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Analysis of the relevance of deploying Smart Readiness Indicator (SRI) in India

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Imprint

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Foreword

The Government of India set up the Bureau of Energy Efficiency (BEE) on 1st March 2002 under the provisions of the Energy Conservation Act, 2001. The mission of the Bureau of Energy Efficiency is to assist in developing policies and strategies with a focus on self-regulation and market principles within the overall framework of the Energy Conservation Act, 2001 with the primary objective of reducing the energy intensity of the Indian economy. BEE coordinates with designated agencies, designated consumers, and other organizations working in the field of energy conservation/efficiency to recognize and utilize the existing resources and infrastructure in performing the functions assigned to the Bureau under the Energy Conservation Act.

BEE has implemented various successful programs such as the globally recognized industrial efficiency program of India – Perform, Achieve and Trade (PAT) scheme which currently is in its sixth cycle, the Standard and Labelling (S&L) program for appliances and industrial equipment, Energy Conservation Building Codes (ECBC) for commercial buildings, Energy Conservation Building Code-Residential (Eco-Niwas Samhita) for residential buildings, and Certification of Energy Managers and Auditors and many more.

The report on 'Analysis of the relevance of deploying Smart Readiness Indicator (SRI) in India' has been prepared as a part of the European Union -Clean Energy Climate Partnership (EU-CECP) project, which is a strategic document outlining the feasibility study conducted on smart technologies in building sector in India. This document will eventually portray a possible framework and roadmap for adoption and implementation of SRI in buildings. The document focuses on the present status and the potential of smart services across various technology domains and its possible impact on energy savings. It also discusses the EU strategy for adoption of SRI to assess the possible elements which are relevant to the Indian context and can be used as a reference for best practices by India.

The document presents a deep dive into penetration of smart technologies in India, policy framework relevant to SRI and the demand for SRI from technology provider, building developer and consumer perspective which will help in development of a roadmap for adoption of SRI in the country. This guiding document has been made to provide an impetus for policymakers to take the best practices from the EU and apply them to the Indian context, to firmly set India's path towards a successful green transformation that does not disrupt its development aspirations. A wide range of stakeholders must come together to envision a future of decarbonized future and realize India's global commitments to Net Zero and sustainable growth going forward.

I would request all policymakers and relevant stakeholders to make themselves familiar with the various interventions and possible strategies outlined in this document so that the nation can embark on a new, greener development paradigm incorporating the best practices from across the European Union. I am confident that with our collective efforts, the ambitious targets set out by India at the Paris Agreement as well as the 2021 Climate Change Conference can be successfully achieved.

New Delhi
May 2022

Shri Abhay Bakre
Director General, BEE

Acknowledgement

This study 'Analysis of the relevance of deploying Smart Readiness Indicator (SRI) in India' was developed by PricewaterhouseCoopers Private Limited (PwC India) team including Mr. Amit Kumar (Partner), Mr. Rajeev Ralhan (Executive Director), Mr. Gopal Nurani Parasu (Manager) and Mr. Aayush Nautiyal (Associate) and the VITO team including Dr. Stijn Verbeke (Senior R&D expert) and Ms. Birgit Vandevelde (Researcher).

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1. Background

1.1. Introduction

The European Union (EU) – India Clean Energy and Climate Partnership[1] (CECP) was agreed at the EU-India Summit on 30th March 2016. The aim of this partnership is to reinforce cooperation on clean energy and implementation of the Paris Agreement by strengthening joint activities for deployment of climate friendly energy sources in the areas of energy efficiency, renewable energy, smart grids, storage, sustainable finance, and climate mitigation and adaptation between the EU and India.

The building sector is an important sector for the EU-India cooperation in the area of the green energy transformation. The energy consumption has been increasing every year owing to the rapid urbanization, with the building sector being one of the major contributors.

India is witnessing one of the fastest construction growths worldwide. It is estimated that commercial floor area in India will grow by 2.5-3 times in next 2 decades[2]. Whereas, by 2030, residential real estate has the potential to almost double from the current stock of 1.5 million units in key cities of the country[3]. Also, according to the United Nation's data, India alone is expected to account for 17% of the global growth in urban population between 2018 and 2050, adding 416 million urban dwellers. The commercial building sector has been growing at a rate of 10-11%, much faster than the average electricity growth in the economy. For commercial buildings, heating, ventilation, and air conditioning (HVAC) and lighting system constitutes close to 55% and 25%, respectively of the total electricity consumed in buildings.

The world is experiencing quick technological transformation across all sectors. Digital technologies have advanced more rapidly than any other innovation in history. It has reached out to 50% of global population in only 2 decades and transforming societies. Building sector is one of the prime movers for integrating technological advancements into its electrical and mechanical systems. The value of buildings (commercial and residential) has increased over the period of time once they started adopting information (data) based applications, which are termed as smart systems for buildings. Especially in the EU, these smart systems are having a significant impact on building owners and operation and maintenance teams for reducing the operation and maintenance (O&M) costs. Information and Communication Technology (ICT) based systems aims to grow margins and enables features such as monitoring and regulating energy efficient building operations, enhanced occupant's thermal and visual comfort and eventually creating new revenue generation opportunities.

According to an independent analysis conducted by Memoori[4], a company focused on the smart building industry, the number of connected devices in operation in the commercial smart building's vertical is expected to grow from 1.7 billion in 2020 to around 3 billion by 2025 representing a CAGR of 10.8%. Specifically, in the EU, the

[1] https://www.cecp-eu.in/
[2] ICAP
[3] Report of CREDAI CBRE – India's real estate sector on growth trajectory
[4] https://memoori.com/portfolio/the-internet-of-things-in-smart-commercial-buildings-2020-to-2025/

contribution of integration of smart technologies in buildings is estimated to be noteworthy, which is discussed in Section 3. With the objective of identifying and supporting opportunities for EU business engagement in India and assessing the possibility of establishing a framework for Smart Readiness Indicators (SRI) in India, a feasibility study is conducted under EU India CECP project.

1.2. What is SRI?

Smart technologies in buildings comprise of a cost-effective measure to increase energy performance, create healthier and liveable buildings, and enable buildings to integrate into future energy systems characterised by a large share of renewable energy sources. Integration of smart technologies in buildings, offers advantages of optimized energy use and storage, automatic diagnosis and maintenance prediction and improved comfort for occupants via automation.

The Smart Readiness Indicator (SRI) aims at making the added value of building smartness more tangible for building users, owners, tenants, and smart service providers. The indicator is intended to raise awareness about the benefits of smart technologies and ICT in buildings, likely to result in an acceleration of investments in smart building technologies and support of the uptake of technology innovation in the building sector. The indicator can also improve policy linkages between energy, buildings, and other policy segments, and thereby contribute to the integration of the buildings sector into future energy systems and markets.

A Smart Readiness Indicator (SRI) for buildings thus provides information on the technological readiness of buildings to interact with their occupants and the energy grids, and their capabilities for more efficient operation and better performance through ICT technologies.

The SRI is a rating based on the assessment of a building or building unit's capabilities to adapt to occupant and grid's needs and to improve EE and overall performance.

The SRI covers three key functionalities:

- optimisation of **energy performance** and **operation**,
- adaptation to **occupants' needs**, maintaining healthy indoor climate conditions
- **flexibility** of a building's overall electricity demand

The SRI will:

- **raise awareness** about the benefits of smart technologies in buildings,
- **support and orient investments** in smart technologies

The SRI can:

- contribute to enhancing **energy efficiency**, **comfort,** and **well-being** in buildings,
- improve **policy linkages** with connected initiatives,
- contribute to integration of buildings into future **energy systems** and **markets**

What is smartness? ***- Smartness of a building refers to the ability of a building or its systems to sense, infer, communicate, and actively respond in a well efficient manner to the ever-changing conditions in relation to the operation of technical building systems or the external environmental and to the demands from the building occupants.***

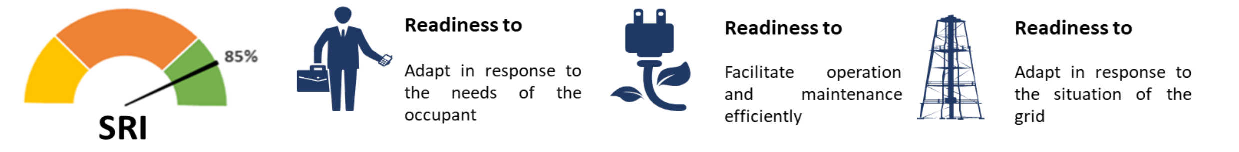


Figure 1: Three key functionalities of smart readiness in buildings (Reference: EPBD)

As creditable information on the smartness of the building can steer/influence the investment decisions, the target audience for the SRI are:

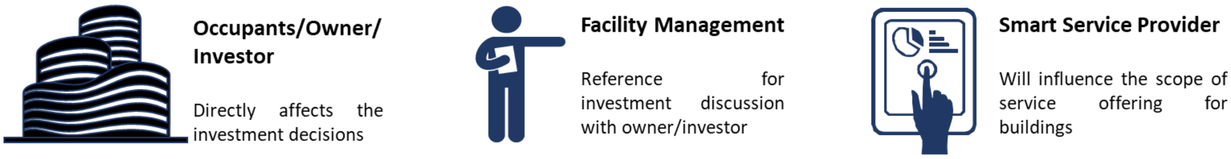


Figure 2: Target audience for SRI for buildings (Reference: EPBD)

For building occupants and owners and for investors for all new and existing buildings, SRI will provide an overview of services in a building and how they can contribute to the smart readiness of that building.

2. Methodology adopted for the study

This study sets out to investigate the relevance of establishing a SRI framework in the Indian context. In order to do so, the following steps are followed and have been elaborated in this section below:

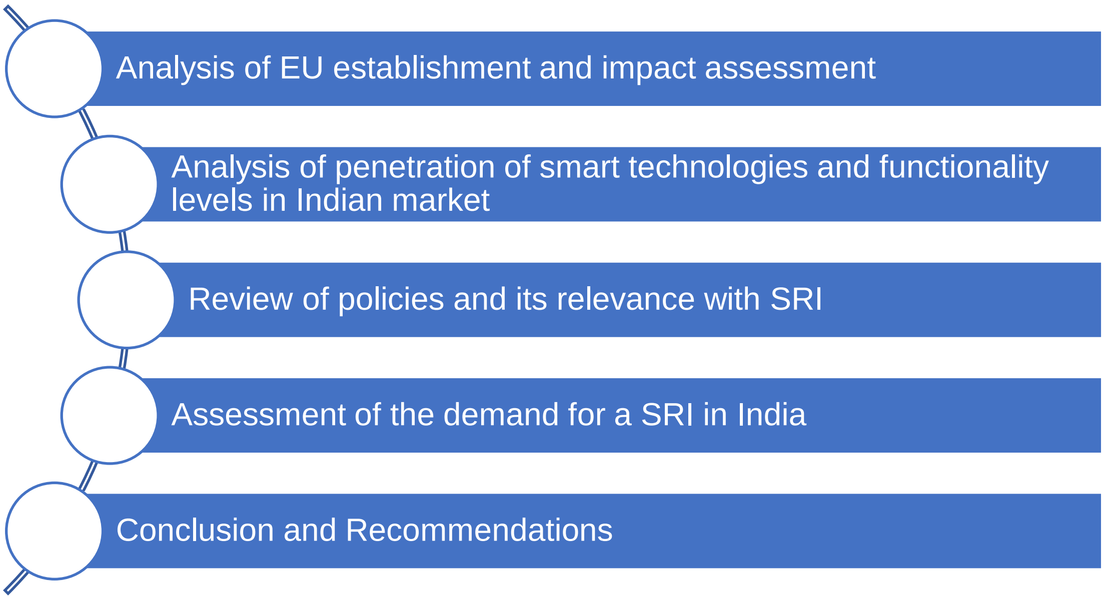


Figure 3 Methodology adopted for feasibility of SRI study

1. As a first step, analysis of the steps undertaken by the EU in order to establish the SRI framework, has been looked into in chapter 3. This chapter also looks at the impact assessment conducted by the EU and also presents the findings.

2. Analysis of the penetration of smart technologies is conducted, which includes identification of technologies which are established, and which have the most potential to be established in the next 2-5 years, in the Indian context. This is seen in conjunction with the study done by the EU, which has identified smart services for each domain along with defined functionality levels, having the most impact in terms of energy savings, which has been described in chapter 4.

   <u>Note:</u> The interrelationship between domains, service, functionality levels and impact criteria is presented in figure 4 at the end of this chapter and is referred to as SRI catalogue.

   Using the same impact criteria established by the EU for each functionality level of a smart service, we will also assess what functionality level is available in India which is based on the survey conducted. A total of 22 responses were received on reaching out to more than 40 various technology providers. Some of the major manufacturers/technology providers who participated in the survey are Honeywell Automation India Limited, Siemens, Blue Star India, Armstrong Fluid Technology, Kanoda Energy Systems and Zenatix Solutions Pvt Ltd.

3. Relevant policies/ codes and rating systems in India are looked at to identify the support it offers for uptake of smart technologies in chapter 5. In addition to the

above, other initiatives by the Government of India have been looked into to assess the possibility of integration of smart technologies and the possible link with the establishment of SRI in India.

4. The possible demand for the use of SRI in India from the business case perspective is looked at in chapter 6. It assesses the need of a SRI framework from the perception of relevant industry leading technology providers, from building constructors and consumers.

5. Chapter 7 provides a summary of key takeaways from chapters 3 to 6. This section also highlights the possible risks and attention points along with providing a roadmap for further activities related to a possible SRI in India.

Domains, services, functionality levels and impact criteria

As discussed in point no 2 above, the following figure presents the interrelation between domains, services, functionality levels and impact criteria. However, a detailed explanation regarding the same is provided in chapter 3.1.

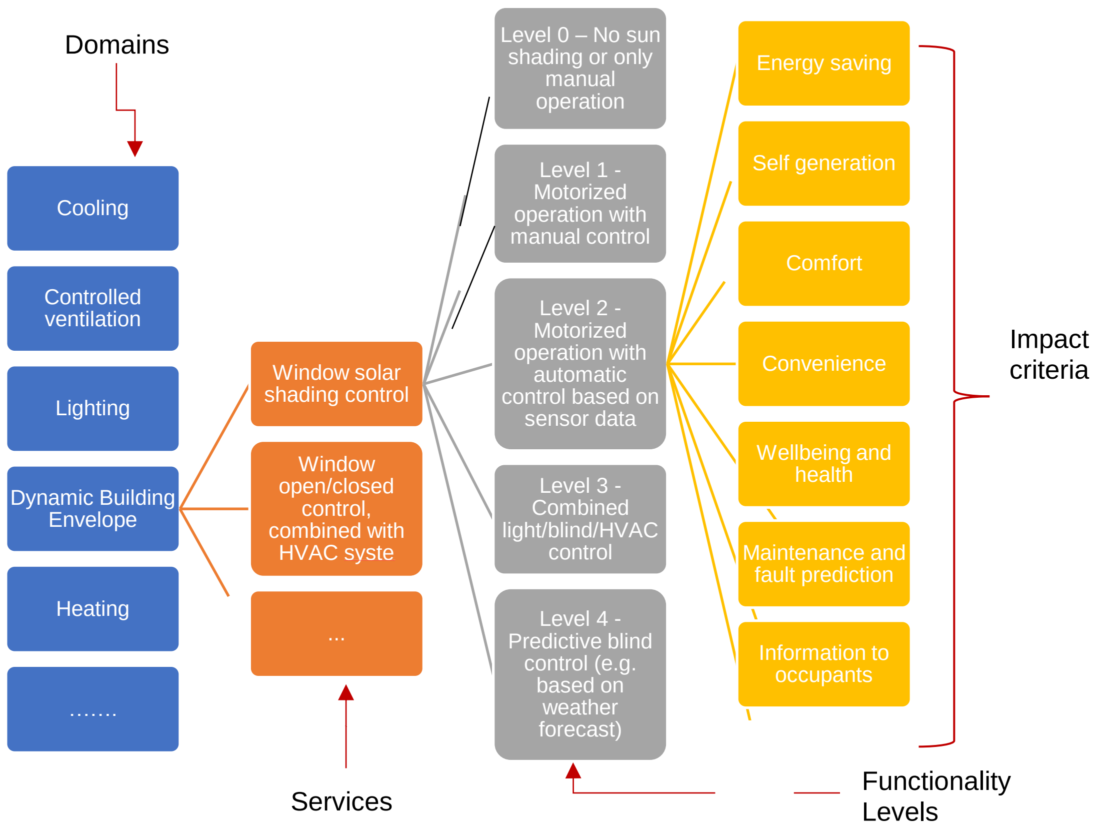


Figure 4 Smart service catalogue indicating domains, services, functionality levels and impact criteria

3. Establishing SRI in the EU - Background

3.1. Introduction

This chapter assesses how the SRI has been established in the European Union and its potential relevance of applying the same methodology in the Indian context.

In March 2017 the European Commission launched a technical study to investigate the relevance of introducing a dedicated assessment scheme to assess the smartness of buildings. The prospect of establishing such 'Smart Readiness Indicator for buildings' (SRI) was investigated by a consortium consisting of VITO NV, Waide Strategic Efficiency, Ecofys and Offis[5]. The aim for the SRI was to raise awareness on the potential of technologies that have the ability to adapt to occupants' needs, to adapt to the grid and to optimise energy efficiency.

The 1st technical study investigated a possible scope and characteristics of the SRI. A set of guiding principles was set for the methodology, including technology-neutrality, transparent and tangible information provision, balance between detail and cost of the assessment, incorporation of multiple distinct domains, possible adaptation to relevant contextual factors and flexibility to allow for regular updates. The study proposed a definition and draft methodology for the SRI, in close collaboration with the stakeholder community.

Informed by the outcomes of this technical support study, the 2018 revision of the European Energy Performance of buildings Directive (EPBD)[6] effectively introduced the concept of a Smart Readiness Indicator (SRI), in line with the emphasis that was put on the potential of smart technologies in the building sector (Refer section 3.1). The EPBD Impact Assessment (IA) reports estimated the following impacts resulting from the framework for the introduction of a smartness indicator:

Table 1 Impact of EPBD assessment on smartness indicator

Impacts on savings in 2030	Impacts on annual energy expenditures in 2030	Impacts on associated construction activity (annual average for 2020 - 2030)
8 – 10 Mtoe	8 – 10 bn€/a	5 – 6 bn €/a

A second technical study was tendered to further refine technical details of the proposed SRI assessment and implementation options. The technical aspects aimed to refine and finalise the SRI definition and calculation methodology, based on the outcomes of the first technical study. A beta version of the methodology was tested on a voluntary basis during an open public testing phase, which provided confirmation of the viability of the approach and led to further improvements of the consolidated methodology. The second study was concluded in June 2020 and the outcomes of the

[5] "Support for setting up a Smart Readiness Indicator for buildings and related impact assessment - final report"; August 2018; Brussels. Authors: VITO: Stijn Verbeke, Yixiao Ma, Paul Van Tichelen, Sarah Bogaert, Virginia Gómez Oñate; Waide Strategic Efficiency: Paul Waide ; ECOFYS: Kjell Bettgenhäuser, John Ashok, Andreas Hermelink, Markus Offermann, Jan Groezinger ; OFFIS: Mathias Uslar, Judith Schulte

[6] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2018.156.01.0075.01.ENG

first two technical studies were taken into account for drafting a delegated regulation and an implementing regulation. Both regulations[7] were officially adopted on October 14th, 2020, making the SRI an optional common EU scheme.

In May 2021 a third support contract was launched by the European Commission services aiming at technical assistance for testing and implementation of the SRI in EU Member States. The detailed steps adopted by the EU to prepare ground for establishment of SRI and its impact has been provided below.

3.2. EU methodology in detail

The EU adopted the following tasks in order to arrive at outcomes which includes setting up a Smart Readiness Indicator for buildings and related impact assessment, which formed part of the 1st technical study as explained in the introduction above.

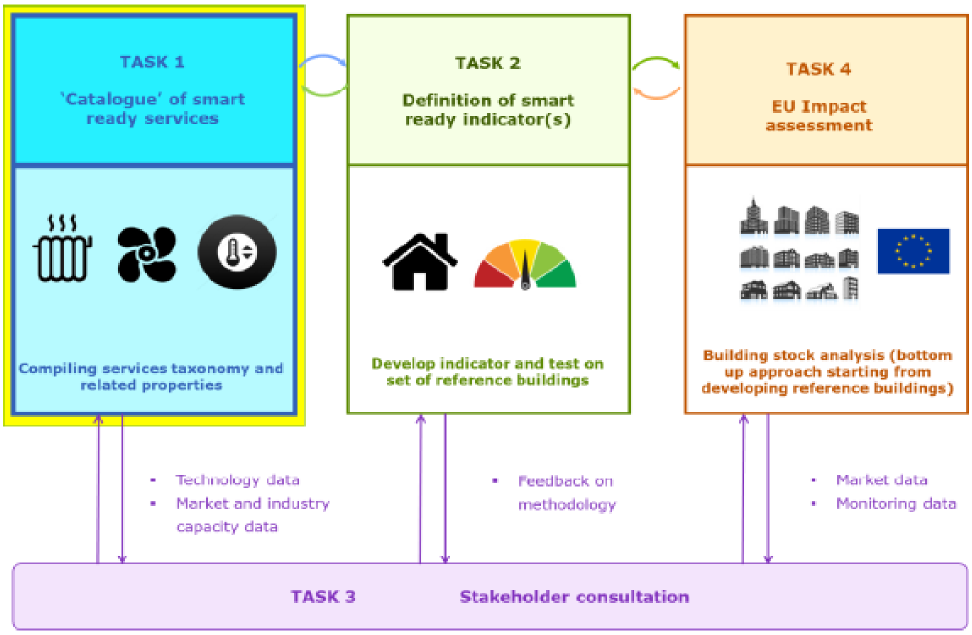


Figure 5 Overview of project structure

Task 1 – 'Catalogue' of smart ready services - The objective of this task was to identify the smart ready services (SRS) and functionalities that these technologies can provide to a building and its occupants. Under this task, suitable technologies are listed which fit the definition of smart-ready technologies that can be integrated into buildings and technical building systems to improve their operations and enhance energy efficiency. Also, the smart services catalogue was updated to reflect feedback from several stakeholder consultations.

Task 2 – **Develop indicator and test on set of referenced buildings** - This task primarily proposed methodological approaches for the calculation of the SRI. A streamlined SRI methodology was proposed that uses a consolidated set of services which were actionable, and which had reasonable confidence in their ability to be assessed and their attribution of impacts to functional levels.

[7] https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32020R2155 and https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32020R2156

The SRI intends to focus on inspection of smart ready services available in buildings, that are enabled by (a combination of) smart ready technologies. Therefore, an inventory of smart ready services that could be available in a building was made as well as an evaluation of the functionalities they can offer. Each service can be implemented with various degrees of smartness, referred to as functionality levels, which has been described in Figure 6.

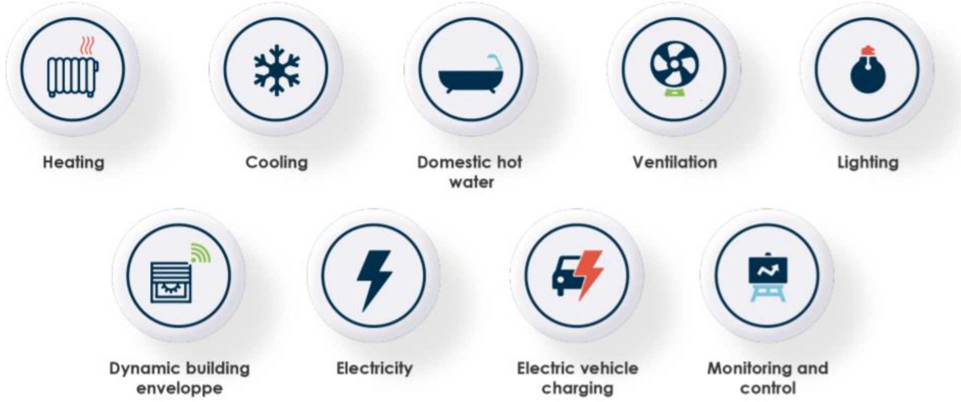


Figure 6: Nine domains grouping services

The services within a building operate in multiple domains (see Figure 6) inducing various kinds of impacts (see **Error! Reference source not found.** 7).

Figure 7 Seven impact categories, grouped into 3 main pillars

To take into account all domains and impact categories, a multi-criteria assessment method was created, allowing to take into account the scores related to the functionality levels of the services present within the buildings for all impact criteria.

Weighting factors allow to create one single score for the Smart Readiness of the building, but also information on impact level is available. The seven impact categories can be combined in three main groups: energy savings and operations, ability to respond to user needs and ability to respond to needs of the grids, that correspond to the pillars mentioned in the revised EPBD.

	Overall SRI score (%) + SRI class							
	%		%				%	
	Optimise energy efficiency and overall in-use performance		Adapt its operation to the needs of the occupant				Adapt to signals from the grid (energy flexibility)	
	%	%	%	%	%	%	%	
	Energy efficiency	Maintenance and fault prediction	Comfort	Convenience	Health, well-being and accessibility	Information to occupants	Energy flexibility and storage	
Heating	%	%	%	%	%	%	%	%
Cooling	%	%	%	%	%	%	%	%
Domestic hot water	%	%	%	%	%	%	%	%
Ventilation	%	%	%	%	%	%	%	%
Lighting	%	%	%	%	%	%	%	%
Dynamic building envelope	%	%	%	%	%	%	%	%
Electricity	%	%				%	%	%
Electric vehicle charging		%		%		%	%	%
Monitoring and control	%	%	%	%	%	%	%	%

Figure 8: SRI score calculated at different levels

The multi-criteria assessment method is proposed as the underlying methodology for calculating the smart readiness indicator. In this multi-criteria assessment, weightings can be attributed to domains and impact criteria to reflect their relative contributions to an aggregated overall impact score.

Apart from the overall scores, sub-scores can be generated at both the domain level and the impact category level and these can also be communicated as part of the SRI.[8]

<u>Task 3</u> – Stakeholder consultation - This was a continuous process and was a part of all the activities. More than 65 representatives were present, from a broad variety of stakeholder organisations representing Member States, EPBD Concerted Action members, industry associations, research institutes, NGOs and individual companies.

<u>Task 4</u> - EU Impact assessment - This activity was based on the description of smart ready services from task 1 and the methodology to calculate the SRI in task 2. The core objective was to calculate the benefits for the uptake of smart ready services in relation to the implementation of the SRI. Task 4 is more elaborated in the section below.

EU Impact Assessment

Implementing task 4, a cost benefit analysis was carried out for the years - 2023, 2030, 2040 and 2050. It considered a range of benefits and effects, while concentrating on assessing the benefits in monetary, energy and emissions units on a cumulative and yearly basis, for the different building segments. Furthermore, a qualitative analysis was also conducted to elaborate on the effects regarding health, indoor air quality, comfort and life-cycle effects. The methodology for the evaluation of impacts was split into two steps.

[8] Support for setting up a Smart Readiness Indicator for buildings and related Impact Assessment

Step 1: The first part was the modelling of the underlying building sector pathways (baseline), which describes the general development of the building sector taking into account new buildings, demolition of buildings and retrofits that included energy efficiency measures which have an impact on building envelope and HVAC systems. These pathways were modelled with the Built-Environment-Analysis Model (BEAM), a bottom-up building sector model used by Ecofys.

Figure 9 Approach followed by Ecofys in Built-Environment-Analysis model (BEAM)

1. The first step for the building sector modelling process was to establish the definition of reference buildings. A reference building is a building that represents a typical building of the building stock. This enables the analysis of an entire building stock by analyzing the stock from bottom-up, based on a different set of reference buildings.

2. After having defined the adequate set of reference buildings, the next step was to determine the energy demands - and thereby the saving potentials of the reference buildings (For case studies of reference buildings, refer Annexure 3). The results of the determination of the energy demands and potentials of the reference building variants were aggregated to represent the EU building stock and its future development.

3. The outputs of the building sector pathway calculation with the BEAM model were the floor area development per building type, energy demand, related CO_2-emissions, and energy costs.

Note: Parameters and assumptions for the building sector pathways were set based on the report and modelling work by Ecofys for the EC study “Ex-ante evaluation and assessment of policy options for EPBD’’

Step 2: As a next step, the smart ready technology (SRT) scenarios quantified the effects of the uptake of SRTs in addition to the building sector pathways. These effects were calculated with an Excel based model for the three scenarios described below:

- **SRT_Business As Usual (BAU):** No SRI, only existing incentives for Smart Ready Technologies
- **SRT_Moderate implementation:** SRI voluntary, moderate accompanying measures and moderate implementation
- **SRT_High implementation:** SRI still voluntary, strong accompanying measures and considerable implementation

The autonomous effects of SRTs due to replacement of systems and systems in new buildings that can be observed today continue in the “SRT_BAU” scenario. In addition to the autonomous effects, the “SRT_Moderate implementation” and “SRT_High implementation" scenarios assume an uptake of SRTs due to the introduction of the SRI.

The following figure gives an overview of the savings regarding final thermal energy, which can be realized by the different scenarios until 2050 due to the introduction and uptake of SRTs for all building types and all geographical regions. The numbers are cumulative, which means that the 2050 numbers represent all effects in the year 2050 of SRTs which were implementation between 2023 and 2050 compared to today.

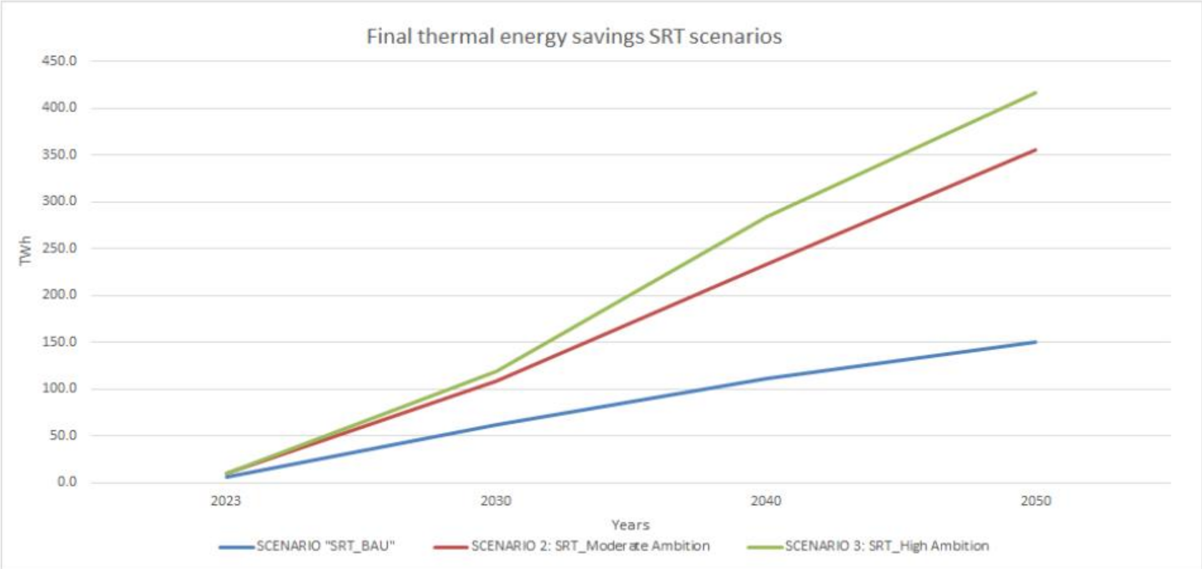


Figure 10 Thermal Energy Savings SRT scenarios

Impact Assessment Results[9]

The total thermal energy savings in 2050 are about 150 TWh/a for the SRT_BAU scenario, while the SRT_Medium and SRT_High implementation scenarios show significantly higher savings with approx. 350 TWh/a respectively 420 TWh/a. While the SRT_BAU scenario assumes constant implementation rates at current level over time, the SRT_Medium and SRT_High implementation scenario show a rather progressive pathway due to a ramping-up period in the beginning where implementation rates are increased and trust in the SRI is built.

The energy cost savings for the SRT_BAU scenario decline from about 460 to 270 million Euro per year due to decreasing efficiency potentials, while the SRT_Moderate an SRT_High scenario rank between 800 and 1,200 Million Euro energy cost savings per year.

Compared to the yearly investments from above, a static payback period between 2-6 years can be calculated.

Regarding CO_2-emissions, the SRT_BAU scenario shows emission reduction by 26 Mt/a until 2050 compared to today's level, while the two other scenarios lead to

[9] Verbeke S., Waide P., Bettgenhäuser K., Uslar M.; Bogaert S. et al.; "Support for setting up a Smart Readiness Indicator for buildings and related impact assessment - final report"; August 2018; Brussels

significantly higher savings. For the SRT_High scenario the total CO_2-emission level can be lower by 70 Mt/a until 2050.

3.3. Conclusion

As indicated in the impact assessment results above, there is a strong case for the uptake of smart technologies and the establishment of SRI in the EU. According to the impact assessment results, the total thermal energy savings in 2050 is between 350 TWh/a and 450 TWh/a while the energy cost savings is between 800 and 1,200 Million Euro per year, depending on the scenarios developed by the EU. Also, the payback period is calculated to be between 2-6 years and the CO_2 emissions reduction until 2050 is estimated to be lower by 70 Mt/a.

4. Penetration of smart technologies in India

4.1. Introduction

As discussed in the methodology, an analysis of the penetration of smart technologies is conducted, which includes the identification of technologies which are established, and which have the most potential to be established in the next 2-5 years, in the Indian context via a survey. The results of the survey are analysed and are presented in the sections below according to specific domains. Also, each functionality level of smart services is depicted as per the energy savings potential under each domain, which is based on the study conducted by the EU.

Cooling	Controlled ventilation	Lighting	Electricity	Electric vehicle charging
Monitoring & control	Heating	Domestic hot water	Dynamic building envelope	

Figure 11 List of technology domains considered in survey questionnaire

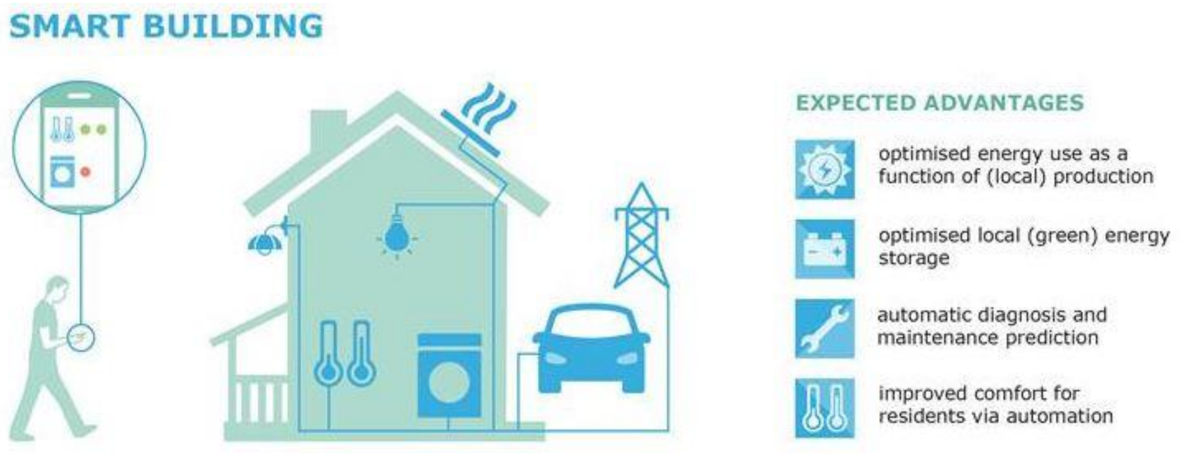


Figure 12 Expected advantages of smart technologies in buildings (Source: SRI technical support studies)

4.2. Smart services under the 'cooling' domain

The cooling domain consists of 10 smart services with different functionality levels. A brief explanation of the services is included below:

- ***Smart service 1: Cooling emission control** - This service allows for either a centralized control or individual rooms control, working on the principle of demand side management. Cooling is provided based on the current occupancy/ demand and the system operates variably to meet the demand.*
- ***Smart service 2: Emissions control for TABS** - Thermally activated building systems (TABS) refers to heating and cooling transmission systems taking advantage of large surface areas and integrated in the building structure. These types of systems take advantage of a building's mass, usually structural floors*

and slabs to thermally condition a building. TABS when coupled with advanced automatic control, can result in significant emissions reduction.

- ***Smart service 3: Control of distribution network chilled water temperature (supply or return) -*** *This smart service provides cooling control on the demand side. It is only applicable in case mechanical cooling systems are present.*
- ***Smart service 4: Control of distribution pumps in networks -*** *This smart service allows for control of flow via the distribution pumps based on the cooling demand available at the moment. This allows for energy savings. This is achieved via VFD integration.*
- ***Smart service 5: Interlock: avoiding simultaneous heating and cooling in the same room -*** *This smart service avoids simultaneous heating and cooling in the same room wherever multiple entryways are provided. This is to avoid spending energy for both heating and cooling services in the same room.*
- ***Smart service 6: Control of Thermal Energy Storage (TES) operation -*** *Thermal energy storage is like a battery for a building's air-conditioning system. It uses standard cooling equipment, plus an energy storage tank to shift all or a portion of a building's cooling needs to off-peak and during night hours.*
- ***Smart service 7: Generator control for cooling –*** *Variable control of cooling production capacity to avoid spending unnecessary energy for cooling.*
- ***Smart service 8: Sequencing of chillers -*** *This smart service is used to control the cooling production facilities. The sequencing of chillers and sub systems allows the systems to meet the cooling requirement of the building and hence a better cooling control. Here, the online chiller numbers and staging time is based on the cooling load conditions.*
- ***Smart service 9: Report information regarding cooling system performance –*** *The smart service focuses on collecting and analyzing the cooling system performance which can be used to access the system health and enables the owner/ administrator to achieve the energy efficiency goals.*
- ***Smart service 10: Flexibility & grid integration -*** *In case of heating / cooling, using structures like demand side management the cooling can be optimized to be most cost effective by avoiding peak hours energy costs. This smart system not only helps save money but can also be an instrument to enhance grid stability and flexibility.*

The following table indicates the smart services under the domain 'cooling' along with their functionality levels, based on the functionality levels used in the EU methodology (see chapter 3.2). The functionality levels for each smart service indicate the levels of advancement as we move from Fn Level 0 to 4. This catalogue primarily acts as a reference point for all analysis conducted under the 'cooling' domain.

Note: The smart services catalogue is presented for all 'domains' in their relevant sections.

This project is funded by the European Union

Table 2 Smart services and functionality levels for domain 'Cooling'

Cooling	**Smart service name**	**Fn Level 0**	**Fn Level 1**	**Fn Level 2**	**Fn Level 3**	**Fn Level 4**
Smart service 1	Cooling emission control	No automatic control	Central automatic control	Individual room control	Individual room control with communi-cation between controllers and to BACS	Individual room control with communi-cation and occupancy detection
Smart service 2	Emission control for TABS (cooling mode)	No automatic control	Central automatic control	Advanced central automatic control	Advanced central automatic control with intermittent operation and/or room temperature feedback control	
Smart service 3	Control of distribution network chilled water temperature (supply or return)	Constant temperature control	Outside temperature compensated control	Demand based control		
Smart service 4	Control of distribution pumps in networks	No automatic control	On off control	Multi-Stage control	Variable speed pump control (pump unit (internal) estimations)	Variable speed pump control (external demand signal)
Smart service 5	Interlock: avoiding simultaneous heating and cooling in the same room	No interlock	Partial interlock (minimizing risk of simultaneous heating and cooling e.g., by sliding setpoints)	Total interlock (control system ensures no simultaneou s heating and cooling can take place)		
Smart service 6	Control of Thermal Energy Storage (TES) operation	Continuous storage operation	Time-scheduled storage operation	Load prediction-based storage operation	Cold storage capable of flexible control through grid signals (e.g. DSM)	
Smart service 7	Generator control for cooling	On/Off-control of cooling production	Multi-stage control of cooling production capacity depending on the load or demand (e.g. on/off of several compressors)	Variable control of cooling production capacity depending on the load or demand (e.g. hot gas bypass, inverter	Variable control of cooling production capacity depending on the load AND external signals from grid	

				frequency control)		
Smart service 8	Sequencing of different cooling generators	Priorities only based on running times	Fixed sequencing based on loads only: e.g. depending on the generators characteristics such as absorption chiller vs. centrifugal chiller	Dynamic priorities based on generator efficiency and characteristics (e.g. availability of free cooling)	Load prediction based sequencing: the sequence is based on e.g. COP and available power of a device and the predicted required power	Sequencing based on dynamic priority list, including external signals from grid
Smart service 9	Report information regarding cooling system performance	None	Central or remote reporting of current performance KPIs (e.g. temperatures, submetering energy usage)	Central or remote reporting of current performance KPIs and historical data	Central or remote reporting of performance evaluation including forecasting and/or bench-marking	Central or remote reporting of performance evaluation including forecasting and/or bench-marking; also including predictive management and fault detection
Smart service 10	Flexibility and grid interaction	No automatic control	Scheduled operation of cooling system	Self-learning optimal control of cooling system	Cooling system capable of flexible control through grid signals (e.g. DSM)	Optimized control of cooling system based on local predictions and grid signals (e.g. through model predictive control)

As indicated in chapter 2 setting out the methodology, each functionality level of the smart service was given an ordinal ranking (---- to ++++) based on the SRI impact criteria with '----' indicating the negative impact and '++++' indicating the highest potential on each category considered for the assessment. The following table depicts assessment done on the **"cooling emission control"** smart service in Europe.

Table 3 Assessment on “cooling emission control”

Fn Lvl	Fn Lvl Name	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Wellbeing and health	Maintenance & fault prediction	Information to occupants
0	No automatic control	0	0	0	0	0	0	0
1	Central automatic control	+	0	+	+	+	0	0
2	Individual room control	+	0	+	++	++	0	0
3	Individual room control with communication between controllers and to BACS	++	0	++	+++	++	+	0
4	Individual room control with communication and occupancy detection	+++	0	++	+++	++	+	0

A similar assessment was carried out for other smart services which is given in the annexure 2 (Table 35). Based on this, the potential impact of all the smart services under “cooling” domain were mapped against the SRI impact criteria.

Table 4 Impact of smart services under “cooling” domain

Highest impact	*Moderate impact*	*Low impact*	*No impact*

S.No.	Smart Service Name	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Wellbeing and health	Maintenance & fault prediction	Information to occupants
1	Cooling emission control	Highest impact		Moderate impact	Highest impact	Moderate impact	Low impact	
2	Emission control for TABS (cooling mode)	Moderate impact		Moderate impact	Highest impact	Moderate impact	Low impact	Low impact
3	Control of distribution network chilled water temperature (supply or return)	Moderate impact		Low impact	Low impact			
4	Control of distribution pumps in networks	Moderate impact						
5	Interlock: avoiding simultaneous heating and cooling in the same room	Highest impact						

6	Control of Thermal Energy Storage (TES) operation							
7	Generator control for cooling							
8	Sequencing of different cooling generators							
9	Report information regarding cooling system performance							
10	Flexibility and grid interaction							

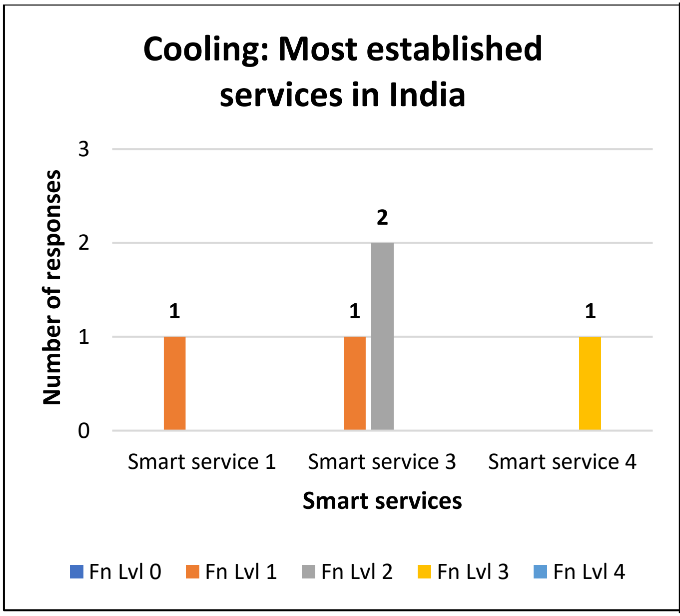
From the above table, it is evident that the following smart services have the highest potential of energy savings:

1. Smart service 1 – Cooling emission control
2. Smart service 5 – Interlock: Avoiding simultaneous heating and cooling in the same room
3. Smart service 8 – Sequencing of different cooling generators

In addition to ***energy savings***, smart service 1 and smart service 8 also have high impact on ***convenience*** and ***flexibility for the grid and storage*** respectively.

Results of the Survey

The following figure lists down the various smart services under 'cooling' domain and the industry perception on its establishment, expressed in the functional level they perceive dominant, currently for this service. However, it is unlikely that all the buildings in India have the most established services as per the figure below as it is based on perception of 05 responses who have responded to the survey questionnaire.



Smart service 3 - Control of distribution network chilled water temperature (supply or return)
Fn Lvl 2 - Demand based control
Fn Lvl 0 - Outside temperature compensated control

Smart service 4 - Control of distribution pumps in networks
Fn Lvl 3 - Variable speed pump control (pump unit (internal) estimations)

Smart service 1 - Cooling emission control
Fn Lvl 1 – Central Automatic Control

Figure 13 Most established smart services for the cooling domain

As per the market response it is perceived that **'Control of distribution network chilled water temperature (supply or return)'** is the most established service in India which is indicated by presence of an advanced level of functionalities, which is followed by **'Control of distribution pumps in networks'** and **'Cooling emission control'**.

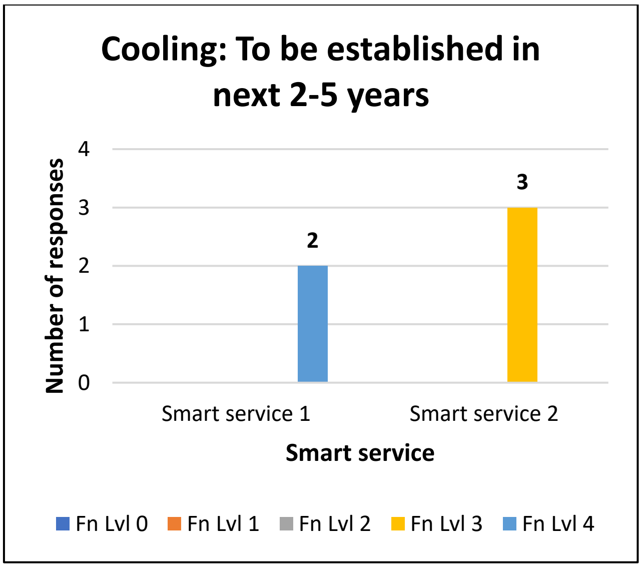
For each established smart service, there may be several factors that would be responsible for its establishment in the market. Below are top three factors that are perceived important by the industry for establishment of above smart services. These factors have played a pivotal role in the establishment of these services and will continue to affect the adoption of these services by the consumers.

Table 5 Top 3 factors perceived important for establishment of above smart services

Smart service 3 - Control of distribution network chilled water temperature (supply or return)	**Smart service 4 - Control of distribution pumps in networks**	**Smart service 1 - Cooling emission control**
Consumer awareness about energy efficiency	Consumer awareness about energy efficiency	Consumer awareness about energy efficiency
Less capital cost	Less maintenance of system	Less capital cost
Less maintenance of system	Convenience	Convenience

It is evident that consumer awareness about energy efficiency is a key driver in establishing a smart service along with lower capital cost and convenience.

The following figure lists the various smart services and corresponding functionality levels under 'cooling' domain which are likely to be established in the **next 2-5 years** based on industry perception. However, it is based on perception of 5 responses to the survey questionnaire.



<u>Smart service 2</u>- Emission control for TABS (cooling mode)
Fn Lvl 3 - Advanced central automatic control with intermittent operation and/or room temperature feedback control

<u>Smart service 1</u> - Cooling emission control
Fn Lvl 4 - Individual room control with communication and occupancy detection

Figure 14 To be established smart services for the cooling domain

'Emission control for TABS (cooling mode)' is perceived to be established in the next 2-5 years, followed by **'Cooling emissions control'**.

Below table indicates the factors which are perceived to be key drivers for establishing of above smart services in the market in the next 2-5 years.

Table 6 Top drivers for successful establishment of services in the next 2-5 years

Smart service 2- Emission control for TABS (cooling mode)	Smart service 1 - Cooling emission control
Consumer awareness about energy efficiency	Consumer awareness about energy efficiency
Convenience	Less maintenance of system
Less Maintenance of system	Convenience

From the above table, it is evident that consumer awareness about energy efficiency, convenience and less maintenance of systems are key drivers for establishment of services in the next 2-5 years.

The following table summarizes the current market scenario, availability, and market adoption potential for the smart services under 'cooling' domain according to the survey and maps it with their respective energy savings potential as determined by study conducted in Europe.

Table 7 Market scenario of smart services under "Cooling" domain

Smart service	Service name	Availability of the smart service	Market scenario of smart services			
			Most established along with EE impact		Potential to be established in the next 2-5 years along with EE impact	
1	Cooling emission control	Fn Lvl 1	Fn Lvl 1	+	Fn Lvl 4	+++
2	Emission control for TABS (cooling mode)				Fn Lvl 3	++
3	Control of distribution network chilled water temperature (supply or return)	Fn Lvl 2 Fn Lvl 1	Fn Lvl 2 Fn Lvl 1	++ +		
4	Control of distribution pumps in networks	Fn Lvl 3 Fn Lvl 1	Fn Lvl 3	++		
5	Interlock: avoiding simultaneous heating and cooling in the same room	Fn Lvl 0				
6	Control of Thermal Energy Storage (TES) operation	Fn Lvl 1				
7	Generator control for cooling					
8	Sequencing of different cooling generators					
9	Report information regarding cooling system performance	Fn Lvl 1 Fn Lvl 2				

10	Flexibility and grid interaction	Fn Lvl 0				

Summary

Based on the survey results for domain 'Cooling', it can be concluded that most of the available smart services have functionality levels which are still in the nascent stage and there are very few smart services with intermediate or advanced functionality levels. However, considering the fact that there is presence of technology providers and technologies which are likely to be in demand in the future, there may be a potential for further development of these smart services in India. The following list summarizes the most promising smart services under the "cooling" domain using the methodology carried out in Europe (Table 4) and based on the market scenario of the smart services in India (Table 7):

1. Smart Service 1- Cooling emission control
2. Smart Service 2- Emission control for TABS (cooling mode)
3. Smart Service 5- Interlock: avoiding simultaneous heating and cooling in the same room
4. Smart Service 8- Sequencing of different cooling generators

Out of these services, only functionality level 1 - **"Central automatic control"** of smart service 1 - **"cooling emission control"** is available and established in India. The rest of these services would need a push from both regulatory and financing bodies for wider availability and market adoption.

4.3. Smart services under 'controlled ventilation' domain

The 'controlled ventilation' domain consists of 6 smart services with different functionality levels. A brief explanation of the services is included below:

- ***Smart service 1: Supply air flow control at the room level*** *– This smart service allows for control of air flow at the room level based on the occupancy and set point temperatures.*
- ***Smart service 2: Air flow or pressure control at the air handler level*** *- This smart service allows the cooling in the cooling zone to be controlled based on the air flow or pressure control at the Air Handling Level.*
- ***Smart service 3: Heat recovery control –*** *This smart service provides recovery of cooling / heating based on outside temperatures and set point temperatures. This prevents loss of heat/ cold via the exhaust air. This is done by normalizing the temperature of the fresh air. Significant savings can be achieved both in heating / cooling.*
- ***Smart service 4: Supply air temperature control at the air handling unit level -*** *This smart service provides cooling control at the AHU level. Different set point temperatures can be provided at the Air Handling Level based on the thermal comfort preferences of the occupants.*
- ***Smart service 5: Free cooling with mechanical ventilation system -*** *This smart service allows for cooling of interior spaces using the outside air, whenever the outside environmental conditions are favourable. This results in lower energy consumption for the air conditioning system.*

- ***Smart service 6: Reporting information regarding IAQ** - This smart service provides important information such as Temperature, Humidity, PM2.5, PM 10 etc. IAQ parameters to the systems manager for action and a greater IAQ control.*

The following table indicates the smart services under the domain 'controlled ventilation' along with their functionality levels:

Table 8 Smart services and functionality levels for domain 'controlled ventilation'

Controlled ventilation	Smart service name	Fn Level 0	Fn Level 1	Fn Level 2	Fn Level 3	Fn Level 4
Smart service 1	Supply air flow control at the room level	No ventilation system or manual control	Clock control	Occupancy detection control	Central Demand Control based on air quality sensors (CO2, VOC, humidity, ...)	Local Demand Control based on air quality sensors (CO2, VOC,...) with local flow from/to the zone regulated by dampers
Smart service 2	Air flow or pressure control at the air handler level	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	Multi-stage control: To reduce the auxiliary energy demand of the fan	Automatic flow or pressure control without pressure reset: Load dependent supplies of air flow for the demand of all connected rooms.	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).
Smart service 3	Heat recovery control: prevention of overheating	Without overheating control	Modulate or bypass heat recovery based on sensors in air exhaust	Modulate or bypass heat recovery based on multiple room temperature sensors or predictive control		

Smart service 4	Supply air temperature control at the air handling unit level	No automatic control	Constant setpoint: A control loop enables to control the supply air temperature, the setpoint is constant and can only be modified by a manual action	Variable set point with outdoor temperature compen-sation	Variable set point with load dependent compen-sation. A control loop enables to control the supply air temperature. The setpoint is defined as a function of the loads in the room	
Smart service 5	Free cooling with mechanical ventilation system	No automatic control	Night cooling	Free cooling: air flows modulated during all periods of time to minimize the amount of mechanical cooling	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).	
Smart service 6	Reporting information regarding IAQ	None	Air quality sensors (e.g. CO2) and real time autonomous monitoring	Real time monitoring & historical information of IAQ available to occupants	Real time monitoring & historical information of IAQ available to occupants + warning on maintenance needs or occupant actions (e.g. window opening)	

As indicated in the methodology, each functionality level of the smart service under “controlled ventilation” domain was given an ordinal ranking (---- to ++++) based on the SRI impact criteria with ‘----’ indicating the negative impact and ‘++++’ indicating the highest potential on each category considered for the assessment. The impact assessment of these services is provided in annexure 2 (Table 36).

The potential impact of all the smart services under "controlled ventilation" domain were then mapped against the SRI impact criteria.

Table 9 Impact of smart services under "controlled ventilation" domain

Highest impact	*Moderate impact*	*Low impact*	*No Impact*

S.No.	Smart service name	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Wellbeing and health	Maintenance & fault prediction	Information to occupants
1	Supply air flow control at the room level	Highest impact						
2	Air flow or pressure control at the air handler level	Moderate impact		Moderate impact	Moderate impact	Moderate impact		
3	Heat recovery control: prevention of overheating	Highest impact		Moderate impact	Low impact			
4	Supply air temperature control at the air handling unit level	Highest impact		Moderate impact	Low impact			
5	Free cooling with mechanical ventilation system	Highest impact		Highest impact	Moderate impact	Low impact		
6	Reporting information regarding IAQ					Highest impact	Moderate impact	Highest impact

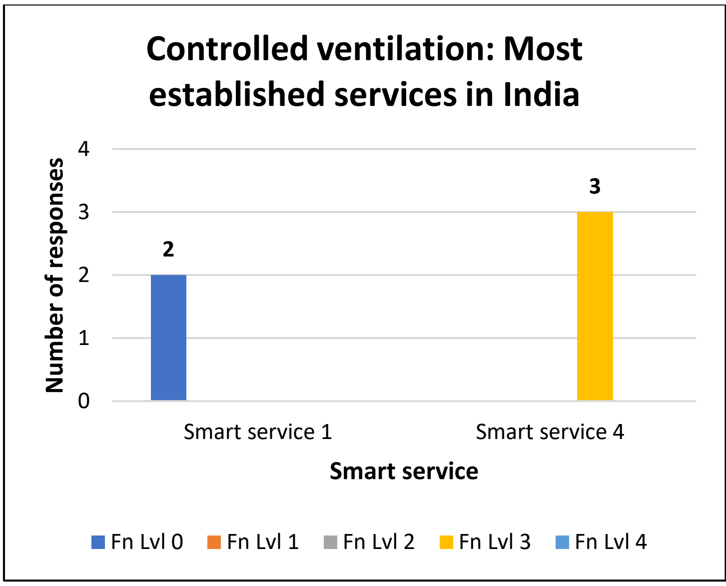
From the above table, it is evident that the following smart services have the highest potential for energy savings:

1. Smart service 1 – Supply air flow control at the room level
2. Smart service 3 – Heat recovery control: prevention of overheating
3. Smart service 4 – Supply air temperature control at the air handling unit level
4. Smart service 5 – Free cooling with mechanical ventilation system

In addition to ***energy savings***, smart service 5 also has a high impact on ***comfort***.

Results of the Survey

The following figure lists down the various smart service under 'controlled ventilation' domain and the industry perception on its establishment, expressed in the functional level they perceive dominant currently for this service. However, it is unlikely that all the buildings in India have the most established services as per the figure below as it is based on perception of 05 responses who have responded to the survey questionnaire.



Smart service 4 - Supply air temperature control at the air handling unit level
Fn Lvl 3 - Variable set point with load dependent compensation. A control loop enables to control the supply air temperature. The setpoint is defined as a function of the loads in the room

Smart service 1 - Supply air flow control at the room level
Fn Lvl 0 - No ventilation system or manual control

Figure 15 Most established smart services for the Controlled Ventilation domain

As per the market response it is perceived that **'Supply air temperature control at the air handling unit level'** is the most established service in India, which is followed by **'Supply air flow control at the room level'**.

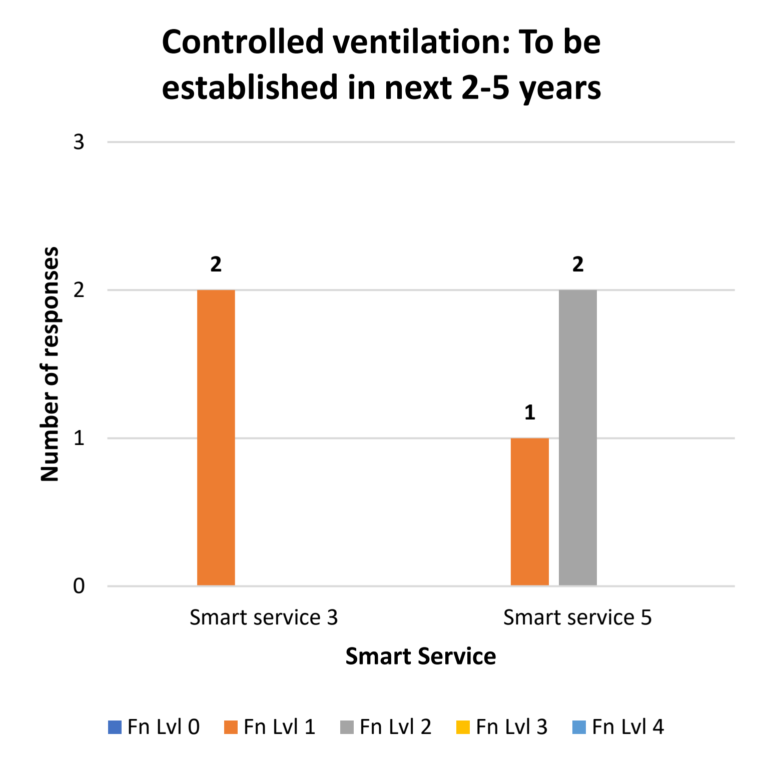
For each established smart service, there may be several factors that would be responsible for its establishment in the market. Below are top three factors that are perceived important by the industry for establishment of above smart services. These factors have played a pivotal role in the establishment of these services and will continue to affect the adoption of these services by the consumers.

Table 10 Top 3 factors perceived to be drivers for establishment of services

Smart service 4 - Supply air temperature control at the air handling unit level	Smart service 1 - Supply air flow control at the room level
Convenience	Consumer awareness about energy efficiency
Less capital cost	Less capital cost
Availability	Availability

It is evident that consumer awareness about energy efficiency is a key driver in establishing a smart service along with availability and lower capital cost.

The following figure lists down the various smart service under 'controlled ventilation' domain which are likely to be established in the **next 2-5 years** based on perception of 05 responses who responded to the survey questionnaire.



Smart service 3- Heat recovery control: prevention of overheating
Fn Lvl 1 – Modulate or bypass heat recovery based on sensors in air exhaust

Smart service 5- Free cooling with mechanical ventilation system
Fn Lvl 1 – Night cooling
Fn Lvl 2 – Free cooling: air flows modulated during all periods of time to minimize the amount of mechanical cooling

Figure 16 To be established smart services for the Controlled Ventilation domain

'Free cooling with mechanical ventilation system' is perceived to be established in the next 2-5 years, followed by **'Heat recovery control: prevention of overheating'**.

Below table indicates the factors which are perceived to be key drivers for establishing of above smart services in the market in the next 2-5 years.

Table 11 Key Drivers for establishment of services in the next 2-5 years

Smart service 3 - Heat recovery control: prevention of overheating	**Smart service 5 - Free cooling with mechanical ventilation system**
Consumer awareness about energy efficiency	Consumer awareness about energy efficiency
Convenience	Convenience
Less maintenance of system	Less maintenance of system

From the above table, it is evident that consumer awareness about energy efficiency, convenience and less maintenance of systems are key drivers for establishment of services in the next 2-5 years.

The following table summarizes the current market scenario, availability, and market adoption potential for the smart services under 'controlled ventilation' domain according to the survey and maps it with their respective energy savings potential as determined by study conducted in Europe.

Table 12 Market scenario of smart services under "Controlled ventilation" domain

Smart Service	Service Name	Availability of the smart service	Market Scenario of Smart Services			
			Most Established along with EE impact		Potential to be established in the next 2-5 years along with EE impact	
1	Supply air flow control at the room level	Fn Lvl 0 Fn Lvl 2 Fn Lvl 3 Fn Lvl 4	Fn Lvl 0	+		
2	Air flow or pressure control at the air handler level	Fn Lvl 1 Fn Lvl 2 Fn Lvl 4				
3	Heat recovery control: prevention of overheating	Fn Lvl 1			Fn Lvl 2	++
4	Supply air temperature control at the air handling unit level	Fn Lvl 1 Fn Lvl 2 Fn Lvl 3	Fn Lvl 3	++		
5	Free cooling with mechanical ventilation system	Fn Lvl 2			Fn Lvl 3	+++
6	Reporting information regarding IAQ	Fn Lvl 1 Fn Lvl 2				

Summary

Based on the survey results for domain 'Controlled ventilation', it can be concluded that most of the available smart services have functionality levels which are still in the nascent stage and there are very few smart services with intermediate or advanced functionality levels. However, considering the fact that there is presence of technology providers and technologies which are likely to be in demand in the future, there may be a potential for further development of these smart services in India. The following list summarizes the most promising smart services under "controlled ventilation" domain based on the assessment done in Europe (Table 9) and market scenario of the smart services in India (Table 12):

1. Smart service 1 – Supply air flow control at the room level
2. Smart service 3 – Heat recovery control: prevention of overheating
3. Smart service 4 – Supply air temperature control at the air handling unit level
4. Smart service 5 – Free cooling with mechanical ventilation system

Out of these services, only functionality level 0 - **"No ventilation system or manual control"** of smart service 1 - **"Supply air flow control at the room level"** and functionality level 3 - **"Variable set point with load dependent compensation"** of smart service 4 - **"Supply air temperature control at the air handling unit level"** are available and established in India, rest of these services would need a push from both regulatory and financing bodies for wider availability and market adoption.

4.4. Smart services under 'lighting' domain

The lighting domain consists of 2 smart services with different functionality levels. A brief explanation of the services is included below:

- ***Smart Service 1**: **Occupancy control for indoor lighting** – This smart service is an artificial lighting control which operates based on the occupancy inside a room or a space.*
- ***Smart Service 2: Control artificial lighting power based on daylight levels** - This smart service controls artificial lighting power based on day light levels such as scene-based light control (during time intervals, dynamic and adapted lighting scenes are set, for example, in terms of illuminance level), different correlated colour temperature (CCT) and the possibility to change the light distribution within the space according to design, human needs, visual tasks.*

The following table indicates the smart services under the domain 'lighting' along with their functionality levels:

Table 13 Smart services and functionality levels for domain 'lighting'

Lighting	Smart service name	Fn Level 0	Fn Level 1	Fn Level 2	Fn Level 3	Fn Level 4
Smart service 1	Occupancy control for indoor lighting	Manual on/off switch	Manual on/off switch + additional sweeping extinction signal	Automatic detection (auto on / dimmed or auto off)	Automatic detection (manual on / dimmed or auto off)	
Smart service 2	Control artificial lighting power based on daylight levels	Manual (central)	Manual (per room / zone)	Automatic switching	Automatic dimming	Automatic dimming including scene-based light control visual tasks)

Like the "cooling" domain, each functionality level of the smart service under "lighting" domain was given an ordinal ranking (---- to ++++) based on the SRI impact criteria with '----' indicating the negative impact and '++++' indicating the highest potential on each category considered for the assessment. The impact assessment of these services is provided in annexure 2 (Table 37).

The potential impact of all the smart services under “lighting” domain were then mapped against the SRI impact criteria.

Table 14 Impact of smart services under “lighting” domain

Highest impact	*Moderate impact*	*Low impact*	*No Impact*

S.No.	Smart service name	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Wellbeing and health	Maintenance & fault prediction	Information to occupants
1	Occupancy control for indoor lighting							
2	Control artificial lighting power based on daylight levels							

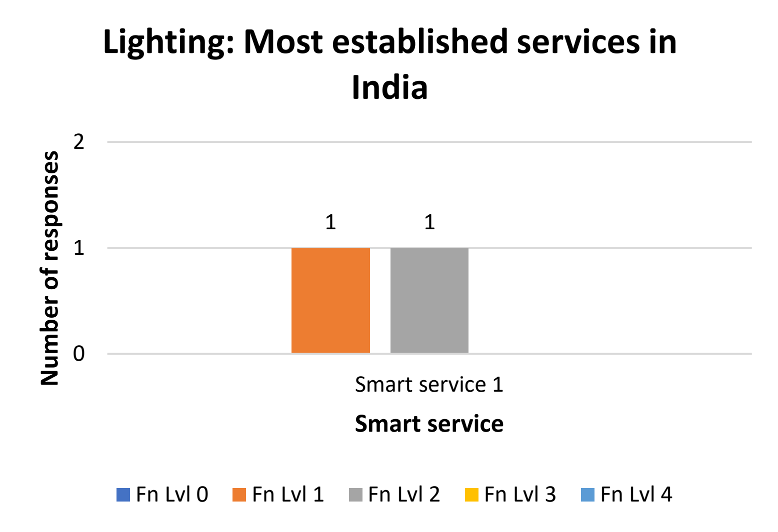
From the above table, it is evident that the following smart services have the highest potential of energy savings:

1. Smart service 1 – Occupancy control for indoor lighting
2. Smart service 2 – Control artificial lighting power based on daylight levels

In addition to ***energy savings***, smart service 2 also has high impact on ***comfort***, ***convenience*** and ***wellbeing and health*** respectively.

Results of the Survey

The following figure lists down the various smart service under ‘lighting’ domain and the industry perception on its establishment, expressed in the functional level they perceive dominant currently for this service. However, it is unlikely that all the buildings in India have the **most established services** as per the figure below as it is based on perception of 02 responses who responded to the survey questionnaire.



Smart service 1 - Occupancy control for indoor lighting

Fn Lvl 1 - Manual on/off switch + additional sweeping extinction signal
Fn Lvl 2 - Automatic (auto on/auto off)

Figure 17 Most established smart services for the lighting domain

'Occupancy control for indoor lighting' is the most established service in India.

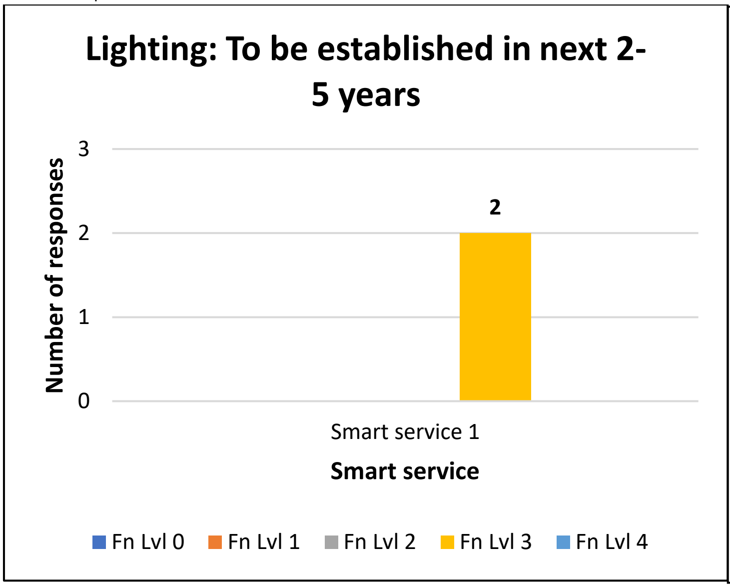
Below are top three factors that are perceived important by the industry for establishment of above smart service. These factors have played a pivotal role in the establishment of these services and will continue to affect the adoption of these services by the consumers.

Table 15 Key drivers for establishment of service

Smart service 1 - Occupancy control for indoor lighting
Consumer awareness about energy efficiency
Less capital cost
Convenience

It is evident that consumer awareness about energy efficiency is a key driver in establishing a smart service along with lower capital cost and convenience.

The following figure lists down the various smart service under 'lighting' domain which are likely to be established in the **next 2-5 years** based on perception of 02 responses who responded to the survey questionnaire.



Smart service 1- **Occupancy control for indoor lighting**

Fn Lvl 3 - Automatic (manual on / dimmed or auto off)

Figure 18 To be established smart services for the lighting domain

Advanced functionality of **'Occupancy control'** is perceived to be established in the next 2-5 years.

Below table indicates the factors which are perceived to be key drivers for establishing of above smart services in the market in the next 2-5 years.

Table 16 Key Drivers for establishment of services in the next 2-5 years

Smart service 1 - Occupancy control for indoor lighting
Consumer awareness about energy efficiency
Less capital cost
Convenience

From the above table, it is evident that consumer awareness about energy efficiency, convenience and less capital costs are key drivers for establishment of services in the next 2-5 years.

The following table summarizes the current market scenario, availability, and market adoption potential for the smart services under 'lighting' domain according to the survey and maps it with their respective energy savings potential as determined by study conducted in Europe.

Table 17 Market scenario of smart services under "lighting" domain

Smart service	**Service name**	**Availability of the smart service**	**Market scenario of smart services**			
			Most established along with EE impact		**Potential to be established in the next 2-5 years along with EE impact**	
1		Fn Lvl 1	Fn Lvl 1	+	Fn Lvl 3	+++

	Occupancy control for indoor lighting	Fn Lvl 2	Fn Lvl 2	++		
2	Control artificial lighting power based on daylight levels					

Summary

Based on the survey results for domain 'Lighting', it can be concluded that only smart service 1 with intermediate functionality levels is available in India. However, considering the fact that there is presence of technology providers and technologies which are likely to be in demand in the future, there may be a potential for further development of these smart services in India. The following list summarizes the most promising smart services under "lighting" domain based on the assessment done in Europe (Table 14) and market scenario of the smart services in India (Table 17):

1. Smart service 1 – Occupancy control for indoor lighting
2. Smart service 2 – Control artificial lighting power based on daylight levels

Out of these services, functionality level 1 – **"Manual on/off switch + additional sweeping extinction signal"** and functionality level 2 - **"Automatic detection (auto on / dimmed or auto off)"** of smart service 1 - **"Occupancy control for indoor lighting"** are available and established in India. The rest of these services would need a push from both regulatory and financing bodies for wider availability and market adoption.

4.5. Smart services under 'electricity' domain

The 'electricity' domain consists of 7 smart services with different functionality levels. A brief explanation of the services is included below:

- ***Smart Service 1: Reporting information regarding local electricity generation-*** *This smart service is used to provide feedback to the owner by reporting the information regarding local electricity generation which includes real time data monitoring, forecasting, and benchmarking using historical data and fault detection.*
- ***Smart Service 2: Storage of (locally generated) electricity -*** *This is a Distributed Energy Resource (DER) such as Battery Energy storage or thermal storage meant for storing locally generated electricity.*
- ***Smart Service 3: Optimizing self-consumption of locally generated electricity -*** *This smart service is used for optimizing the consumption of locally generated electricity based on current renewable energy availability and current and predicted energy needs.*
- ***Smart Service 4: Control of combined heat and power plant (CHP) -*** *Combined Heat and Power (CHP) is the concurrent production of electricity or mechanical power and useful thermal energy from a single source of energy. A flexible CHP system can provide support services to the modern electric grid to keep it stable and secure.*

- ***Smart Service 5: Support of (micro)grid operation modes** - This smart service is used for demand side management designed to manage and optimize a site's energy consumption and reduce costs.*
- ***Smart Service 6: Reporting information regarding energy storage** - This smart service provides information of the energy storage system such as current state of charge (SOC) available, forecasting the demand, predictive maintenance and fault detection.*
- ***Smart Service 7: Reporting information regarding electricity consumption** - This smart service provides information on current electricity consumption, real-time feedback or benchmarking on building and appliance level with automated personalized recommendation.*

The following table indicates the smart services under the domain 'electricity' along with their functionality levels:

Table 18 Smart services and functionality levels for domain 'Electricity'

Electricity	Smart service name	Fn Level 0	Fn Level 1	Fn Level 2	Fn Level 3	Fn Level 4
Smart Service 1	Reporting information regarding local electricity generation	None	Current generation data available	Actual values and historical data	Performance evaluation including forecasting and/or bench-marking	Performance evaluation including forecasting and/or bench-marking; also including predictive management and fault detection
Smart Service 2	Storage of (locally generated) electricity	None	On site storage of electricity (e.g. electric battery)	On site storage of energy (e.g. electric battery or thermal storage) with controller based on grid signals	On site storage of energy (e.g. electric battery or thermal storage) with controller optimising 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

Smart Service 3	Optimizing self-consumption of locally generated electricity	None	Scheduling electricity consumption (plug loads, white goods, etc.)	Automated management of local electricity consumption based on current renewable energy availability	Automated management of local electricity consumption based on current and predicted energy needs and renewable energy availability	
Smart Service 4	Control of combined heat and power plant (CHP)	CHP control based on scheduled ru ntime manag ement and/or current heat energy demand	CHP runtime control influenced by the fluctuating availability of RES; overproduc-tion will be fed into the grid	CHP runtime control influenced by the fluctuating availability of RES and grid signals; dynamic charging and runtime control to optimise self-consumption of renewables		
Smart Service 5	Support of (micro)grid operation modes	None	Automated management of (building-level) electricity consumption based on grid signals	Automated management of (building-level) electricity consumption and electri-city supply to neighbouring buildings (microgrid) or grid	Automated management of (building-level) electricity consumption and supply, with potential to continue limited off-grid operation (island mode)	
Smart Service 6	Reporting information regarding energy storage	None	Current state of charge (SOC) data available	Actual values and historical data	Performance evaluation including forecasting and/or benchmarkin g	Performance evaluation including forecasting and/or benchmarkin g; also including predictive management and fault detection
Smart Service 7	Reporting information regarding electricity consumption	None	reporting on current electricity consumption on building level	real-time feedback or bench-marking on building level	real-time feedback or bench-marking on appliance level	real-time feedback or benchmarkin g on appliance level with automated personalized recommend-dations

Like the "cooling" domain, each functionality level of the smart service under "electricity" domain was given an ordinal ranking (---- to ++++) based on the SRI impact criteria with '----' indicating the negative impact and '++++' indicating the highest potential on each category considered for the assessment. The impact assessment of these services is provided in annexure 2 (Table 38).

The potential impact of all the smart services under "controlled ventilation" domain were then mapped against the SRI impact criteria.

Table 19 Impact of smart services under "electricity" domain

Highest impact	*Moderate impact*	*Low impact*	*No Impact*

S.No.	Smart service name	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Wellbeing and health	Maintenance & fault prediction	Information to occupants
1	Reporting information regarding local electricity generation							
2	Storage of (locally generated) electricity							
3	Optimizing self-consumption of locally generated electricity							
4	Control of combined heat and power plant (CHP)							
5	Support of (micro)grid operation modes							
6	Reporting information regarding energy storage							
7	Reporting information regarding electricity consumption							

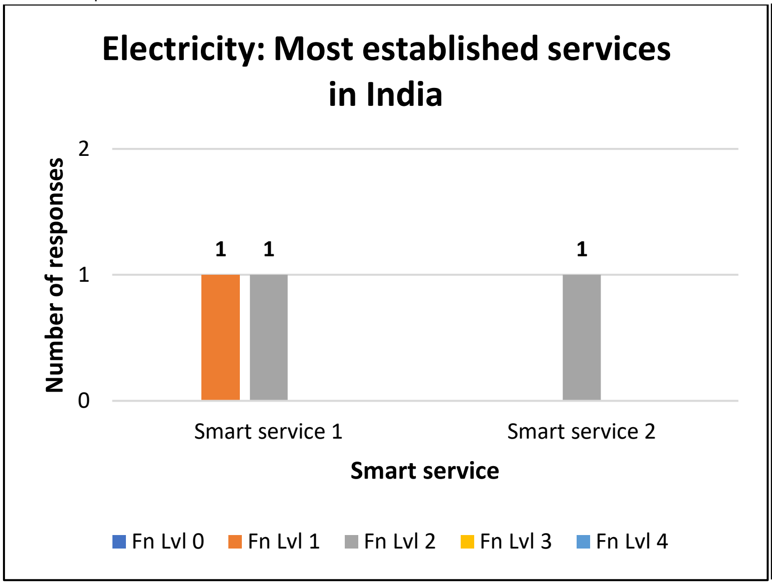
From the above table, it is evident that the following smart service has the highest potential of energy savings:

1. Smart service 7 – Reporting information regarding electricity consumption

In addition to ***energy savings***, smart service 7 also has high impact on ***information to occupants***.

Results of the Survey

The following figure lists down the various smart service under 'electricity' domain and the industry perception on its establishment, expressed in the functional level they perceive dominant currently for this service. However, it is unlikely that all the buildings in India have the most established services as per the figure below as it is based on perception of 03 responses who have responded to the survey questionnaire.



Smart service 1 - Reporting information regarding local electricity generation
Fn Lvl 1 - Current generation data available
Fn Lvl 2 - Actual values and historical data

Smart service 2 - Storage of (locally generated) electricity
Fn Lvl 2 - On site storage of energy (e.g., electric battery or thermal storage) with controller based on grid signals

Figure 19 Most established smart services for the electricity domain

Based on the survey responses received, **'Reporting information regarding local electricity generation'** and **'Storage of (locally generated) electricity'** are the most established services in India.

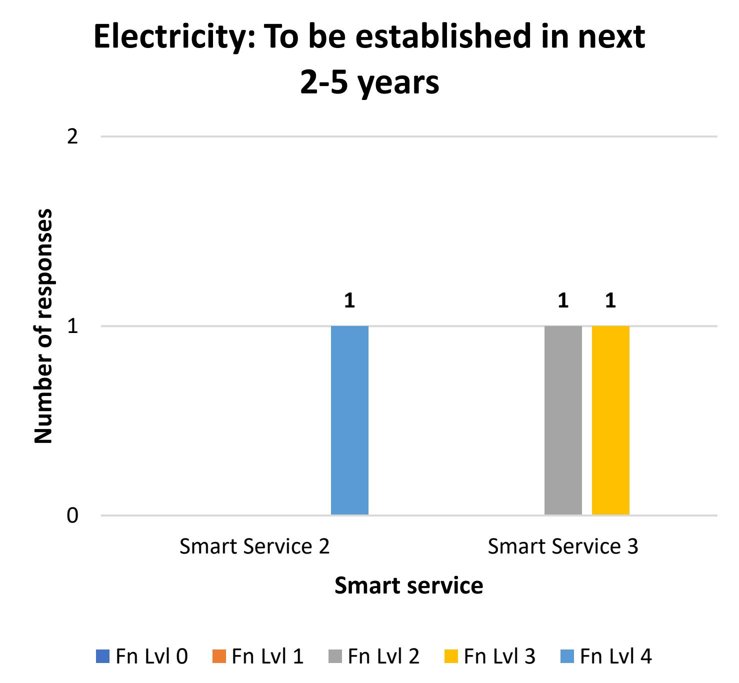
For each established smart service, there may be several factors that would be responsible for its establishment in the market. Below are top three factors that are perceived important by the industry for establishment of above smart services. These factors have played a pivotal role in the establishment of these services and will continue to affect the adoption of these services by the consumers.

Table 20 Top 3 factors perceived to be drivers for establishment of services

Smart service 1 - Reporting information regarding local electricity generation	**Smart service 2 - Storage of (locally generated) electricity**
Less capital cost	Convenience
Less maintenance	Availability
Convenience	No need of additional infrastructure

It is evident that convenience is a key driver in establishing a smart service along with less capital cost and maintenance.

The below figure lists the functionality levels of various smart services under 'electricity' domain which are likely to be established in the **next 2-5 years** based on industry perception. However, it is based on perception of 03 responses who responded to the survey questionnaire.



Smart Service 3 - Optimizing self-consumption of locally generated electricity
Fn Lvl 2 - Automated management of local electricity consumption based on current renewable energy availability
Fn Lvl 3 - Automated management of local electricity consumption based on current and predicted energy needs and renewable energy availability

Smart Service 2 - Storage of (locally generated) electricity
Fn Lvl 4 - 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

Figure 20 To be established smart services for the electricity domain

Based on the survey responses received, **'Optimizing self-consumption of locally generated electricity**' and **'Storage of (locally generated) electricity'** are likely to be the most established services in India in next 2-5 years. These services are described briefly below:

For each established smart service, there may be several factors that would be responsible for its establishment in the market. Below are top three factors that are perceived important by the industry for establishment of above smart services. These factors have played a pivotal role in the establishment of these services and will continue to affect the adoption of these services by the consumers.

Table 21 Key Drivers for establishment of services in the next 2-5 years

Smart service 3 - Optimizing self-consumption of locally generated electricity	**Smart service 2 – Storage of (locally generated) electricity**
Consumer awareness about energy efficiency	Less capital cost
Less capital cost	Less maintenance of system
Convenience	Availability

From the above table, it is evident that consumer awareness about energy efficiency, convenience and less capital costs are key drivers for establishment of services in the next 2-5 years.

The following table summarizes the current market scenario, availability, and market adoption potential for the smart services under 'electricity' domain according to the survey and maps it with their respective energy savings potential as determined by study conducted in Europe.

Table 22 Market scenario of smart services under "electricity" domain

Smart service	Service name	Availability of the smart service	Market scenario of Smart Services			
			Most established along with EE impact		Potential to be established in the next 2-5 years along with EE impact	
1	Reporting information regarding local electricity generation	Fn Lvl 1	Fn Lvl 1			
		Fn Lvl 2	Fn Lvl 2			
2	Storage of (locally generated) electricity	Fn Lvl 2				
		Fn Lvl 3	Fn Lvl 2		Fn Lvl 4	0
		Fn Lvl 4				
3	Optimizing self-consumption of locally generated electricity				Fn Lvl 2	0
					Fn Lvl 3	0
4	Control of combined heat and power plant (CHP)					
5	Support of (micro)grid operation modes	Fn Lvl 2				
		Fn Lvl 3				
6	Reporting information regarding energy storage	Fn Lvl 3				
7	Reporting information regarding electricity consumption	Fn Lvl 1				
		Fn Lvl 2				
		Fn Lvl 4				

Summary

Based on the survey results for domain 'Electricity', it can be concluded that most of the available smart services have functionality levels which are still in the nascent stage and there are very few smart services with intermediate or advanced functionality levels. However, considering the fact that there is presence of technology providers and technologies which are likely to be in demand in the future, there may be a potential for further development of these smart services in India. The following list summarizes the most promising smart services under "electricity" domain based on the assessment done in Europe (Table 19) and market scenario of the smart services in India (Table 22):

1. Smart service 2 - Storage of (locally generated) electricity
2. Smart service 3 - Optimizing self-consumption of locally generated electricity
3. Smart service 7 - Reporting information regarding electricity consumption

Out of these services, only functionality level 2 - **"On site storage of energy (e.g. electric battery or thermal storage) with controller based on grid signals"** of smart service 2 - **"Storage of (locally generated) electricity"** is available and established in India. The rest of these services would need a push from both regulatory and financing bodies for wider availability and market adoption.

4.6. Smart services under ‘electric vehicle charging’ domain

The ‘electric vehicle charging’ domain consists of 3 smart services with different functionality levels. A brief explanation of the services is included below:

- ***Smart service 1: EV Charging Capacity** - This smart service points to the number of EV charging points provided in a residential / commercial building, with the intent to facilitate usage of electric vehicles, which are cleaner modes of commute.*
- ***Smart service 2: EV Charging Grid balancing** - Grid balancing ensures that the energy supply meets the volume of energy demanded. This smart service optimizes energy utilization and achieves grid balancing using EV charging.*
- ***Smart service 3: EV charging information and connectivity** - This smart service focuses on sharing the EV charging status with the user via an IoT platform. This allows for a greater control and customisation for the user.*

The following table indicates the smart services under the domain ‘electric vehicle charging’ along with their functionality levels:

Table 23 Smart services and functionality levels for domain ‘electric vehicle charging’

Electric vehicle charging	Smart service name	Fn Level 0	Fn Level 1	Fn Level 2	Fn Level 3	Fn Level 4
Smart service 1	EV charging capacity	not present	ducting (or simple power plug) available	0-9% of parking spaces has recharging points	10-50% or parking spaces has recharging point	>50% of parking spaces has recharging point
Smart service 2	EV charging grid balancing	Not present (uncontrolled charging)	1-way controlled charging (e.g. including desired departure time and grid signals for optimization)	2-way controlled charging (e.g. including desired departure time and grid signals for optimization)		
Smart service 3	EV charging information and connectivity	No information available	Reporting information on EV charging status to occupant	Reporting information on EV charging status to occupant and automatic identification and authorization of the driver to the charging station (ISO		

				15118 compliant)		

Like the "cooling" domain, each functionality level of the smart service under "EV charging" domain was given an ordinal ranking (---- to ++++) based on the SRI impact criteria with '----' indicating the negative impact and '++++' indicating the highest potential on each category considered for the assessment. The impact assessment of these services is provided in annexure 2 (Table 39).

The potential impact of all the smart services under "monitoring & control" domain were then mapped against the SRI impact criteria.

Table 24 Impact of smart services under "electric vehicle charging" domain

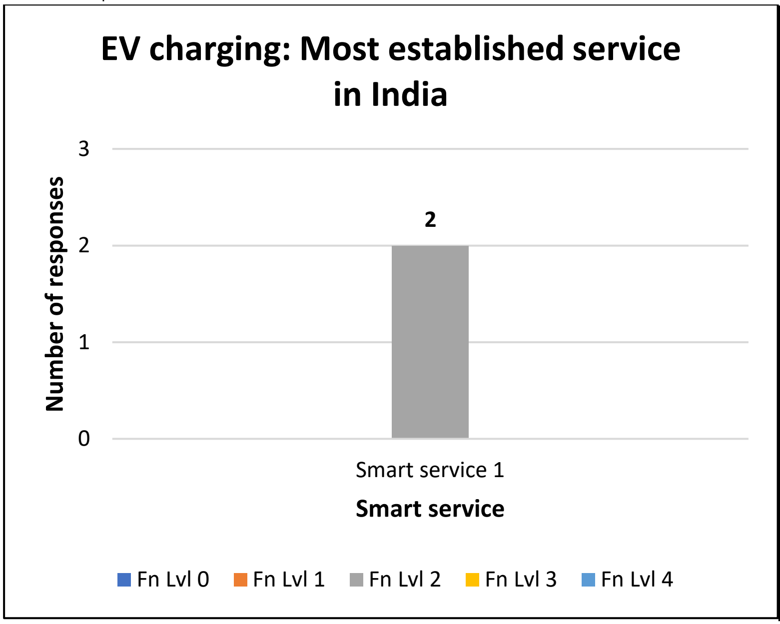
Highest impact	*Moderate impact*	*Low impact*	*No Impact*

S.No.	Smart service name	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Wellbeing and health	Maintenance & fault prediction	Information to occupants
1	EV charging capacity							
2	EV charging grid balancing							
3	EV charging information and connectivity							

From the above table, none of the smart services have energy savings potential.

Results of the Survey

The following figure lists down the various smart service under 'EV charging' domain and the industry perception on its establishment, expressed in the functional level they perceive dominant currently for this service. However, it is unlikely that all the buildings in India have the most established services as per the figure below as it is based on perception of 02 responses who have responded to the survey questionnaire.



Smart service 1 - EV Charging Capacity
Fn Lvl 2 - 0-9% of parking spaces have charging points

Figure 21 Most established smart services for the electric vehicle charging domain

As per the market response it is perceived that **'EV charging capacity'** is the most established service in India.

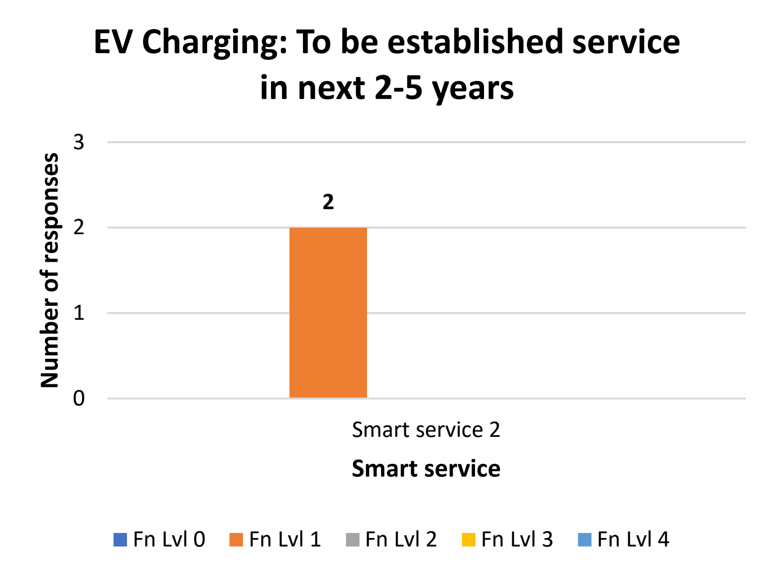
For each established smart service, there may be several factors that would be responsible for its establishment in the market. Below are top three factors that are perceived important by the industry for establishment of above Smart services. These factors have played a pivotal role in the establishment of these services and will continue to affect the adoption of these services by the consumers.

Table 25 Top 3 factors perceived to be drivers for establishment of services

Smart service 1 - EV charging capacity
Consumer awareness about energy efficiency
Convenience
No need for additional infrastructure

It is evident that consumer awareness about energy efficiency is a key driver in establishing a smart service along with convenience and no need for additional infrastructure.

The following figure lists down the various smart service under 'EV charging' domain which are likely to be established in the **next 2-5 years** based on industry perception. However, it is based on perception of 02 responses who responded to the survey questionnaire.



SMART SERVICE 2- EV Charging Grid balancing
Fn Lvl 1 - 1-way controlled charging (e.g., including desired departure time and grid signals for optimization)

Figure 22 To be established Smart services for the electric vehicle charging domain

'EV Charging Grid balancing' is a Smart service perceived to be established in the next 2-5 years.

The key drivers that are perceived to be important for establishment of these services in the next 2-5 years are as below:

Table 26 Key Drivers for establishment of services in the next 2-5 years

Smart service 2- EV charging grid balancing
Consumer awareness about energy efficiency
Convenience
Less maintenance of system

From the above table, it is evident that consumer awareness about energy efficiency, less maintenance and convenience are key drivers for establishment of services in the next 2-5 years.

The following table summarizes the current market scenario and market adoption potential for the smart services under 'EV charging' domain according to the survey and maps it with their respective energy savings potential as determined by study conducted in Europe.

Table 27 Market scenario of smart services under "EV charging" domain

Smart service	**Service name**	**Availability of the smart service**	**Market scenario of smart services**			
			Most established along with EE impact		**Potential to be established in the next 2-5 years along with EE impact**	
1	EV charging capacity	Fn Lvl 2	Fn Lvl 2	0		

2	EV charging grid balancing				Fn Lvl 1	0
3	EV charging information and connectivity					

Summary

Based on the survey results for domain 'Electric vehicle charging', it can be concluded that only smart service 1 with intermediate functionality level is available in India. However, considering the fact that there is presence of technology providers and technologies which are likely to be in demand in the future, there may be a potential for further development of these smart services in India. The following list summarizes the most promising smart services under "EV charging" domain based on the assessment done in Europe (Table 24) and market scenario of the smart services in India (Table 27):

1. Smart service 2 – EV charging grid balancing

The above service is not yet available in India and would need a push from both regulatory and financing bodies for wider availability and market adoption.

4.7. Smart Services under 'monitoring & control' Domain

The 'monitoring & control' domain consists of 8 Smart services with different functionality levels. A brief explanation of the services is included below:

- ***Smart service 1: Run time management of HVAC systems** - This Smart service is used to control the run time of HVAC systems for better regulation of temperature and removal of humidity.*
- ***Smart service 2: Detecting faults of technical building systems and providing support to the diagnosis of these faults** - Fault detection and diagnosis is an important part of the building services and hence, smart systems like these prevent a major catastrophe while prolonging the life of the buildings*
- ***Smart service 3: Occupancy detection: connected services** - This Smart service falls under TBS interaction control which is used to detect occupancy inside a room.*
- ***Smart service 4: Central reporting of TBS performance and energy use** - This Smart service is used to provide feedback to the user by reporting the performance and energy use of different technical components used in Technical Building System (TBS).*
- ***Smart service 5: Smart Grid Integration** - This Smart service makes two-way communication possible between grid and smart buildings, thereby saving energy*
- ***Smart service 6: Reporting information regarding demand side management performance and operation** - Demand Side Management (DSM) refers to a group of actions designed to manage and optimize a site's energy consumption and cut costs. This Smart service provides information on current DSM status and predicts the status of DSM like energy flows.*

- ***Smart service 7: Override of DSM control*** *- Reduces peak demand and consumption costs and enhances equipment operational efficiency with a smart and secure energy switching solution.*
- ***Smart service 8: Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather and grid signals*** *- This Smart service provides a single platform to control & coordinate all the technical components of Technical Building System (TBS) such as heating, cooling, ventilation, hot water, and lighting.*

The following table indicates the Smart services under the domain 'monitoring & control' along with their functionality levels:

Table 28 Smart services and functionality levels for domain 'monitoring & control'

Monitoring & control	**Smart service name**	**Fn Level 0**	**Fn Level 1**	**Fn Level 2**	**Fn Level 3**	**Fn Level 4**
Smart service 1	Run time management of HVAC systems	Manual setting	Runtime setting of heating and cooling plants following a predefined time schedule	Heating and cooling plant on/off control base d on building loads	Heating and cooling plant on/off control based on predictive control or grid signals	
Smart service 2	Detecting faults of technical building systems and providing support to the diagnosis of these faults	No central indication of detected faults and alarms	With central indication of detected faults and alarms for at least 2 relevant TBS	With central indication of detected faults and alarms for all relevant TBS	With central indication of detected faults and alarms for all relevant TBS, including dia gnosing functions	
Smart service 3	Occupancy detection: connected services	None	Occupancy detection for individual functions, e.g. lighting	Centralised occupant det ection which feeds in to several TBS such as lighting and heating		
Smart service 4	Central reporting of TBS performance and energy use	None	Central or remote reporting of realtime energy use per energy carrier	Central or remote reporting of realtime energy use per energy carrier, combining TBS of at least 2 domains in one interface	Central or remote reporting of realtime energy use per energy carrier, combining TBS of all main domains in one interface	

Smart service 5	Smart Grid Integration	None - No harmonization between grid and TBS; building is operated independently from the grid load	Demand side management possible for (some) individual TBS, but not coordinated over various domains	Coordinated demand side management of multiple TBS		
Smart service 6	Reporting information regarding demand side management performance and operation	None	Reporting information on current DSM status, including managed energy flows	Reporting information on current historical and predicted DSM status, including managed energy flows		
Smart service 7	Override of DSM control	No DSM control	DSM control without the possibility to override this control by the building user (occupant or facility manager)	Manual override and reactivation of DSM control by the building user	Scheduled override of DSM control (and reactivation) by the building user	Scheduled override of DSM control and reactivation with optimised control
Smart service 8	Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather and grid signals	None	Single platform that allows manual control 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	

Like the "cooling" domain, each functionality level of the smart service under "monitoring & control" domain was given an ordinal ranking (---- to ++++) based on the SRI impact criteria with '----' indicating the negative impact and '++++' indicating the highest potential on each category considered for the assessment. The impact assessment of these services is provided in annexure 2 (Table 40).

The potential impact of all the smart services under "monitoring & control" domain were then mapped against the SRI impact criteria.

Table 29 Impact of smart services under "monitoring & control" domain

Highest impact	*Moderate impact*	*Low impact*	*No Impact*

S.No.	Smart service name	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Wellbeing and health	Maintenance & fault prediction	Information to occupants
1	Run time management of HVAC systems							
2	Detecting faults of technical building systems and providing support to the diagnosis of these faults							
3	Occupancy detection: connected services							
4	Central reporting of TBS performance and energy use							
5	Smart Grid Integration							
6	Reporting information regarding demand side management performance and operation							
7	Override of DSM control							
8	Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather and grid signals							

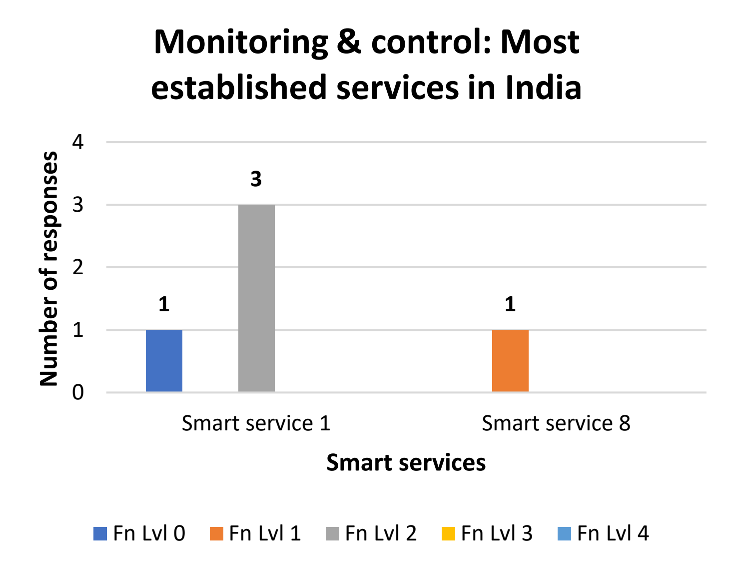
From the above table, it is evident that the following smart service has the highest potential of energy savings:

1. Smart service 1 – Run time management of HVAC systems

In addition to ***energy savings***, smart service 1 also has high impact on ***convenience***.

Results of the Survey

The following figure lists down the various smart service under 'monitoring & control' domain and the industry perception on its establishment, expressed in the functional level they perceive dominant currently for this service. However, it is unlikely that all the buildings in India have the most established services as per the figure below as it is based on perception of 05 responses who have responded to the survey questionnaire.



SMART SERVICE 1 - Run time management of HVAC systems
Fn Lvl 2 - Heating and cooling plant on/off control based on building loads sequencing
Fn Lvl 0 - Manual Setting

SMART SERVICE 8 - Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather, and grid signals
Fn Lvl 1 - Single platform that allows manual control of multiple TBS

Figure 23 Most established Smart services for the Monitoring & Control domain

Based on the survey responses received, **'Run time management of HVAC systems'** is perceived to be the most established service in under the Monitoring & Control domain, which is followed by **'Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather, and grid signals'** service.

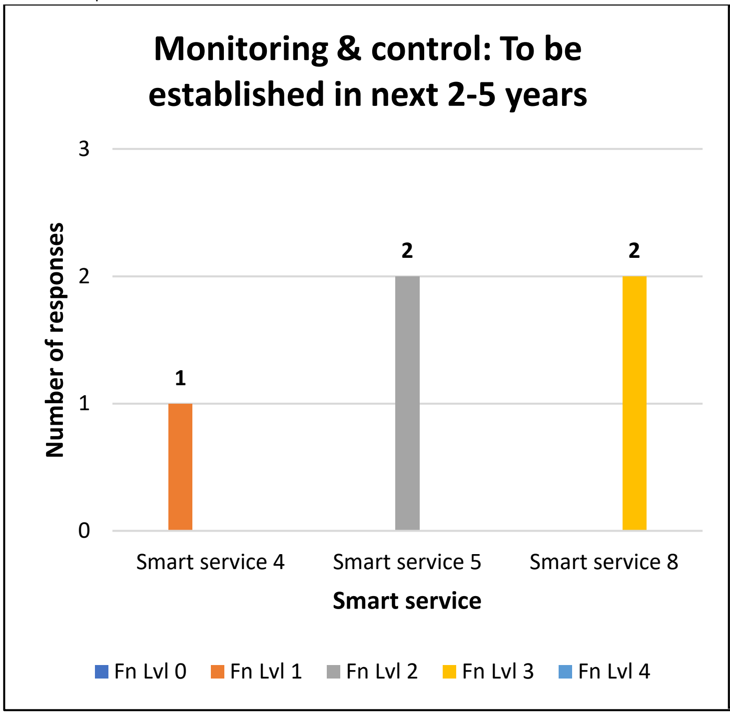
For each established smart service, there may be several factors that would be responsible for its establishment in the market. Below are top three factors that are perceived important by the industry for establishment of above smart services. These factors have played a pivotal role in the establishment of these services and will continue to affect the adoption of these services by the consumers.

Table 30 Top 3 factors perceived to be drivers for establishment of services

Smart service 1 - Run time management of HVAC systems	Smart service 8 - Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather, and grid signals
Less capital cost	Consumer awareness about energy efficiency
Less maintenance	Less maintenance
Consumer awareness about Energy Efficiency	Convenience

It is evident that consumer awareness about energy efficiency is a key driver in establishing a smart service along with less maintenance and lower capital cost.

The following smart services under 'monitoring & control' domain which are likely to be established in the **next 2-5 years** based on industry perception. However, it is based on perception of 05 responses who responded to the survey questionnaire.



Smart service 8 - Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather, and grid signals
Fn Lvl 3 - Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather, and grid signals

Smart service 5 – Smart Grid Integration
Fn Lvl 2 - Coordinated demand side management of multiple TBS

Smart service 4 – Central reporting of TBS performance and energy use
Fn Lvl 1 – Central or remote reporting of real-time energy use per energy carrier

Figure 24 To be established Smart services for the monitoring & control domain

As per the responses received in the survey, **'Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather and grid signals'** is likely to be the most established service in India in next 2-5 years, which is followed by **'Smart Grid Integration'** and '**Central reporting of TBS performance and energy use'**.

Below table indicates the factors which are perceived to be key drivers for establishing of above smart services in the market in the next 2-5 years.

Table 31 Key Drivers for establishment of services in the next 2-5 years

Smart service 8 - Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather, and grid signals	**Smart service 5 – Smart Grid Integration**	**Smart service 4 – Central reporting of TBS performance and energy use**
Consumer Awareness about Energy Efficiency	Less Maintenance of system	Less Capital Cost
Less Capital Cost	Consumer Awareness about Energy Efficiency	Availability
Less Maintenance	Less Capital Cost	No Need for Additional Infrastructure

From the above table, it is evident that consumer awareness about energy efficiency, less maintenance and less capital cost are key drivers for establishment of services in the next 2-5 years.

The following table summarizes the current market scenario, availability, and market adoption potential for the smart services under 'monitoring & control' domain according to the survey and maps it with their respective energy savings potential as determined by study conducted in Europe.

Table 32 Market scenario of smart services under "Monitoring & control" domain

Smart service	**Service name**	**Availability of the smart service**	**Market scenario of smart services**			
			Most established along with EE impact		**Potential to be established in the next 2-5 years along with EE impact**	
1	Run time management of HVAC systems	Fn Lvl 0 Fn Lvl 2 Fn Lvl 3	Fn Lvl 0 Fn Lvl 2			
2	Detecting faults of technical building systems and providing support to the diagnosis of these faults	Fn Lvl 2 Fn Lvl 4				
3	Occupancy detection: connected services	Fn Lvl 2				
4	Central reporting of TBS performance and energy use					
5	Smart Grid Integration	Fn Lvl 1			Fn Lvl 2	+
6	Reporting information regarding demand side management performance and operation	Fn Lvl 2				
7	Override of DSM control					
8	Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather and grid signals	Fn Lvl 1 Fn Lvl 2	Fn Lvl 1		Fn Lvl 3	++

Summary

Based on the survey results for domain 'Monitoring & control', it can be concluded that most of the available smart services have functionality levels which are still in the nascent stage and there are very few smart services with intermediate or advanced functionality levels. However, considering the fact that there is presence of technology providers and technologies which are likely to be in demand in the future, there may be a potential for further development of these smart services in India. The following list summarizes the most promising smart services under "monitoring & control" domain based on the assessment done in Europe (Table 29) and market scenario of the smart services in India (Table 32):

1. Smart service 1 – Run time management of HVAC systems
2. Smart service 5 – Smart grid integration
3. Smart service 8 – Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather and grid signals

Out of these services, functionality level 0 - **"Manual setting"** and functionality level 2 - **"Heating and cooling plant on/off control based on building loads"** of smart service 1 - **"Run time management of HVAC systems"** and functionality level 1 - **"Single platform that allows manual control of multiple TBS"** of smart service 8 - **"Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather and grid signals"** are available and established in India, rest of these services would need a push from both regulatory and financing bodies for wider availability and market adoption.

4.8. Smart services under 'heating' domain

The heating domain consists of 10 smart services with different functionality levels.

- ***Smart Service 1: Heat emission control***
- ***Smart Service 2: Emission control for TABS (heating mode)***
- ***Smart Service 3: Control of distribution fluid temperature (supply or return air flow or water flow)***
- ***Smart Service 4: Control of distribution pumps in networks***
- ***Smart Service 5: Thermal Energy Storage (TES) for building heating (excluding TABS)***
- ***Smart Service 6: Heat generator control (all except heat pumps)***
- ***Smart Service 7: Heat generator control (for heat pumps)***
- ***Smart Service 8: Sequencing in case of different heat generators***
- ***Smart Service 9: Report information regarding HEATING system performance***
- ***Smart Service 10:*** **Flexibility & Grid Integration**

Note: For the heating domain, no results are displayed as there were no entries received from the respondents. This is predominantly due to non-availability of any services (as per respondents) for this domain considering majority of India is tropical climate where heating is least required as well as there is no demand for heating services or smart control thereof.

4.9. Smart services under 'domestic hot water' domain

The 'domestic hot water' domain consists of 5 smart services with different functionality levels.

- ***Smart Service 1: Control of DHW storage charging (with direct electric heating or integrated electric heat pump)***
- ***Smart Service 2: Control of DHW storage charging (using hot water generation)***
- ***Smart Service 3: Control of DHW storage charging (with solar collector and supplementary heat generation)***
- ***Smart Service 4: Sequencing in case of different DHW generators***

- ***Smart Service 5: Report information regarding domestic hot water performance***

Note: For the domestic hot water domain, no results are displayed as there were no entries received from the respondents.

4.10. Smart services under ‘dynamic building envelope’ domain

The ‘dynamic building envelope’ domain consists of 3 smart services with different functionality levels.

- ***Smart Service 1: Window solar shading control***
- ***Smart Service 2: Window open/closed control, combined with HVAC system***
- ***Smart Service 3: Reporting information regarding performance of dynamic building envelope systems***

Note: For the dynamic building envelope domain, no results are displayed as there were no entries. This is predominantly due to non-availability of any services for this domain considering that this domain has not developed in the Indian market. Several steps need to be taken to establish services under this domain.

4.11. Summary

The results of the survey indicates that there is significant availability of smart services across cooling, controlled ventilation, lighting, electricity, electric vehicle charging and monitoring & control domains, most of which are still at nascent stage in terms of functionality levels. There are few smart services which have high energy savings potential as per the EU methodology are also available in India. The most common drivers for the establishment of these smart services across all technology domains are:

1. Consumer awareness about energy efficiency
2. Less capital cost
3. Less maintenance

As no responses were received for the domains - “heating”, “domestic hot water” and “dynamic building envelope”, the smart services for these technologies maybe not be available in India yet and several steps need to be taken for the establishment in Indian market.

Technology domains with availability of smart services in India	Technology domains with non availability of smart services in India
• Cooling • Controlled ventilation • Lighting • Electricity • EV charging • Monitoring & control	• Heating • Domestic hot water • Dynamic building envelope

Figure 25 Technology wise availability of smart services as per survey results

A mapping of smart services with highest energy savings potential under each technology domain and its availability in India is given in Table 34.

5. Policy framework and its integration with SRI

5.1. Introduction

This chapter aims at assessing the relevant policies/ codes and rating systems in India, and their impact on the uptake of smart technologies. In addition to the above, other initiatives by the Government of India have been looked into to assess the possibility of integration of smart technologies and the possible link with the establishment of SRI in India.

5.2. Indian policy framework

India has set a target to reduce the energy intensity by 33-35% by 2030 and energy efficiency will play a significant role in meeting India's objectives. India's energy intensity (at 2011-12 prices) decreased from 0.274 Mega Joules per rupee in 2011-12 to 0.233 Mega Joules in 2017-18[10]. This decline can be explained by the energy efficiency programs and policies developed and implemented by national bodies such as the Bureau of Energy Efficiency (BEE), Energy Efficiency Services Limited (EESL) and their state-level counterparts, as well as the growing share of the services sector in the Indian economy.

As for the smart technologies, various strategies have been instrumental in the rollout of smart technologies as it can deliver substantial reductions in energy consumption. Smart technologies are increasingly becoming a part of Green Building rating systems as showcased in Table 33. Smart systems and technologies allow for greater monitoring and control of various systems related to lighting, HVAC and other parameters in a building, which is based on occupancy patterns and building's usage. The following table outlines the requirements of smart technologies with accepted Green Building rating systems & codes in India.

Table 33 Summary of code/rating systems which integrates smart technologies in buildings

S.No.	Code/Rating System	Integration of smart technologies in requirements
1.	Energy Conservation Building Code 2017	ECBC Compliance for air conditioning systems • Time clock control for automatic start and stop of system • Temperature controls, occupancy controls • Fan controls for cooling tower • ECBC + and Super ECBC Compliance for air conditioning systems • Centralized demand shed control • VAV fan control • ECBC Compliance for lighting systems • Control in daylight • ECBC+ and Super ECBC Compliance for lighting systems • Centralized control system for schedule based automatic lighting shutoff switches

[10] https://www.beeindia.gov.in/sites/default/files/12%282%29_0.pdf

2.	Indian Green Building Council - IGBC	Requirements are based on ECBC (or) ASHRAE Standard 90.1-2010
3.	GRIHA – Green Rating for Integrated Habitat Assessment	Requirements are based on ECBC 2017
4.	USGBC's Leadership in Energy and Environmental Design (LEED)	ASHRAE 90.1 – 2017 (Appendix G) is mandatory for compliance and it includes the following: • CO_2 monitoring system that provides data on ventilation systems of spaces which is used for control of HVAC systems. • Use of variable speed drives in AHU's. • Demand controlled ventilation and energy recovery strategies. • Mandatory auto shutoff (occupancy sensor, timer or BAS) in all spaces. • Bi level zone switching or dimming for better use of daylight. • Occupancy sensors in car parking for CO monitoring and control of exhaust fans. • Control of plug loads in commercial spaces and classrooms by up to 50%. • Additional requirements for submetering. • Encouraged to digitally capture data for energy, water, tVOC and CO_2.
5.	EDGE	EDGE - Natural ventilation for guest room equipped with auto controls for HVAC and lighting (hotels)
6.	GEM Sustainability (Green) program	Refers clauses of ECBC 2017 for commercial buildings

In 2018, the BEE formulated the Strategic Plan for Energy Efficiency in India, titled UNlocking NATional Energy Efficiency Potential (UNNATEE). Based on a BAU scenario, the plan estimated a total energy efficiency potential of 94 MTOE by 2031, from different demand sectors including buildings, domestic, industries, municipal, transport, agriculture, etc. This energy efficiency potential would be equivalent to a market size of over INR 9.7 lakh crores by 2031.[11]

Buildings (commercial and residential) present as high as one-third of India's electricity demand. In the backdrop of increasing urbanization and increased emphasis in cooling demand, the share is expected to rise higher in coming years.

Some of the main policies and programs under Buildings are highlighted below:

- **New commercial buildings: Energy Conservation Building Codes (ECBC):** Adoption of ECBC 2017 for new commercial building construction is estimated to save about 300 bn units of electricity and peak demand reduction of over 15 GW annually. This is further complemented by a star labeling program for commercial buildings.

[11] UNLOCKING NATIONAL ENERGY EFFICIENCY POTENTIAL (UNNATEE) https://beeindia.gov.in/sites/default/files/press_releases/UNNATEE%20Report.pdf

- **Residential buildings**: Notification of the residential labeling program is a big step forward, which is expected to save over 388 bn units of electricity by 2030. This is supported by enabler programs such as **Eco Niwas Samhita**[12]**.**
- **Existing buildings:** EESL is implementing the Buildings Energy Efficiency Program (**BEEP**[13]) as a retrofit solution for buildings of the government, industry, and institutions to implement and retrofit energy efficient appliances and systems including LED lights, ceiling fans, energy efficient AC's at affordable prices. More than 10,000 buildings are already covered under the program by EESL.
- **Smart City Mission**[14] is an urban renewal and retrofitting program to develop smart cities across the country, making them citizen friendly and sustainable.

The Government of India has launched measures to augment capacity of grids to anticipate and control energy demand through digital, remotely controlled technologies and to increase penetration of renewable energy sources in power generation by installing 450 GW capacity by 2030[15]. At some point in future, this generation of building energy efficiency policies, renewable energy and, smart supply and transmission infrastructure (beginning to be built) will have to be seamlessly integrated for attaining maximum energy use optimization in building sector. Essentially building energy efficiency polices will have to mandate buildings and building technologies to be designed for participation in a dynamic energy supply and management framework.

5.3. Conclusion

Relevant policies/ codes and rating systems in India like ECBC 2017 and various Green Building certification systems are prevalent in India, but do not explicitly mention the requirements of smart building technologies. Currently, most of the policies aimed towards achieving energy efficiency for new and existing buildings' stock are in transition phase, i.e., predominantly in adoption phase. The SRI framework could provide a roadmap for use of advanced technologies to be explored, which would aid in adoption of existing building policies.

SRI framework also fits very well into India's Smart Cities Mission initiative and the net-zero transition framework which is being developed. As indicated in the survey, the use of technology for evidence-based reporting and monitoring is very much evident, as energy efficiency is achieved by use of these advanced systems. Development of SRI framework will provide a market push for uptake of smart building technologies, which could be a driver for achieving required performance in buildings and will also be beneficial for India in achieving its policy targets.

[12] Energy Conservation – New Indian Way for Affordable & Sustainable homes: https://www.econiwas.com/
[13] https://eeslindia.org/en/building-energy/
[14] https://mohua.gov.in/cms/smart-cities.php
[15] Ministry of New and Renewable Energy| https://mnre.gov.in/

6. The demand for SRI in India

This chapter assesses the possible demand for the use of smart technologies in India from the business case perspective. It assesses the need of a SRI framework from the perception of relevant industry leading technology providers, from building developers and consumers.

6.1. Technology provider perspective

The survey results indicate that at present there is already a significant uptake of some smart technologies by frontrunners in the Indian building sector. The following table summarises the smart services under each domain which have the most impact potential with respect to energy savings based on the study conducted by the EU and services which are available in India as per the survey conducted. The summary indicates that most of the services which have the most energy efficiency savings potential are present in the Indian market.

Table 34 Smart services across each domain as per highest energy savings potential and market scenario in India

Highest impact	*Moderate impact*	*Low impact*	*No Impact*

Smart service	**Smart service name**	**Availability of the service**	**Impact on energy savings potential**
	Cooling		
Smart service 1	Cooling emission control	✓	
Smart service 2	Emission control for TABS (cooling mode)		
Smart service 5	Interlock: avoiding simultaneous heating and cooling in the same room	✓	
Smart service 8	Sequencing of different cooling generators		
	Controlled ventilation		
Smart service 1	Supply air flow control at the room level	✓	
Smart service 3	Heat recovery control: prevention of overheating	✓	
Smart service 4	Supply air temperature control at the air handling unit level	✓	
Smart service 5	Free cooling with mechanical ventilation system	✓	
	Lighting		
Smart service 1	Occupancy control for indoor lighting	✓	
Smart service 2	Control artificial lighting power based on daylight levels		

Electricity			
Smart service 2	Storage of (locally generated) electricity	✓	
Smart service 3	Optimizing self-consumption of locally generated electricity		
Smart service 7	Reporting information regarding electricity consumption	✓	
Electric vehicle charging			
Smart service 2	EV charging grid balancing		
Monitoring & control			
Smart service 1	Run time management of HVAC systems	✓	
Smart service 5	Smart grid integration	✓	
Smart service 8	Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather and grid signals	✓	

In addition to the above, technology consultants provided their perspective on the usefulness of SRI, in a stakeholders meeting, which was conducted on 5 May, 2022. Key points of the discussion are mentioned below:

- The SRI framework should look into residential buildings as well as in existing commercial buildings.
- As India is a price sensitive market, the costing from the manufacturers and consumers perspective should be investigated.
- The internal electricity distribution losses should be considered in optimizing the energy use and could also be a part of the SRI catalogue.
- The smartness of microgrid is also an important aspect which needs to be investigated in order to enhance energy efficiency for buildings.
- A regulatory push will be required in adoption of the smart technologies in buildings. Also, there is a need to incentivize the adoption of these technologies from the consumer perspective.

6.2. Building developer perspective

Due to the benefits of smart technologies in buildings, various real estate and facility management companies are adding value to their services by inclusion of smart technologies. Some of the major Indian real estate companies which have invested in smart infrastructure projects are DLF Ltd, Godrej Properties Ltd and SOBHA Ltd. Also, several facility management companies which offer smart technology services for buildings are CBRE Inc. and Updater services.

The market survey did not include building designers or facility managers. At the stakeholders meeting on 5 May 2022 a special discussion took place on the demand for an SRI in India from a building developer perspective, which resulted in the following considerations:

- Demand of smart technologies in commercial buildings would be higher than for residential buildings.
- Smart technologies such as automated blinds and occupancy sensors are in great demand in standalone high-end residential buildings.
- There is a demand for green buildings in India and a SRI framework would act as a catalyst to achieve further energy efficiency in buildings.
- SRI rating for buildings will be beneficial as it will not only determine how smart a building is, but it will also determine convenience, which is often demanded by consumers.
- Rating a building's smartness via the SRI framework would not be a complex affair.
- The SRI catalogue should be modified to suit the Indian context to ensure adoption of the framework.

6.3. Consumer perspective

As mentioned in chapter 6.2, the real estate and facility management companies have been expanding their services by inclusion of smart technologies which indicates a growing interest of these technologies among consumers and investors.

The market survey did not include consumers. At the stakeholders meeting on 5 May 2022 a special discussion took place on the demand for an SRI in India from a consumers and investors perspective, which resulted in the following considerations:

- Consumers are getting adept at using smart technologies to improve operational effectiveness. This in conjunction with awareness about energy savings potential via use of smart technologies will ensure uptake of SRI.
- Commercial consumers will be more inclined to adopt SRI framework as multinational companies (MNCs) and Indian companies have sustainability as one of the mandates to combat climate change.
- Residential consumers will be sceptical to adopt SRI framework due to possible higher upfront capital costs. Therefore, incentives should be provided to consumers by the Government to ensure better adoption of SRI framework.
- Data security and privacy is a major concern for consumers.

6.4. Summary

The survey results indicate that most of the smart services under each domain are either not well established or only have a low or medium functionality level, although for each smart service there is some presence of technology. Nevertheless, a market for smart technologies is available in India, although a push from both regulatory and financing bodies would make the availability wider and encourage further market adoption. The recognition from the government will help the technology providers to understand the requirement and invest more in these technologies which will promote innovation. On the other hand, due to the benefits of these technologies, the building developers will be more aware and encouraged to integrate these smart technologies in the building which will have tangible outcomes for the consumers.

Building developers indicated that a SRI framework would be better suited to commercial and high end residential sectors. There could be possible adoption of SRI framework, as it can complement the green building rating standards and also take care of the ‘convenience’ aspect which is in high demand. However, the SRI framework should not be complex and cost intensive.

Commercial consumers will be more likely to adopt SRI framework due to existing corporate mandates in the field of sustainability and climate change. Higher upfront costs can be deterrent for consumers, especially in the residential sector for adoption of SRI framework. Also, data security and privacy are major concerns of consumers.

7. Conclusions and recommendations

7.1 Main conclusions

This chapter summarises the main conclusions of the different steps followed under this study (see chapter 2), it identifies the challenges and risks of the establishment of an SRI framework in India and it sets out a possible way forward for SRI in India.

Chapter 3 clearly sets out that in theory, as indicated in the study conducted by the EU, there is a high potential for smart services to deliver thermal energy savings along with energy cost savings and CO_2 emissions reductions, together with a lucrative payback. According to the impact assessment results for the EU situations described in chapter 3.2, the total **thermal energy savings** by 2050 is estimated to be between **350 TWh/a and 450 TWh/a**, whereas the **energy cost savings** is estimated to be between **800 and 1,200 Million Euro per year**, depending on the different scenarios. Also, the **payback period** is calculated to be between **2-6 years** and the **CO_2 emissions reduction** until 2050 is estimated to be lower by **70 Mt/a.**

Chapter 4, which sets out for each domain the **penetration of each service** and the available functionality level for each domain in India, indicates that the **market for smart technologies** is indeed available in India, although a further push from both regulatory and financing bodies would make the availability wider and encourage further market adoption, which would further the energy savings potential in buildings. The market at present is mainly limited to the **commercial sector**.

Chapter 5 investigates **policies/codes** and rating systems in India relevant to the integration of SRI framework. Existing polices/ codes do not explicitly mention the requirements of smart building technologies. However, **smart technologies** form an **integral part** of the policies and codes including **India's Smart Cities Mission** initiative and the **net-zero transition** framework which is being developed. The SRI framework could provide a roadmap for use of **advanced technologies** to be explored, which would aid in **adoption** of existing building policies.

Chapter 6 explains the demand for SRI in India from perspective of **manufacturers/technology providers**. Table 34 in chapter 6.1 summarises the market scenario of smart technologies from technology provider perspective with respect to energy savings based on the study conducted by the EU and services which are available in India as per the survey conducted.

During a special discussion held on 5 May, 2022 which included technology providers, building developers and consumers, key issues were discussed which have been summarised in points below:

- Consumers and building developers indicated that SRI framework would complement existing green building rating systems which would further the **smartness quotient** of a building along with **energy savings potential**.
- Stakeholders indicated that **commercial consumers** are more likely to adopt SRI framework than consumers in the residential sector.
- H**igh upfront costs** could act as a deterrent for adoption of SRI framework. Also, **data security and privacy** are major concerns of consumers.
- Smart Readiness Indicators (SRI) framework should be looked for existing buildings as well.

- The SRI catalogue should be **modified** to include technologies relevant to the Indian context.
- A **regulatory push** will be required in adoption of the smart technologies in buildings. Also, there is a need to **incentivize** the adoption of these technologies from the consumer perspective.
- Further round of **discussions** could be planned with relevant stakeholders in order to formulate a way forward for development of the SRI framework in India.

SRI encourages **evidence based reporting** and **monitoring** and it also provides a roadmap for use of **advanced smart technologies** which can be a great catalyst for all the beneficiaries including the **building's owners, technology providers** and the **Government**.

7.2 Possible risks and attention points

Below is a non-exhaustive list of possible risks and attention points related to the development of an SRI-methodology:

1. If the implementation of the SRI is pursued through a legal foundation of the scheme, provisions must be taken to enable future updates.
2. Various types of SRI assessor profiles can be envisaged. Opting for a detailed technical assessment executed by professional experts requires setting up training schemes and potentially accreditation protocols and verification activities.
3. Data security and privacy provisions should be put in place for handling and storing some of the data streams that occur during the assessment process.
4. Alignment with the fast-growing industry of smart technologies and quickly evolving smart services is key for the long-term impact of SRI. This challenge has been recognized by the technical support studies on the SRI in the EU context, leading to a method sufficiently flexible to be updated e.g., by expanding the SRI service catalogues. A process needs to be put in place to steer the evaluation and update activities, which is likely to require a broad range of stakeholders including policy actors, academics and market actors.
5. As the industry of smart technologies is growing rapidly, a balance needs to be found on when services are considered mature enough to be included in the service catalogue.
6. Communication is important and should be adjusted to the target audience aimed for, e.g., facility managers can be addressed in a more technical way than homeowners.
7. Smart readiness is an additional aspect in the strive for a more sustainable built environment and works complementary with other measures like building insulation and inclusion of renewable energy.
8. The SRI methodology for the EU was developed with the intention to use it for a broad range of building types. When limiting the scope while adopting the methodology (e.g., to only larger or more complex buildings), it might require additional studies to perform a data-driven check if adjustments are needed.
9. Adopting the methodology in a specific context might require additional technologies to be considered.

10. Maximal consistency with other schemes investigating the building's sustainability should be strived for as this could limit the work of assessments (on-site).

7.3 Action plan for SRI in India

Taking cues from the studies conducted in the EU, the following activities can be adopted:

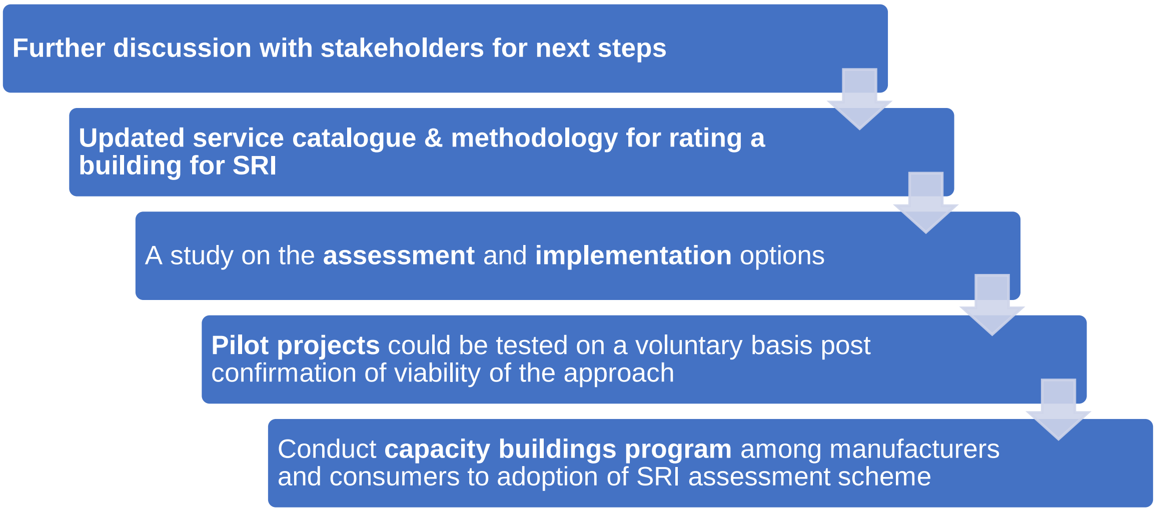


Figure 26 Action plan for SRI in India

Other parallel activities which could be taken up are:

1. Framing policies to promote the smart technologies, for example inclusion in codes and standards for increased awareness and adoption
2. Promotion of smart services through incentivization and running accelerator programs to promote smart technologies while promoting technology transfer to Indian Manufacturers.
3. Inclusion of certain smart technologies directly (if undressed entirely) or indirectly in codes and standards such as ECBC, Eco Niwas Samhita (ENS), Green Certification Ratings.
4. Last but not least, providing financial support for implementation of these smart technologies.

The following activities are suggested with respect to the Smart Readiness Framework:

1. Since the present market survey did not include stakeholders such as building designers and facility managers; the primary step would be to set up surveys or structured interviews involving other stakeholders, especially also including investors, building designers and facility managers. The intent is to investigate prior knowledge on building smartness (and related impacts), and the perceived need for an independent assessment of smart building performance.
2. Impact assessment on the roll-out of an Indian smart building certification system. This impact study will investigate various scenarios, e.g., including various assessment scheme methods, various scopes (new buildings vs

existing buildings / offices vs other typologies / etc.), various implementation methods (expert assessors vs self-assessment / voluntary vs obligatory / etc.)

3. Depending on the outcome of the prior steps, a study could be set up that tests a smart building assessment scheme based on the EU SRI approach, with potential adaptations to the local context in India. The SRI scheme is modular, allowing to alter elements such as weighting factors, services, functionality levels, etc. or even domains and impact categories.
4. Finally, it could be decided whether or not such assessment scheme would be launched at a larger scale. This requires further definition of implementation modalities, e.g., certification of assessors, voluntary or obligatory assessments, software development, etc.

Annexure 1: Smart service catalogue

Table 35 Detailed service catalogue of technologies yet to be penetrated in the Indian market

Domain	Smart Ready Service	Functionality Level 0 (as non-smart deafault)	Functionality Level 1	Functionality Level 2	Functionality Level 3	Functionality Level 4
Heating	Heat emission control	No automatic control	Central automatic control (e.g. central thermostat)	Individual room control (e.g. thermostatic valves, or electronic controller)	Individual room control with communication between controllers and to BACS	Individual room control with communication and occupancy detection
Heating	Emission control for TABS (heating mode)	No automatic control	Central automatic control	Advanced central automatic control	Advanced central automatic control with intermittent operation and/or room temperature feedback control	
Heating	Control of distribution fluid temperature (supply or return air flow or water flow) - Similar function can be applied to the control of direct electric heating networks	No automatic control	Outside temperature compensated control	Demand based control		
Heating	Control of distribution pumps in networks	No automatic control	On off control	Multi-Stage control	Variable speed pump control (pump unit (internal) estimations)	Variable speed pump control (external demand signal)
Heating	Thermal Energy Storage (TES) for building heating (excluding TABS)	Continuous storage operation	Time-scheduled storage operation	Load prediction-based storage operation	Heat storage capable of flexible control through grid signals (e.g. DSM)	
Heating	Heat generator control (all except heat pumps)	Constant temperature control	Variable temperature control depending on outdoor temperature	Variable temperature control depending on the load (e.g. depending on supply water		

This project is funded by the European Union

				temperature set point)		
Heating	Heat generator control (for heat pumps)	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)	Variable control of heat generator capacity depending on the load or demand (e.g. hot gas bypass, inverter frequency control)	Variable control of heat generator capacity depending on the load AND external signals from grid	
Heating	Sequencing in case of different heat generators	Priorities only based on running time	Control according to fixed priority list: e.g. based on rated energy efficiency	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)	Control according to dynamic priority list (based on current AND predicted load, energy efficiency, carbon emissions and capacity of generators)	Control according to dynamic priority list (based on current AND predicted load, energy efficiency, carbon emissions, capacity of generators AND external signals from grid)
Heating	Report information regarding HEATING system performance	None	Central or remote reporting of current performance KPIs (e.g. temperatures, submetering energy usage)	Central or remote reporting of current performance KPIs and historical data	Central or remote reporting of performance evaluation including forecasting and/or benchmarkin g	Central or remote reporting of performance evaluation including forecasting and/or benchmarkin g; also including predictive management and fault detection
Heating	Flexibility and grid interaction	No automatic control	Scheduled operation of heating system	Self-learning optimal control of heating system	Heating system capable of flexible control through grid signals (e.g. DSM)	Optimized control of heating system based on local predictions and grid signals (e.g. through model predictive control)

Domestic Hot Water	Control of DHW storage charging (with direct electric heating or integrated electric heat pump)	Automatic control on / off	Automatic control on / off and scheduled charging enable	Automatic control on / off and scheduled charging enable and multi-sensor storage management	Automatic charging control based on local availability of renewables or information from electricity grid (DR, DSM)	
Domestic Hot Water	Control of DHW storage charging (using hot water generation)	Automatic control on / off	Automatic control on / off and scheduled charging enable	Automatic on/off control, scheduled charging enable and demand-based supply temperature control or multi-sensor storage management	DHW production system capable of automatic charging control based on external signals (e.g. from district heating grid)	
Domestic Hot Water	Control of DHW storage charging (with solar collector and supplementary heat generation)	Manual selected control of solar energy or heat generation	Automatic control of solar storage charge (Prio. 1) and supplemen-tary storage charge	Automatic control of solar storage charge (Prio. 1) and supplementary storage charge and demand-oriented supply or multi-sensor storage management	Automatic control of solar storage charge (Prio. 1) and supplementary storage charge, demand-oriented supply and return temperature control and multi-sensor storage management	
Domestic Hot Water	Sequencing in case of different DHW generators	Priorities only based on running time	Control according to fixed priority list: e.g. based on rated energy efficiency	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)	Control according to dynamic priority list (based on current AND predicted load, energy efficiency, carbon emissions and capacity of generators)	Control according to dynamic priority list (based on current AND predicted load, energy efficiency, carbon emissions, capacity of generators AND external signals from grid)
Domestic Hot Water	Report information regarding domestic hot water performance	None	Indication of actual values (e.g. temperatures, submetering energy usage)	Actual values and historical data	Performance evaluation including forecasting and/or bench-marking	Performance evaluation including forecasting and/or bench-marking; also including

						predictive management and fault detection
Dynamic Building Envelope	Window solar shading control	No sun shading or only manual operation	Motorized operation with manual control	Motorized operation with automatic control based on sensor data	Combined light/blind/HVAC control	Predictive blind control (e.g. based on weather forecast)
Dynamic Building Envelope	Window open/closed control, combined with HVAC system	Manual operation or only fixed windows	Open/closed detection to shut down heating or cooling systems	Level 1 + Automised mechanical window opening based on room sensor data	Level 2 + Centralized coordination of operable windows, e.g. to control free natural night cooling	
Dynamic Building Envelope	Reporting information regarding performance of dynamic building envelope systems	No reporting	Position of each product & fault detection	Position of each product, fault detection & predictive maintenance	Position of each product, fault detection, predictive maintenance, real-time sensor data (wind, lux, temperature …)	Position of each product, fault detection, predictive maintenance, real-time & historical sensor data (wind, lux, temperature …)

Annexure 2: SRI impact assessment on smart services

Table 36 SRI impact assessment of "cooling" domain

Fn Lvl	Fn Lvl Name	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Wellbeing and health	Maintenance & fault prediction	Information to occupants
Smart service 2: Emission control for TABS (cooling mode)								
0	No automatic control	0	0	0	0	0	0	0
1	Central automatic control	+	0	+	+	+	0	0
2	Advanced central automatic control	+	0	+	+	++	0	0
3	Advanced central automatic control with intermittent operation and/or room temperature feedback control	++	0	++	+++	++	+	+
Smart service 3: Control of distribution network chilled water temperature (supply or return)								
0	Constant temperature control	0	0	0	0	0	0	0
1	Outside temperature compensated control	+	0	+	+	0	0	0
2	Demand based control	++	0	+	+	0	0	0
Smart service 4: Control of distribution pumps in networks								

0	No automatic control	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	On off control	**+**	**0**	**0**	**0**	**0**	**0**	**0**
2	Multi-Stage control	**++**	**0**	**0**	**0**	**0**	**0**	**0**
3	Variable speed pump control (pump unit (internal) estimations)	**++**	**0**	**0**	**0**	**0**	**0**	**0**
4	Variable speed pump control (external demand signal)	**++**	**0**	**0**	**0**	**0**	**0**	**0**
Smart service 5: Interlock: avoiding simultaneous heating and cooling in the same room								
0	No interlock	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	Partial interlock (minimising risk of simultanieus heating and cooling e.g. by sliding setpoints)	**++**	**0**	**0**	**0**	**0**	**0**	**0**
2	Total interlock (control system ensures no simultaneous heating and cooling can take place)	**+++**	**0**	**0**	**0**	**0**	**0**	**0**
Smart service 6: Control of Thermal Energy Storage (TES) operation								
0	Continuous storage operation	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	Time-scheduled storage operation	**+**	**0**	**0**	**0**	**0**	**0**	**0**

2	Load prediction based storage operation	++	+	0	0	0	0	0
3	Cold storage capable of flexible control through grid signals (e.g. DSM)	++	++	0	0	0	0	0
Smart service 7: Generator control for cooling								
0	On/Off-control of cooling production	0	0	0	0	0	0	0
1	Multi-stage control of cooling production capacity depending on the load or demand (e.g. on/off of several compressors)	+	+	+	0	0	0	0
2	Variable control of cooling production capacity depending on the load or demand (e.g. hot gas bypass, inverter frequency control)	++	+	++	0	0	0	0
3	Variable control of cooling production capacity depending on the load AND external signals from grid	++	+++	++	0	0	0	0

Smart service 8: Sequencing of different cooling generators								
0	Priorities only based on running times	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	Fixed sequencing based on loads only: e.g. depending on the generators characteristics such as absorption chiller vs. centrifugal chiller	**+**	**0**	**0**	**0**	**0**	**0**	**0**
2	Dynamic priorities based on generator efficiency and characteristics (e.g. availability of free cooling)	**++**	**+**	**0**	**0**	**0**	**0**	**0**
3	Load prediction based sequencing: the sequence is based on e.g. COP and available power of a device and the predicted required power	**+++**	**++**	**0**	**0**	**0**	**0**	**0**
4	Sequencing based on dynamic priority list, including external signals from grid	**+++**	**+++**	**0**	**0**	**0**	**0**	**0**

Smart service 9: Report information regarding cooling system performance								
0	None	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	Central or remote reporting of current performance KPIs (e.g. temperatures, submetering energy usage)	**+**	**0**	**0**	**0**	**0**	**+**	**+**
2	Central or remote reporting of current performance KPIs and historical data	**+**	**0**	**0**	**0**	**0**	**+**	**++**
3	Central or remote reporting of performance evaluation including forecasting and/or benchmarking	**+**	**0**	**0**	**0**	**0**	**+**	**+++**
4	Central or remote reporting of performance evaluation including forecasting and/or benchmarking ; also including predictive management and fault detection	**+**	**0**	**0**	**+**	**0**	**+++**	**+++**
Smart service 10: Flexibility and grid interaction								
0	No automatic control	**0**	**0**	**0**	**0**	**0**	**0**	**0**

1	Scheduled operation of cooling system	+	0	+	+	0	0	0
2	Self-learning optimal control of cooling system	++	+	++	++	0	0	0
3	Cooling system capable of flexible control through grid signals (e.g. DSM)	++	+++	++	+++	0	0	0
4	Optimized control of cooling system based on local predictions and grid signals (e.g. through model predictive control)	++	+++	+++	+++	+	0	0

Table 37 SRI impact assessment of "controlled ventilation" domain

Fn Lvl	Fn Lvl Name	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Wellbeing and health	Maintenance & fault prediction	Information to occupants
Smart service 1: Supply air flow control at the room level								
0	No ventilation system or manual control	0	0	0	0	0	0	0
1	Clock control	+	0	+	+	+	0	0
2	Occupancy detection control	+	0	++	++	++	0	0

3	Central Demand Control based on air quality sensors (CO++, VOC, humidity, ...)	++	0	+++	+++	+++	0	0
4	Local Demand Control based on air quality sensors (CO++, VOC,...) with local flow from/to the zone regulated by dampers	+++	0	+++	+++	+++	0	0
Smart service 2: Air flow or pressure control at the air handler level								
0	No automatic control: Continuously supplies of air flow for a maximum load of all rooms	0	0	0	0	0	0	0
1	On off time control: Continuously supplies of air flow for a maximum load of all rooms during nominal occupancy time	+	0	0	0	0	0	0
2	Multi-stage control: To reduce the auxiliary energy demand of the fan	++	0	0	0	0	0	0
3	Automatic flow or pressure control without pressure	+++	0	0	0	0	0	0

	reset: Load dependent supplies of air flow for the demand of all connected rooms.							
4	Automatic flow or pressure control with pressure reset: Load dependent supplies of air flow for the demand of all connected rooms (for variable air volume systems with VFD).	**+++**	**0**	**0**	**0**	**0**	**0**	**0**
Smart service 3: Heat recovery control: prevention of overheating								
0	Without overheating control	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	Modulate or bypass heat recovery based on sensors in air exhaust	**+**	**0**	**+**	**+**	**+**	**0**	**0**
2	Modulate or bypass heat recovery based on multiple room temperature sensors or predictive control	**++**	**0**	**++**	**++**	**++**	**0**	**0**
Smart service 4: Supply air temperature control at the air handling unit level								
0	No automatic control	**0**	**0**	**0**	**0**	**0**	**0**	**0**

1	Constant setpoint: A control loop enables to control the supply air temperature, the setpoint is constant and can only be modified by a manual action	**+**	**0**	**+**	**+**	**0**	**0**	**0**
2	Variable set point with outdoor temperature compensation	**++**	**0**	**++**	**+**	**0**	**0**	**0**
3	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	**+++**	**0**	**++**	**+**	**0**	**0**	**0**
Smart service 5: Free cooling with mechanical ventilation system								
0	No automatic control	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	Night cooling	**+**	**0**	**+++**	**++**	**+**	**0**	**0**
2	Free cooling: air flows modulated during all periods of time to minimize the amount of mechanical cooling	**++**	**0**	**+++**	**++**	**+**	**0**	**0**

3	H,x- directed control: The amount of outside air and recirculation air are modulated during all periods of time to minimize the amount of mechanical cooling. Calculation is performed on the basis of temperatures and humidity (enthalpy).	**+++**	**0**	**+++**	**++**	**+**	**0**	**0**
Smart service 6: Reporting information regarding IAQ								
0	None	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	Air quality sensors (e.g. CO++) and real time autonomous monitoring	**0**	**0**	**0**	**0**	**++**	**+**	**+**
2	Real time monitoring & historical information of IAQ available to occupants	**0**	**0**	**0**	**0**	**+++**	**+**	**++**
3	Real time monitoring & historical information of IAQ available to occupants + warning on maintenance needs or occupant actions (e.g. window opening)	**0**	**0**	**0**	**0**	**+++**	**++**	**+++**

Table 38 SRI impact assessment on "lighting" domain

Fn Lvl	Fn Lvl Name	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Wellbeing and health	Maintenance & fault prediction	Information to occupants
Smart service 1: Occupancy control for indoor lighting								
0	Manual on/off switch	0	0	0	0	0	0	0
1	Manual on/off switch + additional sweeping extinction signal	+	0	+	+	0	0	0
2	Automatic detection (auto on / dimmed or auto off)	++	0	++	++	0	0	0
3	Automatic detection (manual on / dimmed or auto off)	+++	0	++	++	0	0	0
Smart service 2: Control artificial lighting power based on daylight levels								
0	Manual (central)	0	0	0	0	0	0	0
1	Manual (per room / zone)	+	0	+	+	0	0	0
2	Automatic switching	++	0	+	+	+	0	0
3	Automatic dimming	+++	0	++	++	++	0	0
4	Automatic dimming including scene-based light control (during time intervals, dynamic and adapted lighting scenes are	+++	0	+++	+++	+++	0	0

	set, for example, in terms of illuminance level, different correlated colour temperature (CCT) and the possibility to change the light distribution within the space according to e. g. design, human needs, visual tasks)							

Table 39 SRI impact assessment on "electricity" domain

Fn Lvl	**Fn Lvl Name**	**Energy savings on site**	**Flexibility for the grid and storage**	**Comfort**	**Convenience**	**Wellbeing and health**	**Maintenance & fault prediction**	**Information to occupants**
Smart service 1: Reporting information regarding local electricity generation								
0	None	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	Current generation data available	**+**	**0**	**0**	**0**	**0**	**+**	**+**
2	Actual values and historical data	**+**	**0**	**0**	**0**	**0**	**+**	**++**
3	Performance evaluation including forecasting and/or benchmarking	**+**	**0**	**0**	**0**	**0**	**+**	**+++**
4	Performance evaluation including forecasting and/or benchmarking ; also including	**+**	**0**	**0**	**+**	**0**	**++**	**+++**

	predictive management and fault detection							
Smart service 2: Storage of (locally generated) electricity								
0	None	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	On site storage of electricity (e.g. electric battery)	**0**	**+**	**0**	**++**	**0**	**0**	**0**
2	On site storage of energy (e.g. electric battery or thermal storage) with controller based on grid signals	**0**	**++**	**0**	**++**	**0**	**0**	**0**
3	On site storage of energy (e.g. electric battery or thermal storage) with controller optimising the use of locally generated electricity	**0**	**++**	**0**	**++**	**0**	**0**	**0**
4	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	**0**	**+++**	**0**	**++**	**0**	**0**	**0**

Smart service 3: Optimizing self-consumption of locally generated electricity								
0	None	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	Scheduling electricity consumption (plug loads, white goods, etc.)	**0**	**+**	**0**	**+**	**0**	**0**	**0**
2	Automated management of local electricity consumption based on current renewable energy availability	**0**	**++**	**0**	**++**	**0**	**0**	**0**
3	Automated management of local electricity consumption based on current and predicted energy needs and renewable energy availability	**0**	**+++**	**0**	**++**	**0**	**0**	**0**
Smart service 4: Control of combined heat and power plant (CHP)								
0	CHP control based on scheduled run time manage ment and/or current heat energy demand	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	CHP runtime control influenced by the fluctuating availability of RES; overproductio	**+**	**+**	**0**	**+**	**0**	**0**	**0**

	n will be fed into the grid							
2	CHP runtime control influenced by the fluctuating availability of RES and grid signals; dynamic charging and runtime control to optimise self-consumption of renewables	++	++	0	+	0	0	0
Smart service 5: Control of combined heat and power plant (CHP)								
0	None	0	0	0	0	0	0	0
1	Automated management of (building-level) electricity consumption based on grid signals	0	++	0	++	0	0	0
2	Automated management of (building-level) electricity consumption and electricity supply to neighbouring buildings (microgrid) or grid	0	++	0	++	0	0	0
3	Automated management of (building-level) electricity consumption and supply, with potential to continue limited off-grid	0	+++	0	+++	0	0	0

	operation (island mode)							
Smart service 6: Reporting information regarding energy storage								
0	None	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	Current state of charge (SOC) data available	**+**	**0**	**0**	**0**	**0**	**+**	**+**
2	Actual values and historical data	**+**	**0**	**0**	**0**	**0**	**+**	**++**
3	Performance evaluation including forecasting and/or benchmarking	**+**	**0**	**0**	**0**	**0**	**+**	**+++**
4	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	**+**	**0**	**0**	**+**	**0**	**++**	**+++**
Smart service 7: Reporting information regarding electricity consumption								
0	None	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	reporting on current electricity consumption on building level	**0**	**0**	**0**	**0**	**0**	**0**	**+**
2	real-time feedback or benchmarking on building level	**+**	**0**	**0**	**0**	**0**	**0**	**++**

3	real-time feedback or benchmarking on appliance level	++	0	0	0	0	+	+++
4	real-time feedback or benchmarking on appliance level with automated personalized recommendations	+++	0	0	+	0	++	+++

Table 40 SRI impact assessment on "electric vehicle charging" domain

Fn Lvl	Fn Lvl Name	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Wellbeing and health	Maintenance & fault prediction	Information to occupants
Smart service 1: EV charging capacity								
0	not present	0	0	0	0	0	0	0
1	ducting (or simple power plug) available	0	0	0	+	0	0	0
2	0-9% of parking spaces has recharging points	0	0	0	++	0	0	0
3	+0-50% or parking spaces has recharging point	0	0	0	+++	0	0	0
4	>50% of parking spaces has recharging point	0	0	0	+++	0	0	0
Smart service 2: EV charging grid balancing								

0	Not present (uncontrolled charging)	**0**	**--**	**0**	**0**	**0**	**0**	**0**
1	+-way controlled charging (e.g. including desired departure time and grid signals for optimization)	**0**	**+**	**0**	**++**	**0**	**0**	**0**
2	++-way controlled charging (e.g. including desired departure time and grid signals for optimization)	**0**	**+++**	**0**	**++**	**0**	**0**	**0**
Smart service 3: EV charging information and connectivity								
0	No information available	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	Reporting information on EV charging status to occupant	**0**	**0**	**0**	**+**	**0**	**0**	**++**
2	Reporting information on EV charging status to occupant AND automatic identification and authorizition of the driver to the charging station (ISO 15118 compliant)	**0**	**+**	**0**	**+**	**0**	**0**	**+++**

Table 41 SRI impact assessment on "Monitoring & control" domain

Fn Lvl	Fn Lvl Name	Energy savings on site	Flexibility for the grid and storage	Comfort	Convenience	Wellbeing and health	Maintenance & fault prediction	Information to occupants
Smart service 1: Run time management of HVAC systems								
0	Manual setting	0	0	0	0	0	0	0
1	Runtime setting of heating and cooling plants following a predefined time schedule	+	+	+	+	0	0	0
2	Heating and cooling plant on/off control based on building loads	++	+	++	++	+	0	0
3	Heating and cooling plant on/off control based on predictive control or grid signals	+++	++	++	+++	+	0	0
Smart service 2: Detecting faults of technical building systems and providing support to the diagnosis of these faults								
0	No central indication of detected faults and alarms	0	0	0	0	0	0	0
1	With central indication of detected faults and alarms for at least ++ relevant TBS	0	0	0	+	+	+	+
2	With central indication of detected faults and	0	0	0	++	++	++	++

	alarms for all relevant TBS							
3	With central indication of detected faults and alarms for all relevant TBS, including diagnosing functions	**0**	**0**	**0**	**+++**	**+++**	**+++**	**+++**
Smart service 3: Occupancy detection: connected services								
0	None	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	Occupancy detection for individual functions, e.g. lighting	**+**	**0**	**+**	**+**	**0**	**+**	**0**
2	Centralised occupant detection which feeds in to several TBS such as lighting and heating	**+**	**0**	**+**	**+**	**0**	**++**	**0**
Smart service 4: Central reporting of TBS performance and energy use								
0	None	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	Central or remote reporting of realtime energy use per energy carrier	**+**	**0**	**0**	**+**	**0**	**+**	**+**
2	Central or remote reporting of realtime energy use per energy carrier, combining TBS of at least ++	**+**	**0**	**0**	**++**	**0**	**++**	**++**

	domains in one interface							
3	Central or remote reporting of realtime energy use per energy carrier, combining TBS of all main domains in one interface	+	0	0	+++	0	+++	+++
Smart service 5: Smart grid integration								
0	None - No harmonization between grid and TBS; building is operated independently from the grid load	0	0	0	0	0	0	0
1	Demand side management possible for (some) individual TBS, but not coordinated over various domains	0	++	0	0	0	0	0
2	Coordinated demand side management of multiple TBS	+	+++	0	+	0	0	0
Smart service 6: Reporting information regarding demand side management performance and operation								
0	None	0	0	0	0	0	0	0
1	Reporting information on current DSM status, including man	0	+	0	0	0	0	++

	aged energy flows							
2	Reporting information on currenthistorical and predicted DSM status, including managed energy flows	**0**	**++**	**0**	**0**	**0**	**+**	**+++**
Smart service 7: Override of DSM control								
0	No DSM control	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1	DSM control without the possibility to override this control by the building user (occupant or facility manager)	**0**	**+++**	**-++**	**0**	**0**	**-+**	**-++**
2	Manual override and reactivation of DSM control by the building user	**0**	**+**	**0**	**+**	**0**	**0**	**0**
3	Scheduled override of DSM control (and reactivation) by the building user	**0**	**+**	**0**	**++**	**0**	**+**	**0**
4	Scheduled override of DSM control and reactivation with optimised control	**0**	**++**	**0**	**+++**	**0**	**+**	**0**
Smart service 8: Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather and grid signals								
0	None	**0**	**0**	**0**	**0**	**0**	**0**	**0**

1	Single platform that allows manual control of multiple TBS	**0**	**0**	**0**	**+**	**0**	**+**	**0**
2	Single platform that allows automated control & coordination between TBS	**+**	**0**	**0**	**++**	**0**	**+**	**0**
3	Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather and grid signals	**++**	**0**	**0**	**+++**	**0**	**+**	**0**

Annexure 3: Case study of reference buildings

Case study 1 – Residential[16]

This section applies the streamlined methodology to a Single-Family House case study and reports the outcomes in terms of the scores attained.

For this example, a case study is examined of a hypothetical semi-smart single-family house. This house is essentially the same as the High-Performance single-family house in the Ecofys/WSE technical building systems study (Ecofys & WSE, 2017). The building is a partly refurbished, i.e., the insulation of roofs and walls have been improved to a moderate level, and modern double-glazed windows have been installed. Heating is provided by a gas boiler with radiators, which is the case for more than 40% of the residential space heating consumption of the EU28 building stock (with a heating system exchange rate of about 3.6% per year at EU level, gas fired heating systems will still remain the norm in the near future). Domestic hot water is provided by the heating system without a circulation system. The building has no space cooling and uses natural ventilation.

Reference buildings		External building component	Area [23] [m²]	U-Value [W/m²K]	Thermal bridge [W/m²K]	A/V [24] [m⁻¹]	Floor area [m²]	Share of window area[25] [%]
Semi-detached house	 View Southeast	Facade north	0	0.34	0.1	0.52	165	9
		Facade west	30					
		Facade south	71					
		Facade east	30					
		Roof / upper floor ceiling	100	0.25				
		Ground plate	86	0.52				
		Windows	22	1.3				

Figure 27 Single family home case study

The house is smart in that it has quite sophisticated but perfectly mainstream and cost-effective energy savings controls of its technical building systems including:

– heat demand control for heat emitters via TRVs and for the system via weather compensation and optimum stop/start
– heat production control includes variable temperature control depending on the load (depending on supply water temperature set point)

[16] Verbeke S., Waide P., Bettgenhäuser K., Uslar M.; Bogaert S. et al.; "Support for setting up a Smart Readiness Indicator for buildings and related impact assessment - final report"; August 2018; Brussels

- monitoring & control of HVAC systems can be done by remote control (via smart phone) of the heating system
- reporting information regarding current and historical energy consumption
- basic (dumb) EV charging capabilities.

On the other hand, it is not so smart because it has no on-site distributed generation (and hence no smart control of this), no DSM capability including no EV-related grid balancing capability, and no-fault detection capability. As it has no cooling, hot water storage, controlled ventilation or blinds these domains are excluded.

This building scores 53% out a maximum potential score for this building of 100%.

The weighting of impacts by domain applied in this analysis is as shown in Table 21, however, in principle any (including equal) weightings could be applied. Those used here are intended to better reflect the contribution smart functionalities make to the overall impacts as a function of the domain they apply to; however, many of the values applied are rather arbitrary and more work is required to establish any agreed recommended weightings.

Domain	Energy savings on site	Flexibility for the grid and storage	Self generation	Comfort	Convenience	Health and well-being	maintenance & fault	information to occupants
Heating	52%	2.5%	0%	40%	10%	10%	10%	7%
Domestic hot water	14%	2.5%	0%	10%	10%	10%	10%	7%
Cooling	7%	2.5%	0%	15%	10%	10%	10%	7%
Controlled ventilation	4%	2.5%	0%	10%	10%	10%	10%	7%
Lighting	8%	2.5%	0%	10%	10%	10%	10%	7%
Dynamic building envelope	4%	0.0%	0%	5%	10%	10%	10%	7%
Energy generation	0%	2.5%	80%	0%	10%	10%	10%	7%
Demand side management	0%	40%	10%	5%	10%	10%	10%	7%
Electric vehicle charging	0%	40%	10%	0%	10%	10%	10%	7%
Monitoring and control	10%	5.0%	0%	5%	10%	10%	10%	40%
Total	100%	100%	100%	100%	100%	100%	100%	100%

Figure 28 Domain-level impact weightings used in the Single Family House case study

Case study 2 – Commercial[17]

For this example, a case study is examined of a hypothetical office building. This building is essentially the same as the High-Performance office in the Ecofys/WSE technical building systems study.

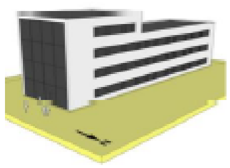
Reference buildings		External building component	Area[35] [m²]	U-Value [W/(m²K)][36]	Thermal bridge (W/m² K)	A/V[37] [m⁻¹]	Reference surface [m²]	Share of window area[38] [%]
Office building	 View Northeast	Facade north	576	0.60	0.1	0.37	1,676	22
		Facade west	187					
		Facade south	598					
		Facade east	234					
		Roof / upper floor ceiling	591	0.40				
		Ground plate	591	0.60				
		Windows	611	1.3				

Figure 29 Office case study: building characteristics

The office is smart in that it has quite sophisticated but mainstream and cost-effective energy savings controls of its technical building systems including:

a. heat demand control for heat emitters via eTRVs and for the system via weather compensation and optimum stop/start
b. Individual room/zone demand driven control with communication between controllers and BACS and presence detection
c. heat production control includes variable temperature control depending on the load (depending on supply water temperature set point)
d. variable airflow and chiller capacity by means of variable speed drives on ventilation fans and the chiller compressor
e. cooling circuit temperature (supply or return) with weather compensation, optimum start/stop and variable speed pump controls for network distribution pumps
f. control of cooling emitters provided by individual room demand control with communication and presence detection
g. air flow control at the room/zone level via demand control: wherein the system is controlled by sensors measuring indoor air parameters or adapted criteria (e.g. CO_2, mixed gas or VOC sensors)

[17] Verbeke S., Waide P., Bettgenhäuser K., Uslar M.; Bogaert S. et al.; "Support for setting up a Smart Readiness Indicator for buildings and related impact assessment - final report"; August 2018; Brussels

h. air flow or pressure control at the air handler level via automatic flow or pressure control with demand evaluation
i. advanced air supply and humidity controls
j. lighting control per task light source using occupancy and daylight responsive controls with dimming and daylight responsiveness for circulation lighting

Under SRI methodology this building scores 64% out a maximum potential score for this building of 100%

Domain	Energy savings on site	Flexibility for the grid and storage	Self generation	Comfort	Convenience	Health and well-being	maintenance & fault prediction	information to occupants
Heating	49%	2.5%	0%	40%	10%	10%	10%	7%
Domestic hot water	10%	2.5%	0%	10%	10%	10%	10%	7%
Cooling	6%	2.5%	0%	15%	10%	10%	10%	7%
Controlled ventilation	7%	2.5%	0%	10%	10%	10%	10%	7%
Lighting	10%	2.5%	0%	10%	10%	10%	10%	7%
Dynamic building envelope	7%	0.0%	0%	5%	10%	10%	10%	7%
Energy generation	0%	2.5%	80%	0%	10%	10%	10%	7%
Demand side management	0%	40%	10%	5%	10%	10%	10%	7%
Electric vehicle charging	0%	40%	10%	0%	10%	10%	10%	7%
Monitoring and control	11%	5.0%	0%	5%	10%	10%	10%	40%
Total	100%	100%	100%	100%	100%	100%	100%	100%

Figure 30 Domain-level impact weightings used in the Office case study

By contrast the eight impact criteria are all weighted equally. In other words, scoring under any of *Energy savings on site*, *Flexibility for the grid and storage*, *Self-generation*, *Comfort*, *Convenience*, *Health* and well-being, *Maintenance & fault prediction*, or *Information to occupants* all counts equally to the final SRI score. Again, these could be weighted differently to give more prominence to some impacts than others.