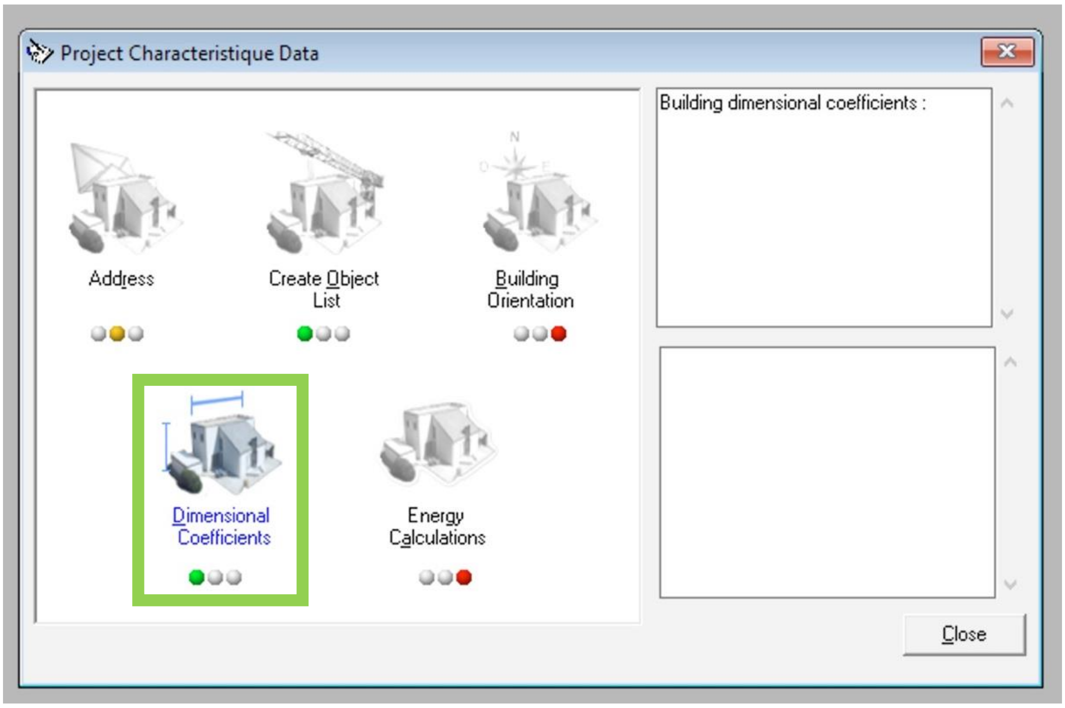


Figure 6: STEP 2 – Selection of the Dimensional Coefficients element and filling of these

If the building renovation we want to check the costs or diagnose is for example the demo case in Geneva, its energy reference surface that must be inputted is 3,485 m^2 and 58 is its number of dwellings. Cells in the second tab named "Cost coefficients" must also be filled out, with 1.54 being the actual factor price (released in April 2022).

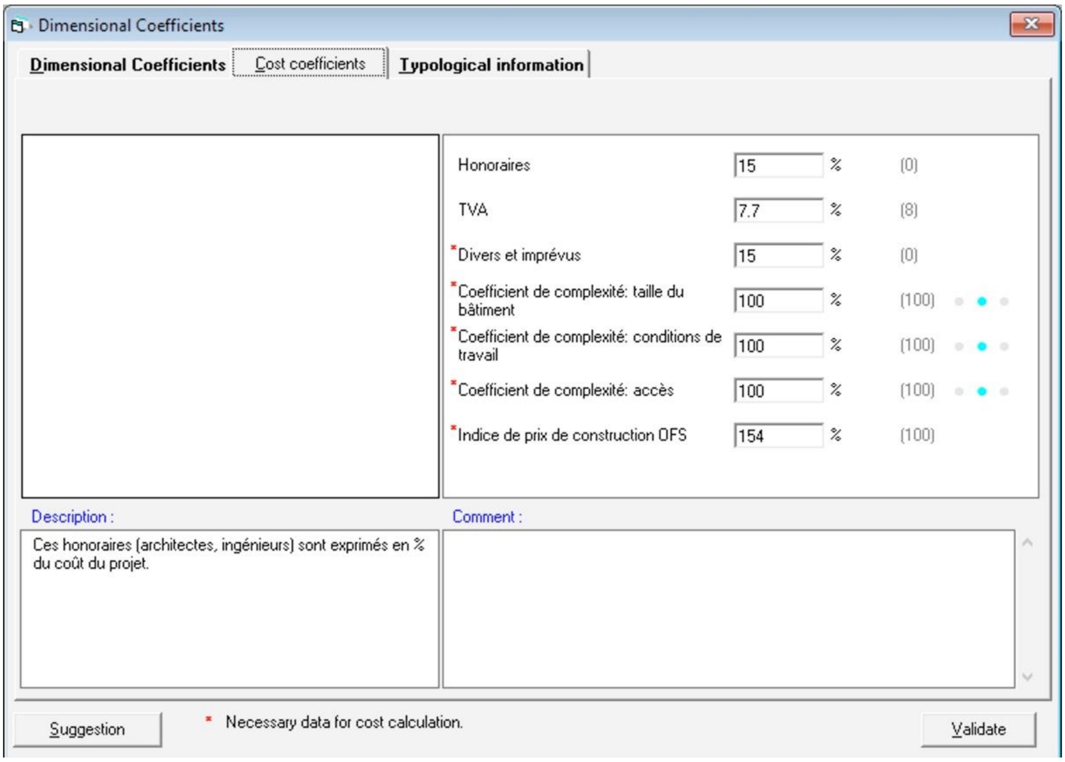


Figure 7: STEP 3 - Selection of the "Cost coefficients" tab, filling of these and closing the window

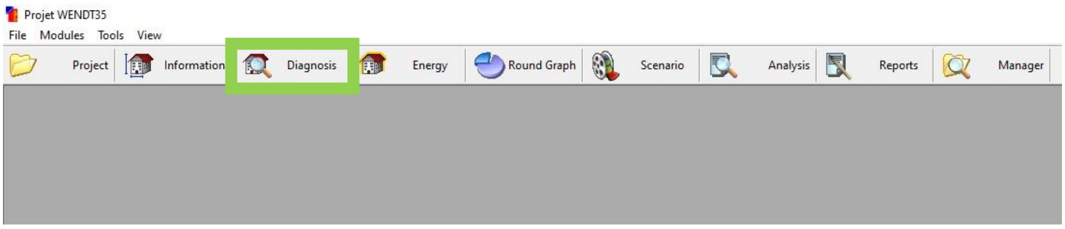


Figure 8: STEP 4 – Selection of the "Diagnostic" tab

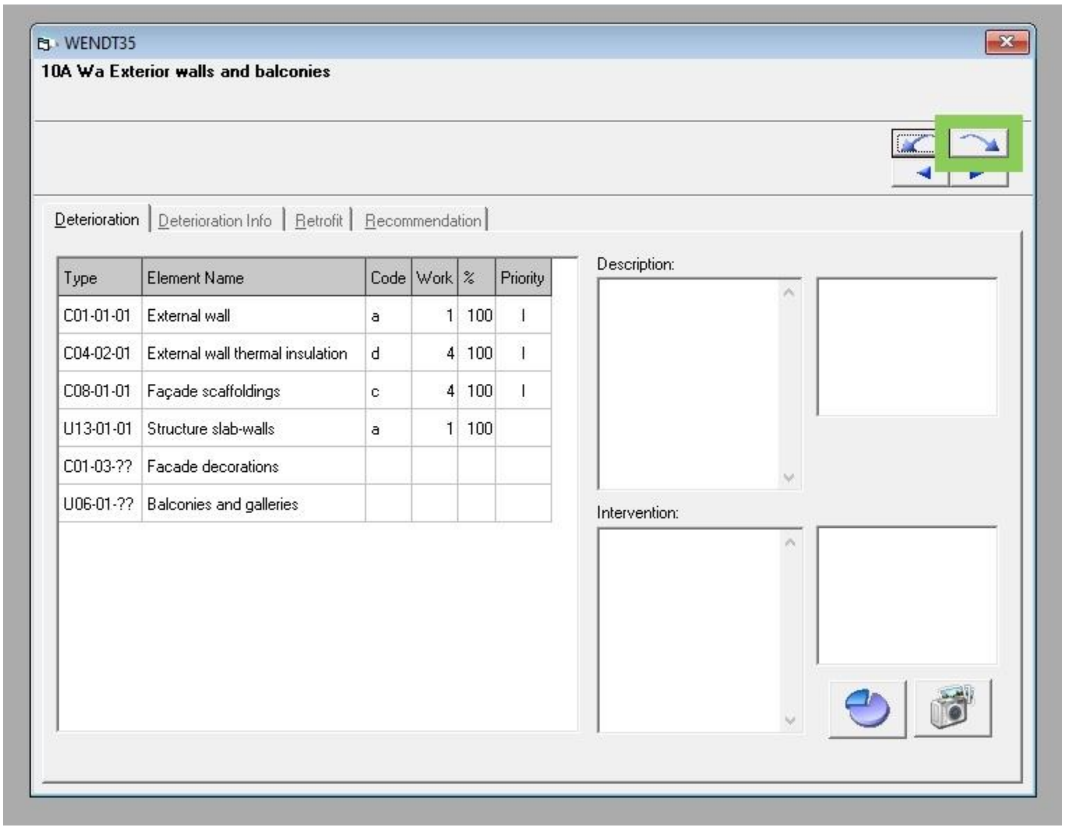


Figure 9: STEP 5 – Selection of the macro-element "Electricity" by clicking several times on the big arrow at the right

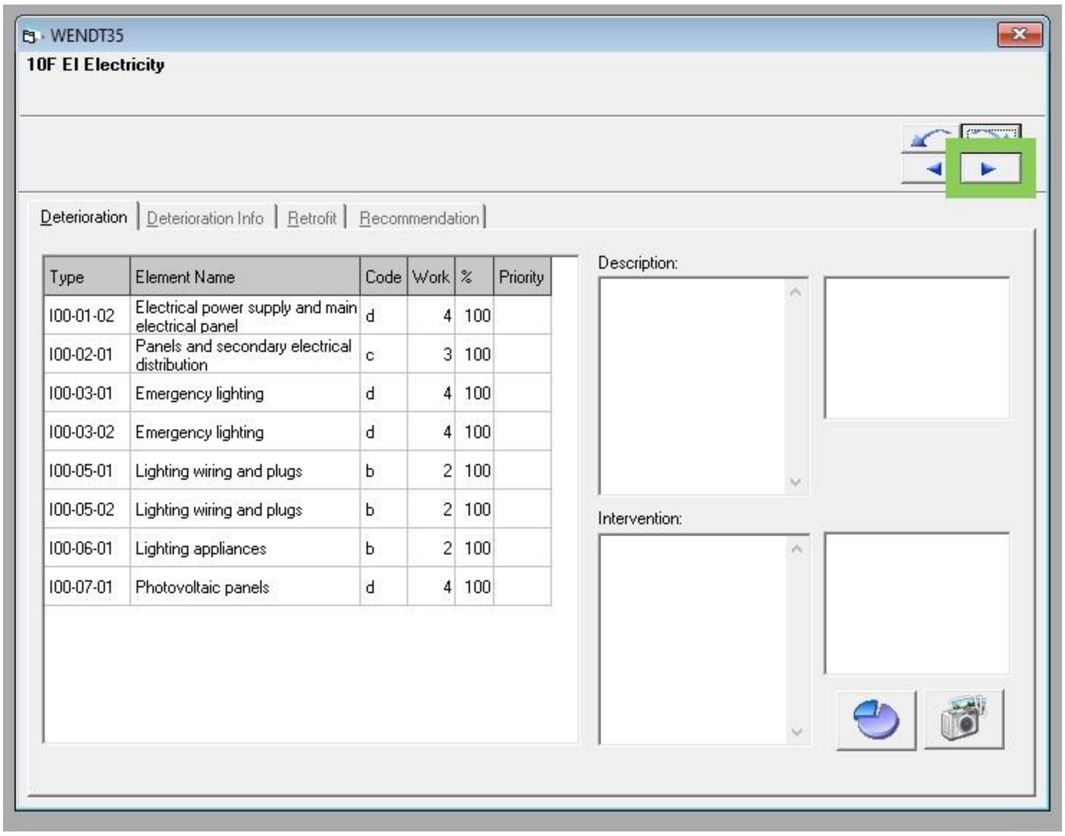


Figure 10: STEP 6 – Selection of the element "Photovoltaic panels" by clicking several times on the small arrow on the right

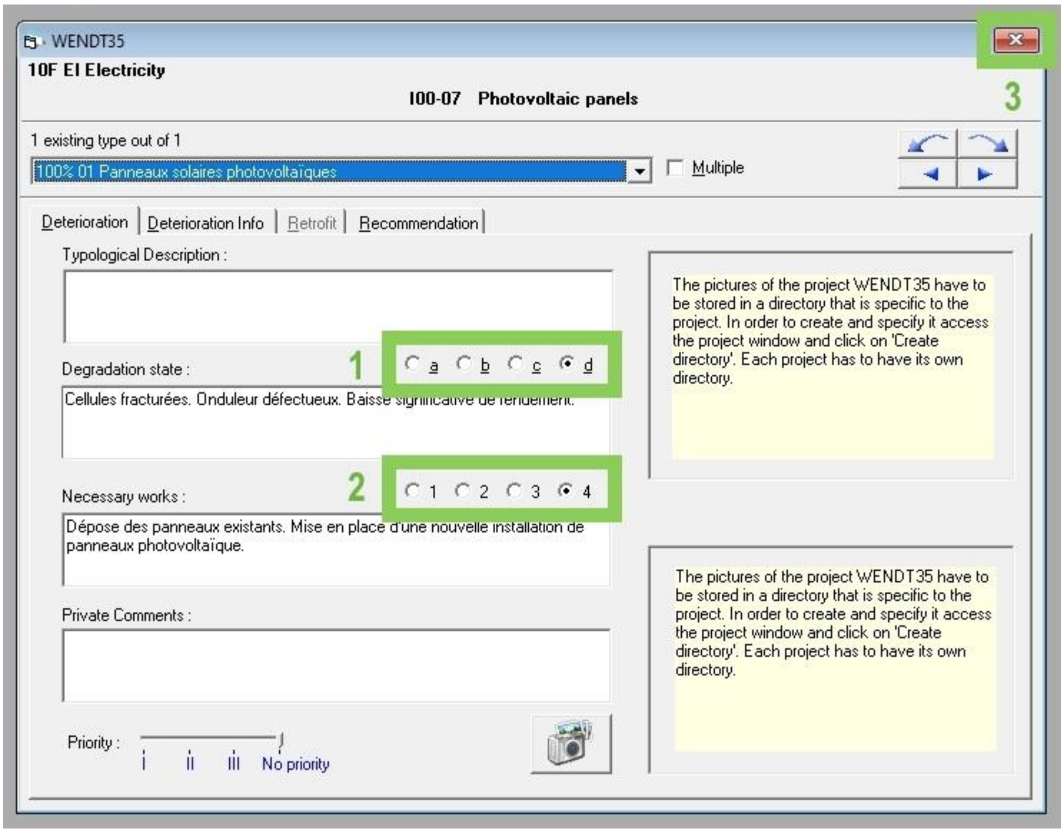


Figure 11: STEP 7 – Selection and description of the degradation state and necessary works for the PV installation and closing of the window

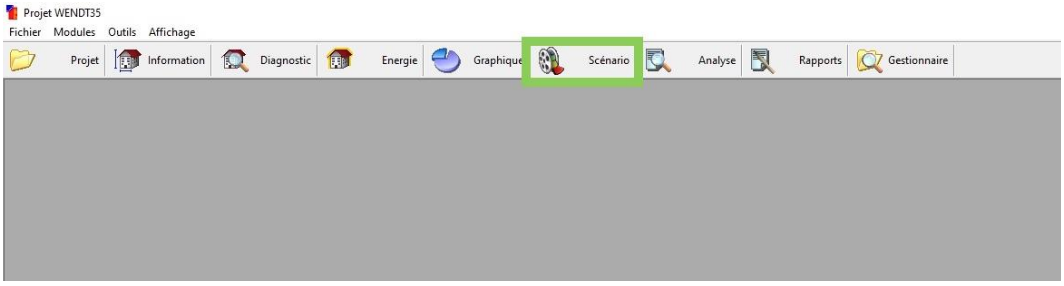


Figure 12: STEP 8 – Selection of the "Scenario" tab and repetition of steps 5 & 6

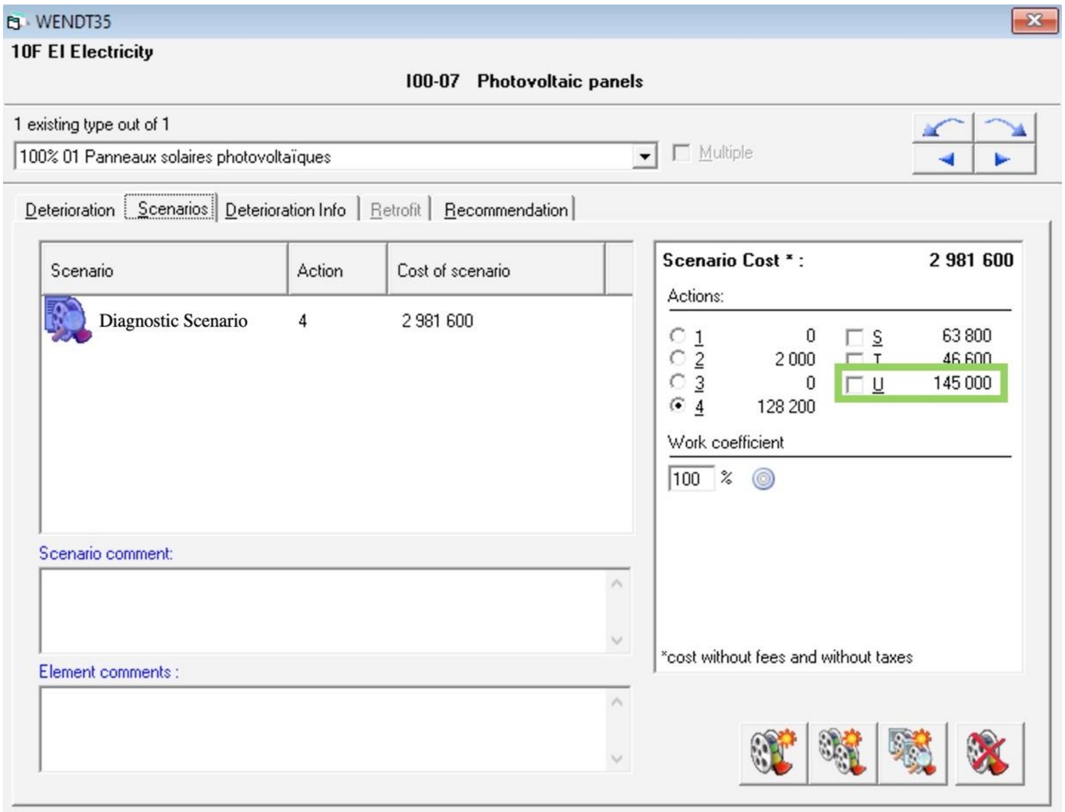


Figure 13: STEP 9 – Selection of the improvement action linked to the installation of charging stations for electric vehicles

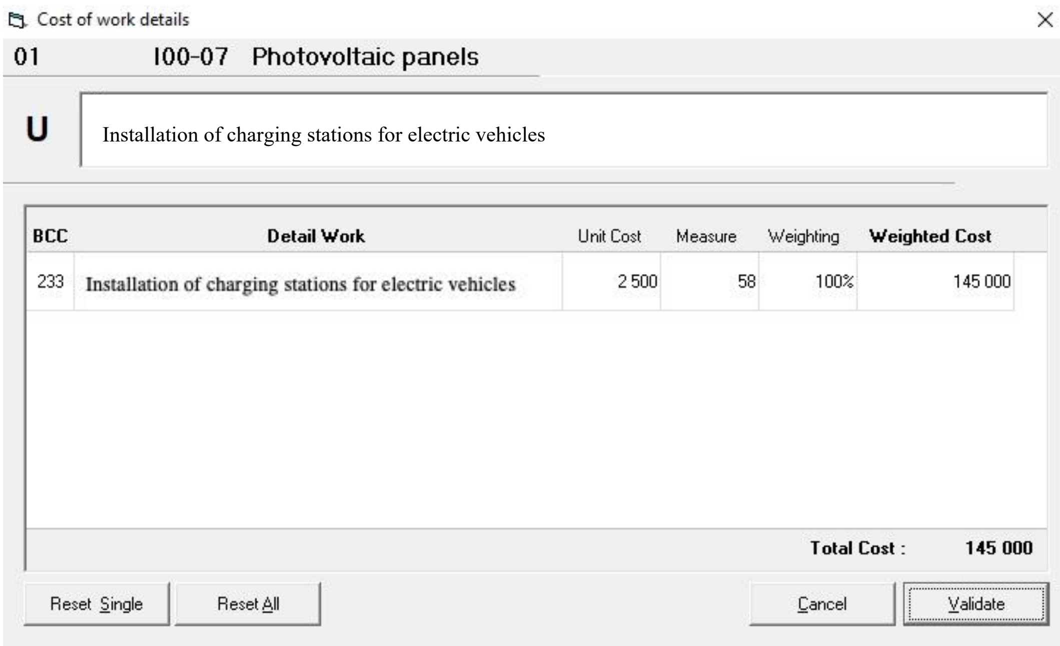


Figure 14: Cost details of the installation of charging stations for electric vehicles

In the Figure 14 above, the cost for one charging station is 2’500.- (corresponding to the unitary cost of 1’623.- shown in the Table 2 multiplied by the actual price factor of 1.54). The number in the “Measure” cell corresponds here to the dimensional coefficient used, knowing the number of dwellings for the Geneva case study building. The cost from the database has not been modified (weighting of 100%) and the total cost of this action is equal to: 2’500 x 58 = 145’000.-, as mentioned in the last cell. For other smart actions, several works can be described linked to different dimensional coefficients, with one line for each of them.

As another example, the total cost of the first action, knowing the installation of an air-water heat pump, is divided into two different works. The first one corresponds to a fixed price based on one day’s work with two persons (1’386 x 1.54 ≈ 2’130.-) and is independent of the building size (“Unitary” in the DC cell). The second cost is for the material and is linked to the heat pump power (in the “Measure” cell) through the dimensional coefficient energy reference surface. To be more precise, the heat pump power is derived from the standard power (100 kW) observed for the baseline building and based on its energy reference surface (1’500 m^2). Thus, the second cost is then equal to: 100 x 3’485/1’500 x 1’294 x 1.54 = 463’000.-. The Figure 15 shows the graphical interface corresponding to this cost detailing.

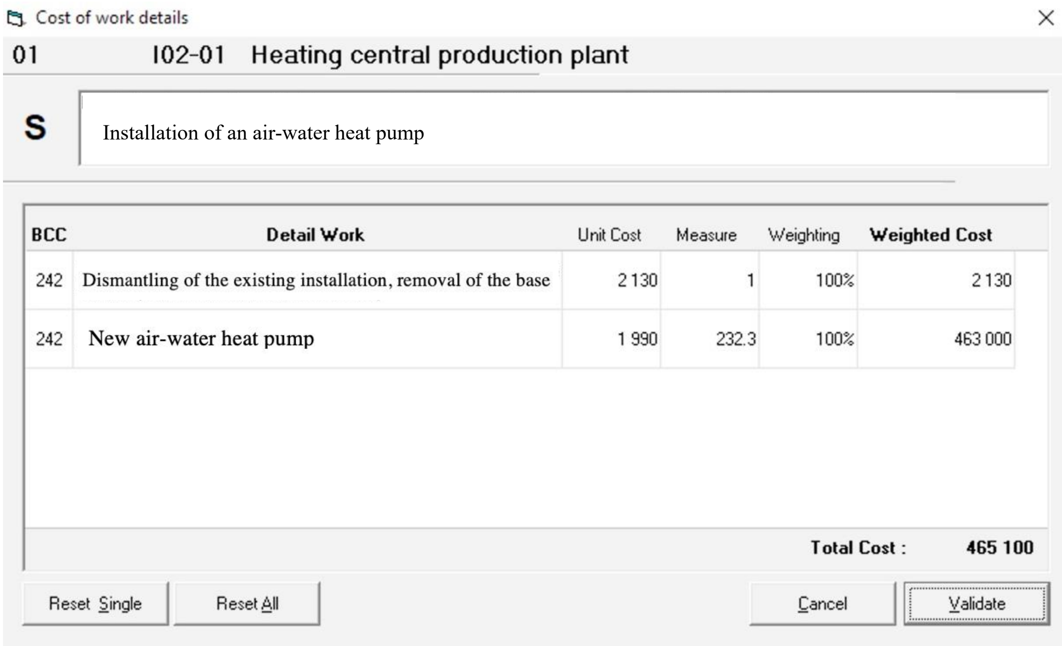


Figure 15: Cost details of the installation of an air-water heat pump

In the new interface, all these previous steps can be done entirely in the “Modelization” and “Evaluation” tabs, as depicted by the Figure 4, and the cost method calculation stay the same.

5 SMART READINESS INDICATOR (SRI)

5.1 Introduction

5.1.1 Development and launching

The EU has recently established a legislative framework aiming to increase the energy performance of buildings, which includes the Energy Performance of Buildings Directive (EPBD) 2010/31/EU and the Energy Efficiency Directive 2012/27/EU. These frameworks aim to promote policies oriented to a decarbonized and energy efficient building stock by 2050 through the creation of a stable environment for investment decisions. Furthermore, the European Commission introduced a proposal for the revision of the directive in December 2021 (COM2021, 802 final), which reflects reassessed and increased ambitions concerning climate and social action (European Commission, 2021). The revised directive aims, among other things, to support the digitalization of energy systems for buildings in order to reach the EU target of at least 60% emissions reduction by 2030, in comparison with 2015 values, for the building sector and climate neutrality by 2050. Smart technologies in buildings have been identified as cost-effective means to achieve lower energy consumption, reduced carbon impact, healthier and more comfortable living conditions, as well as to facilitate renewable energy integration. The EPBD has been particularly focused on the exploitation of smart technologies in the building sector by setting provisions to establish a «Smart Readiness Indicator» (SRI) as a tool to measure the smart readiness of buildings.

In this context, the European Commission services (DG ENERGY) commissioned two studies aiming to provide technical support in order to create a common methodology and potential implementation pathways concerning the SRI (Fokaides, et al., 2020). First, a technical study aiming to support the establishment of the SRI was launched in March 2017 and was conducted by a consortium consisting of VITO NV, Waide Strategic Efficiency, Ecofys and Offis. Subsequently, in 2018, the SRI was introduced as an optional scheme in the revision of the EPBD. The amending directive (2018/844/EC) (European Union, 2018) provides guidance on a wide range of policies concerning the improvement of the European building stock and their energy performance, including a scheme for assessing the smart readiness of buildings. Specifically, the directive set specific requirements regarding building automation and control systems, as well as systems that regulate indoor temperature and consider air quality and ventilation, while addressing user health and well-being (European Commission, 2022). According to (European Union, 2018), the SRI should be used to measure a given building's capacity of using information and communication technologies, as well as electronic systems, in order to improve its energy efficiency and overall performance. Moreover, the SRI should measure the building's capacity of utilizing the aforementioned technologies to adapt the building's operation to the occupants' and the grid's needs. Specifically, the SRI must cover individual smart features that enhance energy savings, flexibility, benchmarking, and improved functionalities stemming from numerous interconnected and intelligent devices. The proposed features cover a wide range of technologies, such as smart meters, devices for the regulation of indoor air temperature, building automation and control systems, electric vehicles charging spots, energy storage systems etc.

Moreover, a second technical study, which further developed the available knowledge in order to deliver the technical inputs needed and to refine and finalize the SRI definition and calculation methodology (Fokaides, et al., 2020), was conducted by VITO NV and Waide Strategic Efficiency during December 2018 to June 2020 (European Commission, 2020). The second study resulted in the development of two SRI assessment methods, as well as the introduction of a third one for future development. Specifically, Method A was defined as a simplified method suitable for residential and small-scale buildings based on a reduced services catalogue, while Method B was defined as a detailed assessment based on an enriched service list, which is mainly addressed to non-residential buildings and can be performed by the user in addition to the third-party assessment. Concerning the third method, it was only introduced for future development and will concern a metered/measured method. Relevant stakeholders participated throughout the entire study through open public consultations, feedback provision, and the testing of the beta version of the calculation methodology, which resulted in 112 assessments. (Fokaides, et al., 2020).

Finally, the European Commission (EC) composed in 2021 an SRI support team which was awarded a two-year service contract to provide technical assistance to the EC and Member States during the testing and implementation phases of the SRI. The SRI support team comprised of VITO (Belgium), Waide Strategic Efficiency Europe (Ireland), Research to Market (R2M) Solution (France) and the Luxembourg Institute of Science and Technology (LIST). In summary, the history of the SRI is presented in Figure 16. Currently, the decision to implement the SRI belongs to EU Member States and formal SRI assessments can be conducted only in the case where a government decides to make the process mandatory. The methodology can be unofficially implemented by private or research stakeholders, who can also participate in relevant discussions as well as to conduct informal SRI-related activities. However, no formal SRI certifications can be issued without prior approval of the Member State.

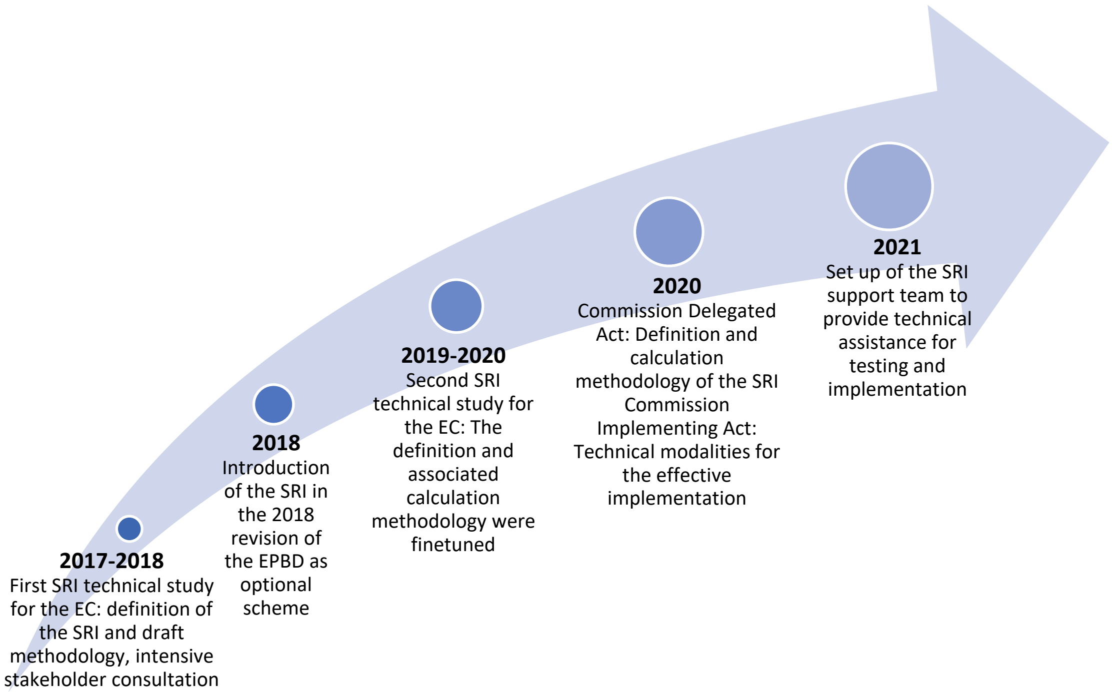


Figure 16: History of the SRI (European Commission, 2022)

5.1.2 Overview of the SRI scoring methodology

The main step of the SRI assessment process, and perhaps the most important one, is the selection of the applicable services, namely the triage process. The latter, combined with the potential subjectivity of the assessor's choices, is identified as a major contributor to the final SRI score of the assessed buildings (Apostolopoulos, et al., 2022); (Becchio, et al., 2021); (Varsami & Burman, 2021); (Fokaides, et al., 2020); (Vigna, et al., 2020); (Janhunen, et al., 2019). The proposed SRI methodology builds on the assessment of the smart ready services which are present in a building and in order to support this, two catalogues of smart ready services have been compiled, i.e., a simplified catalogue of 27 services (assessment Method A) and a detailed catalogue of 54 services (assessment Method B). Table 3 summarizes the smart ready services included in each assessment method.

Table 3: Summary of smart ready services included in simplified (A) and detailed (B) service catalogues

Code	Smart ready service	A	B
H-1a	Heat emission control	×	×
H-1b	Emission control for TABS		×
H-1c	Storage and shifting of thermal energy	×	×
H-1d	Control of distribution pumps in networks		×
H-1f	Thermal Energy Storage (TES) for building heating		×
H-2a	Heat generator control (all except heat pumps)	×	×
H-2b	Heat generator control (for heat pumps)	×	×
H-2d	Sequencing in case of different heat generators		×
H-3	Report information regarding heating system performance	×	×
H-4	Flexibility and grid interaction		×
DHW-1a	Control of DHW storage charging	×	×
DHW-1b	Control of DHW storage charging	×	×
DHW-1d	Control of DHW storage charging (with solar collector)		×
DHW-2b	Sequencing in case of different DHW generators		×
DHW-3	Report information regarding domestic hot water performance	×	×
C-1a	Cooling emission control	×	×
C-1b	Emission control for TABS (cooling mode)		×
C-1c	Control of distribution network chilled water temperature		×
C-1d	Control of distribution pumps in networks		×
C-1f	Interlock: avoiding simultaneous heating and cooling		×
C-1g	Control of Thermal Energy Storage (TES) operation		×
C-2a	Generator control for cooling	×	×
C-2b	Sequencing of different cooling generators		×
C-3	Report information regarding cooling system performance	×	×
C-4	Flexibility and grid interaction	×	×
V-1a	Supply air flow control at the room level	×	×
V-1c	Air flow or pressure control at the air handler level		×
V-2c	Heat recovery control: prevention of overheating		×
V-2d	Supply air temperature control at the air handling unit level		×
V-3	Free cooling with mechanical ventilation system		×
V-6	Reporting information regarding IAQ	×	×
L-1a	Occupancy control for indoor lighting	×	×
L-2	Control artificial lighting power based on daylight levels		×

DE-1	Window solar shading control	×	×
DE-2	Window open/closed control, combined with HVAC system		×
DE-4	Reporting information regarding performance of DE	×	×
E-2	Reporting information regarding local electricity generation	×	×
E-3	Storage of (locally generated) electricity	×	×
E-4	Optimizing self-consumption of locally generated electricity		×
E-5	Control of combined heat and power plant (CHP)		×
E-8	Support of (micro)grid operation modes		×
E-11	Reporting information regarding energy storage	×	×
E-12	Reporting information regarding electricity consumption	×	×
EV-15	EV Charging Capacity	×	×
EV-16	EV Charging Grid balancing	×	×
EV-17	EV charging information and connectivity	×	×
MC-3	Run time management of HVAC systems		×
MC-4	Detecting faults of technical building systems and providing support to the diagnosis of these faults		×
MC-9	Occupancy detection: connected services		×
MC-13	Central reporting of TBS performance and energy use	×	×
MC-25	Smart Grid Integration	×	×
MC-28	Reporting information regarding demand side management performance and operation		×
MC-29	Override of DSM control		×
MC-30	Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather, and grid signals	×	×

In order to proceed with the building's SRI assessment, the assessor must identify the smart ready services which are applicable to the building and define their functionality levels. The service triage method that is proposed in the SRI guidelines (European Commission, 2020), aims to identify the services that are not applicable to the building in order to exclude them from the assessment. However, besides the assessed services, the triage process significantly influences the interpretation of the results. Specifically, every omitted service decreases the maximum attainable score and subsequently increases the final SRI score, ultimately complicating the comparability of the SRI scores among different buildings (Janhunen, et al., 2019). The SRI framework recommends excluding irrelevant services from the assessment (triage method A), although different triage methodologies were also developed and are available in the relevant literature. Specifically, (Janhunen, et al., 2019) proposed two additional triage methodologies, the first of which (triage method B) represents a compromise between the maximum relevance of a given property and the maximum comparability between different properties. In the context of triage method B, overlapping services are excluded from the assessment, although when there is more than one service listed for a specific function, it is suggested to assess only the service relevant to the property. Through the implementation of the aforementioned methodology, a compromise between comparability and relevance is achieved, and while the maximum possible SRI scores will vary, properties won't be awarded a penalty for having only one service for a given category. Furthermore, the second additionally developed triage process (triage method C) pertains to the selection of all services. Specifically, all services are selected as available and, in the cases where a specific service is not implemented for the property, its functionality level is set to zero. This triage methodology poses the most radical approach in order to achieve maximum comparability between different properties, considering the maximum attainable score is the same for all cases. However, it is mentioned that after implementing triage method C, the assessed level of smart readiness is expected to be lower in comparison to triage process A, due to the increased number of applicable services. Finally, the major disadvantage of triage process C is identified as the provision of an unrealistic image concerning the current smart readiness level of a given building, as services that are not applicable within the building are taken into account. The aforementioned triage methods are summarized in Table 4.

Table 4: The triage methods for selecting the applicable services in the case buildings (Janhunen, et al., 2019)

Method	Description	Rationale
A	Only relevant services are selected. If the property does not have a particular service, it is excluded from the assessment.	Maximum relevance for a property. The final score reflects the smart readiness of existing services considering that some services are not applicable in all properties.
B	Overlapping services are excluded. When there is more than one service listed for the same function, only the services relevant for the property are assessed.	Compromission between comparability and relevance. The maximum attainable scores will vary slightly, but properties are not awarded a penalty for having only one service per category.
C	All services are selected. If a service is not implemented for the property, its functionality level is set to zero.	Maximum comparability between properties, as the maximum attainable score remains constant.

The SRI should be implemented in order to assess the building's capacity of using information and communication technologies to adapt its operation to the needs of the occupant and the grid, ultimately aiming to improve energy efficiency and overall performance. In this context, a wide range of features must be covered, including energy enhancement, energy savings, benchmarking, flexibility, and improved functionalities, stemming from improved interconnection and intelligent devices installation. Features to be covered pertain to smart meters, building automation and control systems, indoor air temperature regulation devices, electric vehicle (EV) recharging spots, energy storage etc., while also considering their interoperability (European Union, 2018).

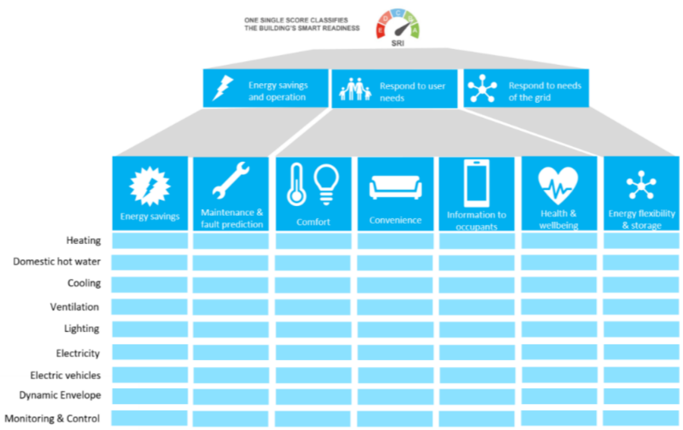


Figure 17: Proposed structure of domains and impacts criteria

The SRI methodology must rely on three key functionalities concerning the building and its technical systems, namely (1) the ability to maintain energy performance and operation by adapting its energy consumption (e.g., using energy from renewable sources), (2) The ability to adapt its operation mode according to the occupant's needs, while maintaining healthy indoor climate conditions, user-friendliness, and the ability to report energy use, (3) The flexibility of electricity demand, including the ability to enable participation in active and passive, as well as implicit and explicit demand response in relation to the grid (e.g., flexibility and load shifting capacities).

These three key functionalities are further divided into a set of seven criteria, but the individual criteria scores can be aggregated along the three functionalities. The seven impact criteria are:

(1) Energy savings on site,
(2) Flexibility for the grid and storage,
(3) Comfort,
(4) Convenience,
(5) Well-being and health,
(6) Maintenance and fault prediction, and
(7) Information to occupants.

Furthermore, the services of the SRI service catalogue are categorized in nine main technical domains, namely (1) Heating, (2) Cooling, (3) Domestic Hot Water (DHW), (4) Controlled ventilation, (5) Lighting, (6) Dynamic building envelope, (7) Electricity, (8) Electric vehicle charging, and (9) Monitoring and control. The proposed structure of the SRI domains and impact criteria is presented in Figure 17.

5.1.3 Foreseen evolutions

To achieve its original goal, the SRI framework should be equally applicable in all climate regions of the European Union. Currently, due to the SRI concept still being very new, there are limited studies in the relevant literature highlighting this issue, however, the need to achieve this goal is apparent. Emphasizing the need for EU-wide applicability, (Janhunen, et al., 2019) who applied the SRI's applicability in cold climate countries, mentioned that the baseline design of the SRI is not feasible for cold climate countries and focused on the need for methodological framework changes in order for the tool to realize its original purpose of an equally applicable European-wide energy efficiency activity. According to the authors, cold climate countries have a significant energy efficiency potential but the technologies available at the market may vary significantly in comparison to the baseline design for European SRI. Moreover, it was suggested that in order to improve the SRI applicability to cold climate countries, the detailed smart ready service catalogue could be used as a baseline to develop an additional dedicated framework. The applicability could also be improved by reconsidering the realization of the triage process in practical experiments in order to eliminate subjective decisions throughout the process. Similarly, (Ramezani, et al., 2021) applied the SRI methodology in two non-residential case buildings in Portugal in order to provide empirical evidence and examine the possible challenges of implementing this indicator in Mediterranean climate buildings and, ultimately, throughout Europe. The authors concluded that the SRI methodology should be reconsidered as it was not completely applicable in the service buildings in Mediterranean condition, while they suggested that the weighting factors introduced in the current methodology need to be partially amended in order to cover all requirements related to climate conditions. In line with the above, various studies highlight the need for the creation of a tailored SRI framework concerning the different building typologies. Specifically, (Apostolopoulos, et al., 2022) highlighted the need for establishing a tailored SRI framework which will be able to consider the peculiarities of the various building typologies, e.g., building size, construction date, autonomous or centralized systems type, and the building's user activities, while (Becchio, et al., 2021) pointed out the need for a more replicable assessment method and (Fokaides, et al., 2020) mentioned that a tailored scheme for the smartness assessment of services installed in historical buildings should be created with special focus on the development of sectoral SRI evaluation schemes which will be able to recognize the variance of systems per building type.

In this context and in line with the SRI framework, the SRI tool already considers local specificities as it allows different climatic zones to be selected during the first phase of the assessment process so that the weighting factors are automatically modified and adapted, while it has also been designed after extensive European-wide stakeholder consultation. However, considering the fast-paced evolvement of the building sector, the common SRI methodology could adapt its elements to local contexts and technological evolutions.

For this reason, and to facilitate exchanges between EU countries and stakeholders concerning various aspects of the assessment tool, the SRI platform was set up in December 2021 (European Commission, 2022). Specifically, the SRI platform is a multi-stakeholder forum aiming to facilitate the need for discussion and experience sharing on the SRI implementation in the EU (European Commission, 2022). Concerning the platform's structure and governance, it includes expert working groups and plenaries. The plenary SRI stakeholder meetings are open to all stakeholders interested in the SRI, with the first meeting occurring on 16th of December 2021. Furthermore, the SRI platform will also support working groups focusing on a wide range of SRI elements, namely the SRI test phase for the Member States, maintenance and potential extension of the SRI calculation methodology, SRI supporting measures and value proposition, SRI rules and procedures, and SRI platform working groups. Each of the aforementioned working groups aims to specific outcomes concerning the evolution of the SRI methodology. Specifically, the scope of the working group on maintenance and potential extension of the SRI calculation methodology addresses all aspects related to the maintenance and potential extension of the methodology of the SRI as described in the relevant delegated act, e.g., the process for updating the scoring, the weightings, and the service catalogue, including the possibility of expanding the catalogue. The ultimate goal is to discuss and report on these methodological aspects in order to achieve a common EU approach as well as to keep the SRI catalogues and scoring matrices up to date. Moreover, the working group on the SRI value proposition and supporting measures aims to clarify and communicate the SRI's value proposition, to support the SRI assessment, to provide professional training, as well as to identify potential linkages between the SRI and other initiatives (European Union, 2021).

Furthermore, concerning the possible integration of the SRI scheme to retrofitting evaluation methods such as the Energy Performance, Indoor environment Quality, Retrofit (EPIQR) methodology, to the best of the authors' knowledge there are currently no dedicated studies examining this topic. However, possible links between the two schemes can be concluded from the relevant literature. Specifically, (Ramezani, et al., 2021) suggested that SRI improvements could be considered as a retrofitting objective to be considered among energy savings, thermal comfort, environmental impact, and cost, in the context of multi-objective optimization studies, while they also mentioned that, taking this into account, the possible retrofit actions could be chosen based on their effectiveness on SRI, in combination with other improvements. Finally, (Fokaides, et al., 2020) noted that once the SRIs will become mandatory throughout the EU, the member states will have to define minimum requirements concerning the overall SRI scores that should be achieved in new or refurbished buildings, similarly to the requirements set for the energy performance of buildings. The latter will lead to the need to monetize the equipment smartness, considering its effect on energy savings, which will initiate extensive corresponding scientific discussions.

5.2 SRI assessment

In this chapter, two case studies are assessed in terms of their smart readiness by implementing the SRI methodology. Specifically, the first case study concerns the Polish demonstration site which is located in Krakow. The demonstration site, that was constructed in the time period of 1965-1968 as an office building, covers a total area of 6795 m^2, while the spaces in which PRELUDE's solutions will be implemented consist of one full floor covering a large open space and four smaller offices. Furthermore, the second case study concerns a full-scale, 850 m^2 state-of-the-art living laboratory called "ENERGETIKUM" which is shared by the University of Applied Sciences Burgenland and Forschung Burgenland in Austria. The living lab acts as a real user behavior environment where new innovative methods for building control and energy supply are being developed and evaluated. The SRI assessment was performed through the implementation of the official experimental assessment tool (version 4.4) which is available upon request[1]. Both the simplified (assessment method A) and detailed (assessment method B) assessment approaches were implemented in both case buildings, in order to obtain the corresponding SRI scores and proceed to their benchmarking. Regarding the triage process methodology and the weighting factors definition, the official SRI guidelines, namely triage method A (cf. Table 4) and the predefined weighting coefficients were implemented in the context of both case studies.

5.2.1 Krakow case study

The building selected for the Polish case study (Figure 18) represents a typical old office housing still in use, as approximately 30% of office spaces located in the main Polish cities are older than 15 years. Concerning the energy consumption of this building category, it lays in the range of 250-500 kWh/m^2/year. It is estimated that the implementation of refurbishment actions can have a positive impact on reducing the aforementioned energy consumption values, thus posing an attractive option for office building owners in order to reduce operational costs and increase rent profitability. The proposed office building presents special characteristics that could increase the PRELUDE demonstration cases' variety, i.e., occupancy schedule which differs significantly from that of a residential building, different behavioral patterns concerning peak hours, presence of a large number of persons with significant rotation throughout the day, and frequent maintenance activities. The PRELUDE activities will be carried out in an entire floor of the building which consists of open space offices, conference rooms, and social rooms that will be monitored though the installation of commercial and fiber optic sensors. No major renovations took place since the building's construction, however some plans focused on thermal modernization are currently considered by the administration. The energy consumption of the building is estimated to 316 MWh/year, the largest fraction of which is related to office hardware such as computers, printers, and servers. Regarding the habits of the tenants, the occupancy hours are very specific and mostly limited to the working hours schedule, namely 7 am to 6 pm, with the exception of the COVID crisis period that significantly decreased the number of people working at the office. Furthermore, the floor is also equipped with fiber optic sensors, aiming to monitor the temperature variation in the open space offices, conference rooms, social rooms, and corridors. Finally, all data monitored by the aforementioned systems will be uploaded to the FUSIX platform.

[1] The SRI assessment spreadsheet is available upon request in the following link: https://ec.europa.eu/eusurvey/runner/SRI-assessment-package

Figure 18: Building demonstration case in Krakow

5.2.1.1 Equipment inventory

The commercial sensors installed and employed for the building's monitoring include particulate matter (PM2.5 and PM10) concentration sensors, windows and doors open/close status sensors, ambient sensors of temperature and humidity, energy meters, heat meter, motion sensors, lux meters, and smart thermostatic heads for radiators. In order to implement the SRI methodology a detailed inventory concerning the installed smart equipment of the building was composed and subsequently the inventory was categorized in domains and correlated with the smart ready services and functionality levels of the official SRI assessment tool in order to calculate the final score, as presented in Table 5.

Table 5: Smart equipment inventory and corresponding smart ready services of Krakow's demonstration site

Domain	**List of installations**	**Corresponding smart ready service**	**Functionality level**
Heating	Smart thermostatic radiator valves	H-1a Heat emission control	4 - Individual room control with communication and occupancy detection
	1 Heat meter		
	Heat pump installation	H-2b Heat generation control for heat pumps	0 - On/off control of heat generator
Cooling	No cooling system	-	-
Domestic Hot Water (DHW)	District heating	DHW-1b Control of DHW storage charging (with solar collector and supplementary heat generation)	3 - DHW production system capable of automatic charging control based on external signals e.g., from district heating grid
Controlled ventilation	Humidity and temperature sensor	V-6 Reporting information regarding IAQ	

	CO_2 sensor		2 - Real time monitoring & historical info of IAQ available to occupants
	PM2.5, PM10 sensors		
Lighting	Energy saving lamps	L-2 Control artificial lighting power based on daylight levels	3 - Automatic dimming
	Lux meter		
Dynamic building envelope	Quantum glass connected with PV or energy efficient glass designed to prevent heat losses	-	-
	External shutters	DE-1 Window solar shading control	2 - Motorized operation with automatic control based on sensor data
	Window & door sensor	DE-2 Window open/closed control combined with HVAC system	1 - Open/closed detection to shut down heating or cooling systems
Electricity	PV panels on roof	E-2 Reporting information regarding local electricity generation	1 - Current generation data available
	Electric sub-meters (appliances level)	E-12 Reporting info regarding electricity consumption	4 - Real time feedback or benchmarking on appliance level with automated personalized recommendations
	Smart plug - signal amplifier		
Electric vehicle charging	No electric vehicle charging	-	-
Monitoring and control	Motion sensor	MC-9 Occupancy detection: connected services	2 - Centralized occupant detection which feeds into several TBS such as lighting and heating
	Monitoring and control system	MC-30 Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather, and grid signals	3 - Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather, and grid signals
	Airly (air quality data platform) integration		

	Integration in Fusix platform (pending)		

5.2.1.2 SRI assessment results

The data presented in Table 5 were used as inputs to the official SRI experimental assessment spreadsheet tool (version 4.4) and the final score was calculated by implementing both the simplified (A) and detailed (B) smart readiness assessment methods, as presented below.

5.2.1.2.1 Simplified method (A) results

Following the correlation of the building's installed equipment to the simplified smart services catalogue (A) and the definition of their functionality levels based on the scale of the official SRI assessment tool, the final SRI score was calculated as 31% which corresponds to SRI class "F", as presented in Figure 19. Regarding the individual impact scores of the seven criteria, the building performed relatively well at health, wellbeing and accessibility (55%), as well as at convenience (45%) and energy efficiency (43%). On the other hand, the building seems to be lagging behind in its ability to achieve energy flexibility and storage (13%), mainly due to the absence of electric energy storage systems and grid information equipment. Furthermore, concerning the individual scores of the nine main technical domains, which are presented in Figure 20, the building achieved high scores on the domains of electricity (78%) due to its ability to report information regarding local electricity generation and consumption, DHW (60%) due to its ability to control the DHW storage charging, and dynamic building envelope (53%) due to the presence of window solar shading control and window open/closed control combined with HVAC systems. On the other hand, three domains were assessed as non-smart, namely the domains of cooling and EV charging due to the complete absence of such systems installed in the building, as well as the domain of lighting whose existing smart ready service (L-2) is not taken into account when implementing the simplified assessment method, as it is not included in the simplified smart ready service catalogue of 27 services (cf. Table 3).

TOTAL SRI SCORE	31%	SRI CLASS	F

IMPACT SCORES

Energy efficiency	43%
Energy flexibility and storage	13%
Comfort	25%
Convenience	45%
Health, well-being and accessibility	55%
Maintenance and fault prediction	29%
Information to occupants	30%

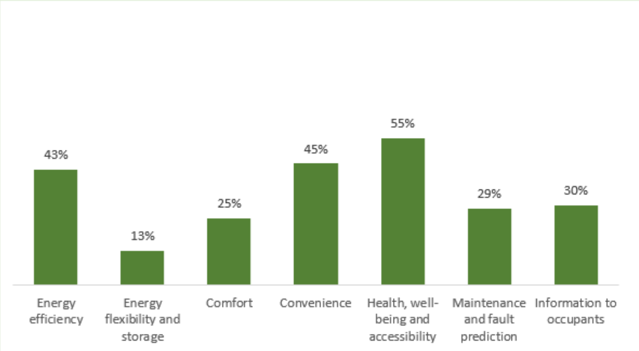


Figure 19: Total SRI score and impact scores of Krakow's demonstration case (simplified service catalogue)

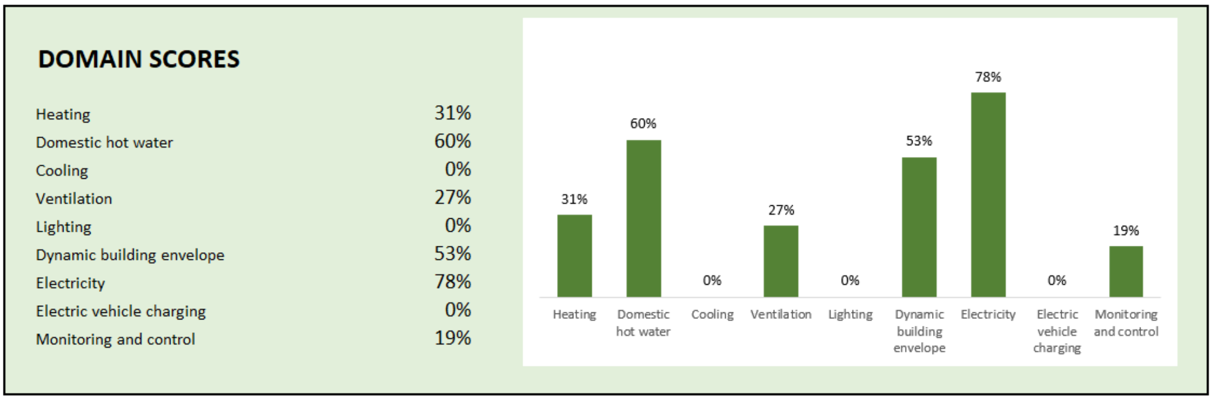


Figure 20: Domain scores of Krakow's demonstration case (simplified service catalogue)

5.2.1.2.2 Detailed method (B) results

Regarding the SRI assessment through the implementation of the detailed assessment method (B), the final SRI score was calculated as 24%, which corresponds to SRI class "F", as presented in Figure 21. As expected, the application of assessment method B resulted in a significantly lower SRI score in comparison with method A, mainly because a wider range of smart services was evaluated. Concerning the individual impact scores of the seven criteria, the highest scores correspond to energy efficiency (39%), health, wellbeing and accessibility (35%), convenience (32%) and comfort (31%). Moreover, in line with the results of method A, the lowest score was assigned to the category of energy efficiency and storage (9%) due to the absence of electric energy storage systems and grid information equipment. The individual scores of the nine main technical domains are summarized in Figure 22. In line with the results of assessment method A, the highest scores correspond to the technical domains of electricity (78%), DHW (60%) and dynamic building envelope (57%), while the domains of cooling and electricity are assessed as non-smart due to their complete absence from the building. Finally, in contrast with the results of method A, a relatively high score is observed in the domain of lighting (49%), as the implementation of assessment method B considers the existing smart ready service (L-2) which is included in the detailed smart service catalogue of 54 services.

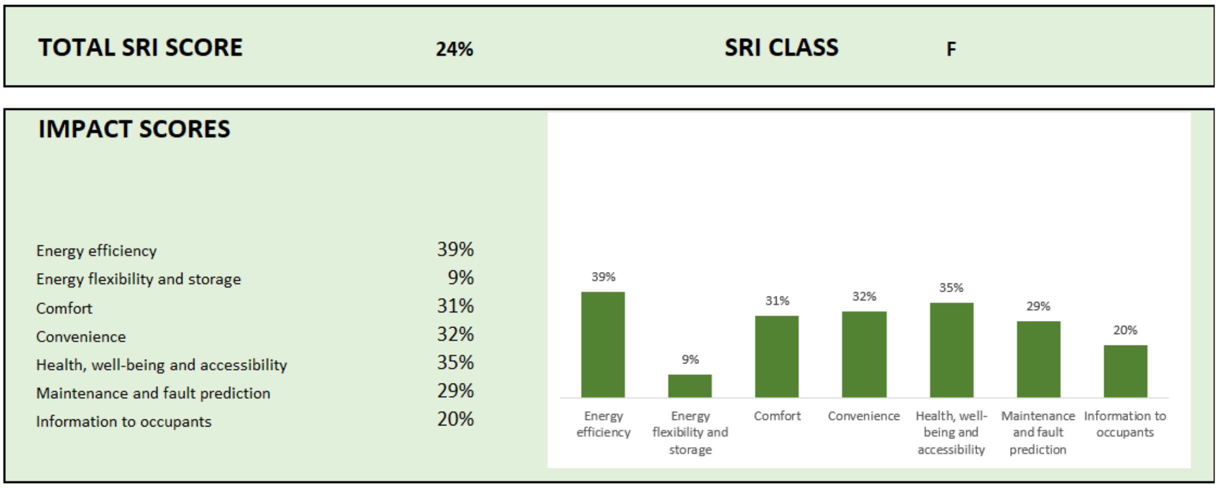


Figure 21: Total SRI score and impact scores of Krakow's demonstration case (detailed service catalogue)

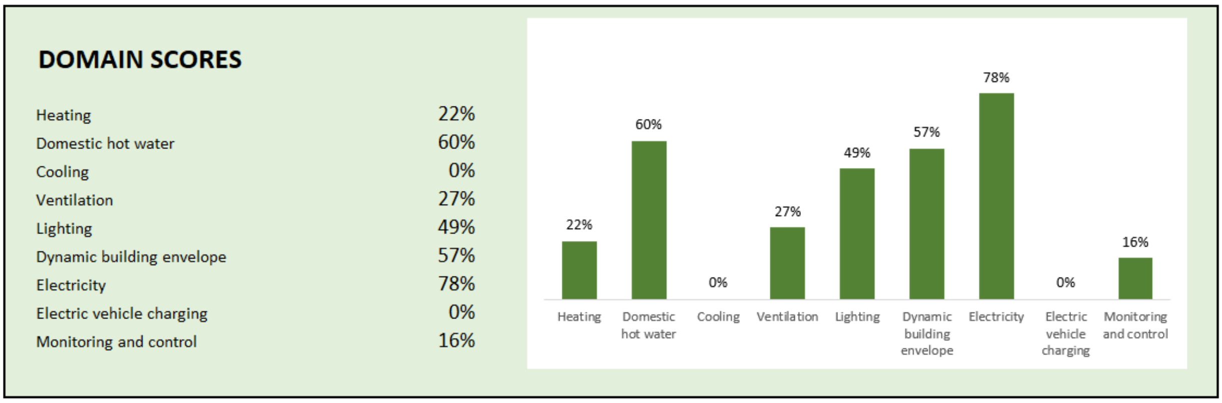


Figure 22: Domain scores of Krakow's demonstration case (detailed service catalogue)

5.2.2 Living lab case study

Regarding the case study of Living Lab, the building, which is presented in

Figure *23*, concerns a full-scale, 850-m² state-of-the art, living laboratory called "ENERGETIKUM", shared by the University of Applied Sciences Burgenland and Forschung Burgenland and acts as a development and evaluation site for new innovative methods of energy supply and building control. The building encompasses a central air conditioning system with variable volume-rate control units for every office, equipped with over 2000 monitoring points for temperature, humidity, CO_2, VOC, water, and air enthalpy flow etc., aiming to achieve a detailed indoor air quality and energy flow analysis. Furthermore, the building is equipped with an open platform communication system, building automation solutions as well as with control network interfaces, which enable the integration of the application demonstrator into the control and communication system of the building. Additionally, the ENERGETIKUM has a HVAC simulation environment (TRNSYS, MATLAB etc.) and an interface for real-time interaction between installed software and hardware, as well as a small weather station equipped with short-wave and long-wave radiation sensors.

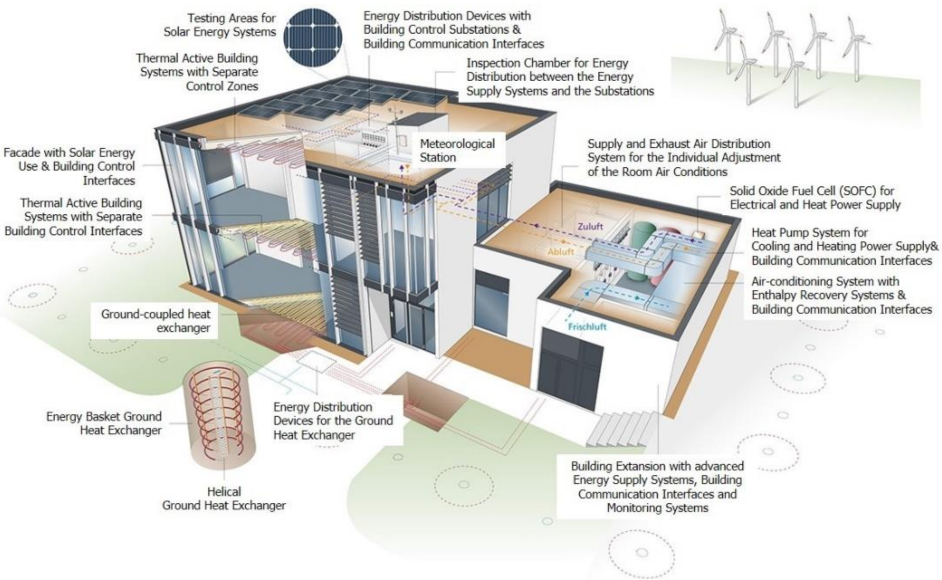


Figure 23: Technical Details of the Living-lab ENERGETIKUM

5.2.2.1 Equipment inventory

In order to implement the SRI methodology a detailed inventory concerning the installed smart equipment of the Living Lab's building was composed and, subsequently, the inventory was categorized in domains and correlated with the smart ready services and functionality levels of the official SRI assessment tool to calculate the final score, as presented in Table 6.

Table 6: Smart equipment inventory and corresponding smart ready services of Living Lab's case study

Domain	**List of installations**	**Corresponding smart ready service**	**Functionality level**
Heating	Heat pump with different ground and air heat exchangers	H-2b Heat generator control (for heat pumps)	2-Variable control of heat generator capacity depending on the load or demand (e.g., hot gas bypass, inverter frequency control)
	Space heating using gas boiler (alternative)	H-2a Heat generator control (all except heat pumps)	1-Variable temperature control depending on outdoor temperature
	Space heating using gas boiler (alternative) Heating with solar gains based on an intelligent shading control system	H-2d Sequencing in case of different heat generators	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)
	Distribution and emittance systems	H-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	2-Demand based control
	High-end building energy management system and high-end monitoring system	H-3 Report information regarding HEATING system performance	4-Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection
	Temperature sensors and energy meters for energy supply, distribution, and emittance systems Automated actuators on room level (every room is	H-1a Heat emission control	4-Individual room control with communication and occupancy detection

	a separately controllable zone)		
	Surface heating systems (floor heating, thermally activated building construction etc.)	H-1b Emission control for TABS (heating mode)	3-Advanced central automatic control with intermittent operation and/or room temperature feedback control
Cooling	High-end building energy management system and high-end monitoring system	C-3 Report information regarding cooling system performance	4-Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection
	Temperature sensors and energy meters for energy supply, distribution, and emittance systems	C-1a Cooling emission control	4-Individual room control with communication and occupancy detection
	Heat pump with different ground and air heat exchangers		
	Automated actuators on room level (every room is a separately controllable zone)		
	Distribution and emittance systems	C-1d Control of distribution pumps in networks	3-Variable speed pump control (pump unit (internal) estimations)
	Surface cooling systems (floor cooling, thermally activated building construction etc.)	C-1b Emission control for TABS (cooling mode)	3-Advanced central automatic control with intermittent operation and/or room temperature feedback control
Domestic Hot Water (DHW)	Decentralized, electrical driven DHW-storage system (because of the office building use, very low demand)	DHW-1b Control of DHW storage charging (using hot water generation)	0-Automatic control on / off
	Energy meters available in the electric power supply	DHW-3 Report information regarding domestic hot water performance	1-Indication of actual values (e.g., temperatures, submetering energy usage)
Controlled ventilation	Temperature, humidity sensors and volume rate monitoring (distribution system, rooms, ventilation unit)	V-6 Reporting information regarding IAQ	2-Real time monitoring & historical information of IAQ available to occupants
	VOC sensors		
	CO2 sensors (distribution system, rooms, ventilation unit)		

	Heat recovery system	V-2c Heat recovery control: prevention of overheating	2-Modulate or bypass heat recovery based on multiple room temperature sensors or predictive control
	Active cooling incl. humidification and dehumidification	V-3 Free cooling with mechanical ventilation system	2-Free cooling: air flows modulated during all periods of time to minimize the amount of mechanical cooling
	Air temperature control	V-2d Supply air temperature control at the air handling unit level	2-Variable set point with outdoor temperature compensation
	Air flow control	V-1c Air flow or pressure control at the air handler level	2-Multi-stage control: To reduce the auxiliary energy demand of the fan
	Air flow control at room level	V-1a Supply air flow control at the room level	3-Central Demand Control based on air quality sensors (CO2, VOC, humidity, ...)
Lighting	Manual controllable lights	L-1a Occupancy control for indoor lighting	0-Manual on/off switch
	Lux sensor in SIM 2 since 07/2022	L-2 Control artificial lighting power based on daylight levels	1-Manual (per room / zone)
Dynamic building envelope	External solar shadings (controlled via Building Management System, position and angle for every room and orientation separately)	DE-1 Window solar shading control	2-Motorized operation with automatic control based on sensor data
	Avoid solar loads due to intelligent shading control system		
	Monitoring of manual window opening and closing	DE-2 Window open/closed control, combined with HVAC system	1-Open/closed detection to shut down heating or cooling systems
	In one room: automatically open and closing of the windows (window actuator)		2- Level 1+ Atomized mechanical window opening based on room sensor data
Electricity	Energy consumption meters, electrical load profiles monitoring for each office room (lighting, plug and IT separately)	E-12 Reporting information regarding electricity consumption	4-real-time feedback or benchmarking on appliance level with automated personalized recommendations
	Energy meters for heating and cooling coils, ventilation system etc.,		

	PV-system incl. monitoring system (temperature, energy supply etc.)	E-2 Reporting information regarding local electricity generation	2-Actual values and historical data
		E-4 Optimizing self-consumption of locally generated electricity	2-Automated management of local electricity consumption based on current renewable energy availability
	Redox-flow battery including control and monitoring system	E-3 Storage of (locally generated) electricity	3-On site storage of energy (e.g., electric battery or thermal storage) with controller optimizing the use of locally generated electricity
		E-11 Reporting information regarding energy storage	3-Performance evaluation including forecasting and/or benchmarking
Electric vehicle charging	Wallbox incl. control & monitoring unit in planning (will be installed until end of 2022)	EV-15 EV Charging Capacity	3- 10 to 50% or parking spaces has recharging point
		EV-16 EV Charging grid	1 – One way controlled charging (e.g. including desired departure time and grid signals for optimization)
		EV-17 EV charging information and connectivity	1-Reporting information on EV charging status to occupant
Monitoring and control	Detailed energy monitoring for heating, cooling, ventilation, and electricity on zone and on HVAC central level	MC-3 Run time management of HVAC systems	3-Heating and cooling plant on/off control based on predictive control or grid signals
	Detailed description of the monitoring system can be found in the requirement definition list (cf. PRELUDE Teams folder)	MC-30 Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather, and grid signals	3-Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather, and grid signals
		MC-9 Occupancy detection: connected services	1-Occupancy detection for individual functions, e.g., lighting
		MC-13 Central reporting of TBS performance and energy use	3-Central or remote reporting of real time energy use per energy carrier, combining TBS of all main domains in one interface

5.2.2.2 SRI assessment results

The information presented in Table 6 were used as inputs to the official SRI experimental assessment spreadsheet tool (version 4.4) and the final score was calculated by implementing both the simplified (A) and detailed (B) smart readiness assessment methods, as presented below.

5.2.2.2.1 Simplified method (A) results

Following the correlation of the building's installed equipment to the simplified smart services catalogue (A) and the definition of their functionality levels based on the scale of the official SRI assessment tool, the final SRI score was calculated as 64% which corresponds to SRI class "D", as presented in Figure 24. Regarding the individual impact scores of the seven criteria, the building performed very well at nearly all listed categories, with the highest scores being observed in the categories of maintenance and fault prediction (86%), information to occupants (83%) and energy efficiency (82%). Moreover, the category of comfort achieved a relatively low score (55%) which is mainly due to the presence of manual lighting control, as well as the low functionality levels of relevant smart services, namely heat generation control, window open/closed control combined with HVAC system, occupancy detection etc. Finally, reduced performance is observed in the category of energy flexibility and storage (26%) despite the presence of an installed system pertaining a redox-flow battery with control and monitoring capabilities, as the building is not adequately equipped with smart systems able to retrieve signals from the energy grid in order to adjust its consumption accordingly. Furthermore, concerning the individual scores of the nine main technical domains, which are presented in Figure 25, the highest performance is observed in the domains of electricity (75%), heating (75%), and ventilation (75%), while the building performed poorly in the domain of DHW (20%) due to the low smartness level of the installed hot water system, which is equipped with basic automatic control. Regarding the domain of lighting, it was assessed as non-smart (0%) due to the presence of a manual only lighting control system, combined with the fact that the existing smart service (L-2) is not taken into account when applying the assessment method (A), as it is not included in the simplified smart ready service catalogue of 27 services (cf. Table 3).

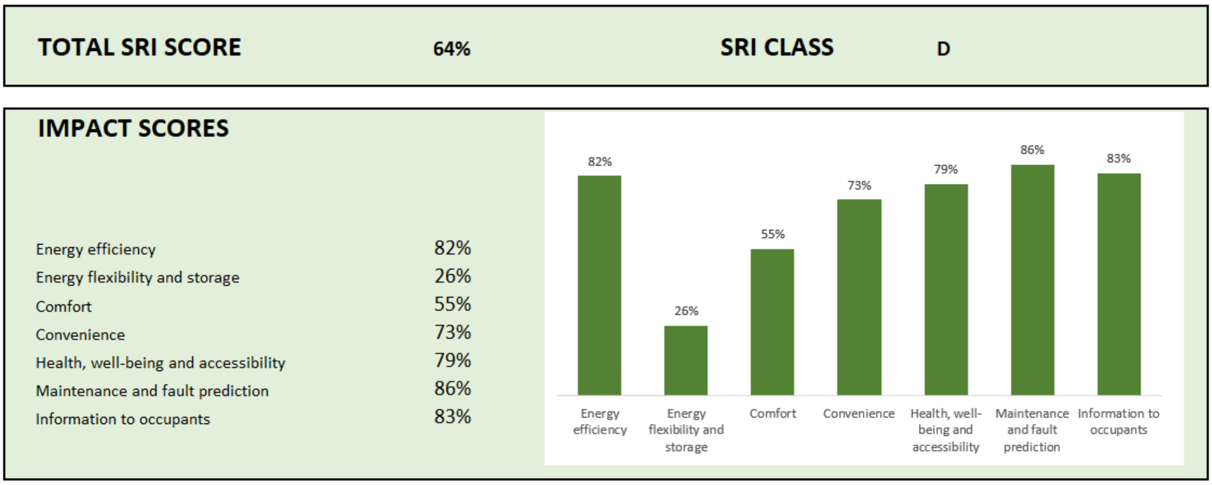


Figure 24: Total SRI score and impact scores of Living Lab's case study (simplified service catalogue)

DOMAIN SCORES

Heating	75%
Domestic hot water	20%
Cooling	46%
Ventilation	75%
Lighting	0%
Dynamic building envelope	53%
Electricity	75%
Electric vehicle charging	44%
Monitoring and control	54%

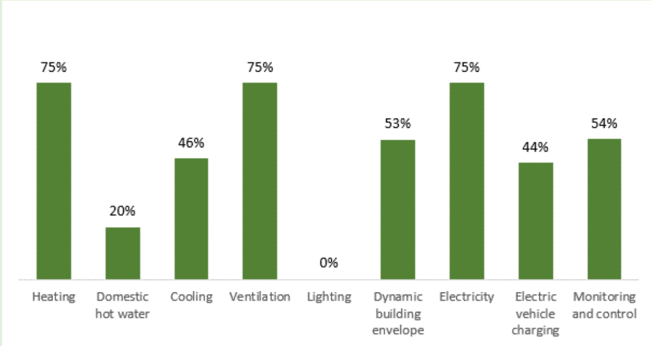


Figure 25: Domain scores of Living Lab's case study (simplified service catalogue)

5.2.2.2.2 Detailed method (B) results

Regarding the SRI assessment through the implementation of the detailed assessment method (B), the final SRI score was calculated as 55%, which corresponds to SRI class "D", as presented in Figure 26. As expected, and in line with the SRI results of the Polish case study, the application of assessment method B resulted in a significantly lower SRI score in comparison with method A due to the fact that a wider range of smart services was evaluated. Regarding the individual impact scores of the seven criteria, the highest scores correspond to energy efficiency (76%), as well as to health, wellbeing, and accessibility (71%). Moreover, a significant increase concerning the score of comfort (64%) is observed, when compared to the results of the aforementioned assessment following the simplified method (A). The observed improvement is due to the inclusion of L-2 smart service which pertains to the control of artificial lighting power based on daylight levels. Finally, the lowest score was assigned to the category of energy flexibility and storage (26%) despite the aforementioned presence of an installed system pertaining a redox-flow battery with control and monitoring capabilities, as the building is not adequately equipped with smart systems able to retrieve signals from the grid in order to adjust its operation accordingly. Furthermore, concerning the individual scores of the nine main technical domains, which are presented in

Figure 27, the highest scores were assigned to the categories of electricity (76%), ventilation (76%) and heating (63%) in line with the results of method (A). Moreover, the building performed poorly in the domain of DHW (20%) due to the low smartness level of the installed hot water system, which is equipped with basic automatic control, as well as in the domain of lighting (15%) because of the absence of sophisticated smart services concerning lighting control.

TOTAL SRI SCORE	**55%**	**SRI CLASS**	**D**

IMPACT SCORES

Energy efficiency	76%
Energy flexibility and storage	26%
Comfort	64%
Convenience	65%
Health, well-being and accessibility	71%
Maintenance and fault prediction	68%
Information to occupants	63%

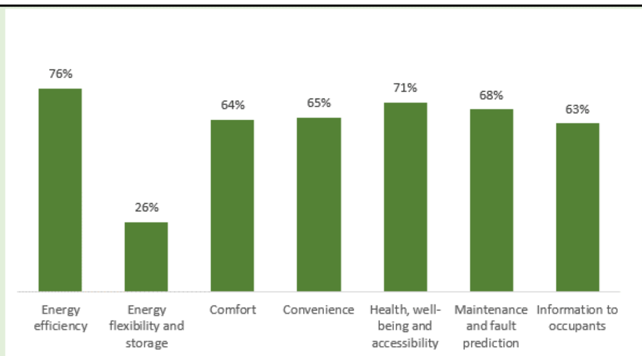


Figure 26: Total SRI score and impact scores of Living Lab's case study (detailed service catalogue)

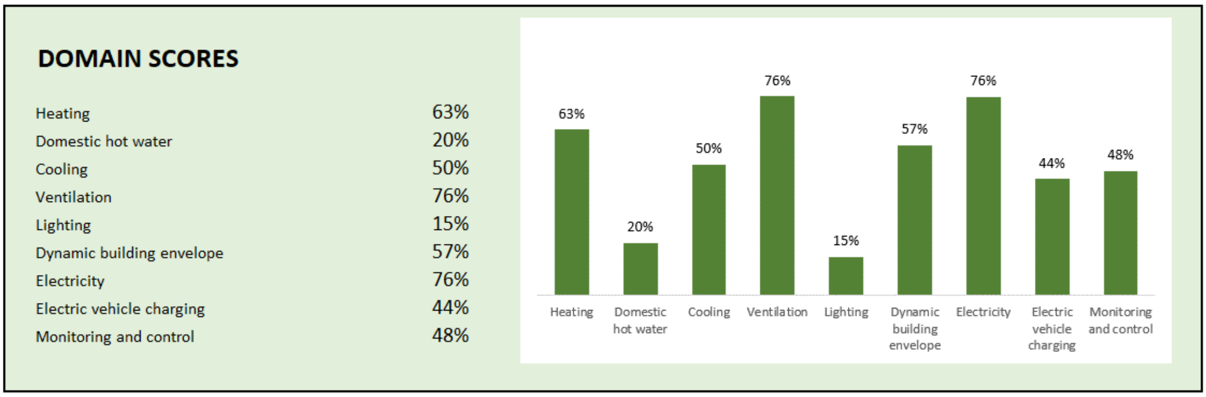
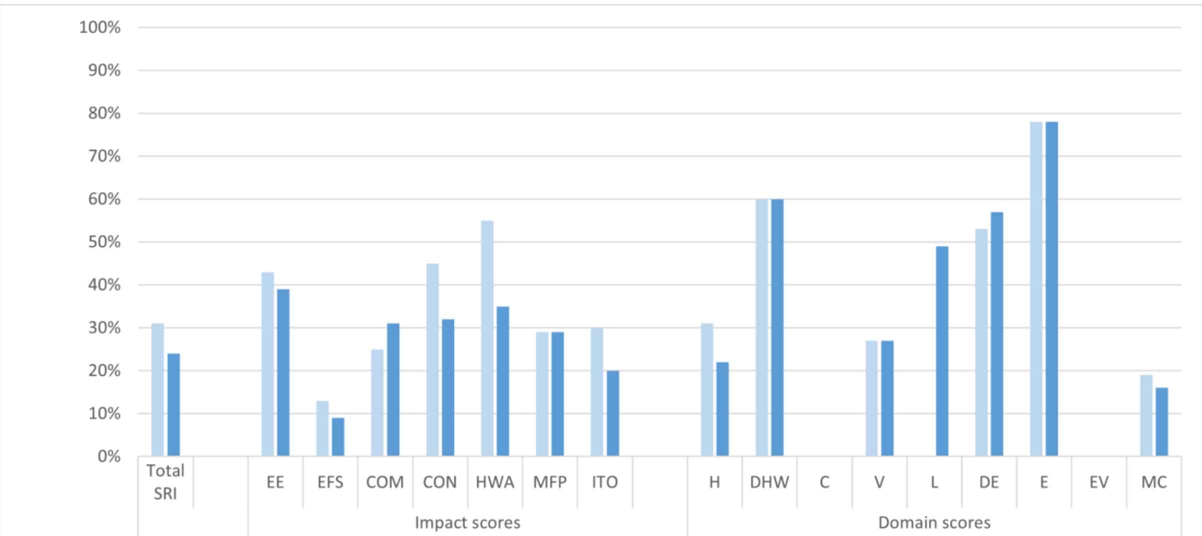


Figure 27: Domain scores of Living Lab's case study (detailed service catalogue)

5.3 Conclusions

In conclusion, the SRI assessment results indicate the superiority of the Living Lab case study building in terms of smart readiness, however the obtained SRI score was relatively lower than expected, considering that the aforementioned building is a state-of-the-art site, dedicated to the development and evaluation of new innovative methods of energy supply and building control. Both case studies were assessed through the implementation of both the simplified (Method A) and detailed (Method B) assessment methods. The results showed that the implementation of Method A generally leads to a higher total SRI score as well as higher impact and domain scores, which is due to the significantly lower number of assessed smart ready services included in the simplified service catalogue. Specifically, concerning the Krakow case study, the implementation of Method A resulted to a 7% higher total SRI score, compared to Method B. Regarding the individual impact scores, namely energy efficiency (EE), energy flexibility & storage (EFS), comfort (COM), convenience (CON), health, wellbeing & accessibility (HWA), maintenance & fault prediction (MFP), and information to occupants (ITO), Method A resulted to a 6% higher score on average, with the most significant differences being observed in the categories of HWA (+20%) and CON (+13%), and the only exception being the category of COM (-6%). Moreover, concerning the domain impact scores, no significant differences were observed when comparing the results of Method A and Method B, except for the domains of heating (+9%) and the domain of lighting (-49%). On average, the scores obtained for the domain scores were 5% lower for Method A in comparison to Method B. The aforementioned results for the Krakow case study are presented in Figure 28.



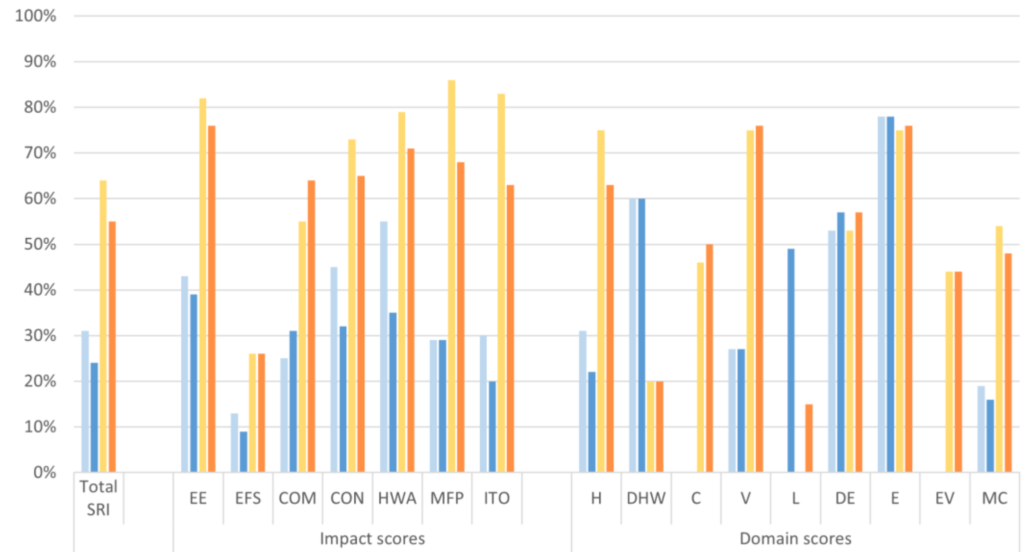
	Total SRI	EE	EFS	COM	CON	HWA	MFP	ITO	H	DHW	C	V	L	DE	E	EV	MC
Method A	31%	43%	13%	25%	45%	55%	29%	30%	31%	60%	0%	27%	0%	53%	78%	0%	19%
Method B	24%	39%	9%	31%	32%	35%	29%	20%	22%	60%	0%	27%	49%	57%	78%	0%	16%

Figure 28: Krakow SRI results - Method A vs Method B

Figure 29: Living Lab SRI results - Method A vs Method B

Concerning the Living Lab case study, the obtained overall SRI score was 9% higher when implementing Method A. Moreover, concerning the individual impact scores, the implementation of Method A led to a 7% higher score on average with the most significant differences being observed in the categories of ITO (+20%), MFP (18%), and COM (-9%). Regarding the domain scores, no significant difference was observed when comparing the results of Method A to those of Method B (-1% on average), however worth-mentioning differences appear on individual level. Specifically, the implementation of Method A led to a 12% higher score concerning the domain of Heating, and a 15% lower score concerning the domain of Lighting, when compared to the results of Method B. The aforementioned results for the Living Lab case study are presented in detail in Figure 29.

Furthermore, the SRI assessment results comparison between the two case studies, concerning both the simplified and detailed assessment methods, are presented in Figure 30. The results show that the Living Lab has performed significantly better than the Krakow's case study building, both in the overall SRI score as well as in almost all the assessed categories. Regarding the results obtained through the implementation of assessment Method A, the Living Lab achieved a 33% higher SRI score compared to that of the Krakow case building, as well as a 35% higher average impact score, and a 19% higher average domain score. Regarding the impact scores, the Living Lab achieved 57%, 53%, and 39% higher scores for the impact categories of MFP, ITO, and EE respectively. Concerning the domain scores, the Living Lab performed better in almost all the listed categories, with the exception of DHW where Krakow's case building achieved a 40% higher score. Concerning the results obtained through the implementation of assessment method B, the Living Lab building achieved a 31% higher overall SRI score in comparison to the Krakow's case building. On average, the Living Lab building performed 34% better in the impact categories, with the most significant differences between the two case buildings being observed in the categories of ITO, MFP, and EE, where the Living Lab achieved a 43%, 39%, and 37% higher score respectively. Finally, concerning the domain scores, the Living Lab case study achieved a 16% higher score on average as it performed better in almost all listed categories, with the exception of DHW (-40%) and lighting (-34%).



	Total SRI	EE	EFS	COM	CON	HWA	MFP	ITO	H	DHW	C	V	L	DE	E	EV	MC
		Impact scores							Domain scores								
Krakow - Method A	31%	43%	13%	25%	45%	55%	29%	30%	31%	60%	0%	27%	0%	53%	78%	0%	19%
Krakow - Method B	24%	39%	9%	31%	32%	35%	29%	20%	22%	60%	0%	27%	49%	57%	78%	0%	16%
Living Lab - Method A	64%	82%	26%	55%	73%	79%	86%	83%	75%	20%	46%	75%	0%	53%	75%	44%	54%
Living Lab - Method B	55%	76%	26%	64%	65%	71%	68%	63%	63%	20%	50%	76%	15%	57%	76%	44%	48%

Figure 30: Overall SRI results comparison (Krakow case study vs Living Lab)

To summarize, the adoption of the SRI framework could be a crucial step in the process of promoting and deploying smart systems aiming to optimize the performance of buildings throughout Europe, as the assessment results could incentivize all relevant stakeholders to align with the corresponding EU 2050 targets. However, in order to realize its purpose, the SRI scheme must become equally applicable over all European climate regions, as well as to overcome significant challenges. Specifically, measures should be taken in order to minimize the element of subjectivity concerning the decisions of the assessor, which can have a significant impact on the final assessment results (Apostolopoulos, et al., 2022); (Becchio, et al., 2021); (Varsami & Burman, 2021); (Fokaides, et al., 2020); (Vigna, et al., 2020); (Janhunen, et al., 2019). Currently, the calculation process allows for subjective choices, which combined with the presence of unclear guidelines can potentially lead to inconsistencies, ultimately hindering the reliability of the results. The access to credible and detailed information is identified a crucial factor to overcome this issue. Furthermore, various improvements concerning the applicability of the SRI framework are proposed in the relevant literature, including the development of a more replicable method which will follow a more objective approach, allowing the comparison with reference building with similar characteristics (Becchio, et al., 2021), and the differentiation between weighting factors in order to account for different building types (Varsami & Burman, 2021), as well as the adjustment of weighting factors considering suitable domains and service performance (Apostolopoulos, et al., 2022).

There is a clear potential linkage between the SRI framework and cost-predictive retrofitting evaluation methods, employed for improving the energy performance and the indoor environment of existing apartment buildings, such as the EPIQR software. As from now, to improve the smartness of a building, inputs from the SRI analysis could initially be used to assess which domain require improvements to then price tag the chosen renovation scenario with the EPIQR method. A second round of SRI evaluation could thus, after the assessment of the recommended EPIQR actions, monitor the improvement of the building smartness. To improve the complementarity of both analyses, the SRI assessment method provided new EPIQR elements to implement in the updated database. The future building renovation roadmap will also benefit from the use of both the SRI and EPIQR analysis to help developing recommendations for actions with a financial point of view.

6 UPSCALING, VERIFICATIONS AND FUTUR STEPS

The EPIQR web-app, which is still under construction, is at the time being available in French and partly in English. Translation into other languages, such as Italian or German, could be done later, in the following phases of the PRELUDE project.

Moreover, this web version of EPIQR is first targeting housing buildings diagnostics. The addition of the remaining building uses present in the software will be studied afterwards.

Regarding the updated database with smart systems and their respective costs, further work will consist of collecting new costs related to the PRELUDE demo-sites monitoring plans, to first verify the already implemented smart-technology costs in the EPIQR database and then confirm the cost-conversion factors between Swiss and other European country currencies at a certain period. As it is done with the Swiss costs, other European actual costs will also be based on a year and a country of reference. The Table 7 below summarizes different cost factor per year that could serve as a baseline in the development of the EPIQR method to calculate the retrofitting actions costs in different locations in Europe:

Table 7: European price factors for EPIQR

Localisation/Year	2015	2016	2017
Austria	117	117.7	121.8
Belgium	99.2	100.8	102.1
Bulgaria	35.5	35.8	36.7
Croatia	44.5	44	43.9
Cyprus	64.1	63.6	63.7
Czechia	59	59.2	60.8
Denmark	151.3	153.7	154.9
Estonia	67.1	66.8	67.6
Finland	132.2	132.9	133.3
France	116.7	116.8	119.6
Germany	137	138.5	142.6
Greece	60.3	59.3	59.4
Hungary	46	46.8	50
Ireland	91.1	91.7	93.3
Italy	73.9	74.1	74.6
Latvia	62.6	66.2	67.8
Lithuania	59.2	60.5	63
Luxembourg	108.4	109.5	111.5
Malta	64.4	65.8	66.9

Netherlands	115.2	117	119.7
Norway	170	174.8	179
Poland	53.6	53.5	53.9
Portugal	51	52	53
Romania	35.5	35.8	38.6
Slovakia	55.8	56.4	58
Slovenia	53.2	52.6	55.1
Spain	69.6	68.7	70.2
Sweden	166.9	170.6	175.1
Turkey	29.4	33.2	37.9
United Kingdom	97	98.1	101

7 CONCLUSIONS

The EPIQR diagnosis method is addressed to any person or organization involved in the renovation of buildings and permits to help the owners in their decision-making scheme, by comparing different renovation scenarios with their corresponding costs. The corresponding web-app, still under development, was born out of the increasing need to have access to informatic tools or data from anywhere. Through the modernization of its graphical interface and the implementation of new functionalities, it also lends a hand to the expert to diagnose more easily and quickly and to have clearer results for the clients.

In addition to the existing costs in the EPIQR database, namely those linked to the diagnosis of architectural (interior and exterior) and technical elements, a non-exhaustive list of the expenses required to make a building smarter have been included in the EPIQR web-app, hence participating in the development of the third renovation strategy set by the European Union through the "Energy Performance of Buildings Directive". About twenty costs, related to a specific work corresponding to a smart system, were added or updated, as seen in the Table 2. They have been selected both for their conformity with the EPIQR method and for their market representation.

Some of these new elements can be linked to smart ready services of the SRI assessment process, such as for examples "Occupancy control for indoor lighting", "EV charging" or "On-site storage of electricity". The bibliography documentation and SRI assessment results presented in the second part of this report indicate the lack of maturity of the SRI assessment method for the whole European area. More precisely, despite the clear superiority of the Living Lab case study building in terms of smart readiness compared to Krakow, both SRI scores were low compared to the expected output. Particularly for the LLE, considering that the aforementioned building is a state-of-the-art site. Despite this lack of maturity for the SRI, it is clear that it should be used with EPIQR to fulfill EU objectives without losing sight of the financial aspects of renovation.

Future work will prioritise the continuity of the development of the EPIQR web-app through, among other things, the evaluation of other building uses diagnosis as well as the verification of the new costs with all the data available from the PRELUDE project. EPIQR assessments of test buildings are needed to validate the new interface and its overall costs in different European locations. Lastly an iterative evaluation between the SRI and the EPIQR analysis, starting with the first one, will allow stakeholders to plan for the implementation of SRI technologies and thus improving the SRI score of the renovated buildings.

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