SRI2MARKET Project – Paving the way to adoption of the SRI into national regulation and market

D2.3 Guidelines to design public funding schemes for SRI upgrades

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HEBES Intelligence

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Abbreviations

API	Application Programming Interface
BACS	Building('s) Automation and Control System
DSO	Distribution System Operator
EC	European Commission
EED	Energy Efficiency Directive
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
EV	Electric Vehicle
EU	European Union
HVAC	Heating, Ventilation, and Air Conditioning system
IAQ	Indoor Air Quality
IPMVP	International Performance Measurement and Verification Protocol
M&V	Measurement and Verification
MS	Member State
NECP	National Energy and Climate Plan
nZEB	nearly Zero Energy Building
P4P	Pay-for-Performance
PV	Photovoltaic
RED	Renewable Energy Directive
RES	Renewable Energy Source(s)
SRI	Smart Readiness Indicator
TBS	Technical Building System
TSO	Transmission System Operator

Executive summary

The Smart Readiness Indicator (SRI) links specific functionalities of a building's technical systems with specific benefits for the building's occupants. At the same time, the SRI should also be regarded as a policy tool that may help EU Member States (MS) to achieve their national policy goals for energy and climate. When MS decide about the adoption of the SRI, as well as the potential adaptations to its calculation method, they should prioritise the services and functionalities that contribute most to the pursued goals. To this end, funding authorities may design public funding programmes that support the installation or upgrade of specific SRI services as a way to steer private investments in energy efficiency towards measures that are best aligned with the national policy goals for the energy performance, the demand characteristics and the technical capabilities of the building stock.

In order to support funding authorities, this deliverable presents a qualitative analysis of the ability of each service and functionality level of the SRI catalogue to contribute to the following policy goals:

- Improvement of the national building stock's energy performance
- Promotion of BACS deployment in commercial buildings
- Deployment of energy generation from renewable sources in buildings
- Improvement of demand-side flexibility
- Electrification of heating
- Monitoring and information collection for building energy performance.

In addition, funding authorities should take into account the fact that the impact of some SRI functionalities – and often, these are highly impactful ones – depends on if and how they are actually utilized inside the building. As a result, they should prioritize their support first and foremost towards services of high potential contribution and low uncertainty of impact.

This deliverable characterizes all the services and functionality levels of the SRI catalogue in terms of the dependencies of their impact on energy efficiency and demand flexibility. These dependencies are categorized as:

- Dependence on building/system design
- Dependence on implementation
- Dependence on occupant behaviour
- Dependence on occupancy profiles
- Dependence on supportive methods and tools
- Dependence on electricity market regulation.

For the case of services of high potential contribution and high uncertainty of impact, funding authorities have two (2) options at their disposal:

(a) Integrate impact verification schemes into the public funding programme so that to determine the actual impact of the relevant services and functionality levels;

(b) Use the public funding programme to support performance-based and as-a-service business models for delivering the relevant services and functionality levels.

The deliverable proposes ways of integrating impact verification schemes into public funding programmes for SRI upgrades with the goal of increasing the programmes' cost-effectiveness. It also offers recommendations for combining public funding schemes with as-a-service business models.

1. Introduction

Scope of the deliverable

The Smart Readiness Indicator (SRI) links specific technology capabilities of a building's technical systems with specific benefits for the building's occupants. However, when EU Member States (MS) have to decide about the adoption of the SRI, as well as the potential adaptations to its calculation method, they need a way to link it to their national policy goals. Accordingly, this deliverable presents a qualitative analysis of the ability of each service and functionality level of the SRI catalogue to contribute to the following policy goals:

- Improvement of the national building stock's energy performance
- Promotion of BACS deployment in commercial buildings
- Deployment of energy generation from renewable sources in buildings
- Improvement of demand-side flexibility
- Electrification of heating
- Monitoring and information collection for building energy performance.

These goals were highlighted by reviewing the energy and climate policy measures of the MS targeted by SRI2MARKET, as well as from the Energy Performance of Buildings Directive (EPBD), the relevant provisions of the Energy Efficiency Directive (EED), and the Renewable Energy Directive (RED) as the main pieces of EU legislation impacting the building sector. The estimation of the ability of each service and functionality level to contribute to the achievement of these goals was carried out through surveys that the SRI2MARKET team forwarded to stakeholders with a good understanding of both the SRI and the EU polices for energy and climate.

Furthermore, public funds constitute a limited resource and, as a result, MS should prioritize the types of energy efficiency measures that may be supported through public funding. To do so, one must take into consideration the main reasons why public funds are used for supporting upgrades in the energy efficiency of a country's building stock, as well as how SRI upgrades align with these reasons.

There are two (2) main reasons for supporting energy efficiency upgrades using public funds:

1. **National-level benefits from the reduction of energy consumption in buildings**. The first reason is that an efficiency upgrade in some buildings will bring benefits at national level in terms of a reduction in electricity prices due to phasing out the more expensive electricity generators and/or an increase in energy security due to reduced needs for fuel imports. These benefits will be shared among all citizens.

In this case, public funding is meant to support the **expected impact** of the upgrades. One of the recommendations of this deliverable is that when the impact of a specific efficiency measure depends significantly on whether and how it is utilized by the building occupants, the post-retrofit impact should be verified in order to decide the extent to which the measure should be supported going forward. This is especially relevant to many of the measures that are required for upgrading the SRI rating of a building.

The EPBD requires that MS link their financial measures for energy efficiency improvements in the renovation of buildings to the targeted or achieved energy savings, as determined by one or more criteria. The following table outlines these criteria and the way they can be applied to SRI upgrades:

Criterion	Applicability to SRI upgrades
The energy performance of the equipment or material used for the renovation	SRI upgrades concern mainly the way the equipment works (its control inputs and control policy). As a result, there is not always a reliable way to reflect the capabilities of the equipment through its rated performance metrics.
Standard values for calculation of	Generally, there are not standard values for calculating energy

Criterion	Applicability to SRI upgrades
energy savings in buildings	savings from upgrades in control functionality. The standard EN 15232:2012 *Energy performance of buildings – Impact of Building Automation, Controls and Building Management* offers a simplified way (BACS factor method) for estimating energy savings from a BACS upgrade when the energy consumption under a reference BACS class (Class C) is known. Still, energy consumption under the reference class must be calculated or estimated.
The improvement achieved due to such renovation by comparing energy performance certificates issued before and after renovation	Energy performance certificates do not always capture the impact of upgraded SRI service functionalities. SRI certificates, on the other hand, do reflect the presence of specific technical capabilities but do not provide information on how they are utilized.
The results of an energy audit	Energy audits will provide accurate results, but they are often expensive and cannot easily scale at the level of a public funding programme.
The results of another relevant, transparent and proportionate method that shows the improvement in energy performance	An impact verification scheme that relies on building data collection and processing fits well with this criterion.

Accordingly, the deliverable characterizes all the services and functionality levels of the SRI catalogue in terms of the **dependencies of their impact** on energy efficiency and demand flexibility. These dependencies are categorized as:

- Dependence on building/system design. This category includes services the impact of which is affected by the design of the building and the available infrastructure inside it. Dependency on climate conditions is also included in this category.
- Dependence on implementation. This case includes services and functionality levels that are provided through smart algorithms and their software implementation.
- Dependence on occupant behaviour. This case concerns services and functionality levels the impact of which depends on how occupants use them (such as the selected settings or the choice to override the default operation).
- Dependence on occupancy profiles. The time-related characteristics of a building's energy demand can affect the extent to which a service of this category is beneficial to the occupants.
- Dependence on supportive methods and tools. This category concerns mainly services for data collection and provision, since the availability of the right methods and tools is necessary so that to translate data into actionable insights. Furthermore, it includes services that require internal procedures and human resource capabilities to achieve their maximum impact.
- Dependence on electricity market regulation. This category concerns services that include the ability to receive and respond to signals from the grid. Their impact depends on the availability of demand response contracts in the electricity market and their profitability for consumers.

This deliverable proposes ways of integrating impact verification schemes into public funding programmes for the services and functionality levels the impact of which depends on implementation, occupant behaviour, and the availability of supportive methods and tools. The goal is to increase the programmes' cost-effectiveness.

2. **Acceleration of market maturity and innovation**. The second reason is that supporting specific technologies may improve the capability of the service providers in the national market to successfully install, configure and optimize them according to the building occupants' needs. Another recommendation of this deliverable is that services and functionality levels the impact of which depends on software/algorithm implementation and/or the availability of the right supportive methods and tools could be promoted through service providers. In this way, a public funding scheme supports a measure if it is offered to consumers through a service provider that is responsible for monitoring and maintaining its performance. This can be achieved through energy performance contracts or through *as-a-service* business models. The deliverable offers recommendations for combining public funding schemes with as-a-service business models.

The results and conclusions of the deliverable will be utilized for further dissemination and communication activities, including:

- Policy guidelines produced by the project;
- Presentations in national workshops and webinars that promote the SRI to the MS policy makers;
- Dialogues within the SRI communities.

Structure of the deliverable

Chapter 2 "Review of national policies and synergies with the SRI" reviews the publicly available information about the energy and climate policy measures of the EU MS targeted by the SRI2MARKET project, so that to identify potential synergies with the SRI.

Chapter 3 "Linking SRI services to policy goals" presents the details of the approach that was employed to define the ability of each service and functionality level of the SRI catalogue to contribute to the achievement of the selected policy goals. In addition, the chapter presents the results of the survey analysis, which are also included in an Excel file that accompanies the deliverable.

Chapter 4 "Dependencies of impact from SRI upgrades" characterizes all the services and functionality levels of the SRI catalogue in terms of the dependencies of their impact with regards to energy efficiency and demand flexibility.

Chapter 5 "Optimizing impact from SRI upgrades" presents ways to integrate impact verification in public funding schemes for SRI upgrades, as well as ways of linking public funding schemes with as-a-service business models.

Chapter 6 "Conclusions and recommendations" summarizes the deliverable.

2. Review of national policies and synergies with the SRI

This chapter reviews the publicly available information about the energy and climate policy goals and financial measures of the EU Member States targeted by the SRI2MARKET project, so that to identify potential synergies with the SRI. The relevant information was collected from the following sources:

- The relevant National Energy and Climate Plans (NECPs) 2021-2030;
- The relevant National Long-Term Renovation Strategies and the European Commission's Staff Working Document (SWD/2022/375) analysing the national long-term renovation strategies 2020 for all EU countries;
- The European Environment Agency's (EEA) database on integrated national climate and energy policies and measures in Europe;
- The European Construction Sector Observatory.

The relevant national partners of SRI2MARKET supported in reviewing and updating the national measures and in selecting the most appropriate measures relevant for the deliverable. The identified policy goals and measures for Austria, Croatia, Cyprus, France, Portugal and Spain are presented in the next subsections.

Austria

One of the key objectives and areas of action of the NECP is the support for the **replacement of fossil fuels with renewable and efficient heating in the building stock** by means of federal funding instruments. Promotion of heat pumps can be coupled by high functionality levels of the heat emission control, the control of the distribution fluid's temperature, as well as functionality for the active control of thermal storage. In addition, the plan includes measures for heating optimization, which can be both linked to and supported by SRI upgrades.

The Mobility Master-plan[1] with the new support programmes of the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK) for **e-vehicles**[2] has synergies with the Electric Vehicle (EV) charging domain of the SRI catalogue, since the availability of charging stations impacts the willingness of consumers to invest in EVs.

The Climate and Energy Fund (KLIEN) supports measures for **on-site electricity generation**. These measures can be accompanied with requirements for high functionality levels for all services that improve self-consumption, since the higher the self-consumption rate, the more profitable on-site generation is for consumers. The Fund's mobility funding programmes[3] can also support the SRI services of the EV charging domain.

The Intelligent Metering Instruments Roll-Out Regulation (IME-VO) foresees the widespread **deployment of smart meters** (95% until 2024). Digitization both at the building level and at the energy system level is important so that to reap the benefits from smart meters. SRI services that focus on the monitoring of a building's technical systems and the control of their operation using data collected through a monitoring system can be supported in parallel to smart meter deployment.

As part of the Renovation Plan, a total of EUR 2.445 billion is to be made available for **switching to climate-friendly heating systems in private households** between 2023 and 2027. Replacing heating systems is an opportunity to introduce SRI functionalities that increase energy efficiency and demand flexibility to benefit both the consumers and the energy system.

The plan includes support for the introduction of **Energy Management Systems (EMS) for small and medium-sized enterprises (SMEs)** for a systematic increase in energy efficiency, reducing the companies'

[1] https://www.bmk.gv.at/themen/mobilitaet/mobilitaetsmasterplan/mmp2030.html
[2] https://www.umweltfoerderung.at/e-mobilitaetsfoerderungen-2024
[3] https://www.klimafonds.gv.at/foerderung/aktionsprogramm-klimaaktiv-mobil-aktive-mobilitaet-und-mobilitaetsmanagement-2024/

energy costs, CO_2 and other pollutant emissions. The programme will support external consultations, training, EMS certification and the purchase of energy monitoring tools.

The programme "Stepping out of Oil and Gas (Raus aus Öl und Gas)" provides high subsidy rates until 2025 for the **replacement of fossil fuel heating systems**. This bonus supports (among other options) heat pump (< 100kW) and solar thermal installations, as well as upgrades in the heat distribution system. While the programme finances equipment purchase, installation and interconnection, it could also prescribe minimum SRI services and functionality levels for the new equipment.

The Austrian Climate Protection Initiative "klima:aktiv" aims at **awareness raising measures** at national level about the advantages of modern heating systems. These measures are expected to increase the boiler replacement rate. Information about the benefits from heating systems with high SRI rating can be included.

The klima:aktiv initiative is made up of a number of programmes that provide a wide spectrum of information, advice and training in four main areas – building and renovation, energy efficiency, renewable energy, and mobility. The klima:aktiv building standard provides a set of sustainability and quality criteria that focus on location, energy supply, building materials and construction, and comfort and health. Accordingly, introducing the SRI tool into the klima:aktiv programmes can further support its dissemination.

The Electricity Consumption Reduction Act includes an incentive model for consumers (commercial companies, business and industry, aggregators) to **reduce their electricity consumption within designated peak periods** between 8-12 am and 5-7 pm, or to shift it out of the peak periods. Programs that support SRI upgrades that increase demand flexibility can also incentivise consumers to participate in demand-side management.

Croatia

The policy goal of **promoting the use of innovative information and communication technologies (ICTs)** to reduce greenhouse gas emissions – Act on Energy Efficiency (OG 127/14, 116/18, 25/20 and 41/21 – is particularly relevant for the SRI, since the policy aims at increasing innovative ICT use so as to monitor energy savings and reduce greenhouse gas emissions. The SRI rating of a building (focusing mainly on energy efficiency and provision of information) can be used as an indicator of the extent to which the policy is reaching its goal.

The National Energy Efficiency Action Plan promotes the **electrification of heating systems using heat pumps** with mandatory production of electricity from photovoltaic systems on-site, where applicable. Supporting heat pumps and on-site generation is an opportunity for promoting SRI functionality levels that correspond to improved energy efficiency and demand flexibility for the consumers.

The promotion of electro-mobility and establishment of **charging infrastructure** in buildings – Act on Construction (OG 153/13, 20/17, 39/19, 125/19) – defines requirements for EV charging infrastructure in new and existing buildings. The rating of a building based on the SRI services of the EV charging domain can be used as an indicator for evaluating the achievement of the policy goals.

Furthermore, the NECP includes the following measures that have synergies with the SRI:

Measure	Synergies with SRI
Promoting the decarbonisation and application of the "energy efficiency first" principle in buildings, 2019-2030 (information measure)	Timely information and assessment of the readiness of buildings for smart technologies in accordance with the Smart Readiness Indicator protocol and a broad dialogue related to the application of SRI in the Republic of Croatia are envisaged.
Energy renovation programme for apartment buildings, 2021-2030 (financial measure, ESCO model and grants). The programme will be accompanied by the	Promoting upgrades that increase the functionality level of SRI services for data collection and monitoring will provide an effective way of advancing savings verification from manually entering energy bills to

Measure	Synergies with SRI
monitoring of energy consumption before and after the energy renovation through the ISGE[4] system.	remotely collecting the necessary data.
Energy renovation programme for family houses, 2021-2023 (financial measure, grants)	The programme will allow for the possibility of implementing individual measures. Accordingly, it could either support measures for SRI upgrades or utilize the buildings' SRI ratings to evaluate the achieved impact.
Energy renovation programme for public sector buildings, 2021-2023 (financial measure, ESCO model and grants). ESCO models will be combined with grants with the aim of meeting the nZEB (nearly Zero Energy Building) standard.	Since SRI upgrades concern the installed equipment, and have typically shorter payback periods compared to building envelope upgrades, the ESCO fee could be linked with verified impact of SRI upgrades.
Systematic energy management in the public sector, 2014-2030 (informative measure). The goal is to cover and regularly monitor all public sector buildings and public lighting systems by the end of 2030 using the ISGE system. The measure also envisions the introduction of measuring devices / sensors to measure indoor temperature and air quality in public buildings and connect them to the ISGE.	Promoting upgrades that increase the functionality level of SRI services for data collection and monitoring can reduce the cost of achieving this goal (automated data collection) and verify its achievement (improved SRI rating reflects the availability of the required technical capabilities).
Systematic energy management in the business (service & production) sector, 2023-2030 (fiscal measure). Using the tax system to encourage systematic energy management in the business sector and adoption of certified energy management systems (ISO 50001).	The provision of incentives for higher SRI ratings can indirectly promote energy management system adoption, since the availability of such systems is required for some of the (higher) functionality levels.

Cyprus

The NECP includes a set of measures to promote the deployment of energy generation from renewable sources (RES) in buildings:

Measure	Synergies with SRI
Plan for electricity generation from RES for own consumption – net-billing, 2018-2030. Measure to install RES systems with a capacity of up to 8 MW for own consumption, aimed mainly at commercial and industrial consumers.	The measure could promote SRI functionalities that improve demand flexibility (interaction with the grid) and provide information regarding local electricity generation.
Plan for electricity generation from RES for own	Since the clearing interval is smaller or equal to an

[4] The ISGE was developed under the United Nations Development Programme in Croatia and monitors the public buildings' energy consumption through energy bills for electricity, heating and water. In some cases, digital meters were installed with 1 hour sampling period, providing more in depth information about onsite consumption.

Measure	Synergies with SRI
consumption – virtual clearing of bills, 2023-2026. Measure for installation of PV systems up to 150 kW for all consumers for own consumption. The measure is mainly targeted at commercial/industrial consumers who do not have space available to install a PV system on their premises.	hour, the availability of highly efficient algorithms for coordinating consumption and storage between multiple sites is necessary. The SRI rating after the equipment installation can be used as a way for consumers to set their expectations about the installed system's performance.
Sponsorship scheme for the installation of a PV system for charging electric and plug-in vehicles in homes, 2020-2030. Financial aid measure for installation of a PV system up to 2 kW, charger and storage system in existing dwellings for charging electric or hybrid vehicle[5].	The installation could be linked to requirements for the corresponding buildings' SRI rating for the services of the EV charging domain.
Sponsorship scheme for the installation or replacement of a solar system for the production of hot water for use in dwellings, 2004-2030. Financial support measure for the installation or replacement of solar hot water production in existing dwellings with a building permit before 21/12/2007.	Requirements for the SRI services for hot water storage and information reporting on hot water performance could be established.
Promoting electricity storage, 2023-2030. A grant for storage systems is being considered at this stage. The use of such systems will help to absorb loads at peak times.	Requirements for the SRI services for self-consumption could be established.

The grant scheme "**Save – Stepping up in homes**" supports energy upgrading of existing dwellings:

- Energy upgrading of a dwelling in a building with zero energy consumption;
- Energy upgrading of a dwelling that will simultaneously install a photovoltaic system operated by the net-billing method;
- Energy upgrading of a dwelling in order to achieve primary energy savings of at least 60% based on the final Energy Performance Certificate (EPC) compared to the original one.

The eligible interventions include thermal upgrades of the envelope, installation of heat pumps, solar collector systems for hot water production, solar PVs and electricity storage. Since the verification of the improvements is based on comparing the EPCs before and after the upgrade, the SRI rating of the retrofitted building could be also used as a means for evaluating the upgrade.

The grant scheme "**Save – step up to businesses and other bodies**" promotes energy saving investments in buildings and facilities, owned and/or used by small and medium-sized enterprises and non-profit organisations. Support is provided for the renovation and energy upgrading of buildings/infrastructure as well as for improving the efficiency of production processes. Similarly to the grant scheme for residential buildings, the SRI rating of the retrofitted building could be also used as a means for evaluating the upgrade.

France

[5] https://resecfund.org.cy/en/ev_charging_2022

In the residential sector, the MaPrimeRénov' state aid programme is managed by the National Housing Agency (Agence nationale de l'habitat) and supports **renovations of both single- and multi-family residential buildings**. The measures that are funded include:

- Thermal insulation (insulation of walls, insulation of roof terrace, installation of double or triple glazed windows);
- Work related to heating (installation of an air/water heat pump, heating regulation and programming system, or thermostatic valves, installation of equipment for supplying domestic hot water using solar thermal energy);
- "Summer comfort" work, i.e. installation of solar protection for windows or installation of double-flow CMV (Controlled Mechanical Ventilation).

This state aid programme can be cumulated with other funding mechanisms such as eco-PTZ, which is a zero-interest eco-loan allowing to finance the energy renovation of houses without making a cash advance and without paying interest.

When the renovation work includes equipment replacement and/or upgrades, the new SRI rating could be used as a way to convey information to the building owners about the capabilities of the new systems.

In addition, the NECP foresees measures for compliance with the Building automation and control systems (BACS) decree of 7 June 2023 on temperature control systems for heating and cooling systems. Compliance with the decree requires buildings with an effective rated output of more than 290 kW to be equipped with a BACS by 1 January 2025. Then, the same obligation will apply to buildings with an effective rated output of more than 70 kW by 2027. Information about the SRI rating of the relevant buildings, especially for the services that require a BACS installation, can support the verification of the compliance with the degree.

Another law in France which can benefit from SRI rating is called Tertiary decree[6]. It specifies the terms of application of Article 175 of the ÉLAN law (Evolution of Housing, Development and Numerical) and requires the **reduction of energy consumption in tertiary buildings**. It concerns owners and tenants of all tertiary buildings (office buildings, shops, administration buildings, schools, etc.) with a surface area of more than 1,000 m². The decree obliges such buildings to make energy savings in relation to a reference year (-40% by 2030, -50% by 2040 and -60% by 2050 in relation to 2010) or in relation to a threshold defined for each type of building (consumption in kWh of final energy/m²/year not to be exceeded). The SRI score and assessment results can help building managers to define the most cost-effective building smartness upgrades (change of use of heat and cold generators, modification of control algorithms in BMS etc.) to generate energy savings and be compliant with this decree.

Concerning electric vehicles, France has set itself the objective of reaching 400,000 EV charging points open to the public by 2030, and the Energy Transition for Green Growth Act sets a target of 7 million public and private recharging points by 2030. Concerning residential multi-family buildings, any occupant (owner or tenant) has the right, by law, to install an EV charging plug in their parking slots. **The installation of public and private charging stations is the subject of financial support**. Individuals who install home terminals are entitled to a tax credit up to a maximum of EUR 500 per charge system and 75 % of the expenditure. Moreover, the ADVENIR programme, financed under the Energy Economy Certificates (EEC), subsidises the installation of charging points in collective residential homes and businesses. These incentives could be coupled with calculating the functionality levels of the SRI services that belong to the EV charging domain.

Finally, a consortium formed by the electricity transmission system (RTE), the main electricity distribution operator (ENEDIS) and associations representing the French smart building value chain (Think SmartGrids, Smart Building Alliance, GIMELEC, IGNES) unveiled "FlexReady", a technical and organisational reference framework designed to unify building management solutions and associated best practices[7]. Simultaneously, the same consortium launches the annual publication of an annual "barometer" to monitor

[6] https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000038812251

[7] https://www.rte-france.com/actualites/optimiser-consommations-electricite-acteurs-francais-flexibilite-passent-action

the development of consumption flexibilities in the commercial and residential sectors: each year, the barometer will report on compliance with the equipment trajectory and the collective impact of actions to shift and modulate consumption on the electricity system[8]. Bridges will be established between the FlexReady framework and the corresponding functionality of the SRI (adaptation to signals from the grid - energy flexibility) in order to ensure consistency between the two approaches and acknowledge the impact on the SRI score of using pieces of equipment complying with the FlexReady framework.

Portugal

The revised NECP, published on October 1st, 2024, and currently under final approval by the Portuguese Parliament, outlines the following measures for reducing the carbon intensity of the building stock:

1. **Promote rehabilitation as the main form of intervention at building and urban development level** (2020-2030). The goal is to increase the useful life of buildings with a consequent return on the environmental resources already invested, contributing to the reduction of greenhouse gas emissions, minimising construction waste and contributing to the conservation of nature and biodiversity. To this end, the measure will promote the use of digital platforms and the creation of one-stop-shop as an information generator and facilitator of small and major renovations of buildings.

2. **Promote the electrification of buildings accompanied by increased incorporation of renewables** (2020-2030). Electrification of final consumption is identified as one of the most important drivers for decarbonising the economy. New buildings should therefore focus on the uptake of local renewable energy sources and electricity, thus promoting the replacement of fossil fuels.

3. **Promote the renovation of heating and cooling systems from renewable energy sources** (2020-2030). The measure aims to encourage the replacement of outdated heat and cold production systems with more efficient and renewable energy systems, as well as the electrification of heating and cooling by promoting the procurement and use of heat pumps in buildings.

4. **Promote storage capacity associated with production systems for self-consumption and energy sharing schemes** (2024-2030). Recognizing the importance of the role of buildings towards carbon neutrality, integrated solutions will be promoted, combining self-consumption, storage and smart charging to obtain a more efficient and dynamic energy system. These measures not only protect consumers from price fluctuations, but also help to smooth out load variations on the utility grid, contributing to a more stable and efficient management of the energy system. Monitoring the SRI rating of the retrofitted buildings, especially for the services and functionalities that contribute significantly to the demand flexibility criterion, can help in evaluating the actions carried out under this measure.

In addition, the NECP outlines the following measures for promoting EVs:

1. **Promote the development of the publicly accessible charging network** (2020-2025). The publicly accessible recharging network will follow the size of the electric vehicle fleet in circulation in Portugal. Given that sales of electric vehicles have been increasing significantly in recent years, it is important to ensure that the charging network increases in order to maintain ratios between vehicles and charging stations. In order to strengthen the charging network, the measure foresees the adoption of criteria requiring the installation of charging stations, particularly in commercial areas. These criteria could be enforced or reinforced through specific requirements for the SRI rating of the respective buildings, focusing particularly on the SRI services of the EV charging domain.

2. **Promote the roll-out of charging points for electric vehicles in private buildings** (2020-2025). The measure aims to create the appropriate conditions, regulations and incentives to scale up the electric vehicle charging network in private buildings, including facilitating new grid connections, strengthening existing ones and adopting smart charging solutions. The SRI ratings of the retrofitted buildings, focusing particularly on the SRI services of the EV charging domain, can be used as a way to track and evaluate the success of this measure.

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[8] https://www.rte-france.com/analyses-tendances-et-prospectives/barometre-flexibilites-consommation-electricite

3. **Promote smart charging of electric vehicles with two-way energy flows** (2020-2030). The measure aims to create the legal framework for the smart charging of electric vehicles and for the use of functionalities enabling reverse flows of energy. These functionalities are included in the SRI services for the EV charging domain (EV-16 EV Charging Grid balancing). Accordingly, the measure could also set requirements for the SRI rating of the retrofitted buildings.

Besides the NECP provisions, the Portuguese Long Term Renovation Strategy has seven (7) areas of intervention, one of which is dedicated to smart buildings. It specifically foresees the introduction of the SRI. The indicator is also already foreseen in the energy certificate layout which "may include (...) smart readiness indicator(s)" by law. Although it is still to be put in practice, it already allows for this innovation, and it is being pushed forward on the new version of the EPC system.

Relevant funding schemes include:

- Sustainable buildings programme. Eligible measures include efficient windows, insulation, renewable heating and cooling equipment, PV systems, water efficiency and bio-climate architecture.
- Support to Renovation and Energy Performance of Services Buildings. Buildings must be under a mandatory EPC evaluation according to national legislation (with the exception of expansion works which are not eligible). At least 30% primary energy reduction. Eligible measures include efficient windows, upgraded technical systems, renewable energy production for self consumption, and can include water efficiency, energy audits.

Spain

The NECP outlines the following measures towards decarbonization that are relevant for the SRI:

1. **Development of self-consumption with renewables and distributed generation**. The promotion of self-consumption is one of the main objectives in the NECP, for which a target of 19 GW of self-consumption installed by 2030 is set. Soft financing and direct investment grants will be utilized to support and promote self-consumption. Soft financing mechanisms are also proposed as a way to facilitate the mobilisation of private investment by allowing investment to be returned on the basis of the economic savings brought about by the self-consumption.

2. **Promotion of electric vehicles**. The objective of this measure is to make the transport sector more energy efficient and reduce the energy consumption of the vehicle fleet, through the electrification of the fleet, which will be achieved by gradually replacing combustion vehicles with electrically-powered vehicles. To this end, a number of legislations are foreseen for the provision of energy charging services for electric vehicles.

3. **Promotion of energy efficiency in existing buildings in the residential sector**. According to the NECP, if the improvement of the energy rating of a building can be achieved by acting on its thermal envelope or on its HVAC and domestic hot water (DHW) systems, the measure prioritises investments in the thermal envelope (façades, roofs and enclosures) so as to avoid oversizing the heating equipment. Nevertheless, the measure aims at supporting HVAC upgrades, the incorporation of thermal renewable energy sources, as well as the use of monitoring, control and automation tools to manage energy efficient equipment.

The NECP links the measure with the operation of the Energy Savings Certificate (CAE) scheme in Spain. A CAE is document that certifies that, after implementing energy efficiency measures, energy savings equivalent to 1kWh in one year have been achieved. A market is created in which obligated parties may purchase savings from those who carry out energy retrofits. Upgrades that enable the monitoring of the equipment's operation can help in tracking the cumulative savings that back a CAE and offer increased transparency in the CAE market. The SRI services of the Monitoring and Control domain can support the scheme.

4. **Promotion of energy efficiency in buildings in the tertiary sector**. The measure aims to reduce the energy consumption of existing buildings used in the tertiary sector, whether they are publicly or privately owned, by means of energy renovation actions to improve their energy rating. The energy renovation of the

buildings will be carried out through public support and funding programmes. The supported actions include upgrades in the envelope's thermal insulation, upgrades of the HVAC systems, upgrades of the interior lighting systems of the buildings, bringing them into line with the required energy performance values according to the use of each area, setting up systems for regulating and controlling lighting according to the activity in each building area, and adapting the level of lighting according to the supply of natural light.

5. **Energy audits and energy management systems**. Companies with an average annual consumption of more than 85 TJ in the last three previous years will have to install an energy management system, and companies that consume more than 10 TJ on average per year and do not have an energy management system will have to carry out energy audits. The functionality level of the SRI services of the Monitoring and Control domain can be used for tracking the impact of the measure.

3. Linking SRI services to policy goals

The policy goals

When MS have to decide about the adoption of the SRI, as well as the potential adaptations to its calculation method, they need a way to link it with specific, national policy goals. Accordingly, this section describes the approach that was utilized to determine the potential impact of each of the SRI services and functionality levels on a number of policy goals. These policy goals were derived from the energy and climate policy measures of the EU Member States targeted by SRI2MARKET, as presented in the previous chapter. The policy goals that were identified are the following:

1. **Improvement of the national building stock's energy performance**. Reducing the energy consumption of the building stock through upgrades in both the building envelope and the building technical systems is a major part of all MSs' strategies towards decarbonization and energy security.

2. **Promotion of BACS deployment in commercial buildings**. The EPBD sets specific requirements to ensure that BACS are installed in large non-residential buildings that are characterised by a high HVAC effective rated output. Many of the SRI2MARKET countries have included measures for supporting BACS deployment in their NECPs.

3. **Deployment of RES generation in buildings**. All the SRI2MARKET countries regard the deployment of distributed energy generation from renewable sources and the self-consumption of this energy at individual consumer or collective (through energy communities, collective self-consumption and/or virtual net-billing schemes) level as an important measure towards the decarbonization of the building stock.

4. **Improvement of demand-side flexibility**. Power system operators (TSOs and DSOs) should consider demand-side resources as an alternative to the supply-side ones when doing so is cost effective. To this end, contracts for auxiliary services must be accessible to consumers, and consumers should already have installed the necessary technical capabilities for providing these services. In addition, MS may plan to introduce dynamic electricity tariffs as a way to reward demand flexibility when it helps reduce the total cost of the power system's operation. The availability of control systems and/or energy storage in buildings as well as the interoperability of all these elements is a requirement for consumers to benefit from dynamic tariffs.

5. **Electrification of heating**. The electrification of heating is an important part of the EU environmental and climate goals towards decarbonisation. Heat pump promotion is an effective tool for MS to achieve the electrification goal. However, a national policy that promotes heat pumps may focus not only on heat pumps themselves, but on creating enabling conditions, such as supporting upgrades in the buildings' circuits for distributing hot water, as well as promoting synergies between heat pumps and on-site energy generation and storage.

6. **Monitoring and information collection for building energy performance**. Many of the SRI2MARKET countries have already acknowledged in their NECPs how important infrastructure for collecting and communicating energy performance data is for helping: (a) consumers to make educated decisions on building upgrades, and (b) public authorities to monitor and evaluate the impact of their energy and climate policies and the achievement of their policy goals. In addition, a new article is foreseen in the proposed revision of the EPBD exclusively referring to the building systems' data. The overall aim is to ensure that building owners, tenants and managers maintain direct access and are eligible for allowing third parties access to these data.

The methodology for linking SRI services with policy goals

The quantification of the contribution of the different SRI services and functionalities in achieving each policy goal was carried out through surveys of pairwise comparisons, i.e. statements of the form "*Functionality level X of service A contributes more than functionality level X of service B*". These surveys were completed first by the SRI2MARKET project team and, then, they were shared with selected stakeholders/expects outside of the consortium. The surveys that were shared with stakeholders/expects focused only on the following three (3) policy goals: (a) improvement of the national building stock's energy performance, (b) promotion of BACS deployment in commercial buildings, and (c) increase in RES adoption in buildings. For the remaining goals, it was decided that either internal contributions were adequate and/or the quantification was straightforward to carry out.

When stakeholders visited any of the surveys, they would first see an introduction page:

Figure 3.1: Survey introduction page

Next, they were asked to select their country (Fig. 3.2) and the type of their organization (Fig. 3.3):

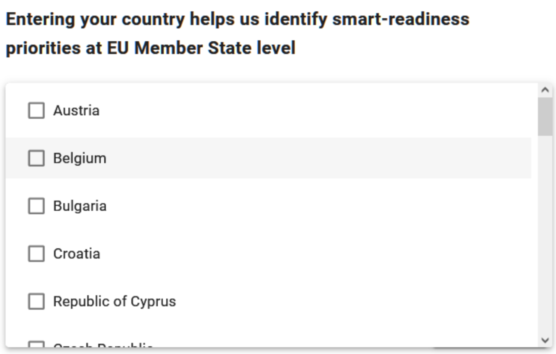


Figure 3.2: Survey question for capturing the stakeholders' country

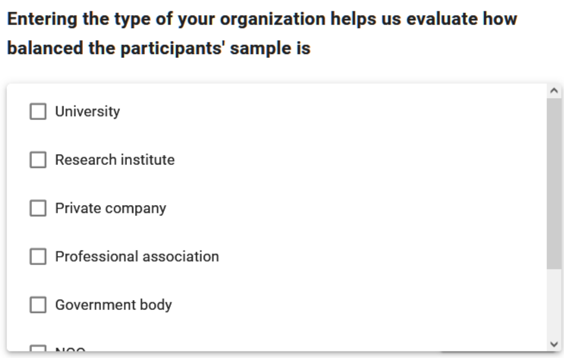


Figure 3.3: Survey question for capturing the stakeholders' organization

The main body of the survey was composed of questions that asked participants to compare a pair of SRI services and select the one that they believed – based on their knowledge and experience – can contribute more to the corresponding policy goal (Fig. 3.4).

Even though the SRI calculation method already provides quantified impacts for energy efficiency and demand flexibility, the surveys (and their analysis) make it possible to compare services across different domains, i.e. how a specific service from the ventilation domain may contribute more than another service in the heating domain with respect to the energy efficiency policy goal. This is particularly useful when prioritizing services to support through public funding schemes.

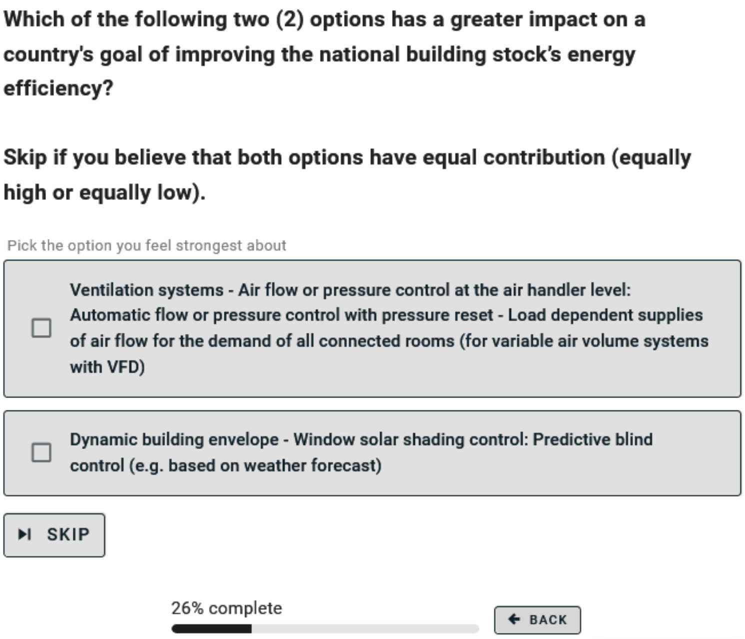


Figure 3.4: Pairwise comparison for quantifying SRI Service impact

The surveys included only the highest functionality level for each service. Based on the rating of that level, the previous levels were rated so that the ranking of the levels within any given service was consistent with the energy efficiency and demand flexibility impacts as defined by the SRI calculation method.

At the end of the survey, a list of links was provided so that participants can learn more about the SRI2MARKET project (Fig. 3.5).

Figure 3.5: Finish page of the survey

Global ranking from pairwise comparisons

This section explains the method that was utilized for ranking the different SRI services and functionality levels according to their contribution to the achievement of a given policy goal. The method aimed at translating pairwise comparisons into global weights reflecting the contribution of each service and functionality level.

The underlying model that was utilized is the Bradley-Terry-Luce (BTL) model, which is typically used to assess the ability of players based on one-on-one matches. Although the BTL model is not the only one that can be used for ranking options through pairwise comparisons, it is both intuitive and easy to set up in a probabilistic framework so that uncertainty about scores can be visualized.

In the BTL model, given the (unknown) ability α_j of player j and the (unknown) ability α_k of player k, the probability that j beats k is given by:

$$p(j > k \mid a) = \sigma\left(a_j - a_k\right)$$

where $\sigma(x) = 1/(1 + e^{-x})$ (i.e. the sigmoid function).

The equation above can also be written as:

$$a_j - a_k = \operatorname{logit}\left(p(j > k \mid a)\right)$$

A fully Bayesian version of the BTL can be written as:

$$y_i \sim Bernoulli(\pi_i)$$

$$\operatorname{logit}(\pi_i) = a_{j[i]} - \alpha_{k[i]}$$

$$a \sim N(0, \sigma^2)$$

where:

T Total number of players

$j[i]$ ID of player j in game i

$k[i]$ ID of player k in game i

y_i The outcome of game i:

$$y_i = \begin{cases} 1 & \text{if player j wins} \\ 0 & \text{otherwise} \end{cases}$$

π_i Probability that player j wins game i

The BLT model is applied on the survey results based on the following assumptions:

- Each question that was presented to the survey participants can be regarded as a game between the two options that the participants were asked to evaluate;
- When a participant selects one of the two options as the option with the larger impact, the selected option wins the game;
- The total number of players is the total number of SRI services and functionality levels that were evaluated through the survey, and the total number of games is the total number of pairs evaluated;
- The estimated ability of a given service and functionality level reflects its strength or utility towards achieving the corresponding policy goal;
- If the estimated abilities are grouped into bins and each bin is assigned an integer number that reflects the overall ranking of the abilities, we get weights in a form that is similar to the weights of the SRI indicator.

Since the results of the survey analysis are meant to be used for ranking / prioritization, rather than creating a new indicator, the scale for the scores was selected to be from [0] to [5]. The extended scale and the fact that the final weights are derived by grouping the estimated abilities into bins lead to some deviations between the weights of the SRI calculation method and the estimated strength of a service's contribution to a policy goal. As an example, the SRI weights and the policy contribution weights of the *H-1a Heat emission control* service are presented below:

Domain	**Heating**
Code	Service
H-1a	**Heat emission control**

Functionality levels		Energy efficiency SRI impact	Energy efficiency policy goal
Level 0	No automatic control	0	0
Level 1	Central automatic control (e.g. central thermostat)	1	1
Level 2	Individual room control (e.g. thermostatic valves, or electronic controller)	2	3
Level 3	Individual room control with communication between controllers and to BACS	2	3
Level 4	Individual room control with communication and occupancy detection	3	5

The following subsections present the survey results for each of the policy goals under consideration.

Improvement of the national building stock's energy performance

The country distribution of the 28 participants is presented in Fig. 3.6, and their organization type in Fig. 3.7:

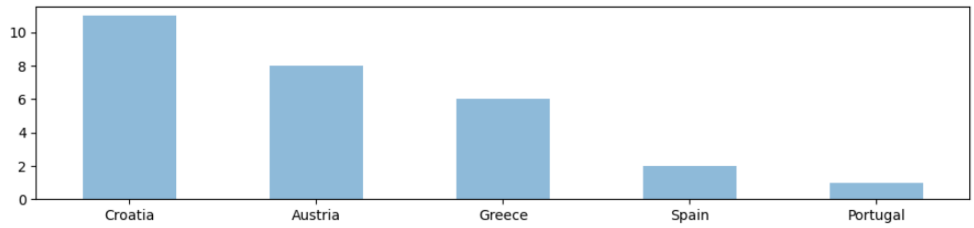


Figure 3.6: The countries of the participants in the energy efficiency survey

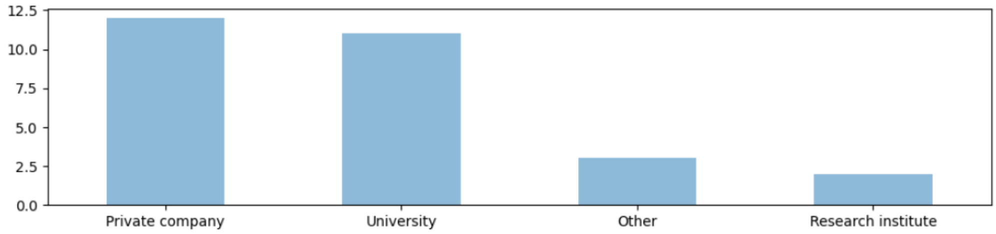


Figure 3.7: The organizations of the participants in the energy efficiency survey

Since the underlying model is a probabilistic one, the results are in the form of distributions for the ability of each evaluated service. The plot of Fig. 3.8 shows the ability distributions (left panel) and the sampling trace, which indicates convergence of the sampling process (right panel).

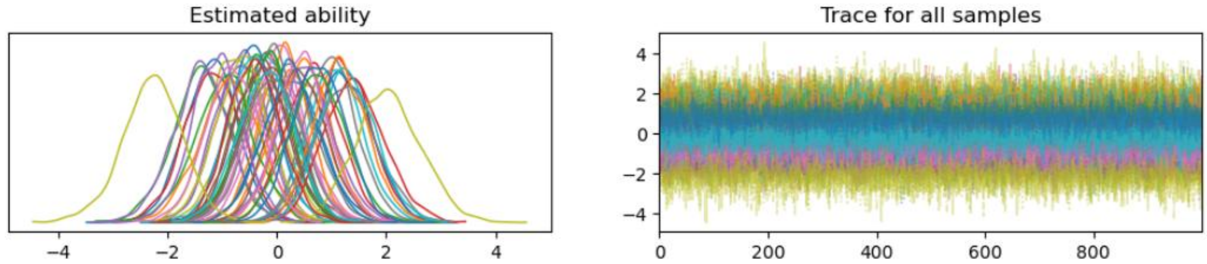


Figure 3.8: Results from training the model on the available data

The results are gathered in an Excel file that accompanies this deliverable. The following services were identified as the most impactful ones:

Heating

- Heat emission control: Individual room control with communication and occupancy detection
- Control of distribution fluid temperature (supply or return air flow or water flow): Demand-based control
- Heat generator control (all except heat pumps): Variable temperature control depending on the load
- Heat generator control (for heat pumps): Variable control of heat generator capacity depending on the load or demand (e.g. hot gas bypass, inverter frequency control)

Cooling

- Cooling emission control: Individual room control with communication and occupancy detection
- Control of distribution network chilled water temperature (supply or return): Demand-based control
- Generator control for cooling: Variable control of cooling production capacity depending on the load or demand (e.g. hot gas bypass, inverter frequency control)

Ventilation

- Supply air temperature control at the air handling unit level: Variable set point with load dependant compensation. A control loop enables to control the supply air temperature. The setpoint is defined as a function of the loads in the room

Monitoring and control

- Run time management of HVAC systems: Heating and cooling plant on/off control based on predictive control or grid signals

Promotion of BACS deployment in commercial buildings

The country distribution of the 16 participants is presented in Fig. 3.9, and their organization type in Fig. 3.10:

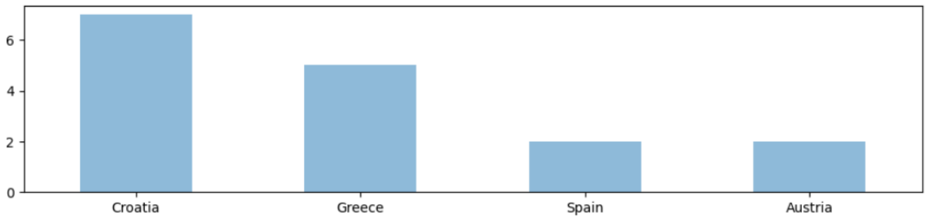


Figure 3.9: The countries of the participants in the BACS survey

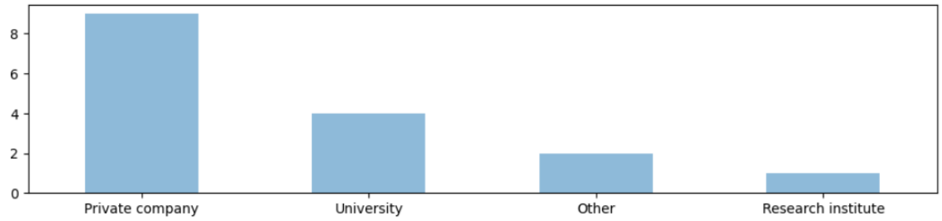


Figure 3.10: The organizations of the participants in the BACS survey

The following services were identified as the most impactful ones:

Heating

- Heat emission control: Individual room control with communication between controllers and to BACS
- Heat emission control: Individual room control with communication and occupancy detection

Cooling

- Cooling emission control: Individual room control with communication between controllers and to BACS
- Cooling emission control: Individual room control with communication and occupancy detection

Ventilation

- Supply air flow control at the room level: Local Demand Control based on air quality sensors (CO2, VOC, ...) with local flow from/to the zone regulated by dampers
- Air flow or pressure control at the air handler level: Automatic flow or pressure control with pressure reset: Load dependent supplies of air flow for the demand of all connected rooms (for variable air volume systems with VFD)

Dynamic building envelope

- Window open/closed control, combined with HVAC system: Level 2 + Centralized coordination of operable windows, e.g. to control free natural night cooling

Monitoring and control

- Detecting faults of technical building systems and providing support to the diagnosis of these faults: With central indication of detected faults and alarms for all relevant TBS, including diagnosing functions
- Occupancy detection: Centralised occupant detection which feeds in to several TBS such as lighting and heating
- Smart Grid Integration: Coordinated demand side management of multiple TBS
- Single platform that allows automated control & coordination between TBS: Single platform that allows manual control of multiple TBS

Deployment of RES generation in buildings

The country distribution of the 15 participants is presented in Fig. 3.11, and their organization type in Fig. 3.12:

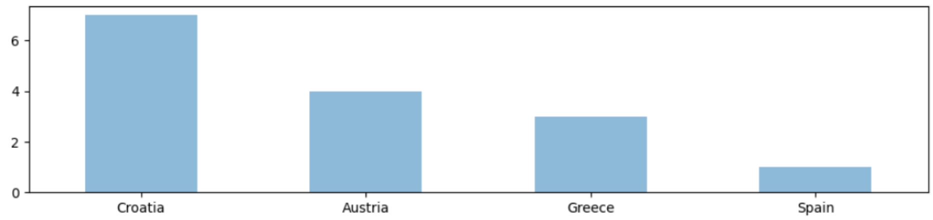


Figure 3.11: The countries of the participants in the RES survey

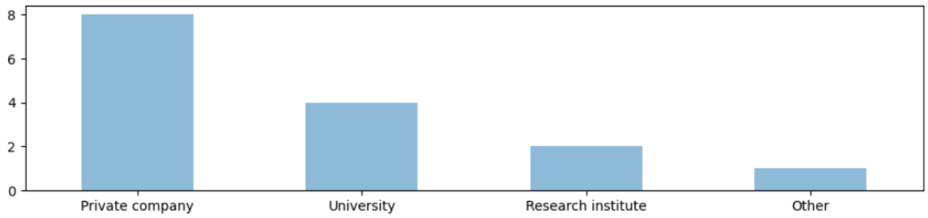


Figure 3.12: The organizations of the participants in the RES survey

The following services were identified as the most impactful ones:

Electricity

- Storage of (locally generated) electricity: On site storage of energy (e.g. electric battery or thermal storage) with controller optimising the use of locally generated electricity and possibility to feed back into the grid
- Optimizing self-consumption of locally generated electricity: Automated management of local electricity consumption based on current and predicted energy needs and renewable energy availability

Improvement of demand-side flexibility

The plot of Fig. 3.13 shows the ability distributions (left panel) and the sampling trace (right panel).

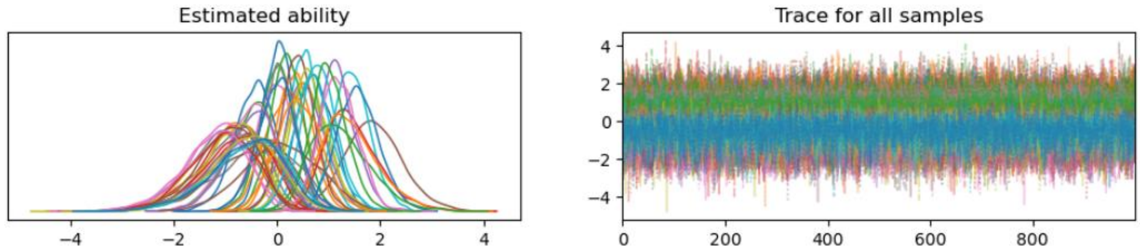


Figure 3.13: Results from training the model on the available data

The plot of distributions reflects the fact that the services can be easily distinguished between those that contribute significantly to demand flexibility and those that do not contribute at all. The following services were identified as the most impactful ones:

Heating

- Thermal Energy Storage (TES) for building heating (excluding TABS): Heat storage capable of flexible control through grid signals (e.g. DSM)
- Flexibility and grid interaction: Heating system capable of flexible control through grid signals (e.g. DSM)

Cooling

- Control of Thermal Energy Storage (TES) operation: Cold storage capable of flexible control through grid signals (e.g. DSM)
- Flexibility and grid interaction: Cooling system capable of flexible control through grid signals (e.g. DSM)

Electricity

- Storage of (locally generated) electricity: On site storage of energy (e.g. electric battery or thermal storage) with controller optimising the use of locally generated electricity and possibility to feed back into the grid

- Optimizing self-consumption of locally generated electricity: Automated management of local electricity consumption based on current and predicted energy needs and renewable energy availability
- Support of (micro)grid operation modes: Automated management of (building-level) electricity consumption and supply, with potential to continue limited off-grid operation (island mode)

Monitoring and control

- Run time management of HVAC systems: Heating and cooling plant on/off control based on predictive control or grid signals
- Smart Grid Integration: Coordinated demand side management of multiple TBS
- Single platform that allows automated control & coordination between TBS: Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather and grid signals

Electrification of heating

This survey was carried out in two (2) steps. First, the services of the SRI catalogue were screened so that to select the services which actually contribute to the corresponding policy goal. Next, a survey was carried out internally to rank the selected services.

The following services were identified as the most impactful ones for the electrification of heating:

Heating

Service: Control of distribution fluid temperature (supply or return air flow or water flow)

Functionality level: Demand-based control

Rationale: There is higher uncertainty about the actual efficiency of a heat pump compared to that of a boiler. The main reason for this, besides installation faults, stems from a higher probability of design errors such as having the flow rate through the heat emitters wrongly adjusted and/or the heating curve of the heat pump being set too high. High-quality control of the distribution fluid temperature could reduce the uncertainty and promote further adoption of heat pumps.

Service: Thermal Energy Storage (TES) for building heating (excluding TABS)

Functionality level: Load prediction based storage operation

Rationale: Thermal storage can increase the value of a heat pump installation when combined with on-site energy generation and/or time-of-day electricity tariffs.

Cooling

Service: Control of distribution network chilled water temperature (supply or return)

Functionality level: Demand-based control

Rationale: Same as for heating.

Service: Control of Thermal Energy Storage (TES) operation

Functionality level: Load prediction based storage operation

Rationale: Same as for heating.

Electricity

Service: Storage of (locally generated) electricity

Functionality level: On-site storage of electricity (e.g. electric battery)

Rationale: On-site electricity storage can be utilized for storing electricity that will be consumed by a heat pump when needed.

Service: Optimizing self-consumption of locally generated electricity

Heading

Service: Control of distribution fluid temperature (supply or return air flow or water flow)

Functionality level: Demand-based control

Rationale: There is higher uncertainty about the actual efficiency of a heat pump compared to that of a boiler. The main reason for this, besides installation faults, stems from a higher probability of design errors such as having the flow rate through the heat emitters wrongly adjusted and/or the heating curve of the heat pump being set too high. High-quality control of the distribution fluid temperature could reduce the uncertainty and promote further adoption of heat pumps.

Service: Thermal Energy Storage (TES) for building heating (excluding TABS)

Functionality level: Load prediction based storage operation

Rationale: Thermal storage can increase the value of a heat pump installation when combined with on-site energy generation and/or time-of-day electricity tariffs.

Cooling

Service: Control of distribution network chilled water temperature (supply or return)

Functionality level: Demand-based control

Rationale: Same as for heating.

Service: Control of Thermal Energy Storage (TES) operation

Functionality level: Load prediction based storage operation

Rationale: Same as for heating.

Functionality level: Automated management of local electricity consumption based on current renewable energy availability

Rationale: Self-consumption optimization can help coordinate the generation of electricity with the generation of heat and/or cold.

Monitoring and information collection for building energy performance

The SRI services were not evaluated with respect to this policy goal through surveys. Instead, the relevant services per domain were identified, since it is expected that a public funding scheme would support them only in combination with other services and with the goal of collecting the data that is needed to evaluate the scheme's cost effectiveness.

The relevant services and functionality levels per domain are:

Heating

- Report information regarding heating system performance: Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection

Cooling

- Report information regarding cooling system performance: Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection

Domestic hot water

- Report information regarding domestic hot water performance: Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection

Ventilation

- Reporting information regarding IAQ: Real time monitoring & historical information of IAQ available to occupants + warning on maintenance needs or occupant actions (e.g. window opening)

Dynamic building envelope

- Reporting information regarding performance of dynamic building envelope systems: Position of each product, fault detection, predictive maintenance, real-time & historical sensor data (wind, lux, temperature…)

Electricity

- Reporting information regarding local electricity generation: Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection
- Reporting information regarding energy storage: Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection
- Reporting information regarding electricity consumption: Real-time feedback or benchmarking on appliance level with automated personalized recommendations

Energy monitoring and control

- Detecting faults of technical building systems (TBS) and providing support to the diagnosis of these faults: With central indication of detected faults and alarms for all relevant TBS, including diagnosing functions
- Central reporting of technical building systems performance and energy use: Central or remote reporting of real-time energy use per energy carrier, combining systems of all main domains in one interface
- Reporting information regarding demand side management (DSM) performance and operation: Reporting information on current historical and predicted DSM status, including managed energy flows

4. Dependencies of impact from SRI upgrades

Introduction

An SRI upgrade introduces new or improved technical capabilities for a building's technical systems. However, the impact of these capabilities has different dependencies for different services. This chapter focuses exclusively on an SRI upgrade's impact on energy efficiency and demand flexibility. The impact dependencies of the SRI services can be categorised into:

1. **Dependence on building/system design**. This category includes services the impact of which is affected by the design of the building and the available infrastructure inside it. Dependency on climate conditions is also included in this category.

2. **Dependence on implementation**. This case includes services and functionality levels that are provided through smart algorithms and their software implementation.

3. **Dependence on occupant behaviour**. This case concerns services and functionality levels the impact of which depends on how occupants use them (such as the selected settings or the choice to override the default operation).

4. **Dependence on occupancy profiles**. The time-related characteristics of a building's energy demand can affect the extent to which a service of this category is beneficial to the occupants.

5. **Dependence on supportive methods and tools**. This category concerns mainly services for data collection and provision, since the availability of the right methods and tools is necessary so that to translate data into actionable insights. Furthermore, it includes services that require internal procedures and human resource capabilities to achieve their maximum impact.

6. **Dependence on electricity market regulation**. This category concerns services that include the ability to receive and respond to signals from the grid. Their impact depends on the availability of demand response contracts in the electricity market and their profitability for consumers.

When using public funds to support SRI upgrades in the building stock, it is important to verify that the actual impact matches the expected one, particularly for the services and functionality levels that depend on implementation, occupant behaviour and the availability of supportive methods and tools, since for these cases the impact cannot be reliably estimated before the upgrade.

This chapter categorizes the services of the SRI catalogue according to the aforementioned dependencies, while the next one proposes ways to design public funding schemes that incorporate impact verification for the SRI services the impact of which depends on if and how the corresponding capabilities are utilised.

Categorization of dependences for the services of the SRI catalogue

Heating Domain

H-1a Heat emission control

Functionality level	Conditions to achieve impact	Dependencies of impact
No automatic control	-	-
Central automatic control (e.g. central thermostat)	Similar utilization patterns for all spaces of the building High variation in internal heat gains between the different building spaces makes the central control energy wasteful	▪ Depends on occupancy profiles
Individual room control (e.g. thermostatic valves, or electronic controller)	Different utilization patterns for different spaces of the building Occupants must use the control capabilities optimally by adjusting setpoint and setback temperatures	▪ Depends on occupant behaviour
Individual room control with communication between controllers and to BACS	There are large heat exchanges between different thermal zones of the building and/or the thermal zones are served by the same HVAC system (distributing warm air/water through a common circuit)	▪ Depends on building/ system design
Individual room control with communication and occupancy detection	Same conditions as previous level + High variance of operating schedule and/or ad hoc utilization of some spaces of the building	▪ Depends on building/ system design ▪ Depends on occupancy profiles

H-1b Emission control for TABS (heating mode)

Functionality level	Conditions to achieve impact	Dependencies of impact
No automatic control	-	-
Central automatic control	TABS react slowly to control signals. As a result, control strategies (typically) change daily settings: the supply water	▪ Depends on implementation ▪ Depends on occupancy profiles

Functionality level	Conditions to achieve impact	Dependencies of impact
	temperature setpoint is determined based on the mean outside air temperature of the last 24 hours (moving time window) and the zone setpoint. The underlying control strategy relies on predefining a heating curve that determines the temperature to which the supply water should be warmed for a given outdoor temperature. High variation in internal heat gains during the day makes the central control energy wasteful	
Advanced central automatic control	Same conditions as previous level, but energy savings are achieved by compensating for known heat gains in the building	▪ Depends on implementation ▪ Depends on occupancy profiles
Advanced central automatic control with intermittent operation and/or room temperature feedback control	Same conditions as previous level, but the controller adapts the setpoint to non-predictable day-to-day variation of the internal heat gains. The water circulation pumps can be operated in an intermittent operation. This saves electrical energy, but it may decrease comfort levels. Occupants may override the control strategy if it is possible.	▪ Depends on implementation ▪ Depends on occupant behaviour

H-1c Control of distribution fluid temperature (supply or return air flow or water flow)

Functionality level	Conditions to achieve impact	Dependencies of impact
No automatic control	-	-
Outside temperature compensated control	Outside-temperature compensation works best when it can maintain low-level distribution fluid temperatures for extended time periods during a day. If a building is heated only for a few hours per day, occupants will likely bypass the control so that to heat the spaces faster.	▪ Depends on occupancy profiles ▪ Depends on occupant behaviour
Demand based control	Setpoint and setback temperatures must be sensibly defined	▪ Depends on occupant behaviour

H-1d Control of distribution pumps in networks

Functionality level	Conditions to achieve impact	Dependencies of impact
No automatic control	-	-
On off control	-	-
Multi-Stage control	Improved impact is always achieved compared to the previous level	-
Variable speed pump control (pump unit (internal) estimations)	Improved impact is always achieved compared to the previous level	-
Variable speed pump control (external demand signal)	The external demand signal may be based on hydraulic requirements, temperature difference, energy optimization or a demand evaluation to reduce the auxiliary energy demand of the pumps. Sensor infrastructure for data collection must be in place.	▪ Depends on building/ system design

H-1f Thermal Energy Storage (TES) for building heating (excluding TABS)

Functionality level	Conditions to achieve impact	Dependencies of impact
Continuous storage operation	Heat is generated from non-dispatchable systems, such as solar thermal panels, and generation mismatches with demand.	-
Time-scheduled storage operation	Stable profiles of heat demand. The building can employ pre-heating strategies based on its daily schedule. Availability of time-of-day electricity prices that make it profitable to generate heat during one part of the day and consume it during another.	▪ Depends on occupancy profiles ▪ Depends on electricity market regulation
Load prediction based storage operation	Load prediction requires access to past energy consumption data and, as a result, the availability of a data collection infrastructure Flexible thermal storage can increase the value of an installed heat pump	▪ Depends on building/ system design

Functionality level	Conditions to achieve impact	Dependencies of impact
Heat storage capable of flexible control through grid signals (e.g. DSM)	Same conditions as previous level + Availability of demand response programs Time-of-use electricity tariffs	▪ Depends on electricity market regulation

H-2a Heat generator control (all except heat pumps)

Functionality level	Conditions to achieve impact	Dependencies of impact
Constant temperature control	-	-
Variable temperature control depending on outdoor temperature	If a building is heated only for a few hours per day, occupants will likely bypass the control so that to heat the spaces faster.	▪ Depends on occupant behaviour
Variable temperature control depending on the load (e.g. depending on supply water temperature set point)	Setpoint and setback temperatures sensibly defined	▪ Depends on occupant behaviour

H-2b Heat generator control (for heat pumps)

Functionality level	Conditions to achieve impact	Dependencies of impact
On/Off-control of heat generator	-	-
Multi-stage control of heat generator capacity depending on the load or demand (e.g. on/off of several compressors)	Improved impact is always achieved compared to the previous level	-
Variable control of heat generator capacity depending on the load or demand (e.g. hot gas bypass, inverter frequency control)	Improved impact is always achieved compared to the previous level	-
Variable control of heat generator capacity depending on the load AND external signals from grid	Same conditions as previous level +	▪ Depends on electricity market regulation

Functionality level	Conditions to achieve impact	Dependencies of impact
	Availability of demand response programs Time-of-use electricity tariffs	

H-2d Sequencing in case of different heat generators

Functionality level	Conditions to achieve impact	Dependencies of impact
Priorities only based on running time	-	-
Control according to fixed priority list: e.g. based on rated energy efficiency	Improved impact is always achieved compared to the previous level	-
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)	Improved impact is always achieved compared to the previous level	-
Control according to dynamic priority list (based on current AND predicted load, energy efficiency, carbon emissions and capacity of generators)	Load prediction requires access to past energy consumption data and, as a result, the availability of a data collection infrastructure	▪ Depends on building/ system design ▪ Depends on implementation
Control according to dynamic priority list (based on current AND predicted load, energy efficiency, carbon emissions, capacity of generators AND external signals from grid)	Same conditions as previous level + Availability of demand response programs Time-of-use electricity tariffs	▪ Depends on implementation ▪ Depends on electricity market regulation

H-3 Report information regarding heating system performance

Functionality level	Conditions to achieve impact	Dependencies of impact
None	-	-
Central or remote reporting of current	Internal processes and availability of personnel with capability	▪ Depends on supportive methods

Functionality level	Conditions to achieve impact	Dependencies of impact
performance KPIs (e.g. temperatures, submetering energy usage)	to identify faults and issues that must be corrected by evaluating real-time information	and tools
Central or remote reporting of current performance KPIs and historical data	Availability of methods and tools for utilizing current and historical data to evaluate the energy performance of the building and its technical systems	▪ Depends on supportive methods and tools
Central or remote reporting of performance evaluation including forecasting and/or benchmarking	Same conditions as previous level	▪ Depends on supportive methods and tools
Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	Same conditions as previous level + Sensor infrastructure, since fault detection typically relies on monitoring (part of) the state of the corresponding equipment	▪ Depends on supportive methods and tools ▪ Depends on building/ system design

H-4 Flexibility and grid interaction

Functionality level	Conditions to achieve impact	Dependencies of impact
No automatic control	-	-
Scheduled operation of heating system	Stable profiles of heat demand. In this case, scheduled operation reduces the probability of heating a building when it is not occupied	▪ Depends on occupancy profiles
Self-learning optimal control of heating system	Predictable profiles of heat demand High-quality implementation of the underlying algorithms	▪ Depends on implementation
Heating system capable of flexible control through grid signals (e.g. DSM)	Availability of demand response programs Time-of-use electricity tariffs	▪ Depends on electricity market regulation
Optimized control of heating system based on local predictions and grid signals (e.g. through model predictive control)	High-quality implementation of the underlying algorithms	▪ Depends on implementation

Domestic Hot Water Domain

DHW-1a Control of DHW storage charging (with direct electric heating or integrated electric heat pump)

Functionality level	Conditions to achieve impact	Dependencies of impact
Automatic control on / off	-	-
Automatic control on / off and scheduled charging enable	Stable profiles of DHW demand	▪ Depends on occupancy profiles
Automatic control on / off and scheduled charging enable and multi-sensor storage management	Same conditions as previous level + Large storage tanks: Multiple sensors make it possible to divide the tank into different parts and monitor them separately	▪ Depends on occupancy profiles ▪ Depends on building/ system design
Automatic charging control based on local availability of renewables or information from electricity grid (DR, DSM)	Same conditions as previous level + Availability of demand response programs Time-of-use electricity tariffs	▪ Depends on occupancy profiles ▪ Depends on building/ system design ▪ Depends on electricity market regulation

DHW-1b Control of DHW storage charging (using hot water generation)

Functionality level	Conditions to achieve impact	Dependencies of impact
Automatic control on / off	-	-
Automatic control on / off and scheduled charging enable	Stable profiles of DHW demand	▪ Depends on occupancy profiles
Automatic on/off control, scheduled charging enable and demand-based supply temperature control or multi-sensor storage management	Same conditions as previous level + Large storage tanks: Multiple sensors make it possible to divide the tank into different parts and monitor them separately	▪ Depends on occupancy profiles Depends on building/ system design
DHW production system capable of automatic charging control based on	Same conditions as previous level +	▪ Depends on occupancy profiles Depends on building/ system

Functionality level	Conditions to achieve impact	Dependencies of impact
external signals (e.g. from district heating grid)	Availability of demand response programs Time-of-use electricity tariffs	design ▪ Depends on electricity market regulation

DHW-1d Control of DHW storage charging (with solar collector and supplementary heat generation)

Functionality level	Conditions to achieve impact	Dependencies of impact
Manual selected control of solar energy or heat generation	-	-
Automatic control of solar storage charge (Prio. 1) and supplementary storage charge	Improved impact is always achieved compared to the previous level	-
Automatic control of solar storage charge (Prio. 1) and supplementary storage charge and demand-oriented supply or multi-sensor storage management	Large storage tanks: Multiple sensors make it possible to divide the tank into different parts and monitor them separately	▪ Depends on building/ system design
Automatic control of solar storage charge (Prio. 1) and supplementary storage charge, demand-oriented supply and return temperature control and multi-sensor storage management	Improved impact is always achieved compared to the previous level	-

DHW-2b Sequencing in case of different DHW generators

Functionality level	Conditions to achieve impact	Dependencies of impact
Priorities only based on running time	-	-
Control according to fixed priority list: e.g. based on rated energy efficiency	Improved impact is always achieved compared to the previous level	-
Control according to dynamic priority list (based on current energy efficiency,	Improved impact is always achieved compared to the previous	-

Functionality level	Conditions to achieve impact	Dependencies of impact
carbon emissions and capacity of generators, e.g. solar, geothermal heat, cogeneration plant, fossil fuels)	level	
Control according to dynamic priority list (based on current AND predicted load, energy efficiency, carbon emissions and capacity of generators)	Load prediction requires access to past energy consumption data and, as a result, the availability of a data collection infrastructure	▪ Depends on building/ system design
Control according to dynamic priority list (based on current AND predicted load, energy efficiency, carbon emissions, capacity of generators AND external signals from grid)	Same conditions as previous level + Availability of demand response programs Time-of-use electricity tariffs	▪ Depends on building/ system design ▪ Depends on electricity market regulation

DHW-3 Report information regarding domestic hot water performance

Functionality level	Conditions to achieve impact	Dependencies of impact
None	-	-
Indication of actual values (e.g. temperatures, submetering energy usage)	Internal processes and availability of personnel with capability to identify faults and issues that must be corrected by evaluating real-time information	▪ Depends on supportive methods and tools
Actual values and historical data	Availability of methods and tools for utilizing current and historical data to evaluate the energy performance of the building and its technical systems	▪ Depends on supportive methods and tools
Performance evaluation including forecasting and/or benchmarking	Same conditions as previous level	▪ Depends on supportive methods and tools
Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	Same conditions as previous level + Sensor infrastructure	▪ Depends on supportive methods and tools ▪ Depends on building/ system design

Cooling Domain

C-1a Cooling emission control

Functionality level	Conditions to achieve impact	Dependencies of impact
No automatic control	-	-
Central automatic control	Similar utilization patterns for all spaces of the building High variation in internal heat gains between the different building spaces makes the central control energy wasteful	▪ Depends on occupancy profiles
Individual room control	Different utilization patterns for different spaces of the building Occupants use the control capabilities optimally by adjusting setpoint and setback temperatures	▪ Depends on occupant behaviour
Individual room control with communication between controllers and to BACS	There are large heat exchanges between different thermal zones of the building and/or the thermal zones are served by the same HVAC system (distributing warm air/water through a common circuit)	▪ Depends on building/ system design
Individual room control with communication and occupancy detection	Same conditions as previous level + High variance of operating schedule and/or ad hoc utilization of some spaces of the building	▪ Depends on building/ system design ▪ Depends on occupancy profiles

C-1b Emission control for TABS (cooling mode)

Functionality level	Conditions to achieve impact	Dependencies of impact
No automatic control	-	-
Central automatic control	The underlying control strategy relies on predefining a cooling curve that determines the temperature to which the supply water should be warmed for a given outdoor temperature. High variation in internal heat gains during the day makes the	▪ Depends on implementation ▪ Depends on occupancy profiles

Functionality level	Conditions to achieve impact	Dependencies of impact
	central control energy wasteful	
Advanced central automatic control	Same conditions as previous level, but energy savings are achieved by compensating for known heat gains in the building	▪ Depends on implementation ▪ Depends on occupancy profiles
Advanced central automatic control with intermittent operation and/or room temperature feedback control	Same conditions as previous level, but the controller adapts the setpoint to non-predictable day-to-day variation of the internal heat gains. The water circulation pumps can be operated in an intermittent operation. This saves electrical energy, but it may decrease comfort levels. Occupants may override the control strategy if it is possible.	▪ Depends on implementation ▪ Depends on occupant behaviour

C-1c Control of distribution network chilled water temperature (supply or return)

Functionality level	Conditions to achieve impact	Dependencies of impact
No automatic control	-	-
Outside temperature compensated control	Outside-temperature compensation works best when it can maintain low-level distribution fluid temperatures for extended time periods during a day. If a building is cooled for only for a few hours per day, occupants will likely bypass the control so that to cool the spaces faster.	▪ Depends on occupancy profiles ▪ Depends on occupant behaviour
Demand based control	Setpoint and setback temperatures must be sensibly defined	▪ Depends on occupant behaviour

C-1d Control of distribution pumps in networks

Functionality level	Conditions to achieve impact	Dependencies of impact
No automatic control	-	-
On off control	-	-
Multi-Stage control	Improved impact is always achieved compared to the previous level	-

Functionality level	Conditions to achieve impact	Dependencies of impact
Variable speed pump control (pump unit (internal) estimations)	Improved impact is always achieved compared to the previous level	-
Variable speed pump control (external demand signal)	The external demand signal may be based on hydraulic requirements, temperature difference, energy optimization or a demand evaluation to reduce the auxiliary energy demand of the pumps. Sensor infrastructure for data collection must be in place.	▪ Depends on building/ system design

C-1f Interlock: avoiding simultaneous heating and cooling in the same room

Functionality level	Conditions to achieve impact	Dependencies of impact
No interlock	-	-
Partial interlock (minimising risk of simultaneous heating and cooling e.g. by sliding setpoints)	Partial interlock means that the cooling and heating interlock controls are separate, so the impact depends on how well the control function is set up: the larger the different between heating and cooling setpoints, the more effective the interlock will be	▪ Depends on implementation ▪ Depends on occupant behaviour
Total interlock (control system ensures no simultaneous heating and cooling can take place)	Improved impact is always achieved compared to the previous level	-

C-1g Control of Thermal Energy Storage (TES) operation

Functionality level	Conditions to achieve impact	Dependencies of impact
Continuous storage operation	Cold is generated by transforming electricity from non-dispatchable systems, such as solar PV, and generation mismatches with demand.	-
Time-scheduled storage operation	Stable profiles of cooling demand. The building can employ pre-cooling strategies based on its daily schedule. Availability of time-of-day electricity prices that make it	▪ Depends on occupancy profiles ▪ Depends on electricity market regulation

Functionality level	Conditions to achieve impact	Dependencies of impact
	profitable to generate cold during one part of the day and consume it during another.	
Load prediction based storage operation	Load prediction requires access to past energy consumption data and, as a result, the availability of a data collection infrastructure Flexible thermal storage can increase the value of an installed heat pump	▪ Depends on building/ system design
Cold storage capable of flexible control through grid signals (e.g. DSM)	Same conditions as previous level + Availability of demand response programs Time-of-use electricity tariffs	▪ Depends on electricity market regulation

C-2a Generator control for cooling

Functionality level	Conditions to achieve impact	Dependencies of impact
On/Off-control of cooling generator	-	-
Multi-stage control of cooling production capacity depending on the load or demand (e.g. on/off of several compressors)	Improved impact is always achieved compared to the previous level	-
Variable control of cooling production capacity depending on the load or demand (e.g. hot gas bypass, inverter frequency control)	Improved impact is always achieved compared to the previous level	-
Variable control of cooling production capacity depending on the load AND external signals from grid	Same conditions as previous level + Availability of demand response programs Time-of-use electricity tariffs	▪ Depends on electricity market regulation

C-2b Sequencing of different cooling generators

Functionality level	Conditions to achieve impact	Dependencies of impact
Priorities only based on running time	-	-
Fixed sequencing based on loads only: e.g. depending on the generators characteristics such as absorption chiller vs. centrifugal chiller	Improved impact is always achieved compared to the previous level	-
Dynamic priorities based on generator efficiency and characteristics (e.g. availability of free cooling)	Improved impact is always achieved compared to the previous level	-
Load prediction based sequencing: the sequence is based on e.g. COP and available power of a device and the predicted required power	Load prediction requires access to past energy consumption data and, as a result, the availability of a data collection infrastructure	▪ Depends on building/ system design
Sequencing based on dynamic priority list, including external signals from grid	Same conditions as previous level + Availability of demand response programs Time-of-use electricity tariffs	▪ Depends on implementation ▪ Depends on electricity market regulation

C-3 Report information regarding cooling system performance

Functionality level	Conditions to achieve impact	Dependencies of impact
None	-	-
Central or remote reporting of current performance KPIs (e.g. temperatures, submetering energy usage)	Internal processes and availability of personnel with capability to identify faults and issues that must be corrected by evaluating real-time information	▪ Depends on supportive methods and tools
Central or remote reporting of current performance KPIs and historical data	Availability of methods and tools for utilizing current and historical data to evaluate the energy performance of the building and its technical systems	▪ Depends on supportive methods and tools

Functionality level	Conditions to achieve impact	Dependencies of impact
Central or remote reporting of performance evaluation including forecasting and/or benchmarking	Same conditions as previous level	▪ Depends on supportive methods and tools
Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	Same conditions as previous level + Sensor infrastructure	▪ Depends on supportive methods and tools ▪ Depends on building/ system design

C-4 Flexibility and grid interaction

Functionality level	Conditions to achieve impact	Dependencies of impact
No automatic control	-	-
Scheduled operation of cooling system	Stable profiles of cooling demand. In this case, scheduled operation reduces the probability of cooling a building when it is not occupied	▪ Depends on occupancy profiles
Self-learning optimal control of cooling system	Predictable profiles of cooling demand High-quality implementation of the underlying algorithms	▪ Depends on implementation
Cooling system capable of flexible control through grid signals (e.g. DSM)	Availability of demand response programs Time-of-use electricity tariffs	▪ Depends on electricity market regulation
Optimized control of cooling system based on local predictions and grid signals (e.g. through model predictive control)	High-quality implementation of the underlying algorithms	▪ Depends on implementation

Ventilation Domain

V-1a Supply air flow control at the room level

Functionality level	Conditions to achieve impact	Dependencies of impact
No ventilation system or manual control	-	-
Clock control	Stable profiles of occupancy, small differences between nominal and actual occupancy times	▪ Depends on occupancy profiles
Occupancy detection control	Improved impact is always achieved compared to the previous level	
Central Demand Control based on air quality sensors (CO_2, VOC, humidity, …)	Similar utilization (mainly number of occupants) of the different spaces of the building Ventilation airflow rate range (from minimum to maximum) is typically very large in commercial and public buildings. This means that correct sizing of the air handling units and correctly defined pressure setpoints are important	▪ Depends on occupancy profiles ▪ Depends on implementation ▪ Depends on building/ system design (need of BMS for continuous monitoring)
Local Demand Control based on air quality sensors (CO_2, VOC,…) with local flow from/to the zone regulated by dampers	Improved impact is always achieved compared to the previous level	-

V-1c Air flow or pressure control at the air handler level

Functionality level	Conditions to achieve impact	Dependencies of impact
No automatic control: Continuously supplies of air flow for a maximum load of all rooms	-	-
On off time control: Continuously supplies of air flow for a maximum load of all rooms during nominal occupancy time	Stable profiles of occupancy	▪ Depends on occupancy profiles

Functionality level	Conditions to achieve impact	Dependencies of impact
Multi-stage control: To reduce the auxiliary energy demand of the fan	Improved impact is always achieved compared to the previous level	-
Automatic flow or pressure control without pressure reset: Load dependent supplies of air flow for the demand of all connected rooms.	Improved impact is always achieved compared to the previous level	-
Automatic flow or pressure control with pressure reset: Load dependent supplies of air flow for the demand of all connected rooms (for variable air volume systems with VFD).	Improved impact is always achieved compared to the previous level	-

V-2c Heat recovery control: prevention of overheating

Functionality level	Conditions to achieve impact	Dependencies of impact
Without overheating control	-	-
Modulate or bypass heat recovery based on sensors in air exhaust	Improved impact is always achieved compared to the previous level	-
Modulate or bypass heat recovery based on multiple room temperature sensors or predictive control	Sensor infrastructure for data collection and monitoring	▪ Depends on building/ system design

V-2d Supply air temperature control at the air handling unit level

Functionality level	Conditions to achieve impact	Dependencies of impact
No automatic control	-	-
Constant setpoint: A control loop enables to control the supply air temperature, the setpoint is constant and can only be	Similar utilization patterns for all spaces of the building	▪ Depends on occupancy profiles

Functionality level	Conditions to achieve impact	Dependencies of impact
modified by a manual action		
Variable set point with outdoor temperature compensation	Improved impact is always achieved compared to the previous level	-
Variable set point with load dependant compensation. A control loop enables to control the supply air temperature. The setpoint is defined as a function of the loads in the room	Improved impact is always achieved compared to the previous level	-

V-3 Free cooling with mechanical ventilation system

Functionality level	Conditions to achieve impact	Dependencies of impact
No automatic control	-	-
Night cooling	Buildings of high thermal mass that are not occupied during the night Availability of wind and rain sensors	▪ Depends on occupancy profiles ▪ Depends on building/ system design
Free cooling: air flows modulated during all periods of time to minimize the amount of mechanical cooling	Free cooling is using cooler outdoors air to cool a space by mixing an outside air source with room air. This system is referred to as *economizer*. The larger the difference between the zone temperature and the outside air temperature, the larger the impact will be. Buildings with high internal heat gains will benefit more.	▪ Depends on building/ system design
H,x- directed control: The amount of outside air and recirculation air are modulated during all periods of time to minimize the amount of mechanical cooling. Calculation is performed on the basis of temperatures and humidity (enthalpy)	Same conditions as previous level + Conditions that create high levels of humidity inside the building	▪ Depends on building/ system design

V-6 Reporting information regarding IAQ

No contribution on energy efficiency or demand flexibility.

Lighting Domain

The higher the functionality level, the larger the impact on energy efficiency will be, without significant dependencies, for all the services of this domain.

Dynamic Building Envelope Domain

DE-1 Window solar shading control

Functionality level	Conditions to achieve impact	Dependencies of impact
No sun shading or only manual operation	-	-
Motorized operation with manual control	Motorized operation is meant to make manual interventions easier. Impact still depends on occupant behaviour	▪ Depends on occupant behaviour
Motorized operation with automatic control based on sensor data	Automatic control aims at minimizing (during summer) or maximizing (during winter) solar gains. Manual intervention is still possible.	▪ Depends on occupant behaviour
Combined light/blind/HVAC control	Improved impact is always achieved compared to the previous level	-
Predictive blind control (e.g. based on weather forecast)	Large buildings with a large part of the envelope composed by glazed surfaces	▪ Depends on building/ system design ▪ Depends on implementation

DE-2 Window open/closed control, combined with HVAC system

Functionality level	Conditions to achieve impact	Dependencies of impact
Manual operation or only fixed windows	-	-
Open/closed detection to shut down	Improved impact is always achieved compared to the previous	-

Functionality level	Conditions to achieve impact	Dependencies of impact
heating or cooling systems	level	
Level 1 + Automised mechanical window opening based on room sensor data	Sensor data is related to temperature, rain, light intensity, sound intensity or wind. Not a commonly found infrastructure and functionality	▪ Depends on building/ system design ▪ Depends on implementation
Level 2 + Centralized coordination of operable windows, e.g. to control free natural night cooling	Same conditions as previous level	▪ Depends on building/ system design ▪ Depends on implementation

DE-4 Reporting information regarding performance of dynamic building envelope systems

No contribution on energy efficiency or demand flexibility.

Electricity Domain

E-2 Reporting information regarding local electricity generation

Functionality level	Conditions to achieve impact	Dependencies of impact
None	-	-
Current generation data available	Internal processes and availability of personnel that can act upon information on local generation	▪ Depends on supportive methods and tools
Actual values and historical data	Same conditions as previous level	▪ Depends on supportive methods and tools
Performance evaluation including forecasting and/or benchmarking	Same conditions as previous level	▪ Depends on supportive methods and tools
Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	Same conditions as previous level + Sensor infrastructure, since fault detection typically relies on monitoring (part of) the state of the corresponding equipment	▪ Depends on supportive methods and tools ▪ Depends on building/ system design

E-3 Storage of (locally generated) electricity

Functionality level	Conditions to achieve impact	Dependencies of impact
None	-	-
On site storage of electricity (e.g. electric battery)	Improved impact is always achieved compared to the previous level, since the self-consumption rate and the flexibility of demand are always higher when storage is available	-
On site storage of energy (e.g. electric battery or thermal storage) with controller based on grid signals	Availability of demand response programmes	▪ Depends on electricity market regulation
On site storage of energy (e.g. electric battery or thermal storage) with controller optimising the use of locally generated electricity	Improved impact is always achieved compared to the previous level Availability of zero feed-in schemes increases the value of a system that optimizes the use of locally generated electricity	-
On site storage of energy (e.g. electric battery or thermal storage) with controller optimising the use of locally generated electricity and possibility to feed back into the grid	Availability of net-metering / net-billing schemes Net-metering / net-billing schemes with short clearing periods increase the value of a system that optimizes the use of locally generated electricity	▪ Depends on electricity market regulation

E-4 Optimizing self-consumption of locally generated electricity

The higher the functionality level, the larger the impact on energy efficiency / self-consumption rate will be, without significant dependencies, for this service.

E-5 Control of combined heat and power plant (CHP)

The higher the functionality level, the larger the impact on energy efficiency / self-consumption rate will be, without significant dependencies, for this service.

E-8 Support of (micro)grid operation modes

Functionality level	Conditions to achieve impact	Dependencies of impact
None	-	-
Automated management of (building-level) electricity consumption based on grid signals	Availability of demand response programs Time-of-use electricity tariffs	▪ Depends on electricity market regulation
Automated management of (building-level) electricity consumption and electricity supply to neighbouring buildings (microgrid) or grid	Same conditions as previous level + Availability of collective self-consumption schemes for the building to participate in	▪ Depends on electricity market regulation
Automated management of (building-level) electricity consumption and supply, with potential to continue limited off-grid operation (island mode)	Same conditions as previous level	▪ Depends on electricity market regulation

E-11 Reporting information regarding energy storage

All functionality levels depend on the availability of tools and methods to process the information and produce actionable insight for building managers.

E-12 Reporting information regarding electricity consumption

All functionality levels depend on the availability of tools and methods to process the information and produce actionable insight for building managers.

Electric Vehicle Charging Domain

The higher the functionality level, the larger the impact on EV adoption and/or energy demand flexibility will be, without significant dependencies for all the services of this domain.

Monitoring and Control Domain

The higher the functionality level, the larger the impact on energy efficiency and/or energy demand flexibility will be, without significant dependencies for all the services of this domain.

5. Optimizing impact from SRI upgrades

This section proposes the integration of impact verification schemes into public funding programmes when the later aim at supporting SRI services the impact of which depends on implementation, occupant behaviour, and the availability of supportive methods and tools. The proposed schemes borrow ideas from the energy efficiency support programs of the USA and Canada that are collectively known as Pay-for-Performance (P4P) programs. These programs couple the financial incentives that are provided to consumers with specific requirements for making the impact of the interventions measurable.

By collecting and aggregating data directly from the beneficiary buildings, the funding authority can decide about the level and the conditions for the support of these measures in the future. As an example, the French Agency for Ecological Transition (ADEME) funded in 2023 a project to monitor the actual performance of heat pumps – financed by public support schemes – over the 2023/2024 heating season (October 2023 to May 2024). The results are meant to help determine the changes in public policy that are needed so as to improve the cost-effectiveness of the heat pump support schemes given that the performance of heat pump systems is sensitive to numerous parameters linked to the environment, the design (sizing, choice of transmitters, control strategy, etc.), as well as implementation, usage and maintenance.

Data-based verification entails the coupling of the SRI services with a requirement for sensor and metering infrastructure that will support the collection of data after the SRI upgrade. In practical terms, direct data collection can become feasible by requiring that higher-uncertainty SRI services are installed in conjunction with the information reporting services of each SRI domain, as well as the services that contribute most to the goal of Monitoring and information collection for building energy performance, and that the collected data should be accessible for verification.

The guidelines for data collection and connectivity are provided by a third-party organization (public or private) that acts as a data aggregator and programme facilitator. The data aggregator provides an API that the buildings' energy monitoring systems will use to send energy consumption data – at whole-building or through sub-metering of the installed TBS – at regular time intervals. For data privacy reasons, the consumer information (names, addresses) is available only to the funding authority; the data aggregator needs to have access to only a unique building ID, unique meter and sensor IDs, and the data associated with each meter and sensor. This data aggregator is also responsible for the impact estimation (Fig. 5.1).

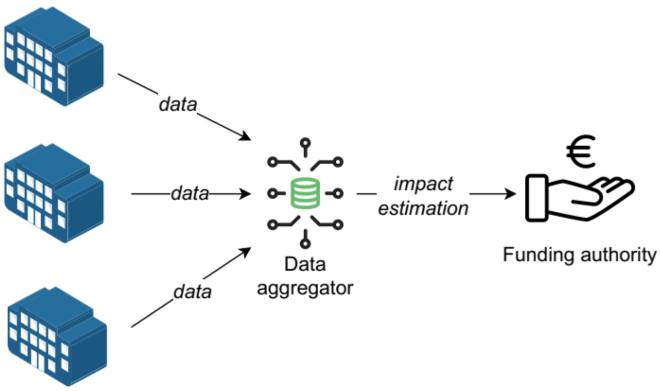


Figure 5.1: Impact estimation through a data aggregator

Not all the beneficiary buildings need to participate in the verification scheme. From the policy makers' perspective, only a sample of them is enough as long as it is adequately large to provide information about the actual performance of the higher-uncertainty SRI services. From the beneficiaries' perspective, large commercial buildings that would benefit anyway from data collection and reporting services are the most appropriate candidates for participation.

Contrary to the goals of a P4P programme, impact verification of the higher-uncertainty SRI services should not aim at estimating energy savings, but rather at **verifying the expectations** about their impact. For this, the impact assessment process can utilize the *backcasting* measurement and verification (M&V) approach of the International Performance Measurement and Verification Protocol (IPMVP). Backcasting is usually employed when more data is available after the energy retrofit compared to the period before it. In this case, a quantitative model for the building's energy consumption is developed using the post-upgrade data. Then, impact verification becomes a two-step task (Fig. 5.2):

(a) Calculate the difference between the energy consumption as predicted by the quantitative model and aggregated at the granularity level of the data that is available before the upgrade, and the energy consumption as observed before the upgrade;

(b) Determine whether this difference is compatible with the expectations about the upgrade's impact.

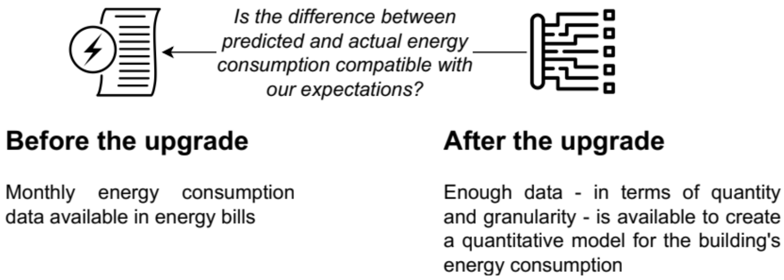


Figure 5.2: Impact estimation as expectation verification

The quantitative analysis of the collected data may utilize one of the following options:

- Estimation of normalized energy consumption using daily data at whole-building level. This option uses simple models of daily energy consumption at whole-building level as a function of outdoor air temperature (heating and cooling degree days). The models are developed using post-retrofit energy consumption data taken from utility bills and/or appropriate meters.
- Estimation of normalized energy consumption using hourly data at whole-building level. This option uses models of hourly energy consumption at whole building level as a function of weather data and other information that strongly correlates with energy consumption. The Time-of-Week-and-Temperature model (TOWT)[9] is a widely-used model of this category. The models are developed using post-retrofit energy consumption data taken from appropriate meters.
- Estimation of normalized energy consumption using hourly data at TBS level. This option uses models of TBS systems, the parameters of which can be identified using sub-metering data after the intervention (retrofit isolation engineering models as described in IPMVP Option B). This option is more appropriate for SRI upgrades in commercial / tertiary buildings, where equipment upgrades can be coupled by SRI services that provide reporting functionality.

An impact assessment may also include the following components:

1. **Evaluation of market effects**. This component is related to identifying the impact of market-wide trends on the energy consumption of the beneficiary buildings. Market-wide trends are changes in energy consumption that can be detected in all the buildings that participated in the programme irrespectively of the type of measures implemented. Identifying such changes is necessary in order to avoid over- or under-estimating the impact of specific measures.

The estimation of the market effects relies on comparing different groups within the population of the beneficiary buildings. The program facilitator can select a control group that is similar to the group of buildings that includes the higher-uncertainty services, and estimate the average impact of the later using the

[9] Mathieu, J. L., P. N. Price, S. Kiliccote, and M. A. Piette (2011) "Quantifying changes in building electricity use, with application to demand response." IEEE Transactions on Smart Grid, 2(3), pp. 507–518.

Difference-in-Differences statistical approach (Fig. 5.3). The degree of similarity between the two building groups can be determined by the similarity of the scale and seasonal patterns of their energy consumption.

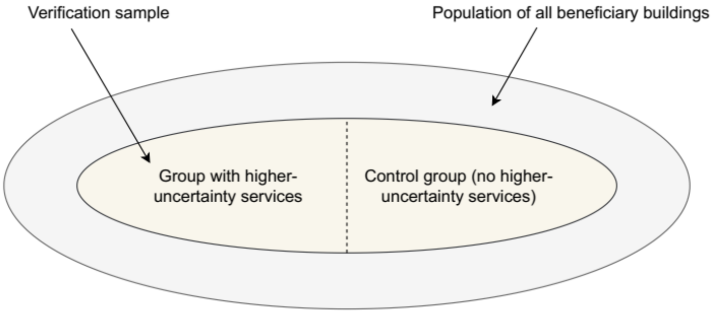


Figure 5.3: Setup for population-based evaluation of market effects

2. **Evaluation of technology trends and maturity**. The uncertainty about the impact of the SRI services and functionality levels that depend on control algorithm implementation and the availability of supportive methods and tools is largely related to the uncertainty about the maturity of the technology itself and/or the level of experience of the local installers. Data collected from SRI upgrades can also be used for verifying whether the uncertainty about the impact of certain services remains high or is reduced over time.

The EU MS agencies and public authorities that are already responsible for monitoring energy efficiency obligation schemes are the best candidates to become programme facilitators:

- **Austria**. The Austrian Energy Agency is the national monitoring body as requested by the federal law on energy efficiency.
- **Croatia**. The National Energy Efficiency Authority, which is part of the Centre for Monitoring Business Activities in the Energy Sector and Investments, is the national administrator of the SMiV system for measuring and verifying energy savings.
- **France**. The French Agency for Ecological Transition (ADEME) provides its expertise regarding the technical analysis and evaluation of the implemented energy efficiency measures.
- **Spain**. The Institute for the Diversification and Saving of Energy (IDAE) is the administrative authority that is responsible for the administration and coordination of M&V schemes for energy efficiency.

It is possible for a funding authority to delegate (and compensate for) the task of data collection to the energy utilities serving the beneficiary buildings (Fig. 5.4). The inclusion of energy utilities in the scheme makes it easier to share pre-retrofit data with the data aggregator.

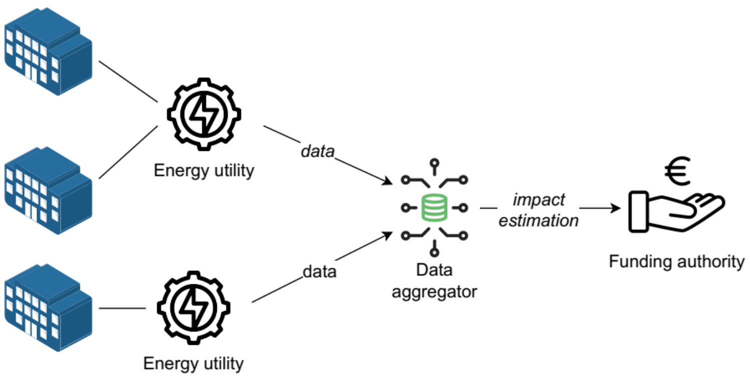


Figure 5.4: Impact monitoring through collaboration between energy utilities and the data aggregator

An alternative option for dealing with the impact uncertainty of some of the services and functionality levels of the SRI catalogue is to support business models that offer them through performance-based and/or as-a-service contracts. Such contracts incentivise service providers to monitor the performance of their solutions and fine-tune them when it is necessary so as to maintain adequate performance levels.

The funding authority can maintain a registry of pre-qualified service providers. Any service provider can apply for inclusion in the scheme as long they exhibit:

- The right technical skills;
- A good administrative, quality assurance and sales setup;
- A setup for monitoring their energy efficiency measures for optimization purposes.

At a minimum, the contracts should include:

- The type of information that consumers should be able to have access to so that to monitor the performance of the installed measures;
- A mechanism for dispute resolution if consumers have doubts about the achieved energy performance;
- An exit strategy that would allow the consumer to terminate the contract;
- The requirements for ensuring that the measured data is protected.

The main benefit of this approach is that a funding authority can rely on market actors for evaluating the maturity of a technology and the extent to which its installation is appropriate for different buildings.

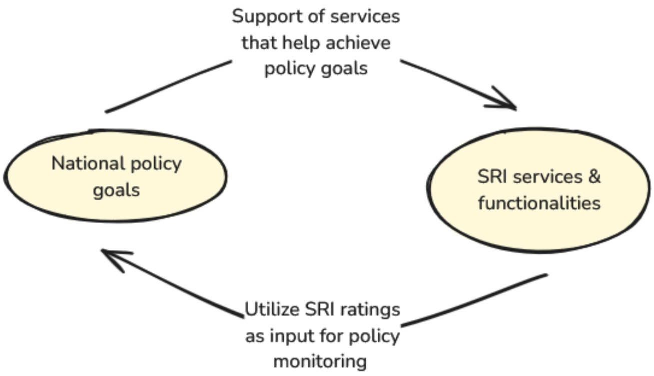
6. Conclusions and recommendations

The SRI links specific functionalities of a building's technical systems with specific benefits for the building's occupants. At the same time, the SRI should also be regarded as a policy tool that may help EU MS to achieve their national policy goals for energy and climate. In particular, different services and functionality levels of the SRI catalogue may contribute to different policy goals. As a result, incentivising specific SRI upgrades may help steer private investments in energy efficiency towards measures that are best aligned with the national policy goals for the energy performance, the demand characteristics and the technical capabilities of the building stock.

Furthermore, information about the SRI ratings of the national building stock can be utilized as a way to evaluate the extent to which the aforementioned goals have been achieved. For instance:

- The ratings of the services that belong to the Electric Vehicle (EV) charging domain can provide feedback for the progress of policies that aim to expand the EV charging infrastructure;
- The ratings of the services that are related to data collection and information reporting can provide feedback for the progress of policies that aim to promote the use of innovative information and communication technologies in the building sector;
- The combined ratings of the services of the Heating domain and the services of the Electricity domain can provide feedback for the progress of policies that aim to promote solar PV for onsite generation of electricity with heat pump installations for improved self-consumption rates.

This creates a closed loop between using the expected SRI ratings as a tool to align private investments with national policy goals and using the actual SRI ratings as an indicator of the progress towards achieving the goals:

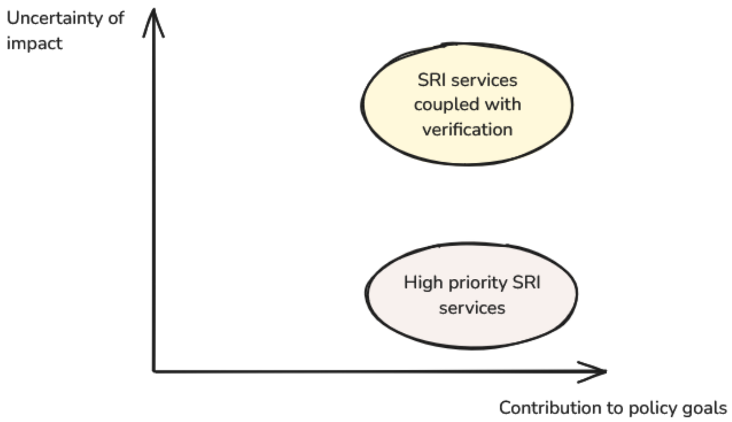


When public funding authorities design programmes that support SRI upgrades, they must take two (2) attributes of the SRI services into account. The first attribute is the potential contribution of each of the SRI services and functionality levels on the policy goals to be achieved. This deliverable offers a possible way to determine this contribution, as well as a ranking order for prioritizing SRI services according to selected policy goals. The second attribute is related to the fact that the impact of some SRI functionalities – and often, these are highly impactful ones – depends on if and how they are actually utilized inside the building. As a result, funding authorities should prioritize their support first and foremost towards services of high potential contribution and low uncertainty of impact.

For the case of services of high potential contribution and high uncertainty of impact, funding authorities have two (2) options at their disposal:

(c) Integrate impact verification schemes into the public funding programme so that to determine the actual impact of the relevant services and functionality levels;

(d) Use the public funding programme to support performance-based and as-a-service business models for delivering the relevant services and functionality levels.



The data collection process that is required for impact verification can be implemented by installing the higher-uncertainty SRI services in conjunction with the information reporting services of each SRI domain, as well as the services that contribute most to the goal of monitoring and information collection for building energy performance. This will create an infrastructure and a know-how that will support the impact verification of the SRI services, but, and more importantly, can be extended beyond SRI upgrades to cover all energy efficiency interventions with the goal of maximizing the cost-effectiveness of the relevant public funding programmes.