FINAL REPORT ON THE TECHNICAL SUPPORT TO THE DEVELOPMENT OF A SMART READINESS INDICATOR FOR BUILDINGS

Final Report
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Directorate-General for Energy
Energy Efficiency: Buildings and Products

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This report builds upon – and contains extracts from – the first technical support study on the establishment of the SRI. We gratefully acknowledge their contributions into this final report. Contributors to the first technical support study are: for VITO: Stijn Verbeke, Yixiao Ma, Paul Van Tichelen, Sarah Bogaert (coordination and management), Virginia Gómez Oñate; for WAIDE STRATEGIC EFFICIENCY: Paul Waide ; for ECOFYS: Kjell Bettgenhäuser, John Ashok, Andreas Hermelink, Markus Offermann, Jan Groezinger ; for OFFIS: Mathias Uslar, Judith Schulte.

Although the persons listed above have provided many constructive comments and suggestions or contributions in the reporting of the first technical support study, they were not asked to endorse the final conclusions and/or recommendations. Responsibility for the final content of this report rests entirely with the authors.

EXECUTIVE SUMMARY

Smart technologies in buildings can be a cost-effective means to assist in creating healthier and more comfortable buildings with a lower energy use and carbon impact and can also facilitate the integration of renewable energy sources in future energy systems. One of the focal points of the Energy Performance of Buildings Directive (EPBD) is to better tap this potential of smart technologies in the building sector. As part of this focus, the EPBD sets out provisions to establish a **"Smart Readiness Indicator" (SRI)** as an instrument for rating the smart readiness of buildings. This optional common EU scheme will assess the technological readiness of buildings to interact with their occupants, to interact with connected energy grids and to operate more efficiently. The aim of the SRI is to raise awareness of the benefits of smarter building technologies and functionalities and make their added value more tangible for building users, owners, tenants, and smart service providers. It seeks to support technology innovation in the building sector and create an incentive for the integration of cutting-edge smart technologies in buildings.

The European Commission services (DG ENERGY) commissioned and supervised two studies with the aim of providing technical support to feed into the discussions on a common methodology and potential implementation pathways of this indicator. The outcomes are structured to help guide the establishment of the SRI by the European Commission and Member States and inform the development of related delegated and implementing acts, in accordance with the provisions of the EPBD. A first technical study proposed a definition and draft methodology for the SRI. The second technical support study has built further on the available knowledge to deliver the technical inputs needed to refine and finalise the definition of the SRI and the associated calculation methodology. Both technical studies have been carried out in close collaboration with the stakeholder community, e.g. through open consultations, five plenary stakeholder meetings, surveys, and collection of written feedback on draft reports, and via input received from three topical stakeholder working groups.

The technical study team has observed a broad consensus among stakeholders on the key principles and methodological choices of the SRI. A beta version of the methodology was tested on a voluntary basis during an open public testing phase, which resulted in 112 assessments being conducted by interested actors across the EU. This provided confirmation of the viability of the approach and led to further improvements of the consolidated methodology. Furthermore, the studies explored various options for the implementation of the SRI in order for the Commission Services and Member States to be informed of the possible arrangements for an effective implementation of the SRI scheme and the associated potential impacts. The EU impact analysis indicates that significant net beneficial benefits can result from implementing the SRI instrument across the European Union.

In conclusion, the technical support studies have developed and tested a viable definition and assessment methodology for the SRI. The proposed approach is aligned with the objectives set out in the EPBD, produces acceptably consistent results, can be readily implemented and has been shown to provide useful information to building users. It has been extensively reviewed and appears to enjoy broadly-based support across a wide range of stakeholders, suggesting that it could be an adequate basis to support an effective implementation of the SRI including, where relevant, further testing at Member State level.

SUMMARY TO THE FULL REPORT

1 CONTENTS OF THE SUMMARY

A first technical study to support the establishment of the SRI was launched in March 2017 and conducted by a consortium consisting of VITO NV, Waide Strategic Efficiency, Ecofys and Offis[1]. A second technical support study - conducted by a consortium consisting of VITO NV and Waide Strategic Efficiency Europe - started in December 2018 and concluded in June 2020.

This summary provides a resumé of the main findings and conclusions discussed in the full report of the second technical support study, which also integrates the outcomes of the first technical support study. Specifically, this document presents a summary of the main conclusions concerning:

- a consolidated proposal for the SRI calculation method and its main components, including the service catalogues of method A and method B
- a proposal of weighting factors for the multi-criteria analysis on impact and domain level
- suggestions on the SRI assessment procedures
- suggested implementation pathways for the SRI
- findings on SRI formatting and value to the respective users
- an overview of the main interactions with stakeholders and member state representatives
- results from the EU-level impact analysis of the SRI instrument.

2 WHY A SMART READINESS INDICATOR FOR BUILDINGS IS NEEDED

There is a clear need to accelerate building renovation investments and leverage smart, energy-efficient technologies in the building sector across Europe. Smart buildings integrate cutting edge ICT-based solutions to optimise energy-efficient control of technical building systems and enable energy flexibility as part of their daily operation. Such smart capabilities can also effectively assist in creating healthier and more comfortable buildings, which adjust to the needs of both the user and the energy grid while reducing building energy consumption and carbon impacts.

A greater uptake of smart technologies is expected to lead to significant, cost-effective energy savings, while also helping to improve indoor comfort in a manner that enables the building to adjust to the needs of the user. Smart buildings have also been identified and acknowledged as key enablers of future energy systems for which there will be a larger share of renewables, distributed supply, and demand-side energy flexibility.

[1] "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

In the **Energy Performance of Buildings Directive** (EPBD)[2], one of the focal points is to improve the realisation of this potential of Smart Ready Technologies in the building sector. Therefore, the revised EPBD requires the development of **a voluntary European scheme for rating the smart readiness of buildings: the "Smart Readiness Indicator" (SRI)**. The SRI aims to make the added value of building smartness more tangible for building users, owners, tenants, and smart service providers. The present technical study was commissioned to support the development of this indicator.

Figure 1 – Expected advantages of smart technologies in buildings

The SRI-scheme is intended to **raise awareness** about the benefits of smart buildings - in particular from an energy perspective - and thereby **stimulate investments** in smart building technologies and **support the uptake of technology innovation** in the building sector. It is also within the scope of the SRI to enhance synergies between energy, buildings and other policy segments, in particular in the ICT area, and through this contribute to cross-sectorial integration of the buildings sector into future energy systems and markets.

In this work, the following definition of smartness of a building is used:

> "*Smartness of a building refers to the ability of a building or its systems to sense, interpret, communicate and actively respond in an efficient manner to changing conditions in relation to the operation of technical building systems or the external environment (including energy grids) and to demands from building occupants.*"

[2] Directive 2010/31/EU on the energy performance of buildings as amended by Directive (EU) 2018/844.

A Smart Readiness Indicator for buildings therefore provides information on the technological readiness of buildings to interact with their occupants and the energy grids, and on their capabilities for more efficient operation and improved performance through using ICT technologies.

For building occupants, owners and investors of both existing and new buildings, the SRI is designed to provide information on the smart services the building could deliver. Valuable information on the smartness level of the building - and potential improvements - could steer investment decisions. A transition towards 'smarter' buildings will induce multiple benefits to the users of the buildings, such as better energy efficiency, health and wellbeing, comfort and convenience. Facility managers will also be an important audience for the SRI as they may operate the smart systems and may influence the investment decisions. The other important audience for the SRI will be service providers, including network operators, manufacturers of technical building systems, design and engineering companies and many others. The SRI can help them to organise and position their service offering by providing a neutral and common framework wherein the capability of their smart services can be directly compared with those of their competitors including the incumbent non-smart services.

By providing a common language for all main stakeholders, the SRI can help boost the market uptake of smart ready technologies through the establishment of a credible and integrated instrument.

Figure 2 – Three key functionalities of smart readiness in buildings

3 TECHNICAL SUPPORT STUDIES

3.1 OUTCOMES FROM THE FIRST TECHNICAL STUDY

The first technical support study proposed an SRI methodology according to a set of guiding principles (see list below) and implemented via inspection of the **'smart ready services'** available in a building. Such services are enabled by (a combination of) smart ready technologies, but defined in a technologically neutral way, e.g. the ability to "*control the power of artificial lighting*". The SRI assessment procedure is based on the establishment of an inventory of the smart ready services which could be available in a building and an evaluation of the functionalities they can offer. Each of the services can be implemented with various degrees of smartness, referred to as **'functionality levels'**. In the example of lighting control this can range from the simple implementation of "*manual on/off control of lighting*" to more elaborate control methods such as "*automatic on/off switching of lighting based on daylight availability*", or even "*automatic dimming of lighting based on daylight availability*".

The services within a building operate in multiple **domains** (e.g. heating, lighting, electric vehicle charging, etc.), inducing various kinds of **impacts** (e.g. energy savings, comfort improvement, flexibility towards the energy grid, etc.). To cope with this multitude of domains and impact categories, a **multi-criteria assessment method** was proposed and developed as the underlying methodology for calculating the smart readiness indicator.

The methodology is flexible with regard to the choice of assessment method, e.g. through on site-inspections by external SRI assessors, self-assessment by building owners, a blend of checklists and self-reporting by intelligent equipment, etc. To demonstrate the methodology, two in-field case studies were carried out. These follow a simple checklist process filled-in by third-party assessors who made site visits to the premises to conduct the SRI assessments and compute the scores.

Principles which have guided the development of the SRI methodology

The SRI:

- *Creates a technology-neutral level playing field for market actors through the definition of functional capability rather than the prescription of certain technological solutions.*
- *Is consistent with the goal of having a simple, expressive, and easy to grasp indicator which conveys transparent and tangible information.*
- *Balances the desire for a sufficiently detailed and reliable assessment with the desire to limit the time and cost requirements of assessing the smartness of a building.*
- *Allows for the incorporation of multiple distinct domains (e.g. both heating services as well as electric vehicle charging capabilities, etc.) and multiple distinct impact categories (e.g. energy efficiency, energy flexibility and provision of information to occupants, etc.).*
- *Is designed to be able to adapt to relevant contextual factors, which include variations by building type, climate, culture, and the collective impact these have on the demand for certain services.*
- *Is flexible enough to allow regular updates to support innovation in line with the rapidly changing landscape of policies and commercially available services.*

3.2 STRONG INVOLVEMENT OF EUROPEAN STAKEHOLDERS

During both technical support studies, the consortium partners have conducted extensive consultations of relevant stakeholders in an open and inclusive process. The feedback gathered has informed and deepened the analysis being undertaken and helped to build awareness and consensus over both the project aims and the most viable approaches to realise them.

During the technical studies, the dissemination and written consultation open to the public was managed via a public website[3]. The draft reports, interim deliverables and other relevant documents have been published regularly. At the end of the second technical support study, 813 people were registered as stakeholders and signed up to receiving updates. In total, five large plenary stakeholder consultation meetings were organised, with an average attendance of over 80 stakeholders in Brussels as well as the numerous stakeholders who followed the web-stream.

During the second technical support study, three dedicated thematic stakeholder working groups were set up specifically to enter into in-depth discussions with compact and well-balanced expert groups of approximately 30 members, representing different sector organisations and Member States, as follows:

- topical group A focused on the SRI value proposition and implementation
- topical group B focused on the consolidation of the SRI methodological framework, including the selection of services and the definition of weighting factors and impacts
- topical Group C was added in autumn 2019 and focusses on future developments of the SRI.

Both study teams have set up structured surveys to request feedback on interim deliverables. In addition, the Commission's DG Energy set up a targeted consultation on its website, to collect further feedback from stakeholders on some key issues related to the SRI. This consultation opened from 9 August 2019 to 11 October 2019. The consultation resulted in the collection of detailed feedback from 93 respondents located in 21 countries. This feedback was processed by the study team to inform the developments on the SRI methodology and implementation pathways.

Furthermore, 55 position papers were sent in by stakeholders and analysed and processed by the study teams. These position papers covered a wide set of topics, ranging from a general appreciation of the SRI concept to feedback on very specific technical suggestions.

Finally, stakeholders were also given the opportunity to test a draft version of the SRI calculation framework on buildings of their choice. In total, 112 complete and unique calculation sheets were received, constituting a rich source of information to assess the viability of the approach and finetune the proposed SRI methodology.

[3] This website was set up for the purpose of the study and is bound to be taken offline when this summary and related report are published by the Commission.

Main conclusions drawn from the public SRI beta testing

- *During the public testing, 112 assessments were performed, covering 81 unique buildings from 21 member states. For 31 buildings, both the simplified methods A and the more detailed method B were applied to the same building.*
- *Based on the analysis of the calculation sheets and the received feedback, the study team concludes that the SRI calculation methodology is generally well-received. Results were generally in line with the expectations, and the results were found to be insightful. The formatting and communication on the SRI will play an important role in creating a reference frame for the results. Additional (default) recommendations could strengthen the role of the SRI as an informative tool.*
- *It is concluded that objectively the results for both methods A and B are generally well-aligned. Furthermore, issues of comparability will not likely arise since in practice only one of the two methods would be applied to a given building. Nevertheless, both service catalogues were updated to harmonize the methods. It is suggested to include a clear reference to the method used in the communication on the SRI of a particular building.*
- *From a practical perspective, the assessment typically took less than one hour for method A, whereas most assessments with method B did not take more than 4 hours. This is in line with the expectations. In general, sufficient information was available to perform the assessment. To facilitate the assessment, the guidance document should include more detailed definitions of the functionality levels and provide additional examples or guidelines for complex systems. The role of the facility manager as a source of information was highlighted.*

4 IMPLEMENTATION ASPECTS OF THE SRI SCHEME

4.1 IMPLEMENTATION PATHWAYS

When considering the implementation of the SRI it is important to recognise that there is a tension between the notion of a centrally managed and coordinated SRI and that of subsidiarity where each EU Member State may seek to implement the SRI as they see fit. The legal framework for the SRI in the EPBD clearly sets out the applicable legal basis, so this is beyond discussion, however, practically, it is still important to consider the implications for the efficacy of the SRI of a more or less harmonised methodology. While the methodology needs to be flexible enough to adequately reflect local specificities such as climatic and building type variations it also needs to be sufficiently unified for it to leverage the power of the Single Market for goods and services. In particular, this implies an approach which is common in the manner in which the smart functionalities of goods and services are classified so that their providers can position their offers in a common way across the Single Market and avoid the need (and associated extra cost) of developing separate offers for each local implementation of the SRI. The discussion of implementation, beginning with the prospective pathways, builds on this understanding of the necessary trade-offs between harmonised and locally flexible approaches.

The investigation of the prospective pathways for the effective implementation of the SRI in the EU involved the following three elements:

- identification of the schemes and initiatives on which the SRI could build on, or connect to, to facilitate its implementation
- identification and analysis of the potential options for implementing the SRI at EU-level and at Member States-level
- definition of a set of robust and flexible implementation pathways for the roll-out of the SRI in the EU.

4.1.1 RELEVANT SCHEMES FOR THE SRI TO BUILD ON

An extensive review was conducted of available schemes at both EU and national level that the SRI could connect to (e.g. Energy Performance Certificate schemes). One of the key factors to assess with regard to the schemes reviewed was to evaluate how they have set about building engagement and stimulating adoption, which will be one of the key success factors for the SRI. The study team undertook a structured analysis of the barriers to adoption that these schemes (and the SRI) confront and the mechanisms they have used to overcome them. Their relative success in doing so has been to derive relevant lessons for the implementation of the SRI. In so doing it is recognised that engagement rates are related to the inherent value propositions of the initiatives and the legal frameworks that apply to them and so these have been considered too.

4.1.2 OPTIONS FOR IMPLEMENTING THE SRI AT EU-LEVEL AND AT MEMBER STATES-LEVEL

The identification and analysis of the possible options for implementing the SRI at EU-level and at Member State-level involved the examination of equivalent frameworks as possible templates for the SRI's adoption. In principle, the SRI's governance will require a final decision-making body, supported by technical group(s) with mechanisms for stakeholder input.

Some models of other initiatives which are instructive for the SRI's governance include the Ecolabelling scheme, and CEN/CENELEC standardisation bodies. Each of these initiatives involves oversight, review and maintenance and incorporates Member State representation with technical support just as the SRI will need to. However, the explicit governance structure that will best suit the needs of the SRI will need to be formally linked to the EPBD's governance and also needs to combine routine review and maintenance functions, with the ability to respond quickly to potentially rapid innovations. This last aspect implies the possible relevance to have a fast track decision making pathway in addition to the conventional review and maintenance functions.

4.1.3 DEFINITION OF A SET OF ROBUST AND FLEXIBLE IMPLEMENTATION PATHWAYS FOR THE ROLL-OUT OF THE SRI

The definition of a set of robust and flexible implementation pathways for the roll-out of the SRI in the EU entailed extensive consultation with SRI stakeholders, including regular physical or virtual meetings with the Topical Group A concerned with *SRI value proposition and implementation*.

This consultation process led to the development of the following set of potential implementation pathways:

A. linkage of the SRI to the EPC (energy performance certificate) (potentially in a mandatory way) so an assessment would be offered each time an EPC is conducted
B. linkage of the SRI to new buildings and major renovations so that each time a new build/or renovation is undertaken it would be a requirement
C. a market-based voluntary scheme where self-assessment is supported by on-line tools and 3rd party certified assessment is offered to those willing to pay for it
D. as option C. but with 3rd party assessments supported, or subsidised, by the state and/or utilities seeking to roll out flexibility, energy efficiency, electromobility and self-generation measures
E. linkage to the BACS (building automation and controls systems) and TBS deployment trigger points in Articles 8, 14 & 15 in the EPBD
F. linkages of the roll-out of smart meters
G. a mosaic of the above noting that Member States have subsidiarity in how they may choose to implement the SRI, so they could choose any of these options – also combinations of A/B/C/D/E/F are possible within any single Member State.

In the case of option E, the trigger points in the recast EPBD include:

- Article 8 provisions regarding the installation, upgrade, and replacement of technical building systems (TBS) and measures to encourage the deployment of automatic temperature regulation and zoning
- Articles 14 (heating inspections) and 15 (cooling inspections) which require all non-residential buildings with equivalent rated capacity > 290 kW to have BACS by 2025.

In principle, SRI deployment could be linked to any one or all of these trigger points.

In reflecting on these it is first important to appreciate that the SRI is expected to exert an influence on the market adoption of smart services and technologies through:

- a **"market pull"** impact of SRI assessments on property investment decisions that encourages the adoption of SRTs
- a **"market push"** impact of SRT and service providers self-organizing and promoting their service offers in line with the SRI criteria.

The market *pull* effect is driven by the impact that SRI assessments on properties have on the deployment of smart services and technologies, through raising awareness among stakeholders in the value chain at the property level. In this regard its impact could be expected to be rather similar to the impact effect associated with EPCs on building energy performance. The SRI impact is rather broader than the EPC's, however, because it also provides a common organisational framework within which the purveyors of smart technologies and services can identify and market the functionality and value proposition of their product and service offerings on a common basis across the EU. This "*market push*" effect will often operate at the Single Market level and hence has more in common with the organisational impacts of say, Ecodesign information requirements, than is the case of EPCs.

The duality of the SRI in this regard is important to appreciate because it implies that at one level (the *push* level) it needs to operate as a harmonised EU-level scheme to maximise impact whereas at the other level (the *pull* level) it could follow the same subsidiarity rationale as is applied to EPCs. Nonetheless, the leading implementation pathways mapped out above are necessarily all orientated to the *pull* level because they address how Member States could choose to implement the SRI. In this context option C would appear to be a common, lowest, dominator because it implies an entirely voluntary engagement with the SRI that in principle could be served by a common EU platform (an on-line SRI assessment and information tool made available in all EU languages). Member states and interested market actors could potentially choose to promote this in whatever way suits their concerns and the Commission could support this by the creation of a common interactive platform; however, while such a platform would provide value to any implementation pathway option C gives the least stimulus to SRI assessment and hence is the most passive pathway.

4.2 FORMAT OF THE SRI

4.2.1 APPROPRIATE FORMAT

The determination of the most appropriate format that the SRI should take needed to consider factors such as:

- Should the SRI be presented in the form of a physical certificate, as a virtual certificate, as a label, or in some other way?
- What information is to be conveyed? SRI scores, guidance on improvement options, or both?
- Should the format vary as a function of the target audience e.g. facility managers, building occupiers, and building owners?
- Should the format vary as a function of the building type e.g. non-residential (medium-large), non-residential (small), and residential?
- What scoring information should be presented? An aggregate overall score or rating, smartness scores for each impact criterion (e.g. energy, flexibility, etc.), smartness scores for each domain (e.g. heating, cooling, lighting etc.), combinations of, or all, of the above?

To help answer these questions an extensive stakeholder consultation process was undertaken. From this the following observations can be made. The most appropriate form of the SRI could depend on the implementation pathway and target audience – but it is likely that some blend of a physical and virtual certificate/platform would add most value. In principle, a virtual platform could be structured in hierarchical layers permitting users to assess the information they are interested in at the level they are interested in and thus could accommodate a spectrum of needs and interests. This can also support transparency which is important for the scheme's integrity. A physical certificate, if it is assessed by a third party, is also useful as it allows the ratings to be readily demonstrated. Most stakeholders surveyed favour allowing the SRI rating (scoring) information to be presented at both the sub-score level (e.g. at the impact criteria and domain level) and the overall level (a whole building rating). Most stakeholders would prefer that improvement guidance be included.

4.2.2 SRI LOGO AND DESIGN

From a design and communication perspective there is another discussion about whether, or not, the SRI should make use of mnemonics and/or a logo to support communication and branding. Mnemonics are used to simplify the processing and retention of information. The most famous example in the energy sector is the energy label that ranks appliance efficiency from A to G and is reinforced by colour coding (Green to Red). Other examples of mnemonics used to simplify rankings are the number of stars e.g. a 5-star hotel. Stakeholders have been asked if:

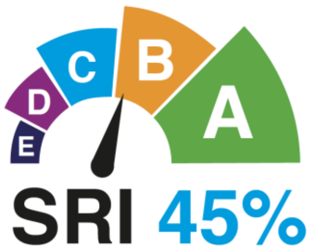
- mnemonics should be used for the SRI? And does the answer depend on the target audience?
- mnemonics should be used in combination with numerical scores or as a replacement?
- Some form of A to G and/or colour-coded mnemonic should be an option, or does it risk confusion vis a vis energy labelling and EPCs?
- other mnemonic scales could/should be considered?

To help answer these questions a professional graphic designer was hired to develop a set of trial SRI design concepts which were subsequently tested in consumer focus groups held in Madrid and Budapest. The designs combined a blend of the following:

- conventional logos
- simple mnemonics which apply a single simple mnemonic scoring system to convey the aggregate performance (e.g. Figure 3)
- more complex, tri-partite mnemonics which apply a mnemonic scoring system for each of the three pillars mentioned in the EPBD text and also for an aggregate score (e.g. Figure 4)
- a comprehensive scoring matrix that includes scores per domain and per impact criterion as well as aggregate scores per impact criterion and the overall SRI aggregate score (Figure 5).

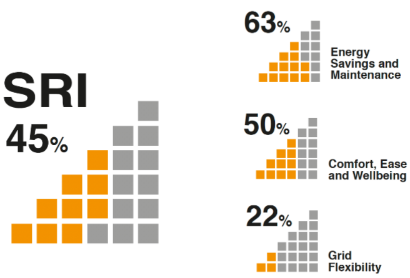
To test the SRI concepts consumer focus groups with a representative set of members of the public were conducted in Madrid and Budapest by a professional market research company (Kantar Millward Brown) and WSEE in state-of-the-art market research premises using professional moderators and best practice methods.

Example 10A



Example 10D

Figure 3 – Examples of single mnemonics to convey the overall SRI score and/or rank



Example 20A

Example 20E

Figure 4 – Examples of Tri-partite mnemonics to convey the overall SRI score/rank and sub-score/ranks for the three SRI "pillars"

IMPACTS

DOMAINS	Energy efficiency	Maintenance and fault protection	Comfort	Convenience	Health and well-being	Information to occupants	Energy flexibility & storage	SRI
Total	39%	18%	60%	71%	48%	59%	0%	42%
Heating	32%	18%	62%	55%	24%	74%	0%	
Sanitary hot water	17%	0%	45%	70%	67%	83%	0%	
Cooling	65%	51%	78%	72%	61%	55%	0%	
Controlled ventilation	41%	0%	55%	60%	34%	44%	0%	
Lighting	85%	14%	90%	100%	83%	15%	0%	
Dynamic building envelope	10%	0%	31%	56%	22%	46%	0%	
Electricity	10%	0%	-	-	-	68%	0%	
Electric vehicle charging	-	38%	-	82%	-	84%	0%	
Monitoring and control	52%	43%	62%	72%	45%	64%	0%	

Figure 5 – Matrix showing SRI scores by domain and impact criterion, aggregate scores per impact criterion and the overall SRI score

4.2.3 Data management and cross-cutting issues

The importance of ensuring data protection and confidentiality has been highlighted as a critical factor that would severely weaken the SRI were it to compromise these factors. GDPR requirements therefore need to be respected as a minimum, including ensuring that only legally mandated actors should have access to the SRI information pertaining to any specific property.

It is equally essential that SRI assessments should not cause any increase in cybersecurity risk and that if/where possible the SRI should be structured to enable information on the cybersecurity status of the smart services and devices being assessed to be reported to the SRI recipient. As it will not be actionable to have an on-site inspection of cybersecurity aspects, the SRI will have to rely on other data sources, e.g. the EU's voluntary cyber-security label which might become available for specific TBSs used within buildings in the future. This could feature on the SRI and its accompanying documents as additional information in addition to other relevant information such as the EC *broadband-ready label*[4] of a building when this information is available from trusted sources.

Additionally, the SRI or accompanying documents could also feature information on the cross-cutting issues of interoperability. It is suggested to take interoperability inexplicitly into account in some of the services which deal with interaction of various systems (e.g. the provision of preventing simultaneous heating and cooling in building zones requires some form of interoperability). Optionally, the SRI and its accompanying documents could report on the standards and communication protocols used by the technical building systems, or introduce a simplified metric to indicate interoperability for each of the technical domains. The latter is likely to be more of a longer-term objective than a near term reality, as currently it is particularly challenging to determine the interoperability status of technologies from on-site (or other) assessment.

[4] See Article 8 of Directive 2014/61/EU of the European Parliament and the Council of 15 May 2014 on measures to reduce the cost of deploying high-speed electronic communications networks.

STUDY TEAM CONCLUSIONS ON FORMATTING

- *An SRI format that combines a mnemonic graphic design such as those shown in Figure 3 or Figure 4 at the top with the matrix shown in Figure 5 somewhere beneath would seem to be viable and address most users' needs – it seems to work well for consumers and professional users. This would combine a whole building score and ranking (which many users have indicated is important) with the detailed information on the scores by domain and impact criterion in a manner that is readily accessible. It would also ensure that users can see how the whole score is comprised from the sub-scores and provide the richness of information that many users desire without putting off those that simply want a whole-building score/ranking. The mnemonic ranking complements the percentage score as it gives a more easily retainable and comparable reference. It is suggested to use this approach for all building types and user segments.*

- *With regard to the set of media used to such an approach (i.e. a top-line mnemonic ranking/score with a matrix of sub-scores beneath) could be presented via a certificate and/or report with the option to access more details through an on-line tool. Such a tool could be accessible via a QR code and/or weblink and could potentially include the option for the user to enter (and/or retrieve) their building details so they could examine how they could improve its smart readiness in detail. The on-line tool could combine the functionalities of: explaining the SRI purpose and calculation to users; explain the higher levels of SRT functionality that are available and their benefits; and being able to calculate SRI scores from raw input data while allowing users to see how improved SRTs would improve their building's overall score and sub-scores.*

- *The use of an on-line platform would provide a solid and flexible foundation for the SRI's informational needs and be most responsive to the range of user needs. It could help to: facilitate SRI assessment, enable interactive determination of the impact of prospective changes in a building's smartness, manage evolutions in the SRI, manage evolutions in the data for any specific property, support data exchange with other service platforms whenever appropriate permissions are granted. Critically, the use of such a platform, if arranged to be in a navigable hierarchical manner, would avoid the need for the scheme to have to present the information in a single condensed format based on assumptions about user needs, as users would be able to readily find the information they are most interested in.*

- *Whatever media and graphic design format is chosen it will be important to ensure that additional explanation is provided which clearly clarifies what it does and does not address if confidence in the scheme is to be established and to protect it from accusations of being misleading. Distinct versions, where calculation methods have evolved, will need to be clearly communicated.*

- *There seems to be no obstacle in terms of user comprehension or perception to integrating the SRI within an EPC or to implementing them jointly. The same is probably true of other building rating, labelling or certification schemes.*

- *There seems to be no obstacle to using a common EU graphical design format for the SRI providing text used within it, such as in the matrix of Figure 5, can be communicated in the local language. It is probably acceptable to use the English acronym SRI as part of a common EU brand providing there is explanation of what the scheme is about offered in the local language.*

- *Information on cybersecurity and interoperability can be communicated together with the SRI and its accompanying documents. Some elements of interoperability are also implicitly integrated in the SRI calculation methodology, thus attributing to the overall score.*

4.3 ASSESSMENT PROCEDURE

The assessment time is strongly linked to the degree of complexity of the SRI definition. At least two different SRI assessment types could be envisioned: a light version with a limited set of services and a detailed version. Differentiating between a light version and a detailed version would allow the costs to be brought down for simple buildings, which in turn could increase the uptake. At the same time, the detailed version would permit validation of the added value of advanced systems in complex buildings. On the downside, differentiation may bring confusion, which could hamper the communication of the SRI. Finally, there is also a demand amongst certain stakeholders to take the SRI a step further by basing it on actual performance data of in-use buildings. From consideration of these aspects, the study team has investigated the three potential SRI assessment methods depicted below:

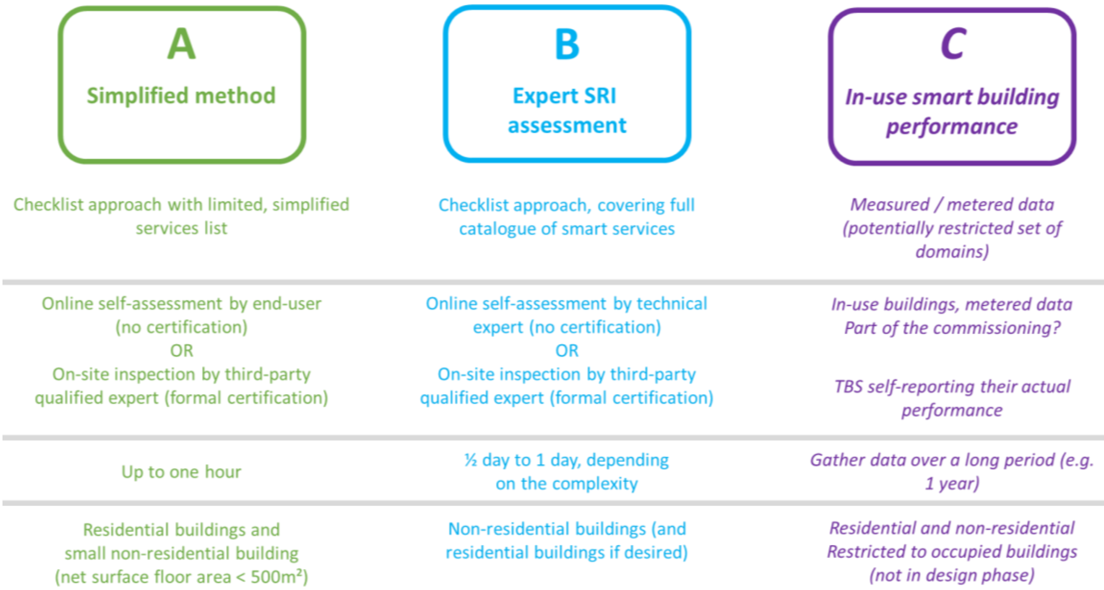


Figure 6 - Three potential assessment methods

- Method A could be a simplified quick scan, focusing mainly on residential buildings and small non-residential buildings. The method could be based on a check-list approach with a limited or simplified services list. It could be a fast method, taking less than one hour for a single-family home. The method could allow (online) self-assessment in addition to a formal third-party expert assessment. Only a third-party expert assessment would issue a formal certification.
- Method B could be a detailed SRI assessment, focusing mainly on non-residential buildings. The assessment could take ½ day to 1 day, depending on the size and complexity of the building. By default, it would require an on-site inspection by a third-party qualified expert. The method could potentially allow self-assessment by a non-independent expert (e.g. facility manager). Only a third-party expert assessment would issue a formal certification.
- Method C could be a metered/measured method. In the long run, Technical Building Systems (TBS)/ Building Automation and Control Systems (BACS) might be able to self-report functionality levels, assisting methods A and B. Method C goes beyond this, and quantifies the actual performance of in-use buildings. Method C will require

benchmarking to assess how much savings, flexibility, comfort improvements, etc. are delivered as a result of smart technologies. Alternatively, the scope could be broadened beyond the scope of the current SRI to become an assessment of actual performance, rather than solely focusing on smart controls. Method C is currently considered to be a potential future evolution of a certification approach for a commissioned building. Many practical and legal implications would hamper a fast roll-out. Therefore, it will not be treated in detail in this technical study but rather considered as a potential future evolution of the SRI.

Transparent processes will be needed to support the evolution of the SRI once it is established. The SRI method may need to be adapted over time to include additional domains, services, functionality levels or impact categories. Transparent frameworks and procedures will have to be defined and set up to manage this process in close interaction with relevant stakeholders.

As the SRI scheme becomes more established, it may evolve into a more sophisticated and less intrusive - thus less costly - assessment process(es). Potential options for this could include the use of Building Information Models (BIM) to facilitate the assessment process, self-reporting of smartness by BACS and the emergence of some form of standardised labelling on (packages of) smart-ready products. The full report discusses several important considerations that should be addressed in the implementation of the SRI scheme or could assist in a practical assessment on-site.

The SRI assessment can be linked to other assessment schemes and voluntary labels. This approach could potentially allow engagement of voluntary schemes introduced by some industry and service sectors that go into greater depth for specific smart services. Potential linkages to various schemes and initiatives are discussed in the full report.

The full report also discusses various approaches to deal with smart services that are only present in a part of the building. By introducing inspection thresholds or defining representative rooms in a building, the assessment efforts can be reduced significantly.

CONSOLIDATED APPROACH ON THE SRI ASSESSMENT METHODS

- *There is strong stakeholder support for distinguishing between a simplified approach (Method A) and a detailed approach (Method B). Method A, the simplified method, is mainly oriented towards small buildings with low complexity (single family homes, small multi-family homes, small non-residential buildings, etc.). The checklist method could be made accessible for non-experts, such as individual homeowners. Method B, the detailed method, is oriented towards buildings with a higher complexity (typically large non-residential buildings, potentially large multi-family homes).*

- *While in principle Method B is mainly oriented to more complex buildings, there is a greater richness of information in Method B and hence the study team are of the view that it should always be presented as an option even for building segments where Method A is the more common choice. Nonetheless, the manner in which this is executed would naturally be dependent on the implementation pathway adopted by each implementing authority.*

- *To support this approach, two separate service catalogues have been developed by the study team in consultation with the stakeholder community: a simplified service catalogue A and a detailed service catalogue B. Both methods have been subject to the public beta test which led to further finetuning and harmonisation of both methods. The consolidated service catalogues are distributed as annex C and annex D of the full report.*

- *For either method self-assessment could be made available. In this case it should be strictly framed as an informative tool that does not issue a formal certificate.*

- *The SRI needs to be a dynamic instrument. Within the framework of the current method, elements such as smart ready services and their scores and functionality levels will need to be adapted over time to keep in line with innovations available on the market. Furthermore, novel assessment methods (e.g. focussing on actual in-use performance) could be introduced. Various initial options for future evolutions of the SRI scheme have been canvassed and discussed with the dedicated topical stakeholder group C. While the outcomes of the technical support study mainly focused on an actionable first version of the SRI which can readily be implemented, the study team suggests that in parallel a process is set-up to discuss and facilitate future updates to the SRI in close collaboration with relevant stakeholders and Member States.*

5 TECHNICAL ASPECTS OF THE SRI SCHEME

5.1 THE CATALOGUES OF SMART READY SERVICES

The proposed SRI methodology builds on the assessment of the **smart ready services** present in a building. Services are enabled by (a combination of) smart ready technologies, but are defined in a technology neutral way, e.g. '*provision of temperature control in a room*'. To support this, two catalogues of smart ready services has been compiled: a detailed method (method B) and a simplified method (method A). Each catalogue lists the relevant services and describes their main expected impacts towards building users and the energy grid. Many of these services are based on international technical standards. In accordance with the requirements from the revised EPBD, three key functionalities of smart readiness in buildings have been taken into account when defining the smart ready services in the SRI catalogue:

1. The ability to **maintain energy efficiency performance and operation** of the building through the adaptation of energy consumption - for example through use of energy from renewable sources.

2. The ability to adapt its operation mode in **response to the needs of the occupant**, paying due attention to the availability of user-friendliness, maintaining healthy indoor climate conditions and ability to report on energy use.

3. The **flexibility of a building's overall electricity demand**, including its ability to enable participation in active and passive as well as implicit and explicit demand-response, in relation to the grid, for example through flexibility and load shifting capacities.

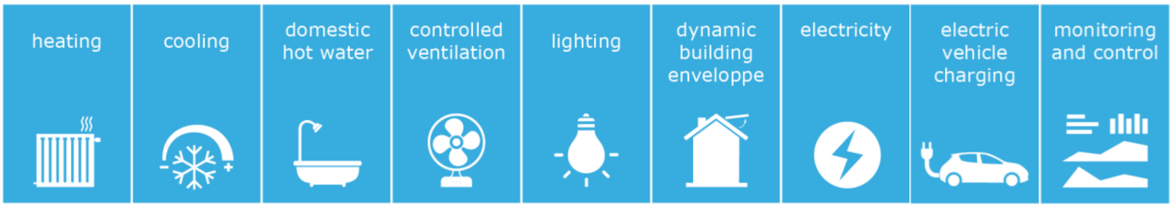


Figure 7 – Domains structuring the SRI catalogue

In the SRI service catalogues developed, services are structured within nine **domains**: heating, cooling, domestic hot water, controlled ventilation, lighting, dynamic building envelope, electricity, electric vehicle charging and monitoring and control.

The detailed service catalogue (method B) and the simplified service catalogue (method A) have been thoroughly reviewed based on various stakeholder feedback, a review session with members of Topical Group B and feedback from the public beta testing. The final consolidated proposal for a detailed service catalogue (method B) consists of 54 services, the simplified (method A) of 27.

For each of the services, 2 to 5 **functionality levels** are defined. A higher functionality level reflects a "smarter" implementation of the service, which generally provides more beneficial impacts to building users or to the grid compared to services implemented at a lower functionality level. The functionality levels are expressed as ordinal numbers, implying that ranks cannot be readily compared quantitatively from one service to another.

5.2 IMPACT SCORES OF SMART READY SERVICES

A smart ready service can provide several impacts to the building, its users and the energy grid. In the proposed approach, a set of seven impact criteria is evaluated, but scores can potentially be aggregated along the three key functionalities mentioned in the EPBD.

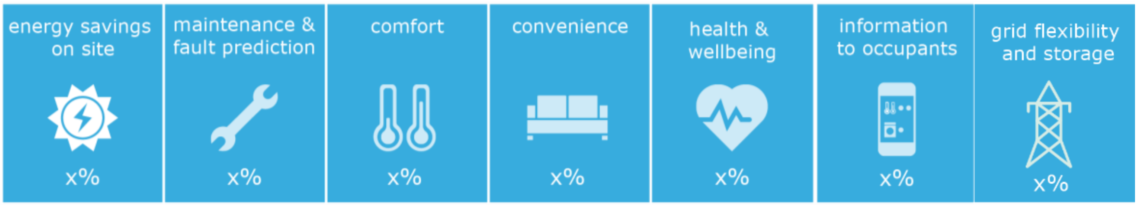


Figure 8 – Smart service impact criteria

The impact criteria are:

- **Energy savings on site**
  This impact category refers to the impacts of the smart ready services on energy saving capabilities. It is not the whole energy performance of buildings that is considered, but only the contribution made to this by smart ready technologies, e.g. resulting from better control of room temperature settings.
- **Flexibility for the grid and storage**
  This impact category refers to the impacts of services on the energy flexibility potential of the building. The study proposes to not solely focus on electricity grids, but also include flexibility offered to district heating and cooling grids.
- **Comfort**
  This impact category refers to the impacts of services on occupant's comfort. Comfort refers to conscious and unconscious perception of the physical environment, including thermal comfort, acoustic comfort and visual performance (e.g. provision of sufficient lighting levels without glare).
- **Convenience**
  This impact category refers to the impacts of services on convenience for occupants, i.e. the extent to which services "make life easier" for the occupant, e.g. TBS requiring fewer manual interactions.
- **Well-being and health**
  This impact category refers to the impacts of services on the well-being and health of occupants. For instance, smarter controls can deliver an improved indoor air quality compared to traditional controls, thus raising occupants' well-being, with a commensurate impact on their health.

- **Maintenance and fault prediction**
  Automated fault detection and diagnosis has the potential to significantly improve maintenance and operation of technical building systems. It also has potential impacts on the energy performance of the technical building systems by detecting and diagnosing inefficient operation.
- **Information to occupants**
  This impact category refers to the impacts of services on the provision of information on building operation to occupants.

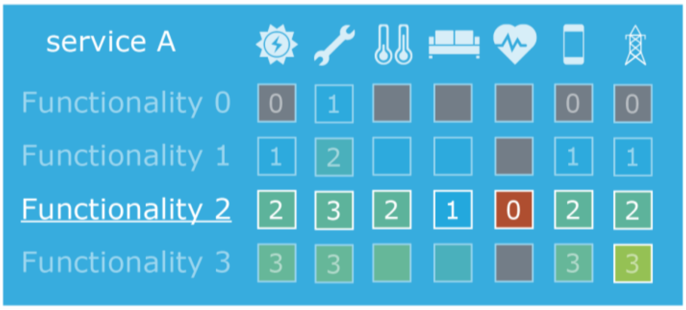


Figure 9 – Matrix displaying the impact scores for the seven impact categories of a fictitious "service A". Functionality level 2 is assumed to be present in the building, which has the following impact scores listed: "2" for energy savings, "2" for flexibility and storage, "2" for comfort, etc.

For each of the smart ready services in the catalogue, provisional impact scores have been defined for their respective functionality levels according to a seven-level ordinal scale. While most of the impacts are positive, the scale also provides the opportunity to ascribe negative impacts.

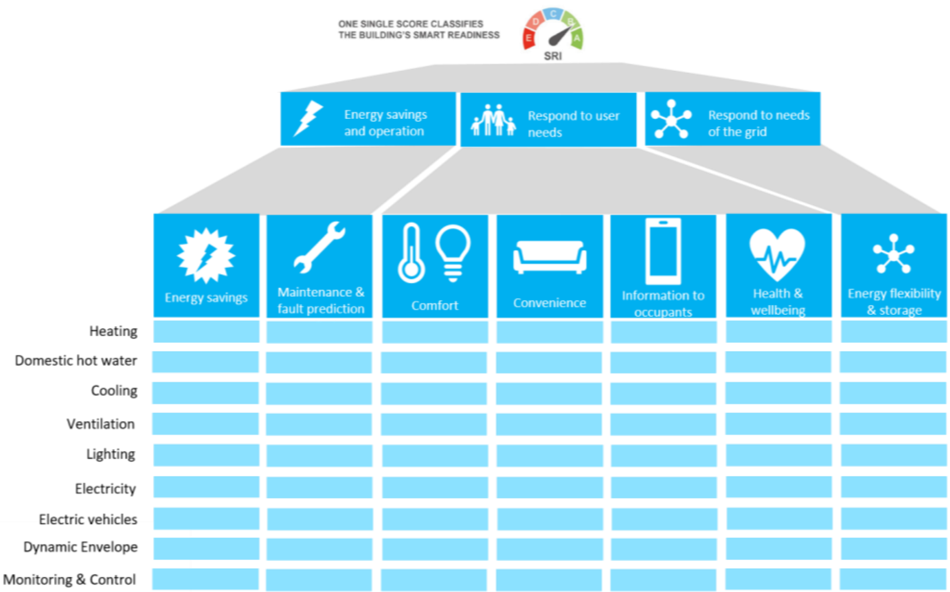


Figure 10 – Proposed structure of domains and impacts criteria

5.3 MULTI-CRITERIA ASSESSMENT METHOD

Under the proposed SRI methodology, the smart readiness score of a building is a **percentage** that expresses how close (or far) the building is to maximal smart readiness. The higher the percentage is, the smarter the building. The percentage can also be converted to another indicator, e.g. star rating or alphabetical score (A, B, C, etc.). This has been further tested through the development of graphical designs and market surveying with selected consumer focus groups.

An aggregated score can be derived as follows:

- The process starts with the assessment of **individual smart ready services**. Services available in the building are inspected and their functionality level is determined. For **each service**, this leads to an **impact score** being ascribed for each of the impact criteria considered in the methodology**.**

- Once all these individual services impact scores are known, an aggregated impact score is calculated for each of the domains considered in the methodology. This **domain impact score** is calculated as the ratio (expressed as a percentage) between individual scores of the domains' services and theoretical maximum individual scores.

- For each impact criterion, a total impact score is then calculated as a weighted sum of the domain impact scores. In this calculation, the weight of a given domain will depend on its relative importance for the considered impact.

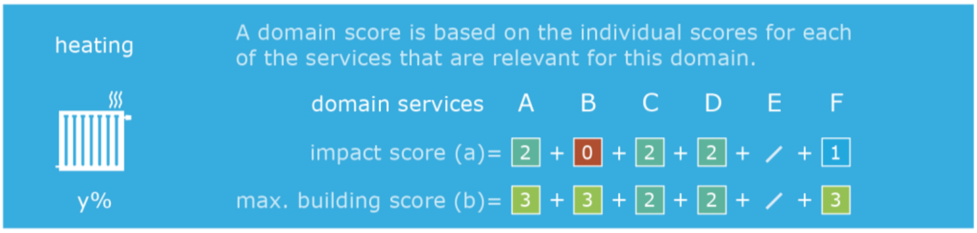


Figure 11 - The domain score is based on the individual scores for each of the services that are relevant for this domain

The SRI score is thus based on a weighted sum of the 7 total impact scores. In this multi-criteria assessment, the **weighting factors** can be attributed to both domains and impact criteria to reflect their relative contributions to an aggregated overall impact score. An aggregated SRI score indicates the overall smartness level of the building, while sub-scores allow to assess specific domains and impact categories. Conceptually, three approaches for the derivation of the domain and service level weighting factors can be envisioned: equal weighting, predicted impact approach and energy balance approach.

The weighting factors for domains will be derived from an energy balance whenever possible. This approach reflects the differences in relative importance with respect to regional differences. By using weightings from an energy balance, the heating domain would gain importance in northern areas of Europe, whereas the relative importance of the cooling domain would increase in southern areas of Europe. For those domains where no direct link with an energy balance can be made (e.g. monitoring & control, dynamic building envelope), a weighting factor can be defined based on the estimated impact of that domain. The methodology also foresees a differentiation in weighting factors for the individual impact criteria.

The proposed methodology provides default weighting factors which are differentiated by building type and climate zone. Figure 12 and Figure 13 provide an overview of the proposed weighting scheme which consist of a blend of fixed weights, equal weights, and energy balance weights, depending on domain and impact.

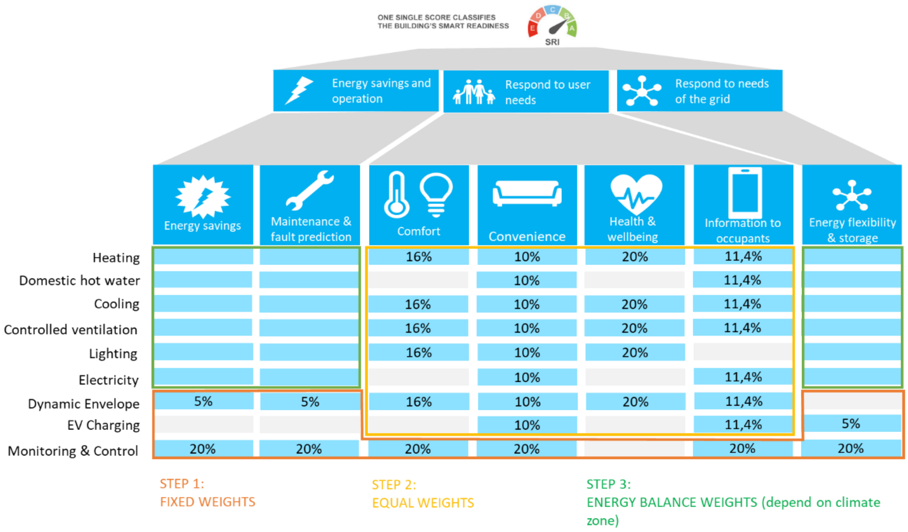


Figure 12 – Overview of the weighting scheme

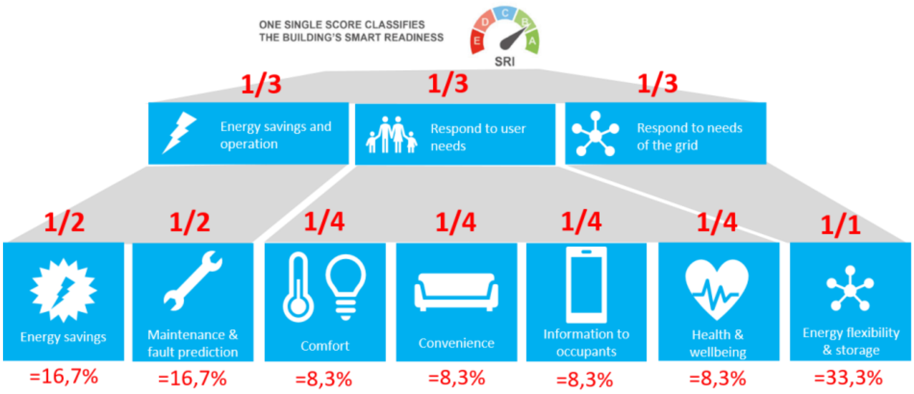


Figure 13 – Aggregation of impact scores to three key functionalities or to a single score

CONSOLIDATED PROPOSAL ON WEIGHTING FACTORS FOR SERVICES AND DOMAINS

- *Based on the input from stakeholders, the study team has developed a hybrid approach for the derivation of the weighting factors. The methodology defines a weighting scheme with three types of weighting factors: fixed weights, equal weights, and energy balance weights. The methodology includes the option to use building-specific energy balance data whenever available (for instance from an EPC calculation).*

- *The proposal allows flexibility regarding the communication of results at the two aggregation levels. The study team has investigated ways to efficiently communicate these impact criteria, aiming to balance clarity and conciseness. Information on cybersecurity and interoperability can be communicated together with the SRI and its accompanying documents. Some elements of interoperability are also implicitly integrated in the SRI calculation methodology, thus attributing to the overall score.*

5.4 Normalisation of SRI score and triage process to select the applicable services

The proposed SRI methodology provides a **flexible and modular framework**. The applicability of the SRI methodology is likely to vary depending on specific circumstances (building type, climate, site specific conditions, etc.). Local and site-specific context will mean that some domains, services and service levels are either not relevant, not applicable, or not desirable and thus the SRI needs to be flexible enough to accommodate this. The maximum nominal impact score is not simply the sum of the impacts of the services listed in the streamlined SRI catalogue. It is highly likely that due to local and site-specific context some domains and services are either not relevant, not applicable, or not desirable. The SRI methodology accommodates this by performing a **triage process** to identify the **relevant services for a specific building**.

It may be that some domains are not relevant, e.g. some buildings might not be able to provide parking (and hence electric vehicle charging facilities) and some residential buildings might not need cooling. Furthermore, some of the services are only applicable if certain technical building systems are present, e.g. a storage vessel for domestic hot water or a heat recovery ventilation unit. Also, some services may be mutually exclusive, since it is unlikely that a building has both district heating and combustive heating and heat pumps. If such services are not present, they obviously do not need to be assessed during on-site inspections. Due to these different factors, in any real building, the number of services to be inspected as part of an SRI assessment will be lower than the 54 (or 27 in case of method A) smart ready services listed in the SRI catalogue.

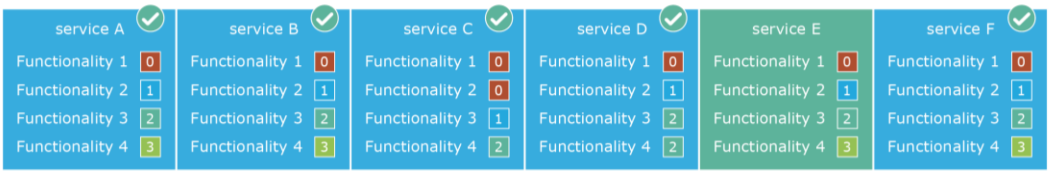


Figure 14 – Visualisation of triage process: for this specific example service E is not considered relevant for the building and thus is not inspected

The triage process does not only affect the inspection time and efforts, but also the 'maximum obtainable score', as it would be unfair to penalise a building for not providing services that are not relevant. The SRI should not promote complexity in buildings and will therefore only take into account services which are either present or desirable. For some services, this can be context specific. For instance, a passive house with solar shades, ventilation and / or window opening control, would not need mechanical cooling and should not be penalised for not having such services.

In essence, two approaches to deal with absent domains or services are combined:

- Some services only have to be evaluated in cases where the relevant technical building systems are present (hence: "smart ready"). This approach is appropriate when assessors cannot unambiguously determine the relevance of the domain. For instance, the relevance of automated shading devices strongly depends on the building's design (orientation, window-to-wall ratio, etc.). Such an assessment cannot be made objectively within the scope of the SRI. When moveable shading is present, the SRI can however assess how smartly the shading devices are controlled.

- Some services might be absent but nonetheless desirable from a policy perspective (hence: "smart possible"). This approach may provide stimuli for upgrading existing buildings with additional (smart) services. For instance, penalising the absence of a controlled ventilation system could create an incentive to install such a system to improve the SRI score.

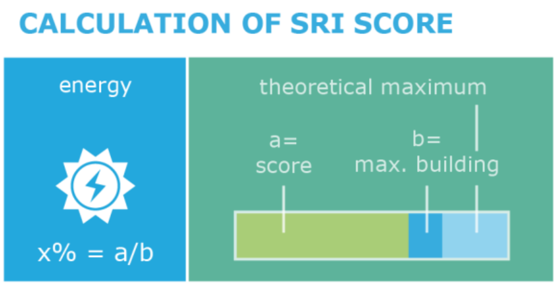


Figure 15 – Normalisation of the domain score. As a result of the triage process, certain services are not included in the maximum score of a building (b), which can therefore be lower than the theoretical maximum score (c). The SRI score is calculated by dividing the building score (a) by the maximum score of the building (b).

CONSOLIDATED APPROACH ON DEALING WITH ABSENT SERVICES

The study team recommends the following approach to deal with absent services

- *For some services, an evaluation is only relevant in cases where the technical building systems it relates to are present. This approach is appropriate when one cannot a priori conclude that a domain or service should be present in a particular building (e.g. a building could be comfortable without cooling systems). If such a service is not present, the service is excluded from the assessment and does not affect the maximum attainable score.*

- *Some services may be mutually exclusive; if such services are not present, they can be excluded from the assessment*

- *Some services might be absent but nonetheless desirable from a policy perspective. This approach may provide stimuli for upgrading existing buildings with additional (smart) services. A suggested solution is to allow implementing bodies to define guidelines depending on contextual factors such as the relevance of specific services and domains to particular building types and climatic zones and requirements in local building codes. These services are included in the assessment.*

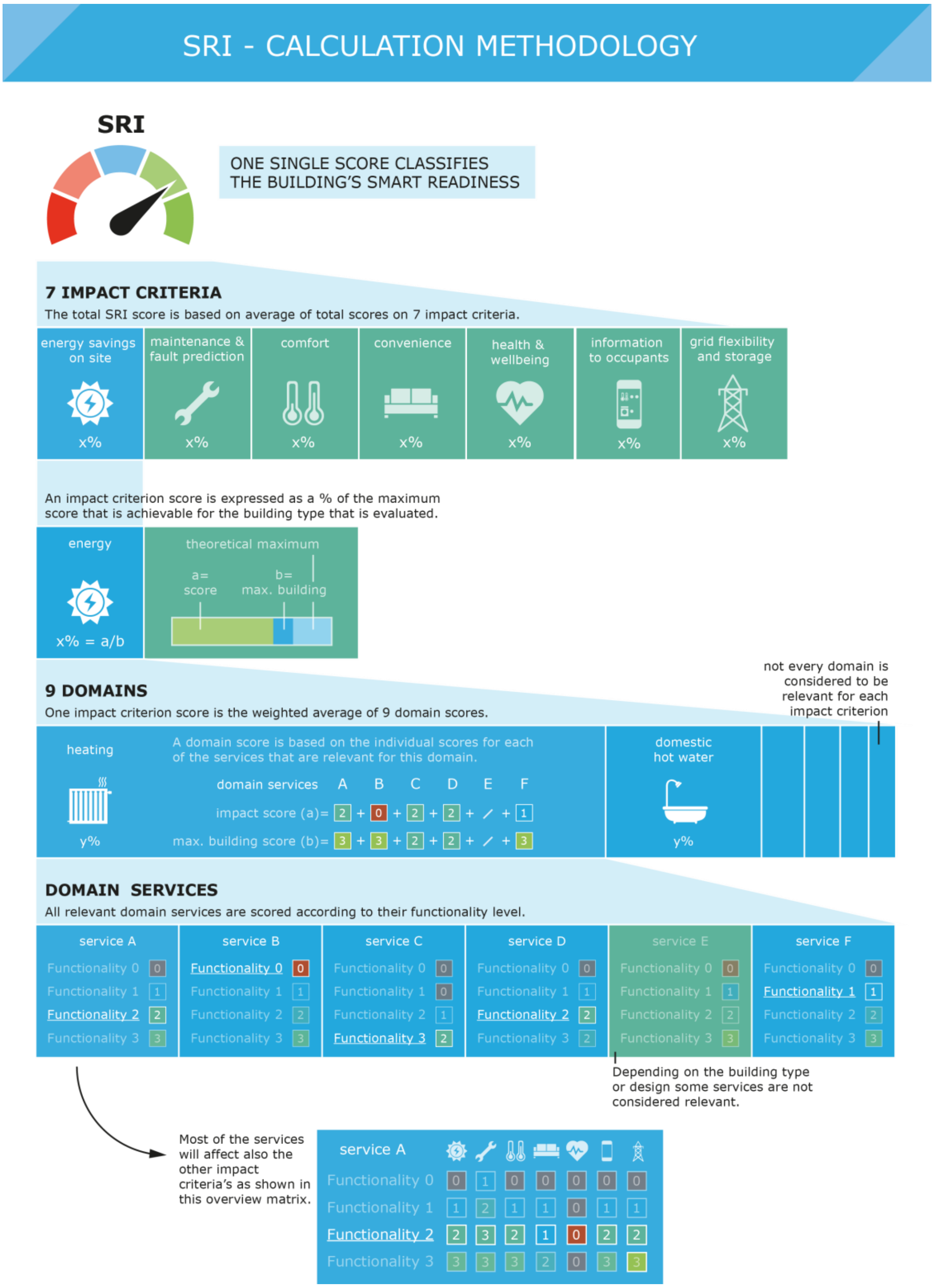


Figure 16 - summary of the calculation method

6 Benefits and costs of the SRI's implementation

As part of the technical study, an **impact analysis** was performed to analyse the benefits and costs of implementing an SRI to support an increased uptake of smart ready technologies in buildings across the EU. It is also intended to help understand the impact of implementing the SRI in conjunction with other accompanying policies to enhance the impact of the SRI. The methodology used to assess the potential impacts of the SRI is split into two steps:

- The first focuses on the modelling of the evolution of the **EU building stock** within the framework of the revised EPBD. The building sector pathways used in this analysis describe the general development of the building sector calculated in five geographic zones across the EU. They consider new buildings, the demolition of buildings and retrofits with regard to energy efficiency measures applied to the building envelope and the heating, ventilation, and air-conditioning (HVAC) systems. These models are in line with the impact assessment carried out in the first technical support study for the SRI.
- In the second part of the impact assessment, the effects of an **uptake of smart ready technologies** (SRTs) is modelled. Various scenarios of how the SRI and accompanying policy measures spur the uptake of SRTs are modelled. For this impact assessment, the level of smart readiness of buildings is clustered into different levels (from I to IV) in the models. If a building undergoes improvements, it will be allocated to a higher smart readiness level (e.g. moving from I to II or from II to IV). This translates into final energy savings, monetary savings and CO_2-savings due to the improved energy efficiency of the buildings and enhanced demand side flexibility. Additional benefits (increased work force, health and well-being…) will be described in a qualitative way but not explicitly quantified.

Various implementation scenarios are investigated in the study, including a potential mandatory linkage to Energy Performance Certification (referred to as 'pathway A1') and a market-based voluntary scheme where self-assessment is supported by on-line tools and 3rd party certified assessment is offered to those willing to pay for it (referred to as 'pathway C').

The business-as-usual (BAU) scenario for the SRI already includes the impacts of all the other policy measures within the Energy Performance of Buildings Directive and thus has already locked-in very significant final energy savings in EU the building sector. These measures pertain to the construction of new energy-efficient buildings, and energy-efficient retrofits of existing buildings with regard to the building envelope and the heating, ventilation, and air-conditioning (HVAC) systems. Nonetheless, the impact analysis indicates that the SRI can unlock up to 5% additional final energy savings by 2050. Under the BAU scenario an investment of 75 billion euro would be made in smart ready technologies over the next 30 years, yet under the SRI A1 implementation pathway this would increase by an additional 126 billion euro, resulting in final energy savings up to 198 TWh by 2050 and 32 million tonnes of avoided greenhouse gas emissions per year. The annual projected cost of conducting the SRI assessments and annual energy savings also depend on the preferred implementation pathways.

Across the EU-28, SRI assessment costs are projected to range from €560m in 2050 (under pathway A1) to just €2m (under pathway C), yet the value of annual avoided energy bills in 2050 is projected to range from €16.8 billion (under pathway A1) to €5.3 billion (under pathway C). The annual net cost savings from implementing the SRI in 2050 are projected to range between 12.9 billion (for pathway A1) and 3.9 billion (for pathway C) – note these costs are the sum of the investments in smart ready technologies, the SRI assessment costs and the value of the energy bill savings. Co-benefits of the SRI roll-out are also assessed in the study. For example, the projected value of health & wellbeing benefits as a result of the SRI-induced investments are estimated to be up to €3.8 billion in 2030 higher compared to BAU (for pathway A1), while the incremental net employment created is up to 72 thousand jobs (for pathway A1). Details on the material circularity impacts and the findings of a detailed sensitivity analysis are presented in the main report.

7 GENERAL CONCLUSION

The Energy Performance of Buildings Directive (EPBD) introduced the concept of a Smart Readiness Indicator (SRI) which is expected to become a cost-effective measure that can effectively assist in creating healthier and more comfortable buildings with a lower energy use and carbon impact, and can also facilitate the integration of renewable energy sources. Within the scope of the first and second technical study on the SRI, the following definition has been adopted:

"Smartness of a building refers to the ability of a building or its systems to sense, interpret, communicate and actively respond in an efficient manner to changing conditions in relation the operation of technical building systems or the external environment (including energy grids) and to demands from building occupants,"

The SRI aims to raise awareness of the benefits of smarter building technologies and functionalities and their added value for building users, energy consumers and energy grids. Thereby it can support technology innovation in the building sector and become an incentive for the integration of cutting-edge smart technologies into buildings.

A first technical study developed a definition and draft methodology for the SRI. The second technical support study has built further on the available knowledge of the first technical study to deliver the technical inputs needed to refine and finalise the definition of the SRI and the associated calculation methodology. Furthermore, it explored possible options for the implementation of the SRI and evaluated their impact at the EU level in order for the Commission Services and Member States to be informed on the possible modalities for an effective implementation of the SRI scheme and related potential impacts.

Throughout this work the consortium partners of both technical studies have consulted with relevant stakeholders and used the findings to inform the analysis while helping to build awareness and consensus with regard to the project's aims and the most viable approach to achieve them.

In the final report the technical study team propose a consolidated methodology to calculate the SRI of a building. The methodology is a flexible and modular multi-criteria assessment method which builds on assessing the smart ready services present in a building. Services are enabled by (a combination of) smart ready technologies but are defined in a technology neutral way. The proposed calculation methodology is structured amongst 9 technical domains and 7 impact criteria. For each of the services several functionality levels are defined. A higher functionality level reflects a "smarter" implementation of the service, which generally provides more beneficial impacts to building users or to the grid compared to services implemented at a lower functionality level.

In the proposed method, the smart readiness score of a building or building unit is expressed as a percentage which represents the ratio between the smart readiness of the building or building unit compared to the maximum smart readiness that it could reach.

The disaggregated scores can express smart readiness for one or more of the following:

- Three key smart readiness capabilities as highlighted in Annex Ia, point 2 of the EPBD:
    1. Energy performance and operation
    2. Response to the needs of the occupants; and
    3. Energy flexibility.

- The seven smart readiness impact criteria:
    1. Energy efficiency
    2. Maintenance and fault prediction
    3. Comfort
    4. Convenience
    5. Health and wellbeing
    6. Information to occupants
    7. Energy flexibility and storage.

- The nine smart readiness technical domains:
    1. Heating
    2. Cooling
    3. Domestic hot water
    4. Controlled ventilation
    5. Lighting
    6. Dynamic building envelope
    7. Electricity
    8. Electric vehicle charging
    9. Monitoring and control.

A smart service catalogue for both a detailed and a simplified assessment method was elaborated in extensive consultation with stakeholders. The simplified Method A would be mainly oriented towards small buildings with low complexity (single family homes, small multi-family homes, small non-residential buildings, etc.), whereas the more detailed Method B is mainly oriented towards buildings with a higher complexity (typically large non-residential buildings, potentially large multi-family homes). For either method an informative self-assessment could be made available as an alternative to a formal certificate. The final report of the study also includes a proposal for weighting factors, a methodology for normalisation of the scores and a suggested triage process which details how to deal with absent services.

The SRI calculation methodology was successfully tested in a public beta test comprising 112 cases across Europe, which proved the viability of the approach. The feedback from the stakeholders participating in this test led to further finetuning and harmonisation of the SRI calculation methodology and the delivery of two consolidated service catalogues which are distributed as annex C and annex D of the full report. The proposed SRI calculation methodology is flexible to allow for adaptations to specific local contexts and allows for future updates in order to keep pace with new innovations in smart products and technologies available on the market.

The study also investigated the potential pathways for the effective implementation of the SRI in the EU. The review of various schemes and initiatives on which the SRI could build or connect to has led to the development of a set of six primary potential implementation pathways and the identification of various trigger points in the building lifecycle that the SRI deployment could link to. The SRI is expected to exert an influence on the market adoption of smart services and technologies by both a "market pull" and a "market push" effect. The market *pull* effect is driven by the impact that SRI assessments on properties have on the deployment of smart services and technologies, through raising awareness among stakeholders in the value chain at the property level. The market *push* effect is a result from the common framework that the SRI provides for service providers to self-organise and promote their service offers on a common basis in line with the SRI criteria across the EU. Research was initiated to determine potential designs for the format of the SRI. This recognises that for the scheme to be effective it will need to have an attractive and recognisable format that gives visibility to the SRI and effectively conveys information to users of the scheme.

Building on the outcomes of this work, the study provides technical guidelines and recommendations addressing (1) the operational, organisational and legal design of the SRI scheme, (2) the efficient and cost-effective assessment of the SRI and (3) the management of the SRI after adoption. These were informed by considerations of costs, data needs, training for assessors, etc. which helped to shape the development of the methodology and implementation pathways in an iterative manner.

Finally, the study quantified the costs and benefits of implementing an SRI in the EU building sector for the horizons of 2030, 2040, 2050. The impact analysis reveals that rolling out the SRI across the EU would be strongly beneficial, with the greatest net benefits arising from linking the SRI assessments to the Energy Performance Certification (EPC) assessments of buildings, or the article 8 requirements under the EPBD. The SRI could lead to 5% higher final energy savings by 2050, unlocking an increase in investment of 181 billion euro over 30 years compared to a business-as-usual case and up to 32 million tonnes of avoided greenhouse gas emissions per year.

The study team concludes that the roll-out of the SRI would result in a strongly beneficial impact and observes a broad consensus among stakeholders on most of the key principles and methodological choices of the proposed SRI developments.

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LIST OF MAIN ACRONYMS

AHP	Analytical Hierarchy Process
BACS	Building Automation and Control Systems
BEMS	Building Energy Management System
BIM	Building Information Model
BRP	Building Renovation Passport
DBE	Dynamic Building Envelope
DER	Distributed Energy Resource
DG	Directorate-General (of the European Commission)
DHW	Domestic Hot Water
DMS	Distribution Management System
DPC	Data Protection Class
DSM	Demand-Side Management
EC	European Commission
EED	Energy Efficiency Directive
EMS	Energy Manegement System
ENISA	European Union Agency for Network and Information Security
EOL	End Of Life
EPC	Energy Performance Certificate
EPBD	Energy Performance of Buildings Directive
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
GHG	Green House Gas
HEMS	Home Energy Management System
ICT	Information and Communication Technologies
IoT	Internet of Things
IPW	Implementation pathway
LENI	Lighting Energy Numerical Indicator
LCA	Life Cycle Analysis
MV	Mechanical Ventilation
MS	Member States
M&C	Monitoring & Control

MCDA	Multi-criteria decision analysis
MCDM	Multi-criteria decision making
MFH	Multi-Family Home
OEM	Original equipment manufacturer
PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rules
PM	Particulate Matter
POP	Persistent Organic Pollutants
RES	Renewable Energy Systems
SAREF	Smart Appliances REFerence (ontology)
SFH	Single Family Home
SME	Small- or medium-size enterprise
SRI	Smart Readiness Indicator
SR	Smart Ready
SRT	Smart Ready Technologies
TBS	Technical Building Systems
TES	Thermal Energy Storage
VOC	Volatile Organic Compound

INTRODUCTION

CONTEXT

Buildings consume 40% of the European Union's final energy. Around 75% of the current EU housing stock is considered to be energy inefficient; annual renovation rates are low (0.4–1.2%) and the renovation depth is generally considered too shallow. There is a clear need to accelerate and finance building renovation investments and leverage smart, energy-efficient technologies.

One of the focus points of the Energy Performance of Buildings Directive (EPBD)[5] is to better tap the potential of smart ready technologies (SRT). A greater uptake of smart technologies is expected to lead to significant energy savings in a cost-effective way, meanwhile improving comfort in buildings and allowing a building to be adjusted to the needs of the user. Additionally, smart buildings have been identified and acknowledged as the key enablers of future energy systems, in which there will be a larger share of renewables, distributed supply and energy flexibility that is also managed on the demand side (e-mobility infrastructure, on-site electricity generation, energy storage). Smart technologies, such as building automation and control systems or smart meters, allow to flexibly adapt the energy consumption of buildings, thereby contributing to the development of smart grids and to a better integration of renewable energy[6] e.g. through self-consumption.

The EPBD aims to provide additional support to information and communication technologies (ICT) and smart systems by:

- introducing building automation and control systems (BACS) as an alternative to physical inspections of technical building systems
- reinforcing building automation by introducing additional requirements on room temperature controls, building automation and controls, and enhanced consideration of typical operating conditions
- using building codes to support the roll-out of the recharging infrastructure for e-mobility
- introducing a 'Smart Readiness Indicator (SRI) for Buildings' to assess the technological readiness of buildings to interact with their occupants and the energy environment and to operate more efficiently.

Introducing such an SRI will raise awareness of the benefits of smarter building technologies and functionalities and their added value for building users, energy consumers and energy grids. It can support technology innovation in the building sector and become an incentive for the integration of cutting-edge smart technologies into buildings. The SRI is expected to become a cost-effective measure that can effectively assist in creating more healthy and comfortable buildings with a lower energy use and carbon impact and can facilitate the integration of renewable energy sources (RESs). Besides providing a framework to rate the level of smartness of individual buildings, the SRI will also contribute

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[5] Directive 2010/31/EU on the energy performance of buildings as amended by Directive (EU) 2018/844.

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

[6] https://ec.europa.eu/energy/en/topics/markets-and-consumers/smart-grids-and-meters/overview

to standardise across the EU the way information on smart readiness of buildings and technical building systems is rated and presented, thus ensuring the information is common and easy to understand.

Aims and objectives of the technical support studies

In order to support the establishment of the SRI, the Commission Services contracted two technical support studies. A first technical study to support the establishment of the SRI was launched in March 2017 and conducted by a consortium consisting of VITO NV, Waide Strategic Efficiency, Ecofys and Offis[7].

This first study aimed at investigating the possible scope and characteristics of such an indicator. It explored the concept of smart ready buildings and compiled a catalogue of smart ready services as well as a provisional methodological framework for the calculation of the SRI score via assessment of these smart ready services. It also presented a provisional EU impact assessment of the SRI

A second technical support study started in December 2018 and was conducted by a consortium consisting of VITO NV and Waide Strategic Efficiency Europe. This second study builds upon the knowledge acquired via the first study, and aims to deliver the technical inputs needed to refine and finalize the definition and calculation methodology for the SRI. This study also explores several options for the implementation of the SRI and evaluates their potential impact at the EU level so that the Commission Services may assess the technical modalities for the effective implementation of the SRI scheme.

Throughout the process, the consortium partners of both technical studies have consulted extensively with relevant stakeholders and used these findings to inform the analysis while helping to build awareness and consensus over the aim and the most viable approach to develop and implement a Smart Readiness Indicator for Buildings.

This final report summarises the outcomes of the second technical support study, thereby integrating the main findings of the first technical support study.

This report is structured amongst the main tasks undertaken in the technical support study:

- Task 1: Technical support for consolidation of the definition and the calculation methodology of the SRI.
- Task 2: Investigation of SRI implementation pathways and the format of the SRI.
- Task 3: Guidance for effective SRI implementation.
- Task 4: Quantitative modelling and analysis of the impact of the SRI at EU level.
- Task 5: Stakeholder consultation and study website.

[7] "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

1 TASK 1 - TECHNICAL SUPPORT FOR THE CONSOLIDATION OF THE DEFINITION AND THE CALCULATION METHODOLOGY OF THE SRI

TASK SUMMARY AND OBJECTIVES

The objective of Task 1 is to extend and consolidate the technical recommendations for the definition and underlying calculation method of the SRI in line with the technical framework given by the Directive. Hereto, this task critically reviews and builds further on the outcomes of the first technical study on the SRI. In the process of doing so, it includes input from relevant national, European and international research projects, stakeholder consultation (Task 5) and simulations outcomes (Task 4) that can fill identified gaps in standards. As such, it aims to deliver technical recommendations that will support the Commission Services to draft a definition and calculation methodology of the SRI which can be applied in practice in an efficient and cost-effective way while being open for innovation. In addition to a unique and consistent definition and underlying calculation method at the EU level, specific attention is given to identifying and drafting possibilities to tailor the calculation method to specific local context, if and where relevant.

In all the activities of this task, specific attention is paid to the formulation of technical recommendations that are technology-neutral and are designed not to constrain the implementation of the scheme.

OBJECTIVES

The objective of Task 1 is to provide extended and finalised technical recommendations on the definition of the SRI and the corresponding catalogue of smart ready services as well as the SRI calculation methodology. As such, it sets out to review, extend and consolidate the work performed in the first technical study on the SRI. To this end, the consolidated SRI framework should:

- cover the key functionalities highlighted in the SRI technical annex of the amended EPBD – ability to maintain energy performance and operation of the building through the adaptation of energy consumption; ability to adapt a building's operation mode in response to the needs of the occupant; flexibility of a building's overall electricity demand
- be complementary to relevant existing initiatives, including policy initiatives such as Energy Performance Certificates (EPCs), Ecodesign and energy labelling, Level(s), Building Renovation Passports (BRPs) and broadband-ready label, but potentially also to other market initiatives such as voluntary labelling schemes for buildings or specific product segments
- be practically applicable in an efficient and cost-effective manner
- provide a fair and well-balanced representation of smart technologies in buildings while remaining technology-neutral
- reflect the potential and added value of advanced and innovative technologies
- pay attention to interoperability, connectivity of buildings and cybersecurity.

TASK APPROACH AND PROPOSED METHODOLOGY

The activities conducted under Task 1 are:

- a targeted state-of-the-art review
- derivation of technical recommendations for the definition of the SRI
- derivation of technical recommendations for the development of the calculation methodology of the SRI.

1.1. ACTIVITY 1: A TARGETED STATE-OF-THE-ART REVIEW

The targeted state-of-the-art review involves conducting a critical review covering the aspects of interest for the definition of the SRI and its calculation methodology. Specifically, it involves:

- analysing the output of the first technical study in relation to the definition of the SRI, the draft calculation methodology and the preliminary analysis of impacts and carrying out a detailed assessment of the feedback collected from stakeholders in the scope of the first technical study
- reviewing other relevant initiatives (at the EU, Member State, local/regional and wider international level when relevant) that are aimed at characterising smart buildings
- reviewing other initiatives that could be related to the SRI or that the SRI could have an impact upon (including certification and labelling schemes, such as EPCs, voluntary building passports, etc.)
- conducting an analysis and synthesis of the findings within a report that will be used to inform the direction and activities taken in the rest of the study.

1.1.1 REVIEW OF STAKEHOLDER COMMENTS ON THE FIRST TECHNICAL STUDY AND SINCE

To do this work the study team of the second technical support study began with a review of the first technical study and the stakeholder comments received, which largely covered the following topics:

- the guiding principles to develop the SRI as set out in the first study (included as ANNEX I in this report)
- the scope of the SRI including whether or not to broaden it, and the most pertinent parameters
- treatment of absent services
- the quality and reliability of the assessment process
- guidance and training of the assessors
- streamlining the assessment procedure
- the scoring system applied
- weightings and weighting systems and the need for also reporting disaggregated scores
- relevance of SRI outputs to specific target groups
- the potential for quantified, rather than ordinal, assessment
- evolving towards remote quantified assessment
- the catalogue of services and functionality levels within them
- the proper interpretation of “smart ready” versus “smart now” capabilities
- commissioning

- cost and cost-benefits
- country/region specificities and implications for the methodology
- climatic specificities
- building type or intrinsic specificities
- data protection
- definitions and terminology (see ANNEX A for a glossary of the main terminology used)
- treatment of specific services, including district heating and electric vehicles (EVs)
- how to best treat demand-side management (DSM) services
- interactions with other schemes such as EPCs, Level(s), building renovation passports, etc.
- testing and validating the methodology
- implementation guidance and protocols
- interoperability of SRTs
- consistency in application of the SRI, including ensuring a level playing field and closing loopholes
- ensuring that the most appropriate terminology and language is used in the definitions
- how to best update the methodology and address innovation
- standardisation and codification of services and functionality levels.

The responses were documented and organised by theme so that the range of views and suggestions per topic are clear, and were summarised prior to discussion with the Commission. The findings were also communicated to the team members responsible for any activity covered by these comments (especially those in the Tasks 1 to 3) so that their work could consider and build upon these comments. Note that to a large extent the stakeholder comments mirrored and informed the set of activities to be conducted in the study and hence it was essential for the study team to be fully cognisant of these. Note, as consortium members also conducted much of the first study they had established communication channels with key stakeholders, they were well aware of their views which had substantively informed the first study.

In addition to this the study team conducted a survey of stakeholder views on a variety of topics prior to the first stakeholder meeting of the second technical study (held on 23 March 2019) and also surveyed opinion on some topics in the first meeting of the two expert Topical Stakeholder Working Groups (see 5.1.2 - Topical Stakeholder Working Groups):

- Group A: SRI value proposition and implementation
- Group B: SRI calculation methodology.

Each Topical Stakeholder Working Group was comprised of a diverse and representative group of expert stakeholders who had been selected through the study consultation process to provide input into key issues for the study. The first meeting of both groups was held on 26 March 2019.

The ensemble of stakeholder comments received after the conclusion of the first technical study are summarised by theme below.

1.1.1.1 Overall approach

The overall approach expounded in the first SRI study was broadly supported by stakeholders both during and after the study period. Some key stakeholders expressed strong support for the initiative and approach adopted by the study team. Other stakeholders representing an array of interests (equipment and service providers, construction sector, property owners or managers, the energy efficiency services sector, consumers associations and NGOs) all expressed support for the initiative and basic approach. No stakeholders said they were not in support, although some expressed views about certain aspects of the approach and or scheme, as will be summarised below.

1.1.1.2 Scope of the SRI

In general, stakeholders did not express any reservations about the scope of the SRI as defined in the EPBD and only had comments about interpretation or areas that are potentially open to interpretation.

With regard to the scope of the SRI, including whether or not to broaden it and the most pertinent parameters, several stakeholders representing property and landowners indicated that:

- they do not favour linking the concept and eligibility of smart buildings to nearly zero-energy buildings (NZEB) or very efficient buildings, but rather see smartness as mostly linked to system functionalities
- although the scope of the SRI (as given by the EPBD) focuses on energy, their members did not see energy as the first area where smartness has impact; rather, security is mentioned first, although comfort and sustainability are also important aspects.

The issue of whether a building would need to attain a high energy efficiency – as, for example, determined by an EPC assessment – before it becomes eligible for the SRI divides stakeholder opinion. In general, stakeholders representing the insulation sector and energy efficiency interests believe that it should do, while those representing other groups – for example property owners, consumers, service suppliers and manufacturing – tended to argue for the opposite. This is the aspect of SRI eligibility where there is most division in stakeholder views.

The other area of scope where some stakeholders have expressed different perspectives is the treatment of smart building aspects that are not explicitly referenced in the EPBD. These can include smart security features, smart accessibility services and smart safety features, e.g. addressing fire safety as well as other systems (e.g. lifts) and services (e.g. water services). In general, suggestions that these factors should be considered have only been made by a small number of stakeholders who were not engaged in the first study's stakeholder consultation process. This implies that they may not have been following the EPBD process and were unaware of the constraints its focus imposes; however, as these issues are undoubtedly of interest to building owners and occupants, clarity in the delineation of the SRI could be important to avoid confusion about what it addresses.

1.1.1.3 Value proposition

Considering that the SRI is voluntary (at least in terms of Member State adoption), several stakeholders have stressed the importance of clearly identifying its target groups and clarifying their needs so that the SRI can be positioned to respond to these and hence be sufficiently enticing to be adopted.

Stakeholders interviewed in between the two technical studies – by the technical study team or the Commission Services – generally had little to say about the SRI value proposition beyond that which was expressed in the first technical study and the wording in the EPBD itself. Their comparative silence on this topic may imply that they broadly agree with how the earlier work framed the SRI value proposition, albeit that it left open many issues with regard to target groups and their specific interests. Nonetheless, some stakeholders have made additional suggestions following the first study's conclusion and consultation process. Stakeholders from different sectors have independently suggested that the SRI would present a stronger value proposition were it to be supported by linkages that access energy efficiency financing, and that were these to be established it would strengthen motivation to engage with the scheme. One stakeholder also hoped that the SRI could be used to help assess the impact of refurbishments.

The members of Topical Group A, which was convened as part of the present SRI technical study to address the value proposition and implementation of the SRI, were asked their opinions on the SRI's value proposition. In general, they suggested that two benefits of smart buildings are the most important:

- extra comfort for the occupier
- monetary benefits (decrease in energy costs).

In addition, it was said that for a successful market uptake, the SRI must have an impact on the value of the property. A group member also commented that the theme of the overall environmental performance of the building was not very well highlighted in the current proposal for the SRI but argued that this is inherently the background of the SRI's development.

Audience

With regard to the intended audience of the SRI, several stakeholders from the property sector asserted that building occupiers, bill payers and owners are the most important audiences and thus their needs should take precedence, not least because of the need to get them to grant permission to access the related data. In contrast, one stakeholder from the same sector proposed that the SRI should target investors more than consumers themselves, particularly for social housing. These responses imply that the target audience(s) could vary as a function of the building type.

In the Topical Group A meeting, which comprised over 20 stakeholders representing a diverse range of interests, including several Member State representatives, the following suggestions on the potential audiences for the SRI were received:

- real estate investors can be a very important part of the success
- cities and municipalities should be considered as a potential user
- it might be sensible to separate occupant-owners and tenants
- potentially add insurance companies

- separate contractors from designers
- include building valuators
- utilities and grid operators might become more interested when zero energy buildings emerge.

It was also remarked that small- and medium-size enterprises (SMEs) could be treated as a separate category of buildings, including pubs, restaurants, etc., as they are a group apart from the residential and non-residential sector split.

Overall, however, the group expressed the view that the important audiences for the SRI are facility managers, owners and occupants.

Relative importance of impact criteria

Topical Group A members were asked to approach the topics from the "user" perspective rather than their own or that of their organisations. They were asked to consider the eight impact criteria in the first SRI study and to determine whether they were sufficient, or if any more should be considered. Apart from a proposal to also score reliability of the SRI as an indicator (which the discussion then acknowledged was a horizontal issue somewhat apart from the impact criteria per se), the group members were content that the eight impact criteria covered the main value propositions of the SRI. When asked to vote to indicate which of the criteria they thought end users would deem to be most important, they concluded:

- comfort was the most important
- energy efficiency was the second most important
- health and well-being, and convenience and flexibility also scored highly
- self-generation was the least important.

This implies that all the eight impact criteria considered in the first study, except potentially the self-generation parameter, could be taken forward into the technical definition work of the SRI. Section 1.3.2 of this report discusses how this input was used to consolidate the proposal to seven impact criteria.

1.1.1.4 Definition

The issue of what would fall within the definition of the SRI and what would belong elsewhere (e.g. within an EPC) was probed in the first meeting of Topical Group B, when members were asked to vote for or against in response to the statement:

> *'The SRI should only score the added value of smarter controllability, information gathering, communication features and interoperability, and not the (energy) performance of the technical building systems themselves (e.g. lighting control irrespective if these are LED or incandescent lights) since the goal of the SRI should be primarily to illustrate the current level of smartness compared to the maximum potential of that specific building rather than to form a comparison framework among buildings.'*

Twenty voted to agree, and none to disagree, which suggests that there is unanimity that the SRI should only aim to address the value-added that is brought by smart technologies and services rather than the inherent energy performance of the TBS away from its control.

Ensuring the most appropriate terminology and language is used in the definitions

Since the first SRI technical study no additional stakeholder comments were received on this issue.

The proper interpretation of "smart ready" versus "smart now" capabilities

As discussed in the first technical study, the distinction between the two concepts "smart ready" and "smart now" is potentially important in the design of an indicator. The term "smart ready" implies that the building itself is smart but its potential to realise the benefits from smart services may be constrained by limiting factors in the capability of the services it connects to at its boundary (e.g. smart meters). This recognises the distinction between smart readiness as opposed to operational smart capability.

The definition of "readiness" was raised in a discussion with Topical Group B[8]. It was argued that having a service does not guarantee that the building is working properly and that this can only be assessed when auditing the building. The study team clarified that commissioning is out of scope of the proposed scope for the SRI at this moment. Only the availability of services would be assessed, not the actual performance.

It was also mentioned that different levels of readiness exist: some services can react to signals from the BEMS, whereas others can also react to external signals. These differences in readiness are captured in the functionality levels of a service: services that can respond to external signals have higher functionality levels (and thus a higher SRI score) than services which only interact with the BEMS.

In a discussion with Topical Group B on the triage process, a related discussion was opened about whether or not the absence of a domain should be penalized. In the context of the triage process, "smart ready" relates to the smartness of the services already present in the building (hence not penalising absent services), whereas "smart possible" relates to the possibility of having (smart) services in the building (hence penalising absent services). More information on the discussion can be found in section 1.3.5.

Cost and cost-benefits

Since the first SRI technical study there have been no additional stakeholder comments received on this issue.

1.1.1.5 Calculation methodology

Those stakeholders interviewed between the first and second technical studies generally expressed support for the SRI calculation methodology set out in the first study; however, some proposed some amendments. When comments were proffered, they tended to be either to support the approach in the first study or to stress the need to keep the process simple – which might imply some simplification. Some proposed starting with a simple method and evolving towards a more detailed approach in a second version of the SRI. The use of a checklist, as is the case in the first study's methodology, was generally supported. While some stakeholders emphasised the need to "keep things simple" they did not put forward suggestions on how the first study's methodology could be further

[8] Topical Group B: Calculation methodology – web meeting 7/5/2019

simplified, except with regard to the choice of impacts to be evaluated (see section 1.2.4). Also, while many stakeholders see the value of having a simplified method, the same stakeholders have sometimes proposed that additional services or functionalities be included (or conversely have only reacted if a suggestion is made not to count a service or functionality that they believe if important), so it was not fully clear where an acceptable balance lies.

Treatment of services

Most stakeholders provided comments on the services to be included in the first technical study, so in general stakeholders interviewed between the studies had little to say on the choice of services, which suggests a relative level of satisfaction with the list proposed. Nonetheless, the following suggestions were made:

- one stakeholder expressed a desire to see more focus on smart metering
- one expressed particular interest in energy flexibility and fulfilment of users' needs, but did not propose changes to the services to be evaluated
- another proposed that systemic benefits should not be reduced to the electricity system, e.g. solutions for a smart integration (load management) of buildings in district heating are already available and being deployed in Europe
- one wanted more emphasis on services related to system monitoring/user feedback, particularly in relation to indoor environmental quality (IEQ).

Impact criteria

A number of stakeholders interviewed between the studies suggested that one means of simplifying the methodology would be to reduce the eight impact criteria set out in the first technical study to the three aspects set out in the EPBD text:

- The ability to adapt its operation mode in response to the needs of **the occupant**, paying due attention to the availability of user-friendliness, maintaining healthy indoor climate conditions and ability to report on energy use.
- The ability to maintain energy efficiency performance and **operation** of the building through the adaptation of energy consumption, e.g. through use of energy from renewable sources.
- The flexibility of a building's overall electricity demand, including its ability to enable participation in active and passive as well as implicit and explicit demand-response, in **relation to the grid**, e.g. through demand side flexibility and load-shifting capacities.

It should be noted that while stakeholders seem to have made this suggestion primarily to simplify the SRI, practically it would not lower the assessment effort as the methodology would still involve assessing the TBSs to determine their basic type and functionality, and once that is done the assessment tool automatically calculates the impacts (whether there are eight or three). Therefore, the real value of this suggestion is in regard to whether it would assist communication (or not) of the SRI value proposition.

As mentioned previously under the value proposition discussion, this topic was also surveyed during the Topical Group A meeting, where each participant was asked to vote up to four times to express which of the impact criteria they thought the target audience for the SRI would find most important. It was concluded that:

- comfort was the most important
- energy efficiency was the second most important

- health and well-being, and convenience and flexibility also scored highly
- self-generation was the least important.

Interestingly, prior to voting, this same group was invited to propose impacts that had not been considered in the first technical study or comment on whether the eight were the impacts that the SRI should assess. In that discussion nobody proposed to add or remove impacts from this list. The voting, however, suggests that self-generation has the least impact.

The scoring system applied

Stakeholders interviewed between the technical studies were generally supportive of the fundamental aspects of the approach to scoring the SRI put forward in the first technical study, which uses ordinal rankings of functionality per domain and service and aggregates them up to attain scores at the domain, impact or whole building level. Some, however, expressed a desire to migrate towards a performance-based calculation method where possible. When the topic was probed further, they conceded that a performance-based approach might only currently be possible for some SRI aspects. One stakeholder wished for more precise, quantified indicators for load-shifting capacity yet acknowledged that in practice this is very hard to do as the calculation of such indicators would require more information/data than is normally available. To this end they suggested that a blended approach could be appropriate where:

- for buildings and projects where detailed information and models are available (typically, new and major renovations of large non-residential buildings), quantitative indicators could be included in the SRI
- for 'average' existing buildings and building units (in particular apartments and houses), a more basic approach such as the one proposed by the first study would be acceptable.

Another stakeholder said they would favour an SRI based on performance data and not only on the assessment of available smart ready services/functionality:

- if the SRI is to be based on functionalities and not on real performances, they would like to see a disclaimer that makes it clear
- they explained that functionalities of smart systems are evolving, and the SRI should not 'lead' to a freeze in this evolution (this is related to the feedback on an innovation-friendly SRI that the study team has received from other stakeholders).

Aggregation of services into service domains

This topic was not spontaneously raised by any of the stakeholders interviewed between the two technical studies and was not addressed in the stakeholder survey or Topical Groups associated with the first stakeholder meeting in March. The lack of spontaneous reaction implied that stakeholders may be content with the approach put forward in the first technical study.

Weightings and weighting systems

Stakeholders interviewed between the two technical studies generally supported the flexibility of the weighting framework (i.e. the option to consciously apply weightings) set out in the first technical study, but the following observations were also made:

- one stakeholder generally supported the framework proposed by the first study but saw many points where further discussion and consolidation would be needed (e.g. individual scoring of services and domain impact weights)
- several stakeholders expressed the view that weightings should be fixed at the overall scheme implementation level and that assessors should not have the liberty to apply weightings
- some stakeholders challenged the specific (actually purely illustrative) weightings by service domain given in the worked examples shown for the first technical study. These weightings specifically applied to the energy balance and hence were only applied when determining the energy savings impacts of SRTs. While the stakeholders suggested that different weightings would be more representative of the actual average energy balance, they all supported the principle that the examples were intending to illustrate.

Building type or intrinsic specificities

Stakeholders representing property and landowners interviewed between the technical studies expressed the opinion that the type of building, ownership and occupancy needs to be taken into account better in the calculation of the SRI. The comments were short on detail but there seems to be an appetite for the SRI calculation (and possibly the related assessment) framework to be tailored to the characteristics of specific building types as appropriate.

Treatment of absent services

The first technical study included extensive discussion about why there could be a need to exclude absent services from the calculation process and how to go about doing this. Stakeholders did not volunteer views on this topic since the conclusion of the first study, except to express agreement that it can be appropriate and necessary to discount absent services in an initial triage process, and to assert that it is important that there are clear guidelines/protocols about how this should be done. The aim would be for the decision on what to include or exclude to be clearly laid out rather than be the prerogative of the assessor.

1.1.1.6 Assessment method and process

The assessment method and process are critical to the success of the SRI and stakeholder views, as set out below, were canvassed between the studies and during the first stakeholder meeting.

On-site or remote assessment

Stakeholders canvassed between the two technical studies representing property and landowners expressed the view that on-site inspections are probably unavoidable if the SRI is to be reliably assessed, but they also envisage prospective forward-looking evolutions, e.g. links to digital models, such as building information modelling (BIM). They also stressed that the assessor should be free to evaluate whether on-site inspection is needed. There are many residential buildings with standard, well-known technical solutions, and they see no need to go to the trouble and expense of conducting inspections for these. This may especially be the case if a good BIM or digital model is available for the building.

Who should do the assessment?

Generally, stakeholders interviewed between the technical studies were supportive of the notion of having an independent third-party expert assessment for the SRI; however, one stakeholder suggested considering more forward-looking approaches to the SRI assessment, based on self-evaluation and/or data obtained directly from the TBSs. On this latter point, they emphasised that constraints resulting from compliance with GDPR should be taken into account.

Streamlining the assessment procedure

The first technical study followed a streamlining process that reduced an initial set of almost 100 smart services to 50 to facilitate the assessment process and improve the viability of the scheme. Stakeholders interviewed between the technical studies did not comment on this specifically, which implies they most likely approved of the streamlining in the first study; however, without mentioning limiting the number of services to be assessed, several stakeholders expressed the importance of keeping the scheme simple, which might imply approval of further reductions in the number of smart services to be assessed.

Evolving towards remote quantified assessment; the quality and reliability of the assessment process; commissioning

Each of these topics was discussed at least partially in the first technical study but few specifics were added in the inter-study stakeholder review process, other than confirming that the quality and reliability of the assessment process is considered to be a very important success factor for the SRI. For that reason, most interviewed stakeholders expressed support for an independent third-party assessment process.

Guidance and training of the assessors

Several stakeholders commented on the importance of ensuring that adequate guidance and training be made available for third-party SRI assessors.

Role of system suppliers

Several stakeholders mentioned that assessment would be facilitated and made more reliable if system suppliers provided readily accessible information on the functionality of their products in a manner that is aligned with the SRI ordinal classification. This could involve suppliers highlighting relevant system capabilities in technical documentation, but perhaps even better could involve application of an easily scannable code (such as a QR code) that an assessor could use to instantly determine the product/system's functionality ranking. From a practical perspective this implies that the system-level functionality is knowable either at the factory (in which case the manufacturer could add the information) or at the point of installation (whereupon the installers would need to supply the information).

1.1.1.7 Data protection

Several stakeholders mentioned the importance of respecting data protection and GDPR provisions but did not comment explicitly about what this might mean for implementation of the SRI.

1.1.1.8 Interoperability of SRTs

At a meeting on the SRI hosted by a stakeholder and held on 15 May 2018, work was presented on what ETSI is doing on standards for interoperability, in particular with regard to SAREF ontologies. It is noted that this is mainly targeted towards interoperability between novel TBSs and the energy grid. In the scope of the SRI, operability among various TBSs can also be of importance, and equally legacy systems should be considered.

1.1.1.9 Interactions with other schemes

Several stakeholders commented on the need to clarify how the SRI will interact with other schemes such as EPCs, Level(s), BRPs, etc. As mentioned previously, some proposed that in the case of the EPC a minimum EPC level should be set below which it is not permitted to have an SRI, whereas others would like buildings to be eligible for the SRI whatever their energy performance. One stakeholder suggested that the SRI could be used as a tool to assess the impact of refurbishments and thereby be linked to energy efficiency financing. A more common comment is to ensure that the SRI is complementary to other building initiatives, such as BRPs, Level(s) and tools/technologies such as digital logbooks and BIM.

Aside from the well-known schemes discussed above, the SRI will be operating in a context wherein major private sector players are aiming to roll out digitalisation services in households. For example, one stakeholder of the utility sector is reported to be developing a new offer for "future energy hubs" – smart homes with PV, batteries, EVs, smart thermostats, etc. – wherein they intend to create a digital customer experience around an advanced software environment for monitoring and control of home energy. This would also include a dashboard to maximise user interaction. They have asserted that they see a link between this type of offer and the SRI, which could give customers a simple and easy-to-understand picture of home smartness (in an analogy with EPCs and energy labels). They think the SRI could contribute to helping to market the benefits of a smart ready home.

1.1.1.10 Testing and validating the methodology

Several stakeholders offered their support to assist in the testing and validation of the SRI methodology. To support this process, the study team initiated an open public testing phase of the draft SRI methodology to capture this feedback from the stakeholder community (see section 5.1.3 for more details).

1.1.1.11 Implementation

Implementation was one of the key foci of Topical Group A. At the meeting held on 26 March 2019 various implementation issues were touched upon briefly.

It was mentioned that implementation pathways can be dependent on local conditions, e.g. the regulatory framework for energy supply can feature differences depending on Member States, and therefore the most viable implementation pathways are dependent on the type of building and the circumstances applicable in each Member State. It was also mentioned that as some Member States already require independent commissioning of large non-residential buildings, the SRI could tie into that process. The most common suggestion, both with Topical Group A and in more widespread stakeholder consultation, is that the SRI should/could be implemented at the same time as an EPC assessment. In many cases this would exploit the synergies that: access to the building is granted; a trained third-party assessor is available; the information gathered in the rest of the EPC could help inform the SRI (e.g. for energy balance weightings) and vice versa; an assessment (and hence coverage of a large part of the building stock) would be guaranteed; communication of both instruments could be managed in a complementary and consistent manner; and costs would be minimised as there would be no duplication of setting up and travel time. Some stakeholders would prefer that the SRI is mandatory at the Member State level, i.e. that Member States decide to implement it in a mandatory manner within their jurisdictions (this is an option within the EPBD formulation).

Aside from the above, many other suggestions were forthcoming. There was a lively discussion, with some advocating that the SRI be focused on new-builds only in its early stages as this would allow system designers and commissioners to factor it into their design deliberations and would also allow it to be piloted on a small part of the building stock before it is rolled out to a large proportion of the stock.

One stakeholder suggested that the SRI could provide answers to tangible questions posed by users and service providers, for example:

- "This building is ready for energy performance contracting"
- "This building is ready to communicate performance data to users".

One stakeholder suggested that the SRI could be promoted effectively by smart energy solution providers; in particular, aggregators and cities/municipalities could also be involved.

Implementation options and pathways have been explored in much more depth with Topical Group A (see 5.1.2.1).

Consistency in application of the SRI

Some stakeholders expressed the importance of the SRI being applied consistently across the EU for the scheme's integrity and impact to be assured. They argued that this would ensure there is a level playing field and help close loopholes. The establishment of common guidelines and protocols are required to achieve this as well as establishing clarity about which elements are fixed centrally versus which, if any, would be locally determined.

1.1.1.12 Standardisation and codification of services and functionality levels

The need to establish a common technical basis for the codification of services and their functionality levels was raised in the first technical study. Some stakeholders commented that this is important but that reliance on formally adopted technical standards risks being too unresponsive to the rapidly evolving nature of smart services. While this is recognised, stakeholders did not proffer any specific suggestions on how the technical consistency and clarity that can be provided by technical standards can be achieved by other means that would be sufficiently responsive. This topic was therefore to be explored by Topical Group A.

1.1.1.13 How best to update the methodology and to address innovation?

This topic was raised as an issue in the first technical study and many stakeholders have since also expressed the importance of the methodology being capable of rapid update so that emerging smart solutions are not impeded due to their not being catalogued and recognised within the SRI methodology. While all agreed on the importance of the issue, no specific suggestions of how best to do this were put forward, apart for some stakeholders suggesting that this was a reason why the SRI should aim to evolve to a quantified performance-based assessment methodology as quickly as possible. It should be noted that many schemes face the same challenge and that the approaches used in other initiatives (see the section 1.2.2) could also be applied.

1.1.2 TARGETED REVIEW OF OTHER RELEVANT WORKS AND INITIATIVES

The next step of the targeted review was the conduct of research into other relevant works and initiatives (at the EU, Member State, local/regional and wider international level when relevant) that are aimed at characterising the smartness of buildings or related aspects. To conduct this work, the study team:

- performed desk research into relevant projects, studies and initiatives (including standards, labels, EU collaborative projects, etc.) and whenever appropriate directly contacted the organisations involved in these activities to discuss the nature of the initiatives, establish their characteristics and consider to what extent they could inform the development of the SRI
- performed desk research into all the initiatives mentioned in the tender document (e.g. EPCs, "broadband ready" label , Level(s), voluntary European Cybersecurity Certification scheme, BIM, a future European industrial digital platform for construction, the digital building logbook, SAREF common ontology for smart appliances, well-established international and national building labelling and certification schemes (e.g. BREEAM, DGNB, LEED, etc.) and emerging initiatives for the promotion of smart buildings (e.g. SBA in France etc.) and whenever appropriate directly contacted the organisations involved in these initiatives to discuss the nature of the initiatives, establish their characteristics and consider to what extent they could overlap with, be pertinent to or interact with the SRI
- performed broader desk research and networking activities to establish details of any other relevant initiatives not mentioned directly in the tender document
- consulted with registered stakeholders to request insights into any pertinent initiative in addition to those mentioned above to ensure that they are considered and addressed in the same manner.

The findings of this review are reported in the sections below together with the outputs of the review of other initiatives that could relate to the SRI.

1.1.2.1 Energy Performance Certificates (EPCs)

EPCs provide information for consumers on buildings they plan to purchase or rent. They include an energy performance rating and recommendations for cost-effective improvements. Certificates must be included in all advertisements in commercial media when a building is put up for sale or rent. They must also be shown to prospective tenants or buyers when a building is being constructed, sold or rented. After a deal has been concluded, they are handed over to the buyer or new tenant. Under the EPBD, all EU countries have established independent control systems for EPCs.

EPCs are mandated under the EPBD but are implemented in different ways at Member State level. Most Member States require EPCs to be produced via a third-party inspection. Many use an asset-based assessment where the inspector enters details of the building's energy characteristics into a software tool that then calculates the energy performance of the building as an asset. Usually these software tools have encoded calculations from building energy performance standards – the tools themselves may or may not be proprietary but are generally approved by a managing authority. Some Member States permit energy performance classifications to be derived from metered energy data and basic building characteristics such as floor area. In some cases, the approach varies depending on the building type, e.g. Germany normally requires asset ratings but permits ratings calculated from energy consumption data for multi-family housing. Third-party assessment is usually conducted via qualified independent assessors, but the degree of training and qualifications required varies by Member State. Member States are also encouraged to conduct quality verification checks on the EPCs issued, but the degree of conformity is not usually reported (see "EPC quality" sub-section below).

Coverage and renewal periods

All Member States require EPCs to be issued for new buildings. In the case of existing buildings, Member States require EPCs to be issued whenever a building changes ownership or tenancy. Some Member States also require it to be done whenever a building undergoes a major renovation (e.g. defined in terms of the percentage of total floor area being renovated) or as a proof to grant support mechanisms. If an EPC has previously been issued for a building undergoing change of ownership or tenancy, the Member State may allow the same EPC to be used without rechecking up to a maximum period (usually 10 years but sometimes as low as 6; Member States sometimes have a shorter renewal period for non-residential building EPCs).

The rules applied make a large difference to the coverage (i.e. share of the total building stock having an EPC) that is achieved. From data reported in the public domain, the UK seems to have the highest annual issuance of EPCs with ~2.5 million issued per year, as compared to ~850,000 in France, ~420,000 in Italy, ~320,000 in Germany, and fewer in smaller Member States. In part, the differences in numbers are explained by:

- whether a fresh EPC must be issued every time a building changes tenancy or ownership, or whether it is only when the validity of a previous EPC has expired, or it is only every time there are major renovations
- whether a single EPC is issued for a multi-family building or a separate one for each apartment within it
- the number of buildings in the national building stock
- the average frequency that buildings change occupancy or ownership
- the share of single- versus multi-family dwellings
- the coverage of EPCs in the non-residential sector
- compliance with the requirements
- how long the scheme has been in effect.

Among eight countries surveyed in 2018[9] (Belgium [Flanders], Bulgaria, Germany, Greece, Poland, Portugal, Romania, Sweden), the total share of the building stock that had received an EPC ranged from as little as 1% (in the case of Bulgaria circa 2017) to 29% (in the case of Flanders circa 2017). The share may be significantly higher in some other Member States, notably the UK. Compliance with requirements is another factor that will have a big impact on the coverage

[9] https://ibroad-project.eu/news/8-country-factsheets/

achieved: while some Member States report compliance in the upper 90% range, others seem to have poor compliance.

Cost

Based on an analysis reported for 8 Member States, the cost of issuing an EPC varies from as much as ~€4.5/m^2 (Germany) to as little as €0.10/m^2 (Romania). Of course, the level of effort required for the appraisal is likely to vary considerably, as is the expertise required by the assessor.

Availability of assessors

All Member States that have data available report a large number of qualified assessors available to conduct the EPC assessments, e.g. there are reported to be over 1000 such assessors in Flanders, over 7000 in France, and over 17,000 in Germany.

Quality of EPCs

The quality of EPCs is sometimes challenged by stakeholders and appears to be quite variable. A survey[10] conducted by the Commission in 2014 asked Member States to indicate the number of EPCs they had subject to validation checks. Among the 19 Member States for which data are reported, the share of EPCs subject to validation checks averaged at about 2.4%, but the share varied considerably by Member State. The nature of these validation checks was unclear (e.g. from as little as checking that data were entered correctly and results calculated properly, to as much as revisiting the same properties and validating that the data collection and entry was done correctly), as was the percentage of checks that revealed problems, so the overall quality is unknown except by individual Member State authorities.

Impact of EPCs

The European Commission published a study on the impact of EPCs in 2013[11]. Based on an analysis of residential markets in Europe, the study found that higher energy savings resulted in substantially higher sale or rental prices on average.

National reports

EU countries have produced reports on the independent control systems they use for energy performance certificates[12].

In addition, a study on a voluntary common EU certification scheme for non-residential buildings has also been conducted for DG Energy[13].

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[10] https://ec.europa.eu/energy/sites/ener/files/documents/ics_art18_epbd_recast.zip

[11] https://ec.europa.eu/energy/sites/ener/files/documents/20130619-energy_performance_certificates_in_buildings.pdf

[12] https://ec.europa.eu/energy/sites/ener/files/documents/ics_art18_epbd_recast.zip

[13] http://ec.europa.eu/energy/sites/ener/files/documents/Final%20report%20-%20Building%20Certification%20Schemes%20-%20FINAL%2026112014.pdf

Relevance to the SRI

The experience of EPCs is mostly relevant to the SRI with regard to implementation but it also has methodological relevance. For the latter EPC data could potentially be used to inform aspects of the SRI calculation. With regard to implementation the EPCs involve direct on-site assessment by qualified (3rd party) assessors and hence provide a useful template and lessons with regard to what can be expected were such an assessment method to be used for the SRI in terms of the time and costs of assessment, gaining access to the property, training assessors, establishing an adequate pool of assessors and quality assurance of the assessments.

1.1.2.2 Level(s)

Level(s) is a framework produced by the European Commission, using voluntary reporting to improve building sustainability. Level(s) is intended to allow for a commonality in the EU's approach to environmental performance assessment of buildings and provide a simple jumping-off point for sustainability. The framework uses a series of indicators to compare and link building impacts with the wider EU-level sustainability priorities, thus giving the user a more manageable set of essential indicators and concepts at a lower level that help to achieve EU and Member State environmental policy goals.

Level(s) can also be used to aid design and construction of sustainable buildings – which are not only more comfortable and healthier, but also use less energy and fewer materials. Sustainable buildings have a reduced environmental impact, and due to their lower running costs are more profitable over longer time periods. The initiative seeks to move away from the "take, make and waste" economic model in favour of greater resource efficiency in sustainable buildings. The initiative recognises that the buildings sector accounts for approximately half of total energy consumption, half of all material extraction, one third of generated waste and one third of water consumption, making it one of Europe's most resource-consuming sectors.

The built environment is therefore a central target of the European Commission's circular economy policy: a regenerative economic system with minimal resource and energy consumption. Level(s) is a tool of this circular economy for the built environment, intended to stimulate life cycle thinking at the level of a whole building, and support users from the design stage all the way through to a building's operation and occupation.

Policy background

In 2014, the European Commission adopted the Communication "*Resource Efficiency Opportunities in the Building Sector*". This initiative's objective is to improve resource efficiency, thus reducing the environmental impact of buildings and improving the related competitiveness of businesses in the sector.

A need was identified for a commonality in the EU approach to the assessment of buildings' environmental performance: a "common framework of core indicators", with the intent to drive performance improvements and simplify comparison between buildings.

In 2015, the Circular Economy Action Plan reiterated this objective and added that, given the extended lifetime of buildings, it is key to encourage improvements in design in order to reduce their impact on the environment and increase the recyclability and durability of their components.

Since then, the work started the Level(s) framework – a flexible system of indicators that can be incorporated into new and/or pre-existing assessment schemes, or be used in their own right by a variety of stakeholders, such as design teams, property investors and local authorities.

Level(s) aims to draw attention to the key aspects of a building's performance, providing a simple entry point to a potentially very complex area.

Users

Level(s) is intended to be used by:

- clients (developers and investors)
- design teams (architects, engineers, quantity surveyors)
- construction management (construction manager, lead contractor)
- facilities managers
- asset managers
- buildings occupants (households or organisations).

Both building professionals and clients can use Level(s) to develop their understanding of how buildings have an impact on the environment. Level(s) explains techniques to reduce environmental impact and can be used to prepare users for other, more advanced tools and assessment schemes.

Level(s) can also be used by certification and assessment schemes to make sure that their criteria reflect the most important priorities for circular economy at a European level, and to enable the comparability of data and results across different building performance rating systems.

Pilot testing

Level(s) is currently undergoing pilot testing following a conference held on 4 December 2017, wherein 80 pioneering organisations committed to test Level(s) and joined a workshop organised by the European Commission, to learn more about the testing phase, how other organisations plan to test Level(s) and what the benefits of the tool can be according to building certification schemes[14]. A recently released report details the test's progress[15].

Information sources

An introduction to Level(s) is provided on line[16,17]. The Joint Research Centre (JRC) website details all information related to the study[18].

[14] Conference report: http://ec.europa.eu/environment/eussd/pdf/Level_publication_EN.pdf

[15] http://ec.europa.eu/environment/eussd/pdf/LEVEL(S)%20CONFERENCE%20REPORT.pdf

[16] http://susproc.jrc.ec.europa.eu/Efficient_Buildings/docs/170816_Levels_EU_framework_of_building_indicators_Parts.pdf

[17] http://susproc.jrc.ec.europa.eu/Efficient_Buildings/docs/170816_Levels_EU_framework_of_building_indicators.pdf

[18] http://susproc.jrc.ec.europa.eu/Efficient_Buildings

In the preparation of the 2014 Communication, the Commission organised a public consultation on sustainable buildings (2013).

Relevance to the SRI

The Level(s) initiative is potentially relevant to the SRI with regard to implementation. At a minimum the SRI has to be complementary to Level(s); however, in principle it should be possible for the SRI to be incorporated as a component within the Level(s) framework and thus potentially issued whenever a Level(s) assessment is undertaken. As Level(s) is designed as a voluntary tool for private sector actors who may wish to apply the methodology to demonstrate the environmental performance of their buildings the SRI could complement this framework through offering insight into an additional element of building performance that also addresses some environmental impacts. If the SRI were offered as part of a package with Level(s) it might increase overall value and engagement for both initiatives; however, this seems most consistent with a self-assessment implementation pathway.

1.1.2.3 Building Renovation Passports (BRPs)

A BRP is defined as a document in electronic or paper format that outlines a long-term (up to 15 or 20 years) step-by-step renovation roadmap for a specific building, resulting from an on-site energy audit fulfilling specific quality criteria and indicators established during the design phase and in dialogue with building owners. The expected benefits in terms of reduced heating bills, comfort improvement and CO_2 reduction are a constitutive part of the BRP and are explained in a user-friendly communication. The renovation roadmap can be combined with a repository of building-related information (log book) on aspects such as energy consumption and production, executed maintenance and building plans.

On-site data gathering is the first step towards the creation of a BRP. The data processing can change according to each model (e.g. by using a dedicated software tool or by adapting existing energy auditing software). The outcome of steps 1 and 2 is a comprehensive step-by-step renovation roadmap, with tailored solutions aiming at achieving deep-staged renovation. This step-by-step renovation roadmap (or staged renovation) involves a renovation plan with a horizon of up to 15–20 years that, by looking at the building as a whole, suggests the installation of selected measures in a certain order to avoid the situation that at any stage of renovation the installation of additional measures is precluded.

Some common principles are applied in the various national/local BRP schemes currently being trialled. These include:

- taking a long-term perspective – the integration of a long-term thinking is essential for the success of BRPs
- timing and sequencing of actions – BRPs include both short-term and long-term measures and clearly indicate the correct order in which to install them (e.g. sequencing of the measures' installation over time) to avoid lock-ins, increase building owners' confidence and enhance the rate of deep renovation
- customer engagement and consideration of the individual renovation context – the wishes, needs (particularly expectations regarding comfort) and the financial situation of the occupants must be considered
- attractiveness and motivation – BRPs should be very attractive and user-friendly for both the auditors and the users, to help them confidently take action without being discouraged by the complexity of the renovations

- automation – experts should be able to perform the audit, input data and deliver the results as easily as possible (modular blocks, indicate default values and highlight errors in cases of incorrect inputs, etc.)

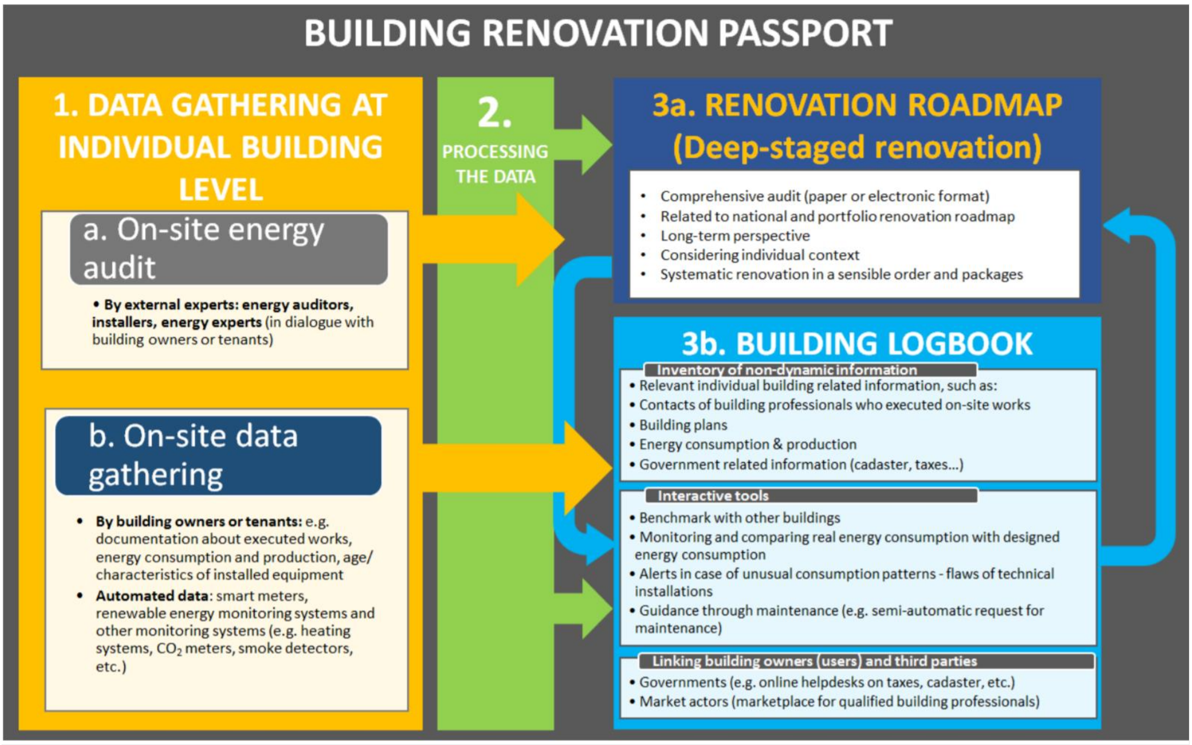

Figure 1 - Building Renovation Passport – overview of components. Source: BPIE

In addition to the renovation roadmap, the BRP can include a separate element, a storage log book where the building's features and information (e.g. stability, durability, water, installations, humidity, maintenance requirement, etc.) can be collected and regularly updated, becoming a proper repository of information and data related to a specific building. The log book could also include other sets of information related to each individual building, such as the financing options available in the area for renovation projects (e.g. green loans, incentives, tax credits) as well as energy bills, equipment maintenance recommendations, insurance and property obligations. All this information could be inventoried in a digital register available to property owners.

The main user of the log book will be the building owner. Depending on the type of log book or its intended use, owners could grant access to some information to public authorities (e.g. municipality, property tax office), building professionals and craftsmen, and make some information publicly available, while keeping other data private or restricted (semi-public upon authorisation to third parties). In its most sophisticated form, the log book could also be used as an interactive tool to monitor (both at individual building level and building stock level) and compare real energy consumption with designed energy consumption, sending alerts in instances of unusual consumption patterns or flaws in technical installations. It could also be linked to market actors (such as building professionals, craftsmen or financial institutions) to provide information regarding (certified) contractors and installers, facilitate invoicing and simplify the process for subsidies or loans repayment.

BRP schemes are currently being implemented or trialled in at least Germany, France and Flanders.

Relevance to the SRI

Like the Level(s) initiative building renovation passports are a new initiative that is still being elaborated and trialled. As with the Level(s) initiative building renovation passports are potentially relevant to the SRI with regard to implementation. At a minimum the SRI needs to be complementary to them, in that it can happily co-exist; however, in principle it should be possible for the SRI to be incorporated as a component within the building renovation passport framework and thus potentially issued whenever a BRP assessment is undertaken. In practice BRPs involve a kind of rolling assessment of a building and therefore an SRI assessment could be integrated within this process and potentially add value to the BRP users. The most obvious time to incorporate an SRI assessment into a BRP would be when the first BRP assessment occurs as this initial assessment would be comprehensive and readily adapted to include the SRI information. In principle as future changes are made the extent to which the BRP is updated could also apply to the SRI for the affected domains. This naturally raises the topic of what type of actor would be doing the initial and update assessments and implementation topics related to shared assessment cost and competence.

1.1.2.4 Digital log books and Building Information Modelling (BIM)

Digital log books for buildings are usually intended to provide a simple, easily accessible summary of a new or refurbished building rather than the detail contained in operation and maintenance manuals. In some Member States the provision of such information to building owners has become mandatory through the form of a building log book (which needn't necessarily be electronic but increasingly is). The log books will typically cover how a building is intended to work and how it is meant to be maintained and serviced. They also provide a means to record the energy use and maintenance of the services within the building. The information in such log books is generally aimed at:

- facilities managers
- building and building services designers
- those replacing or altering building services plant in existing buildings
- building owners/clients.

A typical building log book might include:

- a description of key responsibilities
- a schedule of contacts
- a description of the overall building, including zoning and occupancy
- a description of the building's operational strategy
- a description of the building's services plant, controls and management systems
- changes that have been made to the building
- health and safety considerations
- maintenance requirements
- metering and monitoring strategy
- the recommendations report produced along with the construction EPC
- building performance in use investigations and targets
- references to other documents.

In general, initial preparation of the building log book would be co-ordinated by the lead designer and would be issued to the building's facilities manager at handover. If updates are required during any defects liability period, these would normally be done by the designers. The facilities manager would then take over responsibility for its ongoing development with the common intention that the building log book would be reviewed and updated annually by the facilities manager.

In addition to a building log book, it may also be prudent to prepare a non-technical 'building users guide' with information for users about environmental controls, access, security and safety systems, etc.

BIM is a digital tool aimed at the construction industry as a platform for central integrated design, modelling, and asset planning, running and cooperation. It provides all stakeholders with a digital representation of a building's characteristics in its whole life cycle and thereby holds out the promise of large efficiency gains.

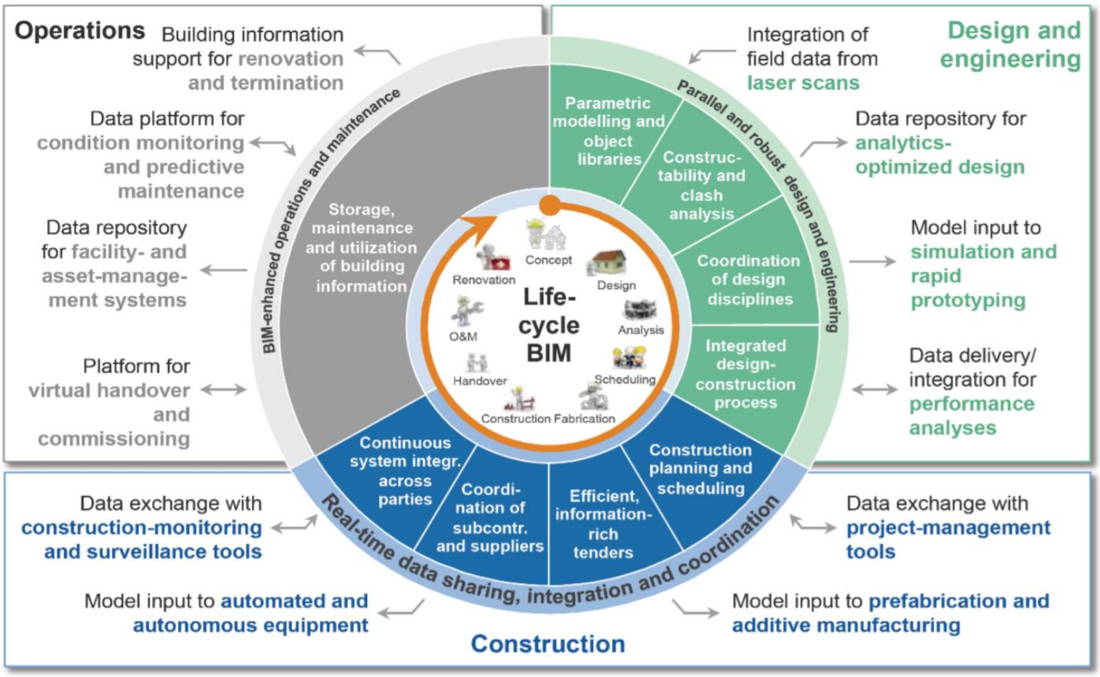

Figure 2 – Applications of BIM along the engineering and construction value chain. Source: Shaping the Future of Construction[19]

The range of BIM 'maturity levels' can be categorised as:

- *Level 0* – unmanaged CAD (Computer Aided Design)
- *Level 1* – managed CAD in 2D or 3D
- *Level 2* – managed 3D environment with data attached, but created in separate discipline models

[19] World Economic Forum, *Shaping the Future of Construction: A Breakthrough in Mindset and Technology*, 2016

- *Level 3* – single, online, project model with construction sequencing, cost and life-cycle management information.

The uptake and sophistication of BIM vary considerably from country to country and from company to company, according to their size and position in the value chain. For some large engineering companies, BIM is already part of business as usual, but most small companies across the value chain have little BIM experience; in fact, even some of the major contractors have never used BIM on any of their projects. The difference in adoption rates within Europe is reported to be considerable but also highly dynamic; for example, according to information published on the JRC website[20], "16% of E&C companies in the United Kingdom are reported never to have used BIM, while in Austria it is 49%"; however, this statement is already out of date. The National Building Specification in the UK conducts an annual survey of BIMs adoption that draws on the views of more than 1000 construction industry professionals. In the most recently published 2016 survey[21] it was found that 54% of respondents were aware of and using BIM (up from 48% the previous year) whilst 42% were just aware of BIM; 86% expected to be using BIM in a year's time, and 97% in 5 years' time. Some 70% had produced 3D digital models in the last year, and 74% had worked collaboratively on design; however, 28% were not confident or not at all confident in their knowledge of and skills in BIM. There was more use of BIM on public sector projects, but there was also significant BIM adoption in the private sector for housing, offices and leisure facilities.

In the UK survey, immediate colleagues were the most commonly used source of information about BIM, along with external professionals and the UK BIM Task Group. Standards used included the RIBA Plan of Work 2013, PAS 1192-2:2013, PAS 1192-3:2014 and BS 1192:2007. However, 65% believed BIM had not been sufficiently standardised. Some 80% did not generate COBie (Construction Operations Building Information Exchange) output or did not know whether they did. COBie is a data format for the publication of a sub-set of building information models focusing on delivering asset data rather than geometric information and is one of the key outputs required by level 2 BIM.

The JRC has identified the same problem at the European level and is arguing that what the industry needs is "big and open" BIM, which integrates the entire value chain and is characterised by full interoperability of software and open access to it. While the technical challenges are likely to be overcome in the near future, it might prove more difficult to change existing processes and to increase collaboration, including data sharing.

One particular area where standardisation on BIM is needed is the exchange of information between software applications used in the construction industry. The leading organisation in this domain is buildingSMART[22], which has developed and maintains Industry Foundation Classes (IFCs) as a neutral and open specification for BIM data models. Other standardisation work includes data dictionaries (International Framework for Dictionaries Libraries) and processes (data delivery

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[20] *Building Information Modelling (BIM) standardization*, Martin Poljanše, JRC Technical Reports 2017 http://publications.jrc.ec.europa.eu/repository/bitstream/JRC109656/jrc109656_bim.standardization.pdf

[21] https://www.designingbuildings.co.uk/wiki/NBS_National_BIM_Report_2016

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

manuals). ISO/TC 59/SC 13 on the "*Organization of Information About Construction Works*", a sub-committee of the International Organization for Standardization (ISO) on the worldwide and CEN/TC 442 "*Building Information Modelling*" is a technical committee of the European Committee for Standardisation (CEN) which operates at the European level to develop and maintain standards in the BIM domain. Liaisons with a plethora of different institutions ensure the completeness and inclusiveness of the process as well as the smooth acceptance of adopted standards.

In addition, the EU is sponsoring projects that aim to develop a common European approach to BIM, such as the EUBIM network[23].

Relevance to the SRI

BIM and digital logbooks are relevant to the SRI with regard to implementation as the information they contain can overlap with SRI needs and in utilising a digital platform opens the possibility of sharing relevant datasets in a manner that is beneficial to both. Acquiring the data needed by BIM entails a site visit and inspection for existing buildings and in principle this process could be done in common for both BIM and an SRI. Once the data has been acquired it is stored digitally and this could facilitate future updates as systems are added or amended as from a technical perspective only a partial assessment (of the part which has changed) is needed. BIM also entails management of data confidentiality in a digital environment and hence has lessons for potential implementation pathways that could be used by the SRI.

BIM is a voluntary private sector practice and is a tool used to manage building projects more efficiently. Therefore, an SRI assessment conducted within a BIM framework would not ordinarily be a 3rd party assessment. For it to have value, even in a B2B capacity it would imply that the BIM assessor would have acquired the requisite skills to conduct the assessment.

1.1.2.5 Cybersecurity and the Voluntary European Cybersecurity Certification scheme

Traditional energy technologies are becoming progressively more connected to modern, digital technologies and networks. This increasing digitalisation makes the energy system smarter and enables consumers to better benefit from innovative energy services. At the same time, digitalisation creates significant risks as an increased exposure to cyberattacks and cybersecurity incidents potentially jeopardises the security of energy supply and the privacy of consumer data. Digital technologies are the backbone of smart ready services in buildings. They might also bring about new risks related to data theft, fraud and system hacking. Ensuring cybersecurity is therefore a key issue to foster trust in digital technologies and prevent their exploitation as a means of compromising the cybersecurity of energy networks and infrastructure.

The European Commission has adopted a series of measures to raise Europe's preparedness to ward off cyber incidents. Securing network and information systems in the EU is an essential aspect of the EU's Digital Agenda. The Network and Information Security (NIS) Directive on security of network and information systems was adopted by the European Parliament on 6 July 2016 and entered into force in August the same year. Member States were given 21 months to transpose

[23] http://www.eubim.eu

the Directive into their national laws, as well as 6 months more to identify operators of essential services.

Recently the EU has set out its approach towards ensuring cybersecurity in the energy sector[24], including the establishment of a comprehensive legislative framework. The framework builds on the EU Cybersecurity strategy (JOIN (2013)01 final[25]) and the Directive on Security of Network and Information Systems (the NIS Directive) (EU) 2016/1148[26] and from September 2017 has been reinforced by the Cybersecurity Package (JOIN (2017) 450 final), which also includes the Cybersecurity Act. In April 2019, the European Commission adopted sector-specific guidance (recommendation C(2019)240 final[27] and staff working document SWD (2019)1240 final[28]) to implement horizontal cybersecurity rules. This guidance aims to increase awareness and preparedness in the energy sector. The above were informed by a study on cybersecurity in the energy sector that highlights the risks and mitigation options[29].

These measures potentially have consequences with regard to the SRTs that could be included within the SRI framework, especially with regard to requirements that energy network operators are likely to aim to impose to assure the cybersecurity of their networks.

Specifically, recommendation C(2019)240 advises that energy network operators should:

> '(a) apply the most recent security standards for new installations wherever adequate *and consider complementary physical security measures where the installed base of old installations cannot be sufficiently protected by cybersecurity mechanisms;*
> *(b) implement international standards on cybersecurity and adequate specific technical standards for secure real-time communication as soon as respective products become commercially available;*
> *(c) consider real-time constraints in the overall security concept for assets, especially in asset classification;*
> *…*
> *Where available, energy network operators should also:*
> *(a) choose a secure communication protocol, taking into consideration real-time requirements, for example between an installation and its management systems (Energy Management System – EMS / Distribution Management System – DMS);*
> *(b) introduce an appropriate authentication mechanism for machine-to-machine communication, addressing real-time requirements.*
> *…*

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24 https://ec.europa.eu/energy/en/topics/energy-security/critical-infrastructure-and-cybersecurity

25 https://eeas.europa.eu/archives/docs/policies/eu-cyber-security/cybsec_comm_en.pdf

26 DIRECTIVE (EU) 2016/1148 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union https://eur-lex.europa.eu/eli/dir/2016/1148/oj

27 https://ec.europa.eu/energy/sites/ener/files/commission_recommendation_on_cybersecurity_in_the_energy_sector_c2019_2400_final.pdf

28 https://ec.europa.eu/energy/sites/ener/files/swd2019_1240_final.pdf

29 https://ec.europa.eu/energy/en/studies/study-evaluation-risks-cyber-incidents-and-costs-preventing-cyber-incidents-energy-sector

In particular, energy network operators should:
(a) ensure that new devices, including Internet of Things (IoT) devices, have and will maintain a level of cybersecurity appropriate to a site's criticality…'

These are not unique, however, as the other cybersecurity actions have been initiated or are pending.

In 2004 the EU set up the European Union Agency for Network and Information Security (ENISA)[30]. ENISA works closely together with Member States and the private sector in facing network and information security challenges, as well as delivering advice and solutions on cybersecurity.

On 13 September 2017, the Commission issued a proposal for a regulation on ENISA, the "EU Cybersecurity Agency", and on ICT cybersecurity certification ("Cybersecurity Act")[31]. This "package" builds upon existing instruments and presents new initiatives to further improve EU cyber resilience and response. This includes the establishment of an EU cybersecurity certification framework that is designed to ensure the trustworthiness of the billions of connected devices (in terms of "Internet of things"[32]) in diverse sectors such as telecom, energy and transport networks, and new consumer devices, such as connected cars, smart buildings and many others.

The proposed certification framework is intended to provide EU-wide certification schemes as a comprehensive set of rules, technical requirements, standards and procedures[33]. This will be based on agreement at the EU level for the evaluation of the security properties of a specific ICT-based product or service.

The rationale for this is that certification plays a critical role in increasing trust and security in products and services that are crucial for the digital single market. At the moment, a number of different security certification schemes for ICT products exist in the EU. Without a common framework for EU-wide valid cybersecurity certificates, there is an increasing risk of fragmentation and barriers in the single market.

The proposed certification framework is intended to provide EU-wide certification schemes as a comprehensive set of rules, technical requirements, standards and procedures. This will be based on agreement at EU level for the evaluation of the security properties of a specific ICT-based product or service, e.g. smart cards. The certification will attest that ICT products and services that have been certified in accordance with such a scheme comply with specified cybersecurity requirements. The resulting certificate will be recognised in all Member States, making it easier for businesses to trade across borders and for purchasers to understand the security features of the product or service.

[30] https://www.enisa.europa.eu/

[31] Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on ENISA, the "EU Cybersecurity Agency", and repealing Regulation (EU) 526/2013, and on Information and Communication Technology cybersecurity certification (''Cybersecurity Act'')

[32] The Internet of things is the extension of Internet connectivity into physical devices and everyday objects. Embedded with electronics, Internet connectivity, and other forms of hardware, these devices can communicate and interact with others over the Internet, and they can be remotely monitored and controlled.

[33] https://ec.europa.eu/digital-single-market/en/eu-cybersecurity-certification-framework

The schemes proposed in the future European framework will rely as much as possible on international standards as a way to avoid creating trade barriers and ensuring coherence with international initiatives.

Specifically, the proposal states:

> *"Cybersecurity certification of ICT products and services in order to establish and preserve trust and security, ICT products and services need to directly incorporate security features in the early stages of their technical design and development (security by design). Moreover, customers and users need to be able to ascertain the level of security assurance of the products and services they procure or purchase. Certification, which consists of the formal evaluation of products, services and processes by an independent and accredited body against a defined set of criteria standards and the issuing of a certificate indicating conformance, plays an important role in increasing trust and security in products and services. While security evaluations are quite a technical area, certification serves the purpose to inform and reassure purchasers and users about the security properties of the ICT products and services that they buy or use. As mentioned above, this is particularly relevant for new systems that make extensive use of digital technologies and which require a high level of security, such as e.g. connected and automated cars, electronic health, industrial automation control systems (IACS)14 or smart grids.*
>
> *Currently, the landscape of cybersecurity certification of ICT products and services in the EU is quite patchy. There are a number of international initiatives, such as the so-called Common Criteria (CC) for Information Technology Security Evaluation (ISO 15408), which is an international standard for computer security evaluation. It is based on third party evaluation and envisages seven Evaluation Assurance Levels (EAL). The CC and the companion Common Methodology for Information Technology Security Evaluation (CEM) are the technical basis for an international agreement, the Common Criteria Recognition Arrangement (CCRA), which ensures that CC certificates are recognized by all the signatories of the CCRA. However, within the current version of the CCRA only evaluations up to EAL 2 are mutually recognized. Moreover, only 13 Member States have signed the Arrangement."*

The proposed Regulation aims to establish a European Cybersecurity Certification Framework for ICT products and services and specifies the essential functions and tasks of ENISA in the field of cybersecurity certification. The present proposal lays down an overall framework of rules governing European cybersecurity certification schemes. The proposal does not introduce directly operational certification schemes, but rather creates a system (framework) for the establishment of specific certification schemes for specific ICT products/services (the "European cybersecurity certification schemes"). The creation of European cybersecurity certification schemes in accordance with the Framework will allow certificates issued under those schemes to be valid and recognised across all Member States and to address the current market fragmentation.

The general purpose of a European cybersecurity certification scheme is to attest that the ICT products and services that have been certified in accordance with the scheme comply with specified cybersecurity requirements. This would include their ability to protect data (whether stored, transmitted or otherwise processed) against accidental or unauthorized storage, processing, access, disclosure, destruction, accidental loss or alteration. In addition to outlining a specific set of security objectives to be taken into account in the design of a specific European cybersecurity certification scheme, the proposal provides what the minimum content of such schemes should be. Such schemes will have to define, among others, a number of specific elements setting out the scope and object of the cybersecurity certification. This includes the identification of the categories of products and services covered, the detailed specification of the cybersecurity requirements (for example by reference to the relevant standards or technical specifications), the specific evaluation criteria and methods, and the level of assurance they are intended to ensure (i.e. basic, substantial or high).

European cybersecurity certification schemes will be prepared by ENISA, with the assistance, expert advice and close cooperation of the European Cybersecurity Certification Group (see below) and adopted by the Commission by means of implementing acts. When the need for a cybersecurity certification scheme is identified, the Commission will request ENISA to prepare a scheme for specific ICT products or services. ENISA will work on the scheme in close cooperation with national certification supervisory authorities represented in the Group. Member States and the Group may propose to the Commission that it requests ENISA to prepare a particular scheme.Recourse to European cybersecurity certification will remain voluntary, unless otherwise provided in Union legislation laying down security requirements of ICT products and services.

In order to ensure harmonisation and avoid fragmentation, national cybersecurity certification schemes or procedures for the ICT products and services covered by a European cybersecurity certification scheme will cease to apply from the date established in the implementing act adopting the scheme. Once a European cybersecurity certification scheme is adopted, manufacturers of ICT products or providers of ICT services will be able to submit an application for certification of their products or services to a conformity assessment body of their choice.

Under the proposal, the monitoring, supervisory and enforcement tasks lie with the Member States. Member States will have to provide for one certification supervisory authority. This authority will be tasked with supervising the compliance of conformity assessment bodies, as well as of certificates issued by conformity assessment bodies established in their territory, with the requirements of this Regulation and the relevant European cybersecurity certification schemes.

Finally, the proposal establishes the European Cybersecurity Certification Group , which is comprised of national certification supervisory authorities of all Member States. The main task of this group is to advise the Commission on issues concerning cybersecurity certification policy and to work with ENISA on the development of draft European cybersecurity certification schemes. ENISA will assist the Commission in providing the secretariat of the group and in maintaining an updated public inventory of schemes approved under the European Cybersecurity Certification Framework. ENISA will also liaise with standardisation bodies to ensure the appropriateness of standards used in approved schemes and to identify areas in need of cybersecurity standards.

The European Cybersecurity Certification Framework (‘Framework’) is intended to provide several benefits for citizens and for undertakings. In particular:

- The creation of EU-wide cybersecurity certification schemes for specific products or services

The Framework aims to establish the primacy of European cybersecurity certification schemes over national schemes such that the adoption of a European cybersecurity certification scheme will supersede all existing parallel national schemes for the same ICT products or services at a given level of assurance.

The SRI will need to be mindful of this framework and ensure that it is complementary to its development. In particular, it will be necessitate to monitor the work programme established for the Voluntary Cybersecurity Certification scheme to see if it is targeting SRTs and smart services related to the SRI and exploring mechanisms to engage with it if it is.

Relevance to the SRI

Cybersecurity is highly relevant to the SRI in terms of data protection and ensuring no action associated with the SRI is responsible for compromising cybersecurity. As the SRI concerns smart technologies which are likely to be connected and hence potentially exploitable through cyberattacks the SRIs implementation needs to be mindful of these risks and take all reasonable steps to minimise them. The nascent European Cybersecurity Certification scheme is thus potentially an initiative that could help to minimise such risks to the extent that it develops criteria that are applied to SRTs and enables cybersecurity status to be communicated to market actors. At the current time this scheme is just being initiated and its initial focus in terms of technology types is yet to be clarified. Therefore, it is more the case that the SRI implementation process needs to monitor developments with this scheme and examine how they could complement or potentially integrate with future editions of the SRI if and when it becomes appropriate to do so.

1.1.2.6 "Broadband-ready" label

Installing physical infrastructure that enables high-speed internet access is more cost-effective and less disturbing for residents if done at the time of construction or implementation of major renovation. If buildings are equipped with the necessary infrastructure, companies can install cables or other active equipment more quickly and at significantly lower costs, allowing them to offer their services faster and to more citizens. With this thought in mind, Articles 8 and 9 of the Directive on "*Measures to reduce the cost of deploying high-speed electronic communications networks*"[34] ensure high-speed-ready, accessible in-building physical infrastructure in all newly constructed and majorly renovated buildings.

To achieve this objective, the buildings for which permits are submitted after 31 December 2016 must be equipped with physical infrastructure, such as mini-ducts capable of hosting high-speed networks, and an easily accessible access point for the providers of public communications networks who wish to terminate their networks at the premises of the subscriber. Such buildings shall be eligible to receive the voluntary "broadband-ready" label in Member States where this is available.

Moreover, without prejudice to property rights, every provider of public communications networks shall have the right to access any in-building physical infrastructure under fair and non-discriminatory terms and conditions, if duplication is technically impossible or economically inefficient.

For buildings not equipped with high-speed-ready in-building infrastructure, every public communication network provider can terminate its network at the premises

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[34] Directive 2014/61/EU of the European Parliament and the Council https://ec.europa.eu/digital-single-market/en/news/directive-201461eu-european-parliament-and-council

of the subscriber subject to the subscriber's agreement and provided that it minimises the impact on the property of third parties.

Specifically, Article 8 states:

> *"1. Member States shall ensure that all newly constructed buildings at the end-user's location, including elements thereof under joint ownership, for which applications for building permits have been submitted after 31 December 2016, are equipped with a high-speed-ready in-building physical infrastructure, up to the network termination points. The same obligation applies in the event of major renovation works for which applications for building permits have been submitted after 31 December 2016.*
>
> *2. Member States shall ensure that all newly constructed multi-dwelling buildings, for which applications for building permits have been submitted after 31 December 2016, are equipped with an access point. The same obligation applies in the event of major renovation works concerning multi-dwelling buildings for which applications for building permits have been submitted after 31 December 2016.*
>
> *3. Buildings equipped in accordance with this Article shall be eligible to receive the voluntary 'broadband-ready' label in Member States that have chosen to introduce such a label.*
>
> *4. Member States may provide for exemptions from the obligations provided for in paragraph 1 and 2 for categories of buildings, in particular single dwellings, or major renovation works in cases in which the fulfilment of those obligations is disproportionate, such as in terms of costs for individual or joint owners or in terms of type of building, such as specific categories of monuments, historic buildings, holiday homes, military buildings or other buildings used for national security purposes. Such exemptions shall be duly reasoned. The interested parties shall be given the opportunity to comment on the draft exemptions within a reasonable period. Any such exemption shall be notified to the Commission."*

A report in 2018 on the implementation of the Directive asserted that Portugal and Italy have introduced broadband-ready labels and that Spain and Germany are considering following suit. In France there is a standard to indicate fibred zones[35].

Relevance to the SRI

As building connectivity is a necessary precursor to many SRTs the "broadband ready" label is also relevant to the SRI with regard to how ready the building is to apply such technologies and the services they offer. Furthermore, the implementation process has several parallels with the SRI's in that the scheme is initiated through an EU Directive but is voluntary for EU Member States and entails an inspection process to determine compliance with the nationally adopted specifications. In theory, where such schemes exist they could potentially be implemented in common with the SRI to share assessment costs and improve the net value proposition of both schemes, albeit that while the focus of both schemes overlap they are not the same.

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[35] https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/7534-berec-report-on-the-implementation-of-the-broadband-cost-reduction-directive

1.1.2.7 Private sector sustainability certification schemes – BREEAM

The Building Research Establishment Environmental Assessment Method (BREEAM) was introduced by BRE in 1990 in the UK. The rationale behind the introduction of the methodology was to allow a holistic building sustainability assessment of a broad variety of criteria related to the performance of the building. Detailed information about the method can be found in the technical manual[36].

Table 1 shows the environmental sections that are used to determine the sustainability assessment. For each environmental section, a weighting factor for the different building types is given. The weighting and ranking exercise is performed by an expert panel. The weightings may be adapted to local conditions. This adaptation has to be reviewed and approved by BREEAM[37].

Table 1 – Example of BREEAM section weightings for common project types (BREEAM Technical Manual 2016)

Environmental section (rounded)	Weighting (rounded)						
	Non-residential (rounded)			Single residential dwellings (rounded)		Multiple residential dwellings (rounded)	
	Fully fitted out (rounded)	Shell only (rounded)	Shell and core (rounded)	Partially fitted (rounded)	Fully fitted (rounded)	Partially fitted (rounded)	Fully fitted (rounded)
Management	12.00%	13.50%	13.00%	11.50%	15.00%	12.50%	12.00%
Health and wellbeing	14.00%	8.00%	8.50%	14.50%	15.00%	15.00%	15.00%
Hazards	1.00%	1.50%	1.00%	1.00%	1.00%	1.00%	1.00%
Energy	19.00%	19.50%	19.00%	18.50%	22.00%	18.50%	20.00%
Transport	8.00%	11.00%	8.50%	8.00%	6.50%	8.50%	8.00%
Water	6.00%	3.00%	6.50%	4.50%	6.50%	4.50%	5.50%
Materials	12.50%	16.50%	13.50%	13.50%	9.00%	13.00%	12.50%
Waste	7.50%	8.50%	8.00%	7.00%	6.00%	7.00%	6.50%
Land use and ecology	10.00%	13.00%	11.00%	11.00%	8.50%	10.50%	10.00%
Pollution	6.50%	1.00%	7.00%	5.50%	6.00%	6.00%	6.00%
Total	100.00%	100%	100%	100%	100%	100%	100%
Innovation (additional)	10.00%	10%	10%	10%	10%	10%	10%

Within those sections a range of criteria are defined for which the building in question may be awarded credits. For most criteria, one or two indicators can be achieved. Credits are always discrete numbers; fractions of credits do not exist. Therefore, for most criteria, the compliance is a discrete (Yes/No) choice of compliance. This compliance is either the presence of a technology, concept or practice or the quantitative fulfilment of a threshold value.

[36] http://www.breeam.com/BREEAMInt2016SchemeDocument/

[37] Note, this is not done on a case-by-case basis, but via an updated version of the "standards and weightings" file which is published regularly. This file indicates for each country which weightings should apply. Also it contains a set of standards which may be applied for the calculations. When a project is first registered to BREEAM, the latest version of this file is assigned to the project and remains unchanged during the course of the project.

The energy performance of the building is the most influential single indicator, being awarded up to 15 credits and thus contributing to a maximum of ~5% of the overall result. The evaluation of the energy use is done by a proprietary metric taking into account a variety of impact factors such as:

- building floor area (m^2)
- notional building energy demand (MJ/m^2)
- actual building energy demand (MJ/m^2)
- notional building primary energy consumption (kWh/m^2)
- actual building primary energy consumption (kWh/m^2)
- notional building emission rate ($kgCO^2/m^2$)
- actual building emission rate ($kgCO^2/m^2$).

These impact factors must be calculated with accredited building software. The resulting indicator, the "Energy Performance Ratio for International New Constructions (EPRINC)", is then calculated with a proprietary tool. The outcome of this tool is mapped to a discrete credit scale, or alternatively, a checklist approach by which up to 10 credits can be awarded is used.

Other criteria with a discrete scale are:

- the accessibility index, which is evaluated with a proprietary tool
- life-cycle impacts.

Both criteria are also evaluated with a proprietary tool.

Table 2 shows an example of a BREEAM rating for a specific building. For each section, the credits achieved are related to the credits available, resulting in a relative performance within this section. The section score can be calculated in combination with the weighting factor, and the sum of all section scores gives the relative performance of the building.

Table 2 – Example of the BREEAM rating overview (BREEAM Technical Manual 2016)

BREEAM section	Credits achieved	Credits available	% of Credits achieved	Section weighting (fully fitted)	Section score
Management	10	20	50.00%	0.12	6.00%
Health and wellbeing	17	21	80.95%	0.14	11.33%
Hazards	1	1	100.00%	0.01	1.00%
Energy	16	34	47.05%	0.19	8.94%
Transport	5	11	45.45%	0.08	3.63%
Water	5	9	55.56%	0.06	3.33%
Materials	10	14	71.43%	0.125	8.92%
Waste	3	13	23.07%	0.075	1.73%
Land use and ecology	5	5	100.00%	0.10	10.00%
Pollution	5	7	71.42%	0.065	4.64%
Surface water run-off	4	5	80.00%	0.035	2.80%
Innovation	2	10	20.00%	0.10	2.00%
Final BREEAM score					64.32%
BREEAM Rating				VERY GOOD	

The overall rating of a building is given on a 6-level rating ranging from "Pass" to "Outstanding" as pass grades, and "Unclassified" as a fail grade. This relative performance is mapped to this rating according to the values in Table 3.

Table 3– The six BREEAM building environmental performance classes and associated scoring thresholds (BREEAM Technical Manual 2016)

BREEAM Rating	% score
OUTSTANDING	≥ 85
EXCELLENT	≥ 70
VERY GOOD	≥ 55
GOOD	≥ 45
PASS	≥ 30
UNCLASSIFIED	< 30

For each rating, minimum requirements for individual criteria can be defined. This ensures that a poor performance in crucial criteria cannot be compensated with an excellent performance in other criteria. Therefore, it is ensured that certain minimum criteria which are regarded as mandatory for a BREEAM certified building are fulfilled.

A certain set of criteria are mandatory for the pass grade and are therefore mandatory to get certified at all. These criteria are:

- all national health and safety legislation and regulations for construction sites are considered and implemented
- all fluorescent and compact fluorescent lamps are fitted with high frequency ballasts
- materials containing asbestos are prohibited from being specified and used within the building
- all water systems in the building are designed in compliance with the measures outlined in the relevant national health and safety best practice guides or regulations to minimise the risk of microbial contamination, e.g. *Legionella*
- all timber and timber-based products used on the project are legally harvested and traded timber.

An outstanding rating requires at least 10 of the 15 credits available in the energy-use criterion.

For each indicator, evidence is required to demonstrate compliance. This evidence may be presented in the form of a report, filled checklists, etc.

In the example shown in Table 4, all minimum criteria for the "very good" rating are achieved; therefore, this rating can be awarded.

Table 4 – Example of a check of minimum standards (BREEAM Technical Manual 2016)

Minimum standards for BREEAM 'Very Good' rating	Achieved?
Man 03 Responsible construction practices	Y
Hea 01 Visual comfort	Y
Hea 02 Indoor air quality	Y
Hea 09 Water quality	Y
Ene 01 Reduction of energy use and carbon emissions	Y
Wat 01 Water consumption	Y
Wat 02 Water monitoring	Y
Mat 03 Responsible sourcing of construction products	Y

Structure

The structure used in the BREEAM system is to define impact categories, apply scoring up a maximum value within each of these and then to aggregate points to give an overall total via the application of weightings to the impact category scores. This structure can be said to be akin to a standard Analytical Hierarchy Process (AHP)[38] impact category weighting system. Like many AHP models it combines qualitative (Yes/No) and quantitative impact categories (where the score is derived on a linear scale and either calculation software based on quantified physical simulation is used or metered data is used and ranked via a normalisation

[38] https://en.wikipedia.org/wiki/Analytic_hierarchy_process

process). The method applied to derive the maximum scores and weightings per impact category is proprietary to the BRE and is not explained to the end users.

Method of evaluation

The BREEAM methodology represents an effective and largely transparent methodology to assess the sustainability performance of a building. Through the inclusion of a broad range of sustainability indicators covering the whole life cycle of the building, a holistic assessment is enabled.

Effectiveness

The methodology uses a very straightforward approach to integrate the broad range of impact criteria into one overall rating. In principle the setting of minimum requirements for crucial indicators ensures that a balanced assessment is attained, although expert judgement is clearly required to determine which indicators are deemed to be crucial and which are not.

Accuracy

For most criteria, discrete choices are the basis for credit assignment. Discrete choices lack the ability to represent the potential range of criteria achievement.

Nevertheless, when the broad number of criteria is considered, this issue is of lower importance for the overall result.

Reproducibility

The use of a discrete-choice approach for the credit assignment allows easy reproduction for most of the criteria. Some of the criteria require the use of proprietary tools relying on rather detailed building information. In principle, the reproducibility for those criteria should be high, although the use of detailed input data could lead to differing assumptions for the calculation.

Enforceability

BREEAM ratings are required by some local authorities as well as private sector companies in the UK. In the public sector a variety of institutions require a minimum BREEAM rating for all new buildings. In practice the energy performance rating process used in BREEAM is aligned with that used in mandatory building energy performance requirements such as building codes and energy performance certificates, and thus takes advantage of the same type of compliance infrastructure and market surveillance mechanisms as have been developed for these. From a technical level the enforceability of BREEAM specifications is roughly the same as for building code requirements, but as BREEAM is a private initiative it relies on the quality of the initial BREEAM assessment to ensure its integrity – rather than ex post evaluations.

No formal legal requirements for BREEAM ratings appear to be in place, although BRE reserves the right to remove licenses to BREEAM users who breach their usage guidelines.

Transparency

The method to be applied is very transparent as the guide is publicly available and the assessment can be followed step by step. Nevertheless, for some criteria, the use of proprietary tools is inevitable, especially for energy use, for which a proprietary indicator that is incompatible with common metrics is used.

The assessment of a broad range of indicators can make interpretation of the results more difficult than for single indicator-based assessments.

The rationale behind the section weightings and the selection of those criteria where it is mandatory to pass are not in the public domain and hence are not transparent.

Ease and readiness

The methodology has been used for almost 30 years and is commonly used on the market. The wide acceptance and international adoption of the scheme suggests that it is sufficiently straightforward to implement.

Capacity to be implemented

A priori the impact assessment methods used within BREEAM are not inconsistent with the methodological aspects of the SRI and both could be adapted to fit within the other's assessment process. The BREEAM approach entails the application of implicit environmental impact criteria aggregator functions based on panel weightings of which criteria should be assessed and the scoring that they can attain. This approach is inherently similar to the SRI methodology.

Relevance to the SRI

BREEAM is relevant to the SRI both in terms of its approach to apply a multi-criteria assessment methodology for buildings and in how it is implemented. The multi-criteria assessment method has many similarities with the SRI's in that criteria are identified, mapped to impacts, aggregated and weighted to attain an overall score while also providing information on scores at the sub-level. The overall score requires relative weightings across impact criteria to be developed and applied. The process used to develop and maintain the calculation methodology is proprietary and is only partly transparent. However, the methods used to communicate the methodology, manage versions, and conduct appraisals are transparent and instructive for the SRI.

1.1.2.8 Private sector sustainability certification schemes – LEED

The rating system Leadership in Energy and Environmental Design (LEED) was developed by the non-profit US Green Building Council in 1994. The LEED system has evolved over time, with the most recent update LEED v4 being introduced in 2013. The use of LEED v4 has been mandatory since November 2016.

Although the general principles of the system are comparable to those of the BREEAM system, some methodological differences exist. Whereas the BREEAM system uses points to calculate a relative target achievement, LEED is a "pure" points system: no weighting factors between the different categories exist, but the weighting is made *implicitly* by the allocation of points to the different criteria.

Within LEED, buildings can qualify for four levels of certification:

- *Certified*: 40–49 points
- *Silver*: 50–59 points
- *Gold*: 60–79 points
- *Platinum*: 80 points and above.

As is the case for the BREEAM system, LEED has mandatory prerequisites to ensure a balanced fulfilment of the criteria. Those prerequisites are mandatory for all certification levels. The overlap of the criteria used in both systems is considerable, but differences exist in the concrete implementation of the indicators.

Structure

The structure used in the LEED points system is to define impact categories, apply scoring up a maximum value within each of these and then aggregate the points to give an overall total. In general, this structure can be said to be akin to a standard AHP model, except the application of bounded maximum points per category is akin to an AHP impact category weighting system. The method used to derive weightings per impact category appears to be proprietary and is not explained to the end users.

Method of evaluation

In general, the evaluation comments that apply to the BREEAM method also apply to LEED because its features are so similar. Differences arise because to some extent the methodology is more complex due to its broader scope and the need for a full life-cycle analysis of the materials used. Nor does it use weighting between impact categories and hence it might be deemed to be slightly less accurate as a result.

On the other hand, the holistic approach goes beyond the BREEAM and LEED approaches and hence could be considered to be more thorough and accurate. The flip side of this is that it will be more demanding to implement as more factors are accounted for and require calculation.

Again, the system used to derive the weighting factors is not explained and is proprietary.

Relevance to the SRI

Like BREEAM, LEED is relevant to the SRI both in terms of its approach to apply a multi-criteria assessment methodology for buildings and in how it is implemented. The multi-criteria assessment method has many similarities with the SRI's in that criteria are identified, mapped to impacts, aggregated and weighted to attain an overall score while also providing information on scores at the sub-level. The overall score requires relative weightings across impact criteria to be developed and applied. The process used to develop and maintain the calculation methodology is proprietary and is only partly transparent. However, the methods used to communicate the methodology, manage versions, and conduct appraisals are transparent and instructive for the SRI. LEED is also interesting in that it awards credits for building performance monitoring and reporting capabilities.

1.1.2.9 Private sector sustainability certification schemes – DGNB

The rating system of the German Society for Sustainable Building (Deutsche Gesellschaft für Nachhaltiges Bauen; DGNB) is the youngest of the building rating systems described in this report.

The current version of the system is the result of a revision in 2015. The general principle of the methodology is comparable to the BREEAM and LEED approach, though there are some differences.

The DGNB system has been designed as a sustainability assessment system. This is clearly reflected in the indicators and their weighting, as shown in Table 5.

Compared to the other schemes, energy issues play a minor role in the assessment. Their major impact is on criterion ENV1.1, which considers life-cycle impacts of the building with a relative relevance of ~8%, and ENV2.1, which considers primary energy use with a relative relevance of 5.6%.

Economic criteria, which are not relevant in BREEAM and LEED, contribute more than 20% to the overall result. As life-cycle costs are considered, energy costs are also relevant in this category.

A point system is used, in which credits are assigned for the individual criteria. The credits are weighted and aggregated to achieve a final score.

Structure

The structure applied in the DGNB points system (see Table 5) is to define impact categories, apply scoring up a maximum value within each of these and then to aggregate the points to give an overall total via the application of weightings to the impact category scores. This structure can be said to be akin to a standard AHP model using impact category weightings, although the application of bounded maximum points per category is akin to a second layer to a standard AHP impact category weighting system. The method applied to derive the maximum scores and weightings per impact category is proprietary to the scheme developers and is not explained to the end users.

Method of evaluation

In general, the evaluation comments that apply to the BREEAM method also apply to DGNB because its features are similar. Differences arise because to some extent the methodology is more complex due to its broader scope and the need for a full life-cycle analysis of the materials used. However, like BREEAM, it uses weighting between impact categories.

On the other hand, the holistic approach goes beyond the BREEAM approach and hence could be considered more thorough and accurate. Conversely, it will be more demanding to implement as more factors are accounted for and require calculation. As a consequence, the reproducibility and capacity to implement scores given by the team are one point lower than for BREEAM.

Again, the system used to derive the weighting factors is not explained in publicly accessible documents and is proprietary.

Relevance to the SRI

DGNB's relevance to the SRI is very similar to the cases of BREEAM and LEED, but in practice is focused on implementation within Germany and German speaking communities.

Table 5 – The impact criteria and weightings applied in the DGNB building environmental rating system

topic	criteria group	criterion no.	criterion	relevance factor	share of total score
Environmental quality (ENV)	Effects on the global and local environment (ENV10)	ENV1.1	Life cycle impact assessment	7	7,9%
		ENV1.2	Local environmental impact	3	3,4%
		ENV1.3	Responsible procurement	1	1,1%
	Resource consumption and waste generation (ENV20)	ENV2.1	Life cycle assessment - primary energy	5	5,6%
		ENV2.2	Drinking water demand and waste water volume	2	2,3%
		ENV2.3	Land use	2	2,3%
Economic quality (ECO)	Life Cycle Cost (ECO10)	ECO1.1	Life Cycle Cost	3	9,6%
	Economic development (ECO20)	ECO2.1	Flexibility and adaptability	3	9,6%
		ECO2.2	Commercial viability	1	3,2%
Sociocultural and functional quality (SOC)	Health, comfort and user satisfaction (SOC10)	SOC1.1	Thermal comfort	5	4,3%
		SOC1.2	Indoor air quality	3	2,6%
		SOC1.3	Acoustic comfort	1	0,9%
		SOC1.4	Visual comfort	3	2,6%
		SOC1.5	User control	2	1,7%
		SOC1.6	Quality of outdoor spaces	1	0,9%
		SOC1.7	Safety and security	1	0,9%
	Functionality (SOC20)	SOC2.1	Design for All	2	1,7%
		SOC2.2	Public access	2	1,7%
		SOC2.3	Cyclist facilities	1	0,9%
	Design quality (SOC30)	SOC3.1	Design and urban quality	3	2,6%
		SOC3.2	Integrated public art	1	0,9%
		SOC3.3	Layout quality	1	0,9%
Technical quality (TEC)	Technical quality (TEC10)	TEC1.1	Fire safety	2	4,1%
		TEC1.2	Sound insulation	2	4,1%
		TEC1.3	Building envelope quality	2	4,1%
		TEC1.4	Adaptability of technical systems	1	2,0%
		TEC1.5	Cleaning and maintenance	2	4,1%
		TEC1.6	Deconstruction and disassembly	2	4,1%
		TEC1.7	Sound emissions	0	0,0%
Process quality (PRO)	Planning quality (PRO10)	PRO1.1	Comprehensive project brief	3	1,4%
		PRO1.2	Integrated design	3	1,4%
		PRO1.3	Design concept	3	1,4%
		PRO1.4	Sustainability Aspects in Tender Phase	2	1,0%
		PRO1.5	Documentation for facility management	2	1,0%
	Construction quality (PRO20)	PRO2.1	Environmental impact of construction	2	1,0%
		PRO2.2	Construction quality assurance	3	1,4%
		PRO2.3	Systematic commissioning	3	1,4%
Site quality (SITE)	Site quality (SITE10)	SITE1.1	Local Environment	2	0,0%
		SITE1.2	Public image and social conditions	2	0,0%
		SITE1.3	Transport access	3	0,0%
		SITE1.4	Access to amenities	2	0,0%

1.1.2.10 Product Environmental Footprint (PEF)

In April 2013 the European Commission launched a Recommendation on the use of common methods to measure and communicate the life-cycle environmental performance of products, also known as Product Environmental Footprint (PEF), as part of their Single Market for Green Products Initiative[39]. The method was developed by the European Commission's Joint Research Centre based on existing, extensively tested and used methods. The Commission also launched a 3-year testing period through an open call for organisations to volunteer to participate in a PEF pilot programme[40]. The call was addressed to stakeholders who wanted to propose a product category for which to develop specific Product Environmental Footprint Category Rules (PEFCRs). Such rules have now been developed for a variety of product types, including batteries and IT products.

The Commission published recommendations on the PEF in the form of guidelines in 2013 (CEC 2013) that set out the process by which specific PEFCR are to be developed. It includes the derivation of 15 default environmental impact categories (Table 6; note that although this table only lists 14 impact categories, "Eutrophication – aquatic" is to be calculated for both freshwater and marine environments, thus giving 15 impact categories in total).

In the framework of the environmental footprint pilot phase, the use of normalisation and weighting factors has been tested. Prior to the establishment of an agreed set of European weighting factors, all impact categories were to receive the same weight (weighting factor = 1). Alternative weighting approaches may also be tested as "additional" compared to the equal weighting approach (the baseline approach). In the event that alternative weighting systems are also tested, a sensitivity analysis will be carried out and the results documented and discussed through a stakeholder consultation process.

For any specific PEFCR, the intention is that a benchmark and performance grades will be established. The benchmark shall be calculated for all 15 impact categories separately. The final PEFCRs also describe the uncertainties common to the product category and identify the range in which results could be seen as not being significantly different in comparisons or comparative assertions.

Next to the calculated benchmark, each pilot defines five classes of environmental performance (from A to E, with A being the best performing class). The benchmark is the characterised results of the PEF profile of the representative product(s) and always represents class C. The definition of the remaining classes should be taken into account the estimated spread around the benchmark results, which might differ from one impact category to another, and an estimation of the expected environmental performance for the best and worst in class products. All relevant assumptions regarding the identification of the benchmark and the classes of environmental performance are documented in the PEFCR and are part of the virtual consultation and review processes.

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[39] http://ec.europa.eu/environment/eussd/smgp/

[40] http://ec.europa.eu/environment/eussd/smgp/ef_pilots.htm

Table 6 – Default environmental footprint (EF) impact categories (with respective EF impact category indicators) and EF impact assessment models for PEF studies

EF Impact Category	EF Impact Assessment Model	EF Impact Category Indicators	Source
Climate Change	Bern model - Global Warming Potentials (GWP) over a 100 year time horizon.	kg CO_2 equivalent	Intergovernmental Panel on Climate Change, 2007
Ozone Depletion	EDIP model based on the ODPs of the World Meteorological Organ-ization (WMO) over an infinite time horizon.	kg CFC-11 (*) equivalent	WMO, 1999
Ecotoxicity for aquatic fresh water	USEtox model	CTUe (Comparative Toxic Unit for ecosystems)	Rosenbaum et al., 2008
Human Toxicity - cancer effects	USEtox model	CTUh (Comparative Toxic Unit for humans)	Rosenbaum et al., 2008
Human Toxicity – non-cancer effects	USEtox model	CTUh (Comparative Toxic Unit for humans)	Rosenbaum et al., 2008
Particulate Matter/Re-spiratory Inorganics	RiskPoll model	kg PM2,5 (**) equivalent	Humbert, 2009
Ionizing Radiation – human health effects	Human Health effect model	kg U^{235} equivalent (to air)	Dreicer et al., 1995
Photochemical Ozone Formation	LOTOS-EUROS model	kg NMVOC (***) equivalent	Van Zelm et al., 2008 as applied in ReCiPe
Acidification	Accumulated Exceedance model	mol H+ eq	Seppälä et al.,2006; Posch et al., 2008
Eutrophication – terrestrial	Accumulated Exceedance model	mol N eq	Seppälä et al.,2006; Posch et al., 2008
Eutrophication – aquatic	EUTREND model	fresh water: kg P equivalent marine: kg N equivalent	Struijs et al., 2009 as imple-mented in ReCiPe
Resource Depletion – water	Swiss Ecoscarcity model	m^3 water use related to local scarcity of water	Frischknecht et al., 2008
Resource Depletion – mineral, fossil	CML2002 model	kg antimony (Sb) equiv-alent	van Oers et al., 2002
Land Transformation	Soil Organic Matter (SOM) model	Kg (deficit)	Milà i Canals et al., 2007

(*) CFC-11 = Trichlorofluoromethane, also called freon-11 or R-11, is a chlorofluorocarbon.
(**) PM2,5 = Particulate Matter with a diameter of 2,5 µm or less.
(***) NMVOC = Non-Methane Volatile Organic Compounds

Structure

The PEF is essentially aimed towards a points system application of the life-cycle analysis process as set out in ISO 14040 and 14044: (i) selection of impact categories, category indicators and characterisation models; (ii) classification: assignment of inventory data to impact categories; (iii) characterisation: calculation of category indicator results; (iv) normalisation: calculating the magnitude of the category indicator results relative to a chosen reference information dataset; (v) grouping: sorting and possibly ranking of the impact categories; and (vi) weighting (valuation): converting and possibly aggregating indicator results across impact categories using numerical values based on value choices is akin to the elements found in a standard AHP model.

The PEF method has certain similarities with other multi-criteria assessment methods such as the Analytical Hierarchy Process[41]. Both begin with multiple criteria, where the criteria in the PEF method are the various environmental impact categories. In both cases, indicator scores are ascribed to each of the assessment criteria (impact categories). The normalisation and grouping steps are directly equivalent to the process within the AHP of ascribing alternatives to each criterion and providing normalised scores. The weighting of the criteria is also directly analogous to the AHP, thus the PEF can be said to be an example of the application of the more generic AHP approach to environmental impact assessment.

Methodology

Some general observations about the status of the PEF methodology are now given.

Robustness of indicators: The PEF methodology requires the assessment of a total of 15 impact indicators. The PEF guidance document v.5.2 indicates that some of these cannot currently be determined in a sufficiently reliable manner. If it is decided in the pilot to publish the normalised and weighted results, then the following disclaimer shall be added to the screening report:

> "*Within the Environmental Footprint (EF) pilot phase normalisation and equal weighting were foreseen to be used in the EF screenings to identify the most relevant impact categories. The use of normalisation and weighting for this purpose remains the objective for the EF pilots and beyond. However, currently PEF screening results after the normalisation and equal weighing present some inconsistencies stemming from errors at various levels of the assessment. Therefore, screening results after normalisation and equal weighting are not sufficiently robust to apply for product comparisons in an automatic and mandatory way in the Environmental Footprint (EF) pilots, e.g. to identify the most relevant impact categories. The interpretation of the results reflects these limitations. To avoid potential misinterpretation and misuse of the EF screening results we highlight that the results after normalisation and equal weighting, – without further error checking and possibly corrections, – are likely to overestimate or underestimate especially the relevance of the potential impacts related to the categories Human toxicity – cancer effect, Human toxicity – non-cancer effect, Ecotoxicity for aquatic fresh water, water depletion, resource depletion, ionising radiation and land use.*"

[41] https://en.wikipedia.org/wiki/Analytic_hierarchy_process

This finding implies that the listed impact parameters cannot yet be adequately evaluated to be used within a regulatory policy instrument.

Application of weighting factors: the JRC is currently developing a weighting method that is intended for use in the derivation of PEFCR. The current approach in the PEF pilot phase is the use of equal weighting factors (all impact categories are considered equally important).

Effectiveness

The method is effective for the indicators that can be reliably measured but not so much for those which are difficult to measure or for which impacts are challenging to quantify. In principle the PEF should be an effective instrument from a technical methodological perspective, but it faces challenges in the derivation of consensual weightings between the impact categories and in establishing the magnitude of some of the impacts.

Accuracy

The level of accuracy is good for readily measurable impact parameters and less so for those that are less readily measured or established. As with the SRI, the initial default application of equal weighting between impact categories is arbitrary and hence potentially inaccurate or subjective; however, were suitable weighting processes to be developed this limitation would be overcome.

Reproducibility

Reproducibility should be reasonable when the impact parameters are readily measurable with an acceptable degree of accuracy (however, this is not presently the case for all of the impact parameters) and when PEFCR have been developed. In cases where such a PEFCR is unavailable the reproducibility is likely to be low.

Enforceability

The PEF should be reasonably enforceable from a technical perspective when the impact parameters are readily measurable with an acceptable degree of accuracy; however, this is not presently the case for all of the impact parameters. The large number of impact parameters will make verification of test results and documentation more challenging than for schemes that require fewer parameters to be assessed.

Transparency

The method is transparent in principle and is being fully documented in a publicly accessible manner.

Readiness and capacity to be implemented

The PEF methodology has currently only been finalised for a limited number of product types.

The PEF method is transparent and in principle should be suitable for implementation once rules have been developed for a given product group; however, the large number of diverse impact parameters add complexity and will always make it more challenging to implement than other product evaluation systems such as Ecodesign regulations, which are focused on a narrower set of parameters.

A priori the life-cycle analysis methods embedded within the PEF are consistent with the legally enshrined methodological aspects of the Ecodesign regulations and would fit, in a legal sense, within the Ecodesign and energy labelling procedural and decision-making process. They are broadly compatible with the MEErP[42] and Ecoreport tool approaches, which constitute slightly simplified implementations of a full life-cycle analysis approach.

Relevance to the SRI

The PEF is mostly relevant to the SRI as another example of a voluntary EU initiative entailing a multi-criteria assessment methodology.

1.1.2.11 Ecolabelling

The European Ecolabelling scheme is established through legal instruments:

- Regulation (EC) No 66/2010 of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel
- Commission Regulation (EU) No 782/2013 of 14 August 2013 amending Annex III to Regulation (EU) No 66/2010 of the European Parliament and of the Council on the EU Ecolabel Text with EEA relevance.

The EU Ecolabel covers a wide range of product groups, from major areas of manufacturing to tourist accommodation services. Key experts, in consultation with main stakeholders, develop the criteria for each product group in order to decrease the main environmental impacts over the entire life cycle of the product. Because the life cycle of every product and service is different, the criteria are tailored to address the unique characteristics of each product type.

Every 4 years on average, the criteria are revised to reflect technical innovation such as evolution of materials, production processes or emission reduction and changes in the market. The intention is that the EU Ecolabel will represent the highest environmental performance for the product or services it is applied to.

Currently, EU ecolabelling criteria have been established for the following products and services:

- rinse-off cosmetic products
- absorbent hygiene products
- all-purpose cleaners
- all-purpose cleaners and sanitary cleaners
- detergents for dishwashers
- industrial and institutional automatic dishwasher detergents
- hand dishwashing detergents
- laundry detergents
- industrial and institutional laundry detergents
- textiles
- footwear
- paints and varnishes

42 https://ec.europa.eu/docsroom/documents/26525/attachments/1/translations/en/renditions/pdf

- imaging equipment
- personal computers
- notebook computers
- televisions
- wooden floor coverings
- hard coverings
- wooden furniture
- growing media and soil improvers
- growing media, soil improvers and mulch
- heat pumps
- water-based heaters
- lubricants
- bed mattresses
- sanitary tapware
- flushing toilets and urinals
- converted paper
- newsprint paper
- printed paper
- copying and graphic paper
- tissue paper
- holiday accommodation
- campsite services
- tourist accommodation services.

Structure

The approach taken to derive the Ecolabel criteria can vary from product to product as the development group determines what best fits the needs of the product. In practice, the first stages of a standard life-cycle analysis approach are followed wherein a set of pertinent environmental impact criteria are established and typical impact magnitudes established. These may subsequently be screened for their potential to be reduced and for the viability of application and potentially limited to a smaller set of impact criteria that will be used within the Ecolabel award system. Once the set of criteria has been established it is common practice to set requirements for each of them. Although aggregation via weighting is not precluded from the EU Ecolabel, thus far there has been no example of it being used. Rather, in the case of quantifiable criteria the practice is to use normalisation and benchmarking to establish minimum values that must be met to be eligible to receive the Ecolabel.

The Ecolabel criteria are binary in the sense that a product/service either satisfies them and hence is eligible to apply for the use of the Ecolabel, or it does not and hence is ineligible. In all instances of the label as currently implemented, all criteria must be met for a product or service to be eligible for the label. However, not all the criteria are quantitative. For example, some may concern the presence or absence of a feature or service.

Thus, for most products the Ecolabel criteria are similar in structure to Ecodesign criteria but tend to address more environmental impact parameters. Furthermore, unlike for Ecodesign regulations, the energy efficiency requirements set within Ecolabels are not guided by an objective of minimising the life-cycle cost.

The EU criteria are developed by ad hoc working groups established for each product of interest and are subject to approval by the Ecolabel Board, which is comprised of a set of notified bodies. Usually the Commission hires an impartial technical consultancy to conduct analysis and develop draft criteria. These are scrutinised and discussed by the ad hoc working group who provide comment that the consultancy then applies to amend the criteria. Consequently, the criteria are developed using a "panel type" assessment process. The resulting draft ecolabel criteria document is then put forward to the Ecolabel board for scrutiny and approval. As with other multicriteria evaluation frameworks the EU Ecolabel sometimes requires trade-off choices to be made between partially conflicting impact criteria and hence the application of values and judgement through the ad hoc groups and Ecolabel Board.

Effectiveness

The Ecolabel has been awarded to over 30,000 products and services across the EU and hence is effective at influencing part of the market. As it is a voluntary scheme it does not have the same scale of impact that is associated with the mandatory energy label or Ecodesign requirements, but it applies to a diverse set of products and services that would not be entirely suited to those instruments. Furthermore, it addresses a broader set of environmental impacts.

Accuracy

In principle the accuracy by which the quantifiable criteria used within the Ecolabelling scheme can be determined is similar to that found for other EU environmentally related product regulations such as Ecodesign, RoHS, WEEE, etc.

Reproducibility

In principle, the reproducibility of the quantifiable criteria measurements used within the Ecolabelling scheme is similar to that found for other EU environmentally related product regulations such as Ecodesign, RoHS, WEEE, etc.

Enforceability

From a technical perspective, the enforceability of the Ecolabelling scheme is similar to that for other EU environmentally related product regulations such as Ecodesign, RoHS, WEEE, etc. The fact that on average a greater number of assessment criteria need to be evaluated implies that document inspection and verification testing against Ecolabelling criteria is a more involved process than for Energy labelling or Ecodesign regulations. From an organisational perspective it is different, however, as Ecolabelling requirements are not mandatory within the Single Market and hence Member States are not required to designate a specific market surveillance body to check compliance with the requirements. Rather, verification of conformity with the requirements would usually be the responsibility of the same trading standards entities that have a broad mandate to enforce truth in advertising and consumer protection legislation – in practice alleged non-conformity is usually brought to the attention of such agencies by other parties rather than through an active market monitoring process.

Transparency

The scheme criteria are fully transparent and within the public domain.

Readiness and capacity to be implemented

The scheme is up and running and relatively straightforward to use; however, the fact that on average a greater number of assessment criteria need to be met than for energy labelling or Ecodesign regulations implies that it requires a greater product design and administrative effort to attain the Ecolabel requirements.

Relevance to the SRI

The Ecolabel is most relevant to the SRI with regard to its implementation and especially its management. It is a voluntary initiative that is founded in an EU legal text, it involves issuance of a label to qualified goods and services based on their satisfaction of eligibility criteria which are established at the EU level through a governance process that combines Member State representation with expert and stakeholder input. Methodologically it also involves a multicriteria evaluation process where diverse impacts are organised into a common evaluation framework.

1.1.2.12 Extended Product Approaches - The "installer energy label" for heating systems

The EU energy label for space heating systems applies to packages of space heater, temperature control and solar device offered for sale, hire or hire-purchase[43].

Methodology and structure

The space heating installer energy label is innovative compared to conventional energy labels in two principal respects:

It is essentially an extended product approach which ranks and displays the energy efficiency of the heating system as a system and not just for each individual component within it.

It is to be implemented by the installer of the system using component ratings supplied by the product component manufacturers.

Ostensibly the method used considers the seasonal heating efficiency of the boiler at the location in isolation, it then adds efficiency credits depending on the nature of controls used (note these only concern the direct control of the boiler not the control of the heating distribution system, which is often where larger energy savings are possible), the impact of using an additional boiler, the impact of using a solar heating device, the impact of using a heat pump, the impact of using a solar heating device and a heat pump, and takes all of this through the calculation structure shown in Figure 3 to derive an overall heating system efficiency score.

This approach is a classic example of a modular approach to determining the energy efficiency of a system. It indicates how the energy performance of individual system modules (components) can be assessed in isolation and then their collective performance, as a specific assembly of components within an overall heating system, can be determined via a set of logical calculations (using credits and multiplicative efficiencies). Although each component has a distinct function and a distinct efficiency in performing that function this does not prohibit

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[43] European Commission. 2013b, COMMISSION DELEGATED REGULATION (EU) No 811/2013 of 18 February 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of space heaters, combination heaters, packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device

their collective efficiency from being estimated in a sufficiently robust manner to permit an overall energy labelling class to be determined for the heating system.

Although the method is relatively innovative, implementation has only recently begun and hence it is too early to be able to report findings on how it is working in practice.

From a technical perspective, the method makes considerable progress in being able to reveal the efficiency of the heating system, but it has the following limitations:

- it does not address the heat losses in the distribution system and hence gives no reward to the use of distribution loss reduction measures such as: zoning, TRVs, individually programmable heat emitter controls and actuators linked to a room thermostat, learning the thermal response of rooms and optimum stop/start controllers, weather compensation controls.
- it does not address the impact of heating system sizing on its overall performance

In practice, these latter two factors (especially the first) can have a very large impact on the overall efficiency of the heating system.

Nonetheless, despite these system boundary analysis limitations the labelling scheme has considerably broadened the extent of the heating system that is taken into account when rating its efficiency and hence has amplified the visibility of the energy savings possibilities. From a technical and policy-making perspective it is a successful example of a workable compromise being struck between technical precision and the overarching policy need to present the public with information on the energy efficiency of the heating systems they are considering procuring.

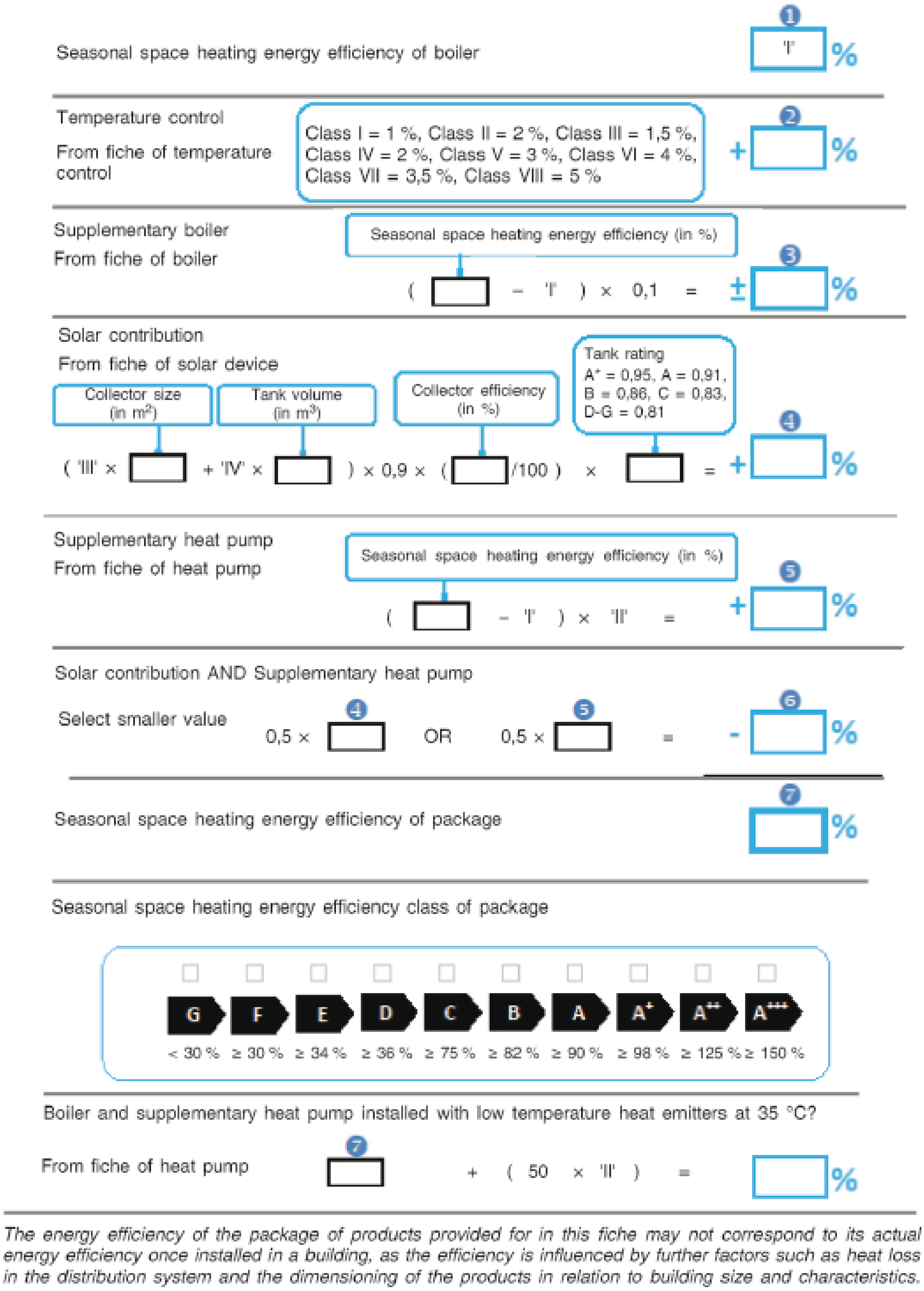

Figure 3 - For preferential boiler space heaters and preferential boiler combination heaters, element of the fiche for a package of space heater, temperature control and solar device and a package of combination heater, temperature control and solar device, respectively, indicating the seasonal space heating energy efficiency of the package offered

This example is also interesting from a technical perspective because it addresses one of the key challenges for complex products, namely, how to characterise the performance of modules (components) that have more than one function? In this case the boilers, solar heaters and heat pumps may well serve dual space and water heating functions. The approach taken is to determine their efficiency for doing each function uniquely and then to separately label the system space heating efficiency and the system water heating efficiency. It does not go so far as to integrate a duty cycle for each function in isolation to derive a combined functional duty cycle, although in principle such an approach could be imagined.

Method evaluation

Effectiveness

The scheme has only recently entered into force and thus there is currently no evidence of its effectiveness, however, if it has even a modest proportion of the impact of other energy labels it will likely lead to energy savings and as a minimum it allows the energy efficiency of the heating system to be made visible in such a manner than it can readily be completed by other policy instruments such as EPCs, building codes, incentives etc.

Accuracy

In principle, the accuracy by which the quantifiable criteria used within the heating system energy label can be determined is similar to that experienced for other labelled products except that because the overall systems efficiency rating is effectively a multiplicative sum of the efficiencies of its individual components compound errors will be propagated through to the system level. This is unavoidable when dealing with multiple components, however, and is not indicative of any methodological weakness.

Reproducibility

The reproducibility of the quantifiable criteria measurements used within the space heating energy label should be similar to that experienced for other EU environmentally-related product regulations such as Ecodesign, RoHS, WEEE etc.

Enforceability

From a technical perspective the enforceability of the space heating energy labelling schemes is similar to that experienced for EU environmentally-related product regulations such as Ecodesign, RoHS, WEEE etc.; however, it introduces a different challenge because it requires the actions of system installers, as well as component suppliers to be addressed.

Transparency

The criteria applied and the process of deriving the space heating systems energy label are fully transparent and within the public domain.

Readiness and capacity to be implemented

The system for installers to determine and apply the space heating systems energy label is readily available and relatively straightforward to use. Nonetheless anecdotally teething issues were reported in the early stages of the scheme's deployment as a large number of heating systems installers needed to become familiarised with the scheme.

Relevance to the SRI

The space heating energy label is probably most relevant to the SRI in terms of its implementation. It requires qualified space heating installation professionals to issue an energy label on site to the customer based on the characteristics of the installed system. This entails the imposition of additional obligations, duties and competences on the affected profession. It is an EU managed scheme which includes Member State input and stakeholder consultation. As it is mandatory Member States are required to implement a market surveillance process under a designated market surveillance agency but organisationally this poses a challenge because verifying conformity with the requirements entails ensuring all concerned products and components within the supply chain meet the requirements, including the installed system as a whole as well as products leaving the factory.

1.1.2.13 Ecodesign Lot 37 lighting systems study

The recent Lot 37 lighting study into lighting systems[44] has established how the energy performance of each separate module of a lighting system can be analysed in a compartmentalised manner and fed into a calculation to determine the overall energy efficiency of the lighting system.

Methodology and structure

In the case of in-door lighting the study presents a technically viable pathway by which the characteristics of each component within a lighting system are combined to give an overall energy performance indicator.

This compartmentalisation and causative flow is shown in Components of a lighting system and the most relevant performance parameters related to energy efficiency wherein each system level element has its own colour code as follows: electrical efficiency (dark green), installation (dark blue), luminaire (sky blue), lamp (orange), control system (light green), control gear (red), and design process (yellow). This demarcation is done to help delineate the various aspects of a lighting system and to enable their contribution to the overall eco-efficiency of the system to be analysed and determined. In the case of non-residential lighting the EN 12464 standard series on indoor lighting is used to define minimum recommended lighting service levels for any given lighting service application and these allow normalised service levels to be established. The energy consumption and efficiency of any given lighting system can then be derived for each required application and normalised against the required lighting service levels. For any given lighting service level requirement, the indicator of the energy performance of the lighting system is given by the Lighting Energy Numerical Indicator (LENI) which is expressed in kWh/year per m2 (see far left of Figure 4). The LENI value for any given in-door lighting system is derived by the application of the standards EN 15193 and EN 13201-5 in conjunction with the light levels required for the specific application under EN 12464.

[44] http://ecodesign-lightingsystems.eu/

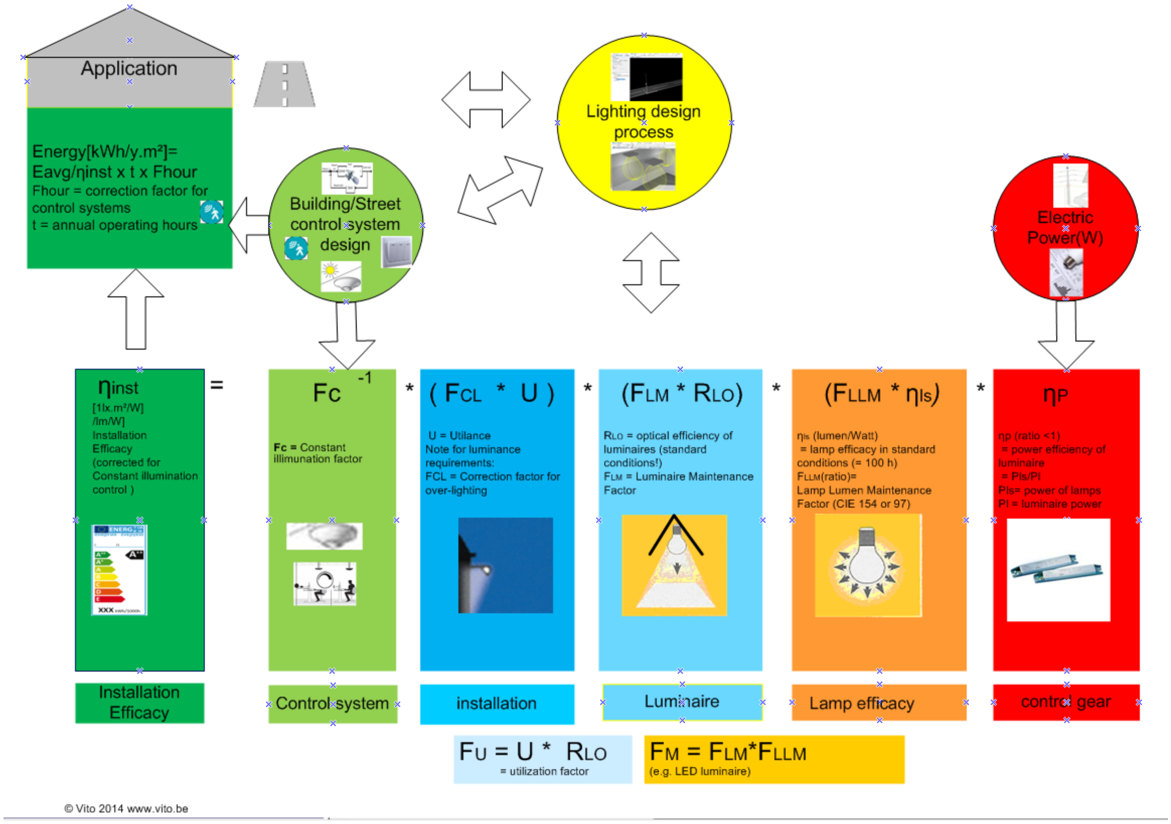

Figure 4 - Components of a lighting system and the most relevant performance parameters related to energy efficiency

By comparing the available average and best available technology (BAT) solutions for each application it's possible to determine the range of viable LENI values per application. If life cycle cost optimisation were to be incorporated into this process it becomes technically possible to devise a specific LENI target for each class of typical lighting system, in a manner that could meet the aims of the Ecodesign regulatory process. However, a priori this would be applicable at the application level rather than the sub-system level and thus this raises the question of on whom regulatory requirements could be placed. The space heater energy label demonstrates that it is at least legally permissible for system labelling requirements to be imposed on installers and not just component manufacturers.

Methodology evaluation

Effectiveness

The LENI approach described above is already adopted in European standards, is incorporated in lighting design software and is embedded in some Member State building codes. While it works from a technical perspective it is voluntary to apply in most of the EU and thought to only being applied by a limited proportion of market actors as a consequence.

Accuracy

In principle the accuracy by which the quantifiable criteria used within the LENI approach can be determined is similar to that experienced for other products subject to Ecodesign or energy labelling requirements except that because the overall systems efficiency rating is effectively a multiplicative sum of the efficiencies of its individual components compound errors will be propagated through to the system level. This is unavoidable when dealing with multiple components, however, and is not indicative of any methodological weakness.

Reproducibility

The reproducibility of the quantifiable criteria measurements used within the LENI calculation at the component level is similar to that experienced for other EU environmentally-related product regulations such as Ecodesign, RoHS, WEEE etc. There are more calculation steps at the systems level necessary to derive the LENI and hence there is more scope to introduce variance than for simple products.

Enforceability

The enforceability of the LENI approach is similar to that of other technical energy using systems specified with the EPBD (Article 8) and has been demonstrated through incorporation into building code requirements in countries such as the UK and Switzerland. It introduces a different challenge compared to standard products within Ecodesign because the actions of system specifiers and installers, as well as component suppliers would need to be addressed.

Transparency

The criteria applied and the process of deriving the LENI calculation are fully transparent and within the public domain.

Readiness and capacity to be implemented

The means to apply the LENI calculation method is readily available and relatively straightforward to use in principle. Nonetheless it is more complex than some less sophisticated lighting energy performance calculations such as the lighting power density indicator.

Relevance to the SRI

The Lot 37 Lighting systems study is mostly relevant for the SRI from a methodological perspective as it shows how various factors within a lighting system can be evaluated to attain an overall performance ranking. Some of the inputs are determined at component level (just as for SRTs within the SRI) and some at the installed system level (again as for smart services within the SRI).

1.1.2.14 Smart Buildings Alliance

The Smart Buildings Alliance (http://www.smartbuildingsalliance.org) is a French association concerned with promoting smart solutions in the French building infrastructure.

Created in 2012, the SBA federates to date 253 organizations representing all building related trades and Smart City stakeholders, to think and define the Smart Building. Its ambition is to enable its members - manufacturers, service companies, consultancy firms, architects, builders, developers, developers or innovative start-ups - to contribute to developing the Smart Buildings sector and derive the value of the building towards the future, for all stakeholders: owners, users and communities.

The SBA has given itself a transversal mission that allows the different actors of the building to exchange upstream taking into consideration the major issues that are related to digital topics, but also the environment and sustainable development.

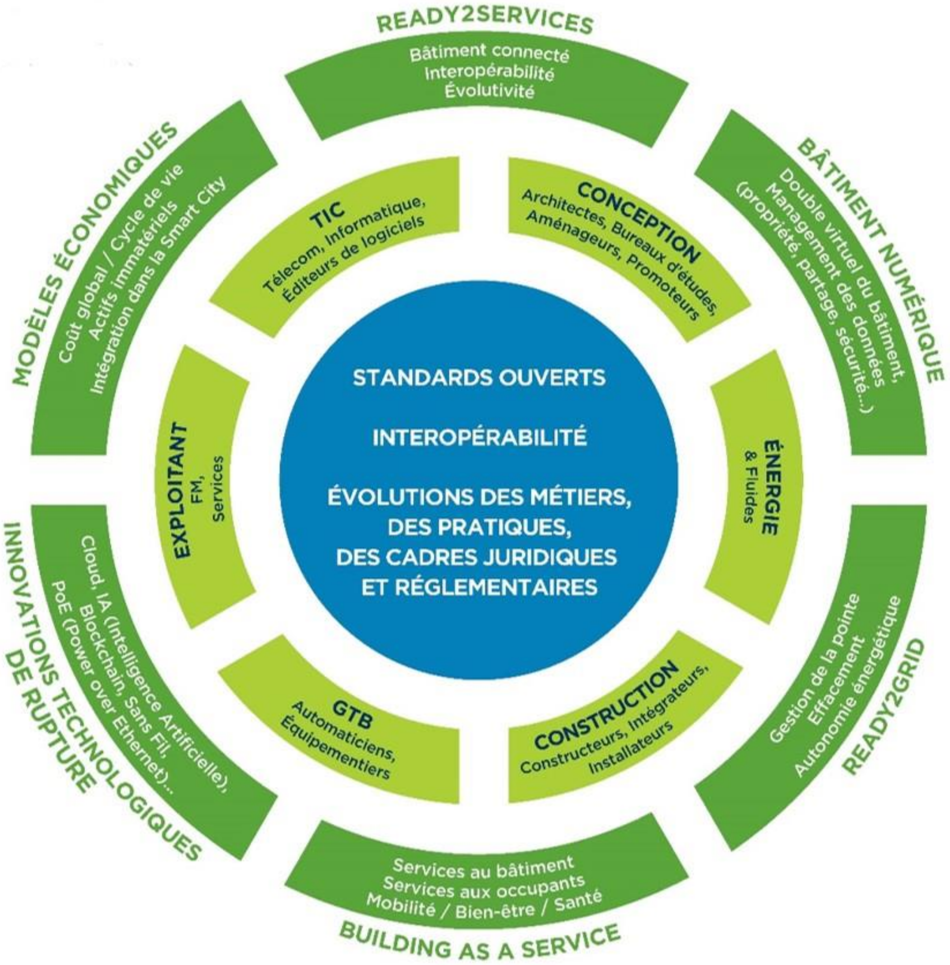

Figure 5 - Inter-relationships in smart buildings (Source: SBA website 2019)

The SBA acts to brings together the entire Smart Building ecosystem and offers stakeholders in the sector the opportunity to harmoniously integrate new technologies, enable the development of new services, optimise the use of resources (particularly energy), and to increase the use value and the financial value of the building assets.

To do this, the development of Smart Buildings involves cooperation between 3 technical areas with different business logic:

- The world of equipment and building control
- The world of IT, Telecom and software
- The world of energy and flow infrastructure

According to the SBA this triptych, which unites the providers of solutions around the concept of smart buildings, must in turn enter into dialogue with the historical stakeholders of the building world:

- Designers (Developers, Developers, Architects, Design Offices, ...)

- Builders (General contractors, integrators, installers, ...)
- Operators (FM, Services, ...)

The SBA, building on the work of its commissions and working groups, develops technical reference systems (Ready2Services, Ready2Grid, Digital Mock-up, Smart Data, etc. ...), as well as smart building valuation models (i.e. Building as a Service, Smart Building for Smart Cities, Asset Valuation, ...). The association produces collaborative work by working together across the entire construction sector from upstream to downstream, integrating new players from the world of new technology.

Its work is structured in a set of commissions including the following:

- Digital building
- Smart buildings for smart cities
- Smart lighting
- Ready2services
- Ready2grids
- Safe city
- Continuous current
- Training

Relevance to the SRI

The SBA actions address a number of domains of relevance to the SRI, but most notably their certification schemes for smart buildings (Ready2Services for commercial buildings and Ready2Grids). These set out criteria that need to be satisfied for a building to be considered smart ready under the scheme, including interoperability criteria and readiness to react to grid signals specifications. The SBA scheme is market driven and thus far has predominantly been adopted by larger and more prestigious building projects for which market actors can monetise value from being able to demonstrate 3rd party certification of smart capabilities. Asides from the criteria themselves the nature of 3rd party assessments are instructive for the SRI, as are the issues associated with training and accrediting a cadre of qualified assessors.

1.1.2.15 Interoperability initiatives

The degree of interoperability of SRTs can be a limiting factor affecting the functionality of the TBSs they manage and also their interaction with the grid. Currently, a variety of proprietary and open-source communication systems are used that can either hinder or facilitate the control of TBSs by SRTs. While the pros and cons of interoperability can be complex, interoperability is important when the TBSs need to facilitate overarching management – this is often the case when they control the same service (for example heating, cooling, ventilation and lighting).

The common solution to provide overarching control for TBSs is to add gateways to the SRT system. Nevertheless, such gateways (e.g. via a Wide Area Network (WAN)) come at extra cost, consume power to function, and can be a source of system failure.

While systems and applications at buildings and utilities in the past were operated separately, today interactions between multiple systems and applications are increasingly important to operate buildings and their technical systems more effectively and provide greater energy services, comfort, well-being and health to the occupants. To do so, coupling of former separated and heterogeneous technical systems is a prerequisite for a widespread adoption of smart services. To boost greater market uptake and prevent vendor-lock-in effects, this will also require connecting physical products and ICT systems from different vendors. The smart services will be invoked from systems of third parties, therefore, also latency, bandwidth[45] and other properties have to be taken into account. Interoperability will also be conditional on the building infrastructure such as broadband connectivity[46].

According to ISO/IEC 2382-01 on *Information Technology Vocabulary, Fundamental Terms*, interoperability is defined as follows: "The capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units". Despite this definition there are also several other definitions used in standardisation. For example, several levels of interoperability[47] were identified in an ETSI white paper[48] which is applied to a multitude of topics and applications:

- Technical Interoperability is usually associated with hardware/software components, systems and platforms that enable machine-to-machine communication to take place. This kind of interoperability is often centred on (communication) protocols and the infrastructure needed for those protocols to operate. (e.g. KNX TP[49], DALI[50], oneM2M[51], SHIP[52]; IPv6[53])
- Syntactical Interoperability is usually associated with data formats (e.g. BACNET (ISO 16484-5), XML[54], KNX TP36, DALI , SPINE[55]).
- Semantic Interoperability is usually associated with the meaning of content and concerns the human rather than machine interpretation of the content (e.g. KNX TP36, DALI , Smart Appliances REFerence (SAREF) ontology[56], etc.)

Unfortunately, today there is not one universal overarching SRT system but there are several ecosystems on the market and a building often includes a multitude of them (e.g. KNX, DALI, IP user interface server). Interoperability between those systems is often a point of concern. The common solution for this is to add gateways to the SRT system, for example a DALI-to-KNX gateway to integrate lighting and KNX IP gateway and router for the user interface with a web browser.

[45] E.g. the call for a voluntary broadband-ready label for buildings, https://ec.europa.eu/digital-single-market/en/building-infrastructure

[46] Directive 2014/61/EU

[47] http://www.internet-of-things-research.eu/pdf/IERC_Position_Paper_IoT_Semantic_Interoperability_Final.pdf

[48] http://www.etsi.org/images/files/ETSIWhitePapers/IOP%20whitepaper%20Edition%203%20final.pdf

[49] https://www.knx.org

[50] https://www.digitalilluminationinterface.org/

[51] http://www.onem2m.org/

[52] https://www.eebus.org/en/technology/communication-channels/

[53] https://en.wikipedia.org/wiki/IPv6

[54] https://www.w3.org/TR/xml/

[55] https://www.eebus.org/en/technology/data-model/

[56] https://sites.google.com/site/smartappliancesproject/ontologies/reference-ontology

Nevertheless, such gateways come at extra cost and complexity and are also power consuming.

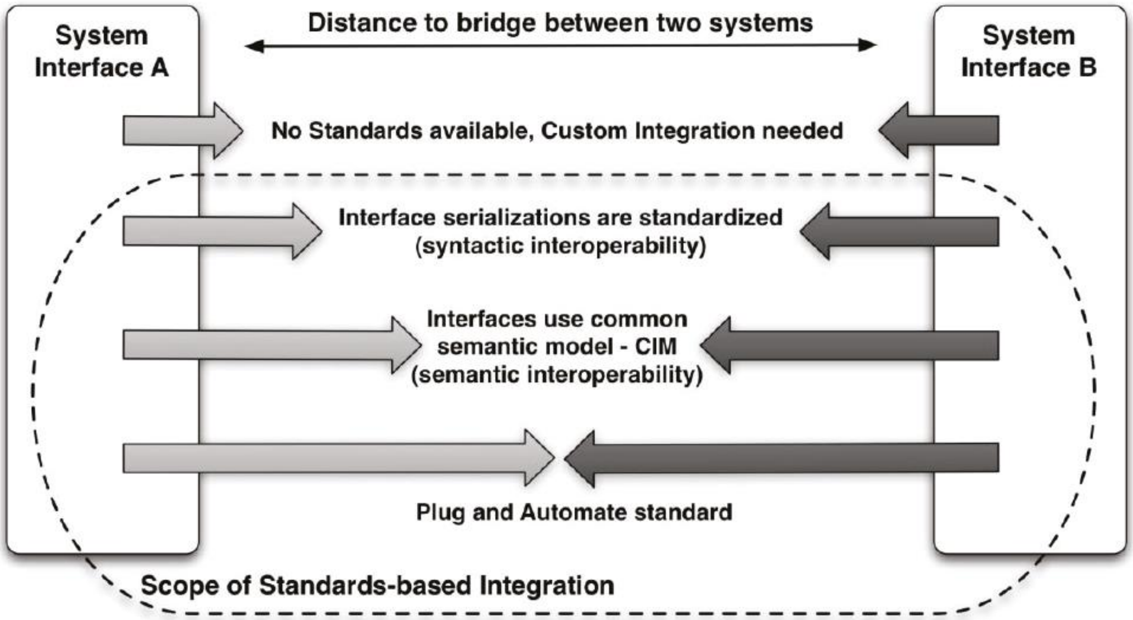

Figure 6 - Semantic integration distance for interoperability (source: Offis)

Figure 6 illustrates the different forms of interoperability; the integration distances range from customised integrations to plug-and-automate integration. This requires solutions to integrate those systems in a way their functionality is still available and can be adapted to changing needs. This figure mainly motivates why technical interfaces in the scope of the SRI shall be standardised in order to achieve a high interoperability, lower integration costs and better operational performance.

To address the issue of the multiple overlapping and competing standards within the smart home -between the energy smart appliances and the home/building energy management system- the European Commission/DG CONNECT ordered a study on "Available Semantics Assets for the Interoperability of Smart Appliances: Mapping into a Common Ontology as a M2M Application Layer Semantics"[57]. The study resulted in the development of a common ontology[58] for this domain, called SAREF (Smart Appliance Reference) and a standard based on it developed by ETSI[59].

> "*The Smart Appliances REFerence (SAREF) ontology is a shared model of consensus that facilitates the matching of existing assets (standards/protocols/data models/etc.) in the smart appliances domain,*

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[57] Information sourced from: Ecodesign Preparatory Study on Smart Appliances (Lot 33) - Final report

[58] Defining semantics for technologies and functions

[59] http://www.etsi.org/technologies-clusters/technologies/smart-appliances

providing building blocks that allow separation and recombination of different parts of the ontology depending on specific needs"[60] *(…). A Device in the SAREF ontology is also characterized by an (Energy/Power) Profile that can be used to optimize the energy efficiency in a home or office that are part of a building*."

SAREF is conceived as a shared model of consensus that facilitates the matching of existing semantic assets in the energy smart appliances domain, reducing the effort of translating from one asset to another. Using SAREF, different assets can keep using their own terminology and data models, but still can relate to each other through the common SAREF semantics which maps the same core concept to each of the assets, instead of a dedicated set of mappings for each pair of assets[57].

The SAREF ontology thus enables semantic interoperability in the energy smart appliances domain matching appliances and systems from different manufacturers, exchanging energy related information and interacting with any other Building Energy Management System. Extensions to the SAREF ontology for smart machine-to-machine communication provide specifications for the energy domain[61] and the building domain[62]. SAREF focusses on an application-independent 'horizontal' service platform with architecture capable of supporting a very wide range of services including smart metering, smart grids, eHealth, city automation (smart cities), consumer applications, car automation and smart appliances [63]. SAREF is however not the only attempt to achieve a common data model and language for energy smart appliances. The Ecodesign study on smart appliances also references amongst others the initiatives SPINE (Smart Premises Interoperable Neutral-message Exchange), IEC TS 62950 ED1, ZigBee DOTDOT, the IoT schema.org initiative and the IotTivity and oneIoTa Data Model Tool by the Open Connectivity Foundation (OCF).

In the field of smart grids, a layered approach of the Smart Grid Architectural Model (SGAM) has been developed by Cenelec and IEC[64]. European Standardization Organizations CEN, CENELEC and ETSI consolidate the standardisation for smart grids through Mandate M/490 of the European Commission[65]. Further details on the landscape of standardisation in relation to smart grids and smart buildings is documented in Annex D of the final report of the first technical support study to the establishment of the SRI.

Within the Ecodesign framework of the European Commission, further focus has been given to interoperability in the product and service design of smart

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[60] http://ontology.tno.nl/saref/

[61] SmartM2M; Smart Appliances Extension to SAREF; Part 1: Energy Domain http://www.etsi.org/deliver/etsi_ts/103400_103499/10341001/01.01.01_60/ts_10341001v010101p.pdf

[62] SmartM2M; Smart Appliances Extension to SAREF; Part 3: Building Domain http://www.etsi.org/deliver/etsi_ts/103400_103499/10341003/01.01.01_60/ts_10341003v010101p.pdf

[63] https://www.etsi.org/technologies/smart-appliances

[64] https://ec.europa.eu/energy/sites/ener/files/documents/xpert_group1_reference_architecture.pdf

[65] https://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=475#

appliances[66] and BACS[67]. The Ecodesign smart appliance preparatory study has a specific focus on electrical load flexibility for appliances or plug loads and domestic hot water (DHW) storage tanks to cope with fluctuations in renewable energy supply, and to manage and dispatch local energy production, such as photovoltaics or storage. In the future there is expected to be an increasing need for Demand Response Management (DRM) to support the Smart Grid[68,69]. In general, there are two types of Demand Response (DR) service categories[70]:

Implicit Demand Response (**iDR SRTs**) refers to SRT services to participate in the wholesale energy market, it is mostly price driven with variable tariffs or peak load tariffs.

Explicit Demand Response (eDR SRTs) refers to SRT services that support the grid operators to provide balancing or congestion management. It can be for example curtailment based on line voltage or grid frequency.

DRM inherently requires interoperability of the various systems to share information on the need and potential for shifting loads. The preparatory Ecodesign smart appliance study investigates various pathways for DRM in appliances or plug loads and domestic hot water (DHW) storage tanks. The study does not however include the building and TBSs as a whole.

In the domain of smart appliances, a Customer Energy Manager (CEM) is proposed as a central management unit that integrates control of distributed energy resources (DER), interfacing with the building automation systems, the electricity meter, etc. Such a central manager overcomes the need for direct interoperability between all of the various connected appliances and TBS.

While this type of common framework or ontology is already in place for some specific technologies such as smart appliances, this is not the case for all the domains and technologies within the scope of the SRI. Non-energy related or domain specific interoperability aspects are not part of the SAREF ontology, e.g. indoor environment quality measurements or shading control. Furthermore, recent developments such as SAREF are not applicable in a straightforward manner to the legacy equipment that is mostly present in existing buildings.

Should any EU-wide certification schemes or labels indicating the interoperability of TBS emerge in the future[71], these could be introduced into the SRI methodology in future iterations. In fact, the Smart Building Alliance's voluntary Ready to Service (R2S) label is already available for use in French building projects and includes assessment and satisfaction of interoperability criteria as a requisite condition for a building being awarded the label.

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[66] Ecodesign Preparatory Study on Smart Appliances (Lot 33) http://www.eco-smartappliances.eu

[67] Ecodesign preparatory study for Building Automation and Control Systems (BACS) http://ecodesignbacs.eu/

[68] https://www.cencenelec.eu/standards/Sectors/SustainableEnergy/SmartGrids/Pages/d efault.aspx

[69] http://smartgridstandardsmap.com/

[70] http://www.europarl.europa.eu/cmsdata/119722/3_JStromback_ITRE_300517.pdf

[71] As recommended by stakeholders in the consultation process

1.2 ACTIVITY 2: TECHNICAL RECOMMENDATIONS FOR THE DEFINITION OF THE SRI

1.2.1 INTRODUCTION

The establishment of technical recommendations for the definition of the SRI builds on the findings of the state-of-the-art review in Activity 1 and the first SRI study to produce definitive recommendations on how the SRI should be defined. To do this, the study team of the second technical support study has taken the review findings from Activity 1 and conducted a structured assessment and analysis of the implications against the findings of the first technical study. This includes determinations on the following topics:

- the scope of the SRI including whether or not to broaden/narrow it and the most pertinent parameters
- the approach for the treatment of absent services
- country/region specificities and implications for the methodology
- climatic specificities
- building type or intrinsic specificities
- the most appropriate level of streamlining necessary to deliver a viable scheme as a function of the organisational pathway considered (see Activity 1 Tasks 2 and 3)
- data protection
- interactions with other schemes such as EPCs, Level(s), building renovation passports, etc.
- appropriate terminology and language
- standardisation and codification of services and functionality levels
- how to allow updates of the methodology, e.g. to properly address innovation.

In particular, emphasis is given to consideration of the following aspects:

- the consistency of the SRI definition with the key functionalities highlighted in the SRI technical annex of the amended EPBD, i.e. the ability to maintain energy performance and operation of the building through the adaptation of energy consumption, the ability to adapt a building's operation mode in response to the needs of the occupant, and flexibility of a building's overall electricity demand
- interoperability between systems (including treatment of data formatting issues)
- connectivity of buildings (particularly the influence of existing communication networks)
- Cyber-security.

Analysis of the findings from the review of initiatives in Activity 1 is also intended to help in determining the extent to which the SRI definition will be complementary to, or potentially overlap, those found in related initiatives, so that this information can also be considered in the appraisal of the SRI definition. This feeds the refinement and consolidation of the definition of the SRI, ready for Commission services to address, with the twofold objective of (i) ensuring that the scope of the SRI covers all aspects of interest and (ii) ensuring that the SRI is fully complementary to relevant existing initiatives, in particular those linked to building performance and those at the EU level.

The analysis and conclusions are presented with the study team's initial proposals for how to proceed with regard to the definition of the SRI and the methodology applied to determine it. These frame the issue and reference stakeholder comments[72] and suggestions, and consider any pros and cons in the approaches proposed before making a recommendation on how to proceed. When appropriate, these are considered on a topic by topic basis; however, in some cases it is possible that an issue, and the potential means of addressing it, might imply a more fundamental alteration in the SRI approach. As such changes would be likely to have much greater implications with regard to the SRI approach, these have been identified as early as possible and assessed in a more holistic manner than topics that can be treated incrementally within the existing SRI methodological framework.

Throughout the study, provisional conclusions have been presented to the Commission Services and their comments taken in, and the findings have been presented to stakeholders via the website and stakeholder meetings to solicit their feedback.

Following the processing of this feedback and the refinement of the recommendations, a mature SRI definition has been established that:

- covers all aspects of interest as agreed with the Commission Services and stakeholders
- is complementary to relevant existing initiatives (particularly those linked to building performance and at EU level, hence EPCs, Ecodesign etc.).

1.2.2 Scope of the SRI

Interactions with stakeholders (Task 1 Activity 1) highlighted the need for clarity regarding the scope of the SRI. In the feedback we received on the first study, some stakeholders suggested adding domains such as safety and security systems, material use and noise reduction, to name a few. This feedback reveals valuable insight into their interpretation of the scope of the SRI:

- safety and security systems may have smart features: for the residential sector, there are smart home applications that cover these features; for non-residential buildings, we may expect to see these features as part of a building management system (BMS)
- material use is an important theme in sustainability assessments, as it significantly contributes to the carbon footprint of the built environment
- attention to themes such as noise pollution is increasing, given their link with the health and well-being of building users.

First, the SRI should be well-positioned in the sustainability landscape. It should be clear to all parties that the SRI fits within the EPBD and thus focuses on energy

[72] Stakeholder feedback has been collected in various ways, including a questionnaire sent out to stakeholders prior to the first Stakeholder Meeting, interactions during the first Stakeholder Meeting and two Topical Group sessions on 26 March 2019 in Brussels, two teleconference calls with Topical Group A on the implementation pathways and value proposition, four teleconference calls with Topical Group B on the calculation methodology, written feedback and other bilateral interactions.

performance. Other sustainability aspects, including material use, do not fit within the scope of the SRI.

In relation to buildings, no universally accepted definition of 'smartness' or 'intelligence' is currently available. Many authors and organisations have proposed their - sometimes conflicting - definitions of smart buildings[73].

Within the scope of the first and second technical study on the SRI, the following definition has been adopted:

"Smartness of a building refers to the ability of a building or its systems to sense, interpret, communicate and actively respond in an efficient manner to changing conditions in relation the operation of technical building systems or the external environment (including energy grids) and to demands from building occupants,"

On top of this definition, it is useful to refer to the three key 'smartness' functionalities given in the Annex 1a of the revised EPBD:

> *'The methodology shall rely on three key functionalities relating to the building and its technical building systems:*
>
> - *the ability to maintain energy performance and operation of the building through the adaptation of energy consumption for example through use of energy from renewable sources;*
> - *the ability to adapt its operation mode in response to the needs of the occupant while paying due attention to the availability of user-friendliness, maintaining healthy indoor climate conditions and the ability to report on energy use; and*
> - *the flexibility of a building's overall electricity demand, including its ability to enable participation in active and passive as well as implicit and explicit demand response, in relation to the grid, for example through flexibility and load shifting capacities.'*

Second, the SRI should be clearly positioned in the field of smart ready technologies (SRTs). Within the scope of the first and second technical study on the SRI, the following definition has been adopted:

> *"Smart Ready Services are delivered to the building user or the energy grid through the use of Smart Ready Technologies. These smart ready technologies can either be digital ICT technology (e.g. communication protocols or optimization algorithms) or physical products (e.g. ventilation system with CO2 sensor, cabling for bus systems) or combinations thereof (e.g. smart thermostats). The smart ready technologies referenced in this study are considered to be active components which could potentially:*
>
> - *raise energy efficiency and comfort by increasing the level of controllability of the technical building systems – either by the occupant or a building manager or via a fully automated building control system;*

[73] Amirhosein Ghaffarianhoseini, Umberto Berardi, Husam AlWaer, Seongju Chang, Edward Halawa, Ali Ghaffarianhoseini & Derek Clements-Croome (2016), What is an intelligent building? Analysis of recent interpretations from an international perspective, Architectural Science Review, 59:5, 338-357, DOI: 10.1080/00038628.2015.1079164

- *facilitate the energy management and maintenance of the building including via automated fault detection;*
- *automate the reporting of the energy performance of buildings and their TBS (automated and real time inspections);*
- *use advanced methods such as data analytics, self-learning control systems and model predictive control to optimise building operations;*
- *enable buildings including their TBS, appliances, storage systems and energy generators, to become active operators in a demand response setting."*

Given the fact that the SRI fits within the EPBD, its scope is (currently) limited to those SRTs that affect the energy performance, indoor climate conditions and energy flexibility of a building. As such, safety and security systems, for instance, are deemed out of scope of the SRI as framed by the EPBD, despite their clear potential to offer smart services to users and their potential to be integrated in BMSs. However, this would not prevent extension to the SRI (e.g. with "optional" domains) to encompass additional services that are not part of the scope set by the EPBD, if it clearly adds value to the SRI from a user perspective.

In section 1.3.1 suggestions from stakeholders to add additional domains are evaluated, keeping in mind the above rationale. Based on the evaluation, a final recommendation for domains to be included in the SRI are presented.

In addition to the high-level discussion of domains fitting within the scope of the SRI based on the three key functionalities in the EPBD, there is a discussion on the scope of each of these key functionalities as such. It should be clear that the SRI is not an evaluation of a building's energy performance, but instead should evaluate its smartness.

The following statement was presented to the members of Topical Group B (on the SRI calculation methodology):

> *'The SRI should only score the added value of smarter controllability, information gathering, communication features and interoperability, and not the (energy) performance of the technical building systems themselves (e.g. lighting control irrespective if these are LED or incandescent lights) since the goal of the SRI should be primarily to illustrate the current level of smartness compared to the maximum potential of that specific building rather than to form a comparison framework among buildings?'*

The statement was unanimously accepted by the Topical Group B members[74] (20 votes), indicating that there is a correct understanding of the scope of the SRI among these members. Clear communication towards the larger stakeholder community, Member States and ultimately end users is highly important.

The issue also strongly relates to the positioning of the SRI within the landscape of other initiatives, such as EPCs and Level(s). Complementarity of the SRI with other initiatives is discussed in section 1.2.6.

Finally, there is a discussion whether a building would need to attain a high energy efficiency as determined by an EPC assessment before it becomes eligible for the SRI. As mentioned in section 1.1, the discussion divides stakeholder opinion:

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[74] Topical Group B: calculation methodology; Topical Group meeting on 26 March 2019 in Brussels.

stakeholders representing the insulation and energy efficiency sector tend to agree, whereas others argue for the opposite.

The study team has identified a number of arguments. It should be noted that these arguments are closely linked to potential implementation pathways, which are discussed in section 2.1. These arguments aim to feed the discussion and identify opportunities.

Advantages of introducing a minimum energy efficiency level for SRI assessments include the following.

- Keeping in mind the aim of the EPBD – to increase the energy performance of the building stock – a significant reduction in energy needs should always come before the optimisation of the remaining energy use, e.g. through smart controls. Without prerequisites on energy efficiency, the SRI could award (potentially high) SRI scores to energy *in*efficient buildings that have implemented a large number of smart services without having reduced the energy needs by improving thermal insulation, for instance. In this case a high SRI score may convey the unwanted message that the building has achieved its maximum potential, thus leaving the remaining energy savings potential untapped. Minimum energy performance requirements present an opportunity to force building owners to prioritise reducing energy needs over implementing smart services to optimise energy use.
- Imposing a minimum energy performance level holds a number of advantages with respect to the assessment. Energy efficient buildings would have an EPC, containing an inventory of TBSs. Having an EPC at their disposal or simultaneously performing an EPC and SRI assessment would lead to a significant reduction in the required assessment time – and thus the cost.
- Having a calculated energy balance at our disposal creates the opportunity to calculate more accurately the impact of a certain smart service on the energy performance of the building. As such, domain weighting factors for energy performance could become redundant. For example, for an intelligently designed building with a low cooling demand, the impact of SRTs for cooling could be automatically reduced, given its low impact on the energy balance of that particular building.

Disadvantages of introducing a minimum energy efficiency level for SRI assessments include the following.

- Limiting the SRI assessment to buildings undergoing – or aiming for – an EPC assessment would significantly reduce the potential uptake of the SRI. By targeting only energy efficient buildings, a large share of the energy savings potential would remain untapped.
- Energy *in*efficient buildings have the highest energy savings potential. An update of technical installations with smart controls can significantly enhance the energy efficiency of a building, and thus should not be discouraged. The SRI could provide building owners with valuable insights into the current smartness of their building and – more importantly – on potential improvements that may improve the energy performance of the building. As such, it could serve as a (pre-)design tool. Insights into current and potential smartness were identified as key goals for the SRI in the stakeholder questionnaire and should not be ignored.

Based on these arguments – and the investigated implementation pathways – the study team recommends not to introduce a minimum energy efficiency level for

SRI assessments, to maximise the uptake of the SRI. However, this recommendation in no sense contradicts an implementation pathway which seeks to link the SRI and the EPC. Rather, making such a linkage would seem to provide the highest net beneficial impacts (per the implementation pathway impact assessment findings presented in section 4.3.2), would provide synergies with existing EPC implementation infrastructure and practice (per the discussion in section 3), and does not seem to pose any significant risk of confused messaging (per the findings of the consumer research presented in section 2.2.12).

1.2.3 EU STREAMLINING OF SRI METHODOLOGY VS NEED FOR DIVERSIFICATION

Intrinsically there is a tension between the notion of a centrally managed and coordinated SRI and that of subsidiarity where each EU Member State may seek to implement the SRI as they see fit. The legal framework for the SRI in the EPBD clearly sets out the applicable legal basis, so this is beyond discussion, however, practically, it is still important to consider the implications for the efficacy of the SRI of a more or less harmonised methodology. On the one hand the SRI methodology needs to appropriately cater to locally specific situations yet on the other hand it needs to leverage the power of the EU Single Market. The sections immediately below consider the importance of the methodology adequately reflecting local specificities such as climatic and building type variations, and this might imply settling on a greater diversity of approach. Conversely, though, there is also a need for the SRI to adopt a methodological approach which is sufficiently unified for it to leverage the power of the single market for goods and services. In particular, this implies an approach which is common in the manner in which the smart functionalities of goods and services are classified so that their providers can position their offers in a common way across the Single Market and avoid the need (and associated extra cost) of developing separate offers for each local implementation of the SRI. The resultant methodology, and the degrees of freedom it permits, thus need to be cognisant of both sets of concerns.

1.2.3.1 Tailoring the SRI to geographic conditions: country/region or climatic specificities and implications for the methodology

It can be envisaged that the SRI score reflects differences in regard to geographic conditions, such as the climate. For instance, the relative importance of heating and cooling with respect to the energy balance varies significantly according to climate conditions. In the first technical study it was suggested that weighting factors could be used to reflect these regional differences.

Three options have been considered:

- a single set of weighting factors for the EU
- weighting factors defined by the Member States
- weighting factors for pre-defined climatic zones, defined within the SRI methodology.

The main advantage of applying a single set of weighting factors across Europe is the comparability of the SRI across Europe. However, user acceptance may suffer, since the relative importance of domains based on uniform European weighting factors may significantly deviate from the perceived relative importance given local conditions.

The definition of weighting factors could also be part of the implementation by Member States, meaning that each country or region would be able to develop its own set of weighting factors. Differences in the approach to define these weighting factors could, however, lead to significant differences in SRI results for buildings in neighbouring countries with similar climatic conditions. This approach would thus limit the comparability of buildings across Europe and could potentially harm its credibility.

Alternatively, weighting factors could be defined for a set of predefined climatic zones, as part of the SRI methodological framework. This solution would have the advantage of being able to reflect the relative importance of certain domains given the local situation, whilst limiting the comparability issues, as only a limited set of weighting factors would be defined.

The stakeholder questionnaire sent out in preparation for the first stakeholder meeting contained questions on various topics, including the tailoring of the SRI calculation methodology to specific conditions, such as climate conditions. The majority of the respondents (59.3%) supported the proposal to introduce weighting factors for climate conditions.

Question: Do you see the need to adapt the calculation method to specific conditions, e.g. using weighting factors? If so, which ones?

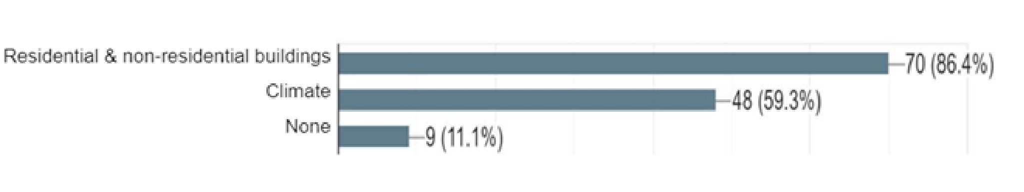

Figure 7 - Stakeholder questionnaire: adaptation to specific conditions

Essentially the same question was also raised during the first Topical Group B meeting. The following statement was presented to the group members:

> *'To balance homogeneity of the SRI while acknowledging not all buildings are subjected to the same boundary conditions, the weight given to specific services and domains in the impact scores should be specified on a climate region level (rather than an overall EU or specific member state level).'*

Out of 22 participants, 20 members agreed to this statement, with only 2 disagreeing.

Accordingly, the study team recommends defining different weighting factors for a number of climate zones. Alternatively, it could be envisaged that for each climate zone and each domain applicable range are defined, rather than fixed values. Such an approach allows Member States to tailor the SRI to their policy, within bounds set by the methodology. Finally, it could be envisioned that weighting factors are (partially) linked to the energy balance of the actual building, for instance using calculated data from EPCs. This approach implicitly takes into account climatic conditions, as well as the building design.

Importantly, in any case the weighting factors or the approach to obtain them will be predefined, based on guidelines by either the Commission or the Member States. Under no circumstances should the assessor have the liberty to adapt weighting factors freely, as this could undermine the credibility of the methodology.

The definition of domain weighting factors – taking into account climatic conditions – is discussed in section 1.3.3.2.

1.2.3.2 Tailoring the SRI to building type or intrinsic specificities

In addition to tailoring the SRI methodology to climate conditions, tailoring the methodology to specific building conditions can also be envisaged.

First and foremost, there may be a distinction between residential and non-residential buildings. These building types have significantly different needs inherently associated with their use. For instance, in large parts of Europe, residential buildings do not typically require active cooling, whereas generally this is needed in non-residential buildings such as office buildings. Hot water provision, on the other hand, has a higher relative importance in the energy balance of residential buildings as opposed to most non-residential buildings such as office buildings.

To reflect the relative importance of certain domains, the use of weighting factors is proposed. The approach of using weighting factors – rather than omitting certain domains or services – holds the advantage of still allowing the evaluation of certain domains and services, although their impact maybe limited under current circumstances.

Based on the results from the stakeholder questionnaire (Figure 7), it can be concluded that there is much support for differentiating between residential and non-residential buildings (86.4%).

Furthermore, in Topical Group A, it was suggested that small- to medium-sized enterprises (SMEs) could be treated as a separate category of building, including pubs and restaurants etc., because they comprise a group outside of the residential and non-residential sector split. The concern is twofold. Firstly, the energy consumption by end use (heating, cooling...) can differ from larger non-residential buildings. This raises the need for a separate set of domain weighting factors. Given the limited availability of data on the energy demand by end use in SMEs, no separate building category will be introduced in the first iteration of the SRI. The issue may be revaluated in future updates of the SRI. Secondly, the size and complexity of SMEs in many cases resembles the complexity of residential buildings, rather than non-residential buildings. To address the concern, it is suggested to allow the application of a simplified calculation method – as is the case for residential buildings – in case of small buildings. This is further addressed in section 1.2.4.

Apart from different weighting factors for residential and non-residential buildings, it can be argued that in the case of the latter, the relative importance of certain domains will differ depending on the specific building type (i.e. distinguished by function). For instance, the consumption of domestic hot water has a higher impact on energy consumption in healthcare buildings than in office buildings.

The study team therefore envisages a differentiation of weighting factors for different non-residential building usages. Results from the stakeholder questionnaire support this approach (Figure 8).

Question: Should the SRI apply distinct weightings for different non-residential building types?

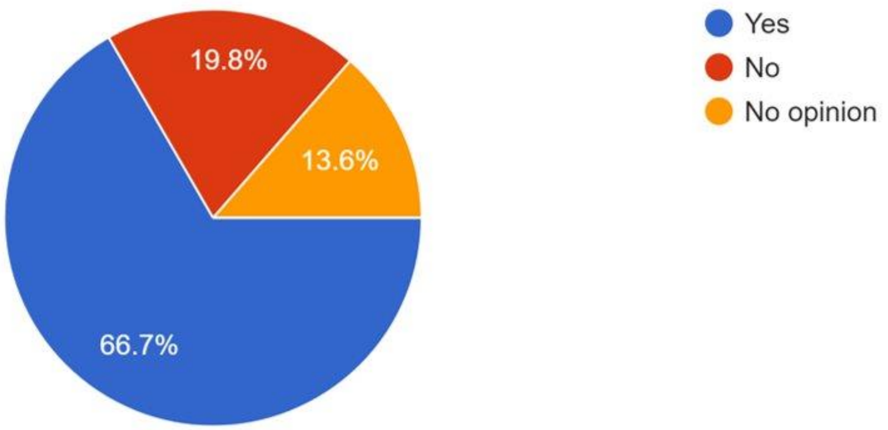

Figure 8 - Stakeholder questionnaire: adapting to building type

In addition to weighting factors, certain specific buildings types could benefit from having additional services that are specific to their usage, e.g. energy management of refrigerated counters in supermarkets, or flexibility aspect of heating water in swimming pools.

In the questionnaire, the majority of respondents indicated that they agree to the inclusion of additional services for certain non-residential building types (Figure 9). This question was also put to the participants of Topical Group B. Out of 21 responses, 15 participants agreed, 3 disagreed and 3 did not have an opinion. During the discussion, the Topical Group participants confirmed that additional services for specific building types are relevant. One group explicitly mentioned, however, that the definition of weightings for these building types is more important than the introduction of additional services.

Question: Should the SRI be tailored to include additional services for different non-residential building types?

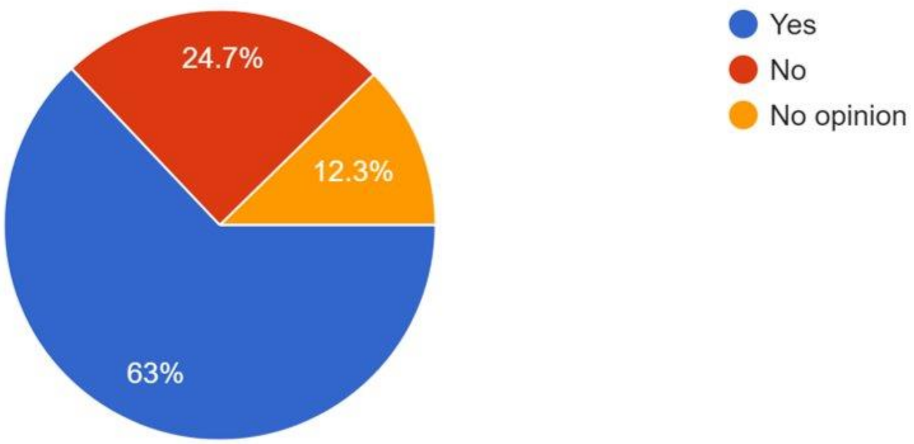

Figure 9 - Stakeholder questionnaire: additional services for specific building types

To select the most relevant non-residential building types for further investigation, the stakeholder questionnaire asked respondents to rank the importance of six non-residential building types. They indicated that offices, healthcare buildings and educational buildings should be prioritised.

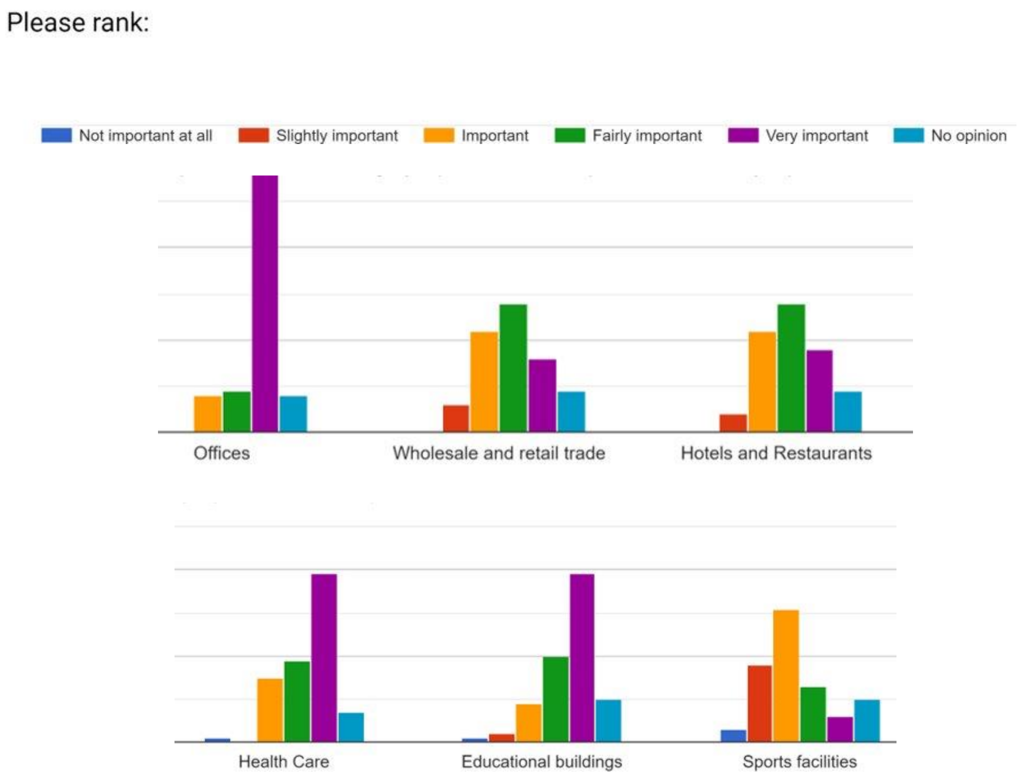

Figure 10 - Stakeholder questionnaire: importance of non-residential building types

The suggestion of prioritising certain building types was introduced in Topical Group B, where the following statement was presented:

> *'If the calculation and assessment methodology would be tailored to building types, the SRI can focus on a restricted set of priority building types, leaving room for later updates on very specific functions (e.g. hospitals, shopping malls, swimming pools).'*

Out of 22 responses, 12 participants agreed, 9 disagreed, and 1 did not express an opinion. Participants indicated that they consider the simplicity of this approach to be an advantage. Considering the constrained timing, this was perceived as a reasonable basis to enable moving forward faster. In Topical Group A, some group members suggested that the SRI needs a good focus to get it started: "*Rome is not built in a day*". They suggested that what is needed is a very successful starting point (e.g. new office buildings) from which the SRI's implementation can evolve further.

A downside of the proposal is its restriction to a more limited set of building types, thereby potentially limiting the (initial) uptake of the SRI (or using less building type adapted approaches for other building types). Careful communication would also be needed on the roadmap of the SRI, explaining the current scope and future development plans.

The study team has carefully investigated the possibility to tailor the SRI based on building usage. Firstly, the most viable option is to define different sets of weighting factors by building use. However, to define these weighting factors highly granular data on energy consumption must be available, allowing a break-down by geographical conditions (e.g. country), energy end use (e.g. heating, cooling…) and building usage (e.g. offices, healthcare…). Analysis of various valuable data sources – including the European Building Stock Observatory – showed that the availability of qualitative data at this level of granularity is currently insufficient to support the definition of separate domain weightings by end use. Secondly, the development of a tailored set of services by building usage is considered. However, investigating a multitude of different building usages and developing a tailored set of services was not deemed feasible within the time constraints of the second technical study. In order to support further tailoring in future updates of the SRI, it could be envisioned to structurally capture feedback from assessors (and the broader stakeholder community) to identify specific services for future inclusion.

Based on the analysis, the study team suggests the following approach:

- In a first step, only distinguishing between residential and non-residential buildings, but not add further differentiation between various types of non-residential buildings (commercial, office, healthcare, various types of sport facilities, etc.). The suggested differentiation between residential and non-residential buildings can be realised in various ways, including the introduction of a separate methodology (for instance, a simplified method for residential buildings, see section 1.2.4) and a different appreciation of the relative importance of various technical domains (for instance, separate weighting factors, see section 1.3.3.2).
- In the case of mixed-use buildings – including both residential and non-residential units – two main approaches may be considered: (1) a weighted single score for the entire building or (2) separate assessments (and SRI scores and labels) for building units of different types. The appropriate approach may depend on the chosen implementation pathway. For instance, if a connection to EPC is envisaged, alignment with national guidelines applicable to the EPC assessment is desirable. The study team suggests that implementing bodies define the appropriate guidelines to deal with mixed-use buildings.
- For multi-family buildings, a similar consideration can be made; residential units can either be assessed individually, or the building can be assessed as a whole. From a technical perspective, the desired approach may depend on the TBS. For instance, in the case of shared systems for heating or ventilation, a building-level assessment may be preferred to reduce the assessment time. However, many other services are expected to differ across units. For instance, this could be the case for lighting control. Similar to multi-use buildings, the most appropriate approach may depend on the chosen implementation pathway. The study team suggests that implementing bodies should define appropriate guidelines to deal with multi-family buildings.

1.2.4 DEGREE OF COMPLEXITY OF THE METHOD

The level of streamlining for the service catalogue should be determined to deliver a viable scheme. The most appropriate level of streamlining will be a function of the organisational pathway considered. In order to obtain a viable scheme, it is crucial to respond to the needs of the end user (see also Activity 1 Task 2 and Activity 2 Task 3). This includes a careful balancing of the desired output (a reliable SRI) and the required input (assessment time, and thus assessment cost).

Assessment time is strongly linked to the degree of complexity of the SRI definition. At least two different SRI assessment types can be envisaged: a simplified version with a limited set of services, and a detailed version. Differentiating between a simplified version and a detailed version would allow costs to be brought down for simple buildings, which in turn could increase uptake. At the same time, the detailed version would permit validation of the added value of advanced systems in complex buildings. On the downside, differentiation may bring confusion, which could hamper the communication of the SRI.

Alternatively, to bring down costs it may be envisioned to allow self-assessment – for instance, via use of assessment guidelines and an SRI calculator accessed through the internet – in addition to a formal assessment performed by a third-party (expert) assessor. Self-assessment has the benefit of being able to provide an indication of the current smartness and the potential to improve, without requiring the cost and inconvenience of a formal assessment. Its main purpose would be to provide insight and raise awareness of the smartness of buildings. The study team envisages that only a third-party assessment would deliver a formal score (e.g. a certificate) to ensure the validity and credibility of the assessment. The communication of the results would clearly state the type of assessment (self-assessment or third-party assessment).

Finally, there is also a demand among certain stakeholders to take the SRI a step further, rather than provide a simplified version. This demand is based on an issue that is found across many labelling or certification initiatives, namely the performance gap. Most initiatives, including the SRI, target the theoretical performance of a building; however, experience has shown that in many cases the actual performance of the building (e.g. energy performance, thermal comfort, etc.) deviates from the theoretical predictions. Many causes can be identified for the performance gap, including deviation from calculation assumptions (occupancy rates, setpoints, etc.), occupant behaviour and execution errors in the technical installations. As a result, a demand arises to have building scores based on actual performance. Although for many services and impact criteria there is a clear potential to derive performance on the basis of measured or metered data, the implementation of a fully measured/metered SRI is not deemed feasible for a first version of the SRI and should be further investigated for subsequent versions.

In the questionnaire send out to stakeholders, a majority of the respondents supported the differentiation between a light and detailed assessment (Figure 11).

Question: which approach would you prefer?

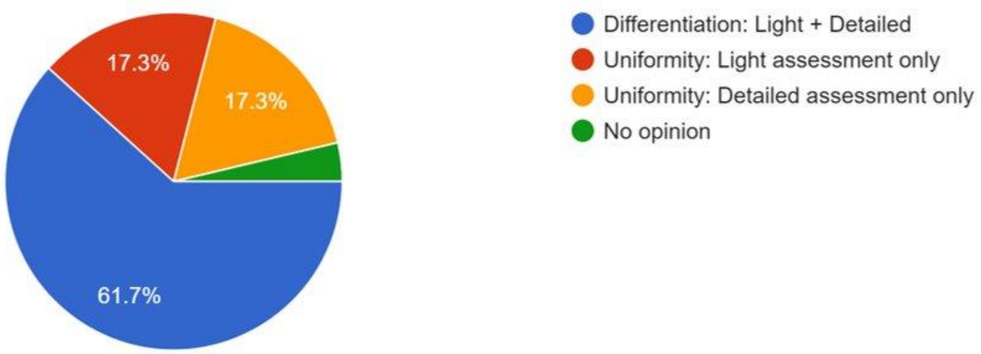

Figure 11 - Stakeholder questionnaire - light versus detailed assessment

When asked to comment on their choice, some stakeholders suggested the assessment approach should be pre-determined based on certain conditions:

- light assessment for residential; detailed assessment for non-residential
- mandatory light assessment; detailed assessment upon request
- light assessment for existing buildings; detailed assessment for new buildings
- start with light assessment; detailed assessment as a future development of the SRI.

With the stakeholder questionnaire, a majority of respondents supported the approach of allowing both a light self-assessment and a detailed third-party assessment; however, it was not clarified whether both methods should be eligible in all cases or whether they should be offered depending on circumstances, per the above discussion.

Question: Do you support the approach of differentiation between a light self-assessment and a detailed 3rd party assessment?

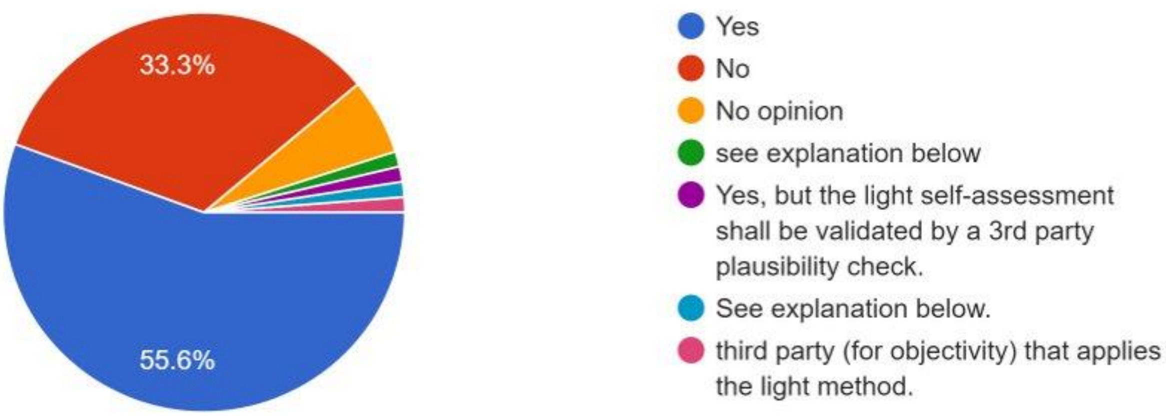

Figure 12 - Stakeholder questionnaire: self-assessment and 3rd party assessment

Based on the feedback received, the study team has developed a set of working assumptions, consisting of three SRI methods (A, B and C), as depicted in Figure 13.

A Simplified method	B Expert SRI assessment	C *In-use smart building performance*
Checklist approach with limited, simplified services list	Checklist approach, covering full catalogue of smart services	*Measured / metered data (potentially restricted set of domains)*
Online self-assessment by end-user (no certification) OR On-site inspection by third-party qualified expert (formal certification)	Online self-assessment by technical expert (no certification) OR On-site inspection by third-party qualified expert (formal certification)	*In-use buildings, metered data* *Part of the commissioning?* *TBS self-reporting their actual performance*
Up to one hour	½ day to 1 day, depending on the complexity	*Gather data over a long period (e.g. 1 year)*
Residential buildings and small non-residential building (net surface floor area < 500m²)	Non-residential buildings (and residential buildings if desired)	*Residential and non-residential* *Restricted to occupied buildings (not in design phase)*

Figure 13 – Three potential assessment methods

1.2.4.1 Method A: simplified method

The scope of the simplified method is defined as follows:

- a checklist approach using a simplified service catalogue *or* a database approach
- possibility for (online) self-assessment, free of charge and accessible to the general public (e.g. single-family homeowners), in addition to a formal third-party expert assessment
- fast assessment: less than one hour for a single-family home
- restricted to residential buildings and small non-residential buildings (net surface floor area < 500m²)
- aim: to raise awareness of the smartness of buildings, provide initial feedback on the current state of a building, e.g. when planning renovations or upgrades.

The envisaged scope of the simplified method has been presented during both stakeholder meetings and to the topical groups. An open brain-storm was organised in Topical Group B[75], focusing on how the service catalogue and corresponding calculation method might be affected by switching from the expert assessment as outlined in the first technical study, to a quick-scan approach (Method A). The opening question was phrased as follows:

> 'If there is to be a quick-scan, which households would complete by online self-assessment: how would the check-list approach need to be altered? Should there be a simplification of the "questioning" or should the quick-scan just evaluate less services (omit services)?'

Participants indicated that the applicability of Method A should be aligned with the complexity and expected level of smartness of the TBSs. In that context, a first suggested approach for Method A (quick-scan) would be to extend the triage process. First, a quick assessment should be conducted based on a number of high-level questions with the aim of identifying the key services. Next, further detailed questions could be posed for "high potential" services.

As an alternative to the simplification (or omission) of the service catalogue for Method A, one participant proposed the idea of a validated SRI product database. Manufacturers could provide SRI scores (functionality levels) for their products. The end user would no longer be required to look up the full technical details. Instead, they would look up the products present in their building and have the appropriate scores applied automatically, which is much easier, faster and simpler. A key benefit to this approach is the end user's reduced need for knowledge on installed TBSs. The approach could also gain support from industry as it would allow opportunities for branding. However, the database needs to be trustworthy and valid. Ideally, such a database should focus not only on new products, but also on existing products, as the SRI should be applicable to existing buildings. A hybrid approach, asking more technical questions in case a product is not represented in the database, could be envisaged.

Participants commented that the benefits of simplifying the questions versus omitting services would depend on the different aspects:

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[75] Topical Group B: calculation methodology – topical group meeting on 26/03/2019 in Brussels

- simplifying the catalogue might be more applicable to old, existing buildings, where a priori the level of complexity in terms of TBSs will be limited.
- for new buildings/major renovations, a simplified service catalogue might not be applicable; in these cases, a qualified person would need to perform the assessment, similar to an EPC auditor.

Regarding the application field of the proposed methods, participants indicated that Method A is expected to be more suitable for residential buildings. Method B was indicated to be more appropriate for non-residential buildings. To support this, one participant added that, for residential buildings, if the SRI is too technical and complex, it could become unmanageable, which would negatively affect the uptake. This concern is less likely to apply to non-residential buildings.

In Topical Group A, SWOT analyses were conducted for the three methods. The analyses indicated that the key concern for Method A is reliability: making the method too simple creates the risk of making it simplistic, which could significantly harm the reliability of the SRI. Opening the SRI to self-assessment leaves it prone to manipulation, which could also harm the reliability. The members do see the advantage of creating awareness and see the self-assessment as a potential stepping stone to a full assessment. Some members were concerned that there could be little interest in the quick-scan and that it would not be used. Finally, as the SRI remains a theoretical calculation, it is not a solution to the performance gap.

In summary, the initial exploration with stakeholders revealed support for introducing a simplified method, particularly for residential buildings. Concerns about the reliability of such a method need to be addressed. From a methodological perspective, either a simplified service catalogue or a database approach are envisaged.

Three dedicated web meetings on the subject were organised with Topical Group B, elaborating on the feasibility of the suggested database method and the alternative of a simplified service catalogue.

A first web meeting[76] discussed the feasibility of a database method. With such an approach, manufacturers could report the functionality levels of their different products in an online database. Occupants (or other users of the simplified method) could select the brands and product types of their TBS from a database, rather than assess the functionality levels themselves. The functionality levels could be attributed automatically to the services. Such an approach would simplify the input efforts for the occupants without reducing the level of detail of the calculation methodology. This approach also creates an opportunity for manufacturers to position themselves in the market.

Although the Topical Group B members acknowledged the potential advantages of the suggested approach, a number of concerns were raised, as detailed below.

Methodological issues

- Functionality levels cannot always be ascribed to products directly. In many cases, the functionality level is achieved by a set of systems.

[76] Topical Group B: calculation methodology – web meeting 11/06/2019

- In many cases products have certain functionalities that may or may not be used. The implemented functionality level depends on the specific installation.
- Free programmable controllers can have a number of functionalities; typically, only a fraction of these functionalities are actually implemented.
- It would not be feasible to include devices that are discontinued. As a result, a large share of legacy equipment would not be represented in the database.
- The method does not capture the potential upgrade of legacy equipment by means of smart add-on equipment.

Practical issues

- A new database would be needed in addition to the EPREL/Ecodesign database. This requires a major effort from manufacturers. Topical Group members indicated that the potential benefits do not justify the effort required, particularly under the assumption of a voluntary method, limited to residential buildings.
- Reluctance of manufacturers to provide the data for the database method could undermine the success of the SRI.

Although some stakeholders remain in favour of the database approach, insufficient support was found to proceed with the approach.

A second web meeting was organised to discussing a simplified service catalogue. As defined in the scope of method A, a fast assessment time (approximately 15 minutes for a single-family home) is desirable[77]. A reduction in the number of services in the detailed service catalogue (currently 54 services) is therefore a clear requirement. To allow occupants to perform a self-assessment, the services should be defined in such a way that no expert knowledge is required. Nevertheless, the simplified service catalogue should cover the features most relevant to the SRI.

The study team proposes an approach where a limited number of services are included for each domain. These services are structured in each domain by the following three topics:

- **controllability of performance** – this includes services that enable control of a TBS's performance, e.g. its energy efficiency, indoor air quality, lighting level
- **storage and connectivity** – this includes services that enable storage of energy and/or services that have the ability to connect to or communicate with other actors, such as other TBSs, a building automated control system (BACS) or the energy grid
- **reporting functionalities** – this includes reporting on performance, temperatures and energy consumption, as well as reporting on maintenance, fault detection and fault prediction.

In principle, this entails providing a maximum of three services for each of the nine domains. However, a few exceptions are foreseen, as follows.

[77] Topical Group B: calculation methodology – web meeting 28/06/2019

- For “heating” and “cooling”, two services will be included for the controllability of performance: one focusing on the controllability of the emissions system and one dealing with the controllability of the production facilities.
- The “electricity” domain covers both on-site renewables and storage (and in the future, potentially plug loads). In light of the simplified method, it is not deemed desirable to limit the simplified method to only one of each. Therefore, for each topic a service on renewables and a service on storage may be foreseen.
- For some of the domains, a topic may not be relevant; for instance, storage and connectivity is not deemed relevant for the domains “lighting” or “controlled ventilation” – keeping in mind that the envisaged field of application is limited to residential buildings.

At the time of discussions, the suggested simplified calculation method would include around 25 services. The consolidated proposal documented in ANNEX E contains 27 smart-ready services.

The suggested approach is well-received by the members of Topical Group B. The structure providing a limited number of services for each topic (one or, exceptionally, two) is generally accepted. A general comment was made that although the service catalogue has been simplified in terms of the number and complexity of services, further simplification is needed in terms of vocabulary.

Upon the study team’s request, experts from Topical Group B have provided their feedback on the defined services and functionality levels, and the study team has updated the simplified service catalogue based on feedback. Topical group members raised the concern that restricting the application of method A to self-assessment would limit the applicability of the method. It is argued that allowing formal 3rd party expert assessments using the simplified method should not be excluded.

A third and final discussion was held with topical group B to discuss the scope of the simplified method, to address previously raised concerns regarding the field of application[78]. The study team presents two potential options for dealing with the simplified method (A) and the detailed method (B):

1. for non-residential buildings, always apply method B. For residential buildings, apply method A for small/simple buildings (e.g. single-family homes) and apply method B for large complex buildings (e.g. large multi-family homes)
2. always decide on the method based on the size/complexity of the building. (hence: method A would be allowed for small non-residential buildings such as small shops etc.).

In both cases only a third-party expert assessment issues a formal certificate. Online self-assessment could be made available for both methods but would not issue a certificate.

Stakeholders generally prefer method 2, provided there are clear guidelines on what small/large or simple/complex means. **The study team suggests that all building with a net usable surface area smaller than 500 m² are**

[78] Topical Group B: calculation methodology – web meeting 04/11/2019

considered "small buildings" and should be evaluated using the simplified method.

One stakeholder raises the concern that mixing methods A and B may be confusing, and suggests to only use method B for 3rd party assessment and only allow online self-assessment in method A. To overcome the issue, the results of the assessment should clearly state whether or not it is a formal assessment or an informative assessment.

The suggested simplified service catalogue for method A can be found in ANNEX E.

1.2.4.2 Method B: detailed method

The scope of the detailed method is defined as follows:

- a checklist approach using the detailed service catalogue developed in the first technical study;
- on-site inspection;
- third-party qualified expert assessment (cf. EPC) OR self-assessment by a non-independent expert (e.g. facility manager);
- assessment time: ½ day to 1 day, depending on the size and complexity of the building;
- open to large non-residential and residential buildings (net surface floor area ≥500m²);
- aim: to raise awareness of the smartness of buildings, formal assessment to provide detailed insight into the smartness of a building compared to its maximum potential smartness.

The detailed Method B remains the default method, applicable to all building types, including residential and non-residential buildings, as well as new constructions, retrofits and existing buildings. The assessment is to be performed by a third-party expert assessor and is currently the only method that issues a formal assessment. Alternatively, self-assessment by a non-independent expert (e.g. facility manager) may be envisioned. Similar to method A, a self-assessment would be merely informative, and would not issue a formal assessment.

Interactions with various facility managers highlighted their general support for SRI as a tool to assess, compare and optimise their building portfolio. In particular, the ability to allow self-assessment for the detailed method was strongly supported[79]. Similar to the simplified method, self-assessment has the benefit of being able to provide an indication of the current smartness and the potential to improve, without requiring the cost and inconvenience of a formal assessment. Its main purpose would be to provide insight and raise awareness of the smartness of buildings. In the case building experts such as facility managers, this could empower them to plan future upgrades of the building in terms of smartness.

[79] Based on discussions at the conference for Future Oriented Facility Management, 22/10/2019, Brussels

Feedback from stakeholders[80] indicates that the third-party expert assessment is considered a key strength and could increase SRI reliability. A site visit by the assessor could further support the reliability. The Topical Group members identified coupling to the EPC as a key opportunity. Other opportunities are potential improvement of the building (design), as well as potential improvements to the quality of technical systems (design and execution). The cost of assessment is seen as a weakness, and the risk of rewarding complexity is considered a threat. The Topical Group members also raised concerns about the required expertise and the independence of third-party assessors. Finally, similar to the case with Method A, it is not a solution to the performance gap.

Both for methods A and B, it could be envisioned that over time TBSs/BACS might be able to self-report functionality levels. Such an approach would allow for a (partial) automated assessment, which would reduce the required effort and cost of the assessment. Since the functionalities of the TBSs/BACS control systems are often the most complex to assess on site, automated reporting by these systems could significantly reduce the required expertise by third-party assessors, and contribute to the overall accuracy of the assessment. Since the methodology relies on data collection from the TBSs/BACS, the field of applicability would be limited to in-use SRI assessments. Hence, it is likely that a non-automated assessment approach remains available alongside the automated approach, to enable assessments in the design phase of the building.

A Topical Group C was created to investigate potential future evolutions of the SRI, including the potential development of an approach for an automated assessment of methods A and B. More information on the work of this topical group is provided in section 5.1.2. The topical group is fully self-managed in terms of organisation and content and will continue to discuss these future evolutions of the SRI beyond the end of this technical study, but has provided intermediate recommendations to the technical study consortium and the Commission Services[81]. Its work is complementary to but fully independent of this study.

In their advice to the technical study consortium and the Commission Services, Topical Group C states that:

- '**Automating methods A and B** is highly likely to increase the EU-wide market uptake of the SRI which in turn would support the performance improvement (also indoor climate) process of the EU's building stock. In many buildings and with the introduction of the revised EPBD, automation or at least more control possibilities than currently available will be introduced in buildings. Developing an SRI which can use these systems to generate automatically comparable indicators on different levels would help the market. The same building technology needed for automated methods A and B enables continuous real-time data monitoring of technical building systems' operation which has high potential in closing building performance gaps throughout a building's life cycle and so introduce a new method C.'

[80] Topical Group A: implementation pathways and value proposition, meeting on 26/03/2019 in Brussels

and Topical Group B: calculation methodology, meeting on 26/03/2019 in Brussels

[81] The full report of topical group C can be found on www.smartreadinessindicator.eu/ stakeholder-consultation

1.2.4.3 Method C: in-use smart building performance

In the long run, TBSs/BACS might be able to self-report functionality levels, assisting Method A and Method B. Method C goes beyond this and quantifies the actual performance of in-use buildings. However, Method C will require benchmarking to assess how the level of savings, demand side flexibility, comfort improvements, etc., are delivered; for example:

- if energy consumption is low, to what extent can this be attributed to smart controls, versus passive measures or occupant behaviour?
- if low CO_2 levels are measured, is this demonstrating that the ventilation system is operating smartly, or is it just a result of the ventilation rate being set high or that the building is very leaky?

Method C is currently considered to be a potential future evolution of a certification approach for a commissioned building, going beyond the currently envisaged scope of the SRI. Therefore, it will not be treated in detail in this technical study; however, it will be kept in mind as one potential future evolution of the SRI.

Multiple organisations have expressed their support to evolve towards an in-use performance-based SRI:

- 'Be future-proof and evolve from a "smart ready assessment" towards "true building performance: the timely introduction of the SRI as a quantitative indicator will help guide necessary investments and upgrades of buildings. However, only if the SRI, as an indicator, evolves into a true quantitative measure of the performance of the building over time, and performance improvement goals are set accordingly will there be a positive impact on the EPBD goals.'
- 'Future developments of the SRI should consider in-use smart building performance assessment.'
- 'A large-scale deployment of state-of-the-art Building Automation and Control Systems will create the conditions, in the future, for having a detailed, in-use assessment performed automatically. […] We agree with the presentation displayed during the Stakeholder meeting: this is not applicable as of today, but it should be the goal of a future evolution of the SRI. The deployment of BACS functionalities in Art. 14/15 of the revised EPBD by 2025 will be key to ensure that this method could become reality in the future.'
- 'A steering committee is needed to update the SRI framework every year to ensure product innovations are included in the catalogue of services and methodology. A subgroup of this Committee should be tasked to investigate how to move towards Method C, i.e. move the SRI towards a quantitative building performance indicator.'

Topical group C has also reflected on the concept of the suggested method C. In their advice to the technical study consortium and the Commission Services, Topical Group C states that method C could be a framework/process that would bring all relevant stakeholders together and gear the digital transformation of the built environment towards reaching the EU's long term goals. On potential benefits of a method C, the recommendations report of topical group C states the following:

- 'For a new method C it is very important to keep in mind that the whole point of this method is to let the SRI evolve from a parameter which consists of factors levelling functionalities of services from the Smart Services Catalogue (currently methods A and B) to a parameter which quantifies the building's impacts for all 3 relevant categories (building occupants needs, building operational efficiency and building energy flexibility) with a strong focus on the impact upon the reduction of CO_2 emissions.'

- 'A new method C would add further value to real estate. Therefore, go-to-market strategy should be considered to support added-value in the market. As such, having a clear and transparent (sustainable) business case (value proposition) from the very beginning is essential. Just considering the goal of decarbonising the EU's building stock, monetisation should be quantified at least in terms of CO_2 savings. In addition, benefits like enhanced productivity by an improved indoor work environment, reduced investment cost for upgrading the energy grid by fully employing the building flexibility potential and reduced total cost of ownership by the use of data driven predictive maintenance techniques should be quantified.'
- 'The actual performance of building services and integrated energy system should be analysed in the existing building stock. Method C would show the real effect of smart installations and can be used to assess the effect of new measures.'

1.2.4.4 Combination of various service levels in one building

In some cases, smart services might only be present in a part of the building. For instance, "control of artificial lighting power based on daylight levels" may be available in the open office space, but not in corridors. From a methodological perspective, this can easily be tackled by assessing all relevant services in all rooms of a building, and subsequently weighting the impact scores depending on their relative presence (e.g. by introducing weighting factors corresponding to the floor areas where services are present). One can however also imagine other assessment approaches which could significantly reduce the assessment efforts. For instance, one could define representative rooms, or only include either the minimum or maximum functionality level present in the building. That way, the assessor does not have to collect information on every service in every room in great detail. Neither is there a need to calculate the applicable net surface floor areas or collect other data to define additional weighting factors, both of which could be quite burdensome and represent a significant share of the assessment efforts.

This issue was also touched upon in the first meeting of Topical Group B, with members being asked to vote for, or against the statement:

> *'To ease the assessment, presence of services is only evaluated in representative spaces, e.g. don't do a walkthrough to assess lighting control of every fixture (including hallways, storage rooms, etc.), but simply evaluate a representative room (e.g. representative office in an office building).'*

Nine participants voted to agree, 11 to disagree and 1 had no opinion, which suggests there was a lack of consensus on this issue.

During the public beta testing, participants were provided with two options to deal with the issue of services which are only present in parts of the building, namely:

- by default, it is assumed that the selected functionality level applies to the *entire building*. Therefore, the highest functionality level that applies to the entire surface area of the building should be selected. Alternatively, one might also indicate the functionality level that applies to the most relevant share of the building (e.g. a services present throughout a dwelling apart from the attic and corridors)

- optionally, a split could be made in the data input, where up to two different functionality levels could be defined to include partial presence of services or service levels in the SRI score calculation (upon actual implementation of the SRI more than two functionality levels per service might also be allowed, should this option be favoured). Assessors were asked to apply a weighting factor based on the net surface floor area.

The second option was seldom used in the testing phase, and the feedback received enabled clear clarification of stakeholders preferences on this issue.

In summary, the following options are possible to deal with services being present in part of the building or with varying functionality levels:

a) introducing a very strict approach in which only the minimum functionality level is reported

b) assessing the service with the highest functionality level, even if only present in small sections of the building

c) assessing a service in all rooms and introducing weighting factors

d) assessing the services only in key areas of the building, e.g. by defining 'representative rooms' for specific building usages.

Option a) is the easiest to implement, but could be too strict, considering that some smart services may not be as relevant in all areas of the building (for instance in areas such as hallways, technical rooms, etc., there is less need for indoor air quality monitoring compared to offices or class rooms). Option b) is equally easy to implement, but could trigger effects of 'gaming' the SRI assessment, by implementing services to a high level but only in very limited parts of the building. This could in turn affect the trustworthiness of the indicator. Option c) is the most detailed approach, but also requires the most effort, both in assessing various service levels as in defining the weighting factors. Besides the net surface floor area, other metrics could be considered. In case of multiple heat generators, for instance, the maximum power or the generators or even the annual delivered energy could be used to express the relative importance of two distinct functionality levels. A variant could be to require such analysis only if differentiation of functionality levels is significant; for instance by introducing a threshold of 80% of floor area. If a service level is present in 80% or more of the net floor area, the alternative functionality levels do not have to be assessed in this case. Finally, option d) also reduces the assessment efforts by requiring the functionality levels only to be assessed in key areas of the building. In principle, all four options - or a blend thereof – are feasible.

The study team suggests that this issue is dealt with by introducing detailed guidelines in the inspection protocols, preferably coordinated at European level.

1.2.4.5 Conclusion

It can be concluded that there is support for distinguishing between a simplified approach (Method A) and a detailed approach (Method B). Method A, the simplified method, is mainly oriented towards small buildings with low complexity (single family homes, small multi-family homes, small non-residential buildings, etc.). The checklist method could be made accessible for non-experts, such as individual homeowners. Method B, the detailed method, is oriented towards buildings with a higher complexity (typically large non-residential buildings, potentially large multi-family homes). Nevertheless, small residential buildings are a priori not excluded from this method.

While in principle Method B is mainly oriented to more complex buildings, there is a greater richness of information in Method B and hence the study team are of the view that it should always be presented as an option even for building segments where Method A is the more common choice. Nonetheless, the manner in which this is executed would naturally be dependent on the implementation pathway adopted by each implementing authority.

For the development of method A, the preferred approach is a simplified version of the service catalogue, with a limited set of services and a change of terminology (asking simpler questions). A potential downside of this approach is the lack of comparability of results if both Method A and Method B were applied to a residential building (for instance, Method A during the pre-design phase and Method B during the design phase). Conflicting results should be avoided, as they could harm the credibility of the SRI. This has been probed as part of the public beta test (see section 5.1.3), which led to a further harmonisation of both service catalogues.

The study has pursued the development of both Method A and Method B, in close consultation with topical group A and B, and informed by the results of the public beta test in which both methods were made available to stakeholders. This resulted in:

- the establishment of two separate service catalogues – a simplified service catalogue and a detailed service catalogue (see ANNEX E and 0 respectively)
- the definition of separate weighting factors for residential and non-residential buildings; the approach is outlined in Task 3 Activity 1.

1.2.5 DATA PROTECTION & CYBERSECURITY

It is clear that the SRI process will need to abide by the provisions of the GDPR and ensure that necessary permissions are given to access (and potentially share) any user data the scheme may require. Stakeholders have offered no comments apart from this on this topic; however, for the development of any specific SRI organisational pathway the study team will need to work through the GDPR requirements and ensure that the approach is set up in a manner that complies with them but is also viable. In this regard it will be important to conduct a Data Privacy Impact Assessment to assess the data protection of the scheme's operational ecosystem whose components could include the smart grids, smart metering systems and connected built-in devices within the target buildings. Such DPIA would need to complement and integrate the existing Impact Assessment template for smart grids and smart metering systems[82].

In this regard it is relevant to consider the views expressed by the European Parliament with regard to the provisions of the recast Energy Efficiency Directive

[82] https://ec.europa.eu/energy/en/data-protection-impact-assessment-smart-grid-and-smart-metering-environment

2012/27/EU at first reading on 26 March 2019[83] which streamlines data protection (see recitals 57 and 91; Art. 2, definition 27; Art. 14(1), letter (h); Art. 17(3), letter (c); Art. 19(1); Art. 20(1), letter (c) and (f); Art. 23(2), (3) and (4); Art. 34; Art. 40(1), letter (m); Annex II, point 2) across the entire 'smart metering system' environment, also mentioning 'best techniques' as *"the most effective, advanced and practically suitable techniques for providing, in principle, the basis for complying with the Union data protection and security rules".*

In particular, Annex II specifies that data protection aspects will be considered for the costs-benefits analysis of the implementation of the recast Energy Efficiency Directive:

> *"1. Member States shall ensure the deployment of smart metering systems in their territories that may be subject to an* ***economic assessment of all of the long-term costs and benefits to the market and the consumer*** *or which form of smart metering is economically reasonable and cost-effective and which time-frame is feasible for their distribution. 2. Such assessment shall take into consideration the methodology for the cost-benefit analysis and the minimum functionalities for smart metering systems provided for in Commission Recommendation 2012/148/EU1* ***as well as the best available techniques for ensuring the highest level of cybersecurity and data protection****."*

With respect to cybersecurity, the main issues that could arise will concern the security of data being shared by any TBS or smart service via the internet (which would be the case for Method C in particular but also for many other smart systems). There will also be cybersecurity risks with databases of either on-line (e.g. Method A) or third-party (Method B) systems.

The SRI cannot be expected to resolve these risks because they are inherent in the use of progressively smarter TBSs and services that are being offered to the market independently of the SRI; however, the SRI must take a responsible approach to this issue and this means that it should aim to draw user attention to the risks and the solutions. The obvious approach will be to highlight that there is (more accurately, will be) a voluntary cyber security label which each interconnected device/TBS could adhere to. The SRI could thus either simply include notification to users to be aware of cybersecurity risks and that the systems that carry the cyber security label are better protected, or indicate which systems have the label and which do not. The viability of the latter approach will depend on how the voluntary cyber security label is eventually implemented. However, as its development is just beginning and choices about which products and services will be addressed are still to be taken, this is likely to be an issue that will need to be revisited after the current technical study is completed.

The conclusion of the technical study consortium is that it is not viable to explicitly assess cybersecurity in the framework of the SRI in the absence of well-established third-party certification schemes.

The proposal of the technical consortium is:

[83] http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P8-TA-2019-0227+0+DOC+XML+V0//EN&language=EN

- in a first version of the SRI: add a disclaimer and warning about cybersecurity aspects
- in future iterations of the SRI: include cybersecurity as an additional assessment, relying on external accreditation according to the EU Cybersecurity Certification Act which aims to put in place an EU-wide third-party certification scheme. Once available, this can be presented as supplementary information, without affecting the SRI score(s).

The additional information could either be optional or mandatory for the implementing bodies. The suggestion of the technical study team is to require this information provision in all Member States as soon as the market uptake of the EU-wide certification scheme in the building sector is deemed sufficient.

1.2.6 INTERACTIONS WITH OTHER SCHEMES

The SRI's interaction with other schemes such as EPCs, Level(s), broadband ready, voluntary cyber security label, building renovation passports, etc., is one of the key issues to be resolved in the lead-up to its implementation. As noted in the previous text there are a great many schemes the SRI could potentially interact with and this text is not comprehensive. Stakeholder remarks (especially those received between the two technical studies) highlight the importance of clarifying this issue. Many stakeholders have expressed a desire for the SRI to be linked to EPCs and stressed the evident synergies that could exist, including taking advantage of the EPC assessment process to also address the SRI and thereby:

- ensure that the SRI is rolled out at least as rapidly as the EPC is (especially if it is made mandatory by Member States)
- use the same third-party assessor, thereby helping to ensure the integrity of the assessment and avoiding duplicate effort.

While this is self-evident, it is also a decision for Member States and hence the study team must proceed on the basis that it is one of the implementation pathways that could be envisaged, but that others may also be pursued.

A more generally applicable principle, which is robust under essentially all imaginable pathways, is that the SRI needs to be implemented in a manner that is complementary to other schemes and initiatives – especially if they are EU-wide initiatives – but also in response to any mandatory Member State initiatives. At a minimum this means that the scheme's boundaries are set so that if they overlap with other EU-wide schemes they offer the potential to either enrich inputs used by other schemes (e.g. the SRI could address aspects of energy performance not currently captured by EPCs and aspects of indoor environment quality performance not yet captured in Level(s)), or to be enriched by those schemes (e.g. the energy balance data from an EPC could help to set the energy savings weightings per TBS used in the SRI).

The issue of potential linkages of the SRI with other schemes has been examined in discussion with Topical Group A amongst others, and the findings have helped to inform the development of the prospective set of implementation pathways described in Task 2.

1.2.7 INTEROPERABILITY

1.2.7.1 Importance of interoperability to SRT functioning

The degree of interoperability of TBS can be a limiting factor affecting the smart services and impacts that can be delivered within a building. Interoperability of systems can avoid duplication of efforts (e.g. investment for occupancy detection systems and monitoring displays for lighting, for space heating and cooling and ventilation systems) and optimise the control and maintenance of TBS (e.g. single interface for controlling heating and cooling facilitates the operation of the building and prevents spilling energy through uncoordinated simultaneous heating and cooling in building zones). Next, interoperability is essential for allowing TBS to interact with the energy grids. Finally, interoperable systems are desirable in the light of future upgrades of the building as they can avoid proprietary lock-in and facilitate innovative solutions.

There can, however, also be a flip side to interoperability. Exploiting interoperability through connecting various systems – potentially stemming from multiple manufacturers – can increase the risk for malfunctioning compared to proprietary systems and protocols. Fault diagnosis in a system of interconnected TBS can also be more intricate compared to a set of stand-alone systems. Finally, the delineation of responsibility for the provision of the service can become blurred in case of interoperable and interconnected systems. This can introduce cybersecurity risks and the risk that an end user is unable to establish who is responsible for the service and hence cannot legally seek recourse if a service they have paid for is not functioning as intended.

The various levels of interoperability (see section 1.1.2.15: technical, syntactical, semantic) further complicate the definition and assessment of interoperability aspects. While in principle the SRI could be structured to encourage interoperability by awarding a higher score for fully interoperable systems (e.g. fully open non-proprietary systems and protocols), this should probably not come at the expense of blurring the ability of procurers to hold a service provider accountable for the service they have procured. In the context of the SRI, this can be solved by not necessarily looking into full technical and semantic interoperability of all TBS and their components, but by focussing on the main features that provide smart services to the occupants. For example, smart ventilation systems could use proprietary protocols for controlling the fans and valves, and open protocols for communication with a building (energy) management systems. In this example the proprietary controls would not necessarily have negative repercussions in the SRI evaluation mechanism, as long as the system is able to communicate insights on energy consumption and indoor air quality to the users through an open interface.

1.2.7.2 Potential approaches to assess interoperability aspects with the SRI

In the proposed methodology developed by the technical study, the smart readiness of a building or building unit is determined on the basis of the assessment of smart ready services (and their functionality level) present in a building. As such, it reflects the capabilities of the building or building unit to adapt its operation to the needs of the occupants and the grid, and to improve its energy efficiency and overall performance. Apart from these key capabilities, there are some cross-cutting issues related to the greater uptake of smart technologies, including interoperability of the technical buildings systems. The SRI could potentially play a role in informing the market actors on this important aspect and even assist in shaping the market. Various ways to do so can be considered, e.g. blending the assessment in the core SRI calculation methodology, using the SRI as a means to disseminate additional information, or supplementing the SRI assessment with additional evaluations of these aspects besides the overall SRI score.

In the second interim report of July 2019, three potential approaches to consider interoperability within the SRI were presented, each with different implications towards SRI calculation methodology and assessment process:

- **Implicit approach:** Define services that require interoperability, without defining the required standards or protocols needed to enable such interoperability. For example, if a service for "avoiding simultaneous heating and cooling" is present, implicitly these systems will inherently have to be interoperable (either directly or through other gateways).

- **Explicit approach:** take into account the level of interoperability of services (based on the standards and protocols featured by a given TBS) in the calculation of the SRI. A higher SRI score could be granted if systems adhere to a list of specific standards and protocols.

- **Informative approach:** Provide information the level of interoperability of services (based on the standards and protocols featured by a given TBS), for instance, in the SRI and accompanying documents. A structured overview of such information provides a valuable source for building owners when planning to upgrade their building systems.

1.2.7.3 Topical group survey on interoperability assessment in the SRI framework

The various potential approaches to treat interoperability have been analysed by the technical study consortium and discussed with the stakeholder community, most notably the topical B expert group which was set up to support the technical study on methodological issues. White papers, open public surveys (e.g. the feedback form on the second interim report) and direct interactions further fed into the discussion.

In July 2019, technical experts of the topical stakeholder working groups A and B where surveyed on the theme of interoperability in the SRI. A total of 21 respondents filled out this survey. Generally, their responses reflect the notion that an extensive assessment of interoperability aspects in the SRI assessment would be intricate and require extensive efforts.

Only 3 respondents agree that visual inspection would be a viable option, while 14 disagree and 4 remained neutral. 13 respondents state that interoperability cannot readily be assessed since this information is generally lacking on product labels and technical documentation (4 ‘disagree’, 4 ‘I don’t know’). 16 out of 21 respondents agree that the efforts required for a detailed assessment of interoperability aspects would significantly increase the time needed to conduct an SRI assessment (3 ‘disagree’, 2 ‘I don’t know’).

When presented with the three approaches suggested by the study team for including interoperability aspects in the SRI, 10 respondents prefer the implicit approach, whilst 6 favour an informative approach and 5 the explicit approach. 2 respondents answered ‘no opinion/not relevant for the SRI’.

In the survey, the topical group members were also presented with various statements on how to potentially deal with interoperability of systems in case an explicit approach would be favoured. Respondents could select multiple options.

- 10 respondents agree with the statement "Technical building systems do not necessarily have to use a common protocol, as long as one gateway (e.g. the building (energy) management system) is able to interact with other technical building systems."
- 10 respondents agree with the statement "If technical building systems are able to communicate through a well-documented protocol, this is sufficient to denote them as 'ready for interoperability'."
- 10 respondents agree with the statement "All systems in a building should use a common protocol to be fully interoperable and this protocol should be an open one."
- 2 respondents agree with the statement "All systems in a building should use a common protocol to be fully interoperable."

In the survey, respondents of the topical working groups were presented with a preliminary list of various candidates for common communication protocols and standards which could potentially be favoured in terms of interoperability. Initially provided suggestions were 1-wire, BACnet, DALI, DMX, EnOcean, KNX, Lonworks, Modbus, M-bus, TCP/IP, X10, ZigBee and Z-Wave. Respondents also had the opportunity to add other protocols and standards. One respondent did so, adding DECT/ULE. Another stakeholder commented that instead of looking for common protocols one should aim for common languages, hereby suggesting SAREF, SAREF4ENER and SPINE. This was however covered in another question. Respondents were able to select multiple options. All of the suggested options received between 1 and 7 votes. This reflects the current heterogeneity of the field. A stakeholder commented that nevertheless the list was still too generic and incomplete, flagging up that for example TCP/IP consists of various versions.

Respondents were also invited to indicate their preferences on the use of SAREF to treat interoperability, especially with regard to flexibility to the energy grid. SAREF (Smart Appliance Reference) is a common ontology in the domain of smart appliances. The European Commission has boosted the development of this common ontology and a technical standard has been developed by ETSI. Four respondents claim that "*Compliance to SAREF should be explicitly assessed as part of the SRI assessment procedure of flexibility services.*", whereas six respondents report that "*Compliance to SAREF should not be assessed in the SRI, as this will anyway be the standard for new products on the emerging field of grid flexibility services in buildings".*

Three respondents indicated "*I consider there are other relevant standards and protocols*", but when asked none of them specified these. It was however correctly commented that SAREF is only an ontology considering data points semantics but not covering communication aspects, thus only covering a part of the interoperability aspects.

1.2.7.4 Stakeholder consultation on interoperability assessment in the SRI framework

Multiple written comments and proposals on interoperability assessment were received from the stakeholder community. The following section summarises and analyses the various inputs.

- Multiple stakeholders have explicitly **stressed the importance of interoperability -** especially from the perspective of the building end-user and investor – but did not specify a methodology or metric to provide an actionable assessment procedure.

- Some stakeholders suggest to support or evaluate **'the use of open standards'** as part of the SRI, e.g. by promoting the use of open communication protocols for TBS to communicate with each other. A few stakeholders state explicit preference for one or multiple specific open standards or communication protocols. Some stakeholders even plead for the use of one or more specific open protocols as a requirement before issuing an SRI. On the topic of open standards, one stakeholder commented that some of the protocols exist in multiple versions, which can affect the interoperability and complicate the assessment. One stakeholder argues that manufacture-specific proprietary protocols could also be considered 'sufficiently interoperable' provided that they have a broad use base. One master thesis testing an approach and scoring mechanism for rating the interoperability potential of various protocols has also been made available to the study team.

Evaluation by the study team:

Inspecting the use of open protocols could be a criterion in the assessment of interoperability aspects in the SRI framework and could be relevant in all three potential approaches delineated before.

There are however some concerns towards establishing a practical assessment procedure:

a) *Using open standards can ease interoperability but is not a synonym; many of the open standards suggested are not mutually interoperable. Nevertheless, their openness allows for developing gateways which can indeed facilitate communication between two distinct protocols; a practice which is very common in the current market. From this perspective, the use of open protocols does not guarantee interoperability, but it would indeed create a form of "readiness" to allow interoperability now or in the future.*
b) *For a practical assessment, the standards and protocols need to be well documented, e.g. in technical product sheets or labels. In the SRI calculation methodology, an evaluation would ideally be performed on the level of smart ready services or domains. In practice, most services and domains of the suggested SRI service catalogue require a smooth collaboration of a multitude of products (e.g. thermostats, pumps, valves, heat generators, etc.). The assessment of the use of open protocols therefore requires the inspection of a great variety of technical products. The assessment can be supported by introducing labels or codes on equipment, structured product databases or a means for TBS to self-report the standards and protocols which are supported.*
c) *If one would pursue this approach, a well-supported list of open standards needs to be defined. A first version of such list was drafted by the consortium in preparation of a topical group B survey on interoperability and cyber-security. This list contained the following protocols: 1-wire, BACnet, DALI, DMX, EnOcean, KNX, Lonworks, Modbus, M-bus, TCP/IP, X10, ZigBee, Z-Wave. All of these were considered relevant by at least one respondent. KNX, BACnet, Dali, TCP/IP and Zigbee were the most commonly selected options by the*

topical group B respondents. The respondents were provided with the opportunity to suggest additional protocols. One respondent suggested SAREF and Spine (which are ontologies rather than protocols), while another expert suggested DECT/ULE. If the approach of using open standards and protocols would be pursued, further actions need to be taken to ensure a broad consensus on the list of standards and protocols included.

- Support for the Smart Appliances REFerence ontology (**SAREF**) and SAREF4ENERGY (ETSI TS 103 410-1) ontologies was expressed explicitly by some stakeholders.

  Evaluation by the study team:

  The SAREF ontology is a promising initiative which receives broad support from stakeholders and EU policy initiatives. The SAREF ontology helps to create a common language, even if various technical products use different protocols. A simple and straightforward assessment criterium for interoperability could potentially consists of simply requiring compliance to the SAREF ontology or one of its domain extensions such as SAREF4BLDG. A few concerns limit the practical applicability of this potential approach:

  a) *SAREF is an ontology considering data points semantics but it does not cover communication aspects. One can imagine systems using two distinct protocols (e.g. one bus type and one wireless) both being capable of translating command through the SAREF translation, but not able to communicate the messages through the different protocols and therefore not achieving actual interoperability. One could mitigate this concern by denote this as 'ready to interoperability', and rely on the introduction of communication gateways to ensure actual interoperable communications.*
  b) *On-site inspection cannot be done by visual means. Assessment would require product datasheets or dedicated databases to be able to discern whether TBS are SAREF compliant. In the longer term, this could partially be solved by introducing product labeling or having updated versions of smart building protocols which inherently fulfill the criterion of SAREF compliance.*
  c) *SAREF is mainly know in the field of smart appliances such as white goods. For buildings however, the SAREF4BLDG ontology and semantics (TS 103 410-3) was more recently published in 2017, whereas many open protocols used in the building sector are preceding this date. Furthermore, some services and devices might not yet be in included in the first iteration of the SAREF4BLDG ontology. The SAREF and SAREF4BLDG ontologies are currently being tested in research projects, but are currently not common in the building industry.*
  d) *Given the rather recent introduction of SAREF(4BLDG) legacy equipment in buildings will most likely not be compliant. In realty, most buildings would therefore have a very low or zero score on the interoperability criterion. In practice however, interoperability might nevertheless be ensured in such building (e.g. by using open standards which are currently not SAREF compliant). This risks to alienate consumers and building experts and cause distrust in the SRI assessment, since the evaluation does not correspond to their actual user experiences in their building.*

- One stakeholder proposed a particular assessment approach consisting of two elements:

    1) Addition of extra domain focused on connectivity. In this domain, the connection of TBS to a converged building network based on international standard network protocol ETHERNET – IP would be evaluated.
    2) Attribution of additional scores to systems that provide WebServices to interface with outside world

    Evaluation by the study team:

    This proposal provides an interesting simplified assessment process which could fit into the current logic of the SRI assessment procedure. Some further considerations on practical aspects of this proposal include:

    a) In the current SRI methodology, services are grouped according to tangible building services: heating, cooling, electrical vehicle charging, etc. This proposed new 'domain' deviates from this logic, and rather positions itself as a cross-cutting issue across all domains.
    b) Opting for one specific communication protocol might not be favoured. Although the proposed Ethernet IP protocol is open and commonly used, a choice for one particular protocol is not technology neutral, especially from the perspective of vendors and installers of bus-systems. Even if one would opt for a more generic approach in which other open protocols are allowed, the issue remains that a closed list of accepted standards might evolve due to technological development. Next, the IP protocol is rather a communication protocol, but does not ensure semantic interoperability of services.
    c) Simply having a webservice is not sufficient to have interoperable smart services. A webservice can have strict limitations on the available data, does not necessarily allow the operational control of assets and might have commercial restrictions (e.g. subject to fees, restricted access to specific application providers,…).

- One stakeholder proposed an assessment approach which introduces a network "network readiness" domain which should always be evaluated. In this proposal, a set of so-called "macro-services" would be introduced to assess the building level on connectivity and interoperability. The "network readiness" macro-services would exclusively focus on the impact criterion "flexibility for the grid and storage". Cybersecurity would be indirectly handled by communication protocol services.

    Evaluation by the study team:

    This proposal bears many similarities with the proposal described before. A few additional comments can be raised:

    a) The proposed structure of macro-services follows a different methodological approach than the currently proposed SRI methodology which is based on the evaluation of the functionality levels of smart ready services. Blending two calculation procedures would significantly complicate the SRI calculation methodology and would hamper the communication on the method and the SRI results of a particular building.

b) *Some of the proposed macro-services overlap with functionalities in the smart ready service catalogues (simplified method A and detailed method B). This is for example the case with macro-service 3 "There is a dashboard to communicate the data collected" which overlaps with the services on reporting facilities introduced in the different technical domains.*
c) *The proposal would restrict interoperability impacts to the impact criterion "flexibility for the grid and storage". Interoperability can however also encompasses the communication of various technical building systems within a building (and avoiding lock-in effects while doing so). Interoperability of systems in the building (and not solely related to the building-grid interface) can also lead to other impacts including better energy efficiency (e.g. avoiding simultaneous heating and cooling), more convenience and better information provision to the occupants and facility managers.*
d) *Some of the proposed 'macro-functions' could potentially be added to the SRI service catalogues A or B (at the onset of the SRI or in later updates), preferably following the same methodological structure as other services. E.g. a service on the "type of electric counter which reads electricity consumption" could be introduced, potentially blended with a service on the set-top box installed by an aggregator, provided that this is reformulated in a technology-neutral way. To retain the logic of the assessment process, additional services would preferably be added to the existing domains instead of introducing an additional domain.*

- One stakeholder suggested to rely on external certification or assessment schemes. It is suggested that in those countries where a framework for building connectivity and systems interoperability exist; it could be referred to in SRI assessment and potentially given additional scores in case of full compliance.

Evaluation by the study team:

This could indeed be a valuable suggestion, but risks to blur the EU wide recognition of the scheme and related benefits to structure the market of smart technologies. If this option would be preferred, the study consortium suggests to implement it as an additional information provision alongside the SRI score, rather than introducing national assessment schemes in the main SRI scoring mechanism.

1.2.7.5 Consolidated proposal on treating interoperability

Based on the observations of the consortium and discussions with topical group members, the study team consortium proposes to include interoperability in a blended approach, combining the implicit approach and a voluntary inclusion of information provision on interoperability aspects.

A formal evaluation of interoperability which affects the SRI scoring process is not retained as a feasible option. Whilst interoperability is acknowledged as a very important concern in relation to the SRI, there are significant limitations to the actionability of the explicit evaluation of the interoperability. This approach would require in-depth information on a very broad range of technology and implementation routes by numerous vendors. This information is usually not readily available to an assessor and would require additional investigations. Especially in the case of legacy equipment it might be very hard or even impossible to retrieve sufficiently detailed information. Furthermore, such an assessment would need to be performed for many of the TBS present in a building (heating, cooling, lighting, ventilation, BMS…), requiring a large amount of time and effort which would have important repercussions on the cost of an SRI assessment. Furthermore, the SRI would in any case only provide a snapshot of the current status of the interoperability features of the TBS. This is a fast-moving field, and many software and hardware solutions emerge which allow interoperability despite using different technologies and protocols, for example a DALI-to-KNX gateway to integrate lighting and KNX control. Finally, this approach would require further efforts to generate a broad consensus on standards and protocols that would be accepted or the development of other definitions and calculation method to explicitly rate interoperability scores. Due to the lack of definitions and standardization and the intricacy of an on-site assessment process covering a very wide range of products and technologies, the explicit evaluation of interoperability as part of the SRI calculation methodology is not considered to be the preferred option by the study consortium. This notion is well supported by the majority of stakeholders, especially also from topical expert group B.

Instead, the proposal of the study consortium is to evaluate interoperability as follows:

a) Implicitly, interoperability is evaluated as part of the standard SRI assessment: a few services explicitly require interoperability in order to achieve higher functionality levels (some services such as MC-S1 and MC-S3 are specifically introduced to this goal).
b) Additionally, information of interoperability aspects can be added to the SRI format. This information does not affect the SRI score in itself.

This approach has been presented during the second stakeholder meeting in Brussels and discussed and finetuned with the topical group B experts at multiple occasions.

Part A: Implicit approach

The implicit approach to interoperability is embedded in the calculation methodology and thus common across the EU. Instead of evaluating various dimensions of interoperability for each of the TBS separately, technology neutral services have been introduced in the SRI catalogue. Some services are defined in a way that they can achieve higher functionality levels and impacts if they demonstrate actual interoperability within systems. Many of the services inherently require multiple sensors, actuators and controllers[84] to be interoperable to collectively deliver the specific service. For example, a service related to room temperature control requires a number of temperature sensors, distribution pumps, heat generators, etc. to work together seamlessly[85] to deliver the required service. Furthermore, specific services have been included in the service catalogue to express how TBSs in different domains can work together or provide performance information in a single user interface across various domains.

[84] Mostly from different vendors and OEMs (Original equipment manufacturers)

[85] In terms of interfaces and sensor interpretation

Inherently, some level of interoperability will be required to make such services actionable at all, hence better interoperability would positively affect the SRI score of a particular building.

Part B: Supplementing the SRI label with additional information on interoperability

The additional information could either be optional or mandatory for the implementing bodies. The suggestion of the technical study team is to have this information as an optional add-on, leaving it to the discretion of the implementing bodies to include it as an optional assessment or even an obligatory assessment (e.g. for particular building types).

The proposal of the technical study team is to develop this additional information provision in two stages:

- **In a first version of the SRI**, the information provision would entail a listing of the communication protocols of the various TBS. In case this information could not be obtained, this could also be explicitly indicated.
- **In future iterations of the SRI**, a dedicated evaluation of interoperability aspects could be added.
  A suggestion to structure this evaluation has been proposed by the study team. It consists of the evaluation of two interoperability aspects on domain level:
    1. The extent to which TBS are capable of sharing operational data (e.g. current and historic energy consumption data) through an open protocol.
    2. The extent to which TBS can also be controlled through an external signal; e.g. through external smartphone apps or building energy managers which can access the actuators through an open and well-documented API.

  This approach was tested by some topical group B members on actual case study buildings. The appraisal of the technical study team is that this approach is promising, but requires further investigation, testing, standardization and development of datasets. It should therefore not be part of the first version of the SRI, but can be added in future updates once fully actionable.

Implementing bodies could be allowed to also include information retrieved from national certification schemes on interoperability aspects, and communicate these results alongside the SRI assessment documents.

1.2.8 CONNECTIVITY

In principle, the level of connectivity that a building offers to external data networks could be a factor that determines its smartness – at least to the degree that limitations in connectivity would inhibit it from fulfilling certain smart services. Besides connectivity of the building to external data networks, the terminology of connectivity is also used in relation to communication of technical building systems in the building (e.g. through wireless access, bus networks, low power IOT networks, etc. The latter will not be evaluated separately, as it is an essential part of the technical interoperability of TBS (see 1.2.7).

While the EU has established an option for Member States to introduce a broadband-ready label for buildings, and a few Member States have implemented such a label, most have not, and the criteria applied do not appear to be harmonised. In practice, it is not clear how much any actual implementation of the SRI, at least in its initial stages where Method C is not envisaged, would be hindered by broadband access constraints unless there were no broadband access at all, or it was at a very low level. It seems prudent therefore to allow the SRI to be complementary with broadband-ready labels where they exist, but otherwise not to explicitly assess connectivity. An alternative approach would be to identify an absolute minimum degree of connectivity (e.g. in terms of bitrate or latency of an internet connection) below which some SRI penalty would be applicable. A caveat of this approach is that the SRI in that case not necessarily reflects on the readiness of the TBS of the building, but also blends this with notions on the presence and quality of a communication grid, which are not under the control of the building owner or investor. Data connectivity is to a large extent governed by market offerings of external players (e.g. fiber to the building or 5G access will depend on commercial companies offering these services, and not to intrinsic qualities of the building). Furthermore, a higher connection speed or lower latency does not directly relate to a smarter operation of the building, for most services a basic connection would suffice.

In line with the implicit approach suggested for dealing with interoperability issues in the SRI, it is therefore suggested to treat connectivity as an implicit requirement to some of the services - e.g. in relation to monitoring and control through handheld devices, or flexibility aspects requiring minimal digital connectivity – but not to perform an explicit assessment. This proposal has been discussed with topical group B in a conference call on 4 November 2019. The topical group experts agree that a separate assessment would be out of scope of the SRI and are supportive of the suggested approach.

1.2.9 STANDARDISATION AND CODIFICATION OF SERVICES AND FUNCTIONALITY LEVELS

Standards can contribute to the development of an SRI by assisting in identifying or quantifying functionalities and services in a fast and harmonised way. The services in this study were to a large extent sourced from standards. ANNEX B provides an overview of the main standards related to smart buildings, as identified during the first technical support study.

This is especially the case for many of the services sourced from EN 15232 *'Energy Performance of Buildings — Impact of Building Automation, Controls and Building Management'* (module M10). This standard is the overarching standard that models the impact of BACS on a building's energy consumption. The standard is developed by CEN/TC 247 and part of a series of standards aiming at international harmonization of the methodology for the assessment of the energy performance of buildings, called "EPB set of standards". This standard contains a list of BACS and technical building management (TBM) functions and categorises them in line with the modular structure defined by the over-arching EPB standard (EN ISO 52000-1). Other examples of standards used include the lighting control systems as defined in EN 15193-1:2017, Smart Grid Use cases from IEC 62559-2:2015, etc. More general background information on relevant standards for smart ready services is reported in Annex D of the final report of the first technical support study for the SRI.

Standards will be used to support the definition of functionality levels and the assignment of ordinal scores for impact criteria wherever possible, in particular the impact criterion “energy efficiency”. At present, certain services are not covered by any standards. Also, for several other impact categories, the quantification of the impacts requires to some extent a subjective judgement at this moment. This is the case, for example, for impact categories “convenience” and "information to occupants”. Such subjective assessment is not to be performed by the individual SRI assessor but shall be defined as an integral part of the SRI methodology. This can be defined, for example, by means of a dedicated expert group comprising representatives of academia, policy experts and relevant industrial stakeholders (see also section 1.2.10). The SRI methodology is set up in such a way that it is sufficiently supple to be updated if more scientific evidence becomes available to support a more accurate definition of functionality levels or ordinal scores.

The suggested approach has been well received by stakeholders. One organisation wrote in their white paper:

> *‘Standardization is key. The methodology should rely as much as possible on standardized solutions. As proposed by the first study, the check-list approach needs to assess the level of functionality of the different smart services. Standards are crucial to assess functionality levels and are defined for most of the services selected by the first study (e.g. EN15232 for BACS).’*

1.2.10 THE PROCESS OF UPDATING THE METHODOLOGY

Numerous stakeholders stressed the importance of the methodology used to update the SRI being sufficiently supple to ensure that new innovative services can be properly represented within it. Some suggested that this meant that reliance on conventional harmonised standards was inappropriate as these usually took too long to be updated.

During a discussion with Topical Group B[86] on this matter, one member reiterated the need to set up a steering committee, responsible for updating the SRI framework. Members suggested that the process of updating could largely be copied from standardisation processes, where typically 5-year cycles exist. Shorter cycles – e.g. 3 years – could be envisaged, although yearly updates are not deemed necessary. In addition to the fixed updating cycles, it was suggested that industry could be allowed to signal product innovations to the committee in case important new services or functionality levels become available. Upon request from industry, the committee could decide to advance an update if needed. Following the discussion, the study team received a number of position papers addressing the issue, in which the aforementioned are largely confirmed. However, agreement on the frequency of the updating cycles is currently lacking.

- 'A Steering Committee is needed to update the SRI framework every year to ensure product innovations are included in the catalogue of services and methodology. A subgroup of this Committee should be tasked to investigate how to move towards Method C, i.e. move the SRI towards a quantitative building performance indicator.’

[86] Topical Group B: calculation methodology; Web meeting on 14/05/2019

- '[Our organisation] agrees that updating the SRI calculation methodology is necessary to ensure it continuously adapts to changing technologies. [Our organisation] welcomes the need for an updating procedure similar to the one used to update standards being considered by the consultants, with a dedicated expert group, updating if necessary, the SRI calculation every 5 years or less. In addition to these fixed updating cycles, [our organisation] actually suggests allowing the industry to signal product innovations to the committee in case important new services or functionality levels become available. Upon request from the industry, the committee could decide to advance an update if needed.'

Additionally, Topical Group C have been tasked to discuss a process for updating the SRI methodology; e.g. updating the service catalogue by adding or removing domains, services, or functionality levels, etc. The topical group has made the following recommendations in terms of format and process[87]:

- ‘At EU/Europe level the set of CEN/ISO Energy Performance of Buildings (EPB) standards (developed for the EPBD's implementation, https://epb.center/epb-standards/background/) seems like a good implementation avenue to consider i.e. make the SRI methodology an EN (maybe also ISO) standard (EN SRI standard would be adopted automatically at national level, although not mandatory, easing the SRI implementation). As such the CEN SRI working group could be integrated in the overall (envisioned) SRI platform and more content in terms of relations to other EN (maybe also ISO) standards would be easily incorporated. High attention should be though given to the length of the updating cycles i.e. the SRI might need shorter cycles because it is dealing with fast evolving technology.’
- ‘At national level the EPC schemes seem to be the most obvious implementation avenues, which are by now mature and poses a lot of "dos and don'ts". The SRI could be a voluntary or mandatory add-on on the current EPC. It could thus be ensured that the framework of the EPC (which is widely accepted and known by the public) acts as a multiplier for the SRI. At the same time a go-to-the market could be a voluntary based scheme.’

In the view of the study team this probably implies a process wherein there is a standing body charged with ensuring the update of the SRI in response to technical developments and any issues that arise from its implementation. The process of inaugurating, resourcing and maintaining such a body is discussed in section 3.3.

[87] The full report of topical group C can be found on www.smartreadinessindicator.eu/stakeholder-consultation

1.3 Activity 3: Technical recommendations for the development of the calculation methodology of the SRI

The main objective of this activity is to provide technical input with regard to the calculation methodology of the SRI that enables the Commission Services to draft the methodology according to the framework provided in the amended EPBD. A key challenge to reaching this goal is to ensure mapping of the smart ready services and their impacts over different KPIs (e.g. energy, comfort, health and well-being, grid interaction, etc.) that both correctly reflects the expected performance of smart ready technologies and is endorsed by the stakeholder community and Member States.

As a starting point, this activity builds on the outcomes of the critical review in Activity 1 and reflects on the updated technical recommendations for the SRI definition and associated smart service catalogue of Activity 2 to identify possible updates and improvements to the calculation methodology. Thus, the focus is on the translation of the functionality levels of smart ready services to the final SRI score of the building being considered. For the SRI to both (i) resonate with building occupiers, service bill payers and owners and (ii) ensure it reaches its goal of stimulating the uptake of smart technologies in buildings, the integrity and credibility of the SRI are of essence. In other words, a higher SRI score should correctly reflect the greater ability of a building to adapt to the needs of its users, to optimise energy efficiency and to adapt to signals from the grid.

This section presents a consolidated calculation methodology for the SRI. The presented methodology is the result of:

- a critical analysis of the ordinal scores for the smart ready services in the service catalogue for all impact criteria
- an evaluation of different propositions of weighting schemes to aggregate the scores for the selected impact domains to an overall SRI score and by extent an evaluation of the selected impact domains themselves

a triage process to identify the optimal set of evaluated technical building services in relation to the specific building context (e.g. residential versus non-residential, climate region, etc.). Throughout the study, the technical study consortium have presented intermediate iterations of the calculation methodology to the stakeholder community, and have captured their feedback for further refinement. This includes various discussions with the topical B expert group which was set up to support the technical study on methodological issues as well as the feedback captured from the public beta testing (see section 5.1.3). White papers, open public surveys (e.g. the feedback form on the second interim report) and direct interactions further fed into the discussion.

1.3.1 Domains

The first SRI study presented 10 domains in the SRI:

1. Heating
2. Cooling
3. Domestic hot water

4. Controlled ventilation[88]
5. Lighting
6. Dynamic building envelope
7. On-site renewable energy generation
8. Demand-side management
9. Electric vehicle charging
10. Monitoring and control.

Feedback received on the first technical study indicates that some stakeholders would like to see additional domains, including the following.

- Transportation systems: lifts/escalators/walkways
  Although currently outside the scope of the EPBD, transportation systems are an interesting suggestion, as they are linked to a building's energy use and may potentially include smart services that contribute to occupant needs and energy savings. The study team suggests to consider including this domain in a later step.

- Safety and security: alarm systems, DAF and intrusion/fire protection
  This is considered to be outside the scope of the EPBD but could be an optional SRI domain in a later step.

- Comfort and sustainability
  SRTs that link to both comfort and energy consumption are currently included in the SRI. Other comfort aspects are deemed out of scope but could be an optional SRI domain in a later step.

- Water consumption and management
  Although smart services (such as monitoring) that would respond to the needs of occupants can be imagined, there is no clear link to either energy consumption or demand side flexibility towards the energy grid. As water consumption is not part of the EPBD, it is deemed to be out of scope for the SRI but could be considered as an optional SRI domain in a later step.

- Material use
  Although material use is a crucial theme in sustainability, there is no clear link to building smartness. It is therefore deemed to be out of scope for the SRI.

- Communication network (e.g. Wi-Fi and LAN/broadband speed and availability)
  Many services rely on a communications network to connect to other TBSs, a BACS or the grid. Also, in a number of cases, higher functionality levels of services related to controllability and demand side flexibility include the ability to react to price signals from the grid. In these cases, smart meters are a required piece of infrastructure to enable functionality.

  Within the scope of the SRI, infrastructure is not assessed explicitly but is valued implicitly as a prerequisite for other smart services. In other words, infrastructure is only valued when the smart service it enables has been

[88] Controlled ventilation refers to a ventilation system with air flow rates that are controlled based on settings chosen by the user and / or other parameters on the indoor environment (e.g. indoor air quality, thermal comfort).

installed. A more explicit consideration of connectivity could potentially be included in future updates of the SRI.

- Passive design features
  During and after the first technical study, some stakeholders raised a discussion on ways to value active versus passive measures in the SRI scheme, with active measures being understood as enhancement of technical systems by smart (control and communication) technologies and passive measures as those related to the design of the building (e.g. passive shading). Using the example of shading versus active cooling, a member of Topical Group B argued that, from an energy efficiency perspective, passive measures are preferred. He stressed that designers should be oriented towards passive measures by building codes or other regulations implementing the EPBD, before moving towards active measures. The SRI should avoid promoting active measures over passive measures and link to local building regulation.

  The study team believes that a distinction should be made between two elements: (i) the passive design feature itself and (ii) the (potential) dynamic management capability of such a feature. The first element refers to measures such as rational window-to-wall ratios, window overhangs or sufficient thermal mass to prevent overheating. The examples given do not entail any dynamic management capabilities and therefore *do not fit* within the scope of the SRI. They are, however, covered by EPCs. This remark illustrates the relevance of aligning with other frameworks and schemes, as discussed in Task 1 Activity 2. A second element relates to the dynamic management capabilities of passive features, e.g. automated control of solar shading devices. Although solar shading can be seen as a passive measure, the controls of solar shading can have different degrees of smartness. Therefore, dynamic control of passive measures *does fit* within the scope of the SRI and is already represented in the service catalogue.

- Monitoring of user behaviour
  Monitoring and providing information on building metrics related to energy efficiency and comfort (gas consumption, temperatures, etc.) are already included in the SRI. Monitoring of activities or presence of occupants is considered relevant only if this enables the building to perform better on the three smartness aspects listed in the scope of the EPBD. For this application, specific services are foreseen in the current service catalogue. The study team does not perceive a need to add a dedicated domain for such services.

- Air circulation
  This is understood by the study team as air circulation that is not caused or prevented by a controlled ventilation system, which is already covered in the SRI. These controlled ventilation systems include both mechanical ventilation systems (i.e. through the use of one or multiple fans) and controlled natural ventilation systems (i.e. through the control of ventilation openings, potentially based on IEQ parameters). Examples of such air circulation are unwanted draught (potentially resulting in comfort and health issues) or uncontrolled natural ventilation (potentially leading to good indoor air quality without a need for a controlled ventilation system). Neither example has controllability, therefore both are considered to fall outside the scope of the SRI.

- Noise reduction
  Although noise and acoustic comfort are relevant to comfort and to health and well-being, acoustic performance is governed by design choices (such as adequate sizing or sufficient dampers) and not by clearly identified TBS

(dynamic) capabilities. Therefore, at this stage noise reduction is not relevant for inclusion in the SRI.

- Seismic damage prevention
  Although seismic damage prevention is relevant within the scope of the EPBD, it is governed by design choices and not by clearly identified TBS (dynamic) capabilities. Therefore, at this stage seismic damage prevention is not relevant for inclusion in the SRI.

As mentioned in section 1.1, a clear definition of the scope of the SRI is crucial for determining which aspects are out of scope and which ones may be relevant. Some aspects do not fit within the scope of the SRI but are taken into consideration in other initiatives. Therefore, it is also important to identify potential linkages to other initiatives.

Apart from the suggestions for additional SRI domains, the study team has investigated possibilities for further optimising the definitions of the currently included domains. At this stage, two major changes are envisioned.

1. Change of scope: "on-site renewable energy generation" becomes "electricity"
   Currently, the domain "on-site renewable energy generation" includes services that monitor, forecast and optimise the operation of decentralised power generation and control the storage or delivery of energy to the connected grid. A few comments can be made about the current definition:

   - The domain favours on-site generation over centralised renewable energy generation or the delivery of renewable thermal energy in district heating systems, even though such solutions may be equally beneficial towards decarbonisation; as such, it could be argued that the domain cannot be considered technology-neutral;
   - Many renewables, such as solar energy and wind energy, cannot be controlled in terms of energy efficiency, nor do they directly respond to the needs of either the occupant or the grid. Generally speaking, the presence of these renewables as such does not match the definition of smartness according to the SRI. Smartness can be attained by improving demand side flexibility, e.g. by introducing storage capacity or by implementing combined heat and power (CHP);
   - Services with respect to storage *are* included in the domain, but the domain name "energy generation" does not clearly reflect this;
   - The domain mainly focuses on electricity consumption, as the production of renewable thermal heat (e.g. thermal solar panels or the heat produced by a CHP) is already covered in the heating domain;
   - Other smart services related to electricity consumption are currently not covered in any other domain. Although adding supplementary services is not envisioned for the first edition of the SRI, the inclusion of this domain could facilitate gradual inclusion of additional smart services related to electricity. If this scope would be expanded in future iterations of the SRI, this domain could potentially include various other services, e.g. monitoring of (domestic) electricity use, (smart) controllability of plug loads and white goods, lifts and escalators.

2. Redistribution of the services in the "demand-side management" domain

The domain "demand-side management" and the impact criterion "energy flexibility" strongly correlate. This raises the question of whether demand-side management should be seen as a technical building system (similar to a heating system or ventilation system) or rather a service that contributes to a certain feature, such as energy flexibility. Although the services in the domain demand-side management are highly relevant to the SRI, in particular towards increasing the flexibility of the building's energy consumption, it can be argued that most of these services are strongly linked to a certain TBS. As such, in many cases these services can be directly linked to one of the other domains, such as heating, cooling or domestic hot water. The remaining services include encompassing services that manage interactions or harmonisation of TBSs and the grid. These services could be included in the domain "monitoring and control".

The study team have redistributed the services to the domains most closely related to each service. As a result, the definition of a dedicated demand-side management domain becomes obsolete. This redistribution may also ease communication, since the term "DSM" is likely to be unknown to the wider public, despite being a well-known concept among experts. It should be emphasized that the redistributing of services does not reduce the importance of demand side management and grid control. On the contrary, the updated detailed service catalogue (see section 1.3.4) now contains 17 services that include DSM and the use of grid signals, whereas formerly only 12 grid-related services were included.

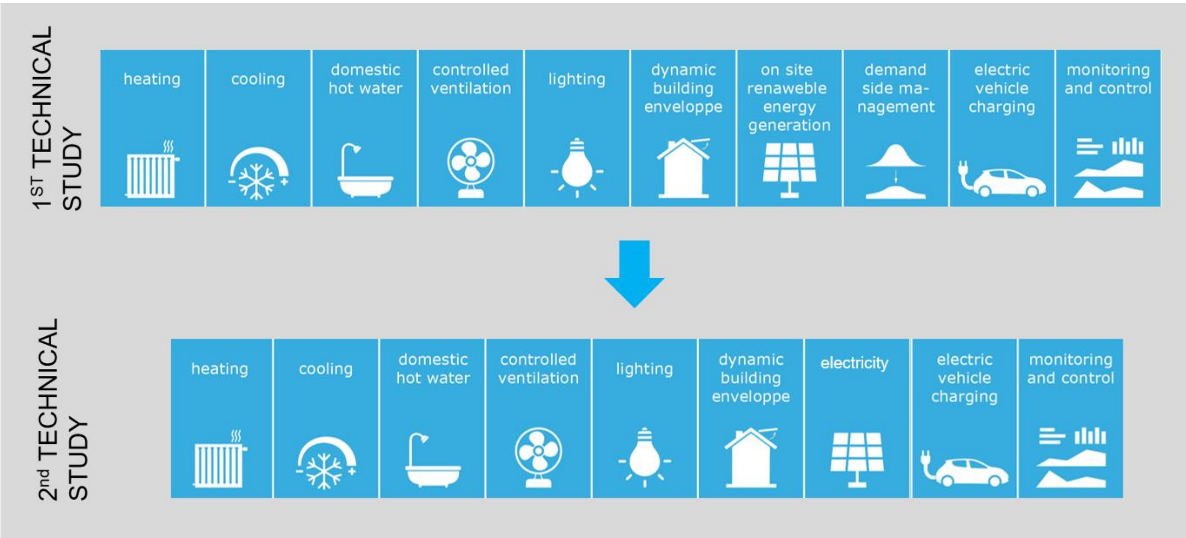

Figure 14 - Changes to the domains

1.3.2 IMPACT CRITERIA

The services in the building service catalogue translate into different impacts related to the three key functionalities defined in the amended EPBD, namely the energy performance of the building, the building users and the energy grid. During the first technical study, eight impact criteria were identified to cover the intended pillars defined in the amended EPBD.

1. Energy efficiency refers to the impacts of smart ready services on energy saving capabilities. It is not the whole energy performance of buildings that is considered, but only the contribution made to this by smart ready technologies, e.g. energy savings resulting from better control of room temperature settings.
2. Energy flexibility and storage refers to the impacts of services on the energy flexibility potential of a building.
3. Self-generation refers to the impacts of services on the amount and share of renewable energy generation by on-site assets and the control of self-consumption or storage on the generated energy in order to provide more autonomy in terms of security-of-supply to the building.
4. Comfort refers to the impacts of services on occupants' comfort, being the conscious and unconscious perception of the physical environment, including thermal comfort, acoustic comfort and visual performance.
5. Convenience refers to the impacts of services on convenience for occupants, i.e. the extent to which services "make life easier" for the occupant, such as by requiring fewer manual interactions to control the TBS.
6. Health and well-being refers to the impacts of services on the well-being and health of occupants. Not being harmful in this respect is a strict boundary condition required of all services included in the SRI assessment. On top of the strict basic requirements, this category valorises the additional positive impact that some services could also provide, e.g. smarter controls could deliver an improved indoor air quality compared to traditional controls, thus raising occupants' well-being.
7. Maintenance and fault prediction refers to automated fault detection and diagnosis, which has the potential to significantly improve maintenance and operation of the TBS. It also has potential impacts on the energy performance of TBSs by detecting and diagnosing inefficient operation.
8. Information to occupants refers to the impacts of services on the provision of information on a building's operation to occupants.

In light of an optimization of these impact criteria to establish a streamlined methodology, the study team reviewed the suggested impact criteria and verified their scope and applicability within the framework of the EPBD.

The analysis revealed an overlap between "energy flexibility and storage" and "self-generation". The former acknowledges services that provide either demand side flexibility (the ability to shift loads in time) or the ability to store energy, with a clear focus on the advantages for the energy grid. The latter also rewards services that allow for energy storage, but from a user perspective. The focus is shifted towards providing more autonomy in terms of security of supply. It can be argued that autonomy should be seen as convenience for the occupant (e.g. guaranteed continuity in energy provision).

In conclusion, the study team has omitted the impact criterion "self-generation", since the advantages of energy storage towards the grid are covered by the impact criterion "energy flexibility and storage", and the inclusion of benefits for autonomy within the criterion "convenience".

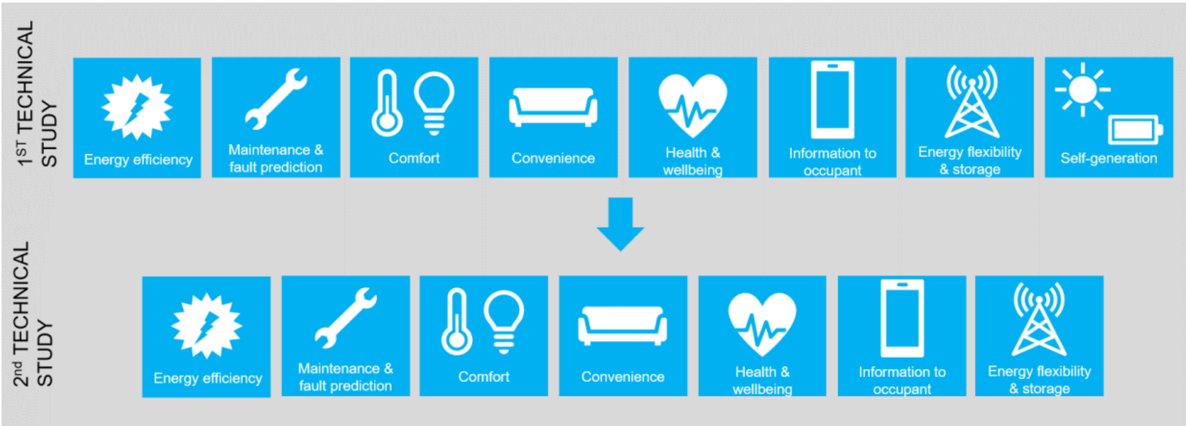

Figure 15 - Changes to the impact criteria

1.3.3 MULTI-CRITERIA ASSESSMENT METHOD

1.3.3.1 General methodological structure

Under the SRI methodology proposed in the first technical study, the smart readiness score of a building is a percentage that expresses how close (or far) the building is from maximal smart readiness. The higher the percentage is, the smarter the building. The process to calculate this global score is straightforward.

1. First, smart ready services are assessed individually. Services available in the building are inspected and their functionality level is determined. For each service, this leads to an impact score for each of the seven impact criteria (energy savings on site; flexibility for the grid and storage; comfort; convenience; health and well-being; maintenance and fault prediction; information to occupants) considered in section 1.3.2.
2. Once the impact scores for all these individual services are known, an aggregated impact score is calculated for each of the nine smart-ready domains considered in section 1.3.1. This domain impact score is calculated as the ratio (expressed as a percentage) between individual scores of the domain services and theoretical maximum individual scores.
3. For each impact criterion, a total impact score is then calculated as a weighted sum of the domain impact scores. In this calculation, the weight of a given domain will depend on its relative importance for the impact being considered. The definition of these weighting factors will be discussed in section 1.3.3.2.
4. The SRI score is then derived as a weighted sum of the seven total impact scores. Again, the weight allocated to each impact will depend on its relative importance for the smart readiness of the building. The definition of these weighting factors will be discussed in section 1.3.3.3.

To summarise, the SRI impact score can be calculated as follows:

$$N = A \times a + B \times b + C \times c + D \times d + E \times e + F \times f + G \times g \qquad (1)$$

where:

- N is the total SRI impact score, weighted score by domain
- A = the impact score (0–100) for energy savings
- B = the impact score (0–100) for energy flexibility and storage
- C = the impact score (0–100) for comfort
- D = the impact score (0–100) for convenience
- E = the impact score (0–100) for health and well-being
- F = the impact score (0–100) for maintenance and fault prediction
- G = the impact score (0–100) for information to occupants
- a = the impact weighting (0–100%) for energy savings
- b = the impact weighting (0–100%) for energy flexibility and storage
- c = the impact weighting (0–100%) for comfort
- d = the impact weighting (0–100%) for convenience
- e = the impact weighting (0–100%) for health and well-being
- f = the impact weighting (0–100%) for maintenance and fault prediction
- g = the impact weighting (0–100%) for information to occupants.

Next, this impact score is normalised by dividing it by the maximum obtainable impact for a particular building. This ratio, expressed as a percentage, is the SRI score of a building or building unit.

The following paragraphs describe potential methods for defining the weighting factors to aggregate scores on domain and impact criterion level, and eventually to a single score SRI indicator.

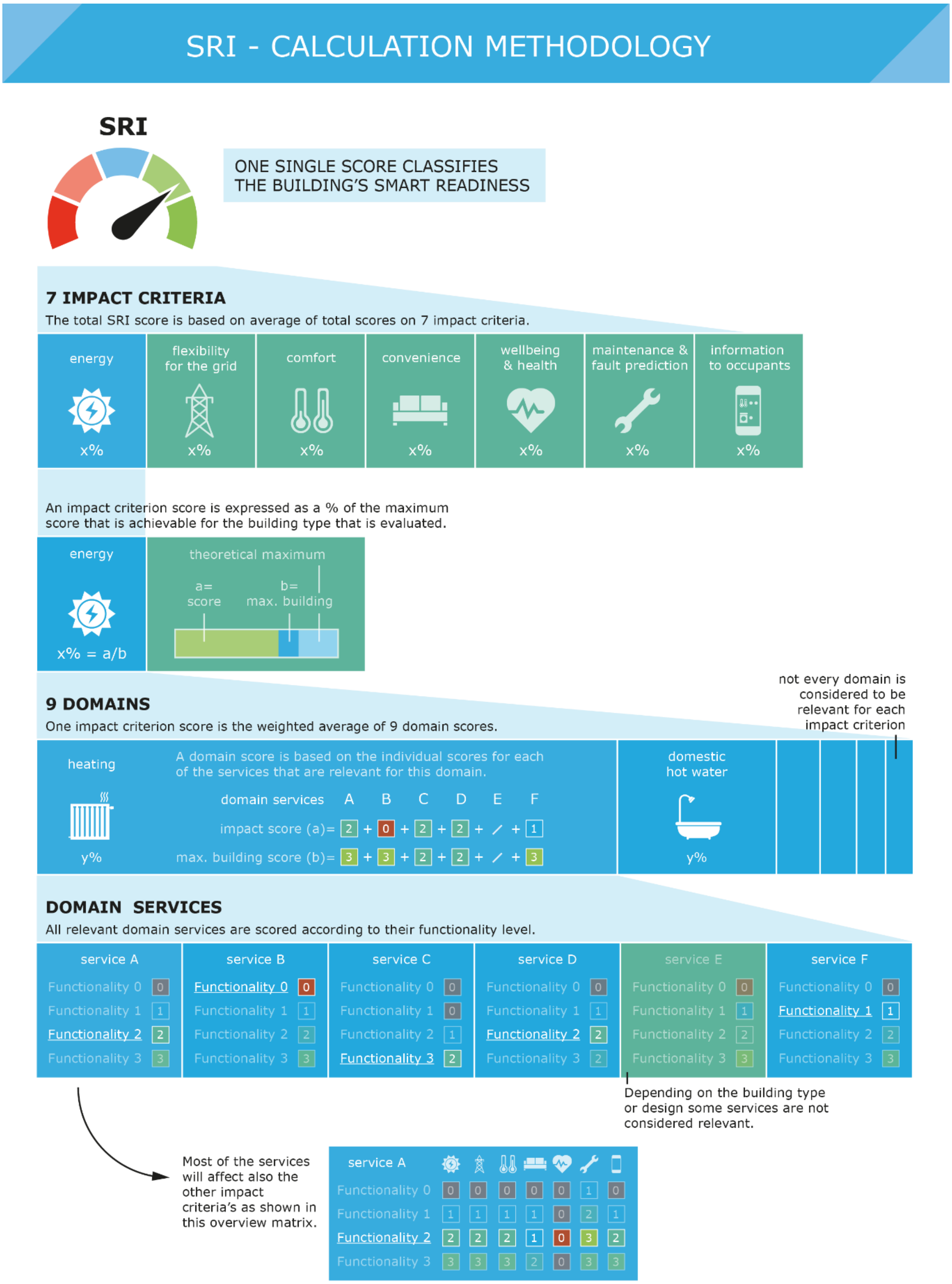

Figure 16 - overview of the SRI calculation methodology

1.3.3.2 Vertical aggregation: weighting factors for services and domains

A two-step approach is applied to aggregate the scores of the individual services to a single impact score for each impact criterion. First, the ordinal scores of the individual services are aggregated to a domain score. Second, the domain scores are aggregated to a single impact score. Different approaches can be envisioned for defining the weighting factors for domains.

Aggregation of services to the domain level

In the first technical study, equal weighting was suggested for the aggregation of services to the domain level. Consequently, each service within a domain is assumed to be of equal importance. Although it can be envisioned that the actual impact of services differs, insufficient data are currently available to accurately quantify the actual impacts of each service related to each impact criterion. The study team suggests proceeding with the implementation of equal weightings at this stage. However, the methodology is sufficiently flexible to implement weighting factors on service levels should these become available at a later stage (for instance, when a metered, performance-based SRI is developed).

Aggregation of domain scores

The aggregation of domain scores for a single impact score accounts for the relative importance of the domains in relation to the impact criteria. As discussed in sections 1.2.3 and 1.2.3.2, the relative importance should depend on the local context (e.g. climate) and building type (e.g. residential versus non-residential buildings). Additionally, further distinction with regard to usage of non-residential buildings can be envisioned (e.g. offices, healthcare facilities, education institute, etc.), although this is not implemented in the methodology set out in this report.

Conceptually, three approaches for aggregation can be envisioned.

1. The "**equal weighting**" approach prescribes a summation of the ordinal score of each evaluated service relative to the sum of the maximum ordinal score of those evaluated services.

   This approach diverts from the ambition to weight the domains (and/or services in the domain) in order to reflect their relative importance to the total score for an impact category. In contrast, an equal weight is given to each service domain and to each of the services within a domain. Note that the hierarchical approach is maintained between domains and services within a domain. Consequently, a domain with more services will not have a higher weight than one with fewer services listed in the service catalogue.

2. The "**predicted impact**" approach prescribes a weighting scheme for the domains (and services within a domain) that reflects the estimated impact of that service on the overall score per impact category.

   With this approach, the weight of domains (or specific services) can differ for the various impact categories. For example, the services in the heating domain might jointly account for 60% of the obtainable score for the "energy savings" impact category, whereas for other impacts such as "convenience" or "comfort", the relative weight of the heating domain is lower, e.g. 25%. Thus, this expresses that added smartness to the operation of cooling systems, ventilation, etc., also offers significant comfort and convenience benefits, even though for a particular building their impact in the total energy balance is much lower than the energy expense of the heating system.

One of the main limiting factors in developing such an approach is the lack of generally accepted calculation methods or even comparison frameworks that allow the differentiation of the importance of the domains in the total score for some of the impact categories. For the impact category "energy savings", multiple sources can provide valuable input (e.g. statistical building stock data, EPCs and standards such as EN52016 and EN15232). To the knowledge of the consortium, for many of the more qualitative impact domains (convenience, information provision, etc.) no scientific evidence is available to support the calculation of weighting factors. Weighting factors will therefore have to be established through other methods, e.g. expert groups or public questionnaires. In any case, deriving scores should not be based on interpretation by individual SRI assessors, but should be defined in the method to ensure a fully replicable SRI assessment.

3. The "**energy balance**" approach prescribes a weighting scheme for the domains (and services within a domain) that reflects the estimated impact of that service on the building's energy balance.

   The weight given to a certain service could reflect the importance of that service in the overall energy use of the building. Typically, an energy balance allows the derivation of the relative importance of different domains. To take into account climatic conditions, an energy balance could be derived for a given building type (e.g. residential buildings) in a certain climatic zone. Statistical building stock data allow the generation of default weighting factors for a given climatic zone. For buildings that have (or are in the process of obtaining) an EPC, it could be envisioned that the weighting factors for energy savings are derived from the EPC calculation. As such, the SRI calculation includes not only climatic conditions but also individualised building characteristics.

   Given the lack of quantification schemes for some of the impact categories (e.g. convenience, well-being, information to occupant), one could consider to extrapolate the weightings for the impact category "energy" to all other impact categories. In other words, the influence of all services is associated with the impact on a building's energy use.

Discussions with Topical Group B resulted in the following conclusions[89].

- The idea of the **predicted impact** method was well received. However, it was acknowledged that no solid grounds for the quantification of these weighting factors are readily available. For domains related to energy consumption, weightings could be derived from an energy balance (hence: energy balance method). For the quantification of the weighting factors for other impact criteria, other sources should be found. Stakeholders were asked to provide data sources that may support the definition of weighting factors, but the study team did not receive any significant sources.
- Focusing on energy-related impact criteria, there is strong support for using existing **energy performance certificates** to derive weighting factors. This

[89] Topical Group B: calculation methodology – web call 7/5/2019

approach solves the need to differentiate for different climate zones and different building types, as the relative importance of each domain would already be reflected in the EPC energy balance. The study team added that it could only be applied to buildings that already have an EPC or which undergo an EPC and SRI assessment at the same time. It is currently envisioned that the SRI is applicable to all buildings. The study team therefore suggests a mixed approach, where default weighting factors are defined using statistical data from the national building stock, but EPC weightings may/must be used when available. The link with EPCs is further investigated in the exploration of implementation pathways (section 2.1 of this report).

- Little to no support was found for the **equal weighting** approach, except for those impact categories for which weighting factors cannot be quantified using scientific evidence and where no clear evidence for prioritising domains is available; "convenience", "comfort" and "health and well-being" were mentioned as potential examples.
- The **energy balance** method was generally well supported for impact criteria related to energy consumption. "Energy savings on site" is an obvious example, but energy balance weightings could also be envisioned for "energy flexibility and storage" and "maintenance and fault prediction". Extending these weightings to occupant-related impact criteria such as "comfort", "convenience" or "health and well-being" was generally not well supported.

Based on the input from stakeholders, the study team has developed a hybrid approach. The study team suggests applying the energy balance method for all impact criteria that are directly linked to energy. In particular, this includes "energy savings", "maintenance and fault prediction", and "energy flexibility and storage". It should be noted that it is currently not possible to derive weightings from the energy balance for all domains. The contribution of the domain "monitoring and control" typically cannot be derived from an energy balance. Also, the impact of a dynamic envelope is typically not quantified in an energy balance. The proposed method attributes a fixed weighting factor to these domains, e.g. 20% for monitoring and control and 5% for dynamic building envelope, with the remaining 75% being determined from the energy balance.

The impact criteria corresponding to the needs of occupants ("comfort", "convenience", "information to occupants", and "health and well-being") require a different approach. Although the study team acknowledges the advantages of implementing weighting factors based on the predicted impact, no objective sources are available. Therefore, an equal weighting is believed to be the most suitable compromise. Figure 17 provides a visual representation of the suggested approach. It should be noted that some domains have no impact on certain impact categories. For instance, "health and well-being" only affects the domains ventilation, lighting and dynamic envelope. The weighting factor for the other domains will be set to zero, and an equal weighting will be applied to the relevant domains.

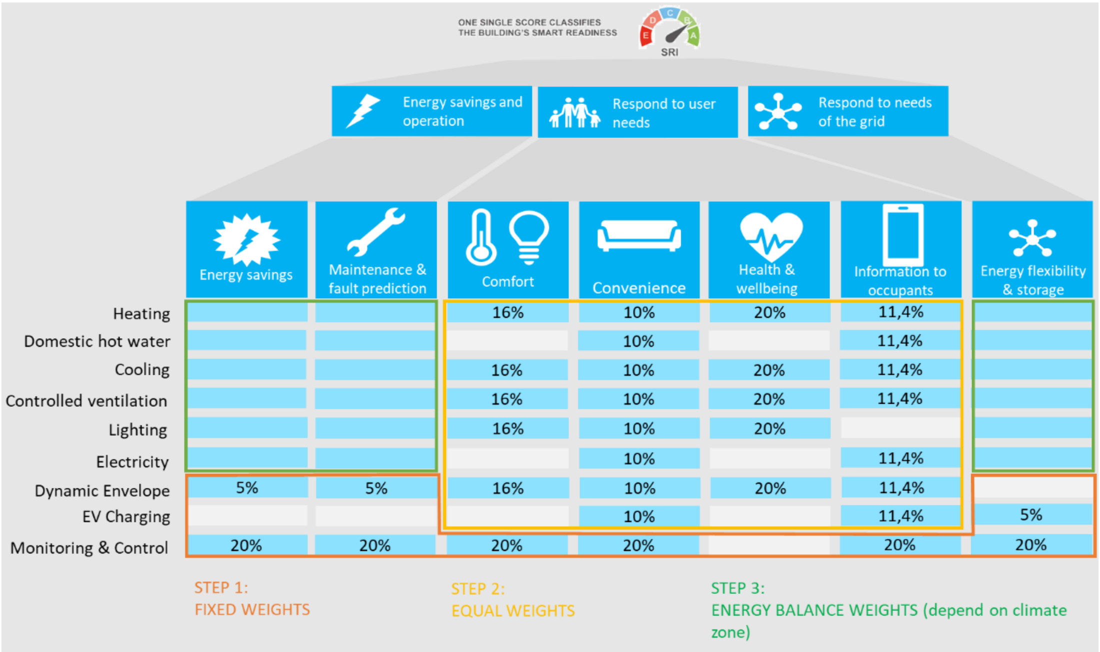

Figure 17 - Proposed approach for domain weighting factors

Methodology for calculating weighting factors for energy-related impact criteria

This section describes the suggested methodology to determine domain weighting factors on the EU level. To reflect the importance of the domains, tailoring to geographical context and building context is foreseen. Regarding the building context, the default weighting factors currently distinguish between:

- Residential buildings
- Non-residential buildings

Although a break-down of non-residential buildings into various building types (offices, healthcare, educational…) is desirable, insufficient data is currently available to quantify this breakdown.

Regarding the geographical context, 5 climate zones have been defined:

- Northern Europe: Denmark, Finland, Iceland, Norway, Sweden
- Western Europe: Austria, Belgium, France, Germany, Ireland, Liechtenstein, Luxemburg, the Netherlands, Switzerland, United Kingdom
- Southern Europe: Cyprus, Greece, Italy, Malta, Portugal, Spain
- North-Eastern Europe: Czech Republic, Estonia, Latvia, Lithuania, Poland, Slovakia
- South-Eastern Europe: Bulgaria, Croatia, Hungary, Romania, Slovenia.

To determine the weighting factor for a climate zone, national statistical data from the Building Stock Observatory[90] (BSO) is used and a weighted average is calculated using the population of the respective countries. The building stock observatory data distinguishes between the following end-uses:

- Space heating
- Space cooling
- Water heating
- Lighting.

Additional operations are needed to obtain a weighting factor for the controlled ventilation domain, as it is not included in the BSO energy balance. The energy demand related to controlled ventilation consists of two components: the (auxiliary) electricity demand for fans and the contribution of ventilation to the energy demand for space heating (= ventilation losses). The ratio between the average transmission heat loss coefficient and the average ventilation heat loss coefficient is used. For details on the calculation procedure, please consult the guidance document (0, section 3.1.1.1).

To determine weighting factors for the cooling domain, additional data is required. Many buildings across Europe do not have a mechanical cooling system. This means that – to avoid underestimation of the importance of the cooling domain – the national energy consumption for cooling should only be applied to those buildings equipped with a mechanical cooling system. Two types of data were used to determine the weighting factor for cooling:

- the annual, national energy consumption for space cooling: the building stock observatory: https://ec.europa.eu/energy/en/eu-buildings-database
- the share of buildings equipped with mechanical cooling installations, broken up by country and by building type (residential or non-residential): https://heatroadmap.eu/wp-content/uploads/2018/11/HRE4_D3.2.pdf.

To determine the weighting factor for a climate zone, national data is weighted using the population of the respective countries. Countries with no data on the energy consumption for space cooling have been excluded from the calculation, to avoid a negative impact on the weighting factors.

Despite the correction for buildings without cooling, the obtained weighting factor is 0% for some conditions (residential buildings in Northern and North-Eastern Europe). Other conditions lead to very low weighting factors as well. Until better quantitative data is available, it is suggested to apply a fixed minimum weighting for the cooling domain (e.g. 5%), or to allow adaptation to the local context.

The obtained weighting factors can be found in the respective service catalogues in ANNEX E and 0.

[90] https://ec.europa.eu/energy/en/eu-buildings-database

1.3.3.3 Horizontal aggregation: weighting factors for impact criteria to obtain a single score

Based on the first technical study and the input and feedback received from stakeholders, Member States and the Commission during and after that first study, three proposals were introduced focusing on three principal alternatives in defining the impact criteria. These proposals vary in the relative importance they attribute to seven previously defined impact criteria and relate back to the initial EPBD definition[91]. The proposals are:

- **Proposal 1:** seven impact criteria as suggested by the first technical study on the SRI
- **Proposal 2:** three impact criteria aligned to the EPBD functionality domains
- **Proposal 3:** seven impact sub-criteria (SRI1) that are aggregated to three impact criteria (EPBD).

The implications on the calculation methodology can be threefold. It can potentially affect (1) the definition of the scores at the impact criterion level, (2) the relative weight of the impact criteria and (3) the communication relating to the impact scores.

First, the proposals could issue a change in the ordinal scores attributed to impact criteria. Currently, for every functionality level of every service an ordinal score is attributed to each of the seven impact criteria. When following Proposal 2, only three impact criteria would be retained. Consequently, instead of attributing a score for "comfort" or "convenience" separately, a score would be attributed that reflects the impact of a given service on the "needs of the occupant" in more general terms. Given the relatively wide scope of each of these three impact criteria, the definition of the ordinal scores is at risk of becoming less transparent and objective. In the case of Proposal 3 (hybrid approach), the scores for the seven impact criteria would be retained, but an aggregation (using a certain weighting) would be applied.

Second, the proposals could – but do not necessarily have to – affect the contribution of an impact criterion on the single SRI score. In the first study, an equal weighting was proposed for the impact criteria. As such, the following weightings would be obtained:

- Proposal 1: equal weight for each impact criterion, namely 14.3% (= 1/7)
- Proposal 2: equal weight for each impact criterion, namely 33.3% (= 1/3)
- Proposal 3: equal weight for the EPBD impact criteria (33.3%), with equal weights within each EPBD criterion:
    - 33% for "energy performance and operation", divided into 16.7% each for "energy savings" and "maintenance & fault prediction"
    - 33% for "needs of the occupant", divided into 8.3% each for "comfort", "convenience", "health and well-being" and "information to occupants"
    - 33% for "energy flexibility and storage".

Third, the selected strategy will affect communication relating to impact scores. In Proposal 1, communication is needed for seven impact criteria, whereas in Proposal 2, only three impact criteria need to be addressed. The high number of impact criteria in Proposal 1 increases the volume of information to be conveyed

[91] At the time of the discussion, 8 impact criteria were considered.

to the end user. A reduction to three impact criteria reduces the volume of information, but since the scope of the impact criteria is broader, more information may be required to clarify the scope of each criterion. In Proposal 3, the option exists to communicate on either of the two levels of aggregation, or even both.

1.3.3.4 Proposal 1: Seven impact criteria as suggested by the first technical study on the SRI

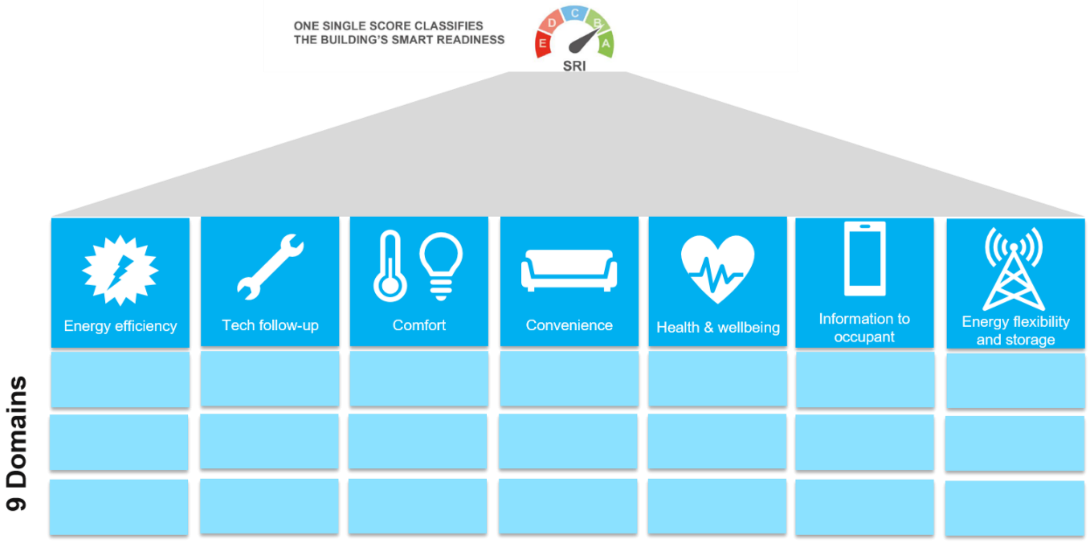

Figure 18 - Seven impact criteria as suggested by the first technical study on the SRI

1.3.3.5 Proposal 2: Three impact criteria aligned to the EPBD functionality domains

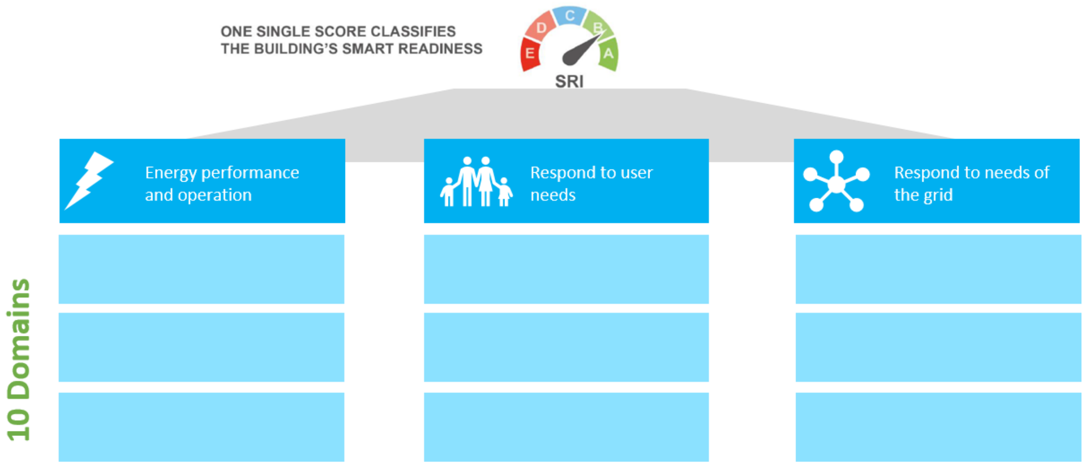

Figure 19 - Three impact criteria aligned to the EPBD functionality domains

1.3.3.6 Proposal 3: Seven impact sub-criteria (SRI1) that are aggregated to three impact criteria (EPBD)

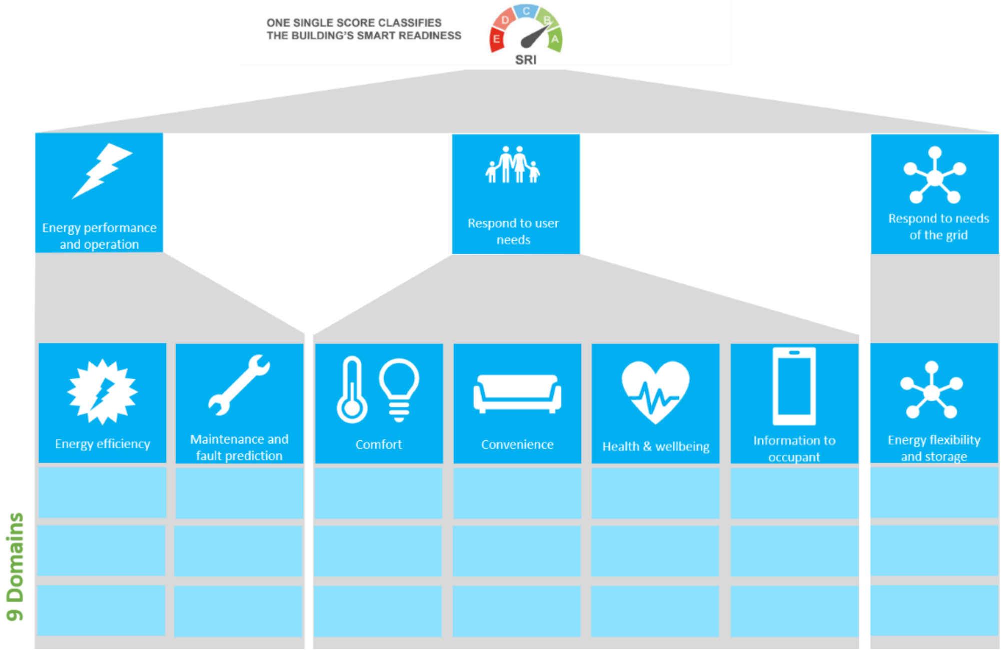

Figure 20 - Seven impact sub-criteria (SRI1) that are aggregated to three impact criteria (EPBD)

The aforementioned options were presented to Topical Group B[92], and a SWOT analysis was performed. The following could be concluded from the discussion.

Stakeholders have different views on the relative importance of certain domains. The SWOT analysis shows diverse opinions about the weight given to impact criteria that can be related to user needs. For example, in the first proposal, four of eight impact criteria relate to the users ("comfort", "health and well-being", "convenience" and "information to the occupant"). In the scenario of an equal weighting this results in 50% of the SRI score being related to user satisfaction[93]. The SWOT analysis points out that some stakeholders identify this as a strength of this approach, while others see this as a weakness or even a threat. Concerns for the different sides were expressed again during the discussion. A similar discussion exists for energy performance. Some stakeholders suggest that the relative importance of energy performance should be high, since they consider it to be the backbone of the SRI, whereas others feel that the topic of energy performance belongs to the EPC and should not be the focus of the SRI. Both Proposals 2 and 3 increase the relative importance of energy in the SRI, as both "energy performance" and "energy flexibility" would each represent one-third of the SRI score.

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[92] This was discussed during the first meeting of Topical Group B: calculation methodology on 26/3/2019 in Brussels.

[93] Note: at the time of the discussion, 8 impact criteria were considered, leading to a 50% contribution of "needs of the occupants". Currently, only 7 impact criteria are considered, leading to a weight of 57% for occupant-related impact criteria.

The communication aspect (and thus the understanding of the occupant) also plays an important role. Stakeholders indicated that Proposal 2 would lead to an important loss of information, since the scope of the three EPBD criteria is fairly large. For Proposal 1, some argue that the set of eight (*currently seven*) impact criteria is too much to communicate. Others state that the three impact criteria in Proposal 2 are too vague and not sufficiently explicit. Proposal 3 has the added advantage of keeping both levels of assessment: information can be provided on the eight (*currently seven*) individual impact criteria but could be summarised to the three essential pillars.

Related to this discussion, participants suggested that building users might want to know more about different aspects of the building smartness rather than just one overall indicator. Even in the case of moving to a single score, there should be opportunity for end users to get impact scores (= sub-score on the impact criterion level), as they provide more insight to the qualities and shortcomings of a building. This was also well reflected in the questionnaire results. It is also pertinent that this conclusion aligns with the views expressed in Topical Group A that the eight impact criteria (perhaps excluding "self-generation") have intrinsic value and should therefore be retained either explicitly (as in the first technical study option) or implicitly (as per the hybrid option).

Finally, the proposals also affect the definition of ordinal scores. Since the three impact criteria in Proposal 2 are relatively broad and vague, the performance assessment of these criteria becomes more complicated; for instance, how is the impact on user friendliness measured? Proposals 1 and 3 share the advantage that the defined eight impact criteria can be assessed individually. In the case of Proposal 3, the score for each impact criterion should further be aggregated to the three EPBD impact criteria.

A voting session was organised at the end of the discussion with Topical Group B[94]. There were 21 participants in total in the voting session, and five of them did not vote. The first proposal (eight impact criteria from the first technical study) received five votes, whereas Proposal 3 (hybrid version) received 11 votes. This exercise suggests that either the eight impact criteria from the first technical study, or the hybrid approach – in which the impact criteria are aggregated into the three EPBD aspects – should be pursued. Among the Topical Group B respondents, there was no support for pursuing the three EPBD aspects in isolation from the underlying impacts.

The horizontal aggregation has been further discussed during a meeting with topical group B. Most stakeholders agreed that the 1/3 weighting of the EPBD key features correctly reflects the intentions of the revised EPBD and should be adopted in the SRI methodology. Stakeholders also confirmed the importance of demand side flexibility as a key aspect of the SRI, justifying the 1/3 weighting of this domain. One stakeholder expresses their concern that the SRI should focus more on user needs and hence should not implement the second layer of impact criterion weighting factors. Hence, no unanimity exists on this subject.

CONCLUSION

In conclusion, the study team proposes to withhold the hybrid approach (Proposal 3), as illustrated in Figure 21. The approach is considered to reflect most

[94] This was discussed during the first meeting of Topical Group B: calculation methodology on 26/3/2019 in Brussels.

accurately the intentions of the EPBD regarding the balancing of the need for energy savings, the needs of occupants and the needs of the energy grid. Simultaneously, the proposal allows flexibility regarding the communication of results at the two aggregation levels. The study team has investigated ways to efficiently communicate these impact criteria, aiming to balance clarity and conciseness.

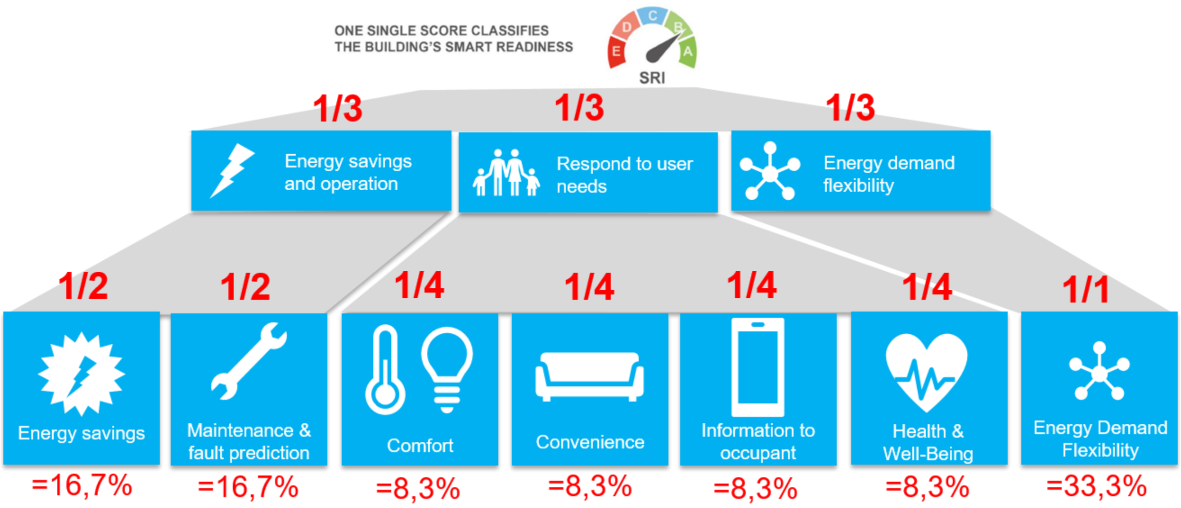

Figure 21 - Aggregation of impact scores to a single score

1.3.3.7 Consolidated proposal on weighting factors in multi-criteria assessment method

Based on the considerations introduced in prior sections, a consolidated proposal on SRI weighting factors is elaborated as part of this technical support study. This approach was also embedded in the calculation method prepared for the public testing of the SRI method. Stakeholders were given the opportunity to test other weighting factors and provide further feedback as part of this testing phase. The technical study team perceives that most stakeholders support the suggested approach, but no full consensus could be reached among all stakeholders. Especially the aggregation along the three key EPBD functionalities of smartness is contested by some stakeholders who want to increase the relative weight of specific impacts. Some stakeholders suggest giving more weight towards the impacts on the grid (flexibility and storage) while others plead for giving more weight to the impacts related to the user needs (comfort, convenience, health & wellbeing, information provision). By providing equal weights to the three key smartness functionalities, the consolidated proposal balances these different viewpoints and aligns with the EPBD text. Furthermore, user feedback on SRI formatting and the consortium's proposal on this matter tends towards also displaying the sub-scores on domain or impact criterion level. By also displaying such sub-scores, a more nuanced message can be transferred to the users of the label, without the need for implementing weighting factors aggregating the various impacts.

The proposed methodology provides default weighting factors which are differentiated by:

- Building type
  - non-residential buildings
  - residential buildings
- Climate zone
  - Northern Europe
  - Western Europe
  - North-Eastern Europe
  - South-Eastern Europe
  - Southern Europe.

The methodology defines a weighting scheme with three types of weighting factors: fixed weights, equal weights and energy balance weights. An overview of the weighting scheme is provided in Figure 22.

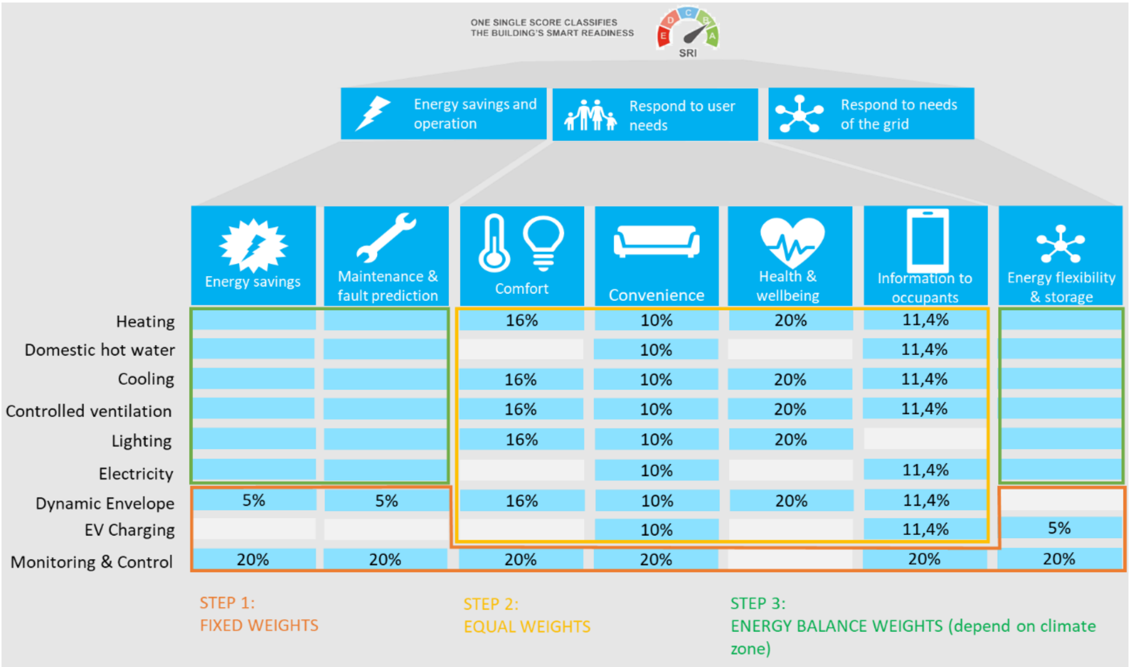

Figure 22 - overview of weighting scheme

The weights are assigned as follows:

STEP 1:

Fixed weights are assigned

- for all impact criteria: a 20% weighting is assigned to the domain "monitoring and control"
- for the impact criteria "energy savings", "maintenance and fault prediction" and "energy flexibility and storage", a 5% weighting is assigned to the domains "electric vehicle charging" and "dynamic building envelope". If no impact scores exist for a given domain, the value is forced to zero.
  - these values are not dependent on the climate zone or building type
  - these values cannot be changed when using an alternative energy balance.

STEP 2:

Equal weightings are assigned to the impact criteria "comfort", "convenience", "health and wellbeing" and "information to occupants". The value of the weighting factor is obtained by dividing the remaining weight for the given impact criterion (100% - Σ(fixed weights)) by the number of domains that are relevant for the given impact criterion:

- these values are not dependent on the climate zone or building type
- these values cannot be changed when using an alternative energy balance.

For instance,

$$f_{HEAT,comf} = \frac{(1 - f_{MC,comf})}{number\ of\ relevant\ domains}$$

$$f_{HEAT,comf} = \frac{(1 - 0{,}20)}{5}$$

$$f_{HEAT,comf} = 0{,}16$$

where $f_{domain,impact\ crit}$ is the weighting factor for a given domain and impact criterion

STEP 3:

Energy balance weights are assigned to the impact criteria "energy savings", "maintenance and fault prediction" and "energy flexibility and storage". The value of the weighting factor is obtained by multiplying the remaining weight for the given impact criterion (100% - Σ(fixed weights)) by the relative importance of the domain in the energy balance:

- these values depend on the climate zone or building type
- these values can be changed when using an alternative energy balance.

The default relative importance of a domain in the energy balance is illustrated below.

For instance, for non-residential buildings in Western Europe the default weighting factor for the domain "heating" on "energy savings on site" is calculated as follows:

$$f_{HEAT,ene} = \left(1 - \left(f_{DE,ene} + f_{MC,ene}\right)\right) \cdot \alpha_{HEAT}$$

$$f_{HEAT,ene} = \left(1 - (0{,}05 + 0{,}20)\right) * 0{,}36$$

$$f_{HEAT,ene} = 0{,}27$$

where

- $f_{domain,impact\ crit}$ is the weighting factor for a given domain and impact criterion
- α_{domain} is the relative importance of a domain in the used energy balance (values to be obtained from Figure 23 or Figure 24).

RESIDENTIAL BUILDINGS

WEIGHTINGS	North	West	South	North-East	South-East
Heating	39.9	45.3	42.2	40.5	27.5
DHW	12.4	10.2	13.3	18.6	7.7
Cooling	0.0	4.1	9.2	0.0	19.5
Ventilation	25.0	23.8	12.3	25.4	14.4
Lighting	4.9	2.0	3.6	0.8	1.2
Electricity	17.8	14.8	19.5	14.7	29.6

Figure 23- relative importance of a domain by climate zone, for residential buildings (α_{domain})

NON-RESIDENTIAL BUILDINGS

WEIGHTINGS	North	West	South	North-East	South-East
Heating	41.8	36.4	40.3	39.0	38.3
DHW	7.2	11.0	14.3	12.5	15.4
Cooling	12.5	16.9	15.7	11.2	9.9
Ventilation	26.2	19.1	11.7	24.4	20.1
Lighting	10.4	13.8	16.0	9.7	11.9
Electricity	2.0	2.8	2.1	3.1	4.4

Figure 24 - relative importance of a domain by climate zone, for non-residential buildings (α_{domain})

TAILORING TO AN EPC ENERGY BALANCE (or other energy balance)

Should the assessor wish to use a building-specific energy balance (for instance from an EPC calculation), the primary energy uses for space heating, domestic hot water, space cooling, controlled ventilation, lighting and production of on-site renewable electricity should be available.

For each of these 6 domains, the correction factor α_{domain} is calculated by dividing the primary energy use of the given domain by the sum of the six primary energy usages.

For instance, the correction factor for heating would be calculated as follows:

$$\alpha_{HEAT} = \frac{Q_{HEAT}}{Q_{TOTAL}}$$

$$Q_{TOTAL} = Q_{HEAT} + Q_{DHW} + Q_{COOL} + Q_{VENT} + Q_{LIGHT} + Q_{RENEW}$$

Where

- Q_{HEAT} is the primary energy use for space heating of the given building
- Q_{DHW} is the primary energy use for domestic hot water of the given building
- Q_{COOL} is the primary energy use for space cooling of the given building

- Q_{VENT} is the primary energy use for ventilation of the given building
- Q_{LIGHT} is the primary energy use for lighting of the given building
- Q_{RENEW} is the renewable energy produced on site, expressed as primary energy.

An example of the weighting matrix for non-residential buildings in Western Europe is given below in Table 7.

Table 7- Weighting matrix for non-residential buildings in Western Europe

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

1.3.4 SMART SERVICES AND ORDINAL SCORES

The detailed service catalogue (method B) and the simplified service catalogue (method A) have been thoroughly reviewed based on various stakeholder feedback, including written feedback on the 2nd interim report, a review session with members of Topical Group B and feedback from the public beta testing. The review resulted in a number of modifications, including:

- adding or removing certain services
- adding or removing functionality levels
- rephrasing the description of functionality levels
- modifying impact scores[95].

The consolidated service catalogues are found in ANNEX E and 0 of this report. Below, an overview of the main modifications is elaborated.

1.3.4.1 DETAILED SERVICE CATALOGUE (Method B)

Heating

- Heating-1e, Heating-1g and Heating-2c have been omitted, given the existence of overlap with other services
- Heating-4 has been merged with elements from Heating-1g and Heating-2c (see above)
- Functionality level added to Heating-1f
- Minor rephrasing of functionality levels in Heating-2d and Heating-3
- Minor alterations to ordinal scores in Heating-1a, Heating-1b, Heating-1c, Heating-1d, Heating-1f, Heating-2b, Heating-2d and Heating-3.

Domestic hot water

- New service DHW-2b added, similar to Heating-2d
- Minor rephrasing of functionality levels in DHW-1b
- Minor alterations to ordinal scores in DHW-1a, DHW-1b, DHW-1d.

Cooling

- Cooling-1e has been omitted, given the existence of overlap with other services
- Cooling-4 has been merged with elements from Heating-1e (see above)
- Functionality level added to Cooling-1f
- Functionality levels of Cooling-2a and Cooling-2b harmonized with corresponding services in the heating domain
- Minor rephrasing of functionality levels in Cooling-1a, Cooling-1g and Cooling-3

[95] Currently, impact scores can range from -3 to +3. A stakeholder suggested to review this scale and allow impacts up to +4, since some of the services can also have four functionality levels. This suggestion can be relevant for future updates of the SRI, but has not been upheld at this stage as this would require reviewing all impact scores throught the service catalogue, potentially causing this to deviate significantly from the version which has been discussed with topical groups and tested by the SRI stakeholder community.

- Minor alterations to ordinal scores in Cooling-1a, Cooling-1b, Cooling-1c, Cooling-1d, Cooling-1g, Cooling-2a, Cooling-2b and Cooling 3
- Minor alterations to the service names in Cooling-1d, Cooling-1f and Cooling-4.

Controlled ventilation

- Ventilation-1b and Ventilation-2b have been omitted
- Modifications to functionality levels 3 and 4 in Ventilation-6
- Minor rephrasing of functionality levels in Ventilation-1c and Ventilation-2d
- Minor alterations to ordinal scores in Ventilation-3 and Ventilation-6
- Minor alterations to the service name in Ventilation-2d.

Lighting

- Minor alterations to ordinal scores in Lighting-1a
- Minor rephrasing of functionality levels in Lighting-2.

Dynamic envelope

- Minor alterations to ordinal scores in DE-4
- Minor rephrasing of functionality levels in DE-1.

Electricity

- New service Electricity-8 added and updated (previously omitted)
- New services Electricity-12 and Electricity-13 added, to harmonize with the simplified service catalogue
- Modifications to functionality levels in Electricity-3, Electricity-4 and Electricity-5
- Minor alterations to ordinal scores in Electricity-3, Electricity-4 and Electricity-5
- Minor alterations to the service name in Electricity-2.

Electric Vehicles

- Minor rephrasing of functionality levels in EV-16 and EV-17
- Minor alterations to ordinal scores in EV-16
- Minor alterations to the service name in EV-15.

Monitoring and Control

- New service MC-30
- Modifications to functionality levels in MC-3 and MC-25
- Minor rephrasing of functionality levels in MC-4, MC-13 and MC-29
- Minor alterations to ordinal scores in MC-3, MC-4, MC-13, MC-25, MC-28.

The detailed service catalogue (method B) now consists of 54 services.

1.3.4.2 SIMPLIFIED SERVICE CATALOGUE (Method A)

In the simplified service catalogue, minor modifications have been made to harmonize with the detailed service catalogue.

Heating

- Minor alterations to ordinal scores in Heating-S1, Heating-S2b and Heating-S4.

DHW

- Minor alterations to ordinal scores in DHW-S1.

Cooling

- Minor alterations to ordinal scores in Cooling-S1, Cooling-S2 and Cooling-S4
- Modifications to functionality levels in Cooling-S2.

Controlled ventilation

- Minor alterations to ordinal scores in Ventilation-S3
- Minor alterations to the service name in Ventilation-S1.

Lighting

- Minor alterations to ordinal scores in Lighting-S1.

Dynamic Envelope

- Minor alterations to ordinal scores in DE-S1 and DE-S2.

Electricity

- Minor alterations to ordinal scores in Electricity-S1
- Minor alterations to the service name in Electricity-S3 and Electricity-S4.

Electric Vehicles

- Minor alterations to ordinal scores in EV-S1 and EV-S2
- Minor rephrasing of functionality levels in EV-S3 and EV-S4
- Minor alterations to the service name in EV-S1.

Monitoring and Control

- Minor alterations to ordinal scores in MC-S2 and MC-S3
- Minor rephrasing of functionality levels in MC-S3
- Minor alterations to the service name in MC-S1.

The simplified service catalogue (method A) now consists of 27 services.

1.3.5 TRIAGE PROCESS

In the first technical study, it was proposed to perform a normalisation of the summed impacts. This is done by dividing the sum of the nominal impact scores by the sum of the maximum possible nominal impact scores that could be reasonably attained for the given building and multiplying by 100. The final aggregate score thus represents an overall percentage of the maximum score.

The maximum nominal impact score is not simply the sum of all the impacts of the 54 (or 27 in case of method A) services listed in the SRI catalogue. It is very likely that due to local and site-specific context some domains and services are not relevant, not applicable or not desirable. The SRI methodology accommodates this by performing a triage process to identify the relevant services for a specific building. In any case, deciding on the applicability of services should not be based on interpretation by individual SRI assessors, but should be defined in the method to ensure a fully replicable SRI assessment.

During the first technical study, a triage process was proposed to deal with the issue. Indeed, some domains may not be relevant, e.g. some buildings might not be able to provide parking (and hence electric vehicle charging facilities) and some residential buildings might not need cooling. Furthermore, some of the services are only applicable if certain technical building systems are present, e.g. a storage vessel for domestic hot water or a heat recovery ventilation unit. In addition, some services may be mutually exclusive, since it is unlikely that a building has both district heating and combustive heating and heat pumps. If such services are not present, they obviously do not need to be assessed during on-site inspections. In cases where a service is not present and not relevant, the service will not be scored, and the maximum attainable score will be reduced. This renormalisation process ensures that the absence of such a service or domain is not penalised. As a result of this triage process, in any real building the number of services to be inspected as part of an SRI assessment will be less than the 54 or 27 smart ready services listed in the streamlined catalogues.

During a discussion with Topical Group B[96], the treatment of absent services was approached from different angles, mostly related to the message to be conveyed by the SRI.

A Topical Group B member linked the question of whether or not the absence of a domain should be penalised to the question of whether the assessment is about being "smart ready" or "smart possible". In this case, "smart ready" relates to the smartness of the services already present in the building (hence not penalising absent services), whereas "smart possible" relates to the possibility of having (smart) services in the building (hence penalising absent services). In this context, a number of members suggested adhering to the essence of the SRI, namely assessing the smartness of services already available. Other members argued that the essence is not to assess the current smartness, but to give a stimulus to improve a building. In other words, the SRI should incentivise the uptake of SRTs.

By not penalising the absence of certain domains, the SRI cannot give an incentive to install certain services that are currently absent, even though they could improve the comfort of the occupant. For instance, controlled ventilation has been proved to contribute to indoor air quality. Nonetheless, there remains

[96] Topical Group B: Calculation Methodology – 2nd Web meeting 14/05/2019

disagreement among stakeholders about whether the absence of a ventilation system in residential buildings – depending on its geographical location – should be penalised in the SRI.

The discussion on the relevance of certain domains or services reveals differences in building practices across Europe. A suggested solution is to allow implementing bodies to define guidelines depending on contextual factors such as the relevance of specific services and domains to climatic zones and requirements in local building codes while also allowing differentiation based on the building type (residential or non-residential) as well as the current state of the building (new construction, retrofit, existing building). For example:

- a domain is deemed relevant for new constructions and retrofit, but not for existing buildings
- a domain is deemed relevant for non-residential buildings, but not for residential buildings
- a mix of both: a domain is relevant for all non-residential buildings and newly constructed or retrofitted residential buildings.

Such an approach is closely linked to the SRI implementation pathways and to local building codes.

Topical Group B members also noted that the triage process affects the comparability of buildings, since the renormalisation process means that buildings are not rated with the same baseline. Differences in approaches across Europe could jeopardise such comparability even further. For example, two buildings with the same score could have completely different TBSs installed. During the discussion, the study team argued that the need for comparability strongly depends on the target audience: for property owners wanting to assess or improve their building's smartness, comparability is probably less important. If the triage process is to tailor the assessed domains to building context, the Topical Group B members concluded that *transparency* of the assessed domains – rather than *comparability* – is essential. To this end, two ideas were raised.

- Communicating all scores: the building score, the building maximum score and the theoretical maximum score. The difference between the building maximum and the theoretical maximum could then illustrate how many services were omitted.
- Using illustrations on the SRI documentation to show which domains were assessed (e.g. greyed-out or strike-through icons for domains not present in the building).

Members of Topical Group B were strongly in favour of the second approach, as it could visualise present services without making the interpretation of the results overly complicated.

A second aspect of comparability relates to the impact of regional differences. Tailoring to local context – including climate-dependent weighting factors and differentiation in triage guidelines – will negatively impact the comparability of buildings across Europe. A member of Topical Group B mentioned that comparison across Europe is usually not relevant for property owners or investors, as the comparison will typically be restricted to a specific region.

However, it should also be mentioned that there is concern for comparability in other schemes as well. For instance, a single EPC score does not reflect the predominance of active or passive measures; some regions address the issue by providing additional information on the energy balance of the building (e.g. differentiation between energy for heating, cooling, lighting, etc.) and/or by introducing supplementary indicators or scores (e.g. for the share of renewable energy or the risk of overheating). In BREEAM, the certificate depicts both the total aggregated score (e.g. "Excellent") and the category scores (bar charts for "energy", "health and well-being", etc.). The discussion illustrates the danger of having only one aggregated score and shows the potential for also showing sub-scores to convey a more nuanced message. This will be investigated in detail in Task 2.

To conclude, the study team recommends the following approach to deal with absent services:

- For some services, an evaluation is only relevant in cases where the technical building systems it relates to are present. This approach is appropriate when one cannot a priori conclude that a domain or service should be present in a particular building (e.g. a building could be comfortable without cooling systems). If such a service is not present, the service is excluded from the assessment and does not affect the maximum attainable score.
- Some services may be mutually exclusive; if such services are not present, they can be excluded from the assessment.
- Some services might be absent but nonetheless desirable from a policy perspective. This approach may provide stimuli for upgrading existing buildings with additional (smart) services. The technical study team recommends to allow implementing bodies to define guidelines depending on contextual factors such as the relevance of specific services and domains to particular building types and climatic zones and requirements in local building codes. These services are included in the assessment.

1.3.6 CONCLUDING PROPOSAL FOR SRI CALCULATION METHODOLOGY

The smart readiness score of a building or building unit is expressed as a percentage which represents the ratio between the smart readiness of the building or building unit compared to the maximum smart readiness that it could reach. The methodology also allows the use of disaggregated smart readiness scores expressed as a percentage. The disaggregated scores can express smart readiness for one or more of the following:

- Three key smart readiness capabilities as highlighted in Annex Ia, point 2 of the EPBD:
    1. Energy performance and operation
    2. Response to the needs of the occupants; and
    3. Energy flexibility.
- The seven smart readiness impact criteria:
    1. Energy efficiency
    2. Maintenance and fault prediction
    3. Comfort
    4. Convenience
    5. Health and wellbeing
    6. Information to occupants
    7. Energy flexibility and storage.
- The nine smart readiness technical domains:
    1. Heating
    2. Cooling
    3. Domestic hot water
    4. Controlled ventilation
    5. Lighting
    6. Dynamic building envelope
    7. Electricity
    8. Electric vehicle charging
    9. Monitoring and control.

The calculation of smart readiness scores is made according to the following protocol:

1.3.6.1 Step 1: Triage process to define relevant smart-ready services in the building or building unit

To avoid unfairly penalising a building or building unit, some smart-ready services may be omitted in the calculation of the smart readiness scores, in case those services are not relevant for that building or building unit.

1.3.6.2 Step 2: Define functionality level of each smart-ready service

For each of the relevant smart-ready services the functionality level implemented in the building or building unit is assessed, e.g. through a visual inspection or retrieved from technical documentation.

1.3.6.3 Step 3: Calculate the impact criterion scores

For each of seven impact criteria, the impact criterion score of each technical domain is determined, as follows:

$$\boldsymbol{I(d,ic)} = \sum_{\boldsymbol{i=1}}^{\boldsymbol{N_d}} \boldsymbol{I_{ic}(FL(S_{i,d}))} \qquad (2)$$

where:

- d is the number of the technical domain in question, $d \in \mathbb{N}$
- ic is the number of the impact criterion in question, $ic \in \mathbb{N}$
- N_d is the total number of services in technical domain d, $N_d \in \mathbb{N}$
- $S_{i,d}$ is service i of technical domain d, $i \in \mathbb{N}, 1 \leq i \leq NS_d$,
- $FL(S_{i,d})$ is the functionality level of service $S_{i,d}$ as available in the building or building unit,
- $I_{ic}(FL(S_{i,d}))$ is the impact criterion score of service $S_{i,d}$ for impact criterion number ic, according to the service's functionality level, $I_{ic}(FL(S_{i,d})) \in \mathbb{N}$
- $I(d, ic)$ is the impact criterion score of domain number d for impact criterion number ic, $I(d, ic) \in \mathbb{N}$.

In case a smart-ready service is implemented according to different functionality levels $FL(S_{i,d})$ in various parts of the building or building unit, the impact criterion score $I_{ic}(FL(S_{i,d}))$ of service $S_{i,d}$ can be calculated as a weighted average. Specifications for this could be further detailed in implementing guidelines.

1.3.6.4 Step 4: Calculate maximum impact scores

In accordance with the catalogue of smart-ready services, the maximum impact criterion score of each technical domain for each impact criterion is determined, as follows:

$$I_{max}(d, ic) = \sum_{i=1}^{N_d} I_{ic}(FL_{max}(S_{i,d})) \qquad (3)$$

where:

- $FL_{max}(S_{i,d})$ is the highest functionality level that service $S_{i,d}$ could have according to the smart-ready service catalogue
- $I_{ic}(FL_{max}(S_{i,d}))$ is the impact criterion score of service $S_{i,d}$ for its highest functionality level, which means the maximum impact criterion score of service $S_{i,d}$ for impact criterion number ic
- $I_{max}(d, ic)$ is the maximum impact criterion score of domain number d for impact criterion number ic.

1.3.6.5 Step 5: Smart-readiness scores for impact criteria

For each of the impact criteria, smart readiness scores (expressed as a percentage) can be determined by weighing the calculated scores as follows:

$$\mathrm{SR_{ic}} = \frac{\sum_{\mathrm{d}=1}^{\mathrm{N}} \mathrm{W_{d,ic}} \times \mathrm{I(d,ic)}}{\sum_{\mathrm{d}=1}^{\mathrm{N}} \mathrm{W_{d,ic}} \times \mathrm{I_{max}(d,ic)}} \times 100 \qquad (4)$$

where:

- d is the number of the technical domain in question
- N is the total number of technical domains
- $W_{d,ic}$ is the weighting factor expressed as a percentage of technical domain number d for impact criterion number ic
- SR_{ic} is the smart readiness score expressed as a percentage for impact criterion number ic.

The domain weighting factors are expressed as a percentage, and for each impact criterion, the sum of the weighting factors of the technical domains equals to 100%. The standard approach to allocate weighting factors to the technical domains is based on:

- climatic zone's energy balance for the weighting factors of 'heating', 'cooling', 'domestic hot water', 'controlled ventilation', 'lighting', and 'electricity' technical domains along the 'energy efficiency', 'maintenance and prediction' and 'energy flexibility and storage' impact criteria
- fixed weighting factors and equal weighting factors otherwise.

The standard weighting factors of technical domains can differ between residential and non-residential buildings for some impact criteria. The full description of proposed domain weighting factors is included in the service catalogues (see ANNEX E and 0).

1.3.6.6 Step 6: Smart-readiness scores along the three EPBD key capabilities

For each of the three key capabilities highlighted in Annex Ia, point 2 of the EPBD, smart readiness scores (expressed as a percentage) can be determined by weighing the calculated scores as follows:

$$\mathrm{SR_c} = \sum_{\mathrm{ic}=1}^{\mathrm{M}} \mathrm{W_c(ic)} \times \mathrm{SR_{ic}}, \qquad (5)$$

where:

- SR_c is the smart readiness score for key capability c
- M is the total number of impact criteria, $M \in \mathbb{N}$
- $W_f(ic)$ is the weighting factor expressed in percentage of impact criterion number ic for key functionality f
- SR_{ic} is the smart readiness score of impact criterion number ic.

The domain weighting factors are expressed as a percentage. Each impact criterion is relevant for only one key functionality and for each key functionality, all relevant criteria have equal weighting factors.

- For the 'energy performance and operation' key capability, the relevant impact criteria are 'energy efficiency' and 'maintenance and fault prediction'.
- For the 'response to user needs' key capability, the relevant impact criteria are 'comfort', 'convenience', 'information to occupants' and 'health & wellbeing'.
- For the 'energy flexibility' key capability, the only relevant impact criterion is 'energy flexibility & storage'.

1.3.6.7 Step 7: Total smart-readiness score for a building or building unit

The total smart-readiness score of a building or building unit (expressed as a percentage) can be determined by weighing the calculated smart-readiness scores of the three key capabilities as follows:

$$\mathrm{SR} = \sum \frac{1}{3} \times \mathrm{Sr_c} \tag{6}$$

where:

- SR is the total smart readiness score
- SR_c is the smart readiness score of key capability c.

1.3.6.8 Step 8: (Optional) Smart-readiness scores for technical domains

Optionally, smart readiness scores of technical domains along each impact criterion are calculated, as follows:

$$\mathrm{SR_{d,ic}} = \frac{\mathrm{I(d,ic)}}{\mathrm{I_{max}(d,ic)}} \times 100 \tag{7}$$

2 TASK 2 - INVESTIGATION OF SRI IMPLEMENTATION PATHWAYS AND OF THE FORMAT OF THE SRI

TASK SUMMARY & OBJECTIVES

The objective of Task 2 is to investigate the potential pathways for the effective implementation of the SRI in the EU and to clarify which are the most promising options regarding the SRI format.

TASK APPROACH AND PROPOSED METHODOLOGY:

The methodological activities conducted under Task 2 are:

- establishment of the SRI implementation pathways
- investigation of the format of the SRI.

2.1 ACTIVITY 1: SRI IMPLEMENTATION PATHWAYS

2.1.1 IDENTIFICATION OF THE SCHEMES AND INITIATIVES ON WHICH THE SRI COULD BUILD, OR CONNECT TO

This section concerns the identification of the schemes and initiatives on which the SRI could build or connect to, in order to facilitate its implementation.

At the EU level and Member State level the relevant schemes or actions include all those concerned with the implementation of the EPBD i.e.:

- energy performance certificates (EPCs)
- the provisions regarding the inspection of HVAC systems as specified under Articles 14 and 15
- they also include the provisions regarding the installation, upgrade and replacement of technical building systems as set out in Article 8(1) and related provisions on assessment and documentation of system performance under Article 8(9) and the measures requiring non-residential buildings with an installed heating or cooling capacity of > 290kW to have BACS installed by 2025 in Articles 14 and 15 respectively.

However, other schemes or activities are also relevant to consider including:

- Level(s) (see section 1.2.2.2)
- BIM and the digital logbook of DG Grow (see section 1.2.2.4)
- Building Renovation Passports (see section 1.2.2.3)

- Cybersecurity and the Voluntary European Cybersecurity Certification scheme[97] (see section 1.2.2.5)
- The broadband ready label[98] (see section 1.2.2.6)
- Product environmental footprint (PEF) (see section 1.2.2.10)
- "Installer" energy label for heating and hot water systems[99] (see section 1.2.2.12).

In addition, at the private organisation level there are: private sector building sustainability certification schemes – BREEAM, HQE, DGNB, LEED; smart buildings/appliances initiatives such as the Smart Building Alliance, the SAREF common ontology etc.; and smart metering roll out initiatives.

To assess the potential interactions between the SRI and these initiatives it's important to consider them in a structured manner. The following framework is put forward to consider this. First the focus and scope (subject matter) of the schemes is considered, second their maturity, third their scale, and fourth their potential fit with the SRI.

2.1.1.1 Subject matter

The subject matter of the schemes is their focus and scope. The focus determines their objective, while the scope is the domain they address. For a meaningful linkage to exist with the SRI both the focus and scope will need to overlap with that of the SRI.

2.1.1.2 Maturity

The maturity reflects how long the scheme has been in existence. For longstanding schemes their maturity will be high, and their characteristics will be well known and defined. For new or emerging schemes there will be less certainty.

2.1.1.3 Scale

In principle, the scale of the scheme could concern everything from the geography and range of target domains they address; however, in the current context what is relevant is how large their scale is in regard to that part that overlaps with the objectives and focus of the SRI. As the SRI principally concerns the assessment of buildings then the scale of the schemes reported here concerns the extent to which they access (cover) Europe's buildings and smart ready technology & services.

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[97] https://ec.europa.eu/digital-single-market/en/eu-cybersecurity-act

[98] Directive 2014/61/EU of the European Parliament and the Council https://ec.europa.eu/digital-single-market/en/news/directive-201461eu-european-parliament-and-council

[99] European Commission. 2013b, COMMISSION DELEGATED REGULATION (EU) No 811/2013 of 18 February 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of space heaters, combination heaters, packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device

2.1.1.4 Fit

The fit is the degree of complementarity between the scheme and the SRI. It is comprised of any sub-elements of which the following are addressed in the current assessment:

- Building assessment
- Site visits/inspections
- Target audience
- Actors directly involved in delivery
- Certification
- Quality Assurance
- Mandate
- Organisation
- Governance.

The *building assessment* fit parameter is whether, or not, the scheme entails conducting an assessment of buildings, or some aspect of the building which is pertinent to the delivery of the SRI. If it does there is likely to be a better fit with the SRI because there may be a potential to share techniques, methods and resources and minimise duplication.

The *site visit/inspections* fit parameter is whether, or not, the scheme entails conducting a site visit and/or inspection of buildings, or some aspect of the building which is pertinent to the delivery of the SRI. If it does there is likely to be a better fit with the SRI because there may be a potential to share processes, methods and resources and minimise duplication. Note, as a major component of cost and delay in doing site visits is the process of contacting the owner/occupant, gaining permission, and travel to and from the site – duplication in these aspects could be minimised where schemes that require site visits/inspections share resources. This could also be less burdensome for property owners/occupiers.

The *target audience* fit parameter is the degree to which the intended audience for the schemes products overlaps. The more that they do the more synergies there are likely to be and the greater the potential to share techniques, methods and resources to minimise duplication.

The *actors directly involved in delivery* fit parameter is the degree to which those involved in the delivery of the scheme’s services are likely to overlap with each other. The more that they do the more synergies there are likely to be and the greater the potential to share techniques, methods and resources to minimise duplication.

The *certification* fit parameter is whether or not the scheme involves issuance of formal certificates to denote that an authorised assessment has been conducted. If they do there may be greater synergy with the SRI, should the latter be implemented in a format that includes certification.

The *quality assurance* fit parameter is the degree to which the service delivery of the scheme is subject to formal and verifiable quality assurance processes. The more that it is the greater the confidence can be expected in the quality/veracity of the outcomes and the less chance that interaction with the scheme could pose any reputational risk for the SRI. Furthermore, it may be possible to link aspects of the two scheme’s QA processes to avoid duplicative effort.

The *mandate* fit parameter is the degree to which the mandate the scheme has to operate is likely to be complementary with that of the SRI. The more that it is the easier it will be to jointly co-manage aspects of the scheme's delivery.

The *organisation* fit parameter is the degree to which the organisation of the scheme's implementation is likely to be complementary to options which could be envisaged and viable for the SRI. The more that it is the easier it is likely to be to share delivery pathways and minimise duplication.

The *governance* fit parameter is the degree to which the governance of the scheme could be complementary to the governance and mandate of the SRI. For example, if the governance is seen to be too partial or structured to favour certain economic interests then linkage with the scheme may risk a conflict of interest for the SRI.

The tables set out below present a first assessment of these elements for the schemes/initiatives previously mentioned.

Table 8 - Subject, Scope, Maturity and Scale of initiatives or actions the SRI could link to

Scheme/initiative or action	Subject matter	Scope	Maturity	Scale
EU schemes				
EPBD associated				
EPCs	EPBD related	EU but implemented at MS level	High	Very high
HVAC inspections	EPBD related	EU but implemented at MS level	High	High but uneven across MS
Article 8 TBS provisions	EPBD related	EU but implemented at MS level	High for some elements, but others are new	High
not-EPBD associated				
Level(s)	Building sustainability	EU but implemented at MS level	New	Uncertain
BIM & digital logbook	Building digital information	Private enterprise	High but still evolving	High but disparate
Voluntary European Cybersecurity Certification scheme	Product cybersecurity	EU Single Market	New	Expected to be High
Broadband ready label	Building connectivity	EU but implemented at MS level	New	Uncertain
Ecodesign/ELR	Energy-related products	EU Single Market	High	High
PEF	Product environmental performance	EU Single Market	New	Uncertain
Other schemes				
Sustainability certification				
BREEAM	Building sustainability	Global - implemented in private sector building projects	High	The highest in Europe of the building sustainability schemes but only has a modest coverage of the

				whole stock (<1%)
HQE	Building sustainability	Mostly in France - implemented in private sector building projects	High	Mostly focused on France
DGNB	Building sustainability	Mostly in Germany - implemented in private sector building projects	High	Focused on Germany
LEED	Building sustainability	Global - implemented in private sector building projects	High	Global but less coverage in Europe than BREEAM
Building renovation passports	Building performance	Implemented at MS/regional level	New	Uncertain
Smart metering related				
Smart metering roll-out	Smart meters	National/local DSO level	High	Very high but uneven across MS
Smart Buildings Initiatives				
SBA ready to services label	Smart buildings baseline	Private enterprise - commercial buildings	High	Focused on France
SAREF	Smart appliances	EU Single Market	New	EU

Table 9 - Assessment, Site/visits, Audience, Actors and Certification of initiatives or actions the SRI could link to

Scheme/ initiative or action	Building assessment	Site visits/ inspect-ions	Target audience	Actors directly involved in delivery	Certification
EU schemes					
EPBD associated					
EPCs	Yes	Yes	Property owners, tenants, facility managers	EPC assessors	Yes
HVAC inspections	Yes	Yes	Property owners, facility managers	Building service engineers	Yes
Article 8 TBS provisions	Sometimes	Yes but no inspections	Property owners, facility managers	Building service engineers	Not a priori
not-EPBD associated					
Level(s)	Yes	Probably	Property owners, tenants	Architects, buildings and systems designers, service engineers, etc.	Not a priori
BIM & digital logbook	Often	Often	Property owners, and construction professionals	Architects, buildings and systems designers, service engineers, etc.	No
Voluntary European Cybersecurity Certification scheme	No	No	Equipment owners	Under development	Yes, of equipment
Broadband ready label	Yes, but for connectivity	Yes, but for connectivity	Property owners, tenants	MS specific	Yes, of building connectivity
Ecodesign/ELR	Yes, for heating and hot water systems	Yes, for heating and hot water systems	Equipment purchasers	Heating engineers/installers, manufacturers	Yes, of installed heating and hot water systems
PEF	No	No	Product purchasers	Manufacturers	No

Other schemes					
Sustainability certification					
BREEAM	Yes	Yes	Property owners, facility managers	Private associations, qualified building professionals	Yes
HQE	Yes	Yes	Property owners, facility managers	Private associations, qualified building professionals	Yes
DGNB	Yes	Yes	Property owners, facility managers	Private associations, qualified building professionals	Yes
LEED	Yes	Yes	Property owners, facility managers	Private associations, qualified building professionals	Yes
Building renovation passports	Yes	Yes	Property owners, tenants	Architects, buildings and systems designers, service engineers, etc.	Yes
Smart metering related					
Smart metering roll-out	Not usually	Yes but no inspections	Property owners, tenants, facility managers	DSOs	No
Smart Buildings Initiatives					
SBA ready to services label	Assessment of degree that buildings are ready for smart services	Yes, including certification	Commercial property owners and developers	Diverse companies concerned with smart building services and the value chain	Yes, but focused on France
SAREF	Smart appliances	No	Diverse	New	EU

Table 10 - Quality, Mandate, Organisation, Governance initiatives the SRI could link to

Scheme/ initiative or action	Quality Assurance	Mandate	Organisation	Governance
EU schemes				
EPBD associated				
EPCs	Assessors must be certified	Governmental, legally binding from EPBD	Government managed with private sector delivery at MS level	National/Federal government managed at MS level
HVAC inspections	Varies by MS	Governmental, legally binding from EPBD	Government managed with private sector delivery at MS level	National/Federal government managed at MS level
Article 8 TBS provisions	MS specific	Governmental, legally binding from EPBD	Government managed with private sector delivery at MS level	National/Federal government managed at MS level
not-EPBD associated				
Level(s)	At project specific discretion	Governmental, voluntary	Voluntary framework for building profession	Framework development supervised by the Commission
BIM & digital logbook	Diverse practice	Private sector	Private sector	Private sector associations
Voluntary European Cybersecurity Certification scheme	Under development	Governmental, voluntary	Voluntary framework for product manufacturers	Commission with ENISA and MS input under Cyber Security Act
Broadband ready label	MS specific	Governmental, voluntary	Government regulated private sector delivery	MS government
Ecodesign/ELR	Nationally specific requirements	Governmental, legally binding from EDD	Government regulated private sector delivery	Commission with MS consultation
PEF	No	Governmental, voluntary	Voluntary framework for product manufacturers	Commission managed
Other schemes				

Sustainability certification				
BREEAM	Quality control of assessors	Private sector	Private sector	Private sector associations
HQE	Quality control of assessors	Private sector	Private sector	Private sector associations
DGNB	Quality control of assessors	Private sector	Private sector	Private sector associations
LEED	Quality control of assessors	Private sector	Private sector	Private sector associations
Building renovation passports	MS specific	Governmental / regional / local, voluntary	Publicly managed with private sector delivery at MS, regional, local level	National/Federal government or regional / local authorities, private sector associations
Smart metering related				
Smart metering roll-out	MS specific requirements	Mixture of governmental and private sector	Government regulated private sector delivery	National energy regulators
Smart Buildings Initiatives				
SBA ready to services label	Yes	Private sector	Private sector	Private sector associations
SAREF	No	ETSI (Standards body)	Standardisation for product manufacturers	EU standards body

This array of information can be rather overwhelming but from it the following observations can be made by theme.

2.1.1.5 Subject matter

The subject matter is closest to the SRI's for the Smart Buildings initiatives and the EPBD related initiatives but even with these there is simply overlap rather than convergence. For all other schemes an overlap exists but is usually quite narrowly focused. The target domains overlap most strongly for those initiatives that target buildings and rather less so for those that target products, or specific services.

2.1.1.6 Scope

The operational scope overlaps most closely for those initiatives implemented at EU, across all Member States, or at the Single Market level. However, for those implemented at a specific Member State level there is stronger overlap for the SRI within that Member State.

2.1.1.7 Maturity

While some of the schemes are quite mature and their characteristics are well established others are new, or under development and hence have significantly more uncertainty.

2.1.1.8 Scale

The scale of the schemes is one of the areas of significant divergence. EPCs cover the majority of the EU's building stock and hence have a very high degree of coverage. The other EPBD related initiatives cover a high to very high proportion of the building stock with the exception of Building Renovation Passports, which are new and being trialled. Like EPCs the Article 8 TBS measures affect installations in a very high proportion of EU buildings (all over time) but are targeted differently as they occur at the moment a new TBS is installed, or an old one is replaced. The Article 14 and 15 measures regarding the mandatory installation of BACS apply to all buildings with > 290kW of effective installed heating & cooling capacity and are to be implemented between now and 2025. In addition, the Article 14 and 15 requirements regarding heating & cooling system inspections for systems of > 70kW apply to a significant part of the building stock but are implemented in different ways by EU member states. The installer energy label for heating and hot water systems will also have a very high coverage of the EU building stock.

The use of BIM is growing rapidly in new build projects and to a lesser extent in major renovations, but these are inevitably slower to cover the building stock than the measures mentioned above (as the rate of new build and major renovations as a proportion of the total building stock is modest). Also, BIM is used on a project-by-project basis and hence is not necessarily coherently implemented across projects, even if some file formats and practices are standardised.

The independent voluntary building sustainability schemes have a high engagement with the buildings they cover but have much lower coverage of the building sector as a whole in practice.

Smart metering has been or is being (depending on the Member State), rolled-out across a large proportion of Europe's buildings.

Inevitably, the new schemes, even those designed to operate at EU level, have uncertain scale as it is not yet known what part of the building-stock they will be successful in covering. In theory initiatives such as the cybersecurity certificates and broadband ready labels could cover a significant part of their target markets and hence overlap with part of the SRIs, but the rate of uptake is highly uncertain.

2.1.1.9 Building assessments + site visits/inspections

Building assessments are done by most of the schemes and generally closely correlates with the conduct of site visits and inspections. They are not done for the purely product focused initiatives such as the PEF, cybersecurity label, or SAREF. However, the nature of assessments and inspections varies quite substantially. The most detailed assessments are conducted for the environmental sustainability initiatives, but detailed assessments are also done for Building Renovation Passports and Level(s) and potentially for some BIM projects[100]. The type of assessments done for EPCs, the other EPBD related measures and the broadband ready label are lighter and/or are more narrowly focused. Similarly, smart meter installations will only focus on the smart meter, while ELR heating/hot water labelling will be exclusively focused on those technical building systems.

2.1.1.10 Target audience

The principal target audiences often overlap around the main groupings of property owners, facility managers and tenants. However, in some cases they are focused more on those responsible for procuring specific types of equipment, which may not be the same.

2.1.1.11 Actors directly involved in delivery

The actors directly involved in delivery include EPC assessors, building service engineers, HVAC engineers and qualified building professionals. In product-focused initiatives, such as cybersecurity certification, they may include manufacturers operating at the Single Market level, while in the case of smart meters they include electrical engineers working for DSOs. It is important to appreciate that these actors will have distinct skill sets, which are more or less well suited to being engaged in SRI assessment.

2.1.1.12 Certification

Certification (as in the issuance of a certificate to denote that a building or service within it has had a qualified assessment) is common for EPCs, HVAC inspections, Building Renovation Passports, heating/hot water system energy labelling, broadband ready label and all the sustainability certification schemes. It will also be done for cybersecurity but at the product specific level and hence prior to leaving the factor gate rather than on site in a building.

2.1.1.13 Quality assurance

Quality assurance is generally carried out for EPCs, in that assessors generally have to be certified as being competent to fulfil their function. The same is true for HVAC inspectors and would be expected for the issuers of Building Renovation Passports. It is certainly the case for the sustainability certification schemes. For other schemes the situation can vary or is not yet clarified.

2.1.1.14 Mandate

The types of mandates applicable to the various schemes encompass:

- governmental, legally binding initiatives (such as those related to the EPBD) which are enshrined in a clear legal framework
- governmental / regional / local voluntary initiatives
- private sector mandates operated through an association
- private sector project-specific.

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[100] Using BIM requires building technical details to be measured/assessed and entered into software. In the case of existing buildings it requires a site visit and assessment.

2.1.1.15 Organisation

At a high level the various schemes fit within one of the following organisation frameworks:

- Government managed with private sector delivery at MS / region level
- Voluntary framework open for use by building profession
- Voluntary framework open for use by product manufacturers
- Government regulated with private sector delivery
- Private sector managed.

There are many details beneath this classification, however, that will have a bearing on the fit the organisation of the scheme could have with the SRI.

2.1.1.16 Governance

The *governance* fit parameter is the degree to which the governance of the scheme could be complementary to the governance and mandate of the SRI. For example, if the governance is seen to be too partial or structured to favour certain economic interests then linkage with the scheme may risk a conflict of interest for the SRI.

The government (EU and/or Member State, region) implemented initiatives have the least risk of conflicts of interest.

Among the private sector schemes the governance is often structured for an association with a privately agreed constitution.

2.1.1.17 Conclusions

The analysis above has illustrated that there is some degree of complementarity and overlap between the SRI and all the schemes, or initiatives mentioned. However, the extent varies, and so does the degree to which they share common aspects (and hence could help to leverage each other by minimising duplicative effort and providing a more comprehensive service offer, which could raise their value proposition).

The collective value proposition of the SRI, were it to be implemented conjointly with the other initiatives, is always complementary as each initiative addresses a different but related topic to the SRI. Some of the initiatives address broad scope, addressing multiple parameters, much as the SRI does, while others are much more narrowly focused.

The government (EU and/or Member State, region) mandated initiatives have the least risk of conflict of interest and as several operate through the EPBD have potential to share similar operational and governance platforms. Those that entail site visits have the potential to support and complement the operational side of the SRI if an SRI is to be based on on-site assessment.

The greatest potential scale benefits, and hence potential impact, is offered by the prospect of linkages with the schemes that have the broadest coverage – EPCs, EPBD Article 8 measures, EPBD Article 14 & 15 measures, energy labelling of installed heating and hot water systems, and smart metering.

More modest scale effects would be expected from linkage with the other initiatives, but they can bring different benefits and could help in a) creating a stronger collective value proposition (especially for the new initiatives) and b) helping to trial SRI implementation in relatively favourable operational environments prior to a more extensive roll out.

2.1.2 Identification and analysis of the potential options for implementing the SRI at EU-level and at Member State-level

This section addresses the identification and analysis of the possible options for implementing the SRI at EU-level and at Member States-level.

In the course of this work the study team have assessed a broad spectrum of prospective implementation options at both the EU and Member State levels and combinations thereof. Specifically, the assessment has determined and analysed:

- the different approaches for assessing the indicator of a given building / building unit (e.g. on-site inspections by certified experts, self-assessment by building owners or third parties potentially coupled with random control, etc.)
- different approaches for the organisation of the scheme (players involved, their roles, interactions and activities)
- different possible connections and coupling with existing schemes – being voluntary environmental performance schemes or national energy performance certificate schemes
- the need for qualification / certification schemes of experts (where relevant); etc.

2.1.2.1 Approaches for assessing the SRI of a given building

As previous sections have described the currently most viable assessment method for an SRI requires a person on-site to conduct the assessment. The only exception to this is the case of a person who is off-site with access to all the requisite information through pre-collected data available via BIM (e.g. a digital twin model), digital logbooks, building renovation passports etc.; however, in the start-up phase of the SRI such instances will be extremely rare if not inexistent. For assessments to be conducted on site there are options with regard to how qualified and how independent the assessor is. If a certified SRI is to be issued the assessor would need to be a certified 3rd party assessor, suitably qualified to do the assessment. If a certified SRI is not required, then the SRI would not have the same status and external market value and hence it is more of a matter for the agency procuring the assessment as to the degree of qualification and independence required. Many building owners, occupants, portfolio managers, or facility managers might wish to conduct self-assessments of the properties they have responsibility for. The degree of technical competence of those delivering such self-assessments could vary appreciably.

A priori it is imagined that both pathways (self-assessment and 3rd party assessment) would be options within the implementation of the scheme but that mechanisms would be established to ensure they are clearly distinguished and are not confused or conflated in the market.

In the case of formal 3rd party assessments quality control instruments would need to be established as discussed further in the sub-section on quality and training in this same section and in section 3.2.2.

2.1.2.2 Approaches for the organisation of the scheme

The organisation of the scheme requires clarification of the following:

- legal framework at EU and MS level
- lead implementation entities at EU and MS levels
- management of the calculation methodology
- management of calculation tools
- assessment methods and establishment of a pool of assessors
- certification
- data management
- promotion and awareness raising
- quality assurance
- training
- conformity assessment and market surveillance
- managing its online presence
- help desk and technical support
- legal enforceability
- legal liabilities.

These are discussed in depth in sections 3.2.1 and 3.2.2.

2.1.2.3 Potential connections and coupling with existing schemes

Section 1.2.2 presented a review of existing schemes that might inform development of the SRI and/or which it could potentially link to. Section 2.2.1 looks explicitly at these schemes and appraises their characteristics. From this the following conclusions can be drawn about the potential linkage of the SRI with these initiatives.

Formal linkage should only be sought if it will bring clear beneficial synergies. Those synergies would include:

- shared assessment costs thereby reducing assessment compared to the case where both schemes conduct assessments in the same building stock independently to each other
- potential to mutually reinforce the value proposition i.e. the value proposition of both schemes implemented collectively or mutually would be greater than were both operated wholly independently
- ability to reinforce the scale of reach i.e. that through the establishment of such linkages the number of the target audience reached by the schemes is increased
- compatibility in terms of objectives
- compatibility in terms of governance
- compatibility with regard to the target audiences to be addressed.

Table 11 shows a matrix of the schemes considered in section 2.2.1 screened against these criteria. From this it can be concluded that all the schemes have compatible objectives with the SRI. Almost all would enhance the overall value proposition were they to be linked with the SRI. They almost all have strongly compatible target audiences. Many have compatible governance. Most undertake site visits which the SRI could potentially leverage to reduce the cost of assessments associated with establishing contact with the target audience, gaining permission for an assessment and travel to and from the premises (a considerable part of the total). The largest differentiator is the extent to which linkage could reinforce the scale of reach of the SRI. In that regard the schemes which have major reach, mostly due to mandatory implementation, offer much greater potential leverage of scale than those which do not.

Table 11 – Screening of linkage factors by scheme or action

Scheme/ initiative or action	Shares assessment costs	Reinforces the value proposition	Reinforces the scale of reach	Compatible objectives	Compatible governance	Compatible target audience
EU schemes						
EPBD associated						
EPCs	Y	Y	VS	Y	Y	Y
HVAC inspections	Y	Y	S	Y	Y	Y
Article 8 TBS provisions	Y -	Y	VS	Y	Y	Y
not-EPBD associated						
Level(s)	Y	Y	L	Y	Y	Y
BIM & digital logbook	Y	Y	M	Y	N	Y
Voluntary European Cybersecurity Certification scheme	N	Y	U	Y	Y	U
Broadband ready label	Y	Y	L	Y	Y	Y
Ecodesign/ELR	Y -	Y	VS	Y	Y	Y
PEF	N	L	L	Y	Y	Related but not direct
Other schemes						
Sustainability certification						
BREEAM	Y	Y	L	Y	U	Y
HQE	Y	Y	L	Y	U	Y
DGNB	Y	Y	L	Y	U	Y
LEED	Y	Y	L	Y	U	Y
Building renovation passports	Y	Y	L	Y	Y	Y

Smart metering related						
Smart metering roll-out	Y -	Y	VS		MS specific	Y
Smart Buildings Initiatives						
SBA	U	Y	in France	Y	U	Y
SAREF	N	Y	U	Y	Y	Only domestic
	Key					
	Y = yes					
	N = no					
	VS = very strongly					
	S = strongly					
	M = medium					
	L = limited					
	U = uncertain					
	MS = Member State					

Considering these factors, it is clear that the impact of the SRI would be greatly enhanced were it possible to establish linkages between it and the most promising of these existing schemes. Even for those that would have less impact for the SRI there is clear complementarity, which means that efforts should be made to ensure the implementation is complementary.

2.1.2.4 Qualification / certification schemes of experts

The reliability of and trust in the experts used to deliver the scheme will be a key success factor in building confidence in the assessments and advice it provides. The most critical aspect will be to ensure that 3rd party assessors mandated by the scheme to formal 3rd party assessments are suitably qualified and deliver an impartial, consistent and accurate assessment in strict accordance with the rules established in the methodology.

This requires high quality training, mechanisms to ensure that assessors are competent and ideally a performance verification process with the option of retraining and/or disqualifying assessors who do not correctly implement assessments.

In general, the approach used to deliver this is to establish the trainer schemes, wherein agencies that are hired to deliver training are accredited for competence and for establishing and abiding by prescribed procedures in delivering the training. Accredited training agencies can deliver certified training for assessors allowing them to be certified as competent and eligible 3rd party assessors and added to registers of available assessors. There are evidently costs associated with developing and delivering such accreditation/training/certification and there are also issues of scale-up and throughput rates that affect how rapidly a pool of trained and certified 3rd party assessors can be established. *A priori* this is an area where the SRI could aim to leverage efforts made with existing schemes such as EPCs, HVAC inspectors, building inspectors, sustainability assessors etc. to make use of the existing training/accreditation and certification infrastructure to speed up the throughput and reduce the costs associated with establishing a pool of qualified assessors. However, the strength of compatibility with the SRI assessment method and the existing training/qualification process would need to be mapped and necessary adjustments made. In particular, as SRI assessment is distinct from the other on-site assessment/inspection/installation activities it would require those who are already qualified/certified to deliver such services to receive additional training, qualification and certification which means that the synergies (through reduced costs) would not be as great as cases for which a prospective assessor is being trained for both schemes. If retraining/re-qualification is required for existing schemes, then the synergy would be greater.

The above discussion presumes that 3rd party assessment will be a component of the scheme; however, for cases where self-assessment is used there is still a need to provide guidance and training for self-assessors. These could encompass online documents, advice and training videos as well as hosting training events at cost for professionals who are willing to pay to be trained to do self-assessments.

2.1.3 DEFINING A SET OF ROBUST AND FLEXIBLE IMPLEMENTATION PATHWAYS FOR THE ROLL-OUT OF THE SRI IN THE EU

Considering the analysis set out above it is clear that there are a broad range of potential pathways the SRI could follow in its implementation. Furthermore, there are a great many variants or combinations of options that could be adopted. Given this and given that very few sub-options are mutually exclusive, the focus for this first draft of these pathways is necessarily to focus on the main distinctions and map the most promising or distinctive set of pathways which capture these.

A principal rationale for making a linkage with other schemes or actions is the degree to which the linkage would help to roll-out the SRI to be able to cover a significant proportion of the EU building stock in an efficient manner. Viewed from this perspective the onus is upon identifying linkages that can help the SRI attain a large scale of deployment. It is therefore appropriate to assess the extent to which the schemes, initiatives and actions presented in section 2.2.1 cover the EU building stock over time. For non-residential buildings the order of scheme/initiative/action coverage (ranked from highest coverage to lowest) is as follows:

- EPCs (>5% per annum)
- HVAC inspections or installation/replacement of technical building systems (~5% per annum)
- smart metering deployment (~3% per annum)
- major renovations (~1% per annum)
- new construction (~0.9% per annum).

For all other initiatives mentioned the annual rate of coverage of the building stock is either less than 0.1% per annum or is unknown.

For residential buildings the order of scheme/initiative/action coverage (ranked from highest coverage to lowest) is as follows:

- installation/replacement of technical building systems (~5% per annum)
- EPCs (~3.4% per annum)
- smart metering deployment (~3% per annum)
- HVAC inspections or installation/replacement of technical building systems (~2.7% per annum)
- new construction (~1% per annum)
- major renovations (~0.8% per annum).

For all other initiatives mentioned the annual rate of coverage of the building stock is either less than 0.1% per annum or is unknown.

The above figures are EU average figures based on analysis of various sources but principally the EU Building Stock Observatory database. The actual future rate of coverage will vary by EU Member State and in response to future plans (rather than historical actions), and hence the reported values are only indicative; however, broadly speaking their relative orders of magnitude are likely to be quite stable for most member states.

Considering that the biggest challenge the SRI will have to deliver significant impact is the volume of assessments that are conducted and considering that there are strong synergies between potential assessment volumes and linkages with other schemes the following set of pathways are proposed.

A. Linkage of the SRI to the EPC (potentially in a mandatory way) so an assessment would be offered each time an EPC is conducted
B. Linkage of the SRI to new buildings and major renovations so that each time a new build/or renovation is undertaken it would be a requirement
C. A market-based voluntary scheme where self-assessment is supported by on-line tools and 3rd party certified assessment is offered to those willing to pay for it
D. As option C, but with 3rd party assessments supported, or subsidized, by the state and/or utilities seeking to roll out demand side flexibility, energy efficiency, electromobility and self-generation measures
E. Linkage to the BACS/TBS deployment trigger points in Articles 8, 14 & 15 in the EPBD
F. Linkage to smart meter deployment.

In principle, a mosaic of the above is also an option, noting that Member States have subsidiarity with regard to the SRI so may choose any of these options – also combinations of A/B/C/D/E/F are possible within any single MS. It is also possible to consider pathways that link to other initiatives that are not mentioned in this list, however, as these are likely to have much lower levels of building stock coverage such options might be most appropriate as complementary actions and/or as vehicles to trial roll-out options.

The set of pathways set out above covers a range of primary options which offer different cases with regard to the main assessment method, the likely rate that assessments are conducted (and hence the coverage of the targeted building stock), staging of trigger events within the building lifecycle, and whether or not the scheme is wholly independent or links to another initiative. A key rationale unpinning the choice of principal pathways is the distinction between them in how they relate to the building lifecycle e.g. new buildings, buildings undergoing major renovation, buildings having new TBS/meter installed, buildings having an inspection, or existing buildings with no specific trigger event.

Of the pathways that link to other initiatives (pathways A, B, E and F) it is relevant that three of these (pathways A, B & E) are linked to other EPBD initiatives while the other (pathway F) is also linked to another government controlled/influenced smart energy-related initiative. This is because these are the most promising set of initiatives which could help leverage the benefits of linkages, which have major scale (and hence support a high rate of SRI assessment deployment) but are also most easily related to the SRI's objectives, governance and stakeholder community. Linkage with the installer energy labelling scheme for space and water-heating systems could also be an option but, as an architype would be expected to behave very similarly to pathway E and thus, they can be considered to be somewhat interchangeable at this stage.

Those pathways that don't necessarily link to other initiatives (pathways C and D) encompass a more voluntary approach where market actors would engage with the SRI only if they consider there to be sufficient merit in the SRI's value proposition as a wholly independent initiative. In addition, a critical distinction is that unlike the pathways with linkages to other schemes, there is no automatic introduction of the SRI to the target audience. Thus, the target audience has to already be aware of the SRI and choose to engage with it for an assessment (online or expert on-site) to be commissioned/undertaken. This means that in the absence of strong and effective marketing efforts uptake rates would be expected to be much lower. Pathway D aims to compensate for this by providing incentives to participate in the scheme, which, dependent on how attractive they are, would help to increase uptake rates. Of course, incentives can be provided with any of these pathways but are likely to add most extra uptake impact when added to pathway C as the other scenarios entail adapting existing delivery mechanisms to ensure uptake occurs. One route by which incentives could be established is to use the powers of the Energy Efficiency Directive Article 7 concerning the establishment of energy efficiency obligations (EEO) for utilities or energy savings policies more generally as a vehicle to create funding for the incentives.

For clarity, pathways A and B are the only ones where linkage is made to an existing assessment scheme (the EPC for pathway A, or the EPC and building code inspectorate process for pathway B). Pathways E and F are linked to an event where an external professional party is visiting the property (to install a BACS/TBS for pathway E, or a smart meter for pathway F), but neither of these ordinarily involves an inspection of the building. Nonetheless, as the professional entities engaged in these activities are qualified in areas which are pertinent to some smart building features, some of them are already required to issue labels or certificates (e.g. energy labels for space and hot water systems or safety certificates), their installations are subject to legal conformity requirements (e.g. meeting Member State imposed energy performance requirements under the terms of Article 8 of the EPBD), and critically they involve high volumes of buildings being visited and hence have the potential to achieve significant scale.

Numerous sub-options to this principal set of implementation pathways can also be envisaged and are discussed further in section 4.3 in relation to the analysis of impacts. Specifically, this makes additional distinctions between pathways based on whether they are mandatory, voluntary or voluntary with the application of incentives.

However, another key issue, which is partly principal pathway independent, is the choice and types of buildings these pathways would be applied to including in terms of both building function (principal pathway independent) and stages in the building lifecycle (does have linkages with the principal pathway).

In practice, the eligible building types could be targeted distinctly and differentiated with regard to the mode of implementation. These differentiations could be designed to evolve over the scheme's roll-out or be permanent structural aspects of the scheme. Choices of this nature will mostly be made at Member State level and may only have limited implications for the centrally managed aspects of the scheme. At the Member State level, they will be critical though. Numerous options exist, but in all cases, except those where only self-assessment is considered, roll-out of the scheme will need to be scaled-up over time to ensure that there are adequately qualified assessors available to deliver the assessment process. This aspect alone could favour targeting certain building types and/or buildings as a function of the engagement mechanism with their lifecycle.

2.2 Activity 2: Investigation of the format of the SRI

This activity involves the conduct of research to determine potential designs for the format of the SRI. This recognizes that for the scheme to be effective it will need to have an attractive and recognizable format that gives visibility to the SRI and effectively conveys information to end users of the scheme such as home owners and tenants, both tertiary building owners and users and facility managers.

The decisions regarding the SRI format need to resolve the following:

- How should the scope of the scheme be communicated in a transparent manner?
- How should intrinsic concepts embedded within the SRI be clarified?
- What information is to be communicated?
- Which information will be presented to which audiences?
- How will the information be presented visually?
- What media will be used to present the information?
- Should the scheme be branded and if so how?
- How should its format be conditional on interactions with other schemes?

2.2.1 Communicating the scope of the scheme in a transparent manner

Besides the policymakers and stakeholders directly involved in the development and implementation of the EPBD, the Directive, and its purpose are unlikely to be widely known. All stakeholders have agreed that transparency will be one of the key success factors for the SRI, because without it there is a heightened risk that the target audiences will:

- not understand the SRI
- not engage with it
- become mistrustful of it.

The first and most essential aspect of this transparency will be to communicate what the scheme does address and what it doesn’t. This is likely to be a critical issue for the SRI’s success because if its target audiences feel that the SRI does not address what they believe it claims to be addressing then they are likely to quickly lose confidence in it. However, communication of the scope is not a simple matter for such a multi-faceted instrument as the SRI. The scope is broadly defined in the Directive as set out in the following three pillars:

- The ability to adapt its operation mode in response to the needs of the occupant paying due attention to the availability of user-friendliness, maintaining healthy indoor climate conditions and ability to report on energy use
- The ability to maintain energy efficiency performance and operation of the building through the adaptation of energy consumption for example through use of energy from renewable sources
- The flexibility of a building's overall electricity demand, including its ability to enable participation in active and passive as well as implicit and explicit demand-response, in relation to the grid, for example through demand side flexibility and load shifting capacities.

The degree to which these pillars are comprehensible, understood and resonant with the target audiences are an open question but a priori it should be expected that the concepts they convey are only partially in line with what many people would consider to be meant by building smartness and that there is much else which concerns aspects of building smartness which are not addressed in the three pillars. In particular, they do not focus on or encompass smart building services related to the following:

- Entertainment
- Communications
- AV environments
- Aesthetics
- Safety
- Security
- Accessibility.

Smart services and technologies which relate to these aspects are already the predominant part of the smart-buildings services/technologies market and thus their relationship to the SRI cannot be ignored. Failing to address this is likely to create confusion and a risk of the SRI being dismissed.

When considering the requirements of the SRI imposed in the EPBD it is clear that all the services and functionalities within its scope are energy-related in some manner. Therefore, the formatting issue to address is how best to communicate that the SRI, at least in its initial framing, is only concerned with energy-related aspects of building smartness.

When considering this it is important to appreciate that informational scope can be communicated both explicitly and implicitly and that contextual framing can be important. For example, were the SRI to be presented as an element or extra aspect with an Energy Performance Certificate, audiences are more likely to implicitly understand its energy related nature because of the broader energy-related context in which the SRI is being framed. On the other hand, if there is no broader context that the SRI is placed within its scope would be in more need of being explicitly framed to avoid confusion. Using text to explicitly explain the SRI's context is always an option but its limitations also need to be understood. If text is lengthy and much has to be read before the basic purpose of something can be understood then there is a risk target users could ignore it and even ignore the whole initiative because they might feel it is too much effort to grasp and that doing so is in competition with other compelling opportunities for their time and attention, whose value proposition might be much more apparent. Thus, the aim is to communicate the essential aspects about its scope as succinctly as possible while also minimising the risk of misinterpretation of what it addresses. As this can involve trade-offs combining a simple indicative and/or implicit framing approach can often be complemented by the provision of more detailed information that users can refer to once they have overcome the first hurdle of knowing what the scheme is broadly about, and hence whether they wish to invest additional time in learning more. Also, it's important to appreciate that in practice there will be a spectrum of users with different informational needs – even if the scheme is designed to be targeted towards specific groups. Thus, there is always a need to devise a communication format that works as effectively as possible for the chosen target audience.

2.2.1.1 Approach to resolving this issue:

To help to understand how the SRI's scope is likely to be understood and how best to transparently and efficiently communicate it the study team set out to test the topic with two key target audiences:

- focus groups made up of the general public who either own or rent buildings
- surveys with facility managers.

The former cover typical prospective SRI users from the residential and small non-residential building sector, while the latter cover prospective users from the mid- and large non-residential building sector and a subset of larger multi-family residences.

The approach entails initially gaining an insight into what the target audiences autonomously understand smart buildings to be about, and what aspects of smartness they think they encompass, before introducing the notion of the smart readiness indicator in a general sense. After having done so they can then be questioned on what areas of smartness they imagine the SRI would address, and what they believe it should address, and then only after that would they be informed of the energy-related scope of the SRI. At this juncture they can be asked how do they think this scope should be clarified to avoid confusion.

2.2.2 CLARIFICATION OF INTRINSIC CONCEPTS EMBEDDED WITHIN THE SRI

Just as there's a need to communicate the scope of the SRI there's also a need to provide information to explain and clarify the intrinsic concepts embedded within the SRI. Users will need to feel that they understand these aspects for the scheme to have any traction, so it's important to present the information in as transparent a manner as possible. This thought has had a significant impact on the discussions about the structure of the SRI reported in section 1.3.3.3. While the EPBD requires the SRI to respond to the three pillars, as reported above, it also clarifies the elements that these need to address, which has led to the impact criteria choices proposed in the first study and modified as set out in section 1.3.3.3. It is likely that if presented in a compound manner the three pillars may be too aggregate to be able to transparently communicate their intrinsic meaning, especially to target audiences (the majority) who are not well versed in energy and energy policy. As experience shows that lack of transparency has a seriously negative impact on the resonance and impact of schemes that aim to trigger a voluntary engagement (in this case stimulate adoption of beneficial smart services) then it is essential to establish the extent to which the format of the scheme is successful at communicating the intrinsic concepts embedded within it. The degree to which the intrinsic concepts are communicable and how that is affected by the structure of the SRI is one of the aspects that needed to be tested with the target audiences.

2.2.2.1 Approach to resolving this issue:

Stakeholder views were canvassed on these topics through the stakeholder consultation process and Topical Group meetings. These tended towards convergence on an SRI structure that uses the three pillars as a structure to arrive at weightings in an aggregated scoring system while the impact categories feed into these as they are inherently more tangible, measurable and communicable. However, the next step was to test this thesis with the SRI's target audiences. As set out above a mixture of consumer focus groups and surveys of stakeholders is used to gain insights into these issues (see sections 2.3.11 and 2.3.12). They have been structured to probe the degree to which the inherent concepts within the SRI are understood and comprehensible, their salience to the target audience, and their capability of being communicated within the SRI's structure. The findings from this research is intended to build on the stakeholder feedback to both clarify the most viable structure and SRI format and identify problem areas where extra care and attention will be needed to avoid losing engagement.

2.2.3 THE SET OF INFORMATION TO BE COMMUNICATED

In principle, the SRI informational set includes information on the following:

- the SRI scores
- guidance and advice on how to improve SRI scores
- explanation of the scope of the scheme
- the calculation methodology
- the SRI functionality levels
- the scheme itself, including its provenance, governance, implementation, data protection and current status
- related topics such as interoperability and cybersecurity.

2.2.3.1 Information on SRI scores

As has been made clear in the previous chapters, the SRI contains information that can be presented at multiple levels. At an aggregate level it could contain an overall ranking on a building's smartness as determined and expressed within the confines of the scope of the scheme and the SRI's definition. Equally, though, at the sub-aggregate level it contains information on intrinsically more tangible aspects such as the energy efficiency performance of a control solution for a specific technical building system, or the delivery of indoor air quality. Proper engagement in the consideration of what information set should be communicated probably has to be presaged by consideration of the conflicting needs of:

- delivering information simply and efficiently
- delivering information clearly, tangibly and understandably.

Not surprisingly, and quite reasonably, when asked about these aspects, stakeholders have tended to demand both; however, they when it comes to the SRI they are not really fully compatible. This is because simplicity and efficiency dictates an informational format that conveys the core message at a glance; however, determining the "smartness of a building" necessarily involves assessment across multiple parameters in the form of a multi-criteria assessment, which requires an aggregation based on ranking the sub-criteria and that requires application of a values-based relative weighting (because the sub-criteria are intrinsically non-comparable for the most part) – this whole process is complex and inherently less transparent.

As discussed previously, smartness scores or rankings could be presented at the whole building (aggregated) level, the domain (technical building service) level, the impact criterion level, and at the intersection of an impact criterion with a technical domain level (including the functionality for each specific domain and impact criterion intersection). All of this information will be embedded within an

SRI assessment tool and hence are options for information that could be presented to a given target audience.

When asked about the importance of presenting information at the levels of an aggregate whole building score, and at the sub-level (e.g. per impact criterion or per technical domain) the majority of stakeholders proposed that it should be presented at both the aggregate and the sub-level. The next preferred option is just to present it at the sub-level (i.e. not to use an aggregate score) and the least preferred option is just to present it at the aggregate level. Discussions on this topic with stakeholders in the two topical groups tended to reveal that a reason for wishing to see sub-score information presented is that it is more tangible, and hence comprehensible, as it avoids aggregation and weighting across impacts etc. Another reason is that it allows users to focus on the aspects of smartness that resonate most for them and thus is more likely to meet their needs. Those that have argued for a single aggregate score have supported this position because they assert that it is much simpler for users to assimilate and does not require investment of significant time to process and retain. This, it is suggested, is likely to appeal to a larger set of the population than a more detailed scoring approach.

Considering these seemingly conflicting approaches is potentially why a majority of stakeholders supported the notion of presenting both an aggregate overall score and sub-scores. In principle, the aggregate score could be presented in the most prominent way to make it clearer that it is the overarching score, while the sub-scores could be organised in a supporting format – such as a table. However, other approaches are also possible depending on the media used to convey the information.

2.2.3.2 Information on guidance and advice on how to improve SRI scores

Most buildings will have plenty of potential to increase their smartness and as the SRI will establish their smart readiness functionality it can also be used to indicate what options exist to improve the building’s smartness by raising the functionality of smart services. This information could simply be structured to show what the available higher levels are, or also, to explain these higher levels in more depth, clarify what extra functionality they would provide and offer information on the types of services that would provide them. Furthermore, guidance on how to improve the SRI score of a building could be provided in a generic way without input from the user, or in a targeted way in response to targeted requests from the user about specific domains or impacts.

When consulted on this topic stakeholders tended to strongly support the notion of presenting guidance on how to improve SRI scores to the SRI target audiences; however, this raises the issue of how best to do this without overloading the user. If a printed document is to be presented to the SRI user, then this is likely to be constrained in size and potentially to be counterproductive if it becomes over long.

Based on the practice with EPCs that include improvement advice, this tends to be quite focused and limited to listing a few improvement options which would have the greatest impact (sometimes also expressed in terms of cost-effectiveness).This SRI is inherently more complex because it addresses multiple impacts, where in principle the same hierarchical approach could be presented per impact criterion e.g. a list of the improvement options which would improve the given impact, ranked in order of their importance for the impact criterion score. However, this risks becoming rather long, and perhaps would risk focusing too much on large jumps in smartness score rather than on (potentially) more affordable incremental steps. The same could be said about a list of the options that would present the greatest improvement in an overall (aggregate) score. The reality is that different users are likely to have different needs.

2.2.3.3 Information to explain the scope of the scheme

As previously discussed, efficiently clarifying the scheme's scope will be critical to establish confidence in it. Again, information could be provided on this verbally (by an assessor), in written documentation, and on-line.

2.2.3.4 Information on the calculation methodology

Many users are likely to want to understand the calculation methodology used in the scheme, but their interest is likely to range from a simple explanation of the basic approach to a detailed explanation of each functionality score and how the aggregate score is derived.

2.2.3.5 Information on smart service functionality levels

Users of the SRI assessment who are considering upgrading the functionality of smart services in their buildings are particularly likely to welcome explanations of the current functionality levels and what the prospective higher functionality levels are for any given service. Thus, presenting information and guidance on this is likely to be a key part of the SRI's success factor as an agent for change towards smarter buildings.

2.2.3.6 Information on the SRI scheme itself, including its provenance, governance, implementation, data protection and current status

Many users will wish to have information on the scheme itself, including who is behind it, what its provenance is, how it is operated, what its governance is, how it uses and protects their data, and its current status. How this can be best provided might be contextual.

2.2.3.7 Information on related topics such as interoperability, cybersecurity and complementary schemes

Lastly, many users will also have informational needs regarding associated topics such as interoperability of smart services, cybersecurity issues, linkages and distinctions between the SRI and other schemes, such as EPCs, Level(s), broadband ready label, etc.

2.2.3.8 Approach to resolving this issue:

Stakeholder views on these topics were partially canvassed, as discussed, and this helped to provide some clear perspectives. The missing element was to establish how actual prospective users of the SRI might respond and react to the various possibilities regarding informational content (addressed in section 2.3.12). A priori, though it was already clear that the more diverse the user needs are with regards to the SRI informational content the more likely that a navigable, hierarchical, on-line information delivery system will be required. This could be complemented by printed media and verbal exchanges with an assessor but if informational richness, and diversity of information, is required then that is best delivered in a digital on-line platform.

To explore the user responses to these issues further the study team set out to probe the responses of the two key target audiences:

- the general public who either own or rent buildings, via focus groups
- facility managers by informal surveys.

The findings are discussed in section 2.3.

2.2.4 TARGETING INFORMATION TO THE NATURE OF THE AUDIENCE

While it's clear that different types of users will have different informational needs and responses to the SRI it's also apparent that there are structural differences between potential SRI audiences. On a first level the audiences (especially when considered in terms of the audience of first contact) can be distinguished between professional and non-professional. Professional audiences at the property level for the SRI will include: (from downstream to upstream) facility managers, property portfolio managers, system commissioners, building service engineers, systems integrators, system designers, builders, architects and developers. Beyond those directly responsible for operation, maintenance and upgrade of a building they will include service providers, utilities and investors. The primary target for the SRI within this structure is the entity of first contact with an SRI assessment, i.e. the facility manager.

A priori it can be anticipated that these professional audiences will have, and demand, a deeper understanding of the SRI and its elements than (the majority) of non-professional audiences. This implies that the richness of information that would be appropriate for the professional users of the SRI will need to be greater than for the typical non-professional. The non-professional audience is superficially simpler in that they entail home owners & tenants; however, there is also a large part of the non-residential building stock that is used by small businesses and has a very similar demographic in terms of those that would be the first receivers of SRI information and make decisions about smart services and investments. Furthermore, many smart services are pioneered in residences and targeted at the spectrum of inhabitants and needs – these include everything from early technology adopters to those with little interest or understanding of technology. Broadly speaking though professional users will usually require more in-depth information presented in more sophisticated formats than non-professional users – they are equally likely to wish to exert more effort to mine and process the information obtained. Considerations of these aspects, informed by stakeholder consultation, gave rise to the following set of archetypal SRI assessment formats. Although it was initially considered that "simplified on-line quick scans" could be offered to residential sector users and expert SRI assessments with on-site inspection by independent 3rd party assessors to non-residential users, discussions with stakeholders have highlighted the request to allow both (informal) self-assessments and (formal) expert assessments on residential and non-residential buildings. As such, these archetypes combine several aspects that are neither necessarily mutually exclusive nor likely to exclusively suit the needs of building sector specific target audiences, so they are better considered as vehicles to frame discussion and analysis than definitive proposals at this stage of the SRI's development.

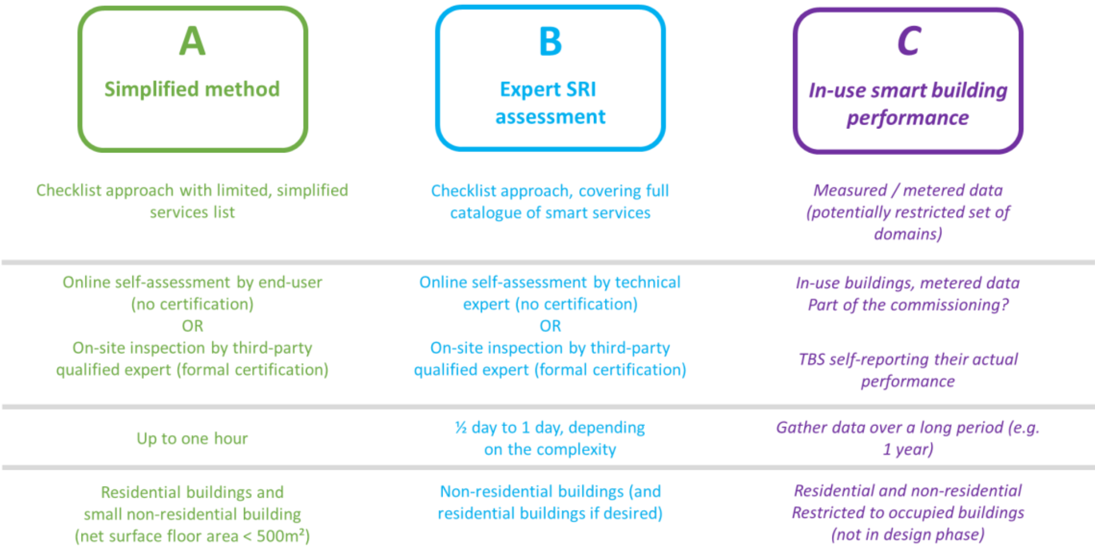

Figure 25 – Archetypal assessment methods

2.2.5 Targeting information to the nature of the building stock

The previous section considered potential informational differentiation in response to the nature of the target audience as these are the recipients an processors of the SRI information; however, the information can also be related to the type and nature of building being assessed, such that small, simple buildings are likely to have more limited TBSs and service domains than larger and more complex buildings, such as multi-modal buildings with a disparate set of occupants engaged in diverse activities. There is clearly a strong correlation between building function and the nature of the primary SRI audience, such that smaller buildings will usually be residential or small commercial premises, while larger buildings, excepting large multi-family residences, will tend to be non-residential; however, this is a correlation but is not deterministic. Furthermore, the smart services which are most appropriate for a given non-residential building could be dependent on the primary building function such that a clinic may well tend to need a somewhat different blend of smart services, than a supermarket, a warehouse, a hotel or a hospital, for example.

2.2.5.1 Approach to resolving this issue

Canvassing of stakeholder views on this topic.

2.2.6 A hierarchy of informational needs

The earlier discussion has highlighted the array of informational circumstances and needs that the SRI should address. This covers everything from a simple logo and/or mnemonic that identifies that the information is related to the SRI by readily associating it with the scheme in a clear format, and possibly conveys high-level ranking information, sub-scores, explanations of smartness and smart functionality, advice on how to upgrade, details of specific functionalities and services, and informational about the scheme itself. At the top of this hierarchy will be the logo/mnemonic/image and simple text that identifies that the scheme is about the SRI - this may also present a high-level score. The next layer down can be sub-scores by domain and/or impact criteria, complemented by such explanation or hints regarding the scheme's scope, beyond this will be the additional explanatory information and guidance.

2.2.7 VISUAL PRESENTATION OF THE INFORMATION

The manner in which the information is presented is likely to make a significant difference to its impact as a change agent. The images used, and structure of the visual organisation of the information, will determine this impact.

2.2.7.1 Logo

A logo is a symbol or other small design adopted by an organization to identify its products, uniform, vehicles, etc. The SRI could make use of a logo to immediately visually brand it in users minds and create an identity for the scheme.

2.2.7.2 Mnemonics

Mnemonics are used to simplify the processing and retention of information. The most famous example in the energy sector is the energy label that ranks appliance efficiency from A to G and is reinforced by colour coding (Green to Red). Other examples of mnemonics used to simplify rankings are the number of stars e.g. a 5-star hotel.

Mnemonics have already been used by the study team to simply convey some aspects of the scheme, as shown below, however, these are simply working ideas and have not been formally elaborated or tested in the field. Alternative mnemonics are possible and in principle could help to communicate both a top line performance classification while also creating an identity for the scheme (much as a logo aims to do). In this sense mnemonics can serve a dual function, as they can fulfil the role of a brand while also conveying a classification or ranking in a relatively concise manner.

Figure 26 – Example mnemonics

Various questions are under consideration about this topic including:

- Should mnemonics be used for the SRI? (does the answer depend on the target audience?)

- If the answer is yes, then, should they be used in combination with numerical scores or as a replacement?
- Is some form of A to G and/or colour-coded mnemonic an option, or does it risk confusion vis a vis energy labelling and EPCs?
- What other mnemonic scales could/should be considered?

2.2.7.3 Approach to resolving this issue:

These are issues best resolved through research with the target audience. To undertake this the study team engaged a professional graphic designer to develop various design options and tested these with consumer focus groups and professional stakeholders – see section 2.2.11 and 2.2.12.

2.2.8 CHOICE OF MEDIA USED TO PRESENT THE INFORMATION

In principle, the following media can be used to present the information assembled through an SRI assessment:

- verbal communication from the assessor to the person present when the assessment was conducted
- physical printed material
- on-line digital information.

Theoretically, any one-, or any combination of these could be used, including all three, to convey the requisite information. The decision about which should be used will be contingent upon:

- the choice of implementation pathway
- the nature of the audience and their anticipated needs & level of interest
- practical constraints that might affect the informational pathways and depth of information which can be offered.

Unless telephonic support services are used verbal communication is contingent on there being a site visit and hence would be undertaken by an assessor. It would become part of the assessor's job to not only conduct the assessment but also explain it, answer user questions on site, and potentially also provide guidance on how to improve smartness. Verbal communication has the advantage that it is interactive and can humanise the scheme which helps to build confidence in it. On the other hand, it has the limitation that it is time constrained, is potentially costly and may be difficult to ensure standardised information.

Printed media, can include:

- a physical mnemonic/logo combined with scores
- a physical printed document
- a physical certificate.

It could be as compact as a label or as lengthy as report. It could encompass, each or all of: a label (that potentially could be placed in a prominent position – much as is done with EPC assessments of public buildings), a certificate (that can be used as evidence that a 3rd party assessment has been done and include scoring information), and a document/report to provide more extensive details about the scheme, the scoring, and advice on the most promising upgrade options. Printed media has the advantage that it provides a certain status and formality/finality to an assessment and is suitable to produce as evidence. It also poses no data security issues or liabilities for the scheme's implementors. It has the disadvantages that it takes up physical space and resources, requires storage and could be lost, but also that it is not interactive and hence necessarily follows a rigid standardised format.

An alternative and/or complementary option is to use electronic media to convey the SRI's information. This can be held on-line and can be interactive. As it is on-line it can be as extensive as required without posing significant issues about resources. It also has the very considerable advantage that it can be structured in a hierarchical navigable manner that would allow users to focus on the aspects of the SRI that they wish to know about in an interactive manner. It can also be readily updated so as new information becomes available that can be added without any limitations, and without requiring a fresh site visit. In principle, an on-line SRI platform can also allow users to examine how their scores would change as a function of smart service upgrades and thus to examine the consequences from making prospective changes – this could provide a major additional motivational aspect to the scheme for some users.

A potential risk with an on-line scheme is that if user building data has to be entered into an on-line database then it could raise risks and concerns about breaches in data confidentiality and cybersecurity. Even if best GDPR and cybersecurity practices are followed the perception of risk could still deter engagement from users who are particularly sensitive to these concerns.

On the other hand, as on-line services are strongly associated with smartness to many users it would seem intuitively appropriate to manage some or all aspects of the SRI on-line and would reinforce its central message and value proposition. For example, if a user were at retail outlet and were considering a smart service purchase to have the option of examining via their smartphone how the proposed product/service would impact their buildings smartness could be seen as being very convenient and immediate, and therefore add value to the SRI's proposition.

As these various media have different pros and cons a blend of methods could be the most appropriate. An on-line platform could be provided for all SRI users regardless of whether they might use it to undertake a self-assessment, to gain advice or updated information, or as a repository for a professional assessment (3rd party or otherwise). The detail of assessment could also be flexible – with a basic assessment, a detailed assessment and even higher levels of detail offered in principle. The nature and status of the assessment could be tracked and could be provable if appropriate user ID were to be confirmed. Different vintages of SRI assessment for the same property could also be stored, allowing the evolution of a property's smartness to be tracked and equated to potentially different vintages of the SRI calculation framework itself. Such a system could also be structured to be downloadable (assuming suitable permissions are conferred) into a BIM system, or conversely for BIM, building logbook, building renovation passport, EPC, Level(s) etc. data to be uploaded into it (and thereby facilitate the assessment process itself). As new services are added to a property their SRI functionality, interoperability & cybersecurity certification status could also be entered into the on-line SRI for the property, thereby allowing both an automated update and facilitating the data entry process. Were products and services to also report their SRI functionality via standardised on-line platforms (e.g. either through on-line data sets, QR codes etc.) then it would greatly facilitate the SRI assessment process too. If product and service providers were to support this data provision this effect could help to ensure that the SRI assessment burden (even if on site and third party) does not increase as the scheme evolves and the number of smart services used in buildings increases.

In addition, an on-line platform could be centrally managed, which means that the approach would be standardised and harmonised across the EU. This could help to ensure consistency, minimise burdens on member state authorities and avoid duplicative effort, while also ensuring that changes/evolutions to the scheme are rolled out in the same way and at the same time across the EU. A centrally managed scheme would also increase comparability which is especially important for product and service providers who sell their products within the context of the Single market, but also for those wishing to manage, or invest in portfolios of buildings across the EU. Lastly, an on-line platform can also facilitate the supportive analysis. For example, an option could be provided to users to share their data (anonymously) into a benchmarking system that would allow the smartness of their property(ies) to be compared to all other properties of a similar type that have granted permission to take part in the benchmarking process. Confidentiality would be maintained because under such a scheme all data that was not the specific users would be anonymous to that user. This kind of benchmarking process is used in many areas and has been shown to be a powerful change agent.

Thus, while the power of using an on-line platform is clear it can also be complemented by the other media. The human presence for an expert assessment stage allows verbal human interaction to complement the on-line element and thus provides a more rounded informational service. Printed labels, certificates or reports can also add weight to the on-line aspects and provide a certain status that the on-line information might otherwise lack.

2.2.8.1 Approach to resolving this issue:

Again, it’s important to complement stakeholder views on these topics with research. The study team examined these topics further via consumer focus groups and professional stakeholders – see section 2.3.11 and 2.3.12.

2.2.9 BRANDING

Branding is a means of giving an identity to a service and helps establish its value with the target audiences. Branding is closely associated with design and particularly with having a distinctive design.

As previously discussed in section 2.3.7. branding of the SRI could make use of a logo and/or mnemonic to help provide the scheme with a visual image and identity. Branding can also be used in associated information or promotional material; however, as this is a scheme initiated and managed by the EU it has to be managed sensitively.

2.2.9.1 Approach to resolving this issue:

The study used a very modest budget to conduct graphical design work to develop some initial concepts – see section 2.3.11; however, should a decision subsequently be made to push ahead with giving the scheme a distinctive brand through design then it is expected that further development work may be needed.

2.2.10 CONDITIONALITY OF THE FORMAT WITH OTHER SCHEMES

In principle, the scheme's format could depend on its implementation pathway and how it interacts with other schemes. For example, were an implementation pathway to be adopted that leveraged the EPC assessment process to also conduct and issue SRI assessments then there would be a choice of whether and, if so, how to integrate the formats of both. The same could be true of other EU schemes such as Level(s), cybersecurity certification, etc. but also of private schemes such as private sustainability certification schemes, private sector smart buildings initiatives, etc. In each case where there is an operational intersection between schemes and an agreement that both schemes would wish to work with each other in a complementary manner, then there would be associated design and formatting decisions to be made. In anticipation that such needs are likely to arise the SRI's format can already be structured to facilitate this kind of interaction. If two schemes are to be presented in the same design-space, then it implies that a compact communication will be required for at least the top-line information. For example, were the SRI to have a logo/mnemonic it would be possible to position this flexibly within other design formats. As such a device would almost certainly not allow sufficient information to be communicated of itself it could be presented with a link or gateway to the rest of the SRI's information e.g. a web address or a QR code that can be flashed by a QR reader on a smartphone and take the user straight to an on-line information repository. Such hierarchical informational access approaches are becoming quite common place and have been under consideration for energy labelling for some time (they are already implemented in some economies).

Clearly there will also be conditionalities linked to the type of assessment method (e.g. the simplified (case A), the 3rd party expert (case B), or potentially in the future the in-use smart building performance (case C).

2.2.11 TRIAL GRAPHICAL DESIGNS TO ILLUSTRATE THE SRI

A professional graphic designer was hired to develop a set of trial SRI design concepts which were subsequently tested in Consumer focus groups held in Madrid and Budapest. The designs combined a blend of the following:

- conventional logos (Figure 27)
- simple mnemonics which apply a single simple mnemonic scoring system to convey the aggregate performance (Figure 28)
- more complex, tri-partite mnemonics which apply a mnemonic scoring system for each of the three pillars mentioned in the EPBD text and also for an aggregate score (
- Figure 29)
- a comprehensive scoring matrix that includes scores per domain and per impact criterion as well as aggregate scores per impact criterion and the overall SRI aggregate score (Figure 30).

Figure 27 – Samples of trial logos

Figure 28 A

Figure 28 B

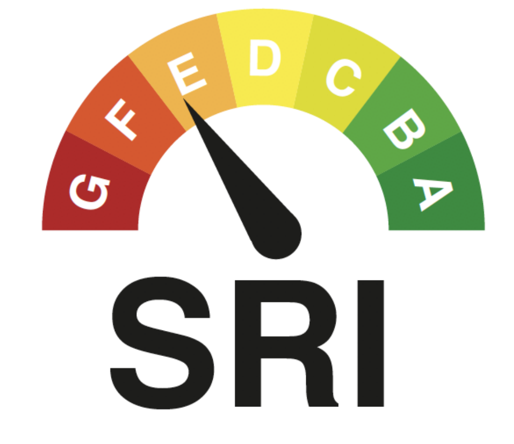

Figure 28 C

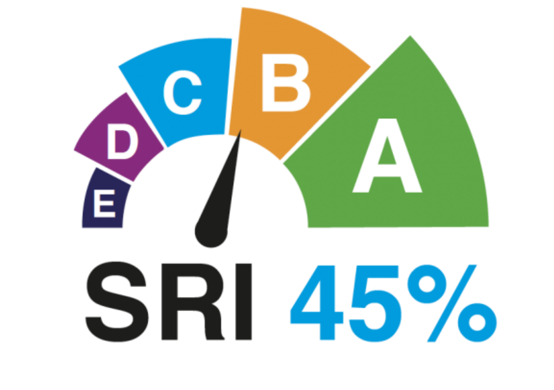

Figure 28 D

Figure 28 – Single mnemonics to convey the overall SRI score and/or rank

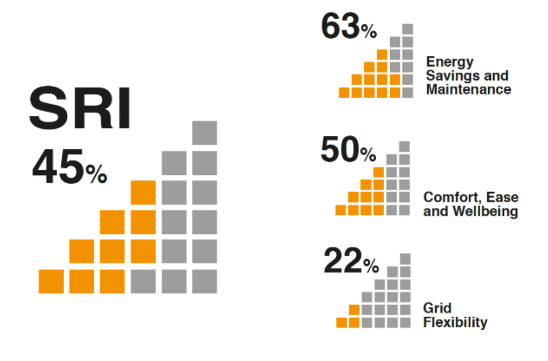

Figure 29 A

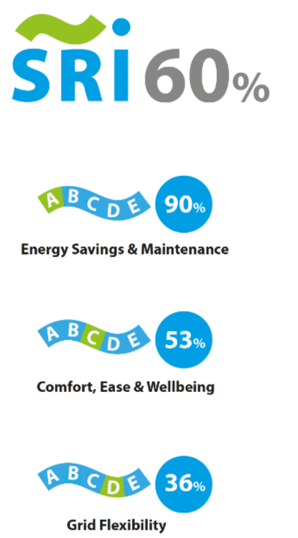

Figure 29 B

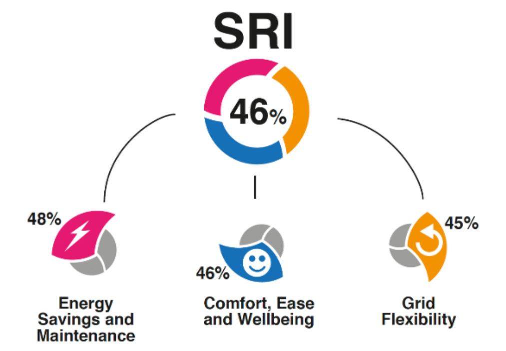

Figure 29 C

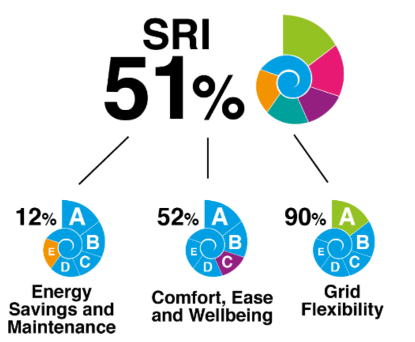

Figure 29 D

Figure 29 E

Figure 29 – Tri-partite mnemonics to convey the overall SRI score/rank and subscore/ranks for the three SRI "pillars"

IMPACTS

DOMAINS	Energy efficiency	Maintenance and fault protection	Comfort	Convenience	Health and well-being	Information to occupants	Energy flexibility & storage	SRI
Total	**39%**	**18%**	**60%**	**71%**	**48%**	**59%**	**0%**	**42%**
Heating	32%	18%	62%	55%	24%	74%	0%	
Sanitary hot water	17%	0%	45%	70%	67%	83%	0%	
Cooling	65%	51%	78%	72%	61%	55%	0%	
Controlled ventilation	41%	0%	55%	60%	34%	44%	0%	
Lighting	85%	14%	90%	100%	83%	15%	0%	
Dynamic building envelope	10%	0%	31%	56%	22%	46%	0%	
Electricity	10%	0%	-	-	-	68%	0%	
Electric vehicle charging	–	38%	-	82%	-	84%	0%	
Monitoring and control	52%	43%	62%	72%	45%	64%	0%	

Figure 30 – Matrix showing SRI scores by domain and impact criterion, aggregate scores per impact criterion and the overall SRI score

2.2.12 FINDINGS OF CONSUMER RESEARCH

To test the SRI concepts consumer focus groups of eight members of the public each were conducted in Madrid and Budapest by a professional market research company (Kantar Millward Brown) in state-of-the-art market research premises and using professional moderators. A moderator's guide was produced by WSEE and the moderators were consulted (to optimise the guide) and fully briefed prior to the conduct of the focus groups. The guide and all relevant materials (including the trial graphic designs) were translated into the national language whenever appropriate. The participants were recruited using best practice market research techniques to ensure the participants were as representative as possible of the general public that might make use of the SRI – this entailed screening candidates for socio-economic and professional groupings, gender, age, education and technological familiarity to ensure they were a good reflection of the population as a whole in each country.

The focus groups were done in their respective national languages (Spanish and Hungarian) and when text was used in the graphic designs this was translated and the designs adjusted to reflect the national language as appropriate. The only instances when this was not done was for the acronym SRI which was maintained in English. In both groups it was understood (and broadly accepted) that an English acronym was being used – both groups said that use of such acronyms was quite common and it would not be a significant barrier to using the graphic designs, although many did ask what SRI meant. The focus groups were witnessed by Paul Waide of WSEE with simultaneous translation provided and English language transcripts were produced from recordings after each group took place.

The trial SRI graphic designs were organised into the structured moderator's guide that set about probing focus group participants' views on the issues raised previously in this section on the SRI format. After an introductory discussion the participants were presented with each of the graphic design concepts to explore which ones they favoured and why and equally which they didn't and why. The focus group process was designed to be non-leading and to explore participants responses to the topics in a natural and progressively deeper way. For this reason, the subject of the focus group and the reason it was being conducted was not revealed until the end. Rather, it was structured to explore the topic progressively in layers so that previous comments were not influenced by expectations and to ensure the responses were much as would be expected were consumers to come across the SRI in a real implementation situation.

It began by asking them what they understood by the term "smart" and asked them to define this. They were then asked to consider whether buildings could be smart and if so in what ways? This was followed by asking the participants to consider how the smartness of a building could be assessed and measured. They were then asked to imagine that an indicator of building smartness was being developed and to consider what aspects it should address and which were the highest priority to them.

Only following these opening discussions were the participants shown the trial graphic designs and asked to indicate what they liked about them, what they didn't and to rank them. This began by showing them the single mnemonics to convey the overall SRI score and/or rank as shown in Figure 28. After this the participants were shown the tri-partite mnemonics to convey the overall SRI score/rank and sub-score/ranks for the three SRI "pillars" from

Figure 29. Subsequent to this they were shown the matrix of SRI scores by domain and impact criterion of Figure 30. At each stage respondents were also asked to complete a questionnaire where they rank-ordered by preference the various images e.g. for the single mnemonic designs and then subsequently for the tri-partite mnemonic designs. They were subsequently shown the logos of Figure 27 and asked which they liked best, least and why and what they thought of a simple logo compared to the earlier mnemonic approaches.

It should be noted that at no stage were participants given answers or explanations for what they were being presented with – rather they were simply asked to offer their explanations and interpretations under the understanding that there were no "right or wrong" answers and that they shouldn't be reticent to say what they thought.

From this process the following findings emerged:

- The respondents were inherently interested in receiving information on how smart buildings were and expressed a consistent view that they would welcome receiving information on this topic

- They indicated that in their opinion the term smartness entailed the following concepts: knowledge, convenience, connectivity, immediacy, programming, intuition, time saving and rapidity, advanced technology, comfort, robotics, simplicity and usefulness.

- In terms of smart buildings and the functions that could be provided some of those proposed were: automatically adjusting consumption and delivering energy savings, adapting the heating system, powering the equipment from solar panels, easy control of appliances and equipment, security and secure access to the building, remote control of equipment and heating, smart charging of EVs, domotics, systems to protect your computer and IT, occupancy sensors and automatic control of lighting and other services related to occupancy, simple and low cost maintenance, monitoring consumption and savings.

- The simple logos (Figure 27) were considered to not be very informative or useful and there was a universally greater preference for the mnemonic designs of Figure 28 and
- Figure 29.

- By contrast both the simple mnemonic designs that showed the overall SRI score and those that showed the tri-partite and overall scores were well received and generally well understood.

- Of the simple mnemonic designs (Figure 28) image A and image D were preferred to images B and C - based on processing the preference rank ordering scores reported by respondents in the questionnaire. This preference was quite clear but there was little to choose between the popularity of images Figure 28 A and Figure 28 D.

- Respondents preferred designs that included both the letter ranking and a numerical score. They found this easier to understand and also more precise (which they mostly liked). Resemblance of aspects of the designs to the existing energy label ranking for appliances or EPCs for buildings was not considered to be a problem or confusing.

- Of the tri-partite mnemonic designs (
- Figure 29) image C and image E were generally preferred to images A, B and D, with no clear favourite between
- Figure 29 C and
- Figure 29 E.

- Most respondents appreciated that the overall SRI score shown in the tri-partite designs is the average of the three sub-scores.

- For the tri-partite designs the term “Energy savings and maintenance” was well understood, the term “Comfort, ease and wellbeing” mostly well understood, but the term “Grid flexibility” (even with good local language translations) was not understood – most respondents wondered what it is and why it’s important. Even at the end of the focus group when the meaning was explained many said they wouldn’t care about this unless they benefitted from lower bills.

- Respondents thought that the matrix of information (Figure 30) was informative and useful. Despite an initial first reaction from one participant that it was "too much" all seemed to understand it (including this participant) when they took a few seconds to examine it and then expressed a view that including such a table as additional information to a mnemonic design would be beneficial and address the questions they had about how the scores in the mnemonic designs were derived. The discussion revealed that participants correctly understood that the overall SRI score was on the top right, the aggregate scores by impact criterion in the top row and that the values in the cells beneath showed how each domain scored against each impact criterion.

- The impact criterion shown in the matrix (Figure 30) were well understood except for there was discussion about what the distinction was between comfort and convenience (which are distinct concepts in English but seem to be almost identical concepts in both Spanish and Hungarian even though there are distinct words for each). There was also confusion about the "Energy flexibility & storage" term although this was slightly better understood than the "grid flexibility" term. In general, the icons to express these concepts were appreciated and considered to be appropriate; however, it is unlikely they would have been understood without the accompanying text.

- In the case of the domains shown in the matrix (Figure 30) they were well understood with the partial exception of: dynamic building envelope (most appreciated that this was related to shading after thinking about it but several thought it would be better to simply say shading); in the Spanish group "controlled ventilation" was questioned because several participants said they thought this was redundant given that cooling was present – the distinction between ventilation and cooling was not clearly understood – this was not a problem in the Hungarian group though; both groups slightly questioned the term "sanitary hot water" as some thought the word sanitary was unnecessary. Despite these issues the clear sentiment was that the matrix was reporting useful information and that while participants would not wish to be presented with this first or in isolation it is a very useful adjunct to the overall score mnemonic (whether expressed as a simple mnemonic design or a tri-partite mnemonic design).

- When initially presented with the tri-partite designs (following the simple mnemonic designs) most respondents appreciated the extra detail they contained, because although this was took more effort to understand it helped their understanding of what was behind the overall SRI score; *however*, opinion was evenly divided about whether it was best to use a simple mnemonic score and the matrix of information (to provide more detail) or to use a tri-partite mnemonic design and the matrix of information – those who favoured the first approach said that the simple mnemonic design conveyed the overall score at a glance and the extra detail was fully present in the matrix, thus there was no need to have a tri-partite design. Overall, respondents thought either approach would be viable.

- In both groups there was a clear desire to have layers of information organised in a hierarchy that includes an overall score but also additional detail that users could probe when they wished to have more information (e.g. via the matrix). When asked about what media format the SRI should take respondents expressed a preference for multiple formats e.g. a certificate (which many thought was important to show credibility), a report (which could accompany the certificate and include more explanation) and online material (perhaps accessed through a QR code on the certificate and which would have navigable pages with a hierarchy of information, so those that wanted to understand exactly how the scoring was done for a given element and potential improvement options could examine this and so users could learn more about higher functionality smart services).

- There was equal support in both focus groups for an approach that initially presented the single overall score mnemonic and then the matrix, or which initially presented the overall score/tri-partite score mnemonics and then the matrix – thus either approach would seem to be viable; however, there are more problems with understanding the demand side flexibility concept in the tri-partite designs than the way this is conveyed in the matrix.

- Participants in both groups saw no problem in presenting the SRI in conjunction with an EPC or within an EPC – they said the informational content was sufficiently distinct that there was no confusion between the two instruments and the information was complementary across them (awareness of the EPC was high – participants knew what they were when shown their national EPCs).

- When asked about the QR code shown on the EPCs slightly over half of respondents indicated that they knew what it was and that it could be used to link to a webpage via a smartphone app. There was apparent unanimity that using a QR code with the SRI would be useful as it would allow those who are interested to access more information.

- When asked who should do the SRI assessment, respondents were of the view that independent qualified assessors should do so – several said they would not trust an assessment done by a commercially interested party. They were open to the idea that self-assessment could be done with the support of on-line tools but did not think it should have any status on a certificate, or publicly claimed score. Nonetheless, several said they would welcome having the opportunity to see how the score on their property could change as a function of the type of smart services they could potentially install and thus would welcome the opportunity to take a formal assessment of their building and examine via an on-line tool what the effect of potential changes could be.

- Overall, there was remarkable consistency between the responses given in the Madrid focus group and the Budapest group which implies that the findings might be relatively robust i.e. tend to be confirmed were additional focus groups to be conducted in other locations, although this has not been proven.

The findings from the consumer focus groups were broadly supported by the findings from the informal survey of facility managers achieved via the communication received with participants in the SRI trials (see 5.1.3) and from discussions held at an event with facility managers (see 1.2.4.2) in that facility managers seem to be quite happy to receive both the overall SRI ranking and the information presented in the table of SRI sub-scores. These findings were further reported back to the final primary stakeholder meeting as well as to Topical Group A and all feedback seemed supportive of this conclusion.

2.2.13 CONCLUSIONS

From the analysis and research conducted above the following conclusions are tentatively drawn by the study team.

- An SRI format that combines a mnemonic graphic design such as Figure 28 A or Figure 28 D, or alternatively
- Figure 29 C or

- Figure 29 E, at the top with the matrix shown in Figure 30 somewhere beneath would seem to be viable and address most users' needs. This would combine a whole building score and ranking (which many users have indicated is important) with the detailed information on the scores by domain and impact criterion in a manner that is readily accessible. It would also ensure that users can see how the whole score is comprised from the sub-scores and provide the richness of information that many users desire without putting off those that simply want a whole-building score/ranking. The mnemonic ranking complements the percentage score as it gives a more easily retainable and comparable reference.

- As such an approach has been found to be viable for the least technically sophisticated set of the potential target users (consumers) yet includes the full set of information on scores by domain/impact criterion that many facility managers and non-residential users have expressed an interest in seeing it seems that it would be viable to use this approach for all building types and segments.

- With regard to the set of media used such an approach (i.e. a top-line mnemonic ranking/score with a matrix of sub-scores beneath) could be presented via a certificate and/or report with the option to access more details through an on-line tool. Such a tool could be accessible via a QR code and/or weblink and could potentially include the option for the user to enter (and/or retrieve) their building details so they could examine how they could improve its smart readiness in detail. The on-line tool could combine the functionalities of: explaining the SRI purpose and calculation to users; explain the higher levels of SRT functionality that are available and their benefits; and being able to calculate SRI scores from raw input data while allowing users to see how improved SRTs would improve their building's overall score and sub-scores.

- The use of an on-line platform would provide a solid and flexible foundation for the SRI's informational needs and be most responsive to the range of user needs. It could help to: facilitate SRI assessment, enable interactive determination of the impact of prospective changes in a building's smartness, manage evolutions in the SRI, manage evolutions in the data for any specific property, support data exchange with other service platforms whenever appropriate permissions are granted. Critically, the use of such a platform, if arranged to be in a navigable hierarchical manner, would avoid the need for the scheme to have to present the information in a single condensed format based on assumptions about user needs, as users would be able to readily find the information they are most interested in.

- Whatever media and graphic design format is chosen it will be important to ensure that additional explanation is provided which clearly clarifies what it does and does not address if confidence in the scheme is to be established and to protect it from accusations of being misleading.

- There seems to be no obstacle in terms of user comprehension or perception to integrating the SRI within an EPC or to implementing them jointly. The same is probably true of other building rating, labelling or certification schemes.

- There seems to be no obstacle to using a common EU graphical design format for the SRI providing text used within it, such as in the matrix of Figure 30, can be communicated in the local language. It is probably acceptable to use the English acronym SRI as part of a common EU brand providing there is explanation of what the scheme is about offered in the local language.

- Both professional stakeholders and consumers seem to welcome that the SRI format should present information on improvement options; however, the most appropriate route for doing this might be implementation pathway dependent. An on line platform could readily be designed to facilitate this.

- As the SRI scheme evolves it is likely that new versions will come into being and hence there will be a need to communicate the version being used at any one time so users are aware when methodologies have changed.

3 TASK 3 - GUIDANCE FOR EFFECTIVE SRI IMPLEMENTATION

TASK SUMMARY & OBJECTIVES

The objective of Task 3 is to investigate possible pathways for an effective implementation of the SRI in the EU. This task provides technical guidelines and recommendations addressing the following three aspects:

- the operational, organisational and legal design of the SRI scheme
- the efficient and cost-effective assessment of the SRI
- the management of the SRI after adoption.

For each of these three aspects, the consortium explores the optimal connection to other schemes and initiatives (EPC, Level(s), etc.) and the potential to tailor the SRI to different implementation pathways and assessment procedures.

TASK APPROACH AND PROPOSED METHODOLOGY:

The methodological activities conducted under Task 3 are:

- assessment of operational, organisational and legal design options for the SRI scheme
- development of technical recommendations for the efficient and cost-effective assessment of the SRI
- development of guidelines for the management of the SRI after adoption.

3.1 ACTIVITY 1: OPERATIONAL, ORGANISATIONAL AND LEGAL DESIGN OPTIONS FOR THE SRI SCHEME

This activity builds upon the findings from Task 2 on the options for implementing the SRI at EU-level and at Member States-level that will have previously been presented and discussed with the Commission and stakeholders to agree upon the most promising pathways to implement/organise the SRI. Specifically, the activity sets out options for the effective implementation of the SRI in accordance with these pathways. It is structured with the intent of providing guidance on the effective operational, organisational and legal design options for the SRI scheme, at EU and at Member States level.

This guidance covers:

- the organisation of the scheme, detailing which players need to be involved in setting up and implementing the scheme, their roles, responsibilities, activities and interactions. Where relevant, the role of the Commission in the implementation of the SRI and its relationships with other players will be clarified
- the operation of the scheme: for a given organisational approach, detailing how the scheme operates when it is in place. This includes e.g. monitoring, quality control, verification, and market surveillance activities

- the legal foundations of the scheme: for a given organisational approach, detailing the legal issues that can emerge when the scheme is put in place and when it operates; clarification of liabilities; mechanisms of resolution of legal issues
- costs of the scheme: for a given organisational approach, assessing the costs that could be borne by the parties involved (e.g. administrative costs, costs of assessment of the SRI, etc.)
- additional supporting measures: for a given organisational approach, devising a portfolio of complementary policy and programmatic measures that could be set up to support the effective implementation of the SRI.

It takes as input the set of implementation pathways elaborated in Task 2 and considers each against the factors described above.

The prospective actors are then mapped against these for the best fit. For each organisational approach the organisational building blocks are identified and described. This includes establishing what activities are required for the scheme to operate and the interactions between them.

3.1.1 Options for the organisation of the scheme

This section considers the organisation of the scheme, detailing actors which would need to be involved in setting up and implementing the scheme, their roles, responsibilities, activities and interactions. Where relevant, the role of the Commission in the implementation of the SRI and its relationships with other players is clarified.

Before considering these aspects, it begins by reflecting on the pros and cons of each of the principal implementation pathways outlined in Task 2. This appraisal is done via SWOT (Strengths, Weaknesses, Opportunities and Threats) analyses which are presented for each of the main implementation pathways in turn below. These SWOT analyses constitute the initial appraisal of the study team. While various elements within them have arisen from stakeholder discussions they have not been put to stakeholders in a structured way and hence do not necessarily reflect the views of the SRI's stakeholder community.

A. Linkage of the SRI to the EPC (potentially in a mandatory way) so an assessment would be offered each time an EPC is conducted

Strengths

- High and predictable assessment volume means a rapid coverage of SRI assessments if made mandatory with the EPC
- 3rd party assessment should maximise assessment quality and increase integrity & market value
- 3rd party assessment allows issuance of a trustworthy certificate
- Assessment can directly inform owner/occupier via targeted advice
- Provides smart assessment at moment of change ownership/occupancy and hence increases SRT upgrade potential as this is a moment when there' more chance that capital investments will be considered

Weaknesses

- Increases EPC time and cost
- Would not address portable assets
- EPC credibility is not always high with all market actors
- Requires extra training/accreditation of EPC assessors
- Does not directly influence the design stage

Opportunities

- Leverages existing EPC assessment process in a complementary manner
- Can emphasise the value of SRTs at a key transition moment
- Could make use of EPC energy balance data
- Assessment could be linked to on-line tools which can be structured to allow users to inspect the aspects of the SRI which are of most interest to them and which provide information at the level they wish to receive it

Threats

- EPC assessors may not be adequately trained/accredited for SRI assessment which risks reputational damage
- If a sufficient number of qualified assessors are not available there may be a risk of slowing down EPC deployment due to added SRI burden
- Greater time and cost of EPC/SRI assessment could create resentment against EPCs and add an incentive to non-conformity with EPC requirements

B. Linkage of the SRI to new buildings and major renovations so that each time a new build/or renovation is undertaken it would be a requirement

Strengths

- Predictable assessment volume means a guaranteed coverage of SRI assessments if made mandatory for new build/major renovations
- Avoids the complication of how to deal with both new and legacy equipment which will occur in unrenovated existing buildings
- Provides smart assessment at moment of change in ownership/occupancy and hence increases SRT upgrade potential as this is a moment when there is more chance that capital investments will be considered
- Incentivises developers, designers and system integrators to incorporate smart services into their projects
- If linked to 3rd party assessment, e.g. via the EPC, it should maximise assessment quality and increase integrity & market value
- Assessment can directly inform new owner/occupier via targeted advice

Weaknesses

- The rate of new build and major renovation is currently < 2% per annum and hence stock coverage will take decades to achieve.
- Adds an additional regulatory cost to new build and major renovations.
- Risks having low to modest awareness of the scheme except in the construction sector
- If linked to the EPC process would increase the time and cost associated with this step and EPC credibility is not always high with all market actors
- Requires extra training/accreditation of EPC/SRI assessors
- Would not address portable assets

Opportunities

- Could leverage existing EPC assessment process in a complementary manner
- Can emphasise the value of SRTs at a key transition moment and hence influence initial choices about building smartness
- Could make use of EPC energy balance data
- Assessment could be linked to on-line tools which can be structured to allow users to inspect the aspects of the SRI which are of most interest to them and which provide information at the level they wish to receive it

Threats

- If the rate of assessment is too limited smart service and SRT providers might not be as willing to organise their product/service offer in terms of the SRI framework which could weaken the "push" effect
- EPC assessors may not be adequately trained/accredited for SRI assessment which risks reputational damage
- If sufficient qualified assessors are not available there is a risk of slowing down EPC deployment due to added SRI burden
- Greater time and cost of EPC/SRI assessment could create resentment against EPCs and add an incentive to non-conformity with EPC requirements

C. A market-based voluntary scheme where self-assessment is supported by on-line tools and 3rd party certified assessment is offered to those willing to pay for it

Strengths

- Allows the market to engage with the SRI in a flexible manner that suits their needs
- Avoids adding additional regulatory costs
- Minimises burdens on regulatory authorities with responsibility for EPBD implementation
- On-line tools can be structured to allow users to assess the aspects of the SRI which are of most interest to them and which provide information at the level they wish to receive it

Weaknesses

- Risks having low engagement and low coverage of the building stock – SRI assessment volumes would be very un-predictable
- Risks having low awareness of the scheme
- Risks providing little incentive to upgrade SRTs and smart services
- Self-assessment increases the likelihood of poor assessment quality and could reduce the quality of explanation of the upgrade potential even if managed on-line
- If self-assessment predominates the assessments would carry almost no value in the marketplace except to those who have done or commissioned the assessment
- Market willingness to pay for 3rd party assessment risks being very low

Opportunities

- Training and qualification of certified assessors can develop organically at the pace the market demands

Threats

- With low assessment volumes there is a real risk that suppliers of smart services and SRTs will see little value in positioning their service/product offerings within the SRI framework and this could result in a much weaker "push" effect.
- A predominance of self-assessment could result in even 3rd party certified SRI assessments having lower value in the market due to misunderstanding the distinction

D. As option C. but with 3rd party assessments supported, or subsidised, by the state and/or utilities seeking to roll out flexibility, energy efficiency, electromobility and self-generation measures

Strengths

- Allows the market to engage with the SRI in a flexible manner that suits their needs
- Avoids adding additional regulatory costs to market actors
- The provision of incentives will stimulate a higher level of adoption than would occur in option C
- Minimises burdens on regulatory authorities with responsibility for EPBD implementation
- On-line tools can be structured to allow users to assess the aspects of the SRI which are of most interest to them and which provide information at the level they wish to receive it

Weaknesses

- If incentives are insufficient risks having low engagement and low coverage of the building stock – SRI assessment volumes could be quite un-predictable
- Risks having low to modest awareness of the scheme
- Unless specifically designed to address this, it could risk providing little incentive to upgrade SRTs and smart services
- Self-assessment increases the likelihood of poor assessment quality and could reduce the quality of explanation of the upgrade potential even if managed on-line
- If self-assessment predominates the assessments would carry almost no value in the marketplace except to those who have done or commissioned the assessment
- Market willingness to pay for 3rd party assessment risks being very low

Opportunities

- If incentives were to cover the cost of 3rd party assessment, then willingness to have an assessment would increase
- If incentives were to cover some of the incremental costs of smart services and SRTs then their rate of adoption would increase
- Were SRT/smart service incentives to be offered to those that have a 3rd party SRI assessment then the scheme would incentivise both
- Training and qualification of certified assessors can develop organically at the pace the market demands

Threats

- If incentives are insufficient, then with low assessment volumes there is a real risk that suppliers of smart services and SRTs will see little value in positioning their service/product offerings within the SRI framework and this could result in a much weaker “push” effect.
- A predominance of self-assessment could result in even 3rd party certified SRI assessments having lower value in the market due to misunderstanding the distinction

E. Linkage to the TBS/BACS deployment trigger points in Articles 8, 14 & 15 in the EPBD

Strengths

- High and predictable assessment volume means a rapid coverage of SRI assessments if made mandatory with the EPBD BACS trigger points
- Could positively influence aspects of the design and procurement phases for BACS
- Were 3rd party assessment used it should maximise assessment quality and increase integrity & market value
- 3rd party assessment allows issuance of a trustworthy certificate
- Assessment can directly inform owner/occupier via targeted advice
- Provides smartness assessment at moment of change of TBS and hence increases SRT upgrade potential as this is a moment when there' more chance that capital investments will be considered

Weaknesses

- Adds a regulatory burden at the EPBD BACS trigger points (e.g. moment TBS's are replaced, when HVAC inspections occur, and for the installation of BACS for buildings >290 kW of installed capacity)
- Many of these trigger points do not normally entail a 3rd party inspection, yet were one to be offered or required in this option it would require provision of inspection skills/capacity which are not currently offered
- Would not address portable assets
- Requires extra training/accreditation of assessors and linkage of SRI inspection to the BACS trigger points

Opportunities

- Could leverage existing HVAC inspection process in a complementary manner
- Could emphasise the value of SRTs at a key transition moment
- Could make use of HVAC inspection energy balance data
- Assessment could be linked to on-line tools which can be structured to allow users to inspect the aspects of the SRI which are of most interest to them and which provide information at the level they wish to receive it

Threats

- Inclusion of SRI inspection duties in the delivery of the EPBD BACS provisions could risk a mismatch between the type and skills of the market actors that would ordinarily be responsible for delivery of the BACS requirements and those needed for the SRI assessment
- SRI assessors may not be adequately trained/accredited for SRI assessment which risks reputational damage
- If sufficient qualified assessors are not made available there is a risk of slowing down BACS deployment due to added SRI burden
- The additional time and cost of the SRI assessment could create resentment against BACS measures and add an incentive to non-conformity with requirements

F. Linkage to smart meter deployment

Strengths

- Were it mandatory there could be a relatively high and predictable assessment volume resulting in a rapid coverage of SRI assessments
- Makes a natural link to the provision of demand side flexibility services and helps to contextualise the scope so the smartness is clearly linked to energy services in the public perception of the scheme, and not to other smart building aspects which are not covered by the EPBD.
- If utilities were to link it to incentives for smart services, this could provide a one stop process to help trigger accelerated smart services deployment
- Linkage to smart meter deployment would make a natural link to 3rd party assessment which should maximise assessment quality and increase integrity & market value
- 3rd party assessment allows issuance of a trustworthy certificate
- Assessment can directly inform owner/occupier via targeted advice

Weaknesses

- Adds a regulatory burden and costs to smart meter roll-out
- The competences required for smart meter deployment are different to those required for SRI assessment and are not obviously complementary, which means additional personnel may be required and/or extensive additional training which could slow smart meter roll out
- Smart meter roll-out is quite mature in some MS so the rate of SRI assessment coverage of the building stock would be low in these cases
- Would not address portable assets
- Requires extra training/accreditation of assessors and linkage of SRI inspection to the smart meter deployment trigger points

Opportunities

- Could leverage existing planned site visits with regard to smart meter deployment
- Could emphasise the value of SRTs at a key moment where building owner/managers are receptive to advice about energy related issues
- Would help to directly engage DSOs in the SRI and thereby increase the likelihood of flexibility services being triggered through its deployment
- It could potentially make use of utility accessed energy data
- Assessment could be linked to on-line tools which can be structured to allow users to inspect the aspects of the SRI which are of most interest to them and which provide information at the level they wish to receive it

Threats

- Inclusion of SRI inspection duties in the delivery of smart meters could risk a mismatch between the type and skills of the market actors that would ordinarily be responsible for delivery of the BACS requirements and those needed for the SRI assessment
- The perceived neutrality and independence of the scheme might be compromised if it is viewed as part of a DSO’s service offer and hence a tool to sell commercial services
- SRI assessors may not be adequately trained/accredited for SRI assessment which risks reputational damage
- If sufficient qualified assessors are not made available there is a risk of slowing down smart meter deployment due to added SRI burden
- Potential users who do not wish to have a smart meter, e.g. due to data confidentiality concerns, would not be served
- The additional time and cost of the SRI assessment could create resentment against smart meters and add an incentive to non-engagement with smart metering

3.1.1.1 Establishment of the scheme

A priori, in the view of the study's authors, the establishment of the SRI requires certain key components to be put in place. These are:

- an entity responsible for overall management of the scheme at the EU level
- an entity responsible for managing the calculation methodology
- an entity responsible for implementing and managing a central executive platform
- Member State level counterparts of the above.

These aspects are discussed more in section 3.3 but for now the nature of their functions and composition (actors) is considered.

The entity responsible for overall management of the scheme needs to govern and manage all the high-level decisions regarding the scheme's scope, governance and implementation within the boundaries established by the legal framework. As a consequence, it needs to include appropriately high-level representation from the EC and Member States and needs to either report to the EPBD governance process or be an integral part of it.

The entity responsible for managing the calculation methodology is inherently more technical and specialist. It has to address all technical issues pertaining to the approved calculation methodology. Ordinarily it would take direction and be subservient to the entity responsible for overall management. Its composition will require more subject matter expertise and depending on how it is structured it would either need the competences to do detailed work and analysis itself and/or the ability to commission such work on its behalf. This implies a composition with strong topical and impartial expertise. The options and rationale are discussed further in section 3.3.

The entity responsible for implementing and managing a central executive platform needs to host the scheme and act as its secretariat. This requires secretariat competences including all technical support requirements necessary to host the SRI in an online platform as are discussed further below.

While the functions associated with these entities are described distinctly above it remains an option to incorporate the responsibility for overall management within the current EPBD governance structure rather than have it addressed by a new entity with a specific SRI focus.

At the Member State level these functions will need to be mirrored with regard to the parts of the scheme's implementation and governance which are within each Member States' purview.

In addition to these entities there is also a need for ongoing stakeholder representation and engagement, both at the EU and Member State levels.

When considering the interaction of the functions described above with the different implementation pathways the following observations can be made:

- Overall governance and management at EU level is not inherently implementation pathway dependent, except to note that the pathways that link most closely to other elements within the EPBD (i.e. pathways A, B and E) share synergistic governance with other aspects of the EPBD while pathways C, D and F do not.

- The key governance distinctions between the implementation pathways resides at Member State level as it is at this level that decisions would be taken regarding whether any aspect of the scheme is to be addressed through regulation. Pathway A1 would entail establishing regulations to make the SRI assessments mandatory as part of the EPC assessment. Pathway B1 would make them mandatory as part of the building regulation compliance process. Pathway E1 would make them mandatory as part of the delivery of the EPBD Article 8, 14 and 15 requirements, while pathways F1 would tie them to the delivery of smart meters under the national frameworks governing smart meter roll-out.

- Management and responsibility of the calculation methodology is not inherently implementation pathway dependent.

- The competences required to implement and manage the central SRI platform and provide secretariat support services will depend on the nature of its implementation, but are not necessarily related to the principal pathways – with regard to these, the key technical competency issues will concern the decisions about the nature of online services including whether to host and manage an online assessment calculation tool and how to manage data submitted into it. These decisions will affect the workload, technical skills and liabilities associated with hosting the central platform. Other tasks associated with this role would/could include: maintenance of a web presence for the scheme, listing of approved calculation tools (if outsourced) and assessors (linking to the Member State level), online help desk and support, promotional actions, management and quality control of training (depending on how centralised this is), provision of online resources, organising and convening meetings and events. Many of these functions could be provided at Member State or pan-EU level so decisions need to be made on the most appropriate division of responsibilities.

3.1.2 OPTIONS FOR THE OPERATION OF THE SCHEME

This section considers options for the operation of the SRI scheme for each given organisational approach, detailing how the scheme operates when it is in place. This includes e.g. monitoring, quality control, verification, and market surveillance activities.

Specifically, it considers options relating to

- assessment
- certification
- calculation methodology
- calculation tools
- data management

- promotion and awareness raising
- quality assurance
- training
- conformity assessment and market surveillance
- managing its online presence
- help desk and technical support
- legal enforceability
- legal liabilities.

It considers each of these in turn and the dependencies they exhibit as a function of the implementation pathway.

3.1.2.1 Assessment

The SRI assessment process could be conducted on-site or remotely (e.g. for the assessment Case C). In the case of on-site assessment, there are choices between whether a specifically organised site visit is required or whether the actors already present in a building could do the assessment (i.e. a self-assessment), however, even this latter case would entail the person doing the assessment being on site unless they had access to the necessary information in the form of documentation held electronically or as printed documents. As previously discussed, remote assessment is not a viable option for the initial implementation of the SRI and hence is not considered further within the current discussion but could be an option that is developed over the longer term. The near-term options thus all entail on-site assessment. The type of actors that would be involved in these is set out in the table below as a function of the implementation pathway. In this table the actors who would implement the principal assessment option are highlighted in **bold,** but the principal option does not preclude also permitting alternative options and these are indicated in *italics*. Thus, under pathway A, an SRI assessment would be conducted by 3rd party EPC assessors who are also qualified to do SRI assessments and this would (or could) occur each time an EPC is issued. However, this doesn't preclude that self-assessment could also be permitted and facilitated as this would allow buildings to be assessed outside (in-between) the EPC issuance cycle, would encourage occupants/owners/facility managers to engage with the SRI and reflect more on its implications (which is especially relevant when an SRT investment decision is being considered), and would allow them to explore and a time of their choosing to explore the various ways that they could upgrade the smart functionality of their property and the benefits that would be expected from doing so – this is especially so if an online assessment platform was always available. Such an online self-assessment could be complementary to a 3rd party assessment carried out at the same time as an EPC is issued, but clearly would not carry the same weight when communicating the SRI to other market actors.

The same is true for pathways B, E and F where the principal assessment is done by a 3rd party professional and self-assessment is an additional option. In these cases, though, the principal assessment distinction between the pathways is the nature of the 3rd party assessor. While pathway A would use a qualified EPC assessor, pathway B would use a qualified building regulations compliance inspector, pathway E would use the building services professionals involved in the installation and inspection of TBSs, and pathway E would use the professionals involved in the installation of smart meters. The key assessment consideration in each case is which group is best placed to issue an SRI. Lastly, pathways C&D are different from the others because they would rely principally on self-assessment and hence do not require site visits by 3rd party professionals, although this would still be an option for those willing to pay for a 3rd party assessment. The upside of these pathways is their low cost for assessment; the downside is the corresponding lack of quality control and standardisation in the assessments which would make the findings much less persuasive to other market actors than those that conducted the assessment. Equally importantly, is that for these pathways the assessment process is only triggered on direct request and not by a predictable external trigger point; thus, the person commissioning the assessment has to already be aware of the SRI and its value proposition.

Table 12 – Actors involved in on-site assessment

Nature of assessment	Implementation pathway				
	A	**B**	**C/D**	**E**	**F**
Self-assessment	*F&M managers, occupants, owners*	*F&M managers, occupants, owners*	**F&M managers, occupants, owners**	*F&M managers, occupants, owners*	*F&M managers, occupants, owners*
3rd party assessment	**3rd party assessors**	**Building inspectors**	*3rd party assessors*	**Building service engineers, HVAC inspectors, TBS installers**	**Electrical engineers**

3.1.2.2 Certification

The issue of certified performance (SRI scoring) is intrinsically linked to that of the permitted assessment pathways. In principle, issuance of a certificate to endorse an SRI assessment gives value to the assessment in the market by demonstrating that an assessment has been done in accordance with agreed norms by an independent qualified assessor and hence, a priori, market actors can place greater credibility in the information it provides than information provided through a self-assessment conducted by an interested party who may or may not be qualified to undertake the assessment. Any assessor who is officially mandated to do an assessment (e.g. pathways A, B, E and F) would also need to be qualified to do the assessment and be independent. In such cases the assessments they provide would be suited to the issuance of certified assessment which would add negligible additional cost but provide more value. In the other pathways (C & D) the principal mode of self-assessment would not (optional 3rd party assessment would be). With regard to the independence of certifiers pathways A and B offer the greatest independence, while pathways E and F would need safeguards to be established to ensure the certification is independent of the installers’ product offer.

3.1.2.3 Calculation methodology

Development and maintenance of the SRI calculation methodology is an integral activity at the core of the SRI and is discussed in-depth in section 3.3. It is best managed at the EU level (see discussion in section 3.3) and is not inherently related to the choice of implementation pathway.

3.1.2.4 Calculation tools

As the SRI's calculation methodology needs to be coherent across the EU (see discussion in section 3.3), is wholly new and is derived from the public sector, there is a rationale to consider the provision of centrally managed and open source calculation tools to support the assessment process. Unlike the situation which arose with EPCs in some member states there is no foundation based upon proprietary assessment tools that could complicate the provision of a single open source calculation tool. Theoretically the mode of applying the tool could vary by implementation pathway, with 3rd party on-site assessment pathways using software on a portable device and self-assessment pathways using an online platform or a downloadable assessment tool, but practically the choice is more related to the reliability of mobile access to the internet and data consent constraints.

3.1.2.5 Management of data

Establishing clear and secure data management protocols linked with appropriate levels of consent will be a priority in all SRI assessment pathways, but there is greater risk of unauthorised use of data and greater data owner concern with online and cloud-based platforms than those that rely on portable calculation methods that do not report data back to a central database. On the other hand, passage of data via the internet would allow the use of centrally managed online calculation software with less risk of inconsistency in the application of version control than downloadable software and greater opportunity to implement a navigable, hierarchical SRI assessment that would allow users to continue to analyse the information embedded in their data after a 3rd party assessor has left the premises, to receive richer and more targeted advice and explore the impact of potential upgrades in SRTs.

Any implementation pathway that makes use of digital data transmission will need to respect GDPR requirements.

3.1.2.6 Promotion and awareness raising

Awareness raising and promotional activities will be required for all implementation pathways, but this requires much greater focus for the pathways (C & D) that do not link SRI assessments to other delivery mechanisms than those which do (A, B, E and F). In those that do a large part of the promotional effort can be targeted up-stream to the actors in the SRT and smart services value chain, whereas for those that are reliant on users requesting an SRI assessment for one to be conducted there would need to be very extensive down-stream (end-user) promotional marketing if demand is to be created.

3.1.2.7 Quality assurance

Stakeholder consultation has confirmed the critical importance of establishing adequate quality assurance and quality delineation mechanisms if the SRI assessments are to carry weight in the market and among end-users. If self-assessment mechanisms are to be permitted, then they must have a clearly distinct and lower status among other market actors than qualified 3rd party assessments per the certification discussion. All the standard means of assuring quality are appropriate for consideration including: training and qualification of assessors, accreditation of agencies conducting training and certifying assessors, establishment of mechanisms to ensure there is an adequate availability of qualified assessors, market surveillance applicable to both assessments and to products and services supplied to the market that claim to provide a given service functionality, imposition of legal liability for the veracity of assessments conducted by 3rd party agencies.

3.1.2.8 Training

Training needs can be distinguished between the training of third-party assessors and the guidance and training which could be provided to support self-assessment. Training of 3rd party assessors would need to ensure they have acquired the competencies necessary to deliver reliable and standardised SRI assessments. They would be trained and required to prove they have the necessary competences by passing qualification tests. Passage of the qualifications would result in them becoming certified SRI assessors enabling them to be registered in the pool of certified assessors. Those agencies providing the training and certification would first need to acquire the necessary competences themselves, thus training the trainer programmes would need to be established with an option of imposing accreditation requirements on the training agencies. In the case of self-assessments simple guidance and training tools could be provided online with greater sophistication offered for those tools and training courses targeted at use by building professionals, such as facility managers, than those required for self-assessment of simpler buildings such as single-family homes and small commercial premises.

If the SRI is to use a common calculation and assessment method across the EU there would be a rationale for training of the trainers to be centrally initiated and supported, at least in the initial stages of the scheme. This could help ensure a standardised approach is followed from the outset and minimise variance in implementation.

3.1.2.9 Conformity assessment and market surveillance

Conformity assessment is the process that the suppliers of goods and services undertake to ensure their products comply with requirements. In the case of the SRI this is the method, or methods, that would need to be specified in order for suppliers to show that there is a legally accepted basis to support claims they make about their products' characteristics in relation to the SRI.

In regard to ensuring the quality of SRI assessments nationally-based Conformity Assessment Bodies with responsibilities for certification and accreditation would have a role in the up-stream assurance of the training and certification of assessors. However, these agencies do not conduct market surveillance to ensure the delivered services are reliable. Market surveillance for SRTs sold as finished goods would be the responsibility of trading standards agencies including designated market surveillance agencies with responsibilities for enforcement of requirements under the Single Market; however, in practice this would mostly only address safety related concerns. Establishing conformity with building regulations applicable to TBSs (including BACS, Lighting and HVAC systems) is tasked to authorised building inspectors. Unless Member States were to require it, there is very little existing downstream market surveillance of SRTs and services unless they fall within building-regulation requirements.

3.1.2.10 Managing an online presence

It will be beneficial to establish an online platform for the scheme to serve as the focal point and information resource for the scheme and also to host and implement any related online services, such as online assessment platforms or downloadable assessment software, provide links to national implementation hubs, provide training functions, etc.

3.1.2.11 Help desk and technical support

Establishment of a helpdesk and technical support service should be considered to complement the scheme's operation. Given national specificities and languages this is best managed at the national and local levels.

3.1.2.12 Legal protection and enforceability

Aside from the mechanisms discussed under conformity assessment and market surveillance the other aspect of legal protection and enforcement of the scheme concerns the option to copyright it to protect its intellectual value and limit the risk of misuse and mis-attribution.

Copyright is a form of intellectual property that grants the creator of an original creative work an exclusive legal right to determine whether and under what conditions this original work may be copied and used by others, usually for a limited term of years. The exclusive rights are not absolute but limited by limitations and exceptions to copyright law, including fair use. A major limitation on copyright on ideas is that copyright protects only the original expression of ideas, and not the underlying ideas themselves.

Copyright is applicable to certain forms of creative work. Some, but not all jurisdictions require "fixing" copyrighted works in a tangible form. It is often shared among multiple authors, each of whom holds a set of rights to use or license the work, and who are commonly referred to as rights holders. These rights frequently include reproduction, control over derivative works, distribution, public performance, and moral rights such as attribution.

Copyrights can be granted by public law and are in that case considered "territorial rights". This means that copyrights granted by the law of a certain state, do not extend beyond the territory of that specific jurisdiction. Copyrights of this type vary by country; many countries, and sometimes a large group of countries, have made agreements with other countries on procedures applicable when works "cross" national borders or national rights are inconsistent[101].

Also relevant to this are the recently adopted Directive (EU) 2019/790 of the European Parliament and of the Council of 17 April 2019 on copyright and related rights in the Digital Single Market and amending Directives 96/9/EC and 2001/29/EC, also known, together with the Infosoc Directive, as the EU Copyright Directive.

Copyrighting the SRI would ensure the ownership and control of the intellectual property of the scheme would be legally protected and ensure that designated operatives had the right to use its intellectual property.

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[101] https://en.wikipedia.org/wiki/Copyright

3.1.2.13 Legal liabilities

Risks of legal liabilities could be associated with any of the following:

- mis-claims or misrepresentation made through or on behalf of the scheme which cause reputational damage or financial loss to a third party
- failures in data management, breaches in data security and failure to acquire required consent
- the behaviour of employees working for entities implementing the scheme
- the liabilities scheme implementors have for the well-being of their employees in the course of their duties.

The latter two are well-known and managed through normal employment practices. Thus, the main need would be to put in place any additional risk mitigation and limitation strategies necessary to minimise the risks associated with the first two aspects.

3.2 Activity 2: Technical recommendations for the efficient and cost-effective assessment of the SRI

Following the formatting and implementation pathways identified in Task 2, this activity translates the definition and calculation methodology consolidated in Task 1 into technical recommendations and guidelines for the efficient and cost-effective assessment of the SRI.

These recommendations and guidelines further describe the step-by-step process to be followed when assessing the SRI for a specific building and cover the three main parts of the SRI assessment:

- data needs and data collection methods, e.g. through on-site inspections.
- processing the gathered data to rate the smartness of the various components and services present in the building up to aggregated scores.
- procedures on storing and updating SRI data.

3.2.1 Data needs and data collection method

Depending on the implementation pathway and SRI calculation method favoured, the assessment of the SRI can follow various approaches.

Various types of assessor profiles can be envisaged:

- independent external expert assessors – a detailed technical assessment executed by a trained and potentially accredited expert
- technically trained, but not necessarily independent, assessors – these may include facility managers, contractors, maintenance engineers of social housing companies, employees of energy utilities, etc.
- self-assessment executed by non-experts, e.g. building owners and/or occupants with no receive specific training on TBS or smart services
- in a forward-looking approach, a fully automated procedure where no human interaction is needed, except perhaps for verification or accreditation of the results.

As described in section 1.2.4, the technical study consortium advises the implementation of the following approach:

- An independent external expert assessor is required whenever a formal assessment is desired (methods A and B).
- Self-assessment can be made available but should be strictly framed as an informative tool that does not issue a formal certificate (methods A and B). Method A, the simplified method, is oriented towards small buildings with low complexity (single family homes, small multi-family homes, small non-residential buildings…). The checklist method is accessible for non-experts, such as individual homeowners. Method B, the detailed method, is oriented towards buildings with a higher complexity (typically large non-residential buildings, potentially large multi-family homes). In these cases, a self-assessment by technically trained, but non-independent individuals such as facility managers is advised.
- Future evolutions of the SRI could envision self-reporting of functionality levels by TBSs (an automated version of method B) or a fully automated SRI assessment (method C). These evolutions could limit the required involvement of an assessor, or even make it obsolete. A dedicated topical stakeholder

working group C has been set up to further assess the feasibility of these evolutions (see section 5.1.2).

Alongside the type of assessor, the data collection procedure itself can vary depending on the implementation pathways and the degree of accuracy and representativeness favoured. Various procedures for data collection include:

- on-site inspections of technical features of the TBS present in a building
- on-site inspections of the actually delivered smart services by the TBS
- desk research on technical features of TBS
- checklist approach based on interviews, technical documentation or knowledge of building owner or facility manager, without forcibly requiring on-site verification
- an automated assessment procedure, whereby the identification and assessment of smart services and the calculation of the SRI score is done in an automated way based upon embedded data monitoring functionalities of the TBS.

In practice, there may be a hybrid solution that combines elements from more than one of the procedural categories. For example, on-site inspections may be supported by automated remote detection procedures to automatically evaluate part of the services in the service catalogue.

Because of various combinations of assessor profiles and data collection procedures, the inspection guidelines need to be formulated in a broad sense, describing the overall assessment processes, including the identification of necessary input and inspection and evaluation steps, rather than concrete assessment protocols. They are developed to facilitate the testing of the assessment pathways but later on will need to be detailed at Member State level to concrete assessment protocols.

It is expected that the efficiency of the assessment process will vary significantly based on the expertise of the assessor, the accessibility of the building, the quality of data available and the characteristics and complexity of the TBSs. Potentially, other factors such as the type of buildings, climate zone and type of ownership, etc., will equally affect the efficiency and effectivity of the assessment process. The applicability of the proposed assessment procedures will be evaluated in terms of time and cost for assessment, availability and accuracy of required building technical information, access to technical services and data protection, etc. Moreover, for each of the assessment pathways, the consortium will evaluate the degree to which it is actionable now, or could be in the future, by identifying potential barriers or technological evolutions that affect the efficiency and cost-effectiveness of the assessment. For example, an automated assessment is not expected to be actionable now, as current technologies mostly do not support open data access and a standardised protocol to compute and/or communicate the smart readiness level of technology has not yet been established.

In order to assist the testing phase or the SRI concept (see section 5.1.3), a provisional information package, including a calculation sheet and a guidance document was developed (see 0). It mainly focuses on the approach of on-site inspections through a checklist of smart services that could be performed by various types of assessors. The document provides step-by-step instructions on how to complete the calculation sheet, providing additional information on the various options that may be selected.

The guidance document first describes the scope of the field trial, where the participants were invited to test a building of their choosing. Participants were given the option to apply method A (simplified method), method B (detailed method) or both methods, where method B was put forward as the default option.

Second, the document provides guidelines on general information to be provided by the assessor. This information may be divided into two categories. On the one hand, general information on the assessor and the building are collected. This includes informative input fields such as contact details of the assessor and a description of the building. It also includes information on the building type, building usage and geographical location (in terms of climate zones). These inputs are used in the calculation methodology to select the appropriate weighting factors.

Next, an essential element in this assessment guidance package is the provision of a protocol to handle missing services. This process is referred to as the triage process. As discussed in section 1.3.5, the triage process can have significant implications in respect of the SRI assessment and scoring. In the calculation sheet used in the field trial, two levels of information are collected to support the triage process. First, the presence of each technical domain is indicated. When present, additional specification of the TBS is required to enable further triage of relevant services. The guidance document provides a detailed description of the various subsystems, aiming to enable an unambiguous selection of the most appropriate system. Further detail may be required as part of the training material for (future) assessors.

Finally, instructions are provided to fill out the check-list based calculation sheet. The instructions are strongly linked to the specific context of the calculation sheet, which was developed for testing purposes only. The document focuses on the use of the calculation sheet and does not elaborate on individual services or functionality levels. As part of the implementation of the SRI methodology, it is advised to develop a more elaborate inspection protocol that may include additional details. Potentially, a protocol for documenting and collecting proof on the functionality level of each service may be included.

As part of this field trial, the efficiency of the assessment process was probed in a broad sample of buildings, comprising various building types, climatic zones and types of assessors. Registered stakeholders were encouraged to take part in this field trial and test the SRI assessment procedure on buildings of their choice. Stakeholders who signed up for this field trial received an information package comprising the calculation sheet and the assessment guidelines. The results of the public field trial are discussed in section 5.1.3.

The lessons learned from the test phase were collected and consolidated in the final technical recommendations on the SRI definition and methodology.

3.2.2 SRI DATA PROCESSING

During the assessment process, the assessor (or an automated system) collects data on the various smart services present in a building. This can cover a wide range of services, e.g. temperature regulation, EV charging capabilities and provisions on automated solar shading control.

In the proposed SRI calculation methodology, information on the individual services is translated into a multitude of impacts. Next, these impact scores are processed into aggregated scores, either a single score at building level, or multiple sub-scores at impact category or domain level.

To make the SRI effective and cost-efficient, the process of converting inspections on smart services to SRI scores should be fully automated. This will also ensure a far more objective and replicable approach, where one does not rely on the appraisal of individual assessors to derive the impacts from smart technologies or provide weighting factors for a multitude of domains and impact categories.

The calculation methodology for the SRI is straightforward and based on simple summations using sets of weighting factors. Nevertheless, the number of services and weighting factors and the potential need for normalisation would make a manual calculation cumbersome and prone to errors. Therefore, it is suggested that the calculation is embedded in a numerical tool. During the field trial a spreadsheet application was provided to the assessors. The information to be provided by the assessor is two-fold: on the one hand, general information on the building and its technical building systems should be provided. This supports the selection of the correct weighting factors and the triage process. On the other hand, the functionality level should be provided for each service. To this end, the list of relevant services – based on the triage process – is presented to the assessor. The calculation of impact scores and the overall scores occurs in an automated manner.

Given the low computational power needs, various other tools can be envisaged during a later implementation phase, including smartphone or tablet applications and online calculators. A priori, it would be possible to have one single calculation core to be used across the entire EU. Some elements within the calculation core (e.g. weighting factors for heating versus cooling needs) could then be further tailored to local conditions in various climatic zones.

3.2.3 PROCEDURES ON STORING AND UPDATING SRI DATA

During the SRI assessment process, a significant amount of data needs to be sourced on topics including:

- smart services that are either present or missing in a building
- the functionality level of the services present
- the type of building usage, in case this is relevant for the assessment.

Potentially, additional information is also collected or generated during the assessment process, such as:

- technical information on specific TBSs, e.g. reporting technical interoperability or cybersecurity aspects
- pictures or notes taken during on-site inspections
- feedback or recommendations given by the assessor.

Much of the data will be processed into an applicable format comprising the results of the SRI assessment. It can be relevant to store such outcomes (label, report, etc.) in a central database. This allows for the handing over of information to new owners or tenants, carrying out statistical analyses to support policy-making and the performance of quality control checks. One might also opt to open up specific parts of the data to external actors, e.g. grid operators requesting insight on the demand-side flexibility offered by a specific set of buildings. In any case, a sound data management and data security process will be required to ensure compliance with GDPR and cybersecurity regulations.

Apart from the assessment outcomes, the source data and accompanying data generated during the assessment process could also be stored. This could be part of an official accreditation process, allowing quality control on the SRI assessments. Second, a data repository would be a powerful instrument when updating the SRI of a building. Depending on the implementation pathways favoured, such updates of an SRI score could happen at fixed intervals (say every 5 or 10 years) or trigger points (e.g. change of owner) or be more flexibly updated (e.g. when installing a new TBS). A smooth and secure process for retrieving previously entered SRI data will greatly support the efficiency of the SRI assessment. For some of the implementation pathways, this could lead to a regular update by the owner, facility manager or contractor every time the building receives a TBS upgrade.

Finally, a secure set of SRI data for a particular building is also essential for forward-looking SRI approaches. These could take various formats, including:

- a regular update of elements of the SRI methodology (e.g. SRI weighting factors, functionality levels, etc.), leading to an automated recalculation of the SRI score
- an automatic recalculation of the SRI score when a TBS receives new functionalities, e.g. an over-the-air update of the control logic of a heat pump that unlocks higher functionality levels compared to the prior assessment
- datasets are essential when one wants to rely on automatically reported data to assess the functionality levels (Method B) or an assessment based on metered performance (Method C). Further consideration needs to be given to the data resolution required and the physical location of the data gathered (e.g. on the premises in a TBS, in a BEMS, in a dedicated SRI dataset managed at national level, etc.).

While the set-up and maintenance of databases can be left to implementation bodies, it can be relevant to consider an overarching European initiative to define a common database structure and ontology.

3.3 Activity 3: Guidelines for the management of the SRI after adoption

Whereas the technical framework for the SRI definition and underlying calculation methodology is proposed in a manner that is open for innovation, a key challenge for the success of the long-term SRI impact is to stay aligned with the fast-growing industry of smart technologies and quickly evolving smart services. This task therefore formulates guidelines for maintaining and adapting the catalogue of smart services and the methodology for calculating the SRI.

In the last part of this activity, implications for the effective management of these processes are set out.

To address technological progress and related market developments the management of the SRI catalogue of services and calculation methodology post introduction of the scheme needs to include the following:

- A regular, periodic review and related development work

- A fast track option to consider the merits of promising emergent technologies and services
- A process to agree and issue version changes and associated reporting requirements
- An appropriate management structure.

Each of these are discussed below with regard to the set of activities that would need to be done and in the case of the management structure it's characteristics. Topical group C has also reflected on the need for updating the SRI – both with regard to the methods A and B and the potential evolution towards a performance based method C. Their suggestions are discussed in the topical group C first recommendations report.

3.3.1 Regular periodic review and related development work

The regular periodic review can be broken down into two reviews:

- a review of the service catalogue
- a review of the calculation methodology.

3.3.1.1 Review of the service catalogue

The purpose of the periodic review of the SRI service catalogue is to ensure that:

- the classification of functionalities is appropriate in ensuring technology neutrality while reflecting the current state of the art
- impact scores ascribed to the functionalities are in line with the evidence
- the most appropriate services are listed within the catalogue.

The steps necessary for these actions are now described in turn.

Ensuring the classification of functionalities is appropriate and reflects the current state of the art

As technologies and services evolve so will the spectrum of functionalities that are available or imminent on the market. As the SRI is a forward-looking tool designed to accelerate the adoption of such functionalities, providing they are within the scope set out by the EPBD, then there is a need to regularly review the functionalities per service to ensure they are still fit for purpose. This review process needs to consider the following for new service solutions:

- What new solutions are available to provide the service and what additional level of functionality do they provide?
- How feasible is it to assess this functionality?
- Does the extra functionality provided merit either adding a new functionality classification above the existing ones in the (usually ordinal) scoring system or implementing a reclassification of all the functionality levels applied for the service?

A review is also necessary for existing services to consider the following:

- Do the existing set of functionalities correctly capture the available means of providing the service and frame them in a technology neutral manner?
- What has been learned about the viability of assessing these service functionality levels and does this require any changes in their definitions which could facilitate assessment?
- Are there any recommendations that could be made about: a) how the operation of the scheme could facilitate more reliable assessment of functionality levels, b) the actions market actors could take to facilitate assessment?

Ensuring that impact scores ascribed to the functionalities are in line with the evidence

The impact scoring used in the current iteration of the SRI service catalogue ascribes ordinal rankings to each smart service functionality level per impact criterion. The evidence used to inform these rankings needs regular review to ensure they correctly reflect current understanding and that impacts are appropriately mapped to functionality levels. This review can be conducted service by service to clarify the relative ranking of impacts per functionality level, but this then needs to be repeated horizontally across all the services to ensure maximum consistency and coherence in how the scores are ascribed across the ensemble of services.

This distinction is potentially important for the management of the review process because while expertise at the service level is necessary to understand the distinct characteristics of each service, multidisciplinary evaluation skills applied within a transparent framework are required to provide an even-handed evaluation of impact scores across the set of service offerings included in the catalogue.

Furthermore, for any specific impact criterion it will be necessary to review whether it is possible to move from ordinal to quantified scoring. This has already been mooted by the study team as a possible option for energy savings as the underlying energy savings scores used for most of the smart services in the current version of the catalogue are derived from the standard EN15232 and the same standard includes BACS factors that report relative quantified energy savings impacts associated with the BACS functionality levels. However, if a switch to quantified impacts is to be made it has to be applicable to all the services that score for the impact criterion in question and has to have a credible and reliable technical foundation.

Ensuring that the most appropriate services are listed within the catalogue

To review whether the smart services contained within the catalogue are the most appropriate the review body will need a distinct but related assessment process for new prospective services that could be added to the catalogue and for existing services. For new prospective services the review body will need to:

- map the array of new services that could theoretically be included within the catalogue
- determine their compatibility with the scope of the scheme as set out in the EPBD and exclude any services that are outside that scope
- assess the expected magnitude of benefits, in terms of the scheme's impact criteria, that each prospective new service offers
- consider how readily the service can be assessed in accordance with the scheme's assessment process (or processes) and determine the viability and level of effort required to conduct such an assessment(s).

For existing services, the review needs to:

- assess the definition and boundaries of the service and whether they are still appropriate given market and technology developments
- review whether the magnitude of impacts the service delivers is still in line with previous expectations
- assess the evidence of the practicality of assessment of the service in terms of its viability of being assessed and level of effort required to assess it.

Once both of the above set of actions are complete the review body should bring the findings together and consider the relative merits of the existing and potential new services for inclusion in the scheme. In doing this they need to consider:

- the relative ranking of benefits per service type
- the extent to which those benefits encompass the three pillars of the SRI to ensure that the service coverage provides a suitable set of services responding to the needs of each pillar
- the viability of adding potential new services without removing existing ones.

In the event that it is viable to add a new service without requiring the removal of existing ones (i.e. that the extra assessment effort associated with the new service would have little impact on the overall assessment process and level of effort) then the prospective new services this applies to could be put forward for consideration for inclusion in the next iteration of the scheme.

For prospective new services where it would not be not viable to include them without excluding an existing service, then:

- the review body needs to determine whether any of the prospective new services would bring more benefits than any of the existing ones
- if it is not the case then the service would not be recommended for inclusion in the next iteration of the scheme but rather return to a prospective service tracking list for future reviews
- if it is the case then an assessment needs to be made of the relative viability of assessment of both the prospective new service and the service it could replace before determining whether the expected extra benefits of the prospective new service compared to the existing one and the practicalities of assessment are sufficiently compelling that it would be recommended for consideration for inclusion in place of the existing service on those grounds.

Once a list of prospective changes in the services to be included in the catalogue is developed from the above processed then an additional assessment is needed to consider whether the added value of including the proposed services (and potentially removing existing ones) justifies the disruption that changes in the service catalogue are likely to make in the implementation and communication of the scheme.

The same is true of any modifications to be made in the catalogue, including those concerning evolution in functionalities and impact scores.

3.3.1.2 Review of the calculation methodology

The review of the calculation methodology will consider a higher-level set of issues than those discussed for the service catalogue. In particular, it needs to consider:

- whether the methodology adequately addresses the current scope of the scheme
- whether the methodology is appropriate for the current implementation of the scheme
- the suitability of weightings to be applied
- treatment of missing services
- suitability of the methodology as a function of building type
- suitability of the methodology as a function of climate type
- how the methodology needs to evolve to encompass envisaged changes in the scope of the scheme
- how the methodology needs to evolve to address envisaged changes in the implementation of the scheme.

Suitability of the methodology for the current scope of the scheme

This review step will consider whether there are any aspects of the methodology which are incompatible with the current scope of the scheme and whether potential changes in the methodology could improve how the scheme addresses the scheme’s scope.

Suitability of the methodology for the current implementation of the scheme

This review step will consider whether there are any aspects of the methodology which are incompatible with the current implementation of the scheme and whether potential changes in the methodology could be made that would help to improve the scheme’s implementation and the reliability and value proposition of the results.

This step will need to ensure that appropriate feedback on the interaction between the scheme’s implementation and the calculation methodology is gathered and analysed so the findings can be taken into account. This will need to take account of the set of implementation pathways being followed, the type of SRI methodology being used (if more than one type of SRI methodology is developed), and the evidence from the field of how the issues encountered in using the methodology in terms of the reliability of the results produced, the strength of the value proposition to the target audiences, the readiness and uptake of the methodology (and related interactions with the nature of the methodology). As more than one SRI methodology could be in use (depending on decisions yet to be made) the review will need to segment the review as a function of the permitted set of combinations of the type of methodology and the implementation pathway it is applied to.

Weightings

Review of the suitability of the weightings applied will be a critical element in the review process and be can expected to require substantial analysis. As the derivation of weightings can be partly deterministic e.g. for climate related impacts on energy and partly subjective (based on application of a set of values which may be held personally or intended to be representative of the broader community) care needs to be exercised to ensure that weighting determinations are documented, are transparent and to the extent possible based on an agreed rationale. Furthermore, this is an area which requires as much impartiality and representativeness as its possible to practically ensure in the composition of the review body.

The weightings review will also need to distinguish any necessary differentiations as a function of the following:

- impact criterion
- domain
- building type
- climate type
- missing services.

Treatment of missing services

The review will also need to consider how the methodology is addressing missing services, including the extent to which the methodological rules:

- have been straightforward to implement, or whether issues have been encountered with regard to their interpretation and application
- are appropriate as a function of the type of SRI assessment being done
- are appropriate as a function of the building type being assessed
- are appropriate as a function of the nature of the locale where the building is located (e.g. as a function of the urban density, or historic nature, etc.)
- are appropriate as a function of climatic and geographical variations.

Evolution of the methodology in response to changes in the scope of the scheme

A critical function and role of the methodological review will be to address changes in the methodology that need to occur due to changes in the scope of the scheme. For example, if changes in the regulatory framework or their interpretation lead to the need to incorporate additional service domains or impacts such as access and security, fire safety, earthquake protection, entertainment services etc. In principle the existing methodology is structured so that it is flexible with regard to the number of domains and impacts that are included, however, each time a new one is added it has some ramifications that need to be addressed.

Evolution of the methodology in response to changes in the implementation of the scheme

Decisions with regard to the specific implementation pathways to be used or with regard to the ultimate choice of permitted assessment methods (especially those concerning on-site versus online and simplified versus expert assessment methodologies) and the ultimate set of calculation methodologies to be applicable in the scheme could affect the nature of the calculation methodologies to be used in the initial stages of the scheme. However, as the implementation of the scheme matures these choices will need to be reviewed and potentially amended or added to in response to developments in implementation.

In the future it is conceivable that tailored versions of the SRI methodology will be required depending on:

- the applicable assessment method(s)
- the complexity and status of the assessment
- the nature of the building type being assessed
- the nature of data acquisition and how it is fed into the calculation tool(s)
- the reporting requirements.

The greatest methodological changes would occur were there to be a migration towards the use of real time data potentially linked to assessment of actual performance rather than just readiness. Such a migration would require a substantial methodological development and maintenance effort.

3.3.2 FAST TRACK PATHWAY TO CONSIDER THE MERITS OF PROMISING EMERGENT SMART TECHNOLOGIES AND SERVICES

Because smart services are a rapidly evolving field addressing important technology and market developments within the constraints of the regular review and maintenance cycles of the SRI as set out in the previous sections may not always be responsive enough to capture important emergent opportunities or to avoid reputational risk e.g. the risk that the scheme claims to classify smart readiness of buildings but isn't smart enough to have included a new service with well-known benefits. As a consequence, the management of the smart services catalogue, in particular, and the methodology (less often) will need to have the option of invoking a fast track process wherein a promising emergent smart service can be scrutinised at short notice to determine whether it might merit fast-tracking an amendment of the scheme to permit its inclusion.

This fast track process will need:

- a trigger mechanism wherein a candidate emergent service or service solution can be put forward for a fast-track screening
- a provisional initial screening assessment wherein the merits of the candidate are provisionally screened to see if it merits a full assessment
- a full assessment mechanism (if the screening stage is passed)
- invoking of the full review assessment steps (as set out in 5.4.1) but just for application to the specific solution if the full assessment determines the candidate solution is likely to merit such a step.

Potentially, the trigger mechanism could be any of:

- private or public-sector actors providing notice of a candidate service, or service solution which they believe merits fast-tracking
- those charged with management of the scheme becoming aware of promising candidates and requesting the mechanism be invoked.

The first point of contact would then ask for the basis of the suggestion and a minimum set of supporting evidence or documentation. If the proposer does not have all of the minimum set of evidence a process would have to be undertaken to appraise if the evidence or arguments submitted are sufficiently compelling to merit making additional efforts to acquire that information. In the event they are, and a minimum required evidence set is compiled this could be submitted to the body charged with the initial screening. That body would be invoked and conduct the screening before making a determination of whether to propose a full assessment be undertaken. If this is the case the body responsible for the full assessment would set about compiling the necessary information, noting that most commonly this would either be requested to be delivered by the proposer (for example, if they are a commercial representative of a company offering the service), or the details of the service provider could be requested (as part of the minimum information set) and then the supplier could be contacted by the body to request they supply the information. If enough information can be compiled the body responsible for the full fast track review can then conduct their assessment and determine whether the case is sufficiently urgent and compelling as to require the full SRI catalogue and/or calculation methodology review process, be invoked at the earliest possible notice. This set of stages and filters is necessary to avoid spurious or immature proposals leading to the unnecessary frequency of a full review process but also to ensure that a proper process is followed. If a candidate service is precluded at any stage due to insufficient evidence the applicant can be informed of this and invited to resubmit their application when the have compiled the required evidence. At each stage the first respondent and scrutiny bodies would be required to record the details of the application and their actions in response to it, so a transparent paper trail is maintained to support the actions of the application and review stages to ensure a proper and transparent process is in place.

Maximum time delays associated with each stage would need to be established, both with regard to the time given to applicants to compile required evidence and with regard to the time the fast track respondents/bodies need to process the material and make determinations.

3.3.3 PROCESS TO AGREE AND ISSUE VERSION CHANGES AND ASSOCIATED REPORTING REQUIREMENTS

Every time changes are made to the SRI service catalogue or methodology it would constitute a change in the manner of SRI assessment and hence would mean a reduced comparability between one assessment and another. This reduction in comparability has consequences in terms of the understanding of the SRI scoring and the organisational effect the SRI has on service offers. If the scheme's criteria change too frequently, they will diminish the ability of service and SRT suppliers to position their offers within the framework and reduce their engagement and the associated strength of the "push" effect. If they change too slowly, they will render the scheme obsolete and make it unresponsive to important changes in technology and the market. Thus, the decision of whether such changes merit issuing a revised catalogue and/or methodology will need to weigh-up the relative importance of these effects. As a consequence, they are not purely technological or technical in nature but require a much broader understanding of how the scheme functions and the different consequences of issuing updated SRI versions. It should be noted that changes that involve adding new services or domains do not ordinarily affect the classification and assessment of existing ones (unless it would lead to a service being demoted from the scheme) and thus, changes of this nature can occur without any negative impacts on the positioning of existing products and services within the framework. On the other hand, it is also the case, as has been experienced with energy labelling, that taking too long to update performance scales can also have a negative impact on the market as services become bunched into the top of the scale and there is insufficient differentiation.

This leads to commoditisation which reduces the value of products and services for their suppliers.

Many existing schemes confront version management issues and the usual response is to clearly delineate versions in the reporting of the scheme, so users are aware of the version which was used in the assessment and can take that into account. It is also technically possible to take data submitted under an old version and calculate how the scoring would change under the latest version. Thus, if the data used under a previous version of the scheme is still accessible a facility could be established to enable this recalculation.

In any case, as the decision regarding whether to issue a new distinct version requires careful deliberation of the merits and demerits a body has to oversee this which has the requisite mandate and competences. It could be imagined that a periodic, or fast-tracked, meeting of the relevant review body leads to a provisional recommendation that from a technical perspective the SRI should be updated to accommodate various evolutions; however, the body charged with the decision of whether to issue a new version (which could be the same as the review body or separate from it) may consider that the stability of the scheme is more important at that stage than the value of including the changes. In which case, the proposed changes could be parked and reconsidered at the next review cycle when additional proposals for change, creating more overall value from the issuance of an up-dated version, may be put forward and lead to a critical mass being reached in favour of issuance of an update.

3.3.4 IMPLICATIONS FOR THE MANAGERIAL STRUCTURE OF THE SRI

The discussion above has set out the functions and some organisational aspects that would be required to:

- conduct a regular, periodic review and related development work of the catalogue and methodology
- provide and administer a fast-track option to consider the merits of promising emergent technologies and services
- undertake a process to agree and issue version changes and associated reporting requirements.

To be viable the management structure used to implement these functions needs to map competences and mandates to the delivery process in an efficient manner that allows effective and cost-effective operation.

The review and maintenance of the service catalogue requires service and domain specific knowledge concerning the available technologies and markets but also knowledge regarding the implementation of the scheme. It also requires multidisciplinary appraisal competences capable of doing horizontal assessments across service offerings and impact categories. In both regards this implies access to experts rather than policy representatives. In principle, the organisation of this work could best be managed by a blend of an overall working group (charged with making overall determinations across services, domains and impacts) supported by domain specific-working groups (perhaps established on a per need or ad hoc basis). The option exists to establish formal "working group(s)" or to hire consultants to conduct the assessments, or a blend of both. The advantage of a formal expert working group structure is that it is more clearly transparent and could bring in a broader set of subject matter experts chosen to represent the range of relevant domains. The advantage of hiring consultants is that their working methods are likely to be more focused and efficient. In either case mechanisms will need to be established to both consult stakeholder input and views and to receive feedback on any implementation issues that have implications for the catalogue. The degree of permanency, and hence stability/coherence, of the working arrangements also needs to be considered to ensure there is sufficient institutional memory in the derivation of the catalogue.

It is a comparable situation with regard to the management of the calculation methodology in that similar competencies are required (especially with regard to the multidisciplinary appraisal skills and also knowledge with regard to assessment and implementation). The same issues apply regarding the representativeness of those charged with fulfilling this function. Given these overlaps and the need for coherence in the evolution of the catalogue and the calculation methodology it could be imagined that the same actors could fulfil the role of the multidisciplinary appraisal function for the catalogue and the review and development of the calculation methodology.

The provision and administration of a fast-track option requires the existence of a permanent structure e.g. a focal point and/or secretariat that serves the role of point of first contact and potentially also the screening and full appraisal roles. As the screening and full fast-track appraisal roles require strong technical knowledge and an in-depth understanding of the scheme they could potentially be outsourced to a consultant or conducted by a lead expert (or small group of experts) who also work on the catalogue and/or methodology.

The decision-making with regard to agreeing and issuing version changes and associated reporting requirements could be undertaken by a more politically representative management committee. It has a higher-level function and requires less direct technical knowledge. Its meeting could be held periodically or convened by request from those responsible for maintenance and upgrade of the catalogue and methodology. Considering that it would be charged with appraising the material presented to it by the catalogue and methodology managers to determine whether an updated version needs to be issued it could also fulfil a scrutiny role on the conduct of the catalogue and methodology managers.

4 TASK 4 - QUANTITATIVE MODELLING AND ANALYSIS OF THE IMPACT OF THE SRI AT EU LEVEL

TASK SUMMARY & OBJECTIVES

The objective of Task 4 is to quantify the costs and benefits of implementing SRI in the EU building sector for the horizons of 2030, 2040, 2050. This impact analysis encompasses the different implementation pathways proposed in Task 2. The benefits and effects along the selected criteria will be accurately quantified (primarily in monetary, energy and emission units) on a yearly and cumulative basis and will be subjected to a sensitivity analysis. This analysis has built further on the outputs from the preliminary analysis of impacts performed in the first technical study on the SRI and has aligned with other recent studies on the wider benefits of energy efficiency and smart ready technologies.

The impact analysis is organised into three parts. First, the building-level impact of increasing levels of smart technology integration is quantified for a carefully selected set of reference buildings covering single-family and multi-family (both small and large) residential buildings as well as offices, wholesale and retail buildings and education buildings. In addition, the analysis diversifies according to climate region, construction period and renovation level.

Second, the impact of different implementation pathways and policy options on the deployment of the SRI is evaluated. Structured around different trigger events and the rate at which SRI assessments would be conducted during these trigger events, depending on the implementation pathways, projections are made on the share of buildings for which an SRI assessment is carried out. As the SRI is a voluntary scheme, the calculation tool reflects implementation pathways and policy options at both the EU level and the regional level. Moreover, differentiation can be made between different building types.

Finally, combining the output from the building-level impact and the projections on the deployment of the SRI, the impact of the different implementation pathways and policy options at the EU level is quantified.

The overall methodology outlined above comprises the following four sub-activities:

- Activity 1: determining the building-level impact of smart technologies and services
- Activity 2: definition of impact scenarios reflecting policy options
- Activity 3: aggregation of individual variants and calculation scenarios
- Activity 4: sensitivity analysis.

4.1 ACTIVITY 1: DETERMINING THE BUILDING-LEVEL IMPACT OF SMART TECHNOLOGIES AND SERVICES

The main objective of this activity is to quantify the impact of smart technologies and smart services at the individual building level for a representative and diverse set of reference buildings. The results can subsequently (in Activities 2 to 4) be used to determine scaled impacts at the whole EU level. Furthermore, these results will support the scenario analyses carried out in Task 1 Activity 3 in support of the calculation methodology development and in Task 3 Activity 2 to investigate the different implementation and assessment pathways.

The bottom-up approach followed in this study starts with the selection of a set of reference buildings. A reference building is defined as a typical building in terms of its function, geometry, thermal quality, HVAC system and BAC system within the building stock. This allows for the subsequent analysis of an entire building stock by conducting analyses – from the bottom up – on different reference buildings and then aggregating the results as a function of how common these buildings are within the whole stock.

The selection of the most relevant reference buildings significantly depends on their shares in the building stock. A detailed presentation of the building stock descriptions used for this study and the selection and definition of the reference buildings is outlined in ANNEX C. Aligned with the first technical study on the SRI, the specified reference buildings will primarily be used to calculate the energy use and savings potentials of different smart technology and service measures at the individual building level for five climate zones in Europe. This disaggregation across both building types and climatic zones (i) allows the more accurate assessment of potential impacts of smart technologies and services and (ii) takes into account the potential differences in implementation pathways and policy measures installed at the Member State level.

To determine the building-level impact of SRTs, six performance criteria have been defined:

- energy use
- greenhouse gas (GHG) emissions
- self-consumption of renewable energy
- energy security
- material circularity
- comfort and well-being.

Since the building-level energy and GHG emissions savings are important input parameters in assessing the EU-level impact of the SRI, a detailed model has been developed and implemented to directly calculate these KPIs. These calculation results are complemented with impacts estimated from a detailed literature study on the other KPIs. The following sub-sections present the approach and results for each of the KPIs.

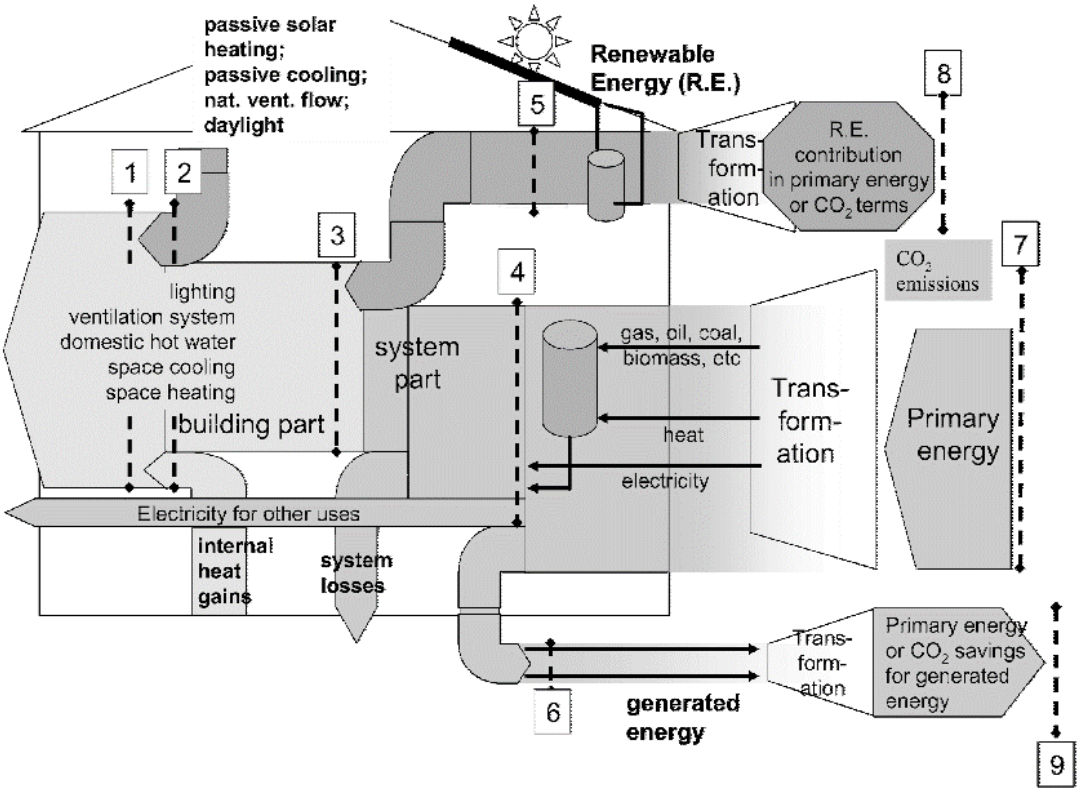
4.1.1.1 Energy use

In the context of the EPBD, the impact of smart ready services and technologies on the energy use of buildings is evaluated as a first key performance indicator. For each of the reference building cases, the energy use is modelled in accordance with the EN 52000-1:2017 series. The energy savings related to smart services and technologies are quantified based on key EU standards such as EN 15232 for the energy performance of BACS and EN 15500/ISO 16484-3 for electronic control equipment in the field of HVAC applications. For TBSs, energy use is quantified using the respective standards:

- heating, EN 15316-1 and EN 15316-4
- hot water, EN 15316-3
- cooling, EN 15243
- ventilation, EN 15241
- lighting, EN 15193
- specification requirements for integrated systems, EN ISO 16484-7.

Smart services and technologies may unlock energy savings both by improving the energy efficiency at building level as well as by allowing the optimization of energy flows on an aggregated energy grid level. The energy use impacts of smart services and technologies targeted in this paragraph only considers the building level impact, using the 'on-site' perimeter definition in EN 52000-1:2017. The impact of smart buildings in relation to the energy grids, e.g. through offering demand-response services, is accounted for in further KPI's on "renewable uptake" and "energy security".

For each of the selected reference buildings, the net energy demand for heating, cooling, ventilation, sanitary hot water and lighting are determined. Based on the reference geometries and building envelope and TBS characteristics, the net energy use for heating and cooling is assessed using EN 52016. As these net demands are primarily governed by the building design and fabric characteristics, which are assumed not to be affected by the SRI, these net energy demands are verified and aligned to match the total energy use of the corresponding segment of the building stock as presented in the EPBD impact assessment and the first technical study on the SRI. Given the wide scope of the analysis and its main purpose of feeding into the EU-level impact analysis, it was decided that the different levels of smartness for the analysis of the impact of SRTs would be defined only at the energy domain level (heating, cooling, ventilation, domestic hot water, lighting) rather than at a technical system level. In other words, the calculation method allows the assessment of the overall energy savings when, for example, improving the level of smartness of the heating system by one or more levels of smartness. As such, the calculation method is technology-neutral and largely follows the proposed calculation method in EN 15232. The energy use for each of these configurations is modelled according to the standards described above. Based on EN 15323 the impact of increasing the smartness of TBSs on final energy use is quantified. An overview of the calculation process, that is followed for each of the building types, is given in Figure 31 based on the umbrella document (CEN/TR 15615). It involves following the energy flows from the left to the right.



(1) Represents the energy needed to fulfil user requirements for heating, cooling, lighting, etc., according to levels that are specified for the purposes of the calculation.

(2) Represents "natural" energy gains: passive solar heating, passive cooling, natural ventilation, daylighting U factor together with internal gains (occupants, lighting, electrical equipment, etc.).

(3) Represents a building's energy needs, obtained from (1) and (2) along with the characteristics of the building itself.

(4) Represents the delivered energy, recorded separately for each energy carrier and inclusive of auxiliary energy, used by space heating, cooling, ventilation, domestic hot water and lighting systems, taking into account renewable energy sources and co-generation. This may be expressed in energy units or in units of the energy ware (kg, m3, kWh, etc.).

(5) Represents renewable energy produced on the building premises.

(6) Represents generated energy, produced on the premises and exported to the market; this can include part of (5).

(7) Represents the primary energy usage or the CO_2 emissions associated with the building.

Figure 31 – Schematic Illustration of the calculation methodology. Source: CEN/TR 15615.[102]

[102] The figure is a schematic illustration and is not intended to cover all possible combinations of energy supply, on-site energy production and energy use. For example, a ground-source heat pump uses both electricity and renewable energy from the ground; and electricity generated on site by photovoltaic could be used entirely within the building, or it could be exported entirely, or a combination of the two.

As a reference for comparison, a comprehensive investigation into the energy savings potentials of the proper utilisation of BACS in the EU's building stock was used[103].

Figure 32 shows a snapshot of the calculation sheet outcome for one of the reference buildings, i.e. a retrofitted single-family building for the Western European climate zone. For the example building, the calculation sheet shows the absolute and relative energy savings for each of the components of energy use (heating, cooling, ventilation, lighting, domestic hot water) when improving the level of smartness of the TBSs. Evidently, the largest savings are obtained when increasing the system smartness from level D to A according to EN 15232, with a resulting 25% total energy saving. Note that just as the relative share of the domains will vary for different building types, total energy savings will depend on the building type as well as the boundary conditions (e.g. climate). The calculation tool allows the rapid selection of combinations of building type, age class, renovation level and climate region for analysis of the detailed energy saving.

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[103] http://www.leonardo-energy.org/white-paper/building-automation-scope-energy-and-co$_2$-savings-eu

Residential

Climate region:	Western Europe
Building type:	Single family house
Construction period:	1960-1990
Retrofit level:	Renovated

SRT level		D	C (Reference)	B	A
Heating system					
	BAC efficiency	1.09	1.00	0.88	0.81
	Qheating	16433	15076	13267	12212
Cooling system					
	BAC efficiency	1.09	1.00	0.88	0.81
	Qcooling	214	197	173	159
Ventilation system					
	BAC efficiency	1.08	1.00	0.93	0.92
	Qventilation	902	835	777	768
Lighting system					
	BAC efficiency	1.08	1.00	0.93	0.92
	Qlighting	635	588	546	541
DHW system					
	BAC efficiency	1.11	1.00	0.90	0.80
	Qdhw	4460	4018	3616	3214

Saving

	D->C	D->B	D->A	C->B	C->A	B->A
Heating	1357	3166	4221	1809	2865	1055
Cooling	18	41	55	24	37	14
Ventilation	67	125	134	58	67	8
Lighting	47	88	94	41	47	6
DHW	442	844	1246	402	804	402

Saving [%]

	D->C	D->B	D->A	C->B	C->A	B->A
Heating	8%	19%	26%	12%	19%	8%
Cooling	8%	19%	26%	12%	19%	8%
Ventilation	7%	14%	15%	7%	8%	1%
Lighting	7%	14%	15%	7%	8%	1%
DHW	10%	14%	28%	10%	20%	11%
Total	**9%**	**19%**	**25%**	**11%**	**18%**	**8%**

Figure 32 – Example of the calculation tool for residential buildings

Based on current energy prices, annual savings are up to 6 €/m² for the oldest, unrenovated houses and 2–3.5 €/m² for recent constructions or renovated buildings when upgrading from level D to level A. When upgrading by one level of smartness, savings vary between 0.2 €/m² and 2 €/m². As expected, these results show a clear dependence on the original energy demand of the building prior to installing the SRTs, since the calculated relative energy savings are found to be independent of the building type. Considering specific investment costs of 4.8 €/m² and 16.8 €/m², respectively, for an upgrade of one level of smartness or an upgrade to level A[104], simple payback times vary between 2.8 years for the oldest unrenovated houses and 4.8–8.4 years for new or renovated houses when upgrading to level A, and 2.4–24 years when upgrading by one level of smartness. The longest payback times are obtained when upgrading retrofitted buildings from level B to level A, as for these cases the original energy demand and hence savings potential were already the lowest.

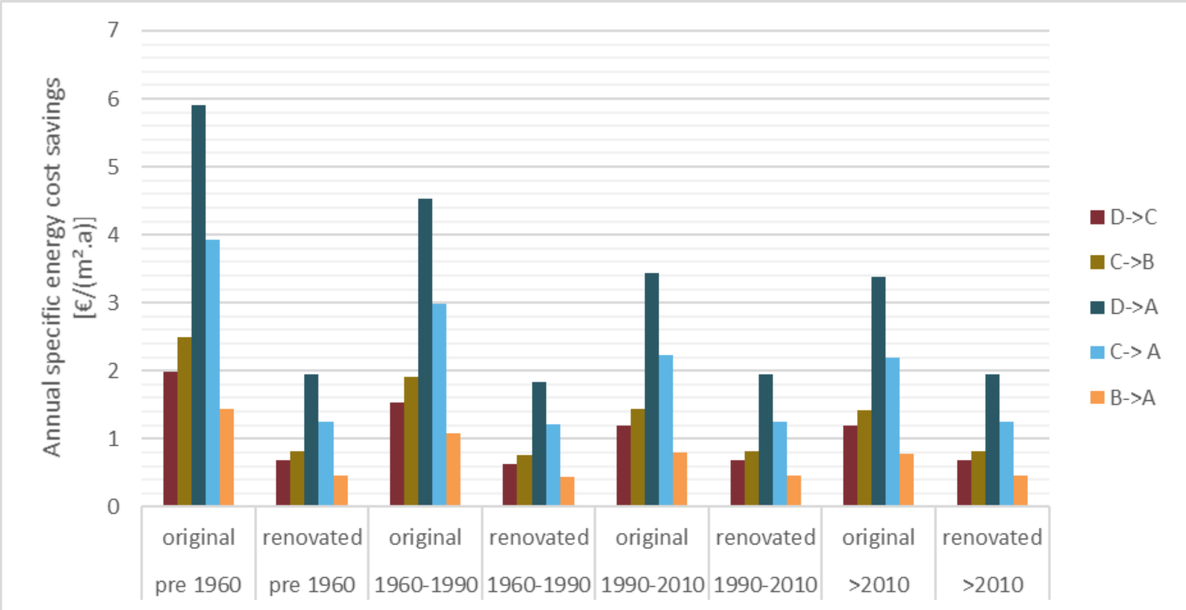

Figure 33 – Specific annual energy cost savings resulting from energy efficiency gains from SRT uptake for the example of single-family houses in Northern Europe as a function of construction year and renovation level

Another outcome of the building level impact calculation are the relative energy savings as exemplified in Figure 34 for offices. The results are shown as a function of the construction period and renovation level. As correction factors defined in EN 15232 vary more significantly among the energy domains, a variation in the relative energy savings is found as function of the building thermal quality depicted by the construction period and building renovation level. Overall, relative energy savings are higher than for the residential buildings, with a maximum relative energy reduction of 45–49% when upgrading Northern European office buildings from level D to level A.

As the distribution of energy use among the energy domains (heating, cooling, ventilation, lighting and domestic hot water) plays a significant role in the relative energy savings following SRT upgrades in non-residential buildings, differences of up to eight percentage points are found when comparing the same buildings for different climate zones (e.g. Figure 35) or different types of non-residential building type (e.g. wholesale and retail buildings in Figure 36).

104 These figures are in line with values reported in Ecofys & WSE (2017), *Optimising the energy use of technical building systems: Unleashing the power of the EPBD's Article 8* – Ecofys and Waide Strategic Efficiency for Danfoss.

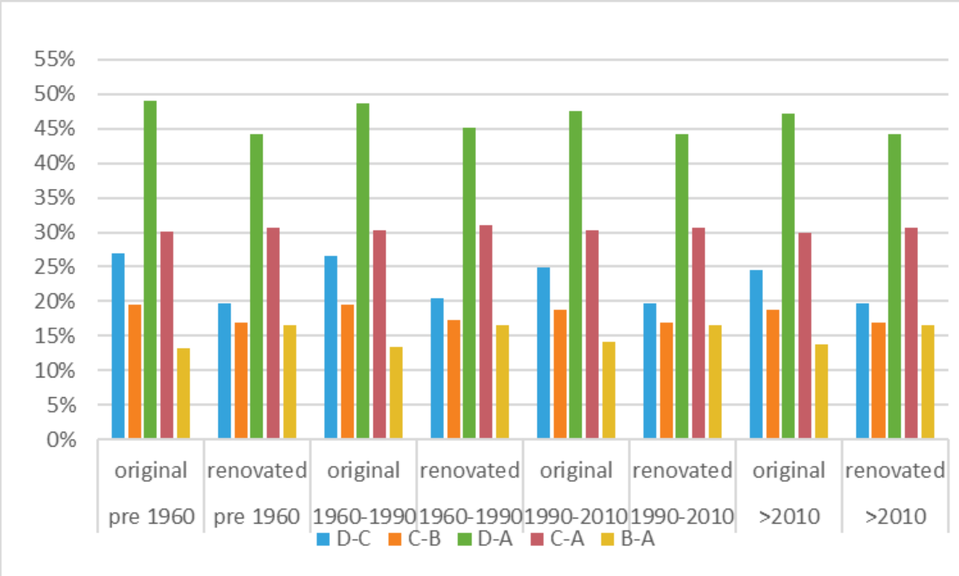

Figure 34 – Relative energy savings resulting from SRT upgrade for the example of offices in Northern Europe as a function of construction year and renovation level

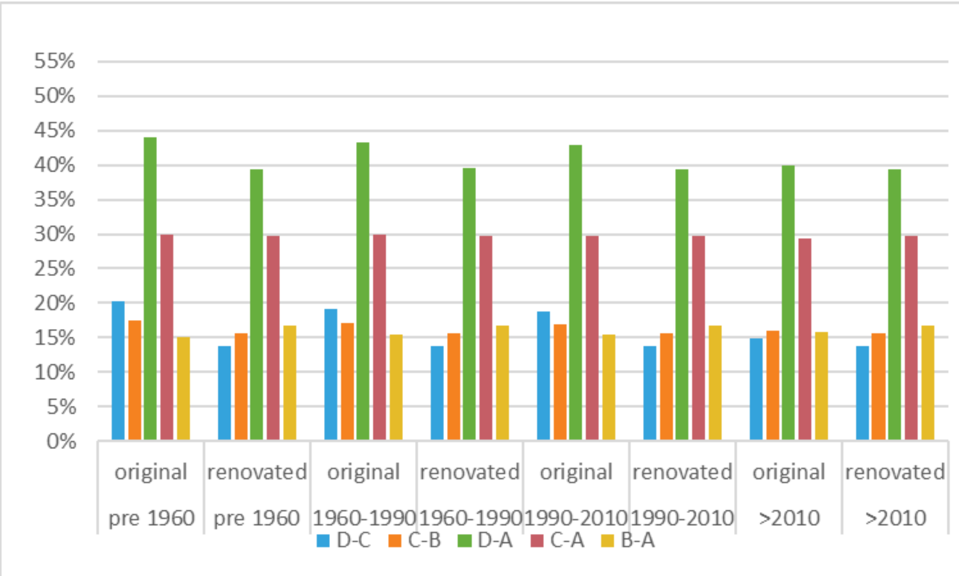

Figure 35 – Relative energy savings resulting from SRT upgrade for the example of offices in Southern Europe as a function of construction year and renovation level

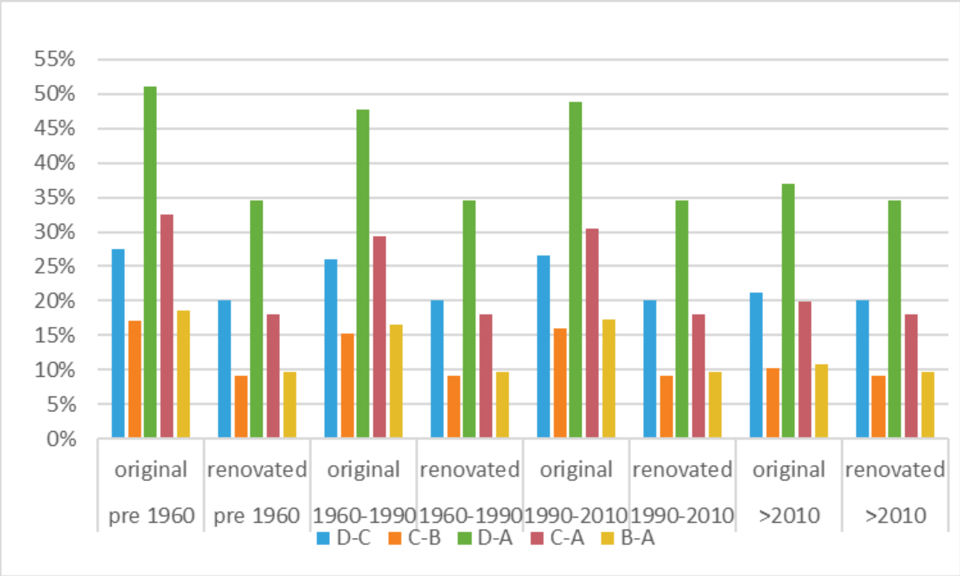

Figure 36 – Relative energy savings resulting from SRT upgrade for wholesale and retail buildings in Southern Europe as a function of construction year and renovation level

The absolute energy cost savings depend not only upon the relative energy savings obtained after integrating SRTs but also on the original energy demand. For the example of offices in Northern Europe, annual energy cost savings resulting from the efficiency improvements when upgrading from level D to A vary between 6.5 €/m² for unrenovated offices built before 1960 to 3.2 €/m² for offices that have been under deep retrofit. In Southern Europe, the annual savings are 11 €/m² and 7 €/m², respectively, for those same building cases. Obtained savings are higher for the Southern European offices as they show significantly higher initial cooling needs. For upgrades by one level of smartness, annual cost savings vary between 1 €/m² and 3 €/m², with the highest savings achieved when upgrading from level D to C in the oldest unrenovated buildings. Considering the investment costs for SRT upgrades estimated in the first technical study (tabulated in Table 46 in ANNEX D.c) significant variations in simple pay-back times are found depending upon the building type and climate zone. When upgrading from a level D to A average payback times may vary between 2 and 12 years whereby higher values are generally obtained as the initial energy demand of the building decreases.

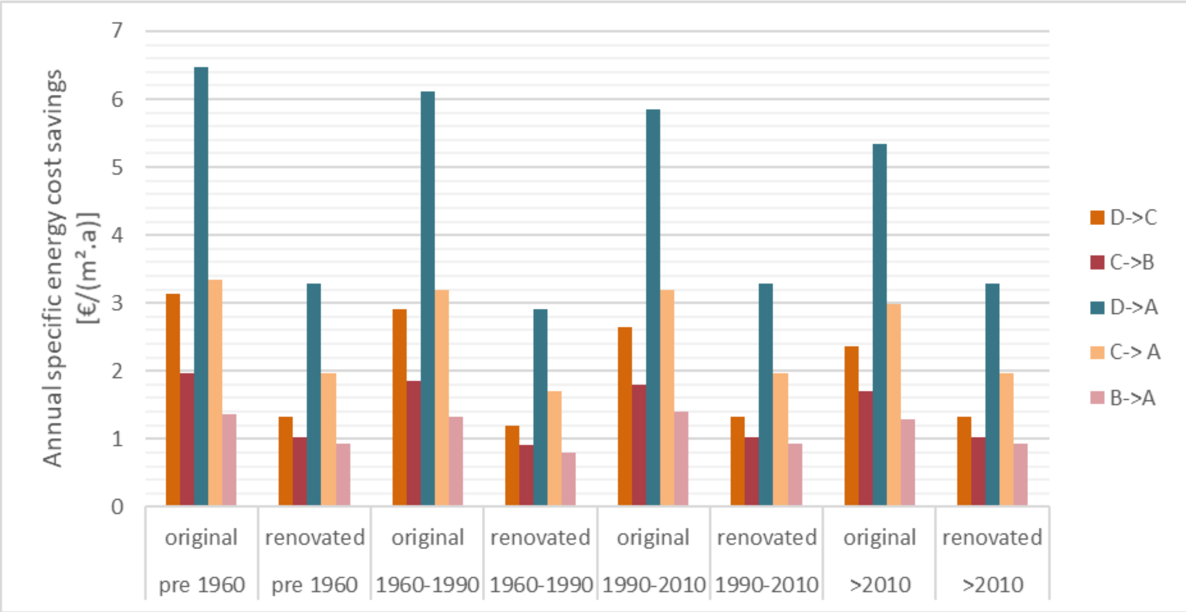

Figure 37 – Specific annual energy cost savings through energy efficiency gains from SRT uptake for the example of offices in Northern Europe as a function of construction year and renovation level

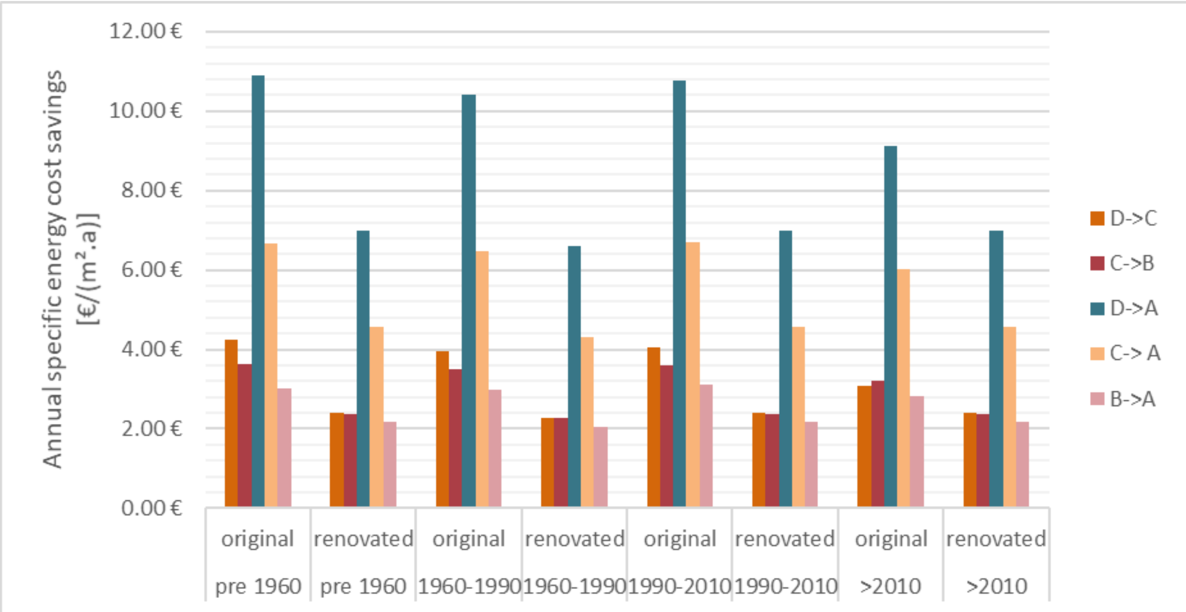

Figure 38 – Specific annual energy cost savings through energy efficiency gains from SRT uptake for the example offices in Southern Europe as a function of construction year and renovation level

4.1.1.2 Building GHG emissions

Based on quantified energy use for each energy carrier and including the CO_2 intensity of the energy vectors, the impact of SRTs and services on GHG emissions are quantified.

CO_2 intensities and prognosis for Member State GHG emissions are taken from the European Energy Agency and Member state prognosis reports.

For the building-level impact, a snapshot for 2020 uses an EU carbon intensity for electricity of 295.8 g CO_2 per kWh[105]; for heating and domestic hot water production the projection from the first technical study is used, resulting in a carbon intensity of 191.5 g CO_2 per kWh.

Figure 39 shows the relative CO_2 emissions savings gained through improving energy efficiency by upgrading the SRT in single-family houses. As these results are directly obtained from the energy use calculations, similar trends are found as for the energy use savings.

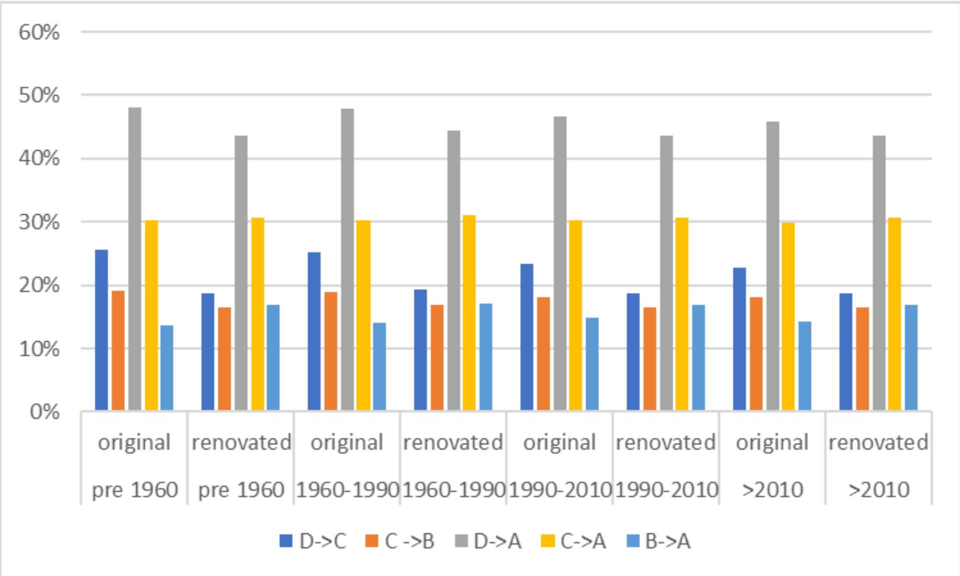

Figure 39 – Relative CO_2 emission savings gained through SRT upgrades for the example of office buildings in Northern Europe as a function of construction year and renovation level

4.1.1.3 Renewable uptake (self-production)

The goal of the SRI, and hence this analysis of impacts, is not directly oriented towards increasing the capacity of renewable energy production on site but rather on stimulating smart technologies and services that allow for an optimal use of

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105 https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-5#tab-googlechartid_chart_11_filters=%7B%22rowFilters%22%3A%7B%7D%3B%22columnFilters%22%3A%7B%22pre_config_ugeo%22%3A%5B%22European%20Union%20(current%20composition)%22%5D%7D%7D

on-site renewable energy production. Therefore, this section assesses the ability of smart ready services to improve self-production of on-site or nearby renewable energy production. Through quantifying the potential increase in self-consumption by smart ready services and technologies, this assessment acknowledges that increased self-consumption through demand-side management and storage services in buildings is expected to increase the renewable hosting capacity of energy grids[106,107,108].

To quantify the measurement of self-consumption, the supply cover-factor method (γ_s) is commonly used in literature. This indicator can be defined as representing the percentage of on-site generation that is used directly on-site. Mathematically, it could be defined as:

$$\gamma_s = \frac{\int_{t1}^{t2} \min[g(t) - S(t) - \zeta(t), l(t)]dt}{\int_{t1}^{t2} [g(t) - S(t) - \zeta(t)]dt}$$

where:

- g = the on-site generation
- S = the storage energy balance
- ζ = energy losses, and
- l = the system load.[109]

Self-consumption and self-generation are widely investigated in scientific literature, mostly focussing on improving the match between local energy use and local renewable production from photo-voltaic production systems in residential buildings. In general, improvements in self-consumption through optimised control of 5–25 percentage points are found. These results depend significantly on the climatic conditions and the ratio between the storage size and the size of the energy generation system. It should be noted that the increase in cover factors in Table 13 are mostly obtained from the combined effects of installing additional storage capacity (e.g. batteries) and the smart control of these systems together with demand response in general. When only smart control without additional

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[106] Camilo, Fernando M.; Castro, Rui; Almeida, Maria Eduarda; Pires, Victor Fernão: 'Self-consumption and storage as a way to facilitate the integration of renewable energy in low voltage distribution networks', IET Generation, Transmission & Distribution, 2016, 10, (7), p. 1741-1748, DOI: 10.1049/iet-gtd.2015.0431
IET Digital Library, https://digital-library.theiet.org/content/journals/10.1049/iet-gtd.2015.0431

[107] Joakim Widén, "Improved photovoltaic self-consumption with appliance scheduling in 200 single-family buildings", Applied Energy, Volume 126, 2014, Pages 199-212, https://doi.org/10.1016/j.apenergy.2014.04.008.

[108] O. C. Rascon, B. Schachler, J. Bühler, M. Resch and A. Sumper, "Increasing the hosting capacity of distribution grids by implementing residential PV storage systems and reactive power control," 2016 13th International Conference on the European Energy Market (EEM), Porto, 2016, pp. 1-5. doi: 10.1109/EEM.2016.7521338

[109] Salom J., Marszal A., Candanedo J., Widén J., Lindberg K. (2014) Analysis of load match and grid interaction indicators in net zero energy buildings with high-resolution data. Applied Energy. Vol. 136 pp 119-131 .

battery capacity is considered, 3–52% increases in self-consumption are found. The high variation can be clustered in 3 main categories. When only load-shifting of domestic loads and space heating are considered increase in self-consumption is generally limited to 3-7%. Studies that also include the use of domestic hot water storage tanks for demand response on average report increases in self-consumption of 15-30%. In contrast to systems where only space heating is considered, domestic hot water systems have a relatively constant heat demand throughout the year whereas space heating requirements reduce over the summer. Finally, the third category reports self-consumption increasing by up to 52% when smart electric vehicle charging is also included.

Based on the literature review, the model has been implemented under the working assumption that only the first category of flexibility can be offered for buildings with smartness levels C, resulting in an estimated 5% increase of self-consumption. For buildings with smartness levels B and A, it is assumed also the available battery or storage tanks systems may be controlled, which is implemented by an increase in self-consumption of 25%. Finally, the additional increase of self-consumption due to smart electric vehicle charging is modelled as function of the uptake rate of electric vehicles.

Table 13 – Overview of the literature on self-consumption

Reference	Technology measures	Percentage of self-consumption without and with technology measures
Braun et al.[110]	Residential battery storage	~35% without storage ~45–50% with 2.3–4.6kWh storage
Bruch & Müller[111]	Residential battery storage	~ 29% without storage ~ 47–51% with 2–4 kWh storage
Li & Danzer[112]	Residential battery storage	~26% without storage ~50% with storage

[110] Braun M, Büdenbender K, Magnor D, Jossen A. Photovoltaic self-consumption in Germany: using lithium-ion storage to increase self-consumed photovoltaic energy. In: 24th European photovoltaic solar energy conference (PVSEC). Hamburg (Germany); 2009.

[111] Bruch M, Müller M. Calculation of the cost-effectiveness of a PV battery system. Energy Proc 2014;46:262–70

[112] Li J, Danzer MA. Optimal charge control strategies for stationary photovoltaic battery systems. J Power Sources 2014;258:365–73.

Schreiber & Hochloff[113]	Residential battery storage	~31% without storage ~72% with storage
Waffenschmidt[114]	Residential battery storage	~38% without storage ~58% with storage
Weniger et al.[115]	Residential battery storage	~35% without storage ~65% with storage
Munkhammar et. al.[116]	Residential battery storage	~31% without storage ~34% with storage
Osawa et al.[117]	Residential battery storage (electric vehicle)	~41% without storage or EV ~79% with storage + EV
Thygesen & Karlsson[118]	Residential thermal and battery storage	~56% without storage ~88% with thermal storage ~89% with battery storage
Vrettos et al.[119]	Residential thermal and battery storage	~20% without storage ~37% with storage

[113] Schreiber M, Hochloff P. Capacity-dependent tariffs and residential energy management for photovoltaic storage systems. In: IEEE power and energy society general meeting; 2013

[114] Waffenschmidt E. Dimensioning of decentralized photovoltaic storages with limited feed-in power and their impact on the distribution grid. In: 8th international renewable energy storage conference and exhibition (IRES 2013). Berlin, Germany; 2013

[115] Weniger J, Tjaden T, Quaschning V. Sizing of residential PV battery systems. Energy Proc 2014;46:78–87

[116] Munkhammar J, Grahn P, Widén J. Quantifying self-consumption of on-site photovoltaic power generation in households with electric vehicle home charging. Sol Energy 2013;97:208–16.

[117] Osawa M, Yoshimi K, Yamashita D, Yokoyama R, Masuda T, Kondou H, et al. Increase the rate of utilization of residential photovoltaic generation by EV charge-discharge control. In: 2012 IEEE innovative smart grid technologies – Asia (ISGT Asia). Tianjin (China); 2012. p. 1–6.

[118] Thygesen R, Karlsson B. Simulation and analysis of a solar assisted heat pump system with two different storage types for high levels of PV electricity self- consumption. Sol Energy 2014;103:19–27

[119] Vrettos E, Witzig A, Kurmann R, Koch S, Andersson G. Maximizing local PV utilization using small-scale batteries and flexible thermal loads. In: 28th European photovoltaic solar energy conference and exhibition. Paris (France); 2013. p. 4515–26.

Williams et al.[120]	Residential thermal and battery storage	~37% without storage ~55% with storage
Castillo-Cagigal et al.[121]	DSM and residential battery storage	~15% without storage or DSM ~27% without storage, with DSM ~35% with storage + DSM
Castillo-Cagigal et al.[122]	DSM and residential battery storage	~33% with storage, without DSM ~42% with storage + DSM
Femia et al.[123]	DSM and residential battery storage	~16% without storage or DSM ~31% without storage, with DSM ~33% with storage, without DSM ~48% with storage + DSM
Widén & Munkhammar[124]	DSM and residential battery storage	~50% without storage or DSM ~53% without storage, with DSM

[120] Williams CJC, Binder JO, Kelm T. Demand side management through heat pumps, thermal storage and battery storage to increase local self- consumption and grid compatibility of PV systems. In: 2012 3rd IEEE PES international conference and exhibition on innovative smart grid technologies (ISGT Europe). Berlin (Germany); 2012. p. 1–6

[121] Castillo-Cagigal M, Caamaño-Martín E, Matallanas E, Masa-Bote D, Gutiérrez A, Monasterio-Huelin F, et al. PV self-consumption optimization with storage and active DSM for the residential sector. Sol Energy 2011;85(9):2338–48.

[122] Castillo Cagigal M, Matallanas de Avila E, Masa Bote D, Caamaño Martín E, Gutiérrez Martín Á, Monasterio-Huelin Maciá F, et al. Self-consumption enhancement with storage system and demand-side management: GeDELOS- PV system. In: Proceedings of the 5th international renewable energy storage conference IRES 2010. Bonn (Germany): E.T.S.I. Telecomunicación (UPM); 2010

[123] Femia N, Toledo D, Zamboni W. Storage unit and load management in photovoltaic inverters for residential application. In: IECON 2013-39th annual conference of the IEEE industrial electronics society. Vienna (Austria); 2013. p. 6800–5.

[124] Widén J, Munkhammar J. Evaluating the benefits of a solar home energy management system: Impacts on photovoltaic power production value and grid interaction. Proceedings of the eceee 2013 Summer Study. Toulon/Hyères, France: European Council for an Energy Efficient Economy; 2013.

		~63% with storage, without DSM ~65% with storage + DSM
Luthander et. al. [125]	Residential battery and EV	~52% without EV or storage ~54% with EV (without smart charging) ~64% with battery
van der Kam & van Sark[126]	EV smart charging	~49% without smart charging ~79–91% with smart charging
Widén[127]	DSM	~29–63% without DSM ~31–67% with DSM
Reynders et al.[128]	Residential thermal storage	~3–7.3% without DSM ~7.3–11.7% with DSM
Vanhoudt et al.[129]	Residential thermal storage	~24% without DSM ~30% with DSM
De Coninck et al.[130]	Office thermal storage	~25% without DSM ~35% with DSM

[125] https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2015/5-energy-use-in-buildings-projects-technologies-and-innovation/self-consumption-enhancement-of-residential-photovoltaics-with-battery-storage-and-electric-vehicles-in-communities/2015/5-117-15_Luthander.pdf/

[126] van der Kam M., van Sark W.Smart charging of electric vehicles with photovoltaic power and vehicle-to-grid technology in a microgrid; a case study, Applied Energy, Volume 152, 2015, pp 20-30, https://doi.org/10.1016/j.apenergy.2015.04.092

[127] Widén J, Munkhammar J. Evaluating the benefits of a solar home energy management system: Impacts on photovoltaic power production value and grid interaction. In: Proceedings of the ECEEE 2013 summer study. Toulon/ Hyères (France): European Council for an Energy Efficient Economy; 2013

[128] Reynders G, Nuytten T, Saelens D. Potential of structural thermal mass for demand-side management in dwellings. Build Environ 2013;64:187–99.

[129] Vanhoudt, D., Geysen, D., Claessens, B., Leemans, F., Jespers, L., Van Bael, J., 2014. An actively controlled residential heat pump: Potential on peak shaving and maximization of self-consumption of renewable energy. Renew. Energy 63, 531–543. https://doi.org/10.1016/j.renene.2013.10.021

[130] De Coninck, R., Baetens, R., Saelens, D., Woyte, A., Helsen, L., 2014. Rule-based demand-side management of domestic hot water production with heat pumps in zero energy neighbourhoods. J. Build. Perform. Simul. 7, 271–288. https://doi.org/10.1080/19401493.2013.801518

4.1.1.4 Energy security (demand response)

In line with supporting renewable energy uptake, smart ready services and technologies enable buildings to offer services to the energy grids. As such, smart ready services aid in increasing energy security and the optimisation of flows in the energy grids. In the context of the IEA EBC Annex 67 project "*Energy Flexible Buildings*", an extensive review of evaluation methodologies and indicators used to quantify the demand-response services that can be offered by buildings has been conducted. That study concludes that the energy flexibility that can be offered by a building cannot be captured by a single-value indicator as it covers multiple dimensions (time, power, energy, rebound, etc.). As an alternative to these bottom-up quantification methodologies, the impact analysis will quantify the impact of smart technologies and services based on quantitative evidence of the energy savings and reductions in GHG emissions obtained when integrating buildings in smart energy grids. This impact criterion will therefore only be discussed from the EU perspective under Activity 3.

4.1.1.5 Material circularity

Smartness stems from combining sensor and actuator technologies with communication and software services. A priori, the impact of the SRI on material use is therefore expected to be limited. Even more, enhanced communication between systems may even reduce the need for additional sensors and controllers in buildings.

The lower the energy consumption in the use phase, the more the construction of the building and the selection of (construction) materials and their processing become important while considering the total environmental impacts of building over their entire life cycle. Increasing the energy efficiency of a building and improving energy system technologies, combined with an increase in the use of renewable energy sources, will affect the total environmental impacts of buildings: the impact of building construction and technical building systems will increase in relative terms while the impacts of the operational energy use will decrease.

A study by Weissberger et. al. analyses life-cycle aspects and cost-benefits of heating systems, derived from an examination of the eco-efficiency of heating and storage systems for the Bavarian Ministry of Environment[131]. The primary objective of the study was to compare environmental and economic performance of various heating and storage systems, using eco-efficiency analysis for new and (partly) refurbished buildings. The simplified and holistic evaluation of different heating and storage systems using the eco-efficiency analysis opens- up a fact-based and application-specific selection of heating and storage systems for house and apartment owners, taking into account the existing support measures and programmes.

The study focuses on a comprehensive view of the various systems over their entire life cycle (i.e. considering production, use, recovery/disposal), including all associated energy sources and material supply chains, to enable a holistic and complete basis for comparison.

The evaluation of the technologies takes place within their operational context, and the influence of the following parameters were examined:

[131] https://www.sciencedirect.com/science/article/pii/S0378778814002485

- the energy performance of the building
- differing levels of hot water consumption
- technology lifetimes
- increases in energy prices
- heat pump efficiencies.

The eco-efficiency analysis in this study contrasts the environmental impacts with the total cost over the whole life cycle of a technology, to identify highly eco-efficient technologies with respect to determining the additional cost of reducing the environmental impact. In order to achieve the broadest possible coverage of environmental issues, in addition to the emission of GHGs, other environmental categories such as acidification, eutrophication, particulate matter, toxicity and resource consumption were included and aggregated via a weighting key (single-score indicator) to allow direct comparability of technologies across all environmental categories.

The study shows that during the lifetime of a heating system, the environmental impact is highest in the utilisation phase. In a new building performing at the passive house standard, the utilisation phase of a gas condensing boiler including solar thermal has a share of 71% of CO_2-equivalents (20-year lifetime). For heat pumps this share is even higher, at 80–95% (including losses of refrigerant). Based on these results, it can be derived that SRTs for HVAC systems, such as control and feedback systems, positively affect the impact on the environment by raising energy efficiency based on advanced methods such as data analytics, self-learning control systems and model predictive control to optimise building operations.

Looking at less efficient buildings, the share of CO_2-equivalents in the utilisation phase increases and consequently the impact of SRTs is higher. For partly refurbished (heating system exchange and partly refurbished envelope) and for un-refurbished buildings (only heating system exchange) the share of CO_2-equivalents of a gas condensing boiler including solar thermal is up to 90%.

Trigaux (2017) compared the life-cycle material cost for different variants of residential houses[132]. He observed that electrical services (6 in Figure 40) only cause a significant impact (up to 10%) in new buildings, due to the installed PV systems. In existing buildings, assumed not to have a PV system, the environmental costs of electrical systems comprised about 1% of the total building environmental cost. As the scope of the SRI concerns stimulating the uptake of smart technologies that add communication and control services to technical building systems, the environmental cost of the materials used for the smart technologies within scope of the SRI might be expected to be in that same order of magnitude.

[132] Trigaux, D. (2017) Elaboration of a sustainability assessment method for neighbourhoods. PhD Thesis, KU Leuven.

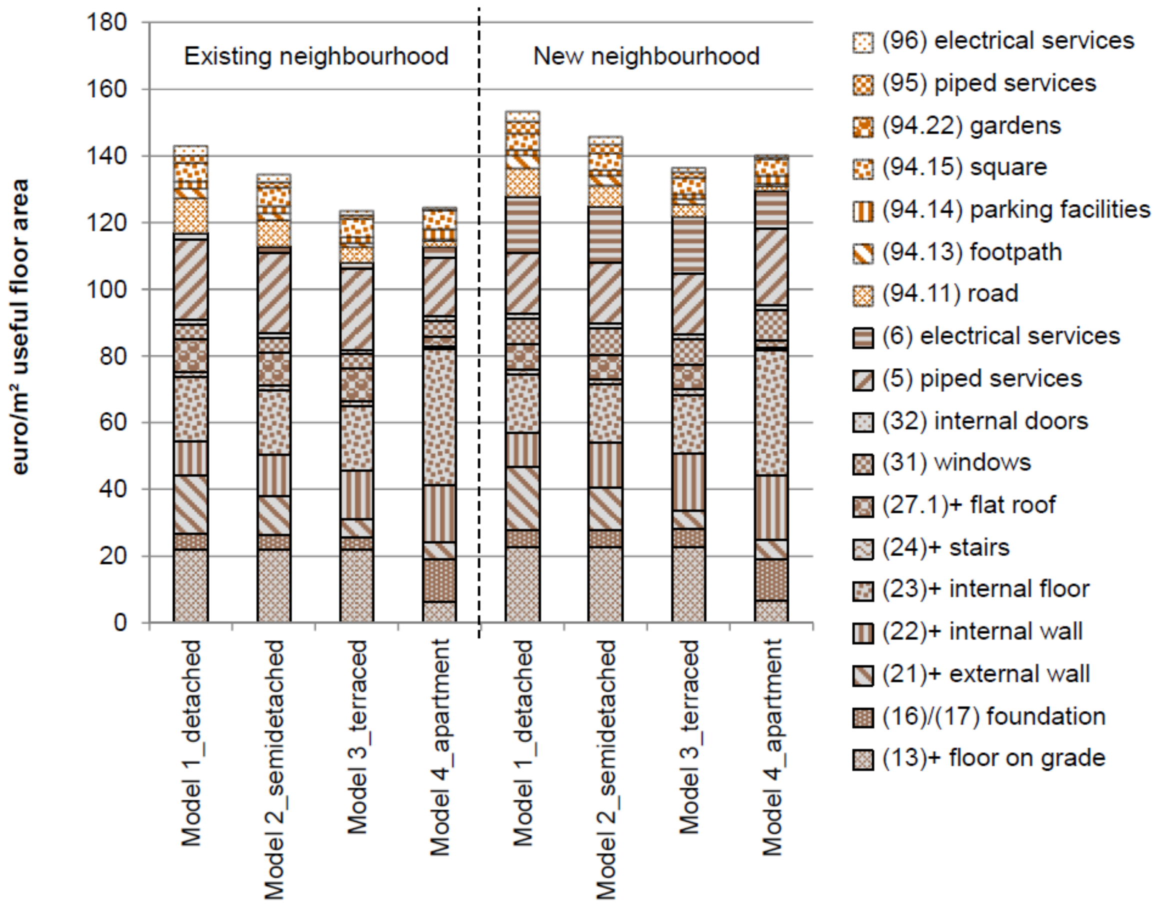

Figure 40 – Environmental cost of material use. Source: Trigaux, 2017

Based on these studies, it is concluded that the impact of the SRI on the environmental cost of material use for buildings is likely to be marginal and the environmental impact as a whole is expected to be positive due to the significant reductions in energy use that can be linked to adopting smart technologies. This conclusion evidently does not account for potential investments into energy technologies such as heat pumps, batteries or PV that may be linked to investments in smart technologies. This presumption is considered fair because energy savings resulting from integration of these technologies are not included in this analysis of impacts; only the impact of improving the smartness in terms of providing controllability, flexibility and communication services to these systems is included. Yet, in order to still include a quantitative estimate of the material impact of the SRI an assessment methodology has been developed based upon the available reports for relevant technologies under the Ecodesign Directive.

There are currently no publicly available compilations of data on the materials used in the manufacture, wholesale, retail, installation and maintenance of SRTs that the study team is aware of; however, there are statistics on these fields for products which have been subject to regulation under the Ecodesign Directive. The MEErP Task 5 analysis, which is conducted for every product subject to Ecodesign regulations, entails the conduct of a lifecycle analysis of products using the Ecoreport tool. This analysis includes the compilation of a bill of materials for baseline products then determining the environmental impacts associated with the materials and the manufacture, delivery, use, and end-of-life, lifecycle stages of the products. These are assessed in the Ecoreport tool and used to determine environmental impacts associated with other resources and waste, emissions to air and emissions to water. In the absence of such a detailed study for SRTs the approach taken in the current analysis is to post-process a basket of these Ecodesign studies using a blend of products chosen to best emulate the nature of SRT products. In each case the environmental impacts of the base case products are normalised as a function of the average price per product so this can then be related to expenditure on SRTs per each SRI implementation pathway.

The products chosen for this purpose and their relative normalised contribution to the overall estimated SRT impact are:

- boilers (22.5%)[133]
- batteries (5%)[134]
- induction motors (22.5%)[135]
- LCD TVs (50%)[136].

The rationale behind this blend is that SRTs are a compilation of electro-mechanical and electronic products with a significant aspect associated with displays, actuators (often motorised), sensors/thermostats, IT & communication technologies, and sometimes also use batteries.

The analysis of material impacts has been directly carried out on the EU-level. Results are presented in section 4.3.2.

4.1.1.6 Comfort and well-being

SRTs offer a range of health and well-being benefits. These include: improved indoor air quality control, ability to better manage thermal comfort, lower pollutant emissions due to reduced energy consumption, and maximising the use of natural daylight while improving lighting regulation with associated well-being and productivity benefits. While there are no current studies (known to the study team consortium) which directly estimate the impacts that SRTs have themselves on these aspects, there is a body of literature that considers the nature, magnitude and monetised value of the co-benefits of energy efficiency in general and especially within buildings. These have been compiled in a draft study under preparation by the JRC[137]and applied to assess the expected impacts of the EPBD

[133]https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/Space%20and%20combination%20heaters/boilers_task_5_final_report_july_2019.pdf

[134] https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/Batteries/ed_battery_study_task5_v3_20190823.pdf

[135] https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/electricmotors/finalreport-motors.pdf

[136]https://circabc.europa.eu/webdav/CircaBC/Energy/Energy%20Efficiency/Library/Ecodesign%20preparatory%20studies/Lot%20%205%20-%20Televisions/

[137] *Development of a Methodology to Include Multiple Benefits in Energy Efficiency Policy Development*, European Commission JRC Technical Reports – draft study, 2019

measures as a whole on co-benefits within Europe's buildings by 2030. The JRC reports a synthesis of co-benefit impacts from many studies but the most significant is the so-called COMBI study (Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe)[138], which compiled an assessment of health and wellbeing impacts from all 28 EU countries and derived monetised benefits for: asthma (DALY), excess winter mortality, indoor air pollution, mortality - ozone, mortality -PM2.5, reduced congestion amongst others.

The JRC study compiles and synthesises the data on the impacts and monetised values of the following:

- reduced winter mortality attributable to lower ozone and PM2.5
- reduced winter morbidity attributable to lower indoor air pollution (units of 1000 YOLL), lower asthma (units of DALY), lower PM2.5 (units of YOLL)
- reduced diseases arising from thermal discomfort
- learning and productivity benefits due to better concentration, savings/higher productivity due to avoided "sick building syndrome" whose value can then be assessed in terms of active days gained (indoor exposure) and workforce performance (mn workdays).

As an illustration of the type of impacts that are reported Figure 41 show that the probability of negative health issues across the EU-28 increases 17 percentage points when living in buildings with bad thermal comfort in winter, while overheating during summer increases this probability by 3 percentage points. Overall, around 22 million Europeans (ca. 4.4%) suffer from bad thermal comfort in winter or summer. Taking into account other deficiencies such as a lack of daylight, damp, etc., the share increases to nearly 17%, i.e. 1 in every 6 Europeans reports living in unhealthy buildings. In some countries, that number is as high as 1 in 3.[139]

Furthermore, a survey from 2015 and 2016[140] examined several characteristics of a healthy home and the importance for healthy living. In this context, participants were asked to score health categories from 1 to 7 (1 being "not important" and 7 being "very important"). Three of the five top drivers can be directly related to the building and score significantly above 5:

- sleeping well received a score of 6.4
- ventilation for fresh air scored 6.1
- plenty of daylight received a score of 5.9.

In this context, SRTs contribute to a decreased probability of poor health caused by functional deficiencies of the HVAC system or structural deficiencies of the building. In addition, they can help occupants to achieve the characteristics of healthy homes, by increasing the level of controllability/automatization with the use of indoor environmental quality sensors (to regulate temperature, humidity,

[138] https://combi-project.eu/

[139] https://www.rehva.eu/fileadmin/REHVA_Journal/REHVA_Journal_2018/RJ3/19-22/19-22_RJ1803_WEB.pdf

[140] Healthy Home Barometer 2016 (Velux)

ventilation, lighting and CO_2) and maintain healthy indoor climate conditions and thermal comfort level[141].

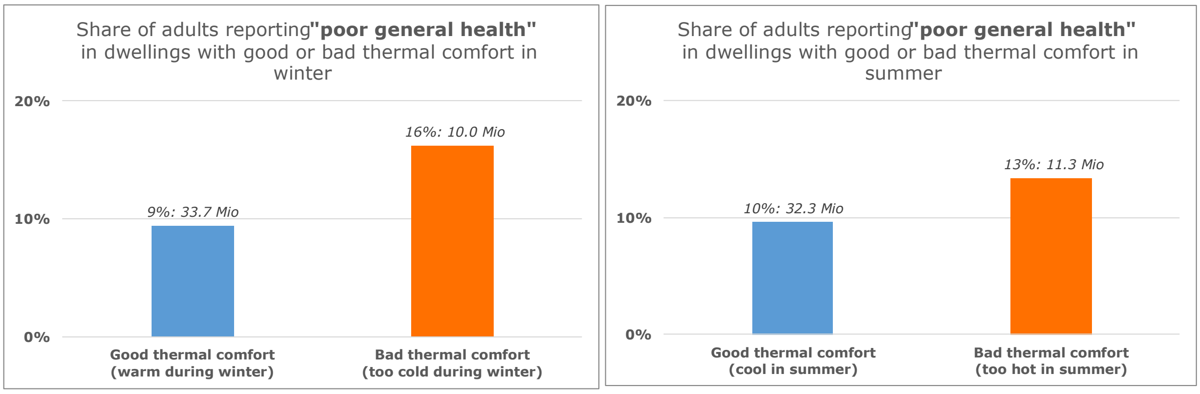

Figure 41 – Share of adults in the EU reporting "poor general health" when perceiving good or bad thermal comfort in winter (left) and summer (right). Source: Hermelink & John, 2017 (Ecofys)

4.2 ACTIVITY 2: DEFINITION OF IMPACT SCENARIOS REFLECTING POLICY OPTIONS

As with the first SRI technical study the starting point against which comparisons with the potential SRI implementation pathways are compared is an EPBD reference scenario, or more specifically the *Agreed Amendments* scenario from the revised EPBD impact assessment. The range of impacts that could be anticipated from implementing the SRI are considered through a set of SRI impact scenarios. These assume identical implementation of all non-SRI related aspects of the EPBD to the *Agreed Amendments* scenario (see the discussion of this scenario in the first SRI technical study).

The definition of the most appropriate impact scenarios to be assessed is closely related to the development of the implementation pathways established in Tasks 2 and 3. In the chapters covering these the following pathways were set out:

A. Linkage of the SRI to the EPC (potentially in a mandatory way) so an assessment would be offered each time an EPC is conducted
B. Linkage of the SRI to new buildings and major renovations so that each time a new build/or renovation is undertaken it would be a requirement
C. A market-based voluntary scheme where self-assessment is supported by on-line tools and 3rd party certified assessment is offered to those willing to pay for it

[141] See also case study from S. Chen & J. Huang, 2012: A Smart Green Building: An Envirionmental Health Control Design. Energies, 1648-1663, 2012.

D. As option C, but with 3rd party assessments supported, or subsidized, by the state and/or utilities seeking to roll out demand side flexibility, energy efficiency, electromobility and self-generation measures
E. Linkage to the BACS/TBS deployment trigger points in Articles 14 & 15, and 8 of the EPBD
F. Linkage to smart meter deployment.

In principle, a mosaic of the above is also an option, noting that Member states may choose any of these options – also combinations of A/B/C/D/E/F are possible within any single MS.

The problem that these pathways aim to address is the limited deployment of beneficial smart-services and SRTs within Europe's buildings, which is considerably below the techno-economic potential and is hindering the contribution to key EU policy objectives in relation to energy and climate change. The SRI is an instrument that is designed to provide consumers and market actors greater awareness and clarity about the status of and potential for such products and services within the building stock and thus aims to help overcome barriers related to low awareness of and lack of clarity and understanding of the potential for such services.

Each of the implementation pathways considered are associated with the manner in which SRI assessments could be delivered and are mostly chosen because they encompass the most logical set of trigger points which could be made use of to implement the SRI. These trigger points constitute moments when there is an event in the building life cycle that presents an opportunity for an SRI assessment to be conducted and which might present synergies in any of the following:

- conducting an assessment
- installing technical building systems
- installing other smart system-related hardware
- trigger points in the building construction cycle
- trigger points in the building occupancy cycle
- the delivery of building services.

These pathways have been developed following consultation with specific stakeholders/experts and encompass the broad set of opportunities that the SRI could link to. The outlier to the above is the most laissez-faire approach of implementation pathway case C. This case does not link the SRI's delivery to any specific set of trigger points but rather offers-up a service that users are free to engage with at any moment. Case D is similar but includes incentives that could encourage users to adopt the SRI – both in terms of conducting assessments but potentially also in terms of subsidising the adoption of smart services and technologies.

These implementation pathways can thus be converted into scenarios. For those that concern forging linkages to trigger points (pathways A, B, E and F) the first aspect to establish is the frequency of the trigger points concerned (which is the moment that the SRI assessment would be offered). The second aspect is the rate at which an SRI assessment is conducted when it is offered. The third is the degree to which the conduct of an assessment is a stimulus to adopt smart services and technologies (SRTs) and how strong that effect is. This logic presumes that the action of conducting SRI assessment leads to greater awareness of the potential for smart services and SRTs to be implemented and bring sought after benefits.

As this awareness rises it is further assumed that it raises the market value of investment in these smart services and SRTs and that this generates extra investment above that which would be expected otherwise i.e. under a default (no SRI) base case scenario. Thus, the action of conducting an SRI assessment will create "market pull" for the procurement, installation and commissioning of smart services and technologies and will accelerate beneficial deployment – in line with the value placed on these services by the market in response to the extra stimulus brought by the SRI.

However, it is important to recognise that the SRI is also likely to have an impact on the suppliers of smart services and SRTs. This is because it creates an organisational framework wherein products and services can be positioned, and their value proposition communicated on a common basis. The fact the that the EU and the EU Member States are the progenitors and implementors of the scheme and can provide a common structure across the Single Market creates an organisational power for the market that individual private entities would not ordinarily be able to generate. If the private sector engage with the scheme and position their products and services within it – e.g. market their product as providing a specific service functionality level as set out in the SRI, it helps to organize and standardise how product value propositions are determined and communicated. This has considerable market power potential because currently almost all stakeholders agree that the major market failure that the SRI can help to address is the lack of clarity in the market place about the benefits that can be delivered by smart services/technologies and a means of classifying these that is transparent to and trusted by the target users of these services. This is related to the sheer range and diversity of smart services on offer, their comparative newness and hence limited levels of familiarity, and the very diverse ways in which they can be (and are being) marketed which risks confusion. In principle, the SRI helps address this by providing a consistent framework across the EU, which hopefully will be trusted and respected by the market. In part this is because the government entities behind the SRI have no commercial stake in the sale of smart services and have a mandate to support the interests of the public and thus can better fill the role of a neutral arbiter of the market than any commercial organization or alliance. Through this mechanism the SRI thus helps to create an organisational power and coherence, much as commonly accepted standards do. If the suppliers of services and products support this framework and position their offer within it, it will provide a significant market push effect that could help remove barriers to the faster deployment of smart ready services.

The strength of this market organisational "push" effect will also be contingent on the strength of the SRI assessment "pull" effect. The more that SRI assessments are conducted, the more than those that procure building technologies and services will wish to know how new smart services will affect their buildings' SRI scores and the impacts it reports on. This means there will be greater reward for service providers who are able to answer that question and offer smart services/SRTs that produce tangible impacts within the SRI framework.

The experience of product energy labelling is instructive in this regard. In the early 1990s when energy labelling was undergoing its initial development the products offered for sale were completely randomly distributed in terms of their energy performance because the market was opaque with regard to product energy performance and there was no agreed framework to report on it or market it. In the case of refrigerators, for example, there was a factor of 8 difference between the most and least efficient products offered for sale and on average the lifecycle energy costs of products were 3 to 4 times the purchase cost. Once the energy label began to be developed it started to influence the market even before it became a regulatory requirement. As soon as the rules and pending performance thresholds were known to industry they began to adjust their product offer to position the energy performance within that framework ahead to the label becoming a mandatory requirement. Within just three years the market evolved from a situation where the energy performance was completely random and very broadly distributed around what would become the class D/E boundary to one where almost all products were either at the class C, B or A boundary – and approximately 1.5 label classes more efficient on average (prior to labelling there were only about 1% of products in the A class).

The SRI is broader and hence necessarily not as focused as the energy label, so its organizational power is unlikely to be so pronounced, but nonetheless it will exist and the greater the proportion of the market which is exposed to the SRI the greater that power will become. Thus, there can reasonably be expected to be a clear feedback between the proportion of buildings that undergo an SRI assessment and the extent to which smart services and products use the SRI to classify their performance and value proposition. The more they do this the more the market will make use of the SRI to frame their procurement decision-making because the market suppliers will add their promotional power to the informational pull effect. Thus, under the more proactive pathways there is expected to be "virtuous circle" where greater deployment of SRI assessments stimulates greater promotion of the SRI by market actors, leading to greater transparency of the value proposition of smart products and services and greater uptake rates.

The challenge for the analysis of impacts is first to structure the analysis (and associated analytical tools) so it is capable of capturing these effects and secondly to quantify/estimate their magnitudes. To address this as effectively and plausibly as possible the responses are broken down by logical step. Beginning with the factors that affect the rate of SRI assessments (the first component of the "pull effect") the study team has compiled evidence of the frequency of the trigger events in pathways A, B, E and F – each of these events constitutes a moment when an SRI assessment would be offered. However, simply offering an assessment does not ensure that the offer is accepted. Rather that is contingent on whether the assessment is:

- offered by default or whether it has to be requested
- is free or has to be paid for
- is mandatory or not
- is incentivised, or not.

Uptake of assessments will be lowest where market actors have to request it and pay for it and will be highest when it is offered as a default (or is mandatory) and is free. The case of subsidised or incentivised assessments falls between these such that adoption rates will depend on how strong the subsidies and incentives are.

For these reasons the scenarios associated with the major implementation pathways set out above are further differentiated as follows:

A. Linkage of the SRI to the EPC (potentially in a mandatory way) so an assessment would be offered each time an EPC is conducted

Option A1 Linkage to EPC is mandatory

Option A2 Linkage to EPC is voluntary
Option A3 Linkage to EPC is voluntary but is subsidised

B. Linkage of the SRI to new buildings and major renovations so that each time a new build/or renovation is undertaken it would be a requirement

C. A market-based voluntary scheme where self-assessment is supported by on-line tools and 3rd party certified assessment is offered to those willing to pay for it

D. As option C. but with 3rd party assessments supported, or subsidised, by the state and/or private players (e.g. utilities) seeking to roll out demand side flexibility, energy efficiency, electromobility and self-generation measures

E. Linkage to the BACS deployment trigger points in Articles 14 & 15 in the EPBD
Option E1 Linkage is mandatory
Option E2 Linkage is voluntary
Option E3 Linkage is voluntary but subsidised

F. Linkage to smart meter deployment
Option F1 Linkage is mandatory
Option F2 Linkage is voluntary
Option F3 Linkage is voluntary but subsidised.

For each of the scenarios associated with clear trigger points of when an SRI assessment could be offered the structure set out above distinguishes between when the offer is a mandatory requirement (and hence would be done), when it is a voluntary requirement (and hence would only be done if the market actor with responsibility for the building wished it to be done and was willing to pay its costs or implement it directly) and when it was subsidized (and thus would be done if the market actor wished to have the information and found the subsidies sufficiently compelling). Note, the term "subsidies" is rather loose in this framing as its intention is to cover the whole spectrum of potential financial inducements. These could encompass at the least the following:

- subsidies to cover the cost of the SRI assessment (from partially to wholly)
- direct subsidies to offset the cost of procuring specific smart services or SRTs which are contingent on an SRI assessment being conducted first
- direct subsidies to offset the cost of procuring specific smart services or SRTs where it is recommended that an SRI assessment is conducted first or that greater subsidies are offered to those that have had an SRI assessment
- free assessments combined with incentives to adopt specific smart services or technologies – for example higher grades of BACS or the capability to use EV batteries as grid power storage with two-way communication and control
- soft loans with low interest rates and favourable repayment terms for smart services and SRTs that are contingent on an SRI assessment being conducted
- soft loans with low interest rates and favourable repayment terms for smart services and SRTs that are contingent on an SRI assessment being conducted and the cost of the assessment is subsidized (partially or fully).

In fact, many more cases can be envisaged, but from a modelling and scenario perspective the important aspect is that they create an added inducement to have an SRI assessment, of varying strength depending on the financial value and overall attractiveness of the incentive (subsidy).

In the scenario cases where SRI assessments are not only offered but are mandatory then the rate that the assessments are conducted is the same as that of the trigger events they are related to. For the voluntary cases the rate of assessment will be the product of the trigger rate and the voluntary uptake rate. For the subsidised rates it is the same except that the voluntary uptake rate will be increased by a factor that reflects the attractiveness of the incentive. The strength of the incentive is thus a kind of floating variable that operates between the upper boundary of a mandatory assessment and the lower one of a completely voluntary and unsubsidised assessment.

It is also important to understand that the trigger events where the SRI is offered are also likely to be much softer trigger events for market actors to consider undertaking an SRI assessment, providing they are aware that the SRI exists and that having an assessment is an option. This is because the trigger events are all related in some way to building energy performance and smartness and hence will have a natural association with thinking of and potentially planning to address this issue. For example, when a TBS is being replaced and/or BACS are being installed service providers might draw it to the relevant market actor's attention that the SRI exists and can help to understand their buildings' capabilities. This can create a much softer linkage between the trigger events and SRI assessments than the directly linked cases, but still a degree of linkage can be anticipated. As a result, it makes sense to relate the SRI assessment uptake rate to the frequency of these trigger points even for the wholly voluntary and passive (laissez-faire) implementation pathway C.

The analysis of impacts is thus structured to model the assessment rates under each of these cases by multiplying the frequency of the trigger points to the probability that the trigger point will result in an SRI assessment being carried out. While the conduct of an SRI assessment for the majority of these scenarios is clearly strongly related to a specific type of trigger point (e.g. to the installation of a smart meter for case F) this does not necessarily preclude the possibility of an SRI assessment being conducted at another moment than the trigger point. For case C, where an SRI assessment is purely voluntary and is unsubsidized, all or the set of trigger points present limited stimuli to the conduct of an SRI assessment and this would be true for all other cases unless SRI assessments were to be exclusively bound to a single or specific set of trigger events. This is not assumed at present, but rather it is assumed that there is always an option to request an SRI assessment and pay for it (if it is not a self-assessment), outside of any other specifically mandated or supported pathway.

Aside from the rate of assessment it is also necessary to consider the stimulus effect that the conduct of an SRI assessment would be likely to have on the rate of procurement of SRTs and smart services. This is likely to be higher in cases where SRTs are subsidised or were there to be any mandatory limits imposed on the level on smartness required in buildings. The former case has already been discussed and is assumed to be so for the subsidized scenarios of A3, D, E3 and F3. The latter case is not considered to be very likely for an ostensibly voluntary scheme and hence is not considered further.

It is also apparent that the implementation pathways scenarios set out above also directly map to policy choices at the Member State and EU level. For example, a Member State policy decision and issuance of a related policy instrument would be necessary to link the SRI assessments to the issuance of EPCs, or to the roll out of smart meters. This necessitates being able to consider the impact of geographical diversity (as a proxy for diversity in Member State policy decisions) to treat the diversity of cases which could occur.

In addition, the building stock is not monolithic and hence nor is the manner in which these implementation pathways could be mapped to it. It would be perfectly possible for a Member State to require issuance of an SRI with an EPC for large non-residential buildings but to apply a less binding pathway (such as scenarios C or D) for non-residential and small commercial buildings, for example. Thus, a blend of pathways could be imagined being applied to different parts of the building stock at the member state level.

Considering these aspects, it is necessary for that modelling of the impacts of these various options should allow differentiation in the implementation of these main scenarios by building type and geography. The impact analysis model is structured to allow this kind of differentiation to occur. E.g. to be able to treat each geographical region distinctly and each building type distinctly[142].

4.3 ACTIVITY 3: AGGREGATION OF INDIVIDUAL VARIANTS AND CALCULATION SCENARIOS

4.3.1 METHODOLOGY

Activity 3 develops the calculation tool – and applies it – to determine the impacts of the various SRI scenarios at the EU level. Thereby, the tool primarily focusses on modelling the uptake of smart ready technologies and services (SRTs) and the resulting the energy savings and reduction of greenhouse gas emissions. Aside from the impact parameters explicitly mentioned above this activity reports the remaining set of impact criteria as discussed with the Commission services. These include parameters such as comfort and well-being, impact to self-consumption and demand response, costs and macro-economic benefits, etc. These KPIs are quantified based on impacts quantified following the results in terms of uptake of SRTs and based on impacts identified from an extensive literature review.

The modelling starts by taking the individual reference building level results from Task 4 Activity 1 and applying representative aggregation methods to create estimates of the EU level impacts in line for the scenarios defined in Activity 2. The methodology involves mapping the reference buildings to the building stock for each EU region to be simulated and then projecting them through time in line with the Activity 2 scenarios to 2050. This is done using a vintage stock model approach as is detailed in ANNEX D, and which draws upon the preceding analysis of impacts done for the first SRI technical study.

Under this approach, the building stock for each EU region is characterised in terms of the types of buildings (i.e. SFH, SMFH, LMFH, office, retail and educational), the types of technical building system (TBSs)/smart service domains found in the buildings and the prevalence of SRTs. In this regard it is similar to the first impact analysis study model but is more detailed. In modelling terms this is done by establishing the distribution of reference buildings (from Activity 1) as a function of the total regional building stock floor area that most closely matches the

[142] The same five regions as used in the first technical study and in the EPBD impact assessment are treated

available data on how the regional building stock is structured in terms of type, TBSs/smart service domains, and SRTs but also the basic energy performance of the building (related to the energy performance of the fabric and characteristics of the TBSs). Once this distribution is known per climatic region for the start year it is possible to project the stock of buildings forward within the model in a manner that characterises the annual changes in its makeup and allows the impacts to be accounted for on an annual basis.

To establish the stock distribution as a function of reference building type in the base year the different blends of reference building types (from Activity 1) are ascribed a share of the building stock by analysis of data on the distribution of buildings as a function of floor area per region considered (see Data section for sources). A similar process is undertaken to establish the prevalence and distribution of TBS/service domains and the expected distribution of SRTs as a function of their service and functionality level (again see the Data section for sources). The result is that each EU climatic region is correctly represented by the ensemble of the building stock that is ascribed to it. This disaggregation of the building stock is detailed further in ANNEX C.

Once this starting point (base year characteristics) is established the evolution of the stock under each of the scenarios is modelled through the systematic replacement of SRT reference buildings in line with the Activity 2 scenario drivers and installation/replacement cycles. This uptake of SRTs linked to the Activity 2 scenarios is modelled using the "SRI and SRT uptake model", as detailed in ANNEX D. Note, as SRTs are liable to be installed/replaced faster than the building fabric is renovated or replaced then this process reflects the installation and renewal of SRTs rather than the fabric. Nonetheless, the dynamic evolution of the fabric, the underlying TBSs/service domains and energy system is also simulated so that the outcome in any given year reflects the overlay of all the relevant effects. As the building stock of each Member State are attributed (i.e. apportioned) to the main regions it subsequently becomes possible to decompose the impacts to the Member State level in approximate terms (by considering each Member State's share of the building stock within their broader aggregate region). Annual impacts fall out of this stock modelling process by applying per-unit-floor-area values of impacts from the Activity 1 reference buildings to the regional stock in a manner that reflects their relative share in the total regional building stock distribution. Thus, as the building stock evolves towards a distribution of the Activity 1 reference buildings that has a higher proportion of SRTs with more advanced capabilities the floor area weighted impacts evolve accordingly.

The scenarios are simulated by considering how rapidly the building stock is expected to evolve as a function of building type, TBS and SRT under the drivers in each scenario defined in Activity 2. The reference scenario is aligned with the reference scenario(s) of the EPBD impact assessment (minus the impact of the SRI on SRTs). Similarly, the SRI scenarios are aligned with the implementation pathways and organisational frameworks being considered in Task 2 Activity 1 and Task 3 Activity 1 (see discussion in Activity 2). Thereby, the effect of the drivers per scenario is determined by mapping realistic impact functions to each scenario, considering the boundaries that they operate within (i.e. their scope of applicability) and the nature of the barriers that they seek to overcome and then applying available evidence to replicate the strength of the drivers and barriers to allow the simulation of the net effect. As was the case for the first SRI study, this needs to simulate SRT adoption rates and the rate of evolution in SRT functionality. This is done by assuming the rate of SRT adoption follows a logistics function (an S-curve). Supporting analysis of the relative strength of the barriers and drivers enables coefficients that describe the curve to be characterised for each segment of the building stock. This is done per SRI implementation pathway scenario considered. The adoption curve coefficients are derived by analysis and simulation of the underlying factors such as the elasticity of demand of SRTs as a function of awareness/exposure, SRT price, life-cycle cost benefits, etc. The same kind of approach is used to simulate the rate of change in the distribution of SRT functionalities. In both cases, the innate characteristics of the SRI scenario and the impacts of supporting measures need to be characterised, decomposed and simulated. Evidently, projections on the SRT adoption rates and market push and pull effects are prone to a high degree of uncertainty and will therefore be subjected to a sensitivity analysis as part of Activity 4.

As SRTs are progressively added to the building stock their associated investment costs will be accounted for and investment and operating costs simulated. Given that the expected savings in operating costs from SRTs lag the up-front investment costs the model simulates and reports annual investment costs, annual operating costs and discounted life cycle costs (using the EU's standard real discount rate to discount the value of future savings as per the Ecodesign Directive Impact Assessments[143] for example). Projected future energy tariffs are in line with the values used in the EPBD Impact Assessment[144].

A more detailed description of the model implementation is given in ANNEX D. Details on the building stock characteristics implemented in the model are given in ANNEX C. Significant effort is put into designing the model to be transparent.

4.3.2 IMPACT FOR DIFFERENT IMPLEMENTATION SCENARIOS

This section discusses the results obtained following the scenarios defined under Activity 2. While the modelling analyses variations in e.g. the implementation pathways across climate regions or building types, it was chosen to present here only the results on the EU28 level. Thereby, scenarios regarding the implementation pathways for the SRI have been applied to the building stock as a whole and assuming the "agreed EPBD amendments" scenario for the building stock evolution. The analysis of a more diverse implementation will be performed during the sensitivity analysis in Activity 4.

4.3.2.1 SRI deployment

As a starting point, Figure 42 shows the deployment rate of the SRI for the different implementation pathways. The deployment rate has been defined as the share of the buildings for which an SRI assessment has been carried out. Significantly higher deployment rates are found between pathways that foresee a mandatory linkage to the trigger events rather than a voluntary link. For the completely voluntary pathways (A2, C, E2 and F2), deployment rates generally reach about 5% coverage, except for the 26% coverage found for pathway A2 for which the SRI assessment is linked on a voluntary basis to the EPC assessment. Due to the high volume of EPC assessment compared to the other triggers,

[143] Ecodesign Impact Accounting – Status Report 2018 - https://ec.europa.eu/energy/sites/ener/files/documents/eia_status_report_2017_-_v20171222.pdf

[144] Commission staff working document SWD(2016) 408 final – Evaluation of directive 2010/31/eu on the energy performance of buildings https://ec.europa.eu/energy/sites/ener/files/documents/1_en_impact_assessment_part1_v3.pdf

significantly higher deployment rates are also observed for the voluntary pathway with supporting measures (A3) and the mandatory pathway (A1). The fastest uptake is obtained for implementation pathways A1 and E1, reaching a coverage of more than 75% of buildings by 2035[145]. It should be noted that the scenarios leading to high deployment rates are driven by the frequency of the trigger events which they are linked to, but do not yet factor in other potential constraints, such as the viability of forming a sufficiently qualified pool of assessors, quality control or rolling out mandatory requirements.

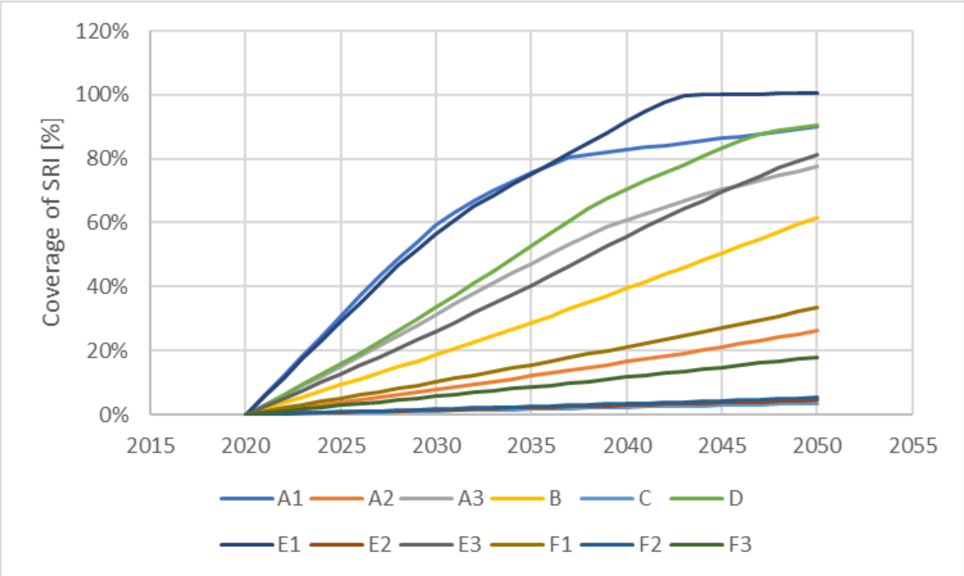

Figure 42 – Evolution of the SRI deployment rate for the implementation pathways as defined in Activity 2

4.3.2.2 SRT uptake and investment cost

Figure 43 and Figure 44 show the evolution of buildings that have undergone an upgrade of their technical building systems increasing the level of smartness of the building respectively by 1 level or to an A level[146]. Under BAU conditions, hence assuming no SRI assessments are carried out, 36% and 0.6% of buildings will by 2050 have been upgraded by 1 level smartness or to an A level respectively. Compared to this BAU scenario, the results for the fully voluntary implementation pathway C show an increase of 4% for SRTs upgrades by 1 level and 0.85% for upgrades to an A level. In the voluntary pathway that foresees a linkage to EPC (A2), increases of respectively 14% and 2.6% are found. These relatively low uptake rates evidently follow from the low SRI deployment rates for the fully voluntary pathway scenarios found in Figure 42 and primarily follow from the

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[145] This is because of the high frequency of trigger events under scenario E1; however, the present analysis does not consider other aspects of the suitability of the pathway, such as the viability of requiring assessment to be done by specific market actors.

[146] Note that, the rate at which SRT upgrades are carried out in the business as usual (BAU) scenario and following SRI assessments being carried are detailed in ANNEX D.d.ii.

market push and pull effects that are unlocked due to the uniform characterization and communication offered by the implementation of the SRI. When supporting measures are linked to the voluntary pathways (A3, D, E3, F3) an increase of SRT upgrades by 1 level of smartness between 12% and 30% are found compared to the BAU scenario, resulting in 48% to 66% of buildings that have undergone an upgrade by 1 level of smartness by 2050. An increase of 2.5% to 6% of SRT improvements towards an A level smartness is found for those respective cases, resulting in 3.1% to 6.6% of buildings having undergone an update from smartness levels D or C directly to level A.

The highest uptake of SRTs is found for the implementation pathway scenarios A1 and E1. For these pathway scenarios 81% and 76% of buildings undergo an upgrade by 1 level respectively. In addition, 9.6% and 8.6% respectively move immediately to an A level of smartness. Note that compared to the SRI deployment (Figure 42), the SRT uptake due to A1 and E1 only differ marginally. This can be attributed to two effects. Firstly, in A1 there is a large number of buildings that undergo more than one EPC assessment (trigger for A1) and hence SRI assessment over the period until 2050. A second or third SRI assessment for a specific building does not contribute to the deployment but can lead to an SRT upgrade. Hence, it should be noted that theoretically values above 100% are also possible as buildings may follow several consecutive upgrades to go from level D or C to level A. Secondly, market push and pull effects play a significant role and are more important when SRI assessments are clustered to specific buildings and/or climate regions.

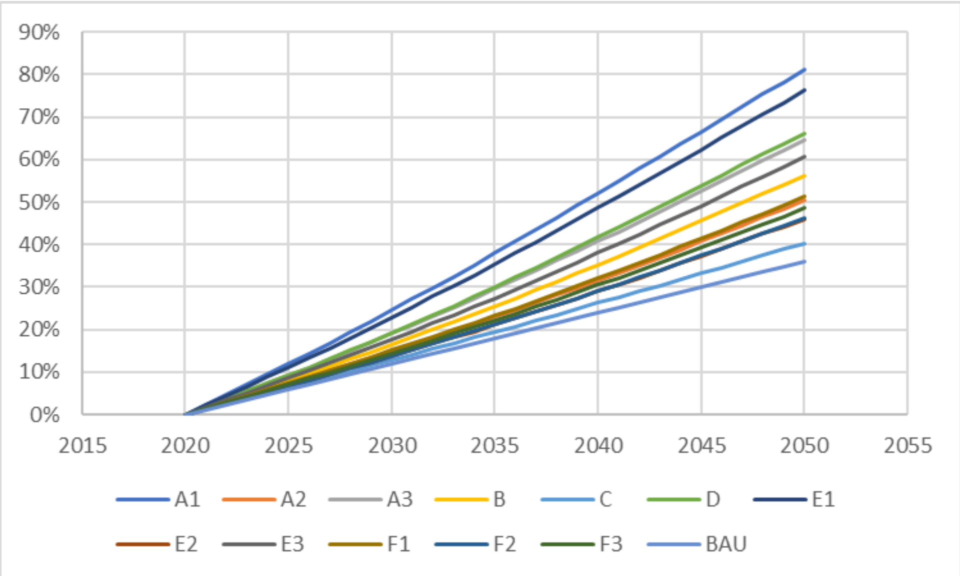


Figure 43 – Evolutions of buildings that have undergone an increase by 1 level of smartness

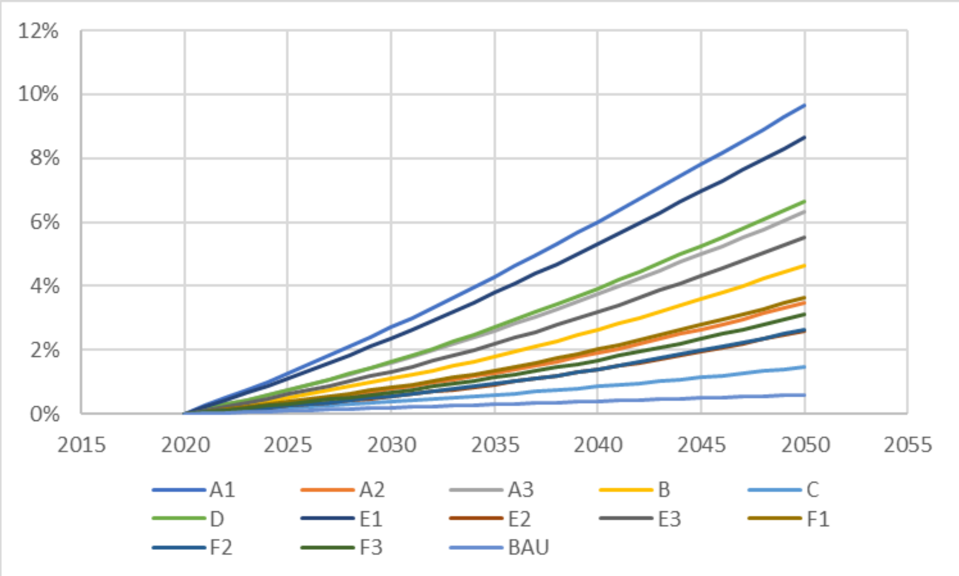


Figure 44 – Evolution of buildings that have undergone an upgrade to smartness level A

Figure 45 and Figure 46 show the annual investments in smart technologies again respectively for buildings increasing their level of smartness by 1 level and buildings upgrading immediately to an A level. Apart from the differences in height across the analysed implementation pathway scenarios, also a significant difference in trend can be found between the voluntary and mandatory pathway scenarios. For the mandatory scenarios the investments start at a high value while slowly decreasing towards 2050. For the voluntary scenarios a slow increase towards 2050 is observed. The decreasing effect for the mandatory cases results from market saturation, whereby the share of buildings that can still do an SRT upgrade rapidly decreases due to the relatively high uptake rate. In contrast, the increasing investments for the voluntary pathways demonstrate the market push and pull effects.

As shown in Figure 47 the high uptake rates for implementation pathway scenario A1 result in a total cumulated investment of 58 billion euro by 2030 and 181 billion euro by 2050. This scenario is closely followed by pathway E1 resulting in a total cumulated investment of 56 billion euro by 2030 and 180 billion euro by 2050. Compared to a BAU investment of 24 and 74 billion euro respectively. The SRI would hence be responsible for a market increase of 32 to 34 billion euro by 2030 for respectively pathways A1 and E1. By 2050 that market increase would evolve to 105 billion euro by 2050 when following respectively implementation pathway A1 and E1.

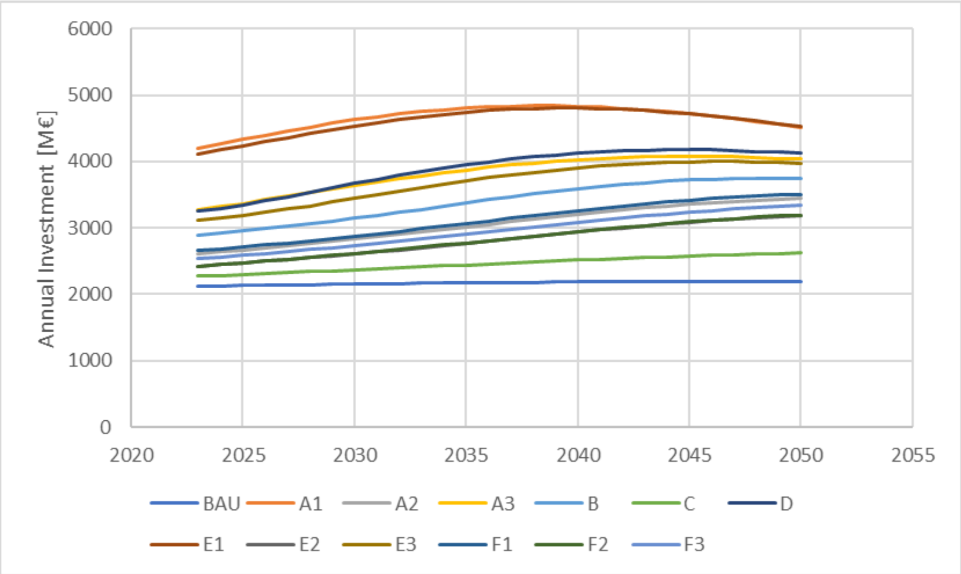


Figure 45 – Annual investment cost in SRT upgrades by 1 level of smartness

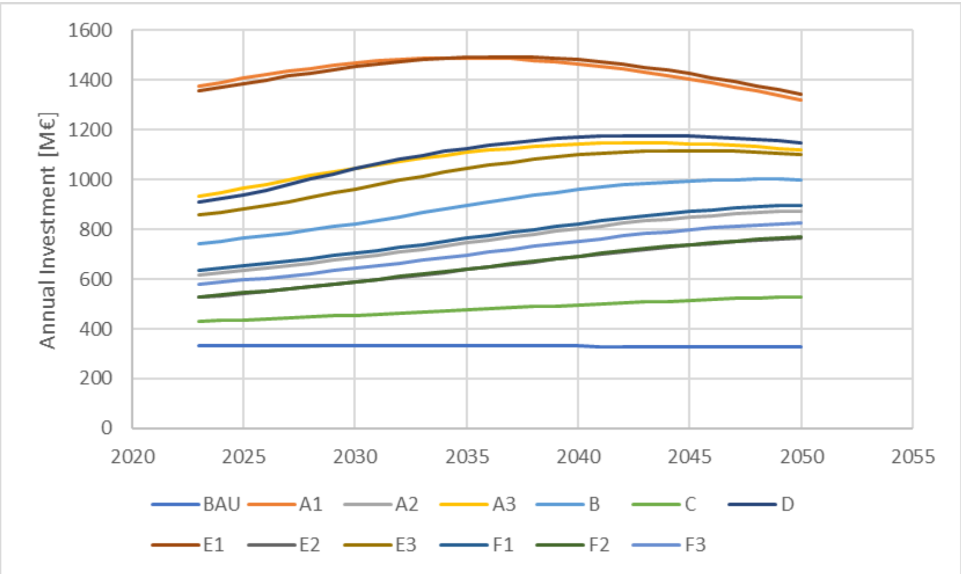


Figure 46 – Annual investment cost in SRT upgrades to smartness level A

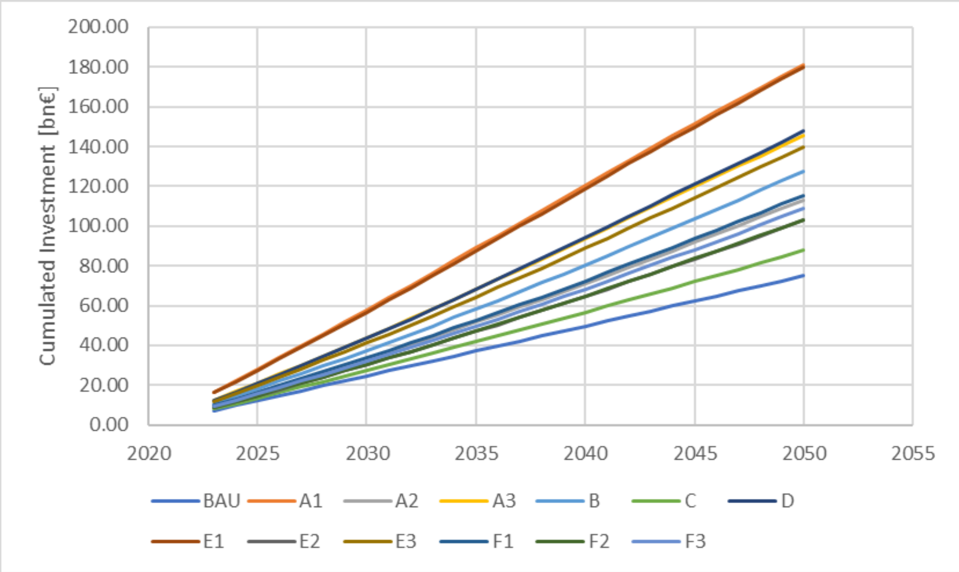


Figure 47 – Cumulative total investment in SRTs

4.3.2.3 Energy Use

This section presents the results of the impact of the SRI on the final and primary energy use in the EU28 building stock as a result of TBS efficiency improvements by upgrading the level of smartness of these systems. As emphasized in section 4.1, the energy savings shown here only represent the energy savings at the building sector resulting from the efficiency gains. The potential energy savings resulting from an improved interaction with the energy grid, is discussed further in the section on "demand-response and self-consumption".

Figure 48 presents the evolution of the primary energy use of the EU building stock as a result the "agreed EPBD amendments" scenario[147] and the energy efficiency gains from the increased SRT uptake as a result of the SRI. The results are shown for the different implementation pathways whereby the BAU depicts the scenario without an SRI implementation. From this figure it clear that energy savings in the building sector will primarily come from the measures proposed in the "agreed EPBD amendments" scenario. On top of these savings, the SRI can unlock up to 5% greater final energy savings by 2050. As shown in more detail on Figure 49 and Figure 50, the highest energy savings are obtained for the A1 and E1 implementation pathways, resulting in final energy savings up to 183-198 TWh or 201-219 TWh primary energy savings by 2050. By 2030, primary energy savings of 96 TWh and 89 TWh are predicted for pathways A1 and E1 respectively.

[147] The results for the reference scenario "agreed EPBD amendments" are taken from the first technical study on the SRI

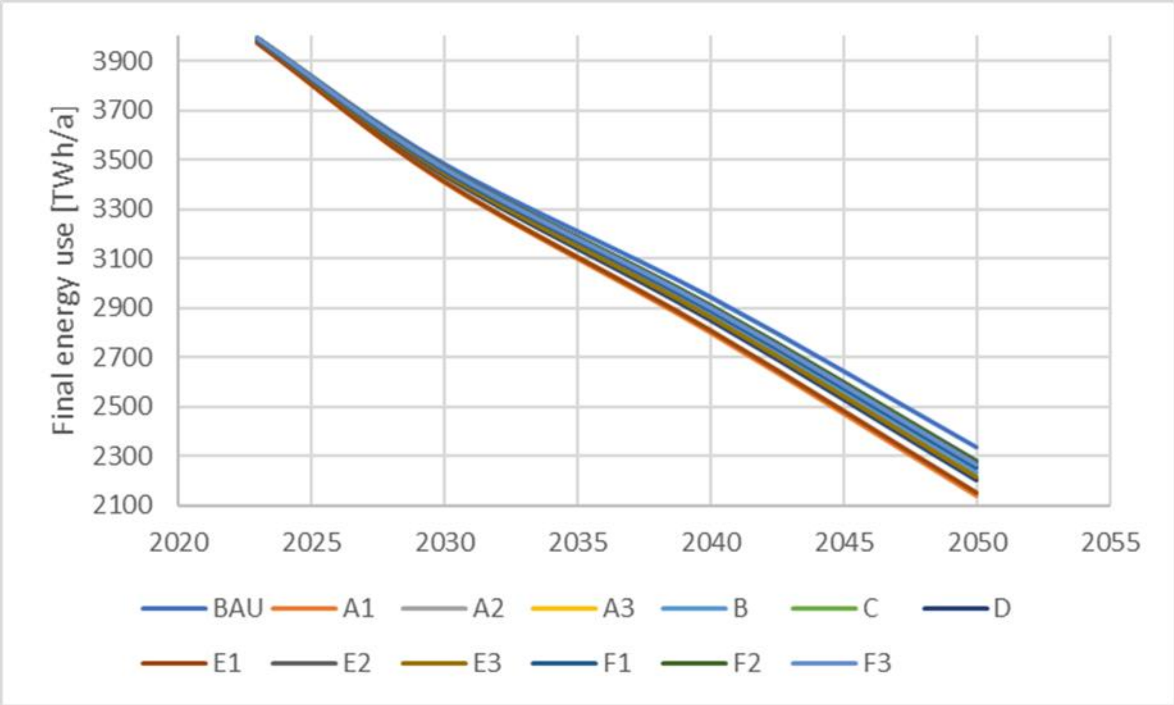


Figure 48 – Evolution of EU28 building stock final energy use as result of different implementation scenarios for the SRI

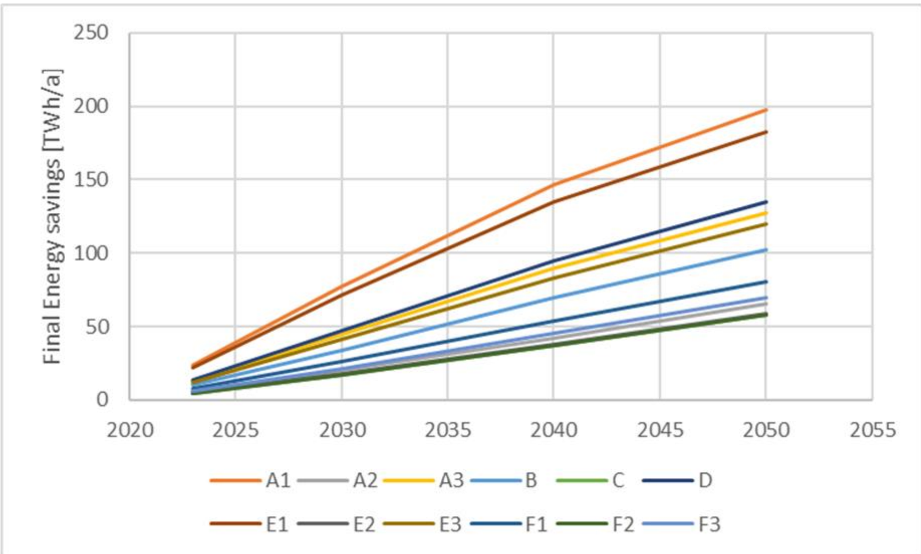


Figure 49 – Annual final energy savings as compared to the BAU scenario

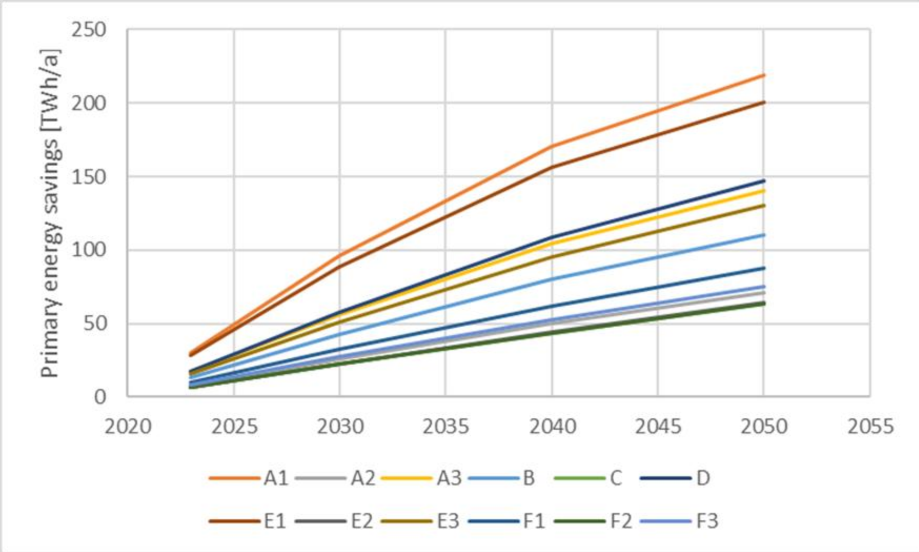


Figure 50 – Annual primary energy savings as compared to the BAU scenario

The energy savings shown in these scenarios are quite compatible with the provisional impact analysis results presented in the first technical study. The first technical study considered *moderate* and *ambitious implementation* scenarios that resulted in primary energy savings in 2050, compared to the BAU, of 204 and 270 TWh/year respectively. In the current study the A1 pathway savings are 219 TWh in 2050. The first technical study did not explicitly link the deployment assumptions in its scenarios to specific implementation pathways tied to any events or trigger points. When this is done, as it has been in the current analysis, the implications of the intervention frequency and strength of implementation mechanisms become more apparent.

4.3.2.4 Greenhouse gas emissions

Based on the energy use obtained by the SRI and SRT uptake model, the reductions in CO_2 emissions have been calculated. Thereby average CO_2 intensities for the building energy use are implemented until 2050 in function of the building type, climate region based on the results of the "agreed EPBD amendments" scenario as modelled in the first technical study on the SRI. Figure 51 shows the CO_2 emission reductions compared to the BAU scenario. In line with the energy savings, the largest reductions are found for the implementation pathway scenarios that consider a mandatory link to the trigger events, resulting in annual savings of up to 32 million ton per year by 2050. For the implementation pathway scenarios involving a voluntary link to the trigger events, emission reductions between 8 and 20 million ton per year are obtained by 2050 given adequate supporting measures are included in the implementation pathway.

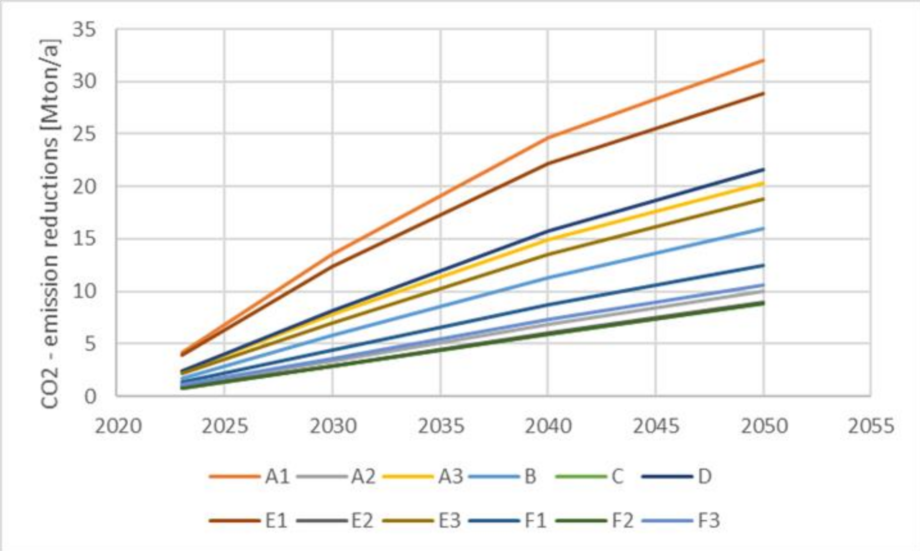


Figure 51 – Annual reduction of greenhouse gas emissions (CO_2) compared to the BAU SRT integration scenario

4.3.2.5 Demand-response and self-consumption

In the future energy system, storage and demand side flexibility – provided by amongst others smart use of appliances and technical building systems – will play an important role in assuring system adequacy and in optimizing the uptake of renewables by reducing curtailing needs. The Metis study S1 "Optimal flexibility portfolios for a high-RES 2050 scenario, outlines four levels of flexibility:

- at the **hourly and sub-hourly level**, increase of flexibility needs are mostly driven by the required ability to face imbalances caused by RES forecasting errors.
- at the **daily level**, the flexibility needs are found to be mostly driven by daily patterns of demand and the daily cycle of solar generation
- at the **weekly level,** the flexibility needs are mostly driven by wind regimes and by the weekday/weekend demand structure
- at the **annual level,** needs are driven by seasonal effects and the load-temperature sensitivity.

From a technical perspective, the impact of smart technologies targeted by the SRI is primarily expected to support the (sub)hourly and daily flexibility level. For example, smart control of heating and cooling systems can efficiently support variations in load profiles on time scales of minutes to few hours, allowing to shift demand away from peak periods and improve match with daily solar production cycles[148]. Smart charging of electric vehicles is similarly constraint by the daily

[148] Stinner, S., Huchtemann, K., Müller, D., 2016. Quantifying the operational flexibility of building energy systems with thermal energy storages. Appl. Energy 181, 140–154. https://doi.org/10.1016/j.apenergy.2016.08.055; Reynders, G., Nuytten, T., Saelens, D., 2013. Potential of structural thermal mass for demand-side management in dwellings. Build. Environ. 64, 187–199. https://doi.org/10.1016/j.buildenv.2013.03.010

usage cycle and hence allows variations up to 4-8h during the stationary hours of the vehicle[149].

In this macro-economic assessment, the consortium does not separate as such the impact of energy flexibility – unlocked by the increased smart ready technology uptake following the adoption of the SRI – in terms of improved self-consumption and security of supply. Rather, we follow the approach outlined in the COWI and METIS studies whereby offering demand response services – or energy flexibility – creates multiple benefits to the energy system, amongst others reduced peak capacity and avoided grid infrastructure extensions, that overall reduce the total system costs at high penetrations of renewables as foreseen in 2050[150]. Hence, taking the increasing share of intermittent renewable production towards 2050 as a given, avoided OPEX and CAPEX cost due to demand side flexibility are quantified. Evidently, prognosis on the value for flexibility in future energy systems, especially towards 2050, depends significantly on the assumed pathways for the energy system in terms of flexible production capacities, interconnection of transmission systems[151], evolution of costs of production and storage technologies, etc.

To estimate the value for increasing flexible capacity due to the uptake of SRTs that is stimulated by the SRI, this impact analysis builds on four important studies related to energy flexibility in the energy sector:

- The final report of DG ENERGY framework service contract SRD MOVE/ENER/SRD.1/2012-409-LOT 3-COWI: "Impact assessment study on downstream flexibility, price flexibility, demand response and smart metering", referred to as the COWI study
- The PhD-thesis of H.C. Gils (2015): "Balancing of Intermittent Renewable Power Generation by Demand Response and Thermal Energy Storage", referred to as the Gils study
- The research paper by A. Faruqui, D. Harris and R. Hledik: "Unlocking the €53 billion savings from smart meters in the EU: How increasing the adoption of dynamic tariffs could make or break the EU's smart grid investment", published in Energy Policy 38 (2010), referred to as the Faruqui study
- The METIS study S1: "optimal flexibility portfolios for a high-RES 2050 scenario", referred to as the METIS study.

In the COWI study, the potential system cost savings resulting from the adoption of flexibility services at the demand side are estimated until 2030. Economic savings up to 6180 M€/year are reported for the most ambitions policy option (option 3 in the study), compared to 4497 M€/year for the BAU scenario. These scenarios would reflect a flexible capacity in 2030 of 34 GW in the BAU scenario (6% of peak load) and 57 GW or (10% of peak load). From these results the value for flexible load can be deduced, leading to a value of 144 €/kW of potential power

[149] Roy, J. Van, Leemput, N., Geth, F., Salenbien, R., Buscher, J., Driesen, J., 2014. Apartment building electricity system impact of operational electric vehicle charging strategies. IEEE Trans. Sustain. Energy 5, 264–272. https://doi.org/10.1109/TSTE.2013.2281463

[150] The METIS study finds that for the METIS-S1-2050 scenario, which is based on the European Commission's EUCO30 scenario and assumes high shares of variable renewable energy production (80% of production from RES of which 60% from PV and Wind), requires a significant increase of flexibility compared to the EUCO30 scenario for 2030: +80% for daily flexibility, +60% for weekly timescale and +50% at the annual timescale.

[151] The METIS study concludes that most of this flexibility shall be delivered from cross-border exchanges (164 GW).

reduction capacity. In contrast, the study by Faruqui presents value of 95 €/kW as the sum of the avoided production capacity (87.12 €/kW) and avoided costs in transmission and distribution system (10% of production capacity costs). The demand side flexibility offered by smart control (hybrid) heat pumps in METIS study is estimated at a peak reduction capacity of 37 GW, unlocking an annual cost reduction of 2.4 billion euro. Hence, an economic value of 65 €/kW for flexible capacity. In summary, the different studies provide a range for the economic value of flexible capacity between 65 €/kW and 144 €/kW annually. In a conservative approach, this impact analysis will work further with the lower value of 65 €/kW per year.

The adoption of the SRI is expected to lead to an increase in smart technology integration in buildings. As outlined in the previous section, SRTs with their ability to provide the necessary communication, control and optimization infrastructure, may have an important effect on the response to grid incentives, hence increasing the offering of flexibility to the grid. The COWI study, based on international studies on price-based DR for domestic costumers and SME's, states that for typical appliances, in the absence of smart, automated control, response rates of the peak demand to the grid incentives are expected to be 2-6% in a time of use pricing context. Yet, when automation is available activated capacity can increase to 21-44%.

To map this with the impact calculation method for the SRI and the resulting SRT uptake, it is assumed that buildings with a smartness level D offer 6 % of flexibility, level C results in 10 % of flexibility, 21% for level B and 44% for level A. Following the modelled distribution of the EU building stock among these classes of smartness, the response rate in the residential sector to grid incentives for the BAU scenario without any impact of the SRI is 6.8% in 2020. Under this BAU scenario for SRT uptake, hence without any effect of the SRI, this would increase to 8.8% in 2030, 11.2% in 2040 and 14.2% in 2050. Remaining at the conservative side, the theoretical demand reduction potential for the traditional residential appliances is based on Gils. The SRI BAU scenario would represent a flexible capacity of 3.1 GW in 2020, 4.0 GW in 2030, 4.9 GW in 2040 and 5.7 GW in 2050.

For the assumption of implementation pathway A1 (a detailed expert assessment), these values would increase to 10.8% (5.0 GW) in 2030, 15% (7.1 GW) in 2040 and 19.5 % (9.2 GW) in 2050. In that scenario, the SRI would hence increase the available demand side flexibility by 1 GW in 2030, 2.1 GW in 2040 and 3.5 GW in 2050. Assuming the conservative value of flexibility of 65 €/kW, the SRI would annually unlock 65 M€/year, 137 M€/year, 227 M€/year in respectively 2030, 2040 and 2050, or 3.3 billion euro of cumulated savings (Figure 53). The increase in flexible capacity unlocked for the other implementation pathway scenarios is shown in Figure 52.

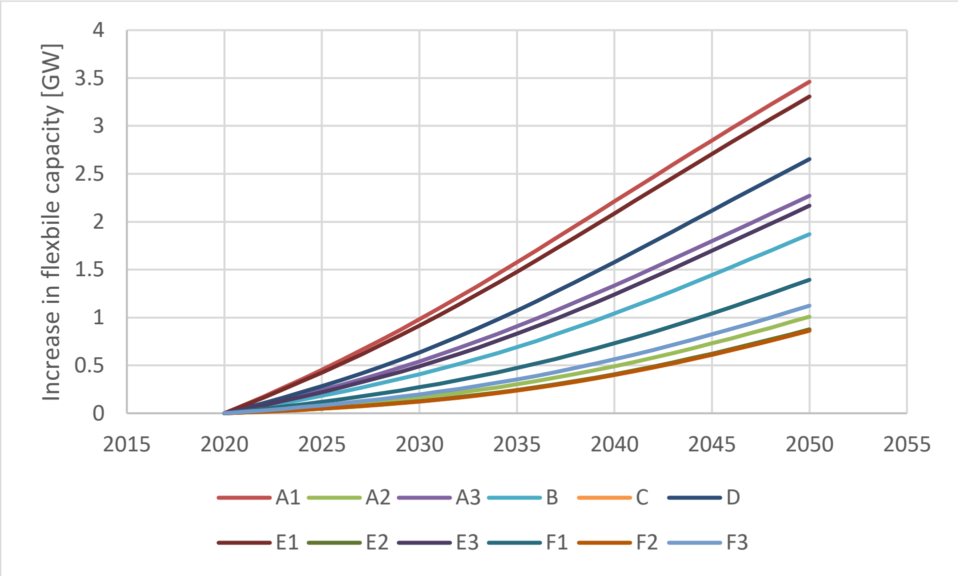


Figure 52 – Increase in flexible capacity (GW) compared to the BAU SRT integration scenario

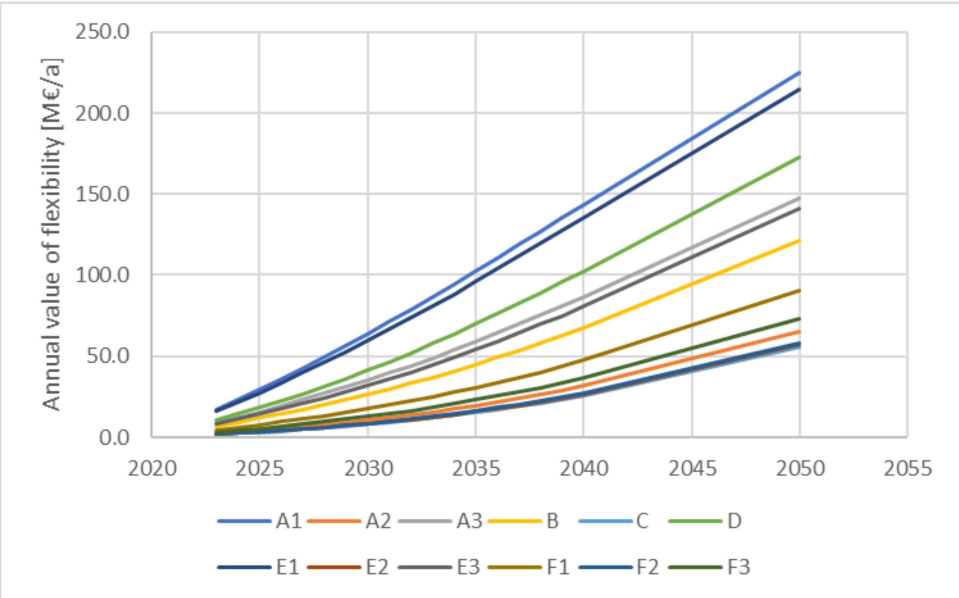


Figure 53 - Annual value of increased demand side flexibility compared to the BAU SRT integration scenario

4.3.2.6 Employment

The approach used to estimate the employment impacts of the SRI is two-fold. First, an analysis is done on the employment related effects due to the influence of the SRI on the uptake of smart ready technologies (SRTs) and related services, and the effect it has on employment in the energy supply sector. Second, an analysis is done of the expected impact of the SRI on employment associated with assessment of the SRI. In both cases the influence that the SRI is expected to have will be contingent on the manner in which it is implemented, expressed through the set of implementation pathways.

SRT and services uptake impacts on employment

In all cases the SRT and related services value chain can be decomposed into the following aspects:

- Manufacture
- Installation
- Wholesale
- Retail
- Maintenance.

The approach taken in this IA is to base the estimated SRI employment effects on the estimated SRT revenues attributed to each of these activities in the SRT value chain. Given the plethora of SRTs and services it is impractical to conduct a detailed analysis of the exact costs and breakdowns related to each type of SRT and related service. Rather the approach adopted is to draw upon the evident parallels with investment and employment effects due to the uptake of more energy efficient products under the Ecodesign directive – many of which exhibit very similar market characteristics in terms of the nature of the market structure to the types of SRTs that could be stimulated by the SRI.

The set of SRTs and related services that could be stimulated by the SRI are rather diverse. They include the following: BACS, EV charging systems, indoor air quality control and monitoring systems & shading controls amongst many others. Overall though the types of technologies that will be used in SRTs include a blend of actuators, motors, sensors, IT systems, monitors and displays, out-stations and batteries. Thus, without knowing in advance the exact blend of technologies and components it is possible to derive estimates based on the evident parallels with similar technologies that have been the subject of Ecodesign assessments and impact analyses. In particular, this analysis makes use of the findings of the 2016 Ecodesign impact assessment by VHK that derived employment impact values for each product subject to Ecodesign requirements.

Direct employment creation in the SRT sector

There are no publicly available statistics on employment in the manufacture, wholesale, retail, installation and maintenance of SRTs; however, there are statistics on these fields for products which have been subject to regulation under the Ecodesign Directive. The Ecodesign Impact Accounting study[152] produced a thorough analysis of the energy and employment impacts of Ecodesign and energy labelling regulations for regulated products in the EU and provides data on many product types that can be used as a proxy for the SRT sector. SRTs are a blend of electro-mechanical technologies such as valves, actuators, thermostats related to heating and cooling systems and of IT technologies (electronic controls, sensors, communication). A significant part of their cost is concerned with system design and installation, rather than hardware. In this regard, it is expected that their

[152] Ecodesign Impact Accounting: Summary Report, Van Holstiejn en Kemna, 2016

levels of employment per unit revenue generated resemble a blend of technical building systems costs (especially those associated with space heating) and of IT equipment costs. The VHK study contains EU average employment per unit revenue data for each aspect of the supply chain for a large variety of equipment types. The current IA assumes that SRTs will have the same level of employment per unit revenue as a blend of combination boilers, space heating only boilers and imaging equipment as follows:

- Average number of industry jobs per €bn of incremental industry revenues
- For imaging equipment = 19946
- For Central Heating combi, water heating = 20078
- For Central Heating boiler, space heating equipment = 19998
- Mean =20007.

- Average number of wholesale jobs per €bn of incremental wholesale revenues
- For imaging equipment = 4369
- For Central Heating combi, water heating = 4029
- For Central Heating boiler, space heating equipment =3972
- Mean =4213.

- Average number of installer/retail jobs per €bn of incremental installer/retail revenues
- For imaging equipment = 16772
- For Central Heating combi, water heating = 20899
- For Central Heating boiler, space heating equipment =29304
- Mean =22325.

Where the average EU employment per €bn of revenue per part of the supply chain for imaging equipment, central heating combi systems, and central heating boilers comes from the VHK (2013) study. Analysis of the data in the same study shows that on average for these three equipment types that:

Acquisition cost = (Ind Rev + Install Rev + Wholesale Rev + Retail Rev) / 0.90

Where:

- Ind Rev = industry revenue i.e. the cost to manufacture the product
- Wholesale Rev = wholesale revenues for the product
- Retail Rev = retail revenues for the product
- Install Rev = installation revenues for the product.

Analysis of the average share of revenues by supply chain activity for these three products shows the following relationships:

Wholesale Rev = 0.23 * Ind Rev

Retail Rev = 0.26 * Ind Rev

Install Rev = 0.84 * Ind Rev

Thus, the acquisition cost formula can be expressed as:

Acquisition cost = (Ind Rev + Ind Rev * 0.84 + Ind Rev * 0.23 + Ind Rev * 0.26) / 0.90

and rearranged to be expressed in terms of the industrial revenue as:

Ind Rev = (Acquisition cost * 0.9) / (1 + 0.84 + 0.23 + 0.26)

The estimated SRT acquisition cost per year following the SRI's launch is derived as explained in ANNEX D and summarized in Table 46 as a function of implementation pathway scenario. Thus, the time series of acquisition costs for each scenario can be inserted into the formulae above to create a time series of estimated revenues for each SRT supply chain activity. These can then be multiplied by the average number jobs per €bn of revenues figures presented at the start of this section to create the time series of expected direct employment per supply chain activity.

It is worth noting that while the blend of values for heating systems and imaging systems were used in the current analysis the VHK values are quite similar across diverse equipment types thus there is a high degree of consistency in the expected ratios of employment per unit spend and equally of the division of employment across the supply chain.

Direct employment losses in the energy sector

Some SRTs are expected to lead to energy savings and hence reduce the consumption of energy – this in turn is likely to produce a reduction in employment in the energy sector. To estimate the expected direct employment losses from reduced energy sales due to the energy efficiency benefits of SRTs it was necessary to establish the employment per unit of revenue in the energy supply sector. Most of the expected energy savings from SRTs are from gas and electricity savings. Scouring the Eurostat datasets did not reveal employment per industry activity data; however, data for the UK (2016) was found for the energy sector and was used as a proxy after adjustment for currency exchange rates. This data showed that the average number of employees per €billion of revenue in the energy sector was just 1607. Employment per unit revenue in the manufacture of equipment is more than a factor of 12 above this, which reflects that the energy supply sector has a very low employment intensity and is the principal reason why energy efficiency measures in general create more jobs than they destroy.

Indirect employment effects

The implementation pathway scenarios show that the value of net savings from greater deployment of SRTs exceed the investment and assessment costs by between ~€4 bn and €13 bn per annum by 2050 depending on the implementation pathway considered. In principle, the money saved from reduced energy bills will be recirculated in the economy and this will generate additional employment. A simple method to estimate the magnitude of this effect is to multiply the average number of employees per €bn of GDP in the EU economy by the net cost savings expressed in €bn to derive the number of indirect jobs created. Analysis of Eurostat (2017) data shows that there were 202 million employees in the EU in 2015 and the GDP was €14600 bn, thus the average number of people employed per €bn GDP is 13808, which implies that there could be additional net indirect employment created of between ~55 and 193 thousand depending on the implementation pathway; however, as these effects are highly uncertain they are not included in the SRI impact accounting presented here. Note, there is expected to be more uncertainty in the indirect employment estimates than the direct employment effects, not least because of the tangential relationship between saved money, expenditure in other areas and related investment in other employment generating activities; but also the degree of delay in the recycling of the expenditure savings into employment creating activities and the extent to which these savings trigger investments within the EU as opposed to elsewhere. Thus, the indirect employment impact estimates are not as robust as the direct employment impact estimates.

Employment impacts related to the assessment of the SRI

The manner in which the SRI is to be assessed could also create direct employment associated with the assessment of the SRI. If professional third-party assessors are used these would need to be hired, trained and certified. If in-house professional assessors are used to conduct self-assessments of properties owned or managed by their employers, then these would also need to be trained and part of their duties assigned to conducting SRI assessments and thus this would also be expected to create a need for more employment of such assessors. However, this kind of "in house" assessment could also potentially be absorbed in the existing duties of facility managers and hence has a much less certain effect on employment than the establishment of qualified 3rd party assessors. In consequence it is, conservatively, assumed not to add to direct employment although in practice it almost certainly would but to a lesser extent than 3rd party assessment.

To estimate the impact of 3d party assessment data from the experience of SRI assessment in the test phase is analysed to determine how long it takes to conduct an SRI assessment in practice. Reasonable assumptions are then made about the length of time it takes to travel to and from a property and, depending on the implementation pathway, the additional time it would take to arrange an SRI assessment. These figures are then processed to determine how much floor area could be assessed per type of building stock per annum by a trained certifier and adjusted to take account of average staff utilisation factors that are consistent with the experience of conducting other kinds of 3rd party building assessments, such as EPCs or environmental assessment. Direct employment impact is determined by dividing the total floor area assessed per type of building per annum by the estimated average annual floor area assessment per 3rd party SRI assessor.

Note, the direct employment data so derived is multiplied by the EU average employment costs for a job of a similar standing to an assessor to determine the estimated assessment employment costs reported in the Costs and Benefits section 6 below.

The share of third party assessment as a proportion of all SRI assessment is assumed to vary by implementation pathway such that all assessment is assumed to be conducted by a 3rd party except for implementation pathway C (where it is assumed to be 5% 3rd party assessment and 95% self-assessment) and implementation pathway D (where it is assumed to be 50% 3rd party assessment and 50% self-assessment). The rationale behind these assumptions is that for the mandatory pathways it is implicit that 3rd party assessment would be used. For all the other pathways that are explicitly linked to an externally driven intervention (trigger point) then again it is assumed that the assessment would be done by the entity concerned with that trigger point and hence would be 3rd party. In the case of implementation pathway C, it is assumed that only a small proportion of market actors are willing to pay for a 3rd party assessment and hence the vast majority of assessments are self-assessments. For pathway D the share of 3rd party assessments rises considerably because the cost of the assessment is assumed to be covered by a subsidy.

Direct employment impacts of the SRI – estimated results

The estimated net employment impacts of the SRI as a function of the implementation pathway are shown Figure 54. Full data showing impacts per pathway on each aspect of employment are presented in Annex D.

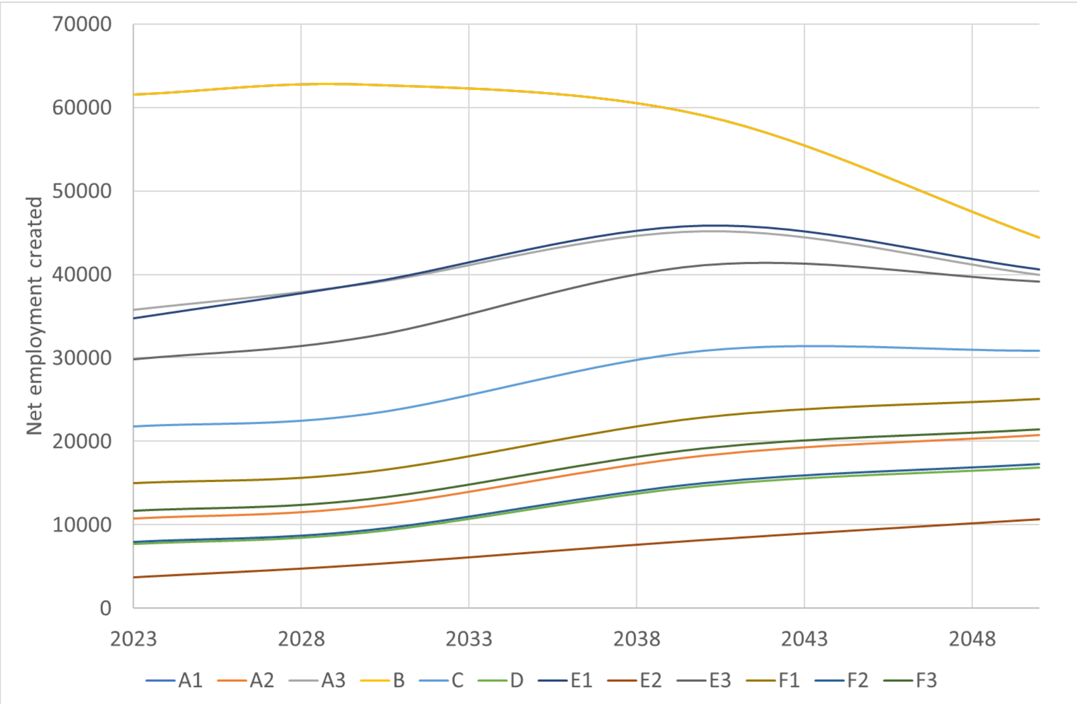


Figure 54 – Net additional employment created compared to the BAU SRT integration scenario

4.3.2.7 Material Circularity

The estimated material related environmental impacts derived from this method are reported in Table 14 and Table 15 for SRI implementation pathways A1 and C respectively, which cover the two extremes from the set of pathways. These include impacts associated with all the product lifecycle stages except the use phase which is already accounted for in the energy and greenhouse gas analysis. The values reported are those which are incremental to the base case (business as usual) scenario, and hence are the additional impacts associated with the higher SRT use induced through the SRI. Full data showing impacts for each implementation pathway are presented in Annex D.

Table 14 - Estimated material related environmental impacts (from manufacture, distribution, EOL) compared to BAU for implementation pathway A1

Impact parameter	Units	2023	2030	2040	2050
Other resources & Waste					
Total Energy (GER)	PJ	20.1	23.2	24.3	21.4
of which, electricity (in primary MJ)	PJ	5.9	6.8	7.1	6.3
Water (process)	billion ltr	3.0	3.4	3.6	3.2
Water (cooling)	billion ltr	6.2	7.2	7.5	6.6
Waste, non-haz./ landfill	kt	172.3	198.9	208.3	183.5
Waste, hazardous/ incinerated	kt	32.4	37.4	39.2	34.5
Emissions Air					
Greenhouse Gases in GWP100	Mt CO2 eq.	1.1	1.3	1.3	1.2
ODP		0.0	0.0	0.0	0.0
Acidification, emissions	kt SO2 eq.	6.2	7.1	7.5	6.6
Volatile Organic Compounds (VOC)	kt	0.1	0.1	0.1	0.1
Persistent Organic Pollutants (POP)	ng i-Teq	1.2	1.3	1.4	1.2

Heavy Metals	t Ni eq.	1.7	2.0	2.1	1.8
PAHs	t Ni eq.	1.7	1.9	2.0	1.8
Particulate Matter (PM, dust)	t	9.2	10.6	11.1	9.8
Emissions water					
Heavy Metals	kg Hg/20	1280.6	1477.8	1547.8	1363.6
Eutrophication	kt PO4	78.8	90.9	95.2	83.9
POP ng-i-tec		0.0	0.0	0.0	0.0

Table 15 - Estimated material related environmental impacts (from manufacture, distribution, EOL) compared to BAU for implementation pathway C

Impact parameter	Units	2023	2030	2040	2050
Other resources & Waste					
Total Energy (GER)	PJ	3.1	4.5	7.0	9.2
of which, electricity (in primary MJ)	PJ	0.9	1.3	2.1	2.7
Water (process)	billion ltr	0.5	0.7	1.0	1.4
Water (cooling)	billion ltr	1.0	1.4	2.2	2.8
Waste, non-haz./ landfill	kt	26.7	38.2	60.1	78.8
Waste, hazardous/ incinerated	kt	5.0	7.2	11.3	14.8
Emissions Air					
Greenhouse Gases in GWP100	Mt CO2 eq.	0.2	0.2	0.4	0.5
ODP		0.0	0.0	0.0	0.0
Acidification, emissions	kt SO2 eq.	1.0	1.4	2.2	2.8
Volatile Organic Compounds (VOC)	kt	0.0	0.0	0.0	0.0
Persistent Organic Pollutants (POP)	ng i-Teq	0.2	0.3	0.4	0.5

Heavy Metals	t Ni eq.	0.3	0.4	0.6	0.8
PAHs	t Ni eq.	0.3	0.4	0.6	0.8
Particulate Matter (PM, dust)	t	1.4	2.0	3.2	4.2
Emissions water					
Heavy Metals	kg Hg/20	198.1	283.5	446.4	585.5
Eutrophication	kt PO4	12.2	17.4	27.5	36.0
POP ng-i-tec		0.0	0.0	0.0	0.0

4.3.2.8 Health & Wellbeing

To give an indicative estimation of the potential comfort, health and wellbeing co-benefits from the SRI the study team has post-processed the JRC findings of the monetized impacts of these benefits due to the energy savings attributable to the EPBD in 2030 to derive the estimated monetised value of SRI benefits for each implementation pathway for the years 2023, 2030, 2040 and 2050 (as shown in Table 16 to Table 19). The method assumes that the energy savings expected from the greater deployment of SRTs under the various SRI implementation pathway scenarios are a proxy for the health and wellbeing co-benefits proportional to the projected energy savings under the EPBD to 2030. While this exercise has been conducted to determine some tentative values of these co-benefits it should be noted that these are clearly subject to significant uncertainties in the absence of a specific investigation of the health and wellbeing impacts directly attributable to SRTs and also given the large spread in values reported in the JRC study itself.

Table 16 - Estimated Value of incremental SRI health & wellbeing benefits compared to BAU in 2023 (€m)

Scenario	Asthma	Indoor Air Pollution	PM2.5	Excess winter mortality	Mortality ozone	Lighting	Total
A1	207	247	480	64	108	52	1157
A2	62	74	144	19	32	15	346
A3	128	152	297	39	67	32	714
B	100	119	232	31	52	25	558
C	54	65	126	17	28	14	304
D	131	156	303	40	68	33	730
E1	204	243	474	63	107	51	1143
E2	55	66	128	17	29	14	308
E3	118	140	273	36	62	29	658
F1	78	93	181	24	41	19	435
F2	54	65	126	17	28	14	304
F3	66	79	153	20	35	16	369

Table 17 - Estimated Value of incremental SRI health & wellbeing benefits compared to BAU in 2030 (€m)

Scenario	Asthma	Indoor Air Pollution	PM2.5	Excess winter mortality	Mortality ozone	Lighting	Total
A1	681	812	1582	210	356	170	3811
A2	215	257	500	66	113	54	1205
A3	433	517	1007	133	227	108	2425
B	337	402	784	104	176	84	1888
C	191	227	443	59	100	48	1067
D	448	535	1042	138	235	112	2509
E1	667	795	1549	205	349	167	3732
E2	193	231	449	59	101	48	1082
E3	398	474	924	122	208	99	2226
F1	266	317	619	82	139	67	1490
F2	191	228	444	59	100	48	1069
F3	229	272	531	70	120	57	1279

Table 18 - Estimated Value of incremental SRI health & wellbeing benefits compared to BAU in 2040 (€m)

Scenario	Asthma	Indoor Air Pollution	PM2.5	Excess winter mortality	Mortality ozone	Lighting	Total
A1	1158	1380	2690	356	606	289	6479
A2	326	389	758	100	171	82	1827
A3	740	882	1718	228	387	185	4139
B	562	670	1306	173	294	140	3145
C	279	333	649	86	146	70	1564
D	785	936	1825	242	411	196	4395
E1	1135	1353	2637	349	594	284	6351
E2	284	339	661	87	149	71	1591
E3	681	812	1582	209	356	170	3810
F1	424	505	985	130	222	106	2371
F2	280	334	651	86	147	70	1568
F3	351	419	816	108	184	88	1966

Table 19 - Estimated Value of incremental SRI health & wellbeing benefits compared to BAU in 2050 (€m)

Scenario	Asthma	Indoor Air Pollution	PM2.5	Excess winter mortality	Mortality ozone	Lighting	Total
A1	1618	1930	3760	498	847	405	9057
A2	574	684	1333	177	300	143	3212
A3	1114	1328	2588	343	583	278	6233
B	895	1067	2080	275	468	224	5009
C	509	607	1182	157	266	127	2848
D	1183	1411	2749	364	619	296	6621
E1	1600	1908	3718	492	837	400	8955
E2	516	615	1198	159	270	129	2886
E3	1050	1252	2440	323	549	263	5878
F1	710	846	1650	218	371	177	3973
F2	510	608	1185	157	267	127	2853
F3	608	725	1413	187	318	152	3404

4.3.2.9 Costs & Benefits

The estimated costs and benefits of the SRI are summarized in Table 20 to Table 23. These include the additional costs for the acquisition and installation of SRTs above the business as usual (reference) case (Table 20), the cost of conducting the SRI assessments (Table 21), the value of the SRI induced energy bill savings (Table 22) and the net cost savings attributable to the SRI (Table 23) which is the simple sum of the above. It should be noted that the value of additional benefits (associated with the health & wellbeing impacts of the SRI, reduced maintenance costs, higher convenience and comfort) and the additional costs (associated with the environmental impacts of materials used in the SRTs) are not included in these assessments due to the high uncertainty in, or unfeasibility of estimating their monetised value.

Table 20 – Incremental SRT cost of the SRI compared to the BAU (€m per year)

Implementation pathway	2023	2030	2040	2050
A1	3125	3606	3777	3328
A2	616	841	1261	1598
A3	1754	2198	2650	2644
B	1180	1480	2029	2242
C	483	692	1089	1429
D	1709	2227	2775	2761
E1	3026	3499	3767	3358
E2	497	707	1107	1445
E3	1513	1914	2484	2569
F1	841	1091	1562	1896
F2	485	694	1092	1431
F3	663	891	1320	1654

Table 21 –SRI assessment costs (€m per year)

Implementation pathway	2023	2030	2040	2050
A1	434	460	515	560
A2	39	42	64	92
A3	307	325	475	526
B	114	121	194	273
C	1	1	1	2
D	299	317	440	513
E1	379	401	474	514
E2	12	13	19	26
E3	223	236	379	500
F1	61	65	101	149
F2	10	11	15	21
F3	48	51	73	103

Table 22 –Value of SRI induced energy bill savings compared to the BAU (€m per year)

Implementation pathway	2023	2030	2040	2050
A1	2150	7079	12035	16823
A2	643	2239	3394	5966
A3	1327	4503	7688	11578
B	1036	3507	5841	9305
C	564	1982	2905	5290
D	1357	4661	8163	12298
E1	2122	6932	11797	16633
E2	573	2010	2956	5360
E3	1223	4134	7077	10918
F1	808	2768	4405	7380
F2	565	1986	2912	5300
F3	686	2376	3652	6323

Table 23 –Value of net SRI induced cost savings compared to the BAU (€m per year)

Implementation pathway	2023	2030	2040	2050
A1	-1409	3012	7742	12936
A2	-12	1357	2069	4275
A3	-734	1981	4563	8408
B	-258	1906	3619	6789
C	80	1290	1814	3859
D	-651	2117	4949	9023
E1	-1283	3033	7556	12761
E2	63	1290	1831	3889
E3	-514	1983	4214	7849
F1	-95	1612	2742	5335
F2	70	1282	1805	3849
F3	-25	1434	2258	4567

4.4 ACTIVITY 4: SENSITIVITY ANALYSIS

As the quantitative modelling of the SRI impact involves a significant amount of simplifications and assumptions a sensitivity analysis has been carried out to investigate the impact of variations to the key model parameters on the uptake of the SRI and the effect on the analysed KPIs. The sensitivity analysis is split in three parts. Firstly, the impact of model parameters on the amount of conducted SRI assessments is evaluated. Secondly, the sensitivity of the uptake of smart ready technologies following an SRI assessment to the model parameters is assessed. In the final step, based on the first two steps, four extreme scenarios are defined in terms of parameter definitions. For these scenarios, the impact of the model parameters to the evaluated KPIs (energy use, CO_2-emissions, etc.) are analysed.

4.4.1 SENSITIVITY ANALYSIS ON THE AMOUNT OF SRI ASSESSMENTS

The amount is SRI assessments that is being conducted given an implementation pathway is modelled based on a set of trigger events and the likelihood that an SRI assessment will be conducted given a certain trigger event. These likelihoods dependent on the implementation pathway. For example, in implementation pathway A1 a mandatory coupling to EPC is foreseen leading to a 100% likelihood that an EPC assessment will lead to an SRI assessment. The underlying modelling is based on statistical evidence of the occurrence of these trigger events as well as a set of model parameters that reflect at which rate a trigger event will lead to an assessment. Especially for the implementation pathways that include some form of voluntary coupling to a trigger event, the likelihood an SRI assessment will be carried out is subject to a significant level of uncertainty.

4.4.1.1 Impact of SRI assessment rate for voluntary links to trigger events

Table 41 (ANNEX D) gives an overview of the implemented rates as implemented in the base scenario. As limited evidence is available to support the SRI uptake rates when a voluntary implementation is proposed, a first step in the sensitivity analysis is to vary these uptake rates to high and low uptake rate scenarios.

and Table 25 show the rates applied under respectively the high and low impact scenario. Note that in both cases only the rate of SRI assessments for voluntary links to a trigger event have been modified. This is done only for the targeted trigger events in that specific implementation pathway. For example, In A2 – a voluntary link to EPC assessments – the rate of SRI assessments has increased from 10% in the default scenario to 20% in the high uptake scenario. In the low impact scenario, these have been reduced to 5%.

Table 24 - rate of SRI assessment per triggers under high impact scenario (in %)

	A1	A2	A3	B	C	D	E1	E2	E3	F1	F2	F3
EPC ASSESSMENT	100	20	60	0.5	1.0	40	0.5	0.5	0.5	0.5	0.5	0.5
REPLACEMENT OR UPGRADE OF TECHNICAL BUILDING SYSTEMS	0.1	0.1	0.1	0.1	0.5	20	100	0.5	40	0.1	0.1	0.1
MAJOR RENOVATIONS	0.0	0.0	0.0	100	3.0	40	100	1.5	60	1.5	1.5	1.5
NEW CONSTRUCTION	0.0	0.0	0.0	100	3.0	40	100	1.5	60	1.5	1.5	1.5
INSTALLATION OF LOCAL RES (E.G. PV)	0.1	0.1	0.1	0.1	0.5	20	0.1	0.1	0.1	0.1	0.1	0.1
EV PURCHASE	0.2	0.2	0.2	0.2	0.2	5.1	0.2	0.2	0.2	0.2	0.2	0.2
SMART METER DEPLOYMENT	0.1	0.1	0.1	0.1	0.1	20	0.1	0.1	0.1	100	10	60
HVAC INSPECTIONS	0.1	0.1	0.1	0.1	0.1	0.1	100	0.5	40	0.1	0.1	0.1
OTHER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 25 - rate of SRI assessment per triggers under low impact scenario

	A1	A2	A3	B	C	D	E1	E2	E3	F1	F2	F3
EPC ASSESSMENT	100	5.0	20	0.5	0.5	10	0.5	0.5	0.5	0.5	0.5	0.5
REPLACEMENT OR UPGRADE OF TECHNICAL BUILDING SYSTEMS	0.1	0.1	0.1	0.1	0.1	5.0	30	0.5	10	0.1	0.1	0.1
MAJOR RENOVATIONS	0.0	0.0	0.0	100	0.5	10	100	1.5	20	1.5	1.5	1.5
NEW CONSTRUCTION	0.0	0.0	0.0	100	0.5	5.0	100	1.5	20	1.5	1.5	1.5
INSTALLATION OF LOCAL RES (E.G. PV)	0.1	0.1	0.1	0.1	0.1	5.0	0.1	0.1	0.1	0.1	0.1	0.1
EV PURCHASE	0.2	0.2	0.2	0.2	0.2	2.1	0.2	0.2	0.2	0.2	0.2	0.2
SMART METER DEPLOYMENT	0.1	0.1	0.1	0.1	0.1	5.0	0.1	0.1	0.1	100	3.0	20
HVAC INSPECTIONS	0.1	0.1	0.1	0.1	0.1	0.1	100	0.5	10	0.1	0.1	0.1
OTHER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

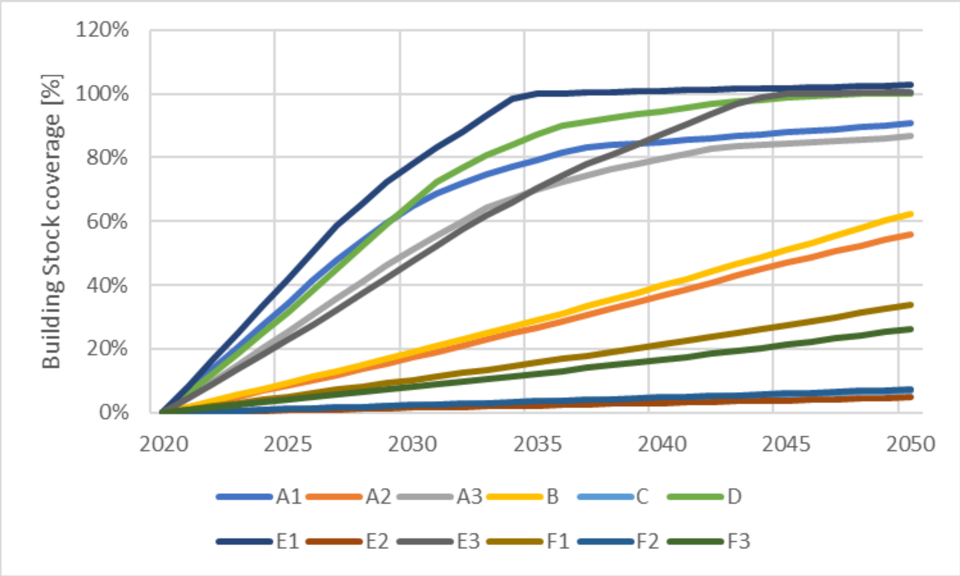


Figure 55 – Sensitivity of SRI deployment rate as percentage of the EU building stock for which an SRI assessment is available. Results for the high SRI uptake rate scenario

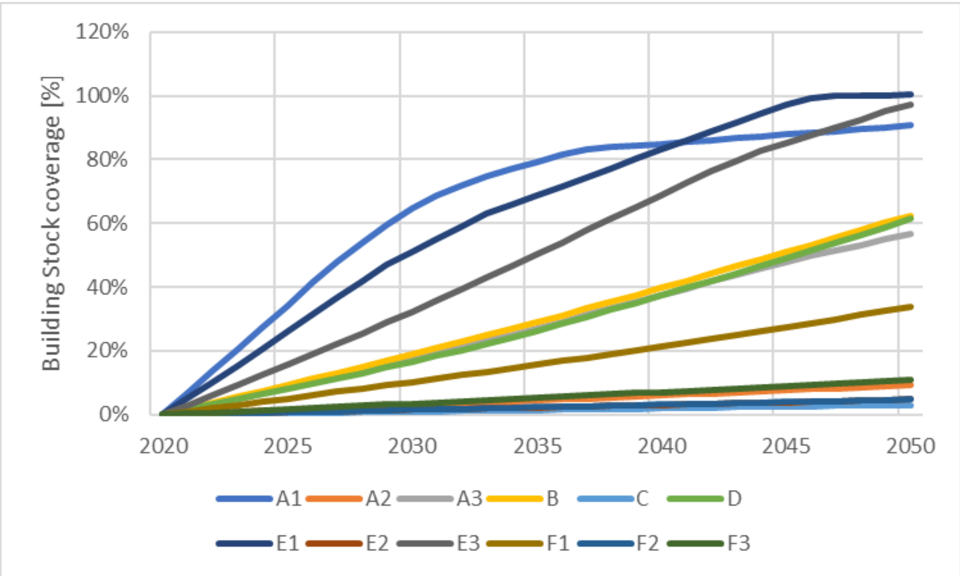


Figure 56 – Sensitivity of SRI deployment rate as percentage of the EU building stock for which an SRI assessment is available. Results for the low SRI uptake rate scenario

As expected, the high impact scenario, especially benefits the outcome of the implementation pathways that provide a voluntary but support link to the trigger events. Under this high impact assumption, also implementation pathways A3, D and E3 lead to more than 85% of the building stock having an SRI assessment carried out by 2050. Also, under these assumptions the E1 scenario has the fastest uptake, exceeding implementation pathway A1 which has the highest uptake in the default scenario. The latter stems from the increase of SRI assessments for technical buildings system upgrade and replacements. In the default scenario, this uptake rate was set to 40% as it was argued unrealistic to expect all TBS upgrades or replacements to yield in an SRI assessment, even under a mandatory implementation pathway. In the high uptake scenario, the 40% value has been increased 100% in line with the other implementation pathways assuming a mandatory linkage. As shown on Figure 56, the unsupported voluntary schemes are not able to exceed a 10% coverage by 2050.

4.4.1.2 Impact of market push and pull effects

In order to reflect that voluntary implementation pathways may gain interest as the SRI get more mature, market push and market pull factors have been introduced. These factors model the increase of the rate of SRI assessments as function of the growing share of buildings with an SRI assessment. In the default scenario, maximum pull and push effect factors are limited to a 2% increase for implementation scenarios with a subsidized voluntary assessment and 1% for a non-subsidized implementation scenario.

To assess the importance of these factors on the results a high- and low-impact scenario is again evaluated. In the high-impact scenario market push and pull effects are set to 4% and 2% for respectively the subsidized and non-subsidized implementation pathways. In the low-impact scenario both are set to 0%. For the implementation pathways that propose a mandatory coupling of an SRI assessment to certain trigger events, the market push and pull effects are assumed to be 0%.

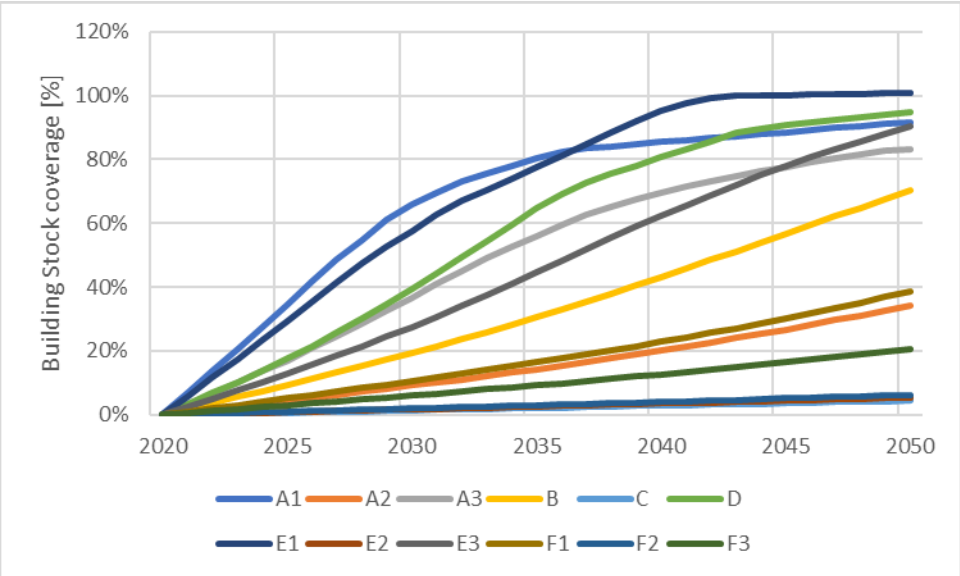


Figure 57 – Sensitivity of SRI deployment rate as percentage of the EU building stock for which an SRI assessment is available. Results for the high market push and pull effect scenario

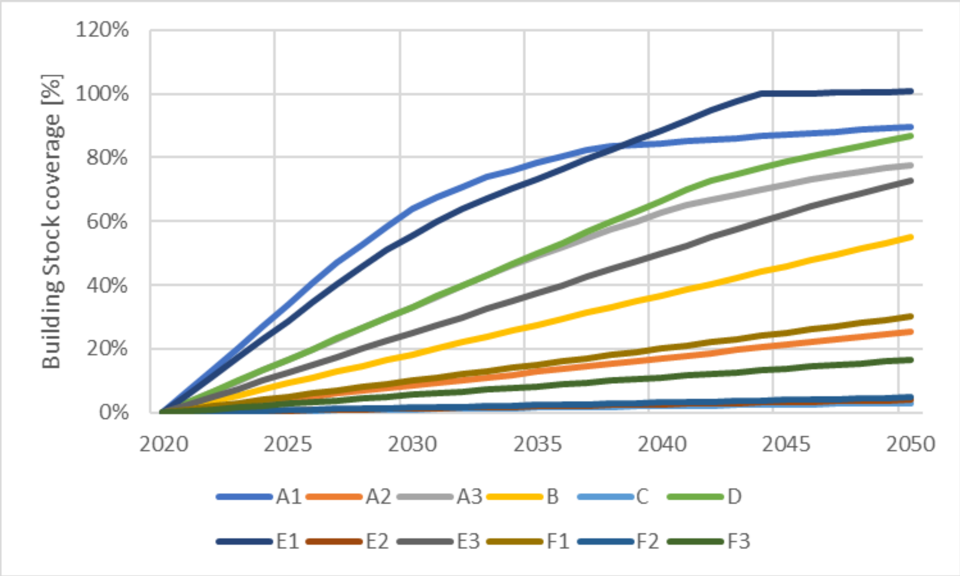


Figure 58 – Sensitivity of SRI deployment rate as percentage of the EU building stock for which an SRI assessment is available. Results for the low market push and pull effect scenario

4.4.1.3 Impact of assessment method

In the methodology description a distinction was made between a detailed and a simplified assessment methodology as well as between a self-assessment and an expert assessment. Given the differences in complexity and cost for the end-user – being the building owner asking for the SRI – an impact of the methodology choice on the SRI deployment rate has also been modelled. Hereto, a correction factor is introduced on the SRI assessment rates.

For the default calculation, a correction of 0.9 and 1.1 was given to respectively the expert assessment and the self-assessment. This reflects that if an external expert needs to be involved in the assessment process, the uptake of the SRI is expected to be lower. Similarly, correction factors of 0.9 and 1.1 were used for respectively the detailed and simplified method. This reflects that a more simplified assessment protocol may yield a higher amount of assessments being carried out.

In the low-impact scenario, the 1.1 values for self-assessment and a simplified methodology have been reduced to 0.8. As such, self-assessment and a simplified method are assumed to result in less SRI assessments compared to detailed and expert assessments. In the high-impact scenario these values have been increased to 1.3, favouring the simplified, self-assessment.

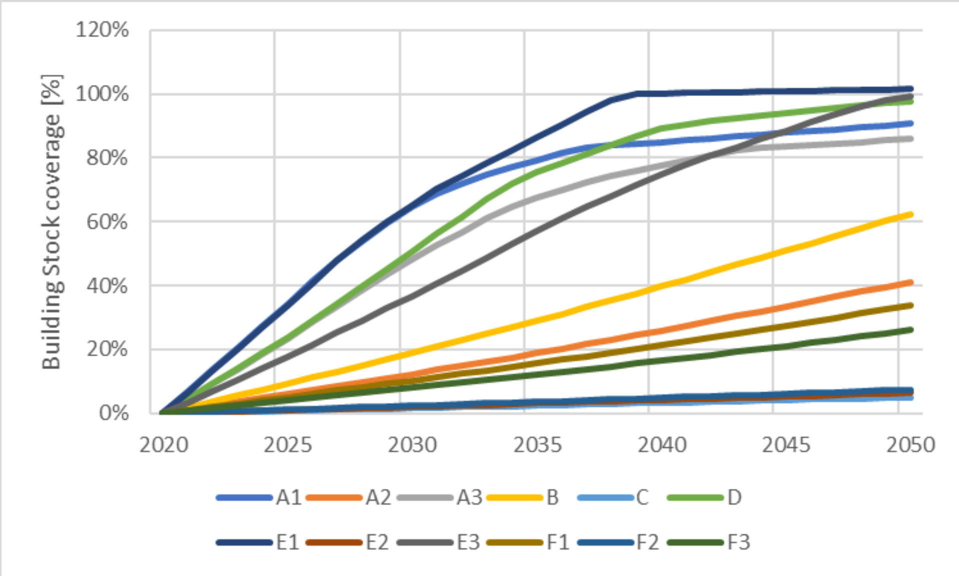


Figure 59 - Sensitivity of SRI deployment rate as percentage of the EU building stock. Results for positive scenario promoting self-assessment

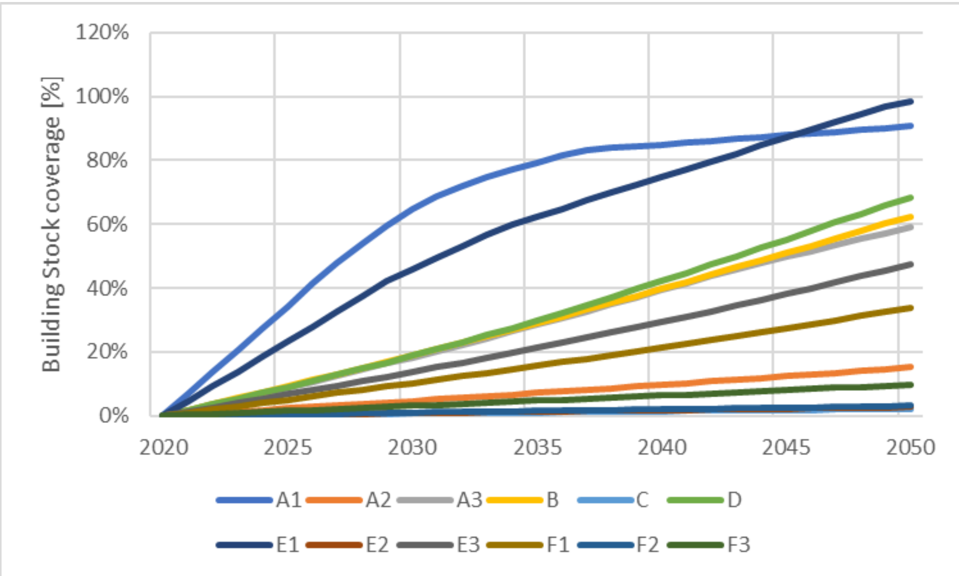


Figure 60 - Sensitivity of SRI deployment rate as percentage of the EU building stock. Results for scenario promoting expert-assessment

4.4.1.4 High and low SRI deployment scenario

Based on the cases above, 2 extreme scenarios are compiled that reflect a high and low deployment scenario for the amount of SRI assessment.

The high uptake scenario assumes the uptake rates of SRI assessments linked to a trigger event as tabulated in Table 24. In addition, high values of market push and pull effects are assumed. The low uptake scenarios assumes uptake rates as specified in Table 25 and low values for the market push and pull effects. The correction factors for the impact of the assessment methodology are kept at the default rates.

4.4.2 SENSITIVITY ANALYSIS OF THE UPTAKE OF SMART READY TECHNOLOGIES

The uptake of smart ready technologies is modelled based on the deployment of the SRI. Hereto three main factors are defined. The base uptake rate as a result of an SRI assessment. In the default scenario these are set to 15% and 3% for respectively an upgrade of SRTs resulting in an SRI score increase by 1 level of smartness and a score increase to level A. Secondly, there is again a market push and pull effect at play that increases the amount of SRT upgrades due to an SRI assessment as the total amount of SRI assessment increases, i.e. as the SRI gains maturity and popularity. Lastly, there is again a correction for the SRI assessment method being applied. The impact of all three factors is evaluated separately.

4.4.2.1 Rate of SRT uptake following an SRI assessment

In the default scenario the rate of SRT uptake following an SRI assessment is set to 15% for upgrades by 1 level of smartness and 3% for upgrades to class A. This value is a conservative estimate compared to values reported in e.g. early energy-labelling studies or the energy star label that was introduced in the US. Reports on the energy star label state that 90% of customers recognize the label. 45% have both labelled products and 74% of those acknowledge that the label has influenced their choice. Therefore, in this sensitivity analyses a high uptake scenario is defined using an uptake rate of 33% and 3% for respectively upgrades by 1 level of smartness and to a level A. Note that the value of upgrades to a level A has not been increased. This is kept constant because upgrades to a level A would in most cases require more disruptive changes to the technical building systems which may require a certain level of building renovation. Increasing this uptake rate above the ambitious 3% building renovation rate target was therefore deemed unrealistic. For the low impact scenario, the 15% rate of upgrades by 1 class has been reduced to 10%. The 3% value for upgrades to level A has been reduced to 1% being in line with the current renovation rate.

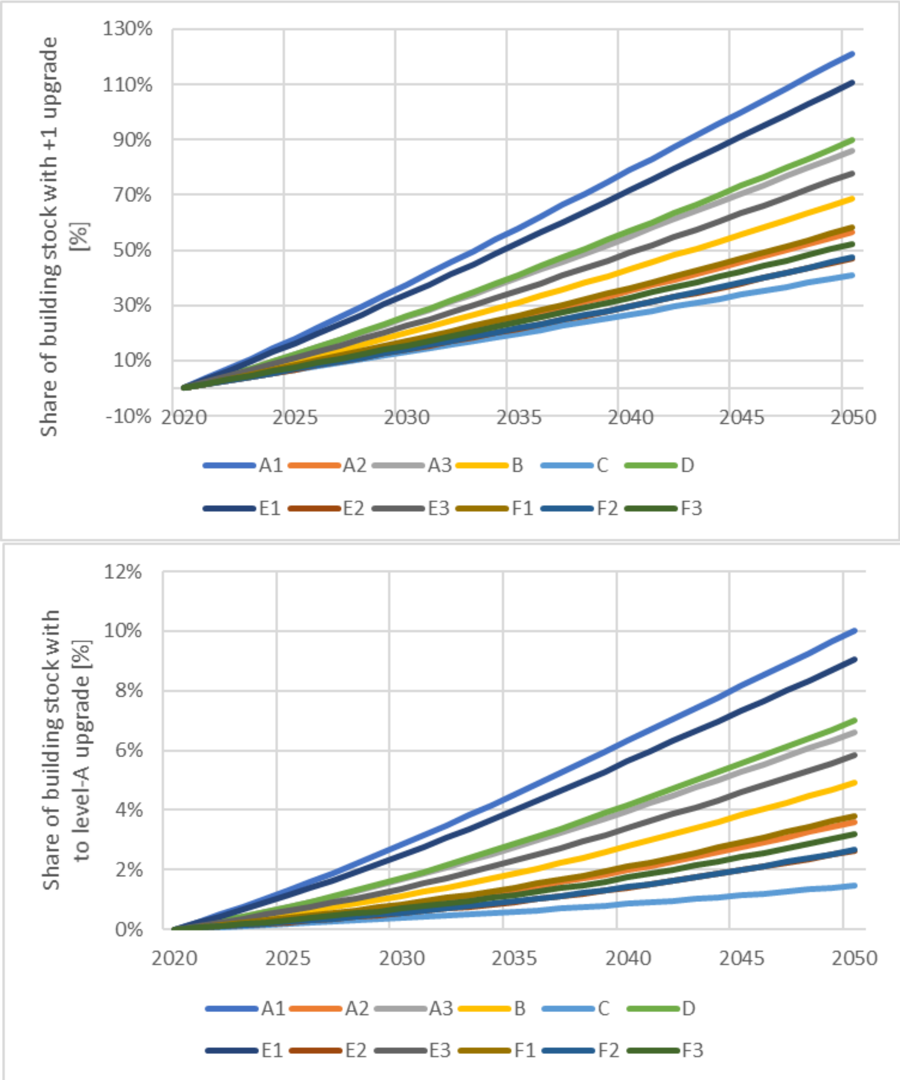
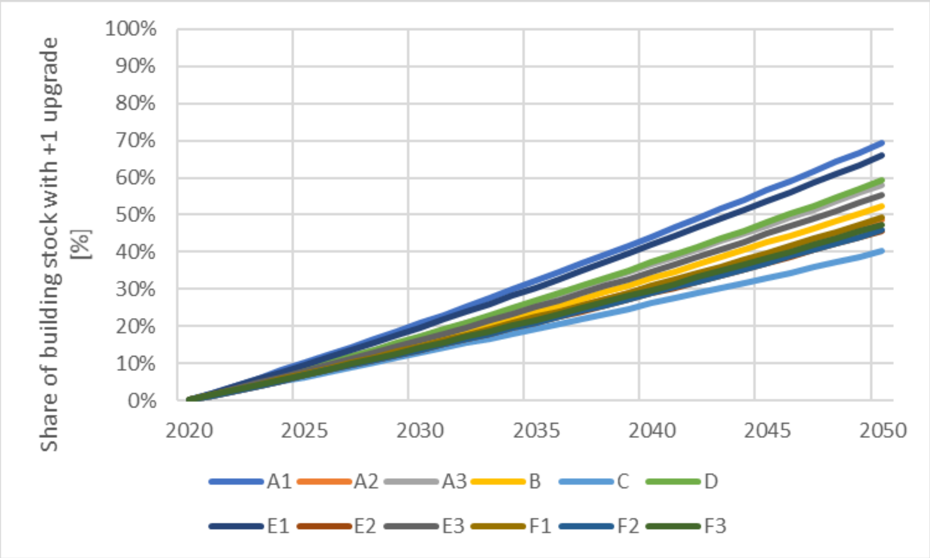


Figure 61 - Results for the high uptake rate scenario, showing SRT upgrades by 1 level (top) and to level A (bottom) expressed as share of the building stock that has had an upgrade.



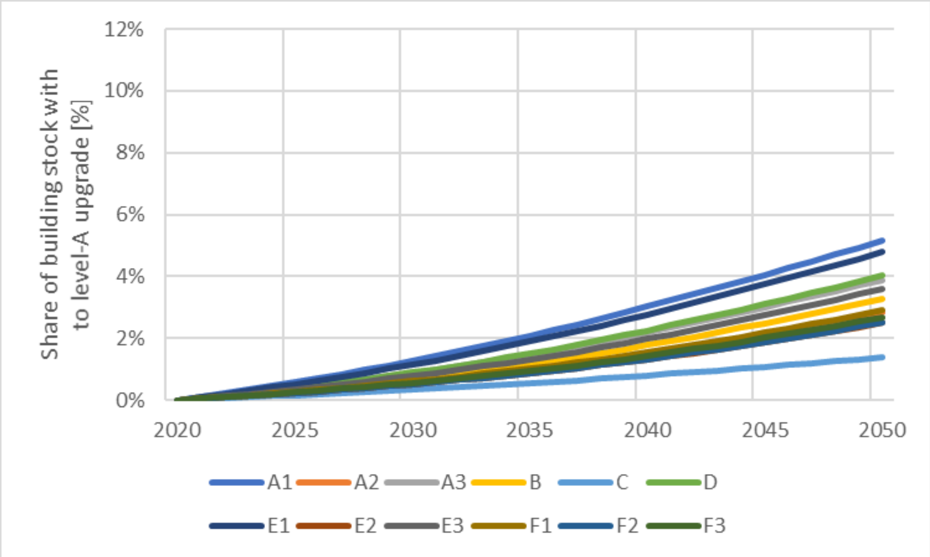


Figure 62- Results for the low uptake rate scenario, showing SRT upgrades by 1 level (top) and to level A (bottom) expressed as share of the building stock that has had an upgrade.

4.4.2.2 Impact of market push and pull effects

The uptake of SRTs in the impact analysis model is influenced by the maturity and popularity of the SRI after implementation. This reflects that as the SRI gets more mature and more widespread, it will have a positive impact on the uptake of smart ready technologies.

In the default scenario market, the maximum value of market push and pull effects was limited to 0.41% and 0.082% for respectively upgrades by 1 class or to a level A. For the high impact scenario, these values are increased to 1.2% and 0.2%. For the low impact scenario, both values are set to 0%. Note that for implementation pathway C, the maximum values for the market push and pull effect parameters have been reduced to half the values of the other implementation pathway. This assumption is maintained in the sensitivity analysis to maintain consistency with the base scenario.

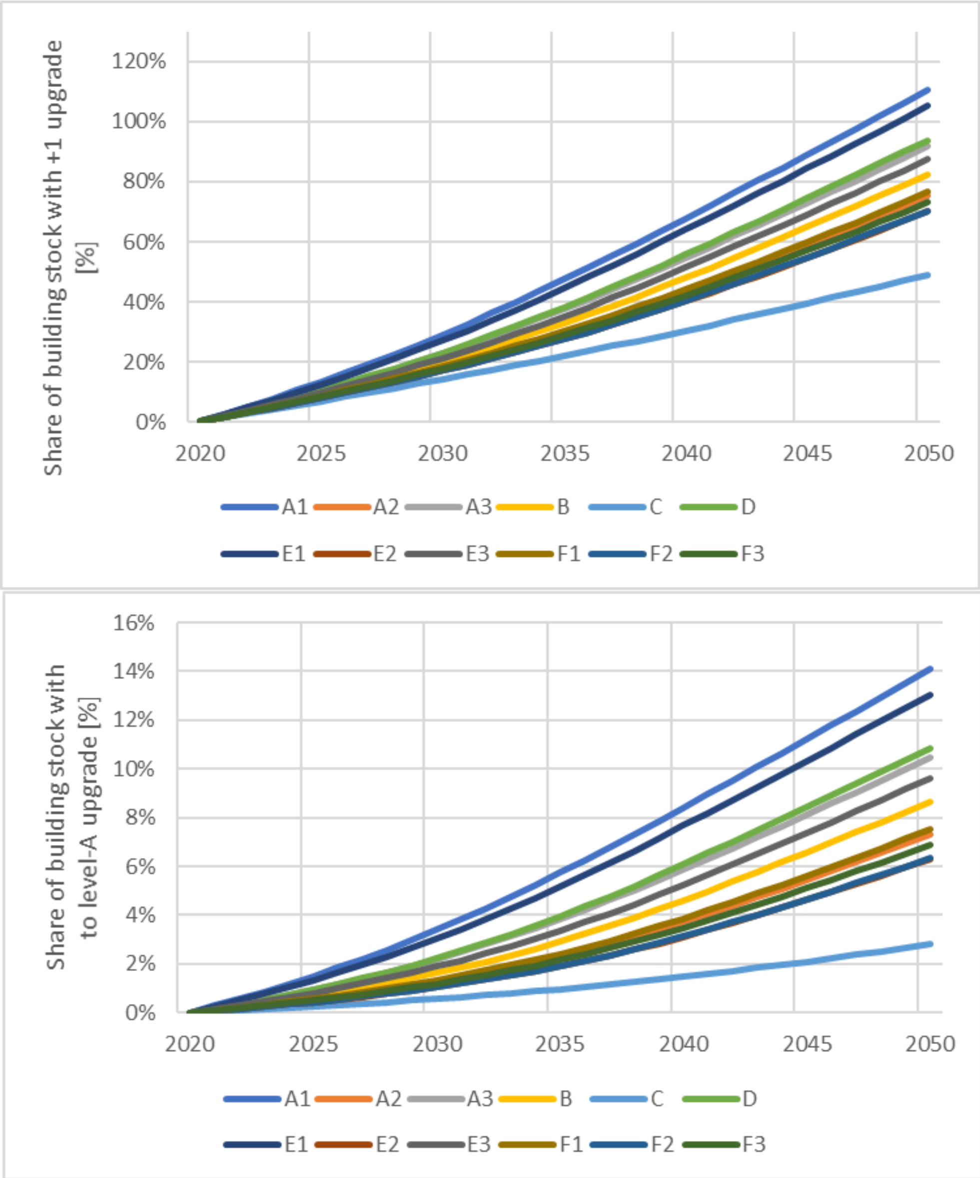


Figure 63 - Results for the high market push and pull effect scenario, showing SRT upgrades by 1 level (top) and to level A (bottom) expressed as share of the building stock that has had an upgrade.

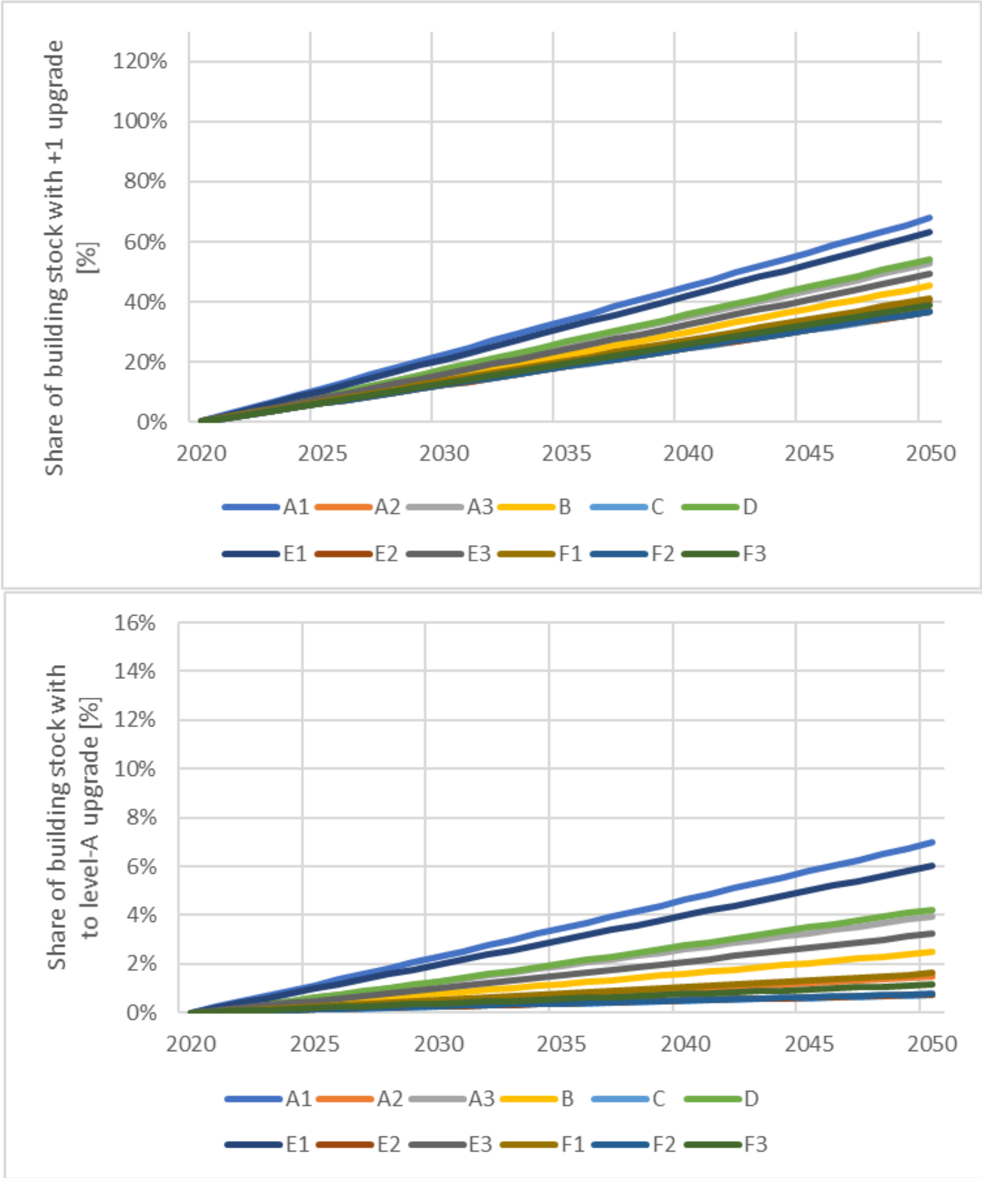


Figure 64 - Results for the low market push and pull effect scenario, showing SRT upgrades by 1 level (top) and to level A (bottom) expressed as share of the building stock that has had an upgrade.

4.4.2.3 Impact of the assessment methodology

In the SRI methodology proposition a differentiation was made between a detailed and simplified assessment method which could be carried out as self-assessment or by an expert assessor. In the default scenario, it is assumed that a detailed assessment carried out by an expert assessor would yield higher uptake of smart ready technologies. This is modelled by introducing a correction for the uptake rate of SRTs. In the default scenarios these factors were set to 0.7 and 0.8 for respectively a simplified methodology and a self-assessment.

Two alternative scenarios are evaluated here. In the positive impact scenario, a simplified self-assessment is expected to yield higher SRT uptake. The correction factors are therefore set to 1 and 1.1 respectively for the simplified method and the self-assessment. In the negative impact scenario, values are set to 0.5 and 0.6, reflecting that due to a lack of confidence in the methodology a simplified self-assessment would yield even lower uptake of SRTs.

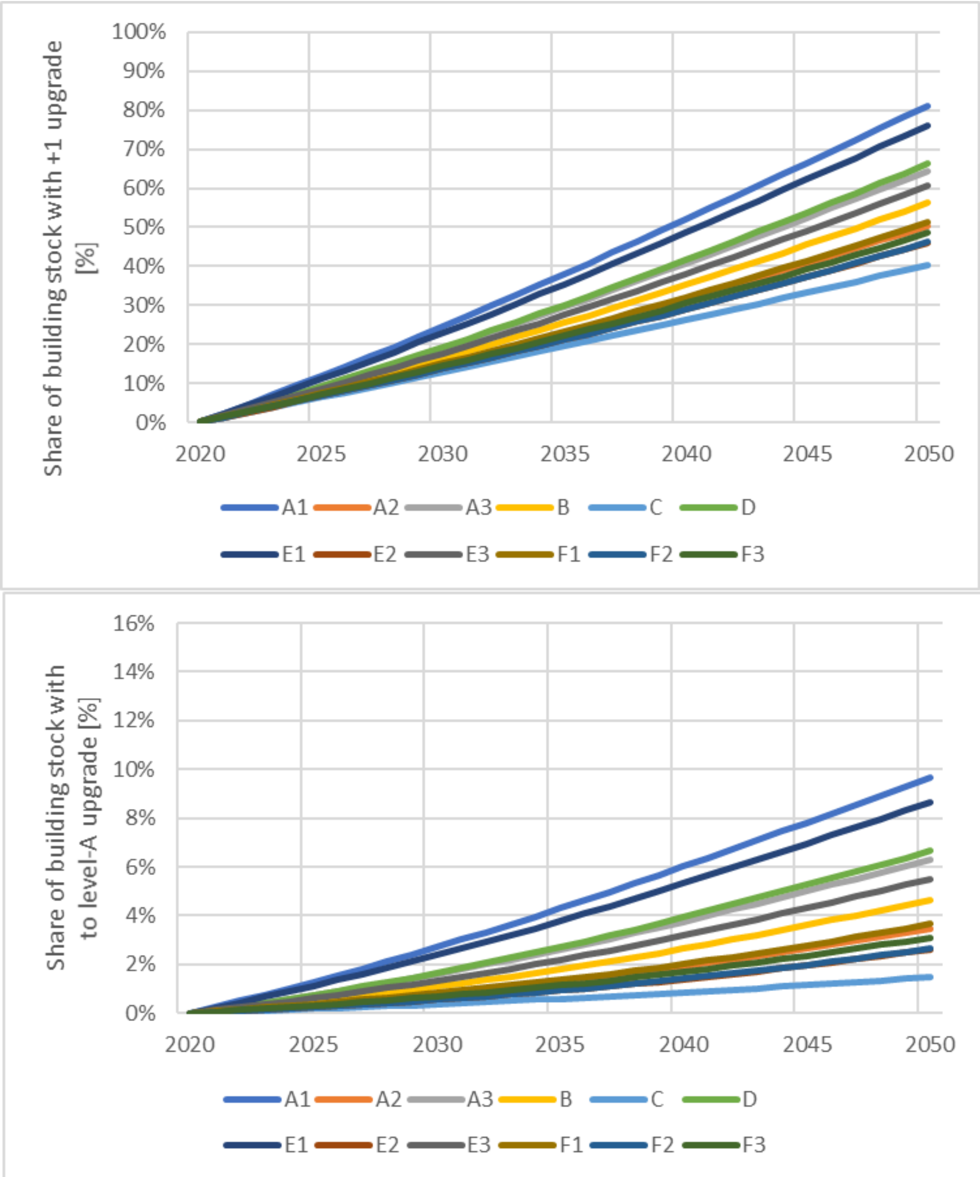


Figure 65 - Results for the positive impact scenario (promoting self-assessment), showing SRT upgrades by 1 level (top) and to level A (bottom) expressed as share of the building stock that has had an upgrade.

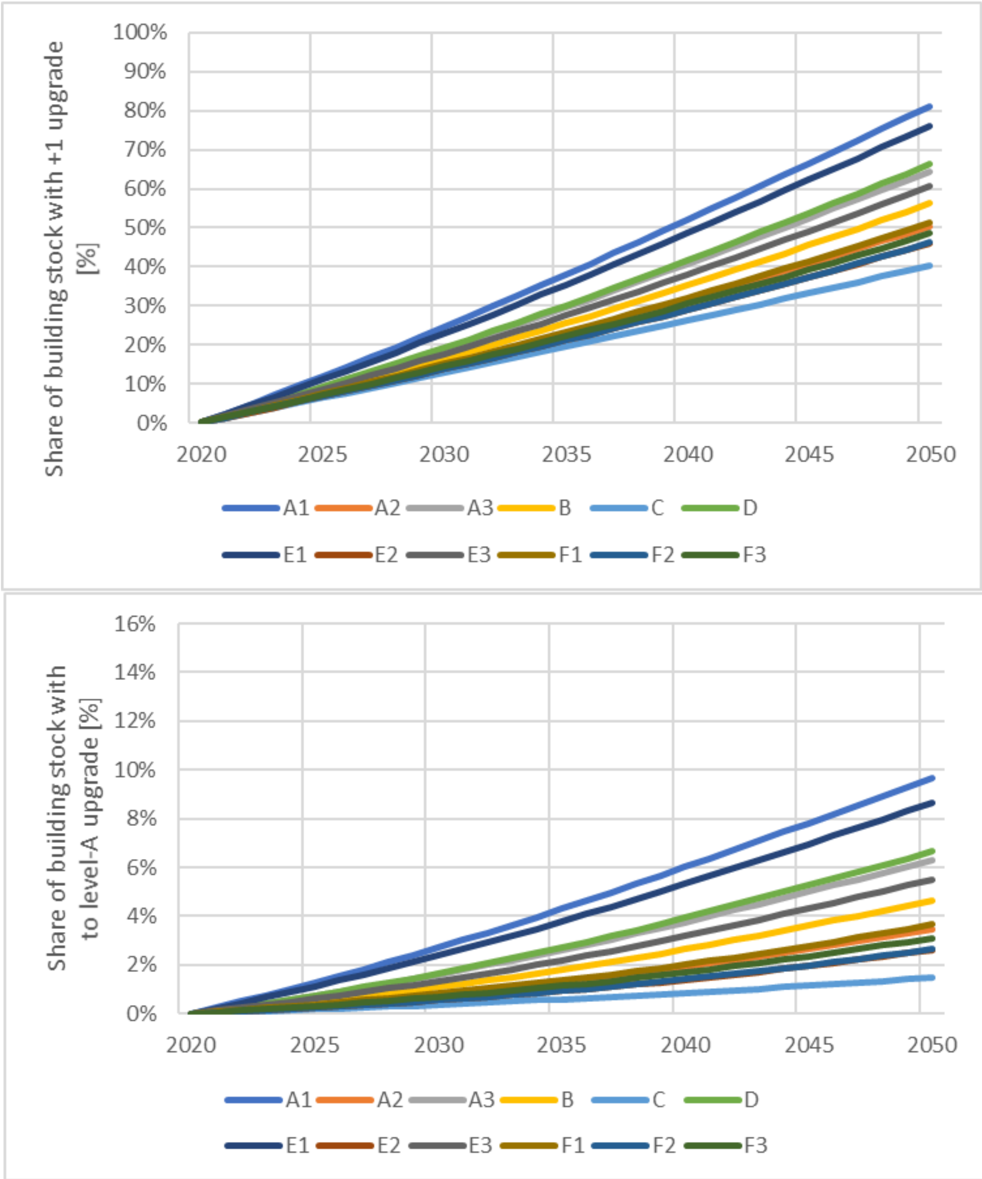


Figure 66 - Results for the negative impact scenario (promoting expert-assessment), showing SRT upgrades by 1 level (top) and to level A (bottom) expressed as share of the building stock that has had an upgrade.

4.4.2.4 High and low SRT uptake scenario

Based on the specific analysis in previous section, 2 reference scenarios are deduced which will be further used to evaluate the sensitivity of the other KPIs. The high impact scenario combines both the high uptake rates (respectively 33% and 3% for upgrades by 1 class or upgrades to class A) with the default market push and pull effects (0.41% and 0.082% respectively). The low impact scenario combines the low uptake rates (10 % and 1% respectively) but combines these with the market push and pull effects set to 0%.

4.4.3 SENSITIVITY ANALYSIS FOR THE ENERGY USE, CO_2 EMISSION REDUCTIONS AND ENERGY COST SAVINGS

Based on the high and low impact scenario for SRI deployment and the high and low impact scenarios for the SRT uptake, four scenarios have been composed and compared against the default scenario that formed the basis for the impact analysis. The four scenarios are listed in Table 26. Scenario 1 and 2 represent the two extreme cases with respectively the highest and lowest estimated effects of the implementation of the SRI. Scenario 3 represents a scenario where the SRI is well appreciated and picked up by the market, but it does not yield the expected uptake of the market in smart ready technologies. This scenario is expected to yield worst case results in terms of costs and benefits as the scenario would reflect a high cost scenario in terms of implementation of the scheme (high number of assessments) yet low investments in SRTs and corresponding benefits. On the contrary, scenario four reflects a case where the number of SRI assessments would stay limited, yet the rate of SRI assessments leading to an SRT upgrade is high.

Table 26 - Overview of sensitivity scenarios

Scenario	Scenario on number of SRI assessments	Scenario on SRT uptake rate linked to an SRI assessment
1	High	High
2	Low	Low
3	High	Low
4	Low	High

Figure 67 and Figure 68 show the impact of the scenarios on the cumulated investment into smart ready technologies in respectively 2030 and 2050. These results are the increased investment compared to the business as usual SRT uptake and hence clearly demonstrate the impact of the SRI on this market. Comparing scenarios 3 and 4, shows significantly higher uptake of SRTs in scenario 4 compared to scenario 3. This suggests that it is more important to assure that SRI assessments lead to an upgrade of SRTs for that building. As pointed out by scenario 3, striving for increasing the number of SRI assessments without assuring an adequate rate of SRT upgrades is not efficient.

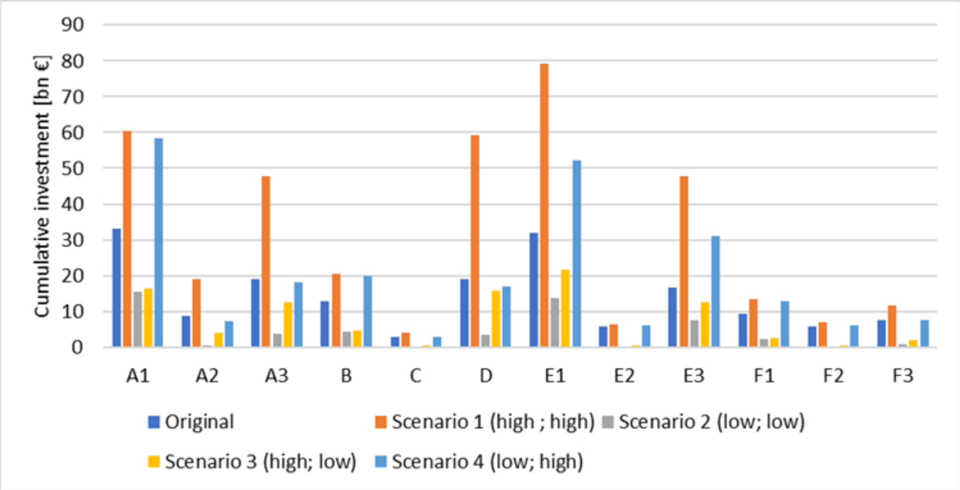


Figure 67 – Impact of sensitivity scenarios on the additional cumulated investment in SRTs by 2030

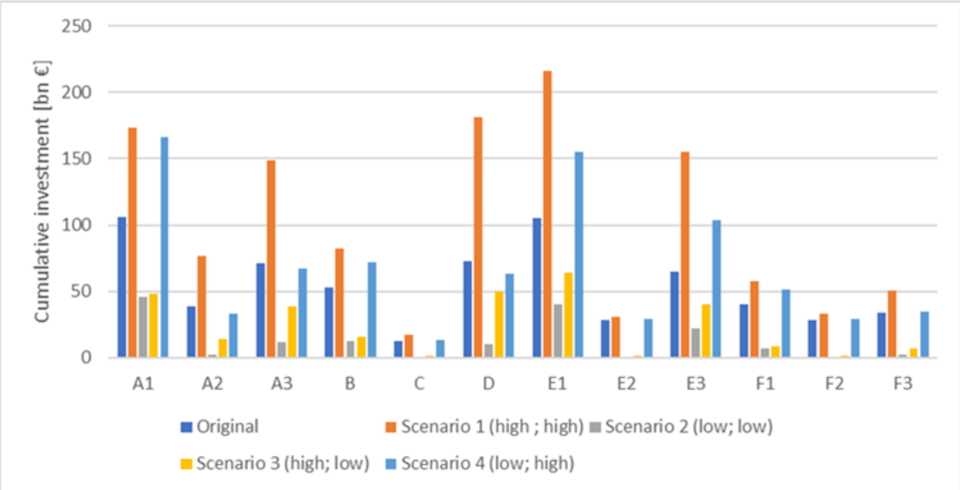


Figure 68 – Impact of sensitivity scenarios on the additional cumulated investment in SRTs by 2050

Figure 69 and Figure 70 show the resulting primary energy savings. These values evidently follow the trends for the results of the SRT uptake. For the high impact scenario (scenario 1), primary energy savings are up to 50% greater. These trends are similar for all pathways. Note the high differences for implementation pathway E1. This follows from the change in the rate of SRI assessments linked to the trigger "upgrade or replacement of technical building systems." Corresponding CO_2-emission savings and energy cost savings are reported in

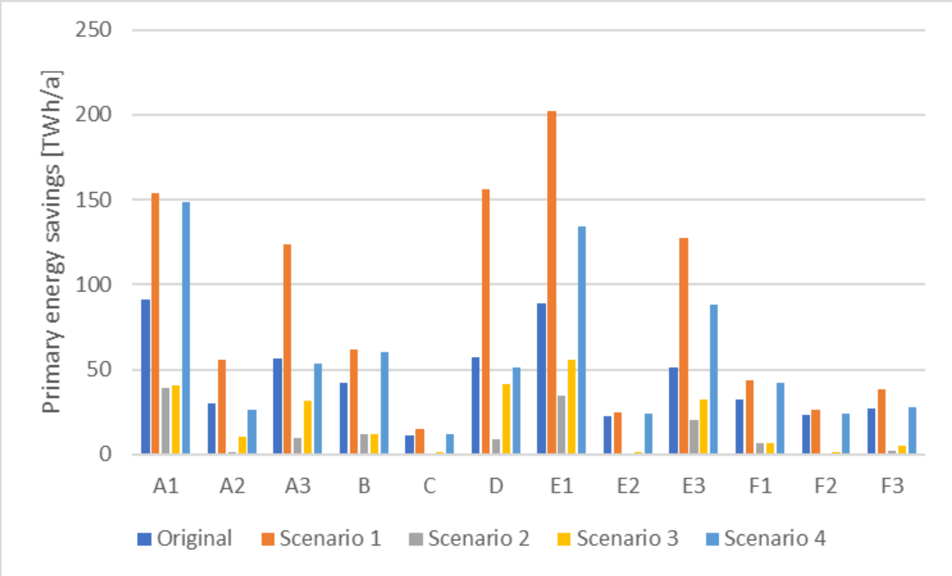


Figure 69 – Impact of sensitivity scenarios on the primary energy savings for the different implementation pathways by 2030

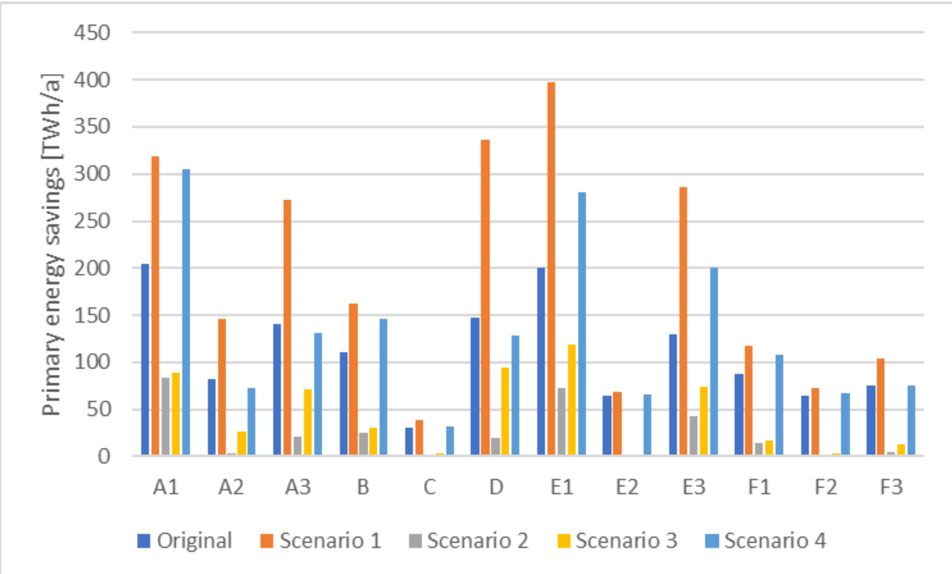


Figure 70 – Impact of sensitivity scenarios on the primary energy savings for the different implementation pathways by 2050

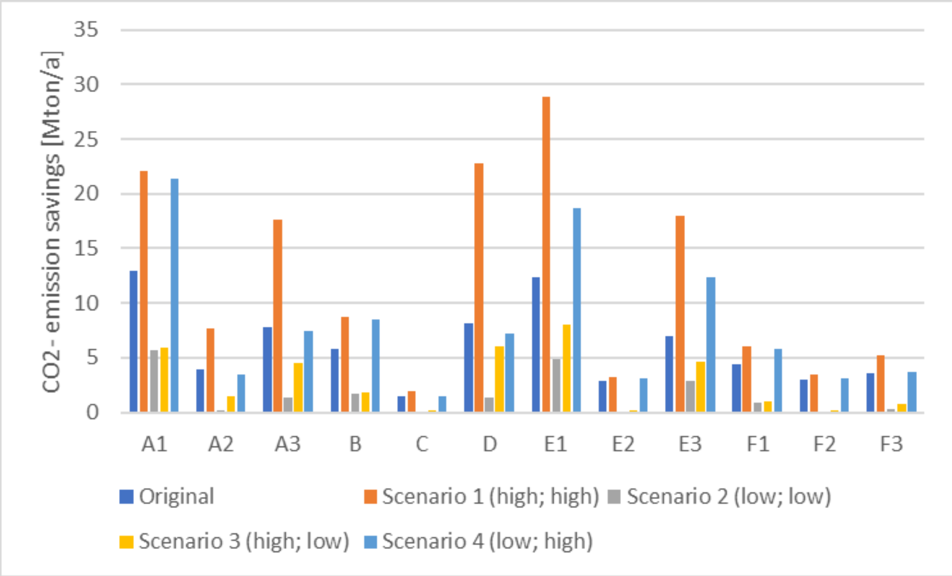


Figure 71 – Impact of sensitivity scenarios on the CO_2-emission savings for the different implementation pathways by 2030

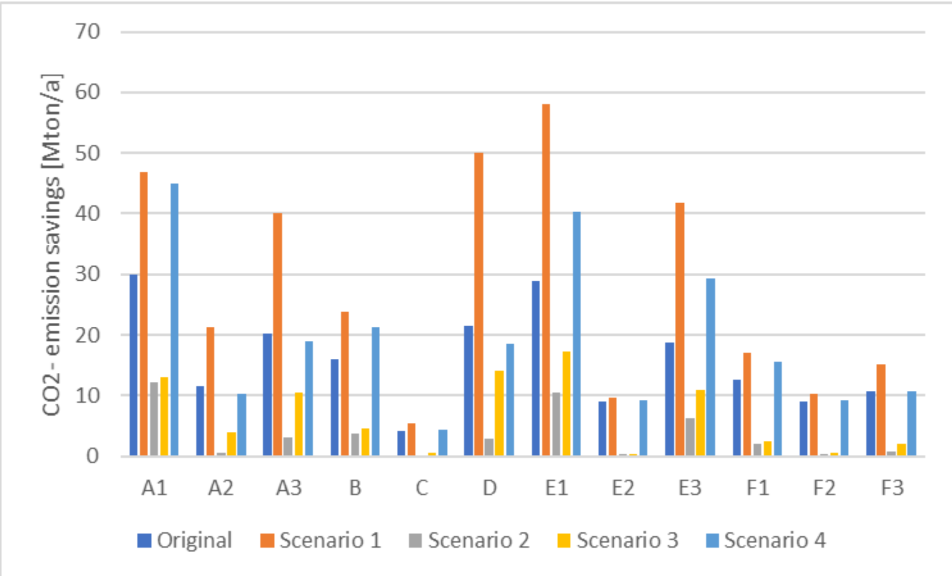


Figure 72 – Impact of sensitivity scenarios on the CO_2-emission savings for the different implementation pathways by 2050

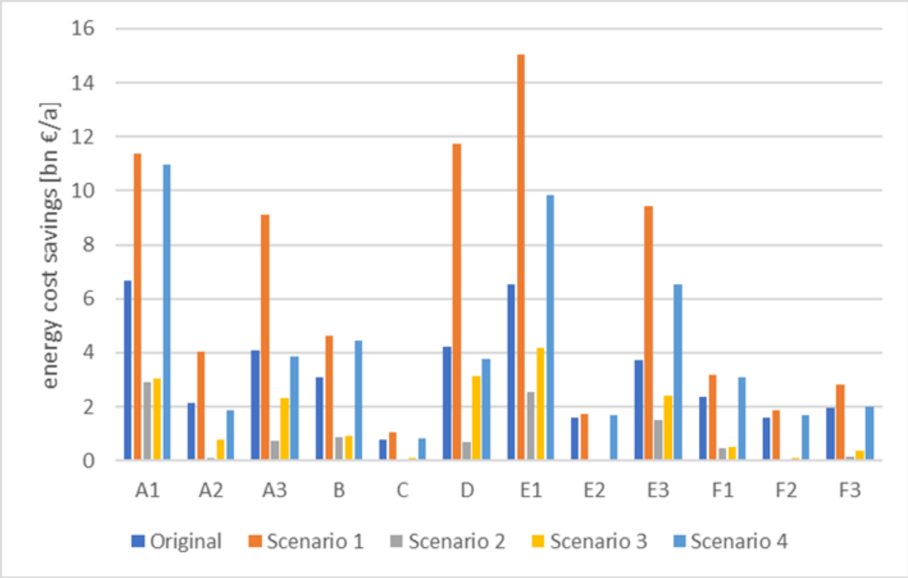


Figure 73 – Impact of sensitivity scenarios on the energy cost savings for the different implementation pathways by 2030

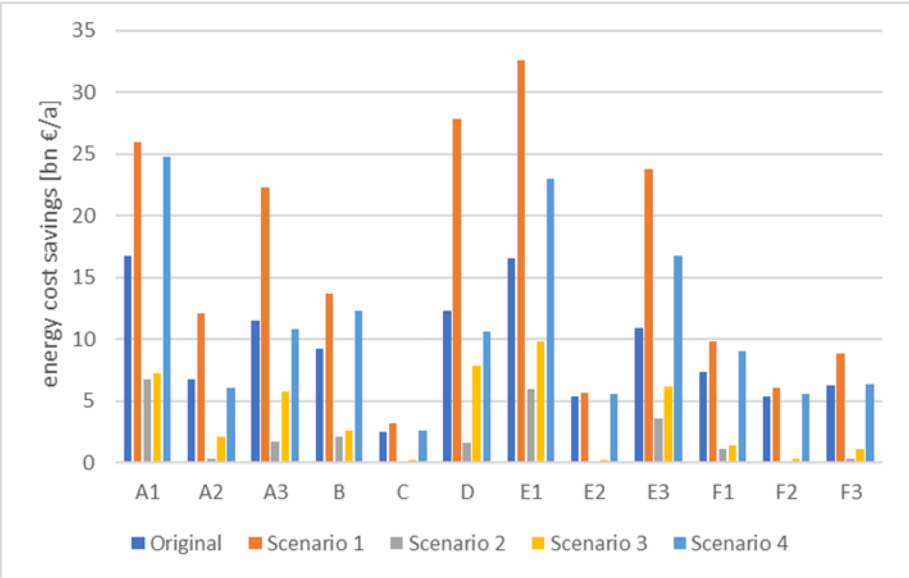


Figure 74 – Impact of sensitivity scenarios on the energy cost savings for the different implementation pathways by 2050

4.4.4 Sensitivity for costs and benefits

The spread in the estimated costs and benefits for the four sensitivity scenarios are shown in Table 27 to Table 30 for the year 2030. In each case the values for the original scenario are also shown as a reference.

Table 27 - Incremental SRT costs compared to BAU (€m) in year 2030

Implementation pathway	Original	Scenario 1 (high, high)	Scenario 2 (low, low)	Scenario 3 (high, low)	Scenario 4 (low, high)
A1	3606	6502	1577	1684	6160
A2	841	1435	62	219	869
A3	2198	5403	387	1351	2047
B	1480	2373	431	479	2209
C	692	840	17	54	706
D	2227	6843	346	1763	1900
E1	3499	8394	1384	2231	5553
E2	707	784	30	39	754
E3	1914	5571	758	1387	3389
F1	1091	1560	232	253	1485
F2	694	825	29	55	728
F3	891	1360	74	198	914

Table 28 - Assessment costs (external) (€m) in year 2030

Implementation pathway	Original	Scenario 1 (high, high)	Scenario 2 (low, low)	Scenario 3 (high, low)	Scenario 4 (low, high)
A1	460	474	446	474	446
A2	42	84	25	84	25
A3	325	511	150	511	150
B	121	127	116	127	116
C	1	2	1	2	1
D	317	635	127	635	127
E1	401	553	349	553	349
E2	13	15	12	15	12
E3	236	472	273	472	273
F1	65	68	62	68	62
F2	11	22	12	22	12
F3	51	75	29	75	29

Table 29 – Energy bill savings compared to BAU (€m) in year 2030

Implementation pathway	Original	Scenario 1 (high, high)	Scenario 2 (low, low)	Scenario 3 (high, low)	Scenario 4 (low, high)
A1	7079	12068	3075	3215	11634
A2	2239	3417	145	480	2296
A3	4503	10018	790	2552	4269
B	3507	5230	1012	1062	5066
C	1982	2320	44	136	2012
D	4661	12871	753	3427	4149
E1	6932	16017	2709	4453	10447
E2	2010	2182	77	97	2115
E3	4134	10484	1684	2683	7250
F1	2768	3746	568	599	3644
F2	1986	2293	76	143	2066
F3	2376	3409	188	483	2417

Table 30 – Net cost savings compared to BAU (€m) in year 2030

Implementation pathway	Original	Scenario 1 (high, high)	Scenario 2 (low, low)	Scenario 3 (high, low)	Scenario 4 (low, high)
A1	3012	5092	1052	1057	5028
A2	1357	1898	59	176	1402
A3	1981	4105	253	689	2072
B	1906	2730	465	456	2742
C	1290	1478	27	80	1306
D	2117	5393	280	1029	2122
E1	3033	7070	976	1669	4545
E2	1290	1383	35	44	1350
E3	1983	4441	653	825	3588
F1	1612	2119	274	278	2097
F2	1282	1446	35	66	1326
F3	1434	1974	85	210	1474

4.4.5 Sensitivity for employment

The spread of the estimated employment impacts for the four sensitivity scenarios are shown in
Table 31 for the year 2030. In each case the values for the original scenario are also shown as a reference.

Table 31 - Incremental net employment compared to BAU (no. of jobs created) in year 2030

Implementation pathway	Original	Scenario 1 (high, high)	Scenario 2 (low, low)	Scenario 3 (high, low)	Scenario 4 (low, high)
A1	72394	138451	66870	69135	102051
A2	6713	56306	35910	39502	44378
A3	48569	124108	43336	65430	63319
B	32895	70558	43053	44076	64076
C	647	45762	34733	35288	41344
D	48654	147691	42166	74055	60360
E1	69392	166908	61909	78446	99719
E2	19204	45257	35164	35360	42349
E3	42161	125820	51183	65061	81755
F1	25943	57488	39097	39550	53593
F2	18955	46374	35158	35784	42314
F3	22719	54791	36155	38931	45011

4.4.6 Sensitivity for Material circularity and health & wellbeing

The spread of the estimated material circularity for the four sensitivity scenarios basically scales proportionately to the SRT cost expenditure (e.g. see Table 27) while the health and wellbeing impacts scale proportionately with the energy consumption.

4.4.7 SUMMARY AND CONCLUSIONS

The sensitivity analysis has evaluated the impact of two main parts of the impact analysis calculation method. First, the assumptions regarding the number of SRI assessments that would follow each of the implementation pathways has been analysed. In the second step, the rate at which SRI assessment would lead to action – in the sense of resulting in increased uptake SRTs – has been studied.

Based on the sensitivity analysis of the underlaying model parameters describing these two aspects, four main sensitivity scenarios have been defined and compared against the default scenario used in the body of the impact analysis. These four scenarios correspond to combinations of 'high' and 'low' scenarios in terms of the number of SRI assessments and 'high' and 'low' scenarios in terms of the SRT uptake following an SRI assessment:

- Scenario 1: high SRI assessment scenario and high SRT uptake scenario
- Scenario 2: low SRI assessment scenario and low SRT uptake scenario
- Scenario 3: high SRI assessment scenario and low SRT uptake scenario
- Scenario 4: low SRI assessment scenario and high SRT uptake scenario.

Analysing the resulting volume of SRT upgrades clearly outlines the effect of these scenarios. Note that the other KPIs scale in either a linear or non-linear way with the amount of SRT upgrades.

Compared to the original impact scenario, the total SRT investment in implementation pathway A1 increased with 62% for scenario 1 by 2050. For scenario 2, the total investment for pathway A1 decreased with 57%. Comparing scenarios 2 and 4 demonstrates that it is primarily the amount of SRT uptakes following an SRI assessment that has a significant impact on the final results, since the total investment increases from 45.6 billion euro to 165.9 billion euro. As such, scenario 4 is only 4% lower than scenario 2.

For implementation pathways for which a voluntary link is to the trigger events is assumed, the impact of stimulating the amount of SRI assessments is greater. For example, in the case of pathway A3, for which a voluntary link to EPC assessments with supporting measures is assumed, the original impact analysis results in a total cumulated investment of 70.9 billion euro by 2050. Sensitivity scenarios 2 and 4 respectively lead to 11 and 66 billion euro. In the original scenario, it was assumed that for pathway A3, 40% of EPC assessments would result in an SRI assessment. Sensitivity scenario 2 clearly shows that if these numbers would only reach 20% or less, e.g. through inadequate supporting measures, and if at the same time the conducted SRI assessments have a limited uptake rate of SRTs, the SRT investments are marginal. This evidently reflects on the other impact criteria, such as CO_2-emission savings, employment, etc.

Based on this analysis it can therefore be concluded that regardless of the implementation pathway it is key to provide a proper value proposition that guarantees that when SRI assessments are carried out that these also lead to SRT upgrades. If the implementation of the SRI fails to unlock these increased SRT investments, the impact of the SRI may be 57% lower compared to the original impact analysis values. Yet, when the SRT uptake rate would exceed the estimates in the original impact – which are deemed conservative estimates, the impact of the SRI may increase by 62%.

For implementation pathways that link an SRI assessment in a voluntary way to the trigger events, it is in addition essential to provide adequate supporting measures that will guarantee high assessment rates. However, also in those cases supporting the SRT uptake should get priority over increasing the amount of assessments.

5 TASK 5 - STAKEHOLDER CONSULTATION AND STUDY WEBSITE

TASK SUMMARY & OBJECTIVES

The objective of Task 5 was to establish an open and inclusive consultation process to provide support to the development of the SRI, by ensuring that all relevant stakeholders are involved and have the opportunity to express their views on the project. Particular emphasis has been given to build a wide consensus among the stakeholders of the construction/renovation value chain – from the architect to the operator of the building – on the design and development of the SRI.

5.1 ACTIVITY 1: ORGANISATION OF STAKEHOLDER CONSULTATION MEETINGS AND OTHER STAKEHOLDER INTERACTIONS

Eight different ways for the stakeholders to interact with the study team have been available during the course of the two technical support studies:

- stakeholder consultation meetings
- topical stakeholder working groups
- testing the SRI in a field-trial
- consumer focus groups
- written comments
- surveys and open public consultations
- dedicated stakeholder interactions upon invitation
- project website (discussed in Activity 2).

5.1.1 PLENARY STAKEHOLDER CONSULTATION MEETINGS

To give a broad range of stakeholders the optimal possibilities to contribute, stakeholder consultation meetings have been organised in Brussels in the course of the project, in close agreement with the Commission Services.

In the framework of the first technical support study, a first stakeholder meeting took place on 7th June, 2017 in Brussels, dedicated to introducing the objectives and scope of the study, the work plan and the first findings. Several invited external speakers presented relevant other initiatives related to the themes of the SRI. 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.

A second stakeholder meeting took place on 21st of December 2017, with an attendance of 88 representatives. During this meeting, the progress of the study as presented in the interim report was shared with the stakeholders. An overview was given of the received comments and how these have been taken into account in the drafting of the interim report.

In consultation with DG Energy, it was decided to organise a third stakeholder meeting within the scope of the first technical study. This meeting took place on 28th May 2018 in Brussels. At this meeting, 71 representatives were present. Prior to this meeting a summarising report was sent out to inform stakeholders on the status of the project. During the meeting, the progress of the technical study and legal framework was discussed and feedback from stakeholders was collected. This was accompanied by the presentation of two practical case study examples.

The fourth stakeholder meeting (the first of the second technical support study) took place on 26 March 2019 and was attended by 120 stakeholders – as well as the numerous stakeholders who followed the web-stream. The study team briefly reminded participants of the outcomes of the first study and presented the work plan of the second technical study. The study team also described the various ways in which stakeholders are invited to be involved in the second technical study. Finally, the study team presented the working assumptions of the second technical support study, based on the feedback from stakeholders collected during and after the first technical support study.

The fifth stakeholder meeting took place on 9 October 2019 and was attended by 71 stakeholders – as well as the numerous stakeholders who followed the web-stream. During this meeting the technical study team consortium presented interim conclusions on the calculation methodology and consolidated results on the evaluation of quantitative impacts as presented in the interim report. Also, ongoing work regarding the format of the SRI and its potential implementation pathways was discussed. Finally, the study team also presented intermediate results from the public bèta testing and reported on the contributions of the Topical Working Groups.

5.1.2 TOPICAL STAKEHOLDER WORKING GROUPS

In the context of this study, the study team has reached out to actively engage stakeholders to cluster with other stakeholders in dedicated thematic groups. Using such an approach, inputs can be gathered more effectively and a consensus on many important issues will likely be more easily obtained.

Initially, two Topical Stakeholder Working Groups were set up, a third one was added more recently:

- Topical Group A on the SRI value proposition and implementation
- Topical Group B on the SRI calculation methodology.
- Topical Group C on future developments of the SRI (added in the autumn of 2019).

All registered stakeholders were invited to apply for membership of one of the Topical Groups. Drawing from the applications received, the study team – in consultation with the Commission services – composed compact and well-balanced expert groups of approximately 30 members, representing different (mainly European) sector organisations and Member States.

Topical Group A and Topical Group B gathered twice in Brussels for meetings in person, back to back with the first and second stakeholder meeting. A plenary feedback meeting with stakeholder topical groups A, B and C was organised on 13 February 2020 to feed the further consultations with EU Member States and support the process of drafting the delegated and implementing acts.

Next to the meetings in person, teleconference meetings have been set up to discuss specific topics.

5.1.2.1 *Topical group A: SRI value proposition and implementation*

The Topical Group A on **SRI value proposition and implementation** aims to reflect upon the business value of the SRI from an end-user perspective and to discuss possible approaches for an effective implementation of the SRI. In total, five meetings were organized, covering the following topics:

- Brussels meeting 26 March 2019:
  - SRI value proposition and audience
  - SRI assessment process: method A/B/C.
- Web meeting 17 May 2019:
  - SRI format.
- Web meeting 31 May 2019:
  - implementation pathways: links to other initiatives.
- Brussels meeting 9 October 2019:
  - implementation pathways and issues
  - formatting
  - interoperability, cybersecurity, & connectivity
- Brussels meeting 13 February 2020 with topical groups A, B and C:
  - Review of the draft legal texts

Topical Group A members are:

	Organisation
1	ACE
2	AIE
3	AT – Federal Ministry for Sustainability and Tourism
4	AT – OIB – Austrian Institute of Construction Engineering
5	AVERE
6	DK – Danish Energy Agency
7	EBC
8	EDSO
9	EPBD CA/BBRI
10	EPF
11	eu.bac
12	EURELECTRIC
13	EURELECTRIC (replacement)
14	EuroACE
15	FI – Finnish nat. SRI methodology/Aalto Univ.
16	FR – Developpement Durable
17	FR – SBA
18	GCP
19	GGBA
20	Housing Europe

21	HQE
22	IFMA
24	REHVA
25	smartEn
26	UEPC
27	UIPI
28	UIPI (replacement)

* Two participants did not consent to sharing their organisation

5.1.2.2 Topical group B: SRI calculation methodology

The Topical Group B on **SRI calculation methodology** aims to focus on the consolidation of the SRI methodological framework, including the selection of services, the definition of weighting factors and impacts, etc. In total, nine meetings were organized, covering the following topics:

- Brussels meeting 26 March 2019:
  - calculation framework: impact criteria and weightings.
- Web meeting 7 May 2019:
  - calculation framework: domains and weightings
  - SRI assessment process: method A/B/C.
- Web meeting 14 May 2019:
  - triage process & missing services
  - updating the SRI framework.
- Web meeting 11 June 2019:
  - simplified calculation method: database approach.
- Web meeting 28 June 2019:
  - update on the framework of domains and impact criteria
  - simplified calculation method: simplified service catalogue.
- Web meeting 23 August 2019:
  - simplified calculation method: simplified service catalogue.
- Brussels meeting 9 October 2019:
  - Beta testing
  - Simplified method
  - Interoperability
  - Review of the service catalogue
  - Contextualisation of the methodology.
- Web meeting 4 November 2019:
  - Interoperability, cybersecurity & connectivity
  - Methods A & B
  - Weightings for domains and impact criteria.
- Brussels meeting 13 February 2020 with topical groups A, B and C:
  - Review of the draft legal texts

Topical Group B members are:

	Organisation
1	Applia
2	AT – EE Institute for Sustainable Technology
3	BBRI
4	BDEW
5	BU – Budapest University of Technology and Economics
6	COGEN Europe
7	CY – Cyprus
8	DE – Federal Energy Efficiency Center
9	DE – IFEU (replacement)
10	DK – Danish Energy Agency
11	EHI
12	EHI (replacement)
13	EHPA
14	EPEE
15	ES – CENER
16	Eu.bac
17	EURIMA
18	Euroheat
19	EVIA
20	FI – Aalto University
21	FI – Aalto University (replacement)
22	FIEC
23	FR – CEREMA
24	FR – IFPEB
25	KNX association
26	Lighting Europe
27	NL – The Netherlands Enterprise Agency
28	REHVA
29	Smart Building Alliance
30	SmartEn

* Four participants did not consent to sharing their organisation

5.1.2.3 Topical group C: future evolutions of the SRI

The Topical Group C on **future evolutions of the SRI** aims to explore how the SRI can remain sufficiently future proof. Members of this topical group have been discussing:

- All elements related to a data-driven assessment; e.g. methodological requirements (benchmarking of smartness, dealing with qualitative SRI impacts such as convenience); technological requirements (data formats, disaggregating data to extract the smartness aspects, required monitoring infrastructure, etc.), and other aspects such as privacy concerns and cybersecurity.
- A process for updating methods A and B; e.g. updating the service catalogue by adding or removing domains, services, or functionality levels, etc.

Unlike topical groups A and B, this topical group is self-managed in terms of organisation and content and reports to the technical study consortium and the Commission services. The work of topical group C is intended to continue beyond the time frame of the technical support study. At some point, topical group C could potentially evolve into a more permanent structure, potentially with a different set-up and composition.During the course of the technical study meetings have been held, covering the following topics:

- Web meeting 2 December 2019
  - Kick-off: scope and practical arrangements.
- Web meeting 27 January 2020
  - Practical arrangements
  - Work plan
- Brussels meeting 13 February 2020 with topical groups A, B and C:
  - Review of the draft legal texts
- Web meeting 13 March 2020
  - Outline for a first internal survey on current status and future evolutions of the SRI
  - Planning for a second internal survey to start approximately mid-May 2020
  - Planning for a recommendations report towards the technical study consortium and the commission services
- Web meeting 20 April 2020
  - Presentation of the results of the first internal survey
  - Planning the recommendations report aggregated 1st draft and recommendations report consolidated 1st draft
- Web meeting 4 May 2020
  - Discussion recommendations report aggregated first draft and finalising recommendations report consolidated 1st draft
- Web meeting 13 May 2020
  - Handover meeting: presentation of intermediate recommendations to the technical study consortium and the Commission Services
  - Presentation of the quasi-final SRI TGC 1st recommendations report which is a snapshot of the progress of the ongoing work in topical group C.

The topical working group has provided recommendations to the technical study consortium and the Commission Services, which are summarised below.

5.1.2.4 Summary of Topical Group C first recommendations report

Topical group C, the independent body operating in parallel to this study, have made the following recommendations regarding the SRI within their 1st recommendations report. The report is available on the project website[153].

Concerning the objectives of the SRI and the definition of smart buildings they recommend:

Overall, the SRI should serve towards the achievement of the EU Green Deal goals, and especially through the Renovation Wave initiative. It should not be just an image tag. Moreover, the SRI assessment should be incorporated in all phases of the building life cycle and furthermore be validated and tracked, therewith providing comfortable buildings at minimum use of energy and maximizing the flexibility potential buildings can deliver in a smart energy grid.

Specifically, for advancing the development in the field of smart buildings, especially in light of the need to continuously improve the SRI methodology and its implementation (as it deals with fast evolving building technology), it would be helpful to have a very basic acknowledged definition of a Smart Building e.g.

"A building that can leverage metadata from technical building systems (building services), occupants and surrounding environment to deliver all expected benefits associated with:

- *Satisfying the evolving needs of the people.*
- *Continuously improving the building's performance.*
- *Continuously improving the energy system's performance."*

More generally the other recommendations are structured under three main pillars:

- Updates to the existing methodology.
- In-use SRI - automated methods A and B (software synced with technical building systems).
- In-use SRI – a new method C based on measured data (real-time building performance).

Concerning updates to the existing methodology Topical Group C state:

For coordinating the process of ***updating the existing methodology*** *considering both lessons learned and emerged needs during the testing and implementation, the key is to ensure consistency between the assessment and final SRI scores at EU level. The Member State level tailoring of the methodology should be done in such a way that the seamless conversion to the EU SRI default methodology is ensured. This would enable and facilitate analysis and comparison of the readiness level in different Member States and regions providing the basics for an inclusive and streamlined updating process.*

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[153] The full report of topical group C can be found on www.smartreadinessindicator.eu/ stakeholder-consultation

Concerning automating methods A and B they state:

Automating methods A and B *is highly likely to increase the EU-wide market uptake of the SRI which in turn would support the performance improvement (also indoor climate) process of the EU's building stock. In many buildings and with the introduction of the revised EPBD, automation or at least more control possibilities than currently available will be introduced in buildings. Developing an SRI which can use these systems to generate automatically comparable indicators on different levels would help the market. The same building technology needed for automated methods A and B enables continuous real-time data monitoring of technical building systems' operation which has high potential in closing building performance gaps throughout a building's life cycle and so introduce a new method C.*

Concerning a new method C they state:

For ***a new method C*** *it is very important to keep in mind that the whole point of this method is to let the SRI evolve from a parameter which consists of factors levelling functionalities of services from the Smart Services Catalogue (currently methods A and B) to a parameter which quantifies the building's impacts for all 3 relevant categories (building occupants needs, building operational efficiency and building energy flexibility) with a strong focus on the impact upon the reduction of* CO_2 *emissions. A new method C would add further value to real estate. Therefore, go-to-market strategy should be considered to support added-value in the market. As such, having a clear and transparent (sustainable) business case (value proposition) from the very beginning is essential. Just considering the goal of decarbonising the EU's building stock, monetisation should be quantified at least in terms of* CO_2 *savings. In addition, benefits like enhanced productivity by an improved indoor work environment, reduced investment cost for upgrading the energy grid by fully employing the building flexibility potential and reduced total cost of ownership by the use of data driven predictive maintenance techniques should be quantified.*

The entire SRI process will be managed and further developed via the so called "SRI platform". The "SRI platform" (for which a basic concept is proposed in the report) should be established by end 2020 to support the work of the SRI TGC and enable the exchange with and between Member States during the SRI national testing.

The national testing provides a unique window of opportunity to assess if/how it is sensible and market relevant to apply the recommendations provided within this report aiming at further consolidating the SRI. Furthermore, having the "SRI platform" operational would also enable the coordination of ongoing and upcoming EU funded projects (e.g. Horizon 2020, Horizon Europe, both Coordination and Support Actions and Innovation Actions) that include activities related to SRI, especially testing, demonstration, further development and market uptake.

Currently, EU strategic priories in the post-COVID Recovery Plan are to invest in green, digital and resilient future including the Renovation Wave as a key component. In this respect, we believe that the SRI has an important role to play in turning our European buildings into healthy, efficient and smart places, and advocate for the SRI broad and fast uptake (as element in the Renovation Wave) in order to speed-up this transition.

More specific recommendations on the above are reported in Topical Group C's 1st recommendations report.

In addition, Topical Group C make the following general considerations and recommendations:

- *The options on the table are either a "checklist" approach (A or B) or an assessment based on measured data (C). A or B and even C would rely on "qualified assessors". It should be acknowledged that this adds a level of subjectivity to the process and as such quality assurance is among the top priorities.*
- *SRI Method C could be used for planning purposes e.g. the desired smart services/capabilities should be specified together with their respective KPIs. For actual performance assessment a link to the CEN/ISO set of EPB standard would be needed e.g. CEN/ISO set of EPB standards might define minimum requirements of capabilities of a smart building.*
- *One challenge to be tackled in method C is how to handle user behaviour. For example, the flexibility of the building's performance, much depends on the user's willingness to be flexible with his needs. Method C will most likely require normalization of the measurements to make results comparable, especially when considering user behaviour.*
- *The lift industry sees several advantages to include lifts within the heart of the discussions or proposal as they can address all the concerns.*
- *All lessons learned from the smart meters' roll-out activities need to be valued to ensure the SRI delivers all (or most) of its promises.*
- *It might be useful to analyse the international building rating schemes using digital online platforms, e.g. LEED ARC platform that calculates a performance score out of 100 across multiple performance dimensions such as Energy and Human Experience, based on data from many sources.*
- *In-use-SRI (automated methods A and B + new method C) should contain and tell the public and market much more than the currently developed SRI. EU-wide SRI communication campaign should be prepared asap.*
- *For the SRI's evolution process to be meaningful and useful it is invaluable to leverage to the maximum extent possible the national SRI testing and ongoing H2020 projects.*
- *Include SRI scores in the EU Building Stock Observatory.*
- *Incorporate SRI assessment in all phases of the building life cycle, validate and track. The SRI should serve towards the achievement of EU Green Deal goals, and especially through the Renovation Wave initiative. It should not be just an image tag.*
- *Integrate SRI in BIM.*

5.1.2.5 Feedback meeting for topical group members

A plenary feedback meeting with stakeholder from topical groups A, B and C was organised on 13 February 2020 to feed the further consultations with EU Member States and support the process of drafting the delegated and implementing acts.

Prior to the meeting, the attendees were provided with a draft version of the interim report and its summary, service catalogues A and B, and a draft version of the discussion documents on the implementing and delegated act.

During the meeting various topics were discussed, including the links between the proposed methods A and B and the viability of a future method C incorporating measured building performance, the potential of online self-assessments, the definition of weighting factors, and the balancing the desire for allowing flexibility in parts of the method versus sufficient commonality to create a common EU market.

Next, stakeholders were able to provide comments on the discussion documents on the implementing and delegated act.

5.1.3 PUBLIC TESTING OF THE SRI

Stakeholders were given the opportunity to test a draft version of the SRI calculation framework. The aim of the public testing is to receive targeted feedback on the feasibility of the approach, allowing the study team to fine-tune methodological framework. Public testing took place in two phases:

- Dry-run testing by the members of topical groups A and B
- Public beta testing, open to all stakeholders.

The **dry-run testing** took place in August 2019. Topical group members were invited to test a draft version of the SRI calculation methodology on buildings of their choice. To this end, they received an information package, including a calculation spreadsheet (for method B) and a guidance document (see extracts in 0). In total, 11 members of topical groups A and B participated to the dry-run testing. Participants were asked to assess the feasibility of the assessment, provide feedback on the user-friendliness of the spreadsheet and the clarity of the guidance document. They were also invited to signal any calculation errors or linguistic issues in the information package. Based on the received feedback, a number of updates were made to the information package.

The wider stakeholder community was invited to participate in the public beta testing. Stakeholders who are interested in participating to the public beta testing were asked to sign up on the SRI website before end of August 2019. Participants received the updated information package on 15 September 2019 and were asked to provide us the completed calculation sheet and their feedback by 15 November 2019. The information package (all in English), including a guidance document and two calculation sheets (methods A and B) were provided to perform an SRI assessment on one or more buildings, chosen by the stakeholder. The beta testing was carried out on a voluntary basis and did not require any specific prior knowledge on the SRI.

5.1.3.1 Description of the dataset

In total, 112 complete and unique calculation sheets were received, covering 81 unique buildings. For 31 buildings, both methods A and B were applied to the same building. Two buildings were only assessed using method A, whereas 50 building were assessed using method B. In total, the dataset contains 33 buildings assessed with method A and 79 buildings assessed with method B.

Figure 75 illustrates the participation by member state and by calculation method. In total, 21 member states participated to the public testing phase. Figure 76 provides additional insights in the types of buildings that were assessed. The table shows that – in terms of climate zone – buildings in Southern (n=43) and Western Europe (n=38) are most represented. Fewer buildings participated in Northern (n=14), North-Eastern (n=7) and South-Eastern (n=10) Europe.

The dataset of 112 buildings composes of 47 residential buildings and 65 non-residential buildings. Within the set of residential buildings, single family homes, small multifamily homes and large multifamily homes are represented. The non-residential buildings include office buildings (n=36), educational buildings (n=14), healthcare buildings (n=5) and other buildings (n=13). In terms of surface floor area, the tested buildings cover a wide range of sizes, ranging from buildings smaller than 200m² to buildings larger than 25.000m². Most tested buildings are already constructed, with a relatively large share of buildings constructed after 2010 (n=40). Only 5 buildings are not yet constructed.

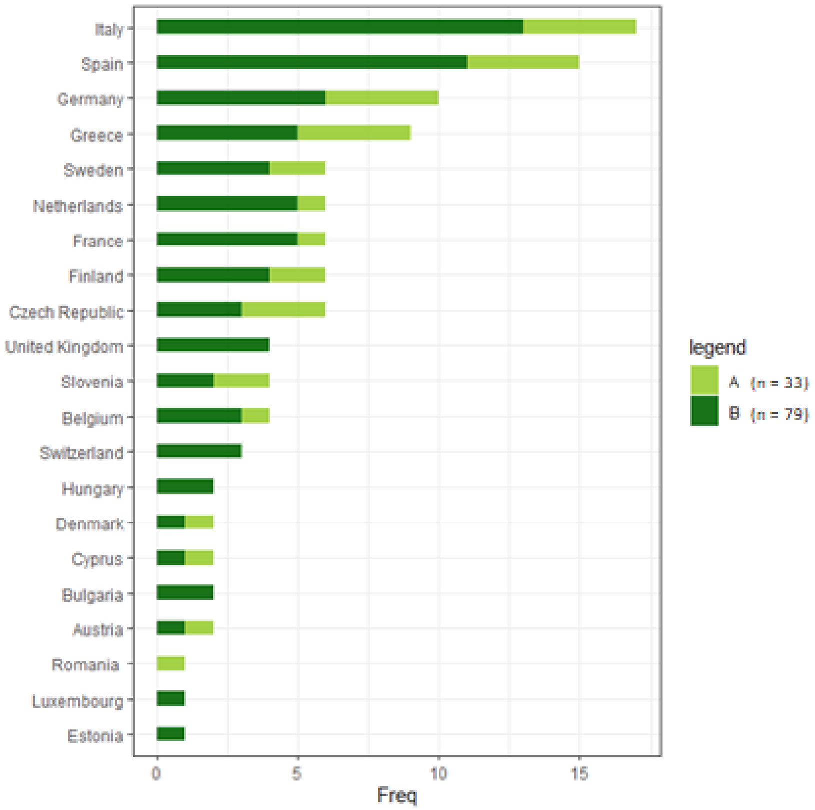

Figure 75 – Buildings participation to public testing by method and member state

Respondents Statistical Data

Building Type	**Method**	Residential	Non-residential					
	A	16	**17**					
	B	31	**48**					
Climate Zone		North-East Europe	North Europe	South-East Europe	South Europe	West Europe		
	A	3	5	3	**13**	9		
	B	4	9	7	**30**	29		
Building Floor Area		<200 m^2	200 - 500 m^2	500 - 1.000 m^2	1.000 - 10.000 m^2	10.000 - 25.000 m^2	> 25.000 m^2	NA
	A	5	4	1	**14**	4	5	0
	B	8	9	6	**38**	7	10	1
Building Year		< 1960	1960 - 1990	1990 - 2010	> 2010	Not yet constructed	NA	
	A	2	8	10	**12**	1		
	B	7	16	22	**28**	4	2	
Building State		Original	Renovated	Not yet constructed				
	A	**10**	12	1				
	B	**47**	30	2				
Building Usage		Single-family	Small-Multi-family	Large-Multi family	Office	Educational	Healthcare	Other
	A	7	3	5	**10**	4	0	4
	B	13	5	11	**26**	10	5	9

Figure 76 - Detailed description of the tested buildings

5.1.3.2 Discussion of the results: total SRI score by method and building type

Figure 77 illustrates the distribution of the obtained SRI scores by method (left) and by building type (right). When comparing the results for methods A and B, no statistically significant difference between these methods is found. This confirms that method A, although using a subset of the full service-catalogue, sufficiently reflects the smart readiness of the building as compared to method B. The distributions for residential and non-residential buildings do reflect significant differences. In general, lower scores are found for residential buildings, compared to non-residential buildings. This is in line with the expectations, since smart ready services are typically found in more advanced technical building systems that are not widely applied in residential buildings. It should be noted that Figure 77 (right) only distinguishes on building type and hence includes both methods A and B. A further break-down of the results by method and building type can be found in Figure 78. The boxplot confirms similar means for both methods, but clearly illustrates the differences between residential and non-residential buildings.

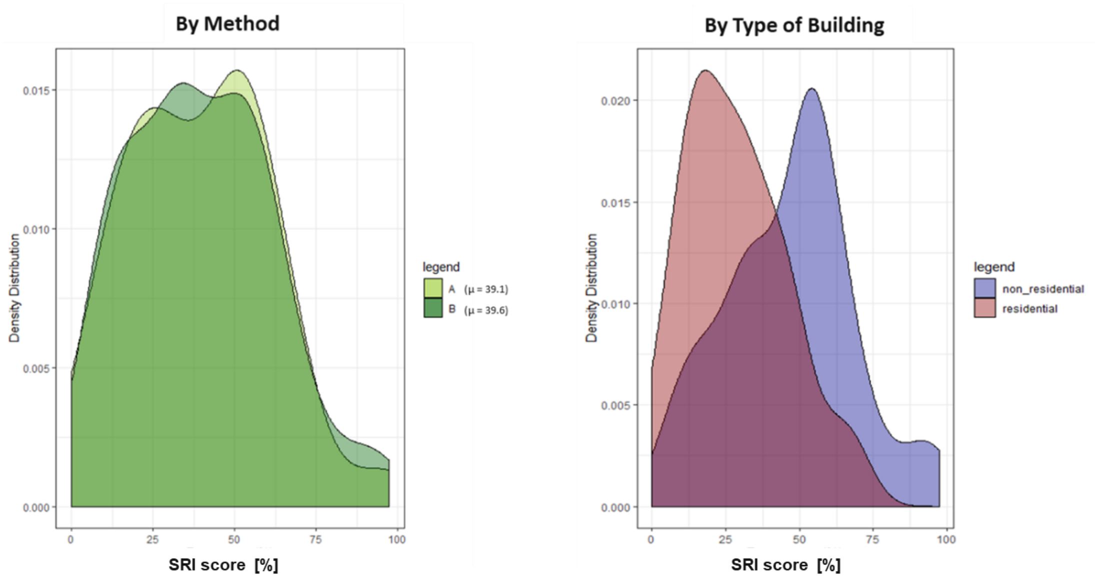

Figure 77 - Distribution of the total SRI score by method (left) and building type (right)

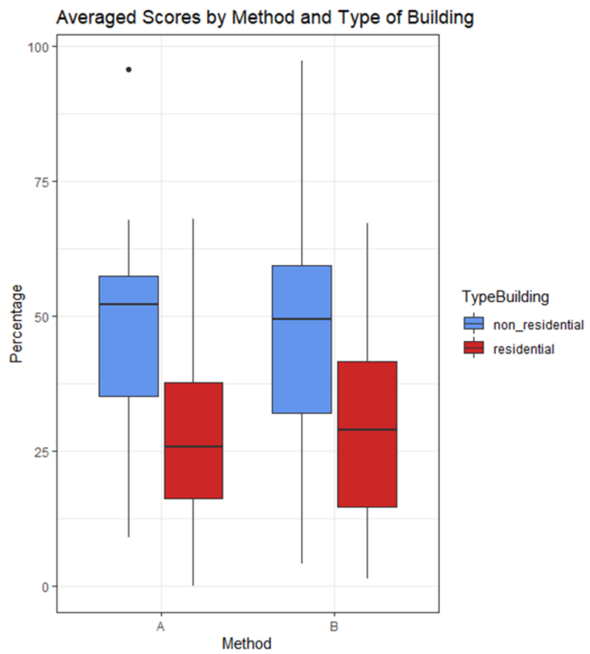

Figure 78 - Box plot of the total SRI score by method and building type

During the public testing, 31 buildings were assessed applying both methods A and B on the same building, and by the same assessor. Figure 79a shows the density plots of the obtained results. Figure 79b presents a direct comparison of the results obtained by both methods. The graphs show that scores obtained through method B tend to be slightly lower than the scores obtained through method A, although the results are generally well-aligned. The statistical analysis revealed no significant difference between both method ($p > .46$). The perceived alignment between methods A and B by assessors is further discussed under "feedback from stakeholders".

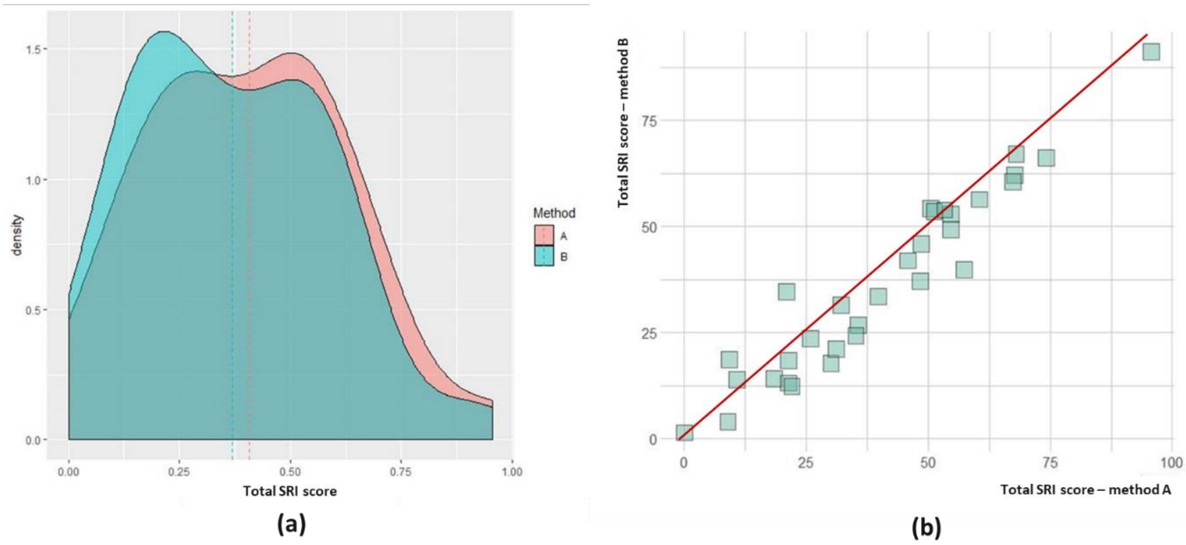

Figure 79 - Comparison of methods A and B, applied to the same buildings during the public beta test

5.1.3.3 Discussion of the results: impact scores and domain scores

In addition to the overall SRI scores, a comparison of the impact scores as a function of the calculation methodology was performed. Figure 80 illustrates the median score by impact criterion and by calculation method. The results showed no significant difference in the impact scores, except for the impact criterion “flexibility for the grid and storage”. Impact scores on “Flexibility for the grid and storage” are higher when evaluated with method B (mean =34.7%) when compared to method A (mean = 14.6%). This might suggest that method B is more sensitive to measure this impact factor.

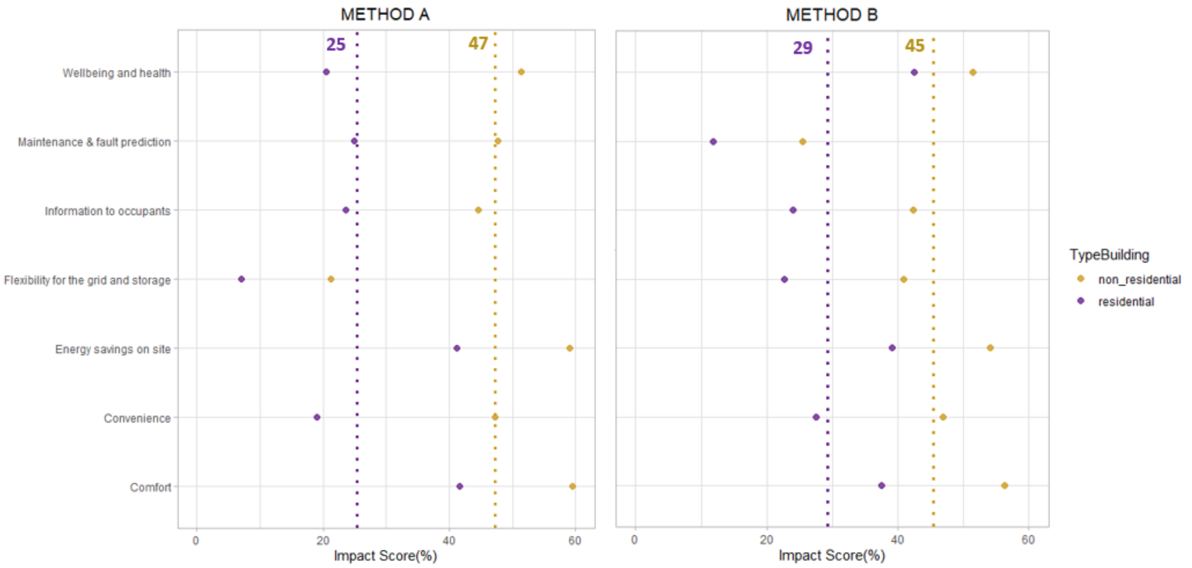

Figure 80 - Analysis of the mean impact score by method

Similarly, the results for various domains are depicted in Figure 81. None of the domains showed significant differences when comparing the two calculation methods. This illustrates that method A sufficiently captures the smart readiness of the individual technical domains as compared to method B, despite the limited set of services.

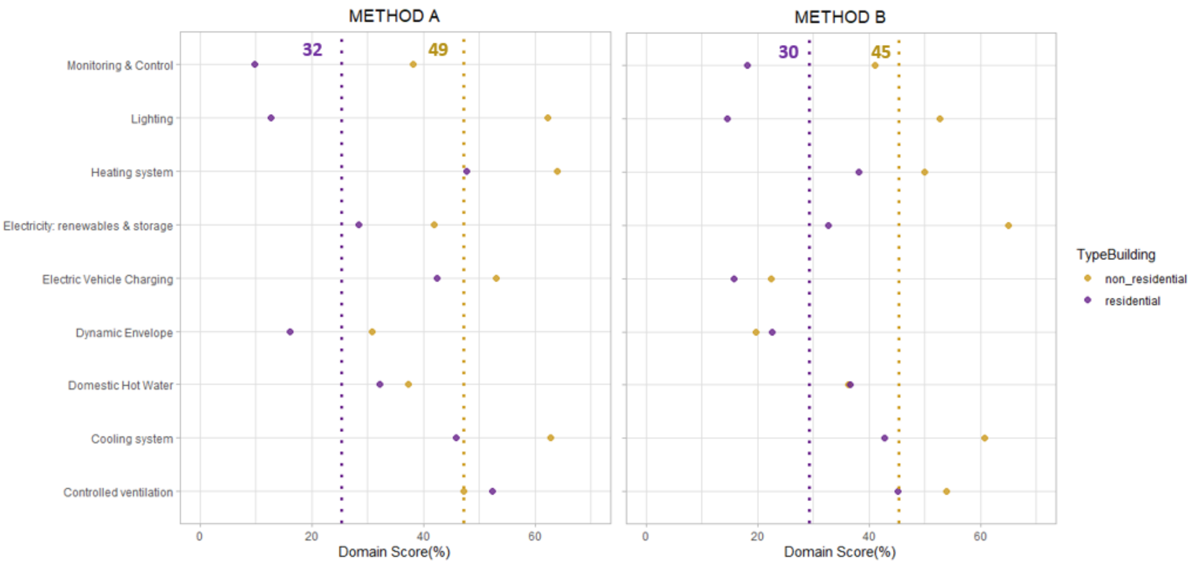

Figure 81 - Analysis of the mean domain score by method

5.1.3.4 Feedback from stakeholders

As part of the public beta testing, participants were asked to provide their feedback on the assessment. The following questions were asked:

- Is the SRI score in line with initial expectations by the assessor or building owner/user?
- Did you do an onsite walkthrough of the building?
- How much time did the assessment process take you (excluding travel, administration, intake discussions)?
- Which information was missing to complete the assessment?
- Are there smart services relevant for this building which are currently not part of the draft SRI methodology?
- Were any relevant functionality levels missing for this particular building?
- Do you have any indications on the interoperability or cybersecurity of the technical building systems?
- For this particular building, you have any other comments?

The stakeholders participating in the public beta test were offered the opportunity to provide additional feedback in a survey, which was completed by 26 respondents. The survey included the following additional questions:

- Did the SRI assessment provide you with new insights on how to upgrade the assessed buildings?
- If you assessed multiple buildings, are the results well-balanced?
- Did you discuss the results with the occupants or the facility manager? Please share feedback
- In your opinion, what are the training needs for an assessor?
- Is the triage process (= the initial multiple-choice questions on the "building information" tab) straightforwardly applicable?
- If you applied both methods to the same building, do you have any comments on the comparability of the results?
- In your opinion, are the services sufficiently forward-looking?

A selection of these questions will be further discussed below. All comments were carefully analysed by the technical study consortium and were taken into consideration for the update of the calculation methodology and the service catalogue.

On the question whether the SRI score is **in line with initial expectations by the assessor or building owner/user**, 52% of the respondents reacted positively (see Figure 82). For 16% of the respondents the results were not in line with their expectations. Within this group, 9 respondents explicitly stated they expected a higher score and 4 respondents stated they expected a lower score. Furthermore, 18 respondents indicated they are lacking a baseline or benchmark.

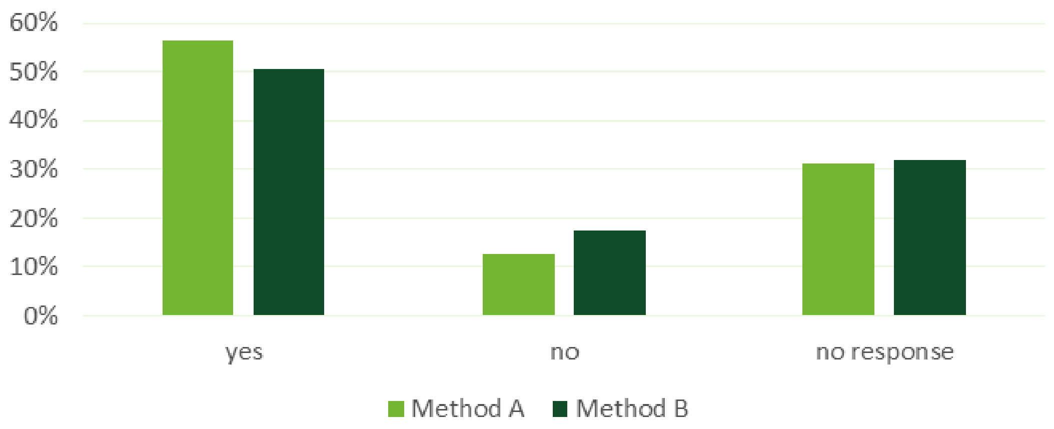

Figure 82 - Is the SRI score in line with initial expectations by the assessor or building owner/user?

A selection of comments received from respondents:

- *"Yes. It's a new building in which we invest time and money to reach high energy efficiency and smartness level. It appears to us that the score is in line with what we can expect."*
- *"No. The first building (an office building) we assessed includes all the technical building systems listed in the triage process. The global SRI score is 51%. It is less than we expected for a building that was awarded in 2013 as a smart building."*
- *"Yes. The […] building opportunity to increase its score is hindered by the limited control over the scheduling of facilities, which is one of the conclusions of the project, the lack of organisational readiness."*
- *"Yes, for assessor. Owners having no awareness of the calculation method have no specific expectations"*

The study team concludes that the results were generally well in line with expectations of the assessor. The analysis did reveal that end users – and in some cases the assessors – were lacking a frame of reference to determine whether the score was "good" or "bad". Special attention should be given to this issue upon implementation, through proper communication and formatting of the SRI. This is discussed in detail in section 2.2.

In the additional survey, stakeholders were asked if the **assessment provided new insights on the potential upgrade of the building**. Out of the 26 respondents, 77% indicated that they gained new insights. A selection of comments received from respondents:

- "Yes. The SRI methodology is a good guidance to explore some other smart functionalities. Overall, during the design project of a new building phase, it is a reminder for not forgetting *(to consider certain smart functionalities, editor's note)"*
- *"Yes. It was interesting to see the score divided by impacts and domains because it quantifies the current strengths and the weaknesses of the building. Also, during the referred H2020 project (HOLISDER) diverse smart devices had been deployed in the assessed buildings, so we could check how thanks to these devices some functionalities have been upgraded."*

- *"No. All necessary measures were already identified. The SRI supports in confirming the already identified actions."*
- *"No. The final SRI result is not informative enough. Default recommendations and/or reporting would be highly beneficial. E.g. the building doesn't have Cooling, Controlled ventilation nor Renewable generation or storage on site. Having controlled ventilation can support the IAQ, cooling can support your thermal comfort, your heating system can be upgraded to support the grid etc.."*

It is concluded that sub-scores at the level of the domains and impact criteria were appreciated by the assessors, as they provided or confirmed insight with regard to the strengths and weaknesses of the building. The provision of (default) recommendations was identified as a way to potentially strengthen the role of the SRI as an informative tool.

As mentioned before, 31 buildings were assessed using both methods A and B by the same assessor. In the additional survey participants were asked if they had any comments on the comparability of the results. A selection of comments received from respondents are:

- *"[…] Generally, the SRI scores using Method A are higher than the SRI scores with Method B. This means Method B provides more precise and realistic assessment. There are significant deviations in the results for certain Impact categories (e.g. Flexibility) and Domains (e.g. Electricity) […]"*
- *The global score is close but domain and impact scores are quite different. Thus, there is not a good comparability between both methods. My recommendation is maintain only one simplify method (Method B).*
- *"The results were almost the same (2% difference) so it might not have a large impact."*
- *"[…]Totally different results. I.E Method A Wellbeing 0% while method B 100%".*

Combining the findings from the statistical analysis and the stakeholder feedback, it is concluded that although objectively the results for both methods are generally well-aligned, the differences in results may be undesirable to some stakeholders. Therefore, it is important to ensure than in practice only one of the two methods would be applied to a given building, so no problem of comparability can arise. Additionally, when SRI results are communicated it should be made clear which assessment method was used. In any case, it is desirable from a methodological point of view to align the methods as much as possible. Based on the received feedback, the study team has updated the service catalogues, including a harmonization of the services and ordinal scores in the catalogues for both the simplified and detailed method (see ANNEX E and 0).

Participants were also asked to indicate **the time spent on the assessment**. Figure 83 shows that the assessment typically took less than one hour for method A, whereas most assessments with method B did not take more than 4 hours. The slightly longer assessment time for method B may be explained by the more elaborate service catalogue, including more detailed and complex services. In this context, it is worth mentioning that at least 53% of the respondents did an on-site walk-through, whereas 30% did not do an on-site walk-through. 14% of the participants did not respond to the question.

Furthermore, it should be noted that most assessors were very familiar with the buildings they assessed. They were also not required to formally document the assessment or collect evidence. As a results, slightly higher assessment times may be expected.

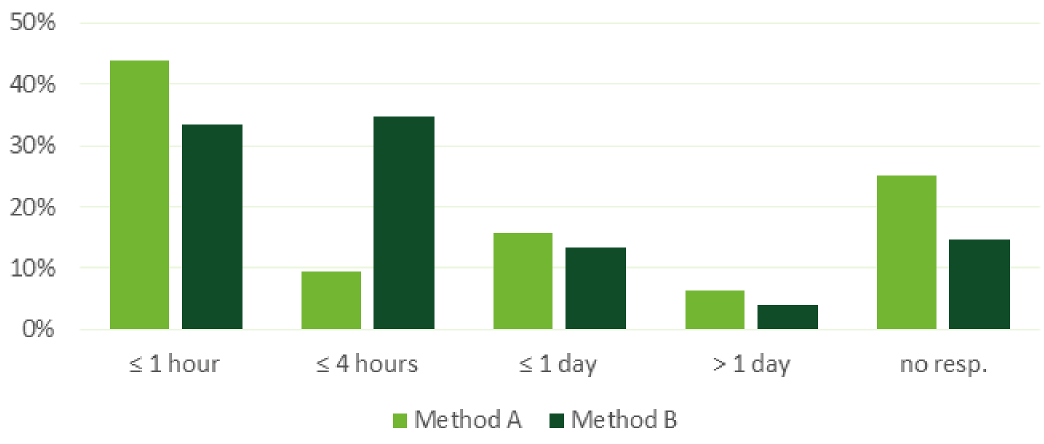

Figure 83 - How much time did the assessment process take you (excluding travel, administration, intake discussions)?

To assess the feasibility of the assessment method and the completeness of the guidance document, participants were asked if there was **any information missing to complete the assessment**. As shown in Figure 84, 44% of the participants did not report any missing information, and many others did not respond to the question. A limited number of participants (18%) provided comments on missing information. These comments mainly include the request to further clarify the definition of services and functionality levels. Others suggested to include examples in the guidance document to further support assessors, in particular for more complex buildings with multiple systems serving a single technical domain. Finally, some participants highlighted the role of the facility manager as a necessary source of information for the assessment.

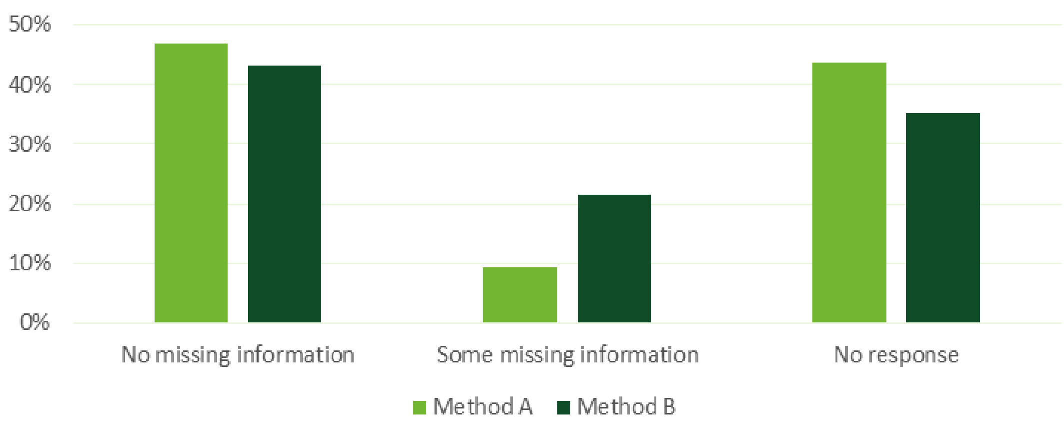

Figure 84 - Which information was missing to complete the assessment?

A selection of comments received from respondents are:

- "No. There was not missing information, however the support of the facility manager in conducting the assessment is required."
- "No. As-built documentation together with on-site walk-through were sufficient to complete the assessment."
- "Yes. The buildings in the hospital are very complex and have a mix of solutions in the assets implemented. More examples of functionality levels could have been helpful."

5.1.3.5 Conclusions from the public testing

During the public testing, 112 assessments were performed covering 81 unique buildings from 21 member states. For 31 buildings, both methods A and B were applied to the same building.

Based on the analysis of the calculation sheets and the feedback received, the study team concludes that the SRI calculation methodology is generally well-received. Results were generally in line with the expectations, and the results were found to be insightful. The formatting and communication on the SRI will play an important role in creating a reference frame for the results. Additional (default) recommendations could strengthen the role of the SRI as an informative tool.

It is concluded that objectively the results for both methods A and B are generally well-aligned. Furthermore, issues of comparability are not likely to arise since in practice only one of the two methods would be applied to a given building. Nevertheless, both service catalogues were updated to harmonise the methods. It is suggested to include a clear reference to the method used in the communication of the SRI for a particular building.

From a practical perspective, the assessment typically took less than one hour for method A, whereas most assessments with method B did not take more than 4 hours. This is in line with the expectations. In general, sufficient information was available to perform the assessment. To facilitate the assessment, the guidance document should include more detailed definitions of the functionality levels, and provide additional examples or guidelines for complex systems. The role of the facility manager as a source of information was highlighted.

5.1.4 CONSUMER FOCUS GROUPS

Consumer focus groups were organised to test the understanding of the SRI by end users. Section 2.3.12 describes the set-up and feedback retrieved.

5.1.5 WRITTEN COMMENTS ON DELIVERABLES

After the plenary stakeholder consultation meetings, all materials, including the presentations and meeting minutes, have been made available through the project website. Stakeholders had the opportunity to send written comments on draft deliverables. The study teams of both technical studies have collected and processed the comments to support the finalisation of the deliverables.

In addition to the structured surveys and requests for feedback on interim deliverables, some stakeholders have reached out to the study team and/or the

Commission Services with position papers. During the first technical support study 38 position papers were received. The technical study team of the second study has received 17 additional position papers. These position papers cover a wide scope, ranging from a general appreciation of the SRI concept to feedback on very specific technical suggestions.

Most position papers originate from European organisations, covering the following sectors:

- technical building systems (HVAC, lighting, etc.)
- organisations representing the construction sector and architects
- property and land-owner organisations.

A number of sector organisations were highly involved, submitting multiple position papers throughout the studies. In cases where additional clarifications were required, additional meetings or conference calls with the stakeholders were set up.

5.1.6 TARGETED PUBLIC CONSULTATION

The Commission's DG Energy set up a targeted consultation on its website, to collect further feedback from stakeholders on some key issues related to the SRI. This consultation opened from 9 August 2019 to 11 October 2019. The consultation was open to all and sought in particular feedback from stakeholders from the fields of interest to the development of the SRI (e.g. product manufacturers, installers, building designers, building developers, contractors, etc.). The survey included 27 questions, articulated in five different sections:

- general information on the respondent
- questions about the audience and scope of the SRI
- questions on communication of the SRI[154]
- questions on the implementation of the SRI
- additional, free comments.

The consultation resulted in the collection of detailed feedback from 93 respondents located in 21 countries. This feedback was processed by the study team to inform the developments on the SRI methodology and implementation pathways. An analysis of the responses received is included in 0.

5.1.7 DEDICATED STAKEHOLDER INTERACTIONS UPON REQUEST

Aside from the large plenary stakeholder consultation meetings, it is deemed important to organise bilateral meetings with individual stakeholders or a group of stakeholders working on the same topic, with (a selection of) individual companies or with key persons from Member States, local authorities or NGOs. Such meetings can be very helpful for in-depth discussion of topics that are not relevant for the whole group attending the large stakeholder meeting, for collecting specific data or viewpoints, for explaining certain issues, for convincing stakeholders to be more active, etc.

[154] Here, communication refers to the way the information on smart readiness is communicated to end users.

5.2 ACTIVITY 2: DEVELOPMENT AND MAINTENANCE OF PROJECT WEBSITE

During the course of the technical studies, the dissemination and written consultation open to the public was managed via a public website (https://smartreadinessindicator.eu/).

The website served as a channel of information, distribution (of questionnaires, results, etc.) and registration. The draft reports, interim overview and other relevant documents have been published regularly.

Stakeholders were able register on the website to be updated of any changes. During the course of the second technical support study, 813 people have registered as a stakeholder on the project website.

6 General Conclusion

The Energy Performance of Buildings Directive (EPBD) introduced the concept of a Smart Readiness Indicator (SRI) which is expected to become a cost-effective measure that can effectively assist in creating healthier and more comfortable buildings with a lower energy use and carbon impact, and can also facilitate the integration of renewable energy sources. Within the scope of the first and second technical study on the SRI, the following definition has been adopted:

"Smartness of a building refers to the ability of a building or its systems to sense, interpret, communicate and actively respond in an efficient manner to changing conditions in relation the operation of technical building systems or the external environment (including energy grids) and to demands from building occupants,"

The SRI aims to raise awareness of the benefits of smarter building technologies and functionalities and their added value for building users, energy consumers and energy grids. Thereby it can support technology innovation in the building sector and become an incentive for the integration of cutting-edge smart technologies into buildings.

A first technical study developed a definition and draft methodology for the SRI. The second technical support study has built further on the available knowledge of the first technical study to deliver the technical inputs needed to refine and finalise the definition of the SRI and the associated calculation methodology. Furthermore it explored possible options for the implementation of the SRI and evaluated their impact at the EU level in order for the Commission Services and Member States to be informed on the possible modalities for an effective implementation of the SRI scheme and related potential impacts.

Throughout this work the consortium partners of both technical studies have consulted with relevant stakeholders and used the findings to inform the analysis while helping to build awareness and consensus with regard to the project's aims and the most viable approach to achieve them.

In the final report the technical study team propose a consolidated methodology to calculate the SRI of a building. The methodology is a flexible and modular multi-criteria assessment method which builds on assessing the smart ready services present in a building. Services are enabled by (a combination of) smart ready technologies, but are defined in a technology neutral way. The proposed calculation methodology is structured amongst 9 technical domains and 7 impact criteria. For each of the services several functionality levels are defined. A higher functionality level reflects a "smarter" implementation of the service, which generally provides more beneficial impacts to building users or to the grid compared to services implemented at a lower functionality level.

In the proposed method, the smart readiness score of a building or building unit is expressed as a percentage which represents the ratio between the smart readiness of the building or building unit compared to the maximum smart readiness that it could reach.

The disaggregated scores can express smart readiness for one or more of the following:

- Three key smart readiness capabilities as highlighted in Annex Ia, point 2 of the EPBD:
    1. Energy performance and operation
    2. Response to the needs of the occupants; and
    3. Energy flexibility.

- The seven smart readiness impact criteria:
    1. Energy efficiency
    2. Maintenance and fault prediction
    3. Comfort
    4. Convenience
    5. Health and wellbeing
    6. Information to occupants
    7. Energy flexibility and storage.

- The nine smart readiness technical domains:
    1. Heating
    2. Cooling
    3. Domestic hot water
    4. Controlled ventilation
    5. Lighting
    6. Dynamic building envelope
    7. Electricity
    8. Electric vehicle charging
    9. Monitoring and control.

A smart service catalogue for both a detailed and a simplified assessment method was elaborated in extensive consultation with stakeholders. The simplified Method A would be mainly oriented towards small buildings with low complexity (single family homes, small multi-family homes, small non-residential buildings, etc.), whereas the more detailed Method B is mainly oriented towards buildings with a higher complexity (typically large non-residential buildings, potentially large multi-family homes). For either method an informative self-assessment could be made available as an alternative to a formal certificate. The final report of the study also includes a proposal for weighting factors, a methodology for normalisation of the scores and a suggested triage process which details how to deal with absent services.

The SRI calculation methodology was successfully tested in a public beta test comprising 112 cases across Europe, which proved the viability of the approach. The feedback from the stakeholders participating in this test led to further finetuning and harmonisation of the SRI calculation methodology and the delivery of two consolidated service catalogues which are distributed as annex C and annex D of the full report. The proposed SRI calculation methodology is flexible to allow for adaptations to specific local contexts and allows for future updates in order to keep pace with new innovations in smart products and technologies available on the market.

The study also investigated the potential pathways for the effective implementation of the SRI in the EU. The review of various schemes and initiatives on which the SRI could build or connect to has led to the development of a set of six primary potential implementation pathways and the identification of various trigger points in the building lifecycle that the SRI deployment could link to. The SRI is expected to exert an influence on the market adoption of smart services and technologies by both a "market pull" and a "market push" effect. The market *pull* effect is driven by the impact that SRI assessments on properties have on the deployment of smart services and technologies, through raising awareness among stakeholders in the value chain at the property level. The market *push* effect is a result from the common framework that the SRI provides for service providers to self-organise and promote their service offers on a common basis in line with the SRI criteria across the EU. Research was initiated to determine potential designs for the format of the SRI. This recognises that for the scheme to be effective it will need to have an attractive and recognisable format that gives visibility to the SRI and effectively conveys information to users of the scheme.

Building on the outcomes of this work, the study provides technical guidelines and recommendations addressing (1) the operational, organisational and legal design of the SRI scheme, (2) the efficient and cost-effective assessment of the SRI and (3) the management of the SRI after adoption. These were informed by considerations of costs, data needs, training for assessors, etc. which helped to shape the development of the methodology and implementation pathways in an iterative manner.

Finally, the study quantified the costs and benefits of implementing an SRI in the EU building sector for the horizons of 2030, 2040, 2050. The impact analysis reveals that rolling out the SRI across the EU would be strongly beneficial, with the greatest net benefits arising from linking the SRI assessments to the Energy Performance Certification (EPC) assessments of buildings, or the article 8 requirements under the EPBD. The SRI could lead to 5% higher final energy savings by 2050, unlocking an increase in investment of 181 billion euro over 30 years compared to a business-as-usual case and up to 32 million tonnes of avoided greenhouse gas emissions per year.

The study team concludes that the roll-out of the SRI would result in a strongly beneficial impact and observes a broad consensus among stakeholders on most of the key principles and methodological choices of the proposed SRI developments.

ANNEXES

ANNEX A. GLOSSARY

Attribute: An attribute of a service is a variable (typically a piece of data) which may take different values, thereby influencing the state of the service. A basic switch of a heating system would for instance take a binary value (on or off), while more complex control devices could take discrete or continuous control values.

Building user is defined as a stakeholder of the building, who can have different roles, e.g. the owner of the building or the occupant. The building user interacts with the services provided by the building, therefore, his or her viewpoints are of highest interest in assessing the perceived smartness of individual technologies in the building and the overall perceived smartness of the building. In addition, the building user can interact with the grid, providing his building to the grid as an asset for flexibility, generation or storage of energy.

(Service) Catalogue: A service catalog (or catalogue), is an organized and curated collection of technology-related services. Each service within such a service catalogue is usually repeatable and is associated to well-defined inputs, processes, and outputs.

In the scope of this study, we define a smart service catalogue for a building technology as the overview of the services provided by a smart building.

Cyber security is defined as preservation of confidentiality, integrity and availability of information in the Cyberspace wherein Cyberspace means the Cyberspace the complex environment resulting from the interaction of people, software and services on the Internet by means of technology devices and networks connected to it, which does not exist in any physical form. The relevant standard is ISO/IEC 27032 - Information technology -- Security techniques -- Guidelines for cybersecurity.

Domain: Within this project, domains are high-level viewpoints used to structure the smart services models. Each domain focuses on a key aspect of the building. Heating, lighting, cooling, etc., are domains of services which are provided by the building.

Enabling technologies: some technologies do not provide smart services themselves, but are providing infrastructure provision to the higher level operations. As an example, a fieldbus or bus system in a house would be an enabling (interoperability) technology. The same way, the broadband connection to a household itself is an enabler to let the building communicate with other buildings in order to, e.g. create a swarm or sensor community.

End user is defined as a building user who always interacts directly with the services provided by the building. The end user is typically providing the trigger event to start a service and use it. In the case of a building this can be an occupant, or a technical facilities manager.

Function: A function represents an interaction between a building user and a building system. In comparison to a service, a function is more basic (in particular with regard to the number of inputs and outputs involved). Functions can be combined into services.

A typical function would be a state change based on a trigger event, e.g. change of state of a switch.

Interoperability: According to ISO/IEC 2382-01 on Information Technology Vocabulary, Fundamental Terms, interoperability is defined as follows: "The capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units". This definition is also in line with the IEEE definition "the ability of two or more systems or components to exchange information and to use the information that has been exchanged." which was, e.g. also used in the context of the EU M/490 mandate and recommended by some stakeholders in the consultation process. Note that the "user" can be a digital device or object within a network.

Readiness: refers to the capability of a technology, a system or a building to implement smart functions and services. This capability is based on the corresponding technology is enabled and the related function is invoked.

For instance, a system can be smart-ready (e.g. a controllable heat pump) but not smart (the controllable heat pump is not connected to a controller and / or has no configuration interface).

Smartness of a building refers to the ability of a building or its systems to sense, interpret, communicate and actively respond in an efficient manner to changing conditions in relation the operation of technical building systems or the external environment (including energy grids) and to demands from building occupants.

On top of this definition, it is useful to refer to the three key 'smartness' functionalities given in the Annex 1a of the revised EPBD, as discussed in section 1.1.1.2.

Smart ready technologies are the foundation for the services to be implemented on. Services use those technologies like e.g. bus systems, communication protocols or building automation systems. These smart ready technologies can either be digital ICT technology (e.g. communication protocols or optimization algorithms) or physical products (e.g. ventilation system with CO2 sensor, cabling for bus systems) or combinations thereof (e.g. smart thermostats).

The smart ready technologies referenced in this study are considered to be active components which could potentially:

- raise energy efficiency and comfort by increasing the level of controllability of the technical building systems – either by the occupant or a building manager or via a fully automated building control system;
- facilitate the energy management and maintenance of the building including via automated fault detection;
- automate the reporting of the energy performance of buildings and their TBS (automated and real time inspections);
- use advanced methods such as data analytics, self-learning control systems and model predictive control to optimise building operations;
- enable buildings including their TBS, appliances, storage systems and energy generators, to become active operators in a demand response setting.

Service: a service is a function or an aggregation of functions delivered by one or more technical components or systems. Services are invoked in order to serve a (business) purpose of a stakeholder and can range from simple (micro services) to complex. In this study, a Smart service makes use of Smart ready technologies and orchestrates them to higher level functions.

Services are enabled by (a combination of) smart ready technologies, but are defined in a technology neutral way, e.g. 'provide temperature control in a room'. Many of the services listed in the catalogue are based on international technical standards, for example BACS control functions (EN 15232-1:2017), lighting control systems (EN 15193-1:2017) and Smart Grid Use cases (IEC 62559-2:2015).

The term "ready" indicates that the option to take action exists, but is not necessarily realized, e.g. due to cost constraints, legal or market restrictions, or occupant preferences. However, the equipment needed to implement the service has to be present in the building.

Taxonomy: In the scope of the project, a taxonomy is the result of the practice and science of classification of things or concepts, including the principles that underlie such classification. Within this context, the aim is to classify certain attributes of building technologies and link to their characteristics in order to find functionality levels.

Technology: Technology is the collection of techniques, skills, methods and processes used in the production of goods or services or in the accomplishment of objectives. Within this project, we consider technology as enabler of functions and services or even readiness.

Technical building system: In the EPBD a "technical building system" is defined as technical equipment for space heating, space cooling, ventilation, domestic hot water, built-in lighting, building automation and control, on-site electricity generation, or a combination thereof, including those systems using energy from renewable sources, of a building or building unit.

Viewpoint is a modeling concept. Modeling has the purpose of reducing the complexity of a given system in order to focus on particular aspects, which are particularly relevant to one or more stakeholders. Viewpoints generally differ from one stakeholder to the other (e.g. for a building, the architect viewpoint will differ from the facility manager or aggregator viewpoint). In modeling, one key objective is to agree on harmonized and complementary viewpoints.

ANNEX B. STANDARDISATION RELATED TO SMART BUILDINGS

a. The Energy Performance of Buildings Directive (EPBD), the Construction Products Regulation (CPR) and its relationship to standardisation and Mandate (M/480)

It is worth noting that the EPBD is an EU directive, which transposition and enforcement are under the responsibility of the Member States and which allows for some flexibility at National and local levels. This is illustrated by the variety of standards and regulations that co-exist in the EU. In order to support a reliable comparison of calculation methods across the EU, and with the aim to support National Authorities in the effective implementation of the EPBD, the European Commission issued mandate M/480 to CEN, CENELEC and ETSI for the elaboration and adoption of standards for a methodology calculating the integrated energy performance of buildings and promoting the energy efficiency of buildings, in accordance with the terms set in the recast of the Directive on the energy performance of buildings.

Complementary to this, the European Commission adopted the Construction Products Regulation (CPR) that lays down harmonized rules for the marketing of construction products in the EU, i.e. Regulation (EU) No 305/2011. Note that CPR is EU Regulation and not a Directive, therefore there is no need additional step for transposition in local requirements neither standardization. The regulation is embedded in the goal of creating a single market ("Article 95") for construction products through the use of CE Marking. It outlines basic requirements for construction works (as the sum of its components) that are the basis for the development of the standardization mandates and technical specifications i.e. harmonised product standards and European Assessment Documents (EADs). The basic idea is to harmonise the way the performance of a construction product is determined and declared in levels or classes while each Member State may have individual requirements regarding the required minimum level or class for a given use.

b. Interaction with the electrical grid and the Smart Grid Standardization Mandate (M/490)

The M/490 Smart grid mandate was issued to the three large standardisation bodies CEN, CENELEC and ETSI in order to consolidate the standardization landscape for smart grids. In order to ensure interoperability for the heterogeneous systems at infrastructure level, standards had to be either found or defined in later stages. The working groups within the mandate created a process for governance of smart grid standardization, created an overview and mapping of existing standards taking into account the various viewpoints from the stakeholders involved and did a gap analysis for the standardization bodies in order to find gaps for new working item proposals for those bodies and their working groups. In the second stage of the four year term of the mandate, security and interoperability testing were the focus. In addition, the results from both the metering mandate as well as the electric vehicles mandate were harmonized and taken into account, making the overview of smart grid as an infrastructure, smart metering as well as electric vehicles seamless. Currently, the platform of ETIP SNET[155] will build upon those results.

c. Interaction with Ecodesign product regulation and standardisation mandate (M/495)

The request from the Commission (EC mandate M/495) is a horizontal mandate covering more than 25 different types of products that use energy or have an impact on the use of energy. Types of products covered by this mandate include: air conditioning and ventilation systems, boilers, coffee machines, refrigeration units, ovens, hobs and grills, lamps and luminaries, tumble dryers, heating products, computers and monitors, washing machines, dryers and dishwashers, sound and imaging equipment and water heaters, etc.

d. Background information on European and international standardization bodies

In the European Union, only standards developed by CEN, CENELEC and ETSI are recognized as European standards.

CEN is the **European Committee for Standardization**.

Within CEN Standards are prepared by Technical Committees (TCs). They do not deal with electrical equipment neither telecommunication which is within the scope of CENELEC and ETSI.

Within CEN TC 371 is the Program Committee on EPB standards. This TC 371 organizes this central coordination team in cooperation with the other relevant CEN TC's:

- CEN TC 89, Thermal performance of buildings and building components
- CEN TC 228, Heating systems in buildings
- CEN TC 156, Ventilation for buildings
- CEN TC 247, Controls for mechanical building services (EN 15232)
- CEN TC 169, Light and lighting (EN 15193, prEN 17037)

CENELEC is the **European Committee for Electrotechnical Standardization** and is responsible for standardization in the electro-technical engineering field. It cooperates in International level with IEC, hence within CENELEC are often mirror committees to what is developed within IEC and therefore often the relevant TC's with work in progress can be found at IEC level.

Relevant CENELEC TC's in the scope of the SRI are:

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[155] http://www.etip-snet.eu/

- CLC/TC 205 is responsible for Home and Building Electronic Systems (HBES)
- Much are mirror committees of IEC, therefore see also IEC operating at international level.

ETSI, the **European Telecommunications Standards Institute**, produces standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and internet technologies.

An overview of important smart grid and building communication and interoperability standards can be found on their website[156].

A European Standard (EN) is a standard that has been adopted by at least one of the three recognized European Standardisation Organisations (ESOs): CEN, CENELEC or ETSI.

Beyond Europe is also the **International Organization for Standardization (ISO**) for non electro-technical standards.

When an ISO document is released, countries have the right to republish the standard as a national adoption. When CEN adopts an ISO standard its reference becomes, e.g. EN-ISO-52000-1, and later on when a Member State adopts this e.g. DIN-EN-ISO. In the context of the ongoing review of EPB standards, many are expected to be published as EN & EN-ISO standards. This means that the old numbering system of 2007 in an EN 15000 series of standards is not necessarily maintained and sometimes replace by the ISO 52000 series of standards.

Relevant ISO TC's are:

- ISO/TC 163 is responsible for Thermal performance and energy use in the built environment and part of the EPBD related standards.
- ISO/TC 205 is responsible for Building environment design, a.o. is responsible for ISO 16484 on BACS.

At international level **the International Electrotechnical Commission (IEC)** is the overarching organization of CENELEC.

Within IEC the most relevant TCs from our view are:

- IEC TC 8 is responsible for Systems aspects for electrical energy supply
- IEC TC 64 is responsible for IEC 60364-8-1 ED2 on Energy Efficiency and IEC 60364-8-1 ED2 on Smart Low-Voltage Electrical Installations
- IEC TC 69 is responsible for Electric road vehicles and electric industrial trucks, amongst they take care of EV chargers.
- IEC TC 57 covers the Smart grid related connections of a building

[156] http://www.etsi.org/technologies-clusters/technologies/575-smart-grids

e. A selection of the most relevant standards for SRI

i. At European Level (EN) related to EPBD calculation methods

The standards from Mandate M/480 consist in general of two parts, where the first part is a normative part (for example with the template) and the second part is an informative part (for example containing proposals for default data). Hereafter is a short description of the main standards. Also, according to The Detailed Technical Rules, and in agreement with the mandate M/480 for each EPB-standard containing calculation procedures an accompanying spreadsheet has been prepared to test and validate the calculation procedure. The spreadsheet also includes a tabulated overview of all output quantities (with references to the EPB module where it is intended to be used as input), all input quantities (with references to the EPB module or other source from where the data are available) and a fully worked example of the application (the calculation method between the set of input and output quantities) for validation and demonstration[157].

EN-ISO 52000-1:2017 Energy performance of buildings — Overarching EPB assessment – Part 1: General framework and procedures

The main output of this standard is the overall energy performance of a building or building part (e.g. building unit). In addition: breakdown in partial energy performance, e.g. per energy service (heating, lighting, etc.), per building unit, per time interval (hour, month, etc.) and breakdown in energy flows at different perimeters and e.g. delivered versus exported energy.

Depending on the application, all or some of the other standards related to the energy performance of buildings that cover other parts of the modular structure are needed (EPB standards). It introduces a modular structure to cover all aspects of the building energy balance and its subsystems, see Table 32.

[157] https://isolutions.iso.org/ecom/public/nen/Livelink/open/35102456

Table 32 - Summary of the main modular structure of the EPB Standards

Overarching		Building (as such)		Technical Building Systems										
	Descriptions		Descriptions		Descriptions	Heating	Cooling	Ventilation	Humidification	Dehumidification	Domestic Hot water	Lighting	Building automation & control	Electricity production
sub 1	M1	sub 1	M2	sub1		M3	M4	M5	M6	M7	M8	M9	M10	M11
1	General	1	General	1	General									
2	Common terms and definitions; symbols, units and subscripts	2	Building Energy Needs	2	Needs									
3	Applications	3	(Free) Indoor Conditions without Systems	3	Maximum Load and Power									
4	Ways to Express Energy Performance	4	Ways to Express Energy Performance	4	Ways to Express Energy Performance									
5	Building Functions and Building Boundaries	5	Heat Transfer by Transmission	5	Emission & control									
6	Building Occupancy and Operating Conditions	6	Heat Transfer by Infiltration and Ventilation	6	Distribution & control									
7	Aggregation of Energy Services and Energy Carriers	7	Internal Heat Gains	7	Storage & control									
8	Building Zoning	8	Solar Heat Gains	8	Generation & control									
9	Calculated Energy Performance	9	Building Dynamics (thermal mass)	9	Load dispatching and operating conditions									
10	Measured Energy Performance	10	Measured Energy Performance	10	Measured Energy Performance									
11	Inspection	11	Inspection	11	Inspection									
12	Ways to Express Indoor Comfort			12	BMS									
13	External Environment Conditions													
14	Economic Calculation													

In general it is important to note that the standard defines system boundaries (the concept of concept of perimeters and assessment boundary, zoning,) and amongst others also defines a Renewable Energy Ratio (RER).

The contribution of building automation and control (BAC) including technical building management (TBM) to the building energy performance is considered in the calculation procedure as the impact of all installed building automation and control functions (BAC functions) on the building energy performance.

It deals with three characteristics:

- Control Accuracy (mainly used in emission and control modules M3-5, M3-4, M3-5)
- BAC Functions (mainly used in modules M3-5, M3-9, M9-5, M9-9)
- BAC Strategies (mainly used for M10-12)

The contribution of one such BAC function is taken into account by one of the following five approaches: time approach, set-point approach, direct approach, operating mode approach and correction coefficient approach. The application of one of the first two approaches – the time approach or the set-point approach - leads in general to a modification of the time programs and set-points, both coming from the module which defines the user profile (M1-6 Building Occupancy and operating conditions). Which approach is applied and how it is exactly done, is described in the EPB standard which is devoted to the module which treats the BAC function (M10). For BAC functions which are treated in one of the EPB standards for modules M3-5, M3-9, M9-5, M9-9, M10-5, M10-9, all five approaches are possible, for BAC functions which are treated in M10-12 the first two approaches are applied.

Directly related to EPB there are about 52 EN and/or ISO standards to define the calculation method (see Figure D1 for an overview). It can already be concluded that this update consists of a complex set of interrelated standards for which the application of the proposed version is still in its infancy and it will need to be judged in how far the data contained herein can be applied for the SRI indicator.

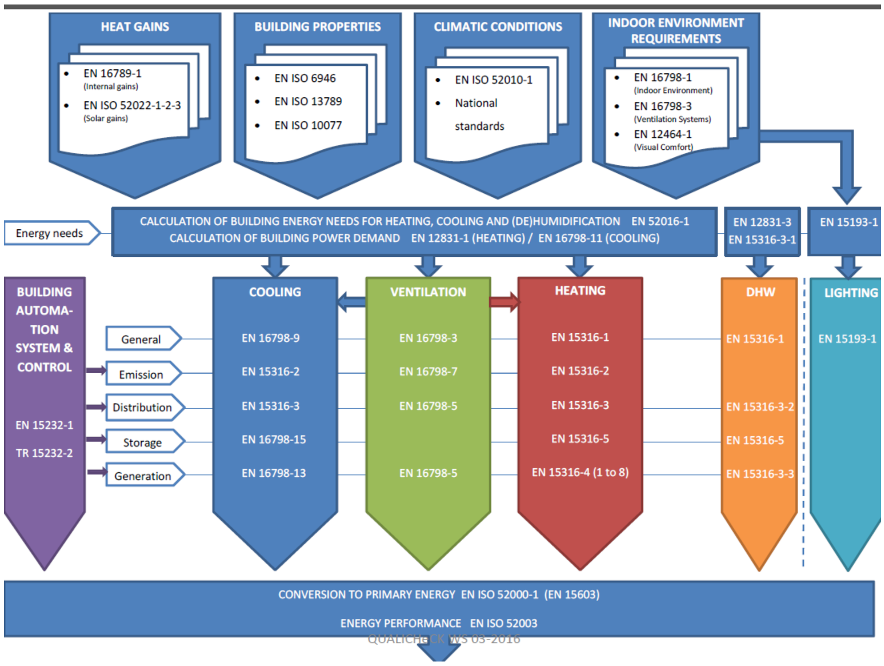

Figure 85 - Overview of applicable standards in the ongoing review of EPB (Hoogeling, 2016)

EN 15232-1:2017 is the standard 'Energy performance of buildings - Impact of Building Automation, Controls and Building Management.' (Module M10)

This European Standard specifies:

- a structured list of Building Automation and Control System (BACS) and Technical Building Management (TBM) functions which have an impact on the energy performance of buildings;

- a method to define minimum requirements regarding BACS and TBM functions to be implemented in buildings of different complexities;
- a factor based method to get a first estimation of the impact of these functions on typical buildings;
- detailed methods to assess the impact of these functions on a given building. These methods enable the impact of these functions in the calculations of energy performance ratings and indicators calculated by the relevant standards to be introduced.

The standard defines the following control functions:

For heating control:

- 'Emission control', e.g. individual room temperature control with BACS including schedulers and presence detection can lower the general heat demand.
- 'Control of distribution pumps in networks', e.g. switching off circulation pumps when not required.
- 'Heat generator control for combustion and district heating', e.g. reducing the return temperature based on load forecasting to increase boiler efficiency by condensation.
- 'Heat generator control for heat pump', e.g. controlling the exit temperature base on load forecasting.
- 'Heat pump control system', e.g. inverter driven variable frequency compressor depending on the load.
- Other functions are 'Sequencing of different heat generators', 'Thermal Energy Storage' or 'control of Thermo Active Building Systems(TABS)'.

For domestic hot water(DHW) supply:

- Reduce stand by losses in hot water storage tank (if any) with automatic on/off control based on forecasted demand.
- Control of DHW pump (if any).

For cooling control:

- Many of those functions are similar to heating (see EN 15232-1:2017).
- 'Interlock between heating and cooling' to avoid simultaneous heating and cooling.

For air supply or ventilation (if any):

- Demand driver variable outside air supply;
- Heat recovery unit, icing protection;
- Free air night time cooling mechanical by automatic opening windows and/or operating the ventilation unit
- Humidity controls (if any)

Lighting controls; they can increase the building cooling demand or decrease the heating demand.

Blind control; there are two requirements which are prevent overheating and reduce glare and therefore controls can be combined with HVAC and lighting.

Technical Building Management (TBM) system, the aim is to adapt easily to the user needs and therefore it shall be checked frequently. TBM functions are (see also EN 16947 with more details):

- Set point management, e.g. web operated heating/cooling temperature set points (20°C/26°C) with frequent resetting to default values where relevant.
- Run time management, e.g. predefined schedule (e.g. a night time set back temperature) with variable preconditions (e.g. no presence in the room).
- Manage local renewable sources or CHP to optimize own consumption and use of renewables.
- Control of Thermal Energy Storage of heat recovery (if available).
- Smart Grid integration.
- Detect faults in the Technical Building System (TBS), for example:
    - Read out alarms from the heat pump, gas boiler, .. and provide understandable building owner feedback and alarm logging
    - Continuous monitoring of SCOP (Seasonal Coefficient Of Performance – for heating) or SEER (Seasonal Energy Efficiency Ratio – for cooling) of a heat pump to verify maintenance needs (e.g. clogged heat exchanger, cooling fluid leakage, ..)
    - Regular checking sequence to verify the maximum power output of a heat pump or gas boiler to verify maintenance needs (e.g. contaminated gas burner, dirt on heat exchanger, valve errors, damage on pipe insulation, installation errors such as reverse connection of heat exchangers, correct control logic and set point of circulation pumps).
    - Check the power consumption of the Air Handling Unit (e.g. increased power consumption due to clogged filter or air inlet/outlet, leakages in or clogged ventilation duct work, broken air dampers/fans)
- Reporting regarding energy consumption relative to indoor conditions:
    - Show actual values and logged trends

The standard also defines four classes that poses specific requirements on the previous control functions. It contains a simplified calculation method based on BAC efficiency factors, for lighting reference is made to EN 15193.

The 4 classes of Building Automation Systems are:

- Class A: High energy performance building automation and control system (BACS) and technical building management (TBM);
- Class B: Advanced BACS and TBM;
- Class C: Standard BACS;
- Class D: Non energy efficient BACS;

For each class minimum control system requirements are defined.

Table 33 - Table 1 on lighting controls defined in EN 15232

		Definition of classes							
		Residential				Non residential			
		D	C	B	A	D	C	B	A
LIGHTING CONTROL									
Occupancy control									
0	Manual on/off switch								
1	Manual on/off switch + additional sweeping extinction signal								
2	Automatic detection Auto On / Dimmed								
3	Automatic detection Auto On / Auto Off								
4	Automatic detection Manual On / Dimmed								
5	Automatic detection Manual On / Auto Off								
Daylight control									
0	Manual								
1	Automatic								

Afterwards the simple method in the standard defines relations between building energy systems and so-called BAC efficiency factors for different types of energy use, including lighting, see figure D-3. These factors enable savings to be estimated. For a detailed calculation on the impact the individual standards should be considered and therefore references to these related standards are included (e.g. EN 15193 for lighting).

Also, according to The Detailed Technical Rules, and in agreement with the mandate M/480 [2], for each EPB-standard containing calculation procedures an accompanying spreadsheet has been prepared to test and validate the calculation procedure. The spreadsheet also includes a tabulated overview of all output quantities (with references to the EPB module where it is intended to be used as input), all input quantities (with references to the EPB module or other source from where the data are available) and a fully worked example of the application (the calculation method between the set of input and output quantities) for validation and demonstration[158].

EN 16947-1:2017 Building Management System - Module M10-12

This is a European Standard which addresses the TBM/BMS functions. This standard covers several functions of the application of the Building management system. Each function is represented by at least one calculation method. The functions are as follow:

- Function 1 – set points is meant for set point definition and set back.
- Function 2 – run time is intended for estimating run times.
- Function 3 – sequencing of generators is intended for estimating the sequential arrangement of different functions to be performed
- Function 4 – local energy production and renewable energies is intended for managing local renewable energy sources and other local energy productions as CHP.
- Function 5 – heat recovery and heat shifting is intended for shifting thermal energy inside the building.

[158] https://isolutions.iso.org/ecom/public/nen/Livelink/open/35102456

- Function 6 – smart grid is meant for interactions between building and any smart grid.

EN ISO 52016-1:2017 Energy performance of buildings -- Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads -- Part 1: Calculation procedures.

This standard defines the building latent heat load using an hourly calculation interval. It describes an important parameter for modelling the impact of for example the BACS night time set back temperature function (EN or thermal storage in smart grids is the building time constant (τ)[hours]. It also contains a parameter to model the impact of the temperature control system (Δθctr), which is 0 for a perfect control system.

EN 15193-1: 2017 Energy performance of buildings - Energy requirements for lighting - Part 1: Specifications, Module M9

This standard deals with energy requirements for lighting and defines different lighting control systems (e.g. occupancy control type, type of daylight control, type of blinds control) and their impact on energy savings (e.g. occupancy factor (Fo), daylight factor (Fd)). It calculates the Lighting Energy Numeric Indicator for a building (LENI) in kWh/m²/y based on assumption for occupants' schedules (EN ISO 17772-1:2017). Background information to this standard is documented in CEN/TR 15193-2: Energy performance of buildings — Energy requirements for lighting; Part 2: Explanation and justification of EN 15193-1, Module M9.

prCEN/TS 17165 "Lighting System Design Process"

This document is developed in the frame of ENER Lot 37 and describes the key design considerations in the process for good quality, energy efficient and effective lighting systems in the tertiary sector.

ISO 17772-1:2017 Energy performance of buildings -- Indoor environmental quality -- Part 1: Indoor environmental input parameters for the design and assessment of energy performance of buildings.

The standard contains indoor environmental input parameters for the design and assessment of energy performance of buildings. It deals also with occupants' schedules for energy calculations which can have important impact on energy calculations. Of course, apart from the assumptions, the real occupant behaviour will have similar impact. Advanced Building Automation and Control Systems (BACS) (EN 15232-1:2017) can include set point management which means that set points (e.g. illumination levels, comfort temperature, air quality, ..) can be redefined over the life time of the building when the task area, zone requirements or real user needs change. Usually however EPBD calculations [kWh/y/m²] are based on predefined occupants' schedules and comfort requirements and therefore they do not model properly the impact from set point management that adapt to changes in the user needs over its life time.

ii. Examples of implementation of EPBD calculation methods at Member State level

The implementation of EPBD calculation methods can vary by Member State; more information can be found in the Book (EPBD, 2016) on 'Implementing the Energy Performance of Buildings Directive (EPBD) – Featuring Country Reports'. It reported that the German transposition of the EPBD resulted in an exemplary all-in-one calculation method based on a local standard series DIN V 18599, see figure D-4. DIN V 18599 has been an important source of information for the development of European Standards.

It should also be noted that not all Member States used a local standard to implement the calculation methods. For example in France (RT2012, 2012), the EPBD is regulated within local decrees and limits the maximum primary energy per year and m² together with a combination of other minimum performance requirements to be calculated. Calculation software to prove compliance needs to be purchased. This software needs to be validated before it is commercialised.

Belgium, e.g. follows the same approach but the software is harmonized and openly available (PEB, 2011). These EPBD calculation methods already validate in some extend smart building controls; for example in Flanders automatic solar shading, presence detection for lighting, demand controlled ventilation, temperature control per room, etc.

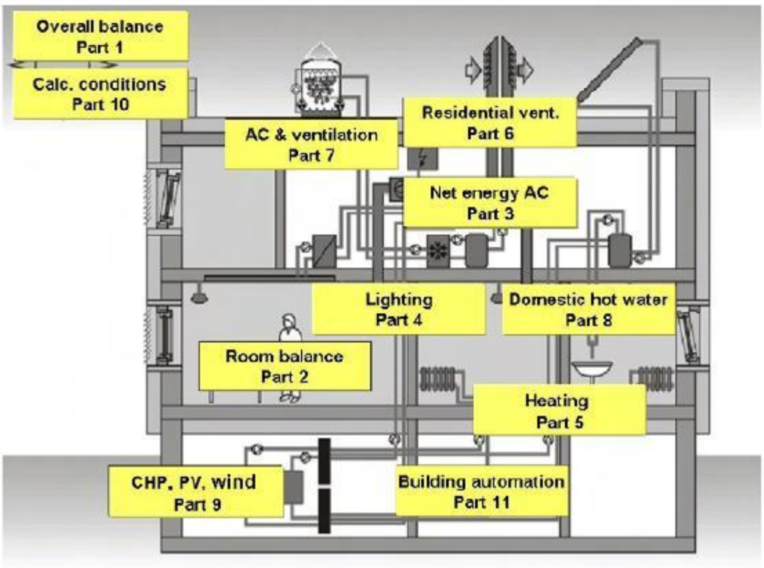

Figure 86 - Structure of German EPBD calculation standard DIN V 18599 Important EN product and/or smart building system standards

iii. Standards related to electrical installation

IEC 60364-8-1 ED2 Low-voltage electrical installations - Part 8-1: Energy efficiency

This standard introduces requirements and advices for the design or refurbishing of an electrical installation with regards to electrical energy efficiency. It proposes a number of various electrical energy efficiency measures in all low voltage electrical installations as given in the scope of IEC 60364 from the origin of the installation including power supply, up to and including current-using-equipment. Amongst others it describes methods to decrease losses in electrical cables and transformers.

IEC 60364-8-2 ED2 Low-voltage electrical installations - Part 8-2: Prosumer Low-Voltage Electrical Installations

This standard is still under development. The standard provides additional requirements, measures and recommendations for design, erection and verification of low voltage installations that include local production and storage. The standard defines therefore how electrical installation requirements should be conceived to be future proof, without infrastructure lock-in effects, could be useful for an SRI to check preconditions for local production and storage (however to be confirmed when the standard becomes available).

IEC PT 60364-8-3 Low-voltage electrical installation - Part 8-3: Evolutions of Electrical Installations

This standard is still under development. This standard provides requirements and recommendations to users and facility managers or similar of low-voltage electrical installations to operate their electrical installations as Prosumer's Electrical Installation. These requirements and recommendations cover safety and proper functioning.

IEC TS 62950 ED1 "Household and similar electrical appliances - Specifying smart capabilities of appliances and devices - General aspects"

This standard is intended to develop the common architecture which applies widely to different use cases and appliance types, and the principles of measuring smart performance within the context of the common architecture. The standard is in the Draft Technical Specification (DTS) stage and is expected to be published in September 2017. The focus of the standard is in smart capabilities for interoperability with Smart Grids.

IEC TS 62898-1:2017 on "Microgrids - Part 1: Guidelines for microgrid projects planning and specification"

provides guidelines for microgrid projects planning and specification. Microgrids considered in this document are alternating current (AC) electrical systems. This

document covers the following areas:
- microgrid application, resource analysis, generation forecast, and load forecast;
- DER planning and microgrid power system planning;
- high level technical requirements for DER in microgrids, for microgrid connection to the distribution system, and for control, protection and communication systems;
- evaluation of microgrid projects.

IEC 61727 Photovoltaic (PV) systems – Characteristics of the utility interface

This standard applies to utility-interconnected photovoltaic (PV) power systems operating in parallel with the utility and utilizing static (solid-state) non-islanding inverters for the conversion of DC to AC. This document describes specific recommendations for systems rated at 10 kVA or less, such as may be utilized on individual residences single or three phases. This standard applies to interconnection with the low-voltage utility distribution system.

IEC 60364-7-712 Low-voltage electrical installations - Part 7-712: Requirements for special installations or locations - Solar photovoltaic (PV) power supply systems.

This part of IEC 60364 applies to the electrical installation of PV systems intended to supply all or part of an installation.

IEC 61851-1:2017 on "Electric vehicle conductive charging system - Part 1: General requirements"

The aspects covered in this standard include:

- the characteristics and operating conditions of the EV supply equipment;
- the specification of the connection between the EV supply equipment and the EV;
- the requirements for electrical safety for the EV supply equipment.

IEC 60364-7-722:2015 on "Requirements for special installations or locations - Supplies for electric vehicles"

The standard applies to circuits intended to supply energy to electric vehicles,

Amongst others it put additional requirements that has an impact in the electrical distribution board, protection devices and cabling within buildings to supply electrical vehicles. For example which and how Residual Current Devices that are needed.

IEC 62933-1 Electrical Energy Storage (EES) systems - Part 3-1: Planning and installation- General specifications

This standard is still under development. This part of IEC 62933 is applicable to EES systems designed for grid connected indoor or outdoor installation and operation at a.c. or d.c. irrespective of voltage.

iv. Standards related to SRI equipment

EN ISO 16484 is a series of 5 standards related to Building automation and control systems (BACS)

The standard is regarding Building automation and control systems (BACS). It consists of 5 parts. ISO 16484-1:2010 specifies guiding principles for project design and implementation and for the integration of other systems into the building automation and control systems (BACS). ISO 16484-2:2004 specifies the requirements for the hardware to perform the tasks within a building automation and control system (BACS). It provides the terms, definitions and abbreviations for the understanding of ISO 16484-2 and ISO 16484-3. ISO 16484-2:2004 relates only to physical items/devices, i.e. devices for management functions, operator stations and other human system interface devices; controllers, automation stations and application specific controllers; field devices and their interfaces; cabling and interconnection of devices; engineering and commissioning tools. ISO 16484-3:2005 specifies the requirements for the overall functionality and engineering services to achieve building automation and control systems. It defines terms, which shall be used for specifications and it gives guidelines for the functional documentation of project/application specific systems. It provides a sample template for documentation of plant/application specific functions, called BACS points list. ISO 16484-5:2007 defines data communication services and protocols for computer equipment used for monitoring and control of heating, ventilation, air-conditioning and refrigeration (HVAC&R) and other building systems. It defines, in addition, an abstract, object-oriented representation of information communicated between such equipment, thereby facilitating the application and use of digital control technology in buildings. ISO 16484-6:2009 defines a standard method for verifying that an implementation of the BACnet protocol provides each capability claimed in its Protocol Implementation Conformance Statement (PICS) in conformance with the BACnet standard.

EN 12098 (parts 1, 3, 5) prepared under CEN/TC247/WG6 committee describe ability of devices and integrated functions to control heating systems. Associated draft Technical Reports CEN/TR 12098 (parts 6, 7, 8) summarise some recommendations for how to design, how to use these functions for energy efficiency of heating systems. Energy impact of these control functions are detailed in EN 15232-1.

CEN 294, 'Communication systems for meters' provides a series of standards with respect to communication interfaces for systems with meters and remote reading of meters for all kind of fluids and energies distributed by network. This can especially be relevant for the services in the 'monitoring and control' domain of the SRI catalogue.

CEN/TS 15810 (Technical Specification) specifies graphical symbols for use on integrated building automation equipment.

v. Standards at European Level (EN) related to construction works and products that bear the CE Marking.

EN 1990 - EN 1999 are the so-called 'EN Eurocodes' which are a series of 10 European Standards, providing a common approach for the design of buildings and other civil engineering works and construction products. This standards might be relevant to check that the construction stability and fire safety preconditions to install photovoltaics, thermal or electrical storage to increase self- consumption of renewables. For example to install photovoltaics in a flat roof it needs to be able to withstand the additional loading, batteries might need fire safe building compartments, etc. .. and those standards could provide approaches to assess those capabilities. Of course, here again also local national standards can apply.

ANNEX C. BUILDING STOCK DESCRIPTION AND SELECTION OF REFERENCE BUILDINGS

A starting point for both the building-level and EU-level impact analysis calculations is the description and disaggregation of the building stock. The following sections provide an overview of the data sources used to gather the necessary input on the EU building stock (ANNEX C.a.i) and its disaggregation across building types, climate regions, etc. (ANNEX C.a.ii). Section ANNEX C.b then presents the reference buildings that have been defined as representative buildings when modelling the impact of SRTs on energy use. In setting up this building stock model, and the consecutive SRT uptake and impact models, this study builds further upon the work carried out in the first technical study on the SRI.

a. Building stock description

i. Building stock data sources

The primary data source for the building stock description is the EU Building Stock Observatory, which monitors the building stock and energy performance characteristics of residential and non-residential buildings across Europe and contains databases, data mappers and factsheets describing Europe's building stock. In addition to information on the share (numbers and total surface areas) of different building types in the EU building stock, it contains information about average U-values of building components, distribution of heating systems, etc. Moreover, it contains information about some of the trigger events used in the SRI deployment model such as the number of EPCs, renovation rates, etc. A comparative analysis of data presented in other EU building stock models and reports, such as the BPIE study "*Europe's Buildings Under the Microscope*"[159] and the report "*Average EU Building Heat Load for HVAC Equipment*" by VHK (2014)[160], showed that although there are differences among the assumed building total floor surface areas and average energy performance characteristics, these differences are small compared to the intrinsic uncertainty of some of the data-sources reported in these studies. Hence, it was deemed valid to extensively build further on the data reported in the EU Building Stock Observatory data.

Nonetheless, for a significant number of input parameters, no or only partial data are available in the EU Building Stock Observatory. A good complementary data source for this task is the TABULA webtool,[161] which provides detailed reference building data for up to 20 European countries, differentiated by residential building type and age class. The national cost-optimality reports from EU Member States also provide useful information for different residential and non-residential buildings[162]. More general examples for European reference buildings are provided in the FP7 project iNSPiRe, especially in its report D2.1a[163].

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[159] http://bpie.eu/publication/europes-buildings-under-the-microscope/

[160] https://ec.europa.eu/energy/sites/ener/files/documents/2014_final_report_eu_building_heat_demand.pdf

[161] http://episcope.eu/building-typology/webtool/

[162] https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings

[163] http://inspirefp7.eu/about-inspire/

ii. Disaggregation of building stock

In the context of this impact analysis the building stock is differentiated across four parameters:

- five climate regions (Northern, Western, Southern, North-Eastern, South-Eastern)
- six building types: single-family houses, small multi-family buildings, large multi-family buildings, offices, wholesale and retail buildings, and educational buildings
- five construction periods (pre-1960, 1960–1990, 1990–2010, post-2010)
- two renovation levels (original construction, renovated).

Climate regions

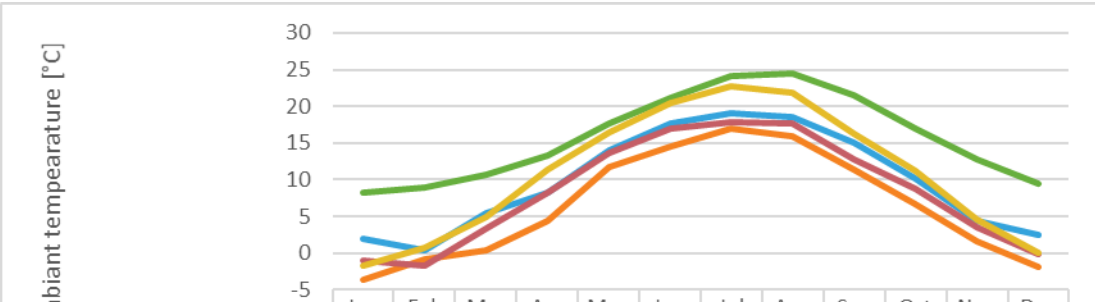
To appropriately address the effect of different climate conditions on the energy demand calculations, the EU building stock is disaggregated into five climate regions, as defined in Table 34 and shown in Figure 87. For the energy demand calculation, climate data for the Member States highlighted in bold in Table 34 have been used to represent the climate for each of the five regions.

Table 34 – Definition of climate regions

Northern Europe	Finland, **Sweden**, Denmark
Western Europe	UK, Ireland, **Germany**, Austria, France, Belgium, Luxembourg, The Netherlands
Southern Europe	Portugal, Spain, Cyprus, Malta, **Italy**, Greece
North-Eastern Europe	Estonia, Latvia, Lithuania, **Poland**, Slovakia, Czech Republic
South-Eastern Europe	Slovenia, Croatia, Hungary, Bulgaria, **Romania**

Figure 88 shows the monthly averaged outdoor temperature profiles for the climate regions as main driving factor for the heating demand calculation. The distribution of the building stock (in terms of total floor surface area) among the different climate regions is shown in Figure 90.

Figure 87 – Geographical regions of Europe



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Western Europe	1.9	0.3	5.4	8.3	14	17.6	19.1	18.5	15	10.2	4.4	2.4
Northern Europe	-3.6	-0.8	0.3	4.4	11.7	14.5	17	16	11.3	6.7	1.6	-1.9
Southern Europe	8.3	9	10.6	13.3	17.6	21.2	24.2	24.4	21.5	17	12.8	9.4
North-eastern Europe	-1.1	-1.8	3.4	8.3	13.7	16.9	17.8	17.7	12.8	8.8	3.5	-0.2
South-eastern Europe	-1.7	0.8	5	11.4	16.5	20.4	22.7	21.8	16.2	11.2	4.5	0.1

Figure 88 – Monthly outdoor temperatures for the selected climate regions

Building types

Six building types have been selected, covering both residential and non-residential sectors. For residential buildings, the building stock of single-family houses, small multi-family buildings and large multi-family buildings are modelled. While there is no split between small and large multi-family houses within the EU Building Stock Observatory, this split is included for the impact analysis as implementation pathways might differ for both types of multi-family buildings. For the non-residential sector, the model explicitly targets office buildings, wholesale and retail buildings, and educational buildings. These types have been selected as they cover the highest share in the non-residential building stock. The total floor area covered by these building types across the different climate regions is shown in Figure 90.

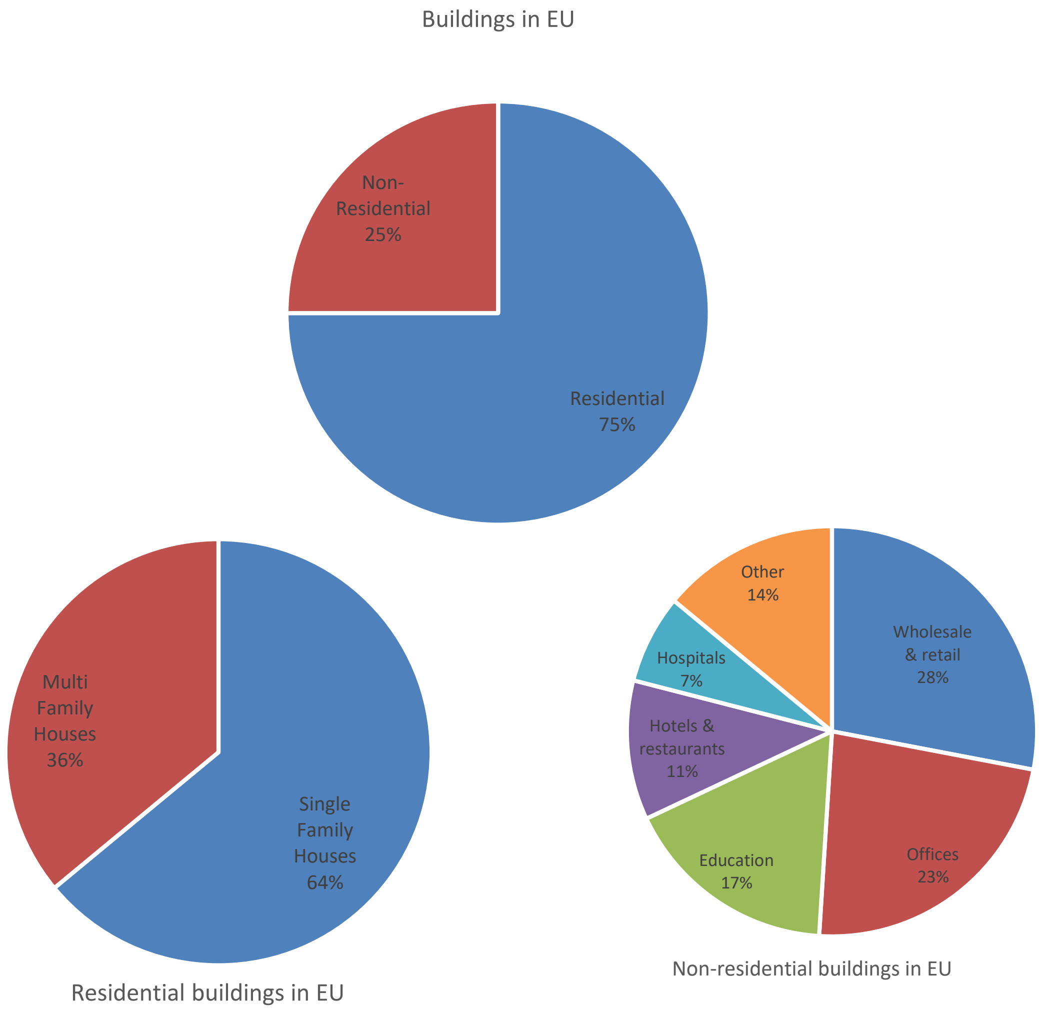


Figure 89 – Distribution of EU building stock among building types [source: EU Building Stock Observatory]

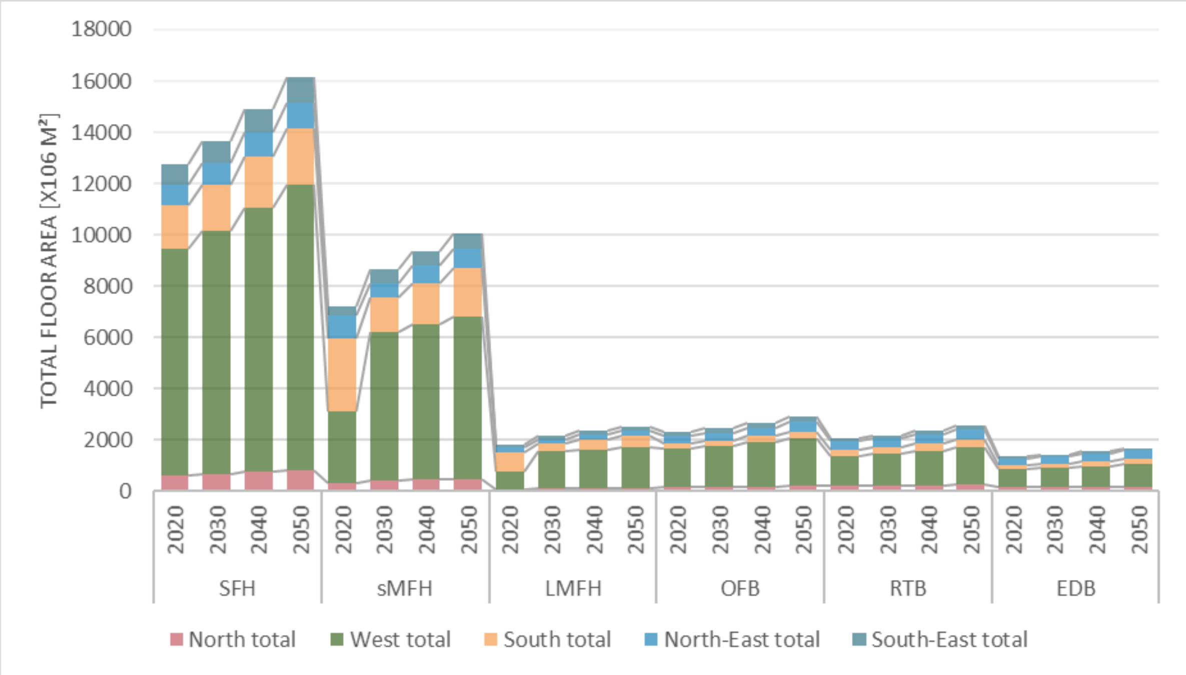


Figure 90 – Disaggregation of building stock across building type and climate region

Construction periods

Four construction periods are defined, corresponding to the breakdown used in the EU Building Stock Observatory:

- pre-1960
- 1960–1990
- 1990–2010
- post-2010.

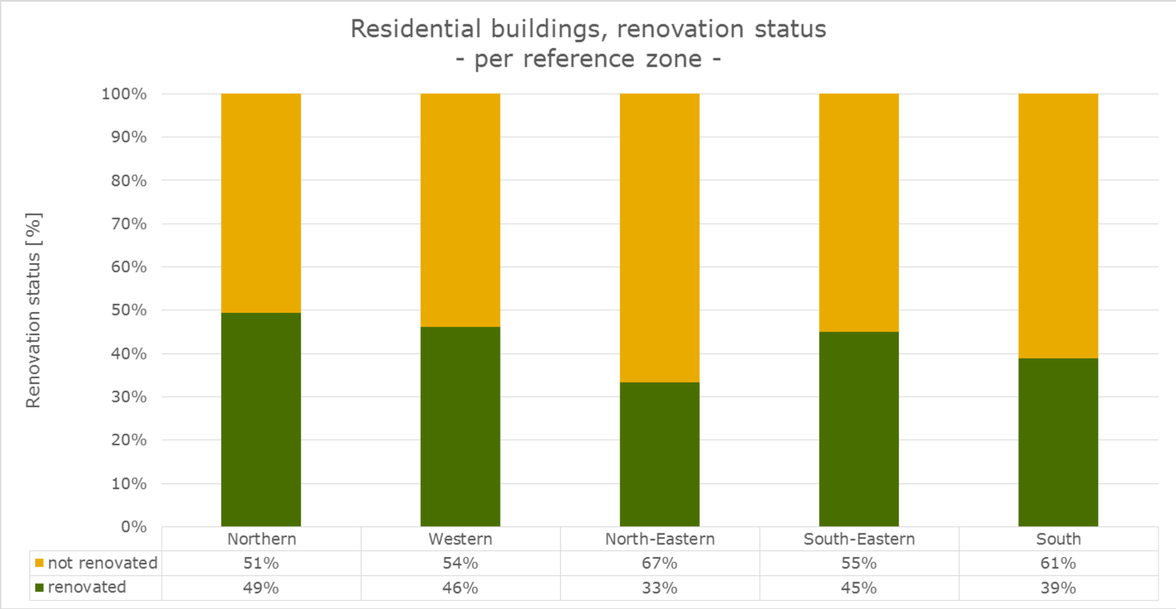
Renovation levels

The stock is further disaggregated into two sub-groups:

- renovated
- unrenovated.

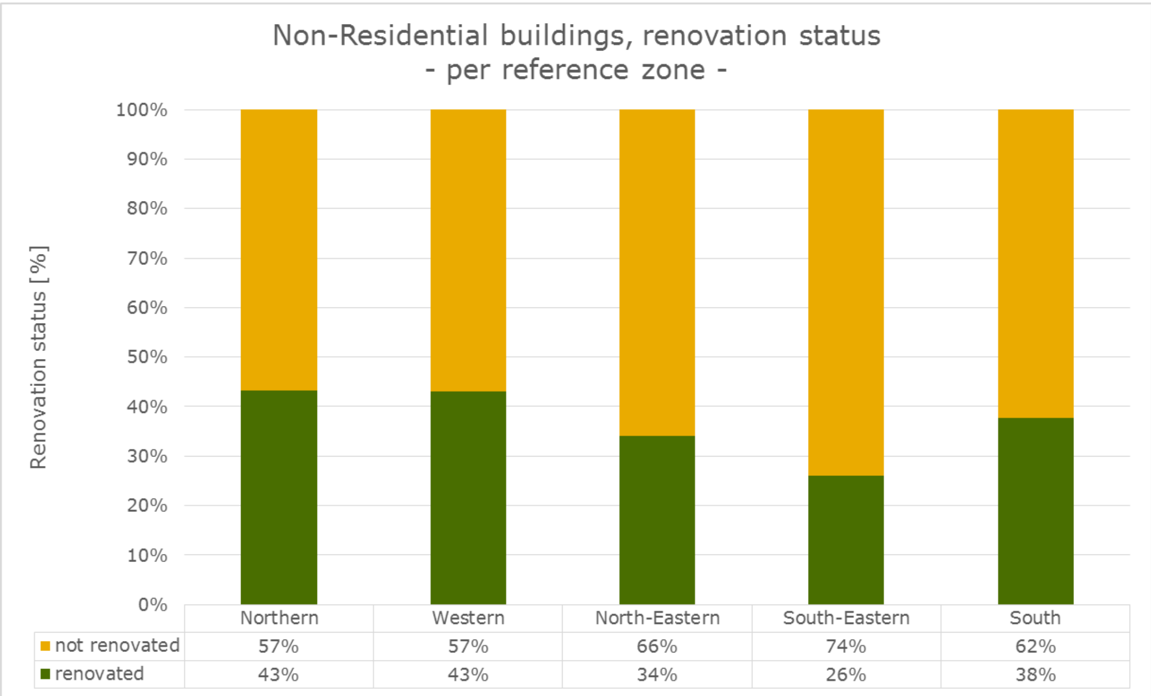
This disaggregation enables the establishment of two levels of thermal characteristics for each segment being considered. In the scenario calculation for both residential and non-residential buildings and for each climate zones, one retrofit level (major renovation) is used. The fact that not every renovation is a major renovation will be considered in the full thermal retrofit rates assumed for each specific scenario. The thermal qualities assumed for both residential and non-residential buildings in the renovated and unrenovated cases are defined in section ii.

Figure 91 shows the share of retrofitted residential buildings per reference zone. Figure 92 shows the share of retrofitted non-residential buildings per reference zone.



	Northern	Western	North-Eastern	South-Eastern	South
not renovated	51%	54%	67%	55%	61%
renovated	49%	46%	33%	45%	39%

Figure 91 – Share of retrofitted residential buildings. Source: First technical study on the SRI based on [ECOFYS, 2012], based on [Euroconstruct, 2005] with further updates and assumptions for 2005–13.



	Northern	Western	North-Eastern	South-Eastern	South
not renovated	57%	57%	66%	74%	62%
renovated	43%	43%	34%	26%	38%

Figure 92 – Share of retrofitted non-residential buildings. Source: First technical study on the SRI for 2014 based on [Euroconstruct, 2005].

b. Selection of reference buildings

Considering both the relative share of the buildings stock and an ex ante identification of buildings that are likely to be targeted by different implementation pathways, a set of reference buildings is selected and identified as:

- single-family house (SFH)
- small multi-family house (SMFH)
- large multi-family house (LMFH)
- office buildings (OFB)
- wholesale and retail buildings (RTB)
- educational buildings (EDB).

i. Geometry

The geometry parameters for the chosen reference buildings are shown in Table 35. As for the first technical study on the SRI, the residential building geometries are obtained from the iNSPiRe study (2014)[164]. The reference buildings for non-residential buildings are defined along the Annex I.5 of the EPBD[165]. The geometries are based on data from the European Copper Institute (ECI) for the study "*Panorama of the European Non-Residential Construction Sector*"[166].

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[164] http://inspirefp7.eu/about-inspire/

[165] Hospitals are listed under health buildings and hotels and restaurants under touristic buildings. Sport facilities are addressed with other non-res buildings.

[166] http://www.leonardo-energy.org/resources/506

Table 35 – Geometry parameters for the selected reference buildings. Source: iNSPiRe, 2014.

Parameter	SFH	SMFH	LMFH	OFB	RTB	EDB
Total floor area (m²)	96	500	2340	1801	1448	2552
A/V ratio (1/m)	0.90	0.50	0.30	0.25	0.36	0.45
Average room height (m)	2.5	2.5	2.5	2.6	3.6	2.6
Exterior building volume (m³)	281	1672	7484	4683	5214	6556
Exterior walls (m²)	128	513	699	277	302	318
Windows (m²)	26	128	699	150	130	106
Cellar ceiling (m²)	52	124	462	360	724	1216
Roof/upper ceiling (m²)	52	124	462	360	724	1216

ii. Building physical and HVAC system characteristics

Building physical and HVAC system characteristics of the EU28 building stock will be analysed in a simplified manner starting with the five climate zones, each represented by one country if data availability allows it. If not, EU-28 averages are used. Wherever possible, building type and/or age-band-specific values are used for the parameters serving as an input to calculate serial steady-state (monthly) energy balances. This calculation is executed for the building stock in its original state and for the renovated building stock.

Thermal transmittance coefficients (U-values)

Average thermal transmittance values for existing ("original") buildings are taken from the EU Building Stock Observatory database for residential and non-residential buildings per type of envelope construction part (walls, floors, roofs, windows) and for different age-band categories.

For renovated buildings, U-values for walls, roofs and floors of residential and non-residential buildings are taken equal to these cost-optimal levels. Annex 2 of the Ecofys study executed for Eurima in 2007[167] contains results for optimal U-values for cost-efficiency purposes. These U-values have been compared with the World Energy Outlook 2006 reference price scenario of cost-optimal U-values.

[167] U-values for better energy performance of buildings - Thomas Boermans and Carsten Petersdorff, Report established by ECOFYS for EURIMA, 2007: https://www.eurima.org/uploads/F_EURIMA-ECOFYS_VII_report_p1-65.pdf

U-values for walls, roofs and floors are presented in Table 36 for the capital cities of Germany, Sweden, Italy, Poland and Romania. These are considered to be representative for the Western, Northern, Southern, North-Eastern and South-Eastern Europe regions of the EU-28 countries.

Table 36 – U-values (W/m²K) for reference buildings after retrofit

Region	U_{wall}	U_{roof}	U_{floor}	U_{win}*
Northern Europe	0.20	0.16	0.26	1.1
Western Europe	0.20	0.16	0.24	1.1
Southern Europe	0.32	0.25	0.84	1.2
North-Eastern Europe	0.21	0.19	0.26	1.1
South-Eastern Europe	0.23	0.20	0.33	1.1

*derived from retrofit packages (as a function of wall U-values)

No cost-optimal U-values are reported for windows in the Eurima study. Therefore, the U-values for renovated building windows used in the current study are derived from the retrofit packages implemented in the Eurima study and are modelled as a function of the U-value of the wall of the corresponding retrofit packages. It can be expected that similar wall to window insulation ratios are implemented. The resulting U-values of the windows are included in Table 7.

Window heat-transfer properties: solar transmittance

A simplified model is constructed to calculate the g-value of a window based on its U-value. It is based on glazing characteristics[168] and a simplified model to calculate the U-value of the window based on U-values of glazing and frame. Typical combinations of glazing and frames are considered to estimate input for frame characteristics.

Table 37 gives an overview of the assumptions and description of the model. For cooling-load calculations, a shading factor of 0.5 is assumed independent of the building type.

Table 37 – Solar transmittance data as a function of window U-value

Simplified model		Assumptions							
		glazing			frame		window		
U_w [W/(m².K)]	g-value [-]	description	U_g [W/(m².K)]	g-value [-]	description	U_f [W/(m².K)]	fg [-]	Psi [W/m.K]	U_w [W/(m².K)]
$U_w \le 1{,}5$	0,50	triple glazing with coating	0,7	0,5	wood thickness ≥150mm	1,3	0,7	0,11	1,21
$1{,}5 < U_w \le 2{,}0$	0,65	double glazing HR ≥2000	1,4	0,65	wood thickness ≥100mm	1,7	0,7	0,11	1,82
$2{,}0 < U_w \le 2{,}5$	0,70	double glazing HR <2000	2	0,69	wood thickness ≥100mm	1,7	0,8	0,06	2,12
$2{,}5 < U_w \le 4{,}0$	0,77	double glazing	2,9	0,77	wood	2,2	0,8	0,06	2,94
$U_w > 4{,}0$	0,85	single glazing	5,8	0,85	wood	2,2	0,8	0	5,08

[168] http://www.vgi-fiv.be/wp-content/uploads/2015/07/Een-glasheldere-kijk-op-de-Belgische-beglazingen-Juni-2015-LowRes.pdf (dutch)

Heating system efficiency (space heating and domestic hot water)

Heating system efficiency is the factor used to translate net energy demand to end energy consumption; it is the ratio of the net energy demand to the total energy required at the building location to meet the net energy demand in magnitude, temperature level and at the time it is needed. It comprises the combined efficiencies of the production, storage (if any), distribution, emission (only in case of space heating) and control systems.

Kemna et al. reported values for system efficiency for residential and service sector[169]. The average value (weighted by the heat output for each heating technology type) is low compared to, for example, the default efficiencies for space heating that are used in EPCs in Flanders (for residential and small, non-residential buildings)[170]. The latter values for system efficiency are supposed to be conservative in the sense that most systems in practice will reach higher efficiencies. These are not representative for large non-residential buildings. Also, when comparing the Kemna efficiency values with the values reported in the frame of the Stratego project as function of energy source[171], the Kemna values are relatively low. On the one hand this is illogical given the fact that the Kemna values are for space heating alone while the Stratego values are for combined space heating and domestic hot water, as it is expected that efficiency would be lower for domestic hot water (usually at a higher temperature on average, intermittent production and or storage, possible circulation loop for distribution). On the other hand, the Stratego values only represent production efficiencies, implying that these need to be decreased by taking the storage, distribution, emission and control losses into account.

The average system efficiency value of 0.55 derived from the Kemna et al. report is retained for the current analysis for space heating and domestic hot water for residential and non-residential buildings in the original state of the building stock. For renovated buildings, an average system efficiency of 0.82 is retained.

Ventilation

VHK reports average effective ventilation rates for residential and non-residential buildings of 0.68 and 1.15 ACH, respectively [Kemna et al.; 2019]. The value reported effective ventilation rate (ACH) also includes infiltration. These values also take heat recovery into account assuming on average 7% of residential and non-residential buildings are equipped with heat recovery systems. Calculated at an average efficiency of the heat recovery of 60%, the average recovery efficiency on building stock level becomes 5%. The ventilation rates become 0.72 ACH and 1.21 ACH for residential and non-residential buildings on average.

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[169] Kemna, R.; 2014; Average EU building heat load for HVAC equipment - Final report contract No. ENER/C3/412-2010/15/FV2014-558/SI2,680138; VHK; Delft; August, 2014;

[170] VEA; 2019; EPB-Cijferrapport 2019 - Procedures, resultaten en energetische karakteristieken van het Vlaamse gebouwenbestand - periode 2006 – 2018. [in Dutch]; Vlaams Energieagentschap (VEA); Brussel, België; april 2019

[171] https://ec.europa.eu/energy/intelligent/projects/en/projects/stratego

Table 38 – Effective ventilation rates and heat recovery factors for the different reference buildings and renovation levels

Renovation level	Parameter	SFH	SMFH	LMFH	OFB	TRB	EDB
Original	η_{vent} (%)	5	5	5	5	5	5
	$n_{vent\&inf}$ (ACH)	0.72	0.72	0.72	1.21	1.21	1.21
Renovated	η_{vent} (%)	25	25	25	25	25	25
	$n_{vent\&inf}$ (ACH)	0.68	0.60	0.56	1.04	1.56	1.04

Energy use by ventilation systems is assumed to be 0 W/(m^3/h) for the original residential buildings built pre-1990 as ventilation in these building types is assumed to result primarily from infiltration and natural ventilation. From 1990 onwards and for renovated buildings, a mix of exhaust ventilation (Type C) and balanced supply and exhaust systems (Type D) is assumed, with 33% of buildings implementing type D and 67% type C. Type D is used for non-residential buildings. The specific energy use of both ventilation types is given in Table 39.

Table 39 – Specific energy use by ventilation systems

	System D	System C
Ventilation electricity use [W/(m3/h)]	0.28	0.07

ANNEX D. SRI AND SRT UPTAKE MODEL

As a first building block for the impact analysis tool, the "SRI and SRT uptake model" quantifies the number of SRI assessments carried out for the different building types and climate regions. This assessment rate is evidently a function of the implementation pathways. In a second step, the effect of the SRI implementation pathway on SRT uptake is modelled based on volume of SRI assessments, as well as market push and pull effects. This section explains in detail the methodology behind the modelling, allowing readers to also assess the impact of certain implementation options and the sensitivity to the underlying assumptions.

In the modelling, differentiation is made between building types and climate zones. This also allows the evaluation of different implementation pathways for different types of buildings as well as for different Member States. The methodology is, however, uniform for all building types and climate zones.

a. Modelling the evolution of SRI assessments

i. Methodology

The starting point for the impact analysis is the quantification of the number of SRI assessments being conducted in relation to a specific implementation pathway. This number of assessments in the next step will feed into the SRT uptake model, which in turn is the starting point for calculating, amongst others, the energy savings corresponding the potential SRI implementation pathways.

Evidently, the number of SRI assessments carried out depends primarily on the implementation pathways adopted by the Member States. To make the calculation flexible and transparent regarding the assumptions and impacts proposed for the different implementation pathways, it was decided to build the calculation around the foreseeable trigger events that could lead to SRI assessments. The calculation includes the following trigger events for which annual occurrence rates have been assessed:

- EPC assessments
- replacement of technical building systems (e.g. boiler replacement)
- major renovation
- new constructions
- installation of local RES (e.g. PV)
- purchase of an EV
- smart meter installation
- inspection of HVAC (according to Art. 14 and 15 of the EPBD)
- other (e.g. link to other voluntary schemes, such as BREEAM).

For each of these trigger events a rate is defined by which each trigger results in an SRI assessment. There rates are modelled depending on the implementation pathways and policy options. For example, if the implementation pathway would adopt a mandatory SRI assessment linked to each EPC assessment, the rate of SRI assessments would be 100% for the trigger event EPC assessment, see Table 40.

Table 40 – Example of triggers and rate of action for single-family houses in Northern Europe for implementation pathway A1

Triggers for SRI assessment	Annual rate of trigger events	rate of SRI's granted during trigger event
- EPC assessment	0.95%	100.00%
- Replacement of technical building systems	4.91%	0.08%
- Major renovations	0.79%	0.00%
- new construction	0.98%	0.00%
- Installation of local RES (e.g. PV)	0.05%	0.08%
- Buying an EV	1.42%	0.16%
- Smart meter deployment	0.93%	0.08%
- HVAC inspections	0.00%	0.08%
- Other	0.00%	0.00%

When a certain implementation pathway would foresee a voluntary assessment of the SRI, e.g. when a smart meter is installed, then it could be expected that the rate at which the trigger "Smart meter deployment" results in an SRI assessment would increase as the SRI scheme grows more mature. Such an increase may result from a market pull effect, i.e. the end-user interest in the SRI increases as the SRI deployment rate increases, or a market push effect, i.e. as the SRI deployment rate increase manufacturers and installers may start promoting or advising SRI assessments. To reflect these growth effects, it is possible to include the foreseeable increase in the rate of SRI assessments that follow from each trigger event due to market push and pull effects. For example, for an implementation pathway that foresees a voluntary SRI assessment for major renovations, more building owners can be expected to carry out an assessment as the market penetration of the SRI increases. These push and pull effects are modelled using a typical S-shape growth model as a function of the deployment rate of the SRI. The deployment rate is defined as the percentage of buildings of that specific type and climate region that have already undergone an SRI assessment. Figure 93 shows a theoretical example of the push and pull effect size. This effect size is a percentage point increase in the rate of SRIs granted during the trigger event.

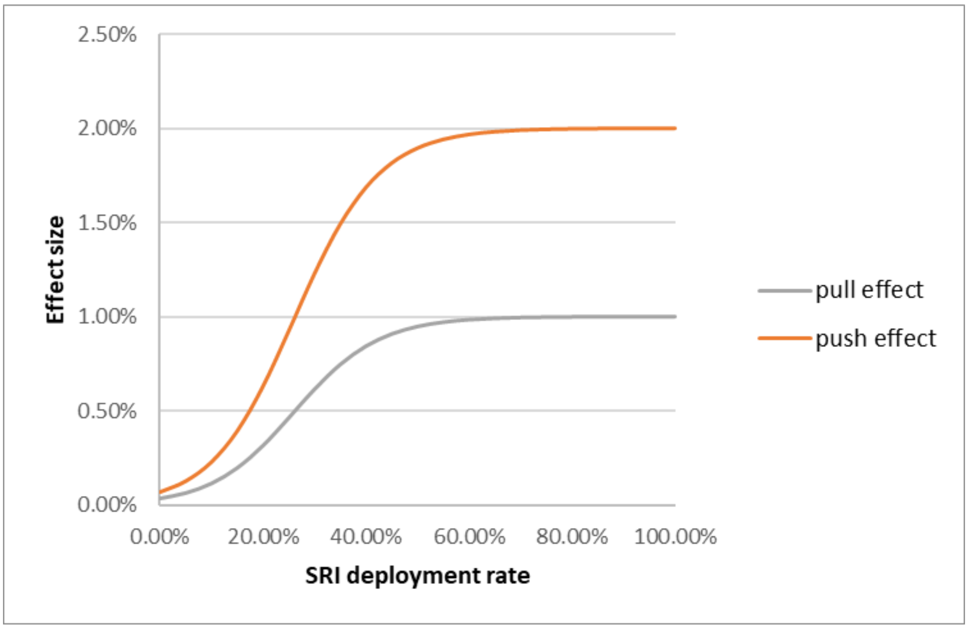

Figure 93 – Example of market push and pull effect on SRI assessment

In summary, for a certain implementation pathway (ipw), the annual number of SRI assessments obtained as the sum over all triggers (tr) is given by:

$$SRI_{ipw} = \sum_{tr} SRI_{ipw,tr}$$
$$SRI_{tr,ipw} = n_{tr}(\alpha_{tr,ipw} + \beta_{tr,ipw} + \gamma_{tr,ipw})$$
$$\beta_{tr,ipw} \sim SRI_{depl}, \beta_{tr,ipw,max}$$
$$\gamma_{tr,ipw} \sim SRI_{depl}, \gamma_{tr,ipw,max}$$

where:

- n_{tr} = the number of trigger events (e.g. number of EPC assessments for that building type in that climate region)
- $\alpha_{tr,ipw}$ = the base rate of SRI assessments linked to the trigger
- $\beta_{tr,ipw}$ = the market push effect as a function of the SRI deployment rate (SRI_{depl}) and the maximum effect size $\beta_{tr,ipw,max}$, and
- $\gamma_{tr,ipw}$ = the market pull effect as a function of the SRI deployment rate (SRI_{depl}) and the maximum effect size $\gamma_{tr,ipw,max}$.

ii. Definition of trigger events

In order to estimate the deployment rate of SRI assessments, the methodology has identified different moments during a building's construction and use phase as potential trigger events for an SRI assessment. As such, the estimation of the total number of SRI assessments for a given implementation pathway is broken down into a quantification of the occurrences of these trigger events and the rate of SRI assessments that follow from a trigger event. The rate of trigger event that lead to an SRI assessment can be directly linked to the actual implementation pathway, as discussed in section iii. On the contrary, the frequency of trigger events can be estimated based on the analysis of available building stock data. The following paragraphs describe this process for the selected trigger events.

EPC assessments

As one of the implementation pathways suggests a possible linkage of the SRI to EPC assessments, the first trigger event is the number of EPCs carried out annually for a given building type and climate region.

Data on the annual and total number of EPCs granted at Member State level are available in the EU Building Stock Observatory[172]. As these data are only partially available at Member State level and not with the detailed granularity of building types used in this impact analysis, the data have been extrapolated to obtain input values for each building type and climate region. More specifically, the number of residential and non-residential EPCs per climate region has been estimated by calculating the average assessment rate (number of EPCs issued per total number of buildings in that category) based on the Member States within a climate region for which data are available. This average rate is then applied to all Member States within that climate region. At the climate region level, the number of residential EPCs issued is then distributed over the sub-types (single-family houses, small multi-family buildings, large multi-family buildings) according to the relative number of buildings within each subtype. This same approach is followed for non-residential buildings.

In addition to the extrapolation of the number of EPC assessments reported in the EU Building Stock Observatory, it was assumed that by 2030 all member states would have implemented a mandatory EPC assessment for new-built and major renovation for all building types. As such, the number of EPC assessments is from 2030 onwards at minimum equal to that of new buildings and major renovations. Also, the number of EPC assessments per building type and climate region is limited to at most 15% per year, reflecting that as most member states adopt a validity of 10 years, buildings would at most have an EPC assessment every 7 years[173].

Replacement or upgrade of TBSs

The replacement of TBSs can also be expected to be an opportunity to initiate an SRI assessment. The trigger for an SRI assessment is thereby expected to link to replacement of larger components of the HVAC system, such as boiler replacement or upgrading the ventilation system, rather than maintenance-related replacement of small components, e.g. valves. Taking into account a practical average life expectancy of those components of 20 years, the number of TBS replacement trigger events is calculated by assuming that all buildings shall undergo a replacement at least once every 20 years and distributing

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[172] https://ec.europa.eu/energy/en/eu-buildings-database

[173] Note, annual EPC issuance rates of up to 48% of the building stock as a function of the building type and Member State have been reported in the building stock observatory so this limit of a maximum rate of 15% (and much less on average) is a significant conservatism

these occurrences uniformly over time. Again, this assumption is conservative as the major TBSs of heating, hot water, lighting, ventilation and air conditioning will each be replaced (on average) once every 20 years or less, and theoretically each is an opportunity to conduct an SRI assessment; however, it is assumed that in practice for the pathways E1, E2 and E3 that Member States will only task the major TBS replacements with also conducting an SRI and that only one or possibly two types of TBS would be taken into account.

Major building renovations and new constructions

To calculate the number of major renovations and new constructions, fixed renovation and construction rates are based on the first technical study. For residential buildings, the major renovation and new construction rates are 0.8% and 1%, respectively; for non-residential buildings rates of 1% and 0.9%, respectively, are assumed. Again, these values are in line with the historical levels and more conservative projections.

Installation of local RESs

Given that renewable energy generation is one of the services evaluated in the SRI, the installation of RESs can be expected to be a potential trigger for SRI assessment. To estimate the number of trigger events, data on the annual capacity installed and connected to the grid obtained from the EurObserv'ER database[174] are combined with the EU28 installed PV capacity from Eurostat[175].

The Eurostat data show that within the EU28, 21% of PV capacity stems from small installations of less than 20 kWp, 44% stems from medium-size installations with a peak capacity of 20 kWp to 1MWp, and 35% results from large installations of more than 1 MWp.

In the next step, the average distribution in plant size is used to calculate the annually installed capacity of plants with a peak power <20 kW and those with a peak power of 20 kW to 1 MW for each country. The total capacity per country is thereby given by the EurObserv'ER data.

In the final step, the installed capacity of small- and medium-size PV systems for each country is distributed over the different building types. It is assumed that all installations smaller than 20 kWp are installed at residential building premises, with an average plant size of 10 kWp. The majority (75%) of the medium-size systems are assumed to be located in non-residential building premises, with an average plant size of 250 kWp. The resulting number of residential and non-residential systems are then distributed among the building types according to their share of the total number of residential and non-residential buildings, respectively.

Purchase of EVs

Charging facilities for EVs is one of the domains evaluated by the SRI. Hence, the purchase of an EV is also a likely trigger event. In the current iteration, vehicle purchase volumes have been implemented per Member State according to data obtained from ACEA[176]. Further data sources such as the European alternative fuel observatory will be incorporated in future iterations of the model. The number of EVs has been estimated following the 15% ambition level of ZLEV for 2025. For the impact analysis it is assumed that the purchase

[174] https://www.eurobserv-er.org/online-database/

[175] https://ec.europa.eu/eurostat/data/database

[176] https://ec.europa.eu/transport/modes/road/news/2017-11-08-driving-clean-mobility_en

of an EV would only be a trigger event for residential buildings. The total number of EV purchases is hence distributed over the residential building types according to the relative share of the building type in the total number of residential buildings.

Smart meter installations

In the report drafted by DG ENER and JRC titled "Benchmarking smart metering deployment in the EU-27 with a focus on electricity"[177], the progress in the deployment of smart metering in the EU Member based on information on received Member States' deployment plan.

To date, Member States have committed to rolling out close to 200 million smart meters for electricity and 45 million for gas by 2020 at a total potential investment of €45 billion. By 2020, it is expected that almost 72% of European consumers will have a smart meter for electricity while 40% will have one for gas.

As prescribed in the EU directive 2019/944 "common rules for the internal market for electricity", issued in June 2019 and amending Directive 2012/27/EU, all consumers should be able to benefit from directly participating in the market, in particular by adjusting their consumption according to market signals. They should therefore have the possibility of benefiting from the full deployment of smart metering systems and, where such deployment has been negatively assessed, of choosing to have a smart metering system and a dynamic electricity price contract. Article 19 of that directive includes that Member States shall ensure the deployment in their territories of smart metering systems. Such deployment may be subject to a cost-benefit assessment which shall be undertaken in accordance with the principles laid down in Annex II of the directive. Where the deployment of smart metering systems is assessed positively, at least 80 % of final customers shall be equipped with smart meters either within seven years of the date of the positive assessment or by 2024 for those Member States that have initiated the systematic deployment of smart metering systems before 4 July 2019. In the case of a negative cost-benefit assessment Member States shall ensure that this assessment is revised at least every four years. Also, in the case of a negative assessments, consumers are still entitled to a smart meter upon request.

Finally, Article 19(6) states that "Smart metering systems that have already been installed, or for which the 'start of works' began, before 4 July 2019, may remain in operation over their lifetime but, in the case of smart metering systems that do not meet the requirements of Article 20 and Annex II, shall not remain in operation after 5 July 2031."

Acknowledging that smart grids will become increasingly profitable in future energy systems that rely heavily on renewable energy sources, it can be expected that following the directive EU 2019/944 more than 95% of buildings will be connected by smart metering systems by 2050. Based on the data presented in the DG ENER and JRC report and taking into account a lifetime of 25 years for the smart meter, annually 1% of buildings are estimated to install a smart meter. Given the current state of deployment across the EU, the smart meter implementation rates that may lead to a trigger event for an SRI assessment varies significantly among Member States. This spread is not considered in the current implementation of the model. Also, in view of the lack of data for the non-residential sector, the same implementation rate is assumed as a working hypothesis.

Mandatory building inspections

Articles 14 and 15 of the EPBD require mandatory regular inspections for heating and ventilation/cooling systems in buildings if the installed capacity is greater than 70 kW. The

[177] https://ses.jrc.ec.europa.eu/smart-metering-deployment-european-union

analysis of building types and thermal building systems show that 80% of the large multi-family houses (LMFHs) have systems >70 kW in place. Since 31% of all residential floor area is covered by LMFHs, systems >70 kW are installed for a total of 25% of residential buildings floor area. Furthermore, 30% of the non-residential buildings have systems with a capacity greater than 70 kW in place, which translates to 55% of the total non-residential floor area. It is assumed that this corresponds to 40% of all offices, 40% of all wholesale and retail buildings, and 70% of all schools.

iii. SRI assessments for the trigger events as a function of the implementation pathways

As outlined in section i, the actual number of SRI assessments for each of the trigger events is determined by the base rate at which SRI assessments are actually conducted when a trigger event occurs, as well as by the market push and pull effects that represent the increase in interest in SRI assessments as the deployment of the SRI increases. All three effects are closely linked to the supposed implementation pathway as outlined in section 4.2.

To model the impact of implementation pathways, three different options are implemented regarding the rate at which SRI assessments are conducted for each trigger event. When a certain pathway prescribes a mandatory SRI assessment for a certain trigger, the rate is evidently set to 100%. This would be the case when, for example, there is a mandatory link to EPC assessments. In that case, the rate for the trigger "EPC assessment" is set at 100%.

Alternatively, if an SRI assessment is linked to a trigger event on a voluntary basis, without any subsidised incentive mechanism, the default rate is set to 0.1%. An intermediate option is implemented when links to trigger events are on a voluntary basis but supporting incentive mechanisms are installed. In those cases, the default rate is set to 40%. For both voluntary scenarios, there may be exceptions implemented for these default values based on expert judgement and in order to increase the differentiation among the different implementation pathways.

Table 41 gives an overview of the rates at which SRI assessments follow each of the trigger events for the different implementation pathways (as outlined in section 4.2) as proposed for the impact analysis. The structure of the calculation tool allows users to rapidly adapt these scenario parameters based on specific contexts. These default values will be further subjected to a sensitivity analysis in Task 4 Activity 4. Note, these values are provisional estimates derived by the study team from assessment of relevant information in publicly available literature; however, there is uncertainty with regard to many of these values.

Table 41 – Default rates (%) of SRI assessments following trigger events

Triggers for SRI assessment	A1	A2	A3	B	C	D	E1	E2	E3	F1	F2	F3
EPC assessment	100	5.0	40.0	0.5	0.5	20.0	0.5	0.5	0.5	0.5	0.5	0.5
Replacement of TBSs	0.1	0.1	0.1	0.1	0.1	10.0	100	0.5	19.9	0.1	0.1	0.1
Major renovations	0	0	0	100	1.5	20.0	100	1.5	41.0	1.5	1.5	1.5
New construction	0	0	0	100	1.5	20.0	100	1.5	41.0	1.5	1.5	1.5
Installation of local RES (e.g. PV)	0.1	0.1	0.1	0.1	0.1	10.0	0.1	0.1	0.1	0.1	0.1	0.1
Buying an EV	0.2	0.2	0.2	0.2	0.2	5.0	0.2	0.2	0.2	0.2	0.2	0.2
Smart meter deployment	0.1	0.1	0.1	0.1	0.1	10.0	0.1	0.1	0.1	100	0.5	40.0
HVAC inspections	0.1	0.1	0.1	0.1	0.1	0.1	100	0.5	19.9	0.1	0.1	0.1
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

In addition to the base rates, the market push and pull effects are important model parameters. As for the base rates, the maximum effect sizes are function of the implementation pathway. When an implementation pathway prescribes a mandatory linkage to a certain trigger event, market push and pull effects are set to 0% for that trigger, as the base rate is already 100%. In cases of voluntary linkage to the trigger events, the parameters are set to 1% and 2% for the non-subsidised and subsidised scenarios, respectively. As for the base rates, these values will be subjected further to a sensitivity analysis. Note, these values are derived by the study team based on expert judgement; however, they may subsequently be amended based on Member State and stakeholder review.

Table 42 – Default maximum effect sizes for the market push and pull effects on the SRI assessment rate

	Maximum pull effect	Maximum push effect
Subsidised voluntary assessment	2%	2%
Non-subsidised voluntary assessment	1%	1%

Mandatory assessment	0%	0%

b. Modelling the uptake of SRT

After modelling the number of SRI assessments carried out, this section discusses at what rate an SRI assessment will lead to upgrades of the smart readiness level of a building. To limit the model complexity, the model distinguishes two types of SRT upgrades: a gradual upgrade for which the smartness level increases by one class at a time; and a major upgrade for which the smartness level is increased to level A in one upgrade.

To set the parameter values for the SRT uptake rates, the model distinguishes three driving forces for an SRT upgrade. First, there is the business-as-usual SRT uptake, estimated by the current uptake of SRT in the market. Based on projections in the "Digital Transformation Monitor – Smart Building: energy efficiency application"[178], the smart building market is expected to grow 15% between 2015 and 2025. Assuming this growth is independent of the SRI deployment, an annual upgrade rate of 1.2% is implemented for buildings upgrading by one class and 0.02% for buildings upgrading to the highest level of smartness. A second driving factor evidently reflects the impact of the SRI. It is defined as the rate of the buildings that undergo an SRI assessment and will carry out SRT improvements as a result of that SRI assessment. The percentage of buildings undergoing an SRT upgrade due to the SRI evidently depends on the potential supporting mechanisms that are tied to the implementation pathway; default rates have been used as shown in Table 43. Note, these default rates constitute approximately a 1/3rd of the market transformation impact levels observed from the introduction of energy labelling for domestic appliances. This is intentionally conservative but also reflects that procurement decisions for SRTs are more complex than for appliances and hence the impact of the provision of information via the SRI on any specific SRT procurement decision are likely to be diluted compared to the impact of the energy label on an appliance procurement decision.

Finally, the impact of market push and pull effects on the SRT upgrade are modelled. An S-shaped growth function is used for which the maximum effect size is the main input parameter. As a driving force for the push and pull effect (horizontal axis in Figure 94), the total percentage of buildings in classes A and B have been used as the driving factor for market push and pull effects. In other words, the uptake of smart technologies will increase with the number of buildings with a high SRI score.

178 https://ec.europa.eu/growth/tools-databases/dem/monitor/content/smart-building-%0Benergy-efficiency-application

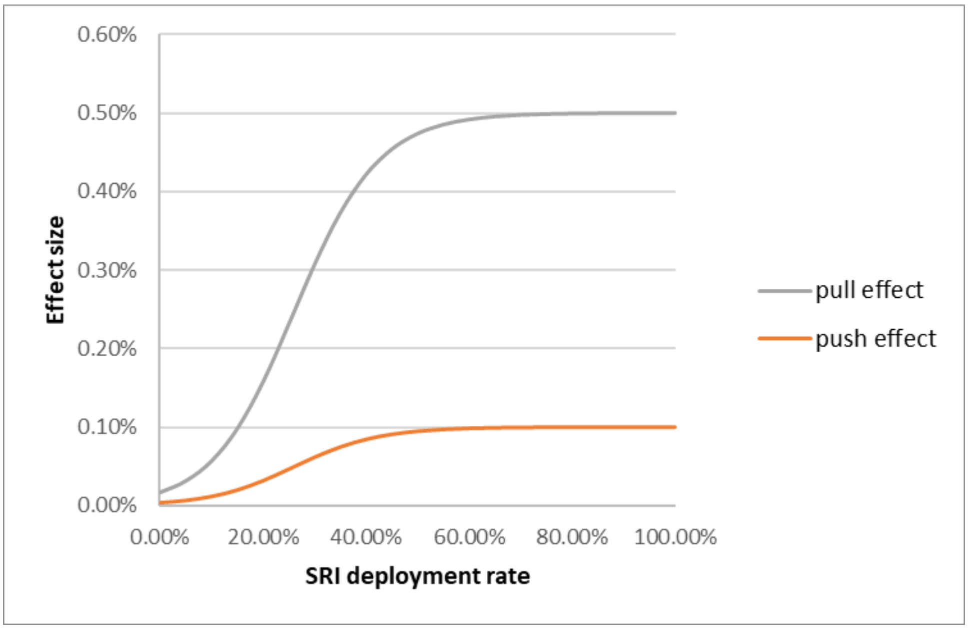

Figure 94 – Example market push and pull effect on SRT uptake

In summary, for a certain implementation pathway (ipw), the SRT growth rate, i.e. the percentage of buildings moving up one level (subscript $+1$) or to level A SRT configurations (subscript $X \rightarrow A$), is given by:

$$SRT_{ipw,+1} = \delta_{+1} + \omega_{+1} SRI_{ipw} + \beta_{+1} + \gamma_{+1}$$
$$SRT_{ipw,X\rightarrow A} = \delta_{X\rightarrow A} + \omega_{X\rightarrow A} SRI_{ipw} + \beta_{X\rightarrow A} + \gamma_{X\rightarrow A}$$
$$\beta \sim SRT_A + SRT_B, \beta_{max}$$
$$\gamma \sim SRT_A + SRT_B, \gamma_{max}$$

where:

- δ = the business-as-usual SRT uptake rate
- ω = the share of buildings undergoing an SRI assessment (SRI_{ipw}) and an SRT upgrade due to the SRI, and
- β and γ = the market push and pull effects, respectively.

Table 43 – Default parameters for SRT uptake linked to SRI assessments

Parameter	SRT uptake prognosis Increase by 1 class	Increase to level A
BAU SRT growth	1.2%	0.02%
SRT upgrade after SRI assessment	15.0%	3.0%
Maximum SRT upgrade push effect	0.5%	0.1%

Maximum SRT upgrade market push effect	0.5%	0.1%

The SRT uptake rates linked to an SRI assessment tabulated in Table 43 reflect the uptake rates linked to an SRI assessment following the *detailed, expert-assessment* methodology. As an alternative to the detailed assessment a simplified methodology has also been proposed as part of the technical study, moreover an optional self-assessment implementation has been proposed as an alternative to a 3rd party expert assessment. In general, it is expected that self-assessment will be less reliable than 3rd party expert assessment and hence the impacts triggered by an SRI assessment will be somewhat diluted. Similarly, as the simplified method assesses less SRT domains and functionality than the detailed method it is also expected that some prospective improvement options will not be acted upon as a result of the information it provides. Therefore, correction factors are introduced take this into account, see

Table 44. These are derived from the expert judgement of the study team informed by the experience from the testing phase of the SRI combined with a review of the loss of informational content from application of the simplified method.

Table 44– Default factors to express the influence of the assessment method and assessment methodology on the push and pull effects

Information: Implementation Pathways		Assessment factor	Method factor
A. Linkage of the SRI to the EPC (potentially in a mandatory way) so an assessment would be offered each time an EPC is conducted			
Option A1	Linkage to EPC is mandatory	1	1
Option A2	Linkage to EPC is voluntary	0.82	0.88
Option A3	Linkage to EPC is voluntary but is subsidized	0.925	0.95
B. Linkage of the SRI to new buildings and major renovations so that each time a new build/or renovation is undertaken it would be a requirement		1	1
C. A market-based voluntary scheme where self-assessment is supported by on-line tools and 3rd party certified assessment is offered to those willing to pay for it		0.715	0.81
D. As option C. but with 3rd party assessments supported, or subsidised, by the state and/or utilities seeking to roll out flexibility, energy efficiency, electromobility and self-generation measures		0.925	0.95
E. Linkage to the BACS deployment trigger points in Articles 8, 14 & 15, 19 in the EPBD			
Option E1	Linkage is mandatory	1	1
Option E2	Linkage is voluntary	0.82	0.88
Option E3	Linkage is voluntary but subsidized	0.925	0.95
F. Linkage to smart meter deployment			
Option F1	Linkage is mandatory	1	1
Option F2	Linkage is voluntary	0.82	0.88
Option F3	Linkage is voluntary but subsidized	0.925	0.95

Based on the SRT uptake scenario, parameterised by a percentage of buildings undergoing a gradual (+1) or major ($X \rightarrow A$) SRT upgrade, the evolution of SRT configurations in the building stock is modelled. The starting point for this calculation is the initial distribution of classes of SRT configurations for each type of building.

Data for the distribution of SRTs by region and building type are derived from the following studies, amongst others:

- Building Automation: The Scope for Energy and CO_2 Savings in the EU: http://www.leonardo-energy.org/resources/249/building-automation-the-scope-forenergy-and-co2-savings-in--57f7a23e8b452

- Optimising the Energy Use of Technical Building Systems – Unleashing the power of the EPBD's Article 8: https://www.ecofys.com/files/files/ecofys-2017-optimising-theenergy-use-of-tbs-final-report.pdf
- Ecodesign Preparatory Study for Building Automation and Control Systems (BACS) Implementing the Ecodesign Working Plan 2016–2019 Ecodesign Scoping Study for BACS (http://www.ecodesignbacs.eu/)
- Short Study Energy Savings Digital Heating [in German]: https://www.bdhkoeln.de/fileadmin/user_upload/Publikationen/energieeinsparungen_digitale_heizung__2017_01_12.pdf

Table 45 shows the initial values for the SRT configurations as a function of building type and climate region.

Table 45 – Initial distribution of SRT configurations (%)

SRI range (%)	Western Europe				Northern Europe				Southern Europe			
	SFH/ SMFH	LMFH	OFB	RTB	SFH/ SMFH	LMFH	OFB	RTB	SFH/ SMFH	LMFH	OFB	RTB
I: 0–25	20	25	30	20	25	30	35	25	15	20	25	15
II: 25–50	70	60	55	40	70	60	55	45	80	70	65	55
III: 51–75	8	11	11	20	4	8	8	15	5	9	9	20
IV: 76–100	2	4	4	20	1	2	2	15	0	1	1	10

The annual change in buildings in each category moving up one class or moving all the way to class A is then explicitly modelled until 2050 given $SRT_{ipw,+1}$ and $SRT_{ipw,X\rightarrow A}$

c. Data sources for costs and benefits

This section gives an overview of the data sources that have been investigated so far for SRT costs and benefits. This list is still being worked on by the study team and all studies/data sources that were mentioned in the proposal are scanned and are available to the consortium. In addition, BACS Standard EN15232 is an important starting point for the energy savings related to the eight BACS dimensions.

Ecodesign Preparatory Study on Smart Appliances (Lot 33) MEErP Tasks 1–6, 2017

The final report of Ecodesign Preparatory Study on Smart Appliances (Lot 33) provides an analysis of the current situation and potential development of the smart appliances market from technical, economic and societal perspectives. The focus of this study is on smart appliances and the potential demand side flexibility they provide to the end user. The study uses a generic optimisation model to calculate the economic and environmental impact of smart appliances over three benchmark years –2014, 2020 and 2030 – for two scenarios: the business-as-usual (BAU) and 100% scenarios.

The data are available for theoretical monetary benefits of providing flexibility per smart appliance per year per scenario per year as well as on an aggregated level for the EU-28. The study considers and presents cost elements from the end-user perspective, such as the initial investment costs for the appliance and the recurrent operational costs, as well as the expected increase in the retail price of devices by adding a demand-response interface.

Preparatory Study on Lighting Systems (Lot 37), 2016

The Preparatory Study on Smart Appliances (Lot 37) final report provides information on the markets, users and technologies of lighting systems and an analysis of their development, including technical, economic and environmental aspects. The focus of this study is on indoor and road lighting systems. It presents and develops further the results of the Model for European Light Sources Analysis (MELISA) for calculating the economic and environmental impact of electricity consumption for lighting and lighting system improvements over two benchmark years – 2030 and 2050.

Data are available on specific capital expenditure for acquisition and installation of LED luminaires, optimising the design and addition of controls as well as a summary of EU-28 savings resulting from lighting system improvements, in terms of annual electricity savings, GHG emission reductions, annual energy cost savings and annual user expense savings per scenario.

Added value of smart energy management in low-energy homes of the future, 2016

The core aim of the SMART HOME project was to understand the potential role of smart energy management technologies in nZEB homes and to quantify related energy and energy cost savings. The study is based on modelling a sample home. The report estimates total energy consumption and annual energy costs under three scenarios reflecting different levels of use of energy management systems (EMSs): (i) no EMS; (ii) an EMS that integrates all energy management functions; and (iii) an EMS that also controls energy demand based on a variable electricity price.

Scope for energy and CO2 savings in the EU through the use of building automation technology, 2014

This report presents an analysis that examined the potential of building energy controls to accelerate energy savings. Data relate to estimated building automation technology (BAT)/building energy management systems (BEMS) sales by residential building and service sector building types in Europe, as well as the costs to procure, install and commission BAT and BEMS per building type and estimated average savings per building type and projected BAT penetration.

Scope for energy savings from energy management, 2016

This report outlines the potentials of EMSs with respect to energy savings and assesses the status of EMS technology in Europe. The data in this report include the theoretical potentials and typical actual energy, cost and emissions savings achievable via energy management. The analyses are then applied to derive holistic pan-EU savings potentials through the application of scenarios for the main energy end uses in the EU (service sector buildings and industry).

Chancen der Energetischen Inspektion für Gesetzgeber, Anlagenbetreiber und die Branche

This report provides data on energy cost savings resulting from the optimisation of systems and the installation of more efficient components for ventilation and cooling equipment.

Technische Optimierung und Energieeinsparung

This report presents data on final energy savings based on measured data before and after optimisation of heating systems per residential building type.

Based on the reports listed above, and following the assumptions made during the first technical study on the SRI, the investment costs for SRTs are implemented as shown in Table 46.

Table 46 – Investment costs (€/m²) for SRTs per building type and region

	Northern Europe		*Western, South-Eastern & North-Eastern Europe*		*Southern Europe*	
	Residential	Non-residential	Residential	Non-residential	Residential	Non-residential
D -> C	4.8	3.6	4.0	3.0	3.2	2.4
C -> B	6.6	18.0	5.5	15.0	4.4	12.0
D -> A	16.8	36.0	14.0	30.0	11.2	24.0
C -> A	14.4	30.0	12.0	25.0	9.6	20.0
B -> A	9.6	24.0	8.0	20.0	6.4	16.0

d. Results for implementation pathway A1 and C

This section presents detailed results obtained for pathway A1 ("Mandatory linkage of the SRI to an EPC assessment") and pathway C ("Market-based voluntary scheme where self-assessment is supported by online tools and third-party certified assessments for those willing to pay for it"). These pathways cover the extreme ends of the spectrum in terms of rates at which SRI assessments will be carried out, as shown in Table 41. While the modelling allows the further diversification of the implementation pathways across building types and climate regions, a uniform implementation across the EU and all building types is assumed for the example results shown here.

i. SRI deployment rate

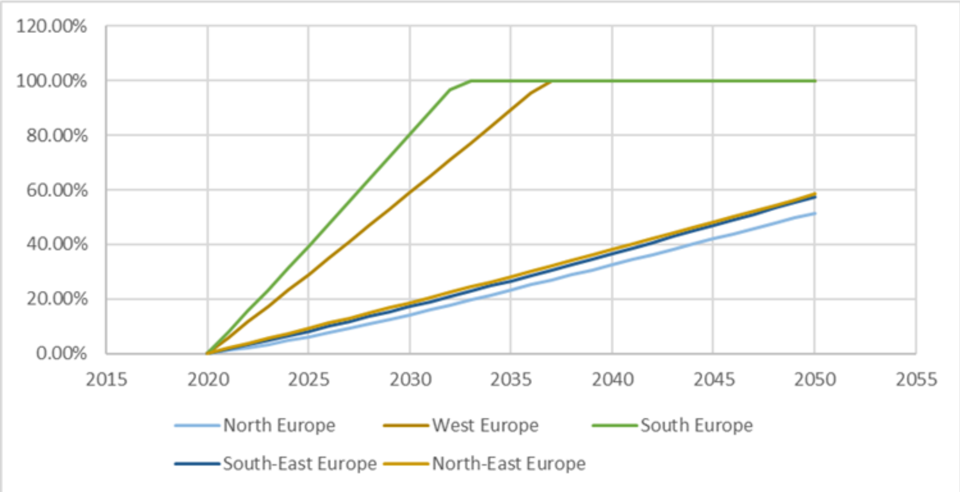

Figure 95 – SRI deployment rate for single-family houses, under implementation pathway A1

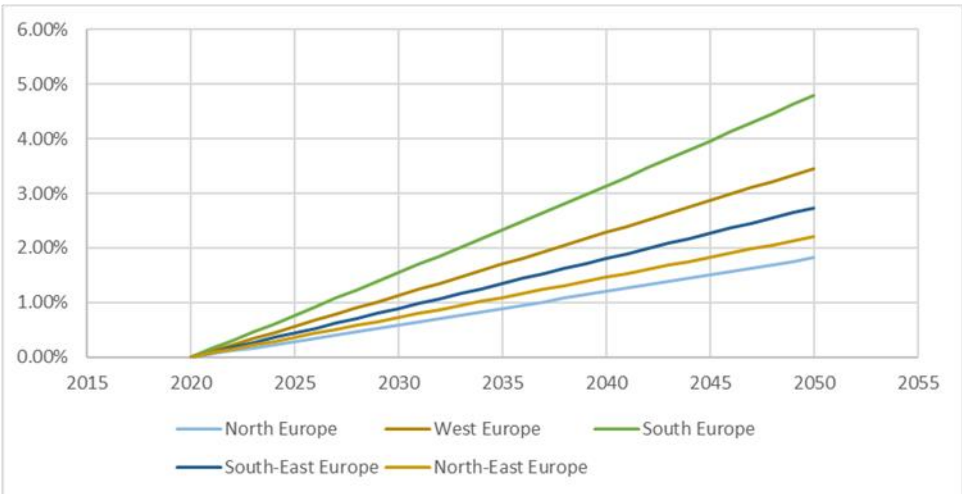

Figure 96 – SRI deployment rate for single-family houses, under implementation pathway C

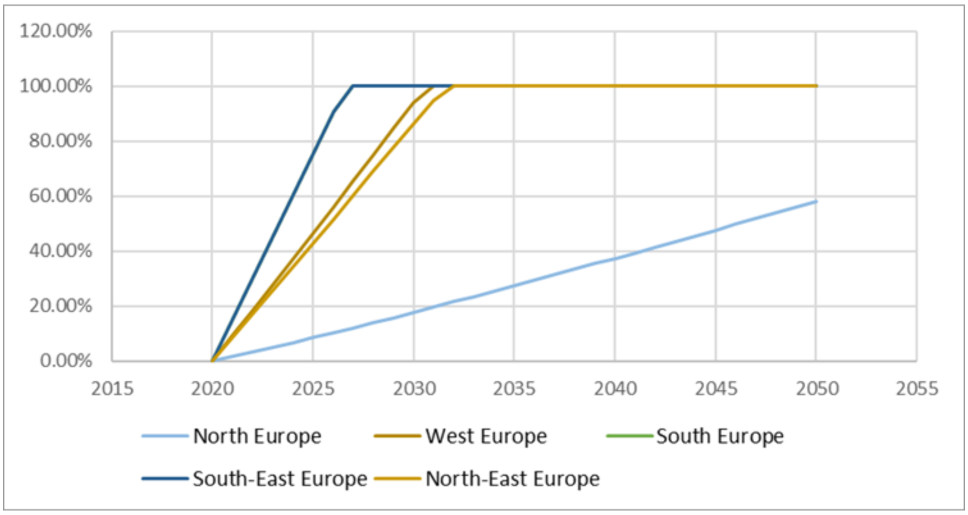

Figure 97 – SRI deployment rate for office buildings, under implementation pathway A1

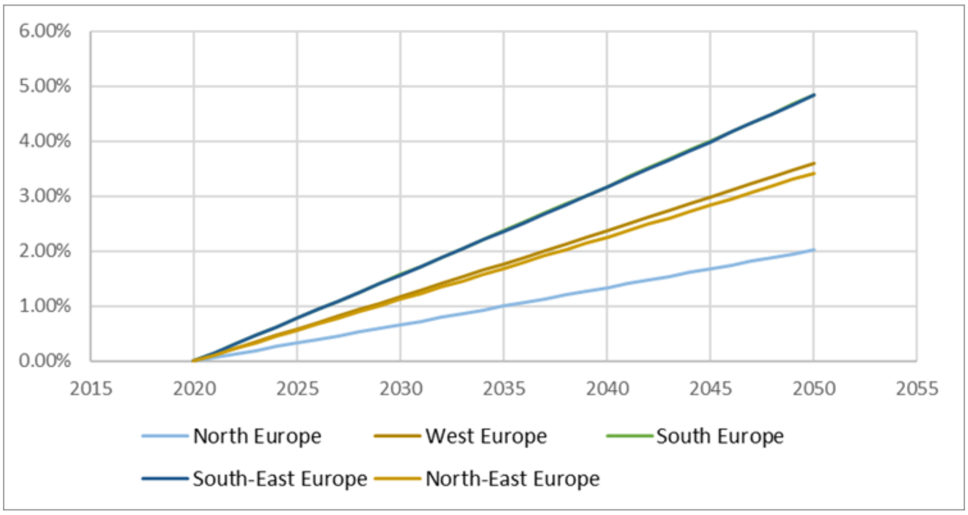

Figure 98 – SRI deployment rate for office building, under implementation pathway C

ii. SRT uptake

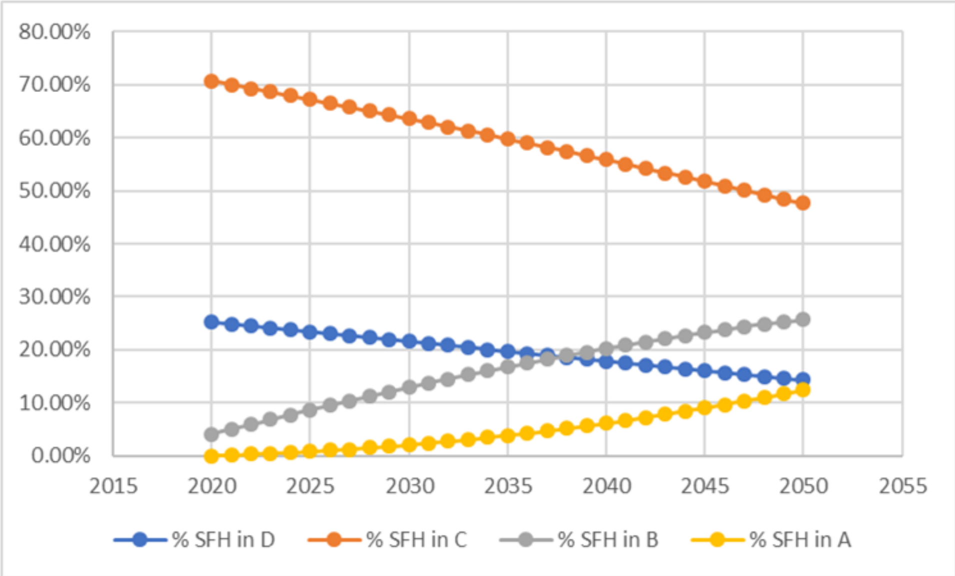

Figure 99 – Distribution of SRT classes (A–D) among single-family houses (SFH) in Northern Europe, under implementation pathway A1

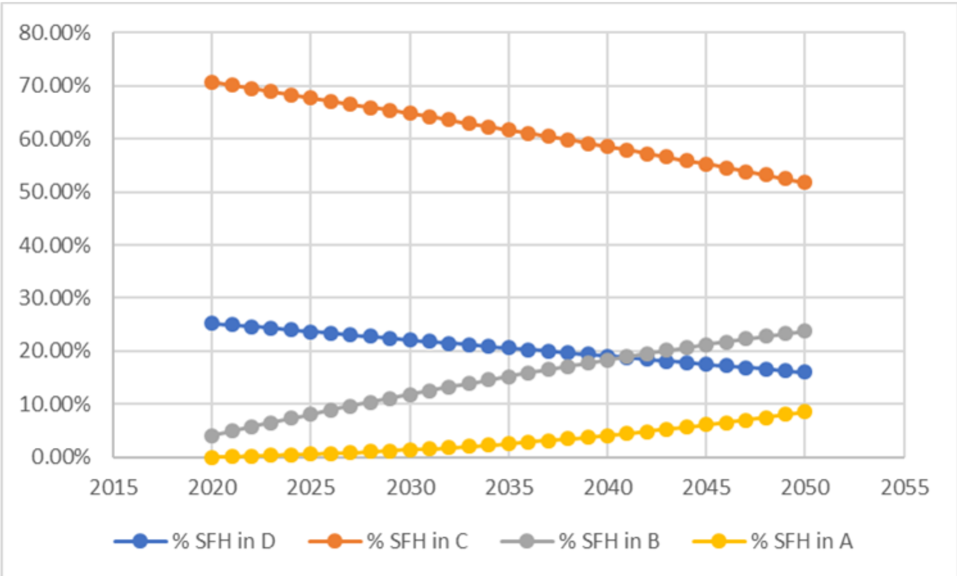

Figure 100 – Distribution of SRT classes (A–D) among single-family houses (SFH) in Northern Europe, under implementation pathway C

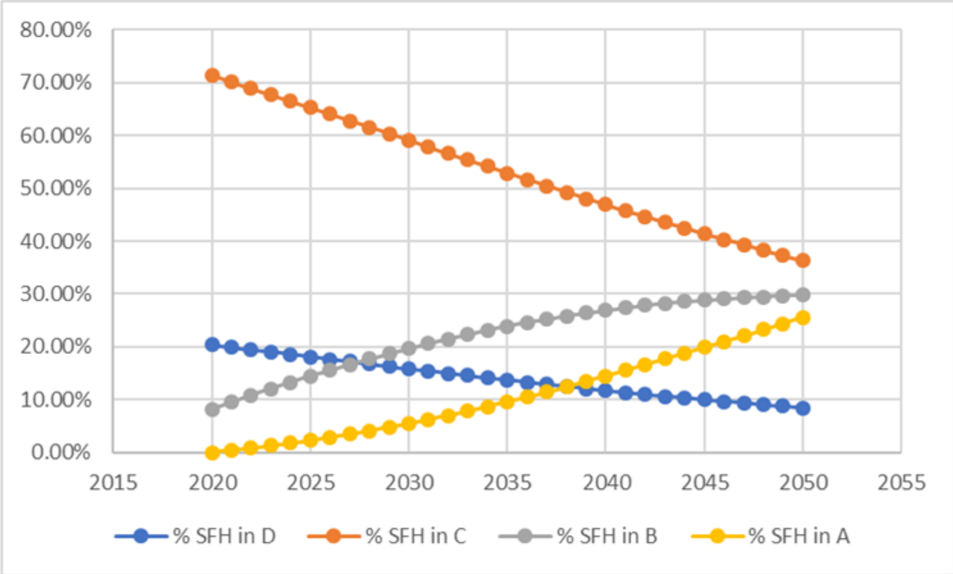

Figure 101 – Distribution of SRT classes (A–D) among single-family houses (SFH) in Western Europe, under implementation pathway A1

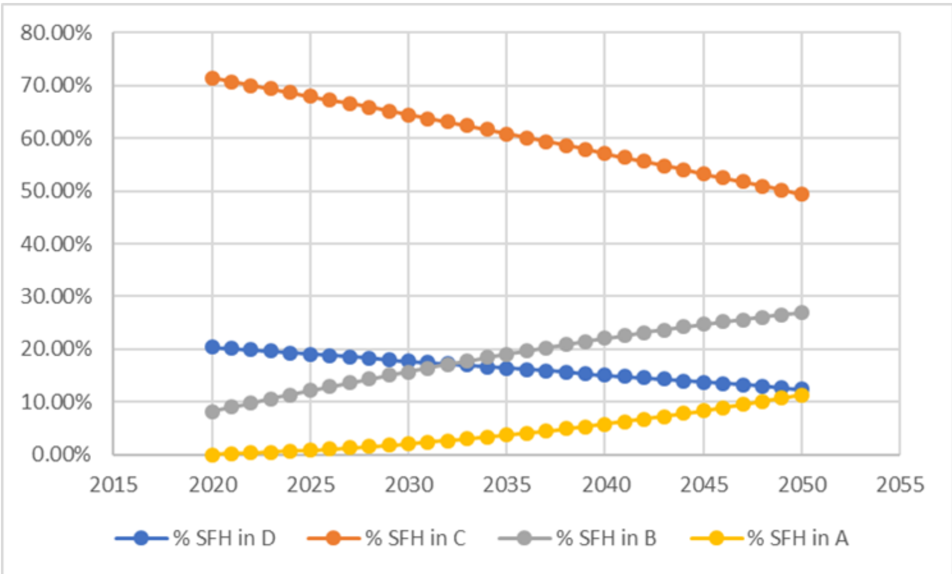

Figure 102 – Distribution of SRT classes (A–D) among single-family houses (SFH) in Western Europe, under implementation pathway C

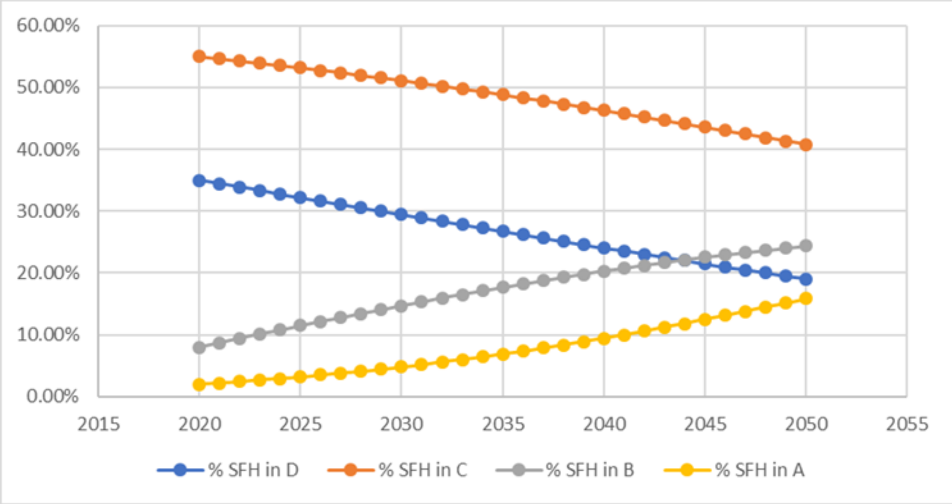

Figure 103 – Distribution of SRT classes (A–D) among office buildings in Northern Europe, under implementation pathway A1

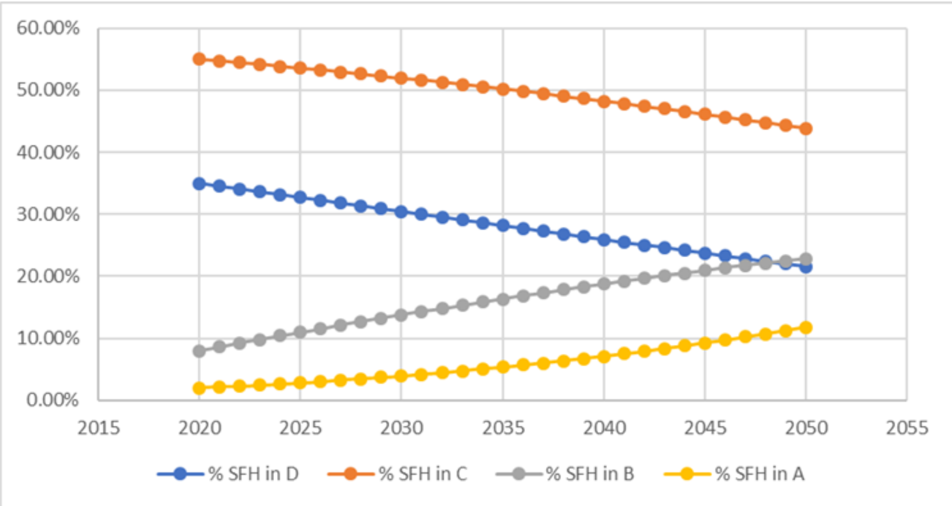

Figure 104 – Distribution of SRT classes (A–D) among office buildings in Northern Europe, under implementation pathway C

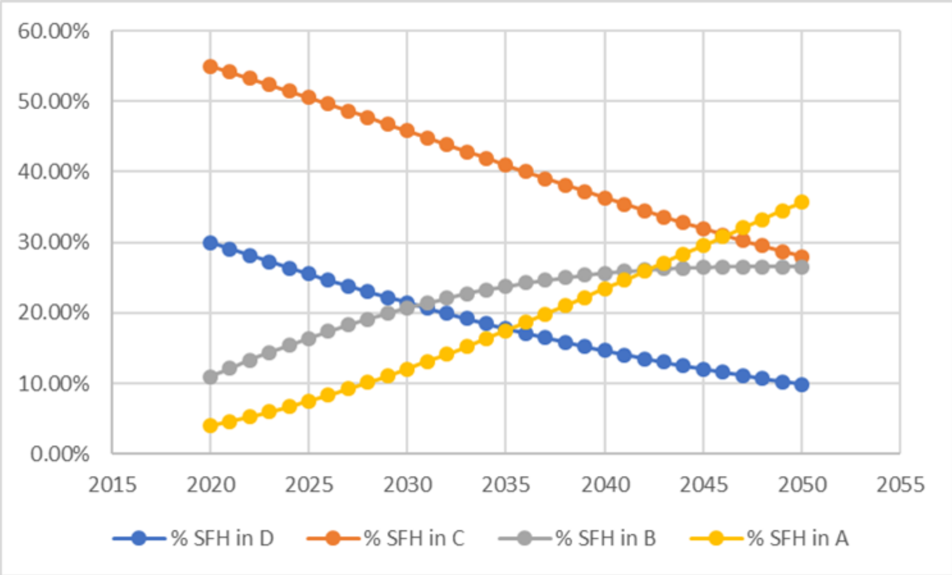

Figure 105 – Distribution of SRT classes (A–D) among office buildings in Western Europe, under implementation pathway A1

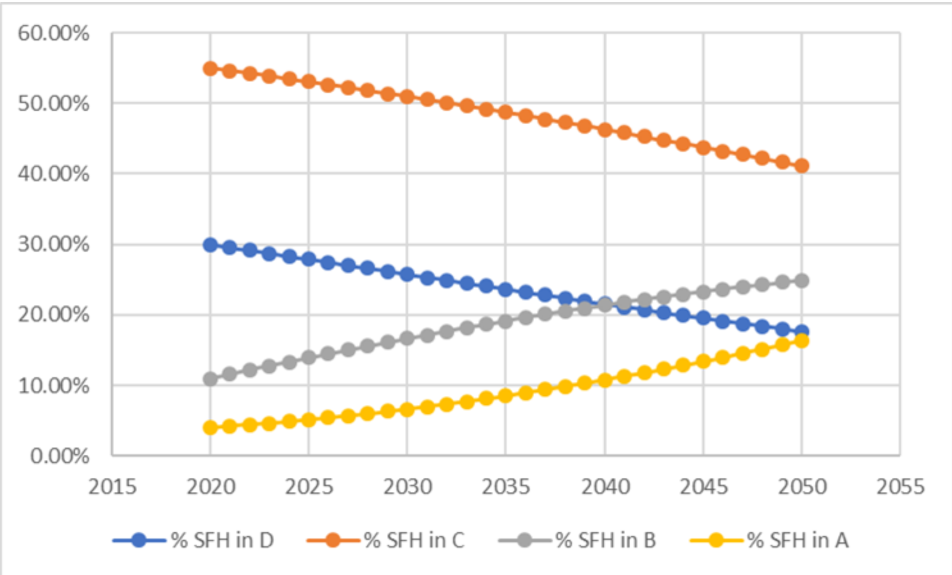

Figure 106 – Distribution of SRT classes (A–D) among office buildings in Western Europe, under implementation pathway C

iii. Relative energy savings

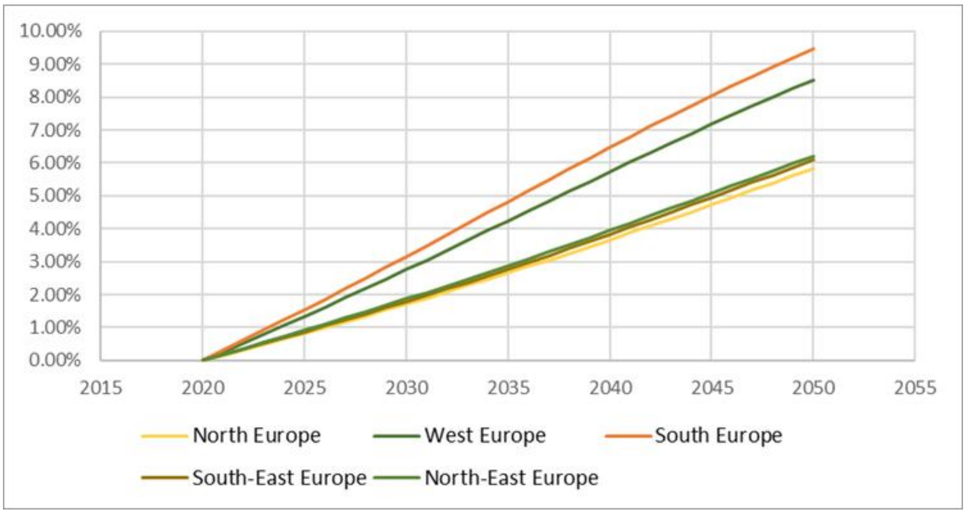

Figure 107 – Cumulative relative energy savings resulting from SRT upgrades in single-family houses, under implementation pathway A1

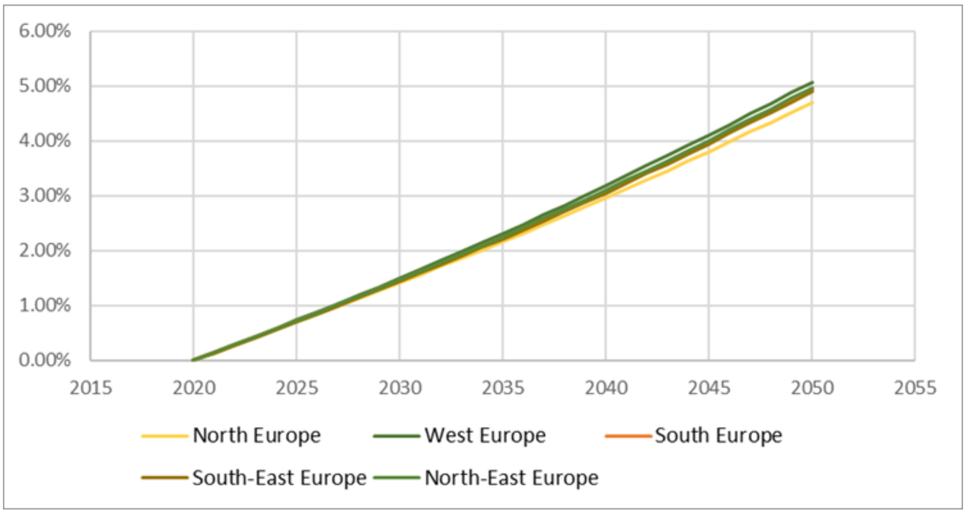

Figure 108 – Cumulative relative energy savings resulting from SRT upgrades in single-family houses, under implementation pathway C

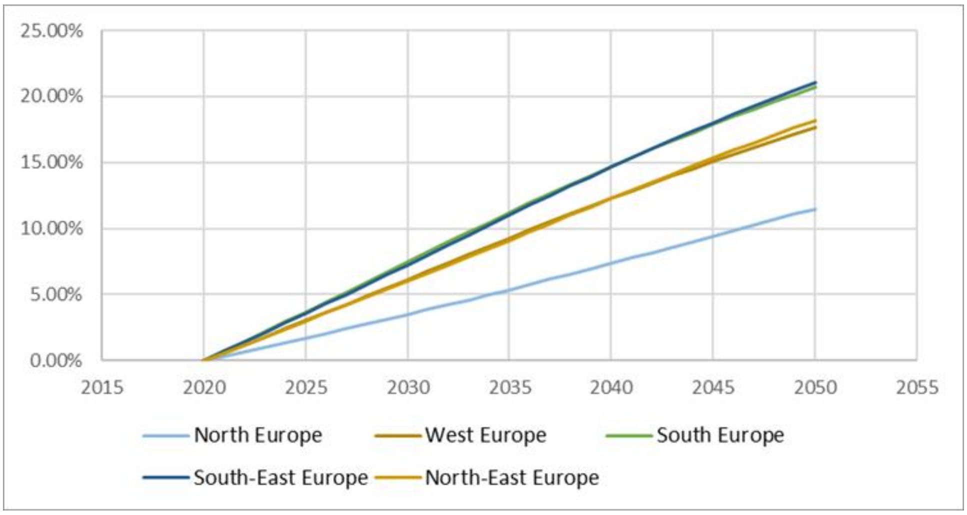

Figure 109 – Cumulative relative energy savings resulting from SRT upgrades in offices, under implementation pathway A1

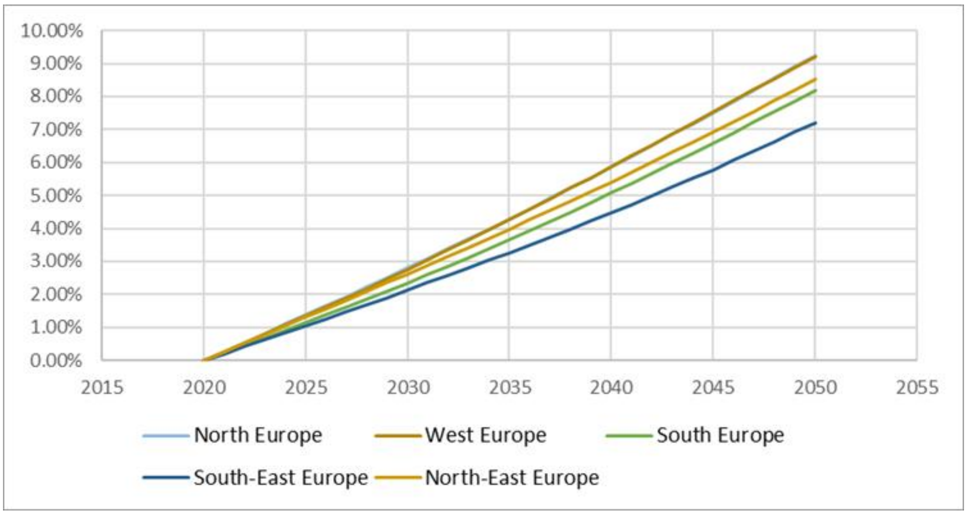

Figure 110 – Cumulative relative energy savings resulting from SRT upgrades in offices, under implementation pathway C

iv. Employment impacts

Table 47 - Incremental employment impacts of the SRI compared to the BAU for implementation pathway A1

	2023	2030	2040	2050
Manufacturing jobs	23131	26692	27957	24630
Installation jobs	21628	24958	26140	23029
Wholesale jobs	1160	1338	1402	1235
Retail jobs	6977	8051	8432	7429
Maintenance jobs	2442	2818	2951	2600
Assessment jobs (external)	9709	10294	11528	12529
Energy supply jobs	-3455	-11375	-19340	-27035
Net jobs	61591	62775	59071	44416

Table 48 - Incremental employment impacts of the SRI compared to the BAU for implementation pathway A2

	2023	2030	2040	2050
Manufacturing jobs	4558	6223	9336	11831
Installation jobs	4262	5818	8729	11062
Wholesale jobs	229	312	468	593
Retail jobs	1375	1877	2816	3568
Maintenance jobs	481	657	986	1249
Assessment jobs (external)	879	931	1422	2057
Energy supply jobs	-1033	-3598	-5453	-9587
Net jobs	10750	12219	18303	20774

Table 49 - Incremental employment impacts of the SRI compared to the BAU for implementation pathway A3

	2023	2030	2040	2050
Manufacturing jobs	12984	16269	19618	19571
Installation jobs	12140	15212	18343	18299
Wholesale jobs	651	816	983	981
Retail jobs	3916	4907	5917	5903
Maintenance jobs	1371	1717	2071	2066
Assessment jobs (external)	6860	7265	10623	11768
Energy supply jobs	-2132	-7237	-12355	-18607
Net jobs	35790	38949	45200	39982

Table 50 - Incremental employment impacts of the SRI compared to the BAU for implementation pathway B

	2023	2030	2040	2050
Manufacturing jobs	23131	26692	27957	24630
Installation jobs	21628	24958	26140	23029
Wholesale jobs	1160	1338	1402	1235
Retail jobs	6977	8051	8432	7429
Maintenance jobs	2442	2818	2951	2600
Assessment jobs (external)	9709	10294	11528	12529
Energy supply jobs	-3455	-11375	-19340	-27035
Net jobs	61591	62775	59071	44416

Table 51- Incremental employment impacts of the SRI compared to the BAU for implementation pathway C

	2023	2030	2040	2050
Manufacturing jobs	8732	10953	15015	16594
Installation jobs	8165	10241	14040	15515
Wholesale jobs	438	549	753	832
Retail jobs	2634	3304	4529	5005
Maintenance jobs	922	1156	1585	1752
Assessment jobs (external)	2553	2707	4337	6115
Energy supply jobs	-1665	-5635	-9387	-14952
Net jobs	21778	23275	30872	30861

Table 52 - Incremental employment impacts of the SRI compared to the BAU for implementation pathway D

	2023	2030	2040	2050
Manufacturing jobs	3578	5120	8064	10576
Installation jobs	3346	4788	7540	9888
Wholesale jobs	179	257	404	530
Retail jobs	1079	1544	2432	3190
Maintenance jobs	378	541	851	1116
Assessment jobs (external)	21	22	29	38
Energy supply jobs	-906	-3186	-4668	-8501
Net jobs	7676	9086	14653	16837

Table 53 - Incremental employment impacts of the SRI compared to the BAU for implementation pathway E1

	2023	2030	2040	2050
Manufacturing jobs	12651	16486	20540	20439
Installation jobs	11829	15415	19205	19111
Wholesale jobs	634	826	1030	1025
Retail jobs	3816	4972	6195	6165
Maintenance jobs	1336	1740	2168	2158
Assessment jobs (external)	6684	7085	9835	11487
Energy supply jobs	-2180	-7490	-13119	-19763
Net jobs	34769	39035	45854	40621

Table 54 - Incremental employment impacts of the SRI compared to the BAU for implementation pathway E2

	2023	2030	2040	2050
Manufacturing jobs	3441	4893	7659	10000
Installation jobs	185	262	411	536
Wholesale jobs	1110	1578	2471	3226
Retail jobs	389	552	865	1129
Maintenance jobs	279	295	425	579
Assessment jobs (external)	-920	-3230	-4750	-8614
Energy supply jobs	8163	9585	15270	17550
Net jobs	3680	5233	8191	10695

Table 55 - Incremental employment impacts of the SRI compared to the BAU for implementation pathway E3

	2023	2030	2040	2050
Manufacturing jobs	11201	14168	18386	19012
Installation jobs	10474	13247	17192	17776
Wholesale jobs	562	710	922	953
Retail jobs	3379	4273	5546	5734
Maintenance jobs	1183	1496	1941	2007
Assessment jobs (external)	5000	5290	8469	11195
Energy supply jobs	-1965	-6643	-11373	-17546
Net jobs	29833	32541	41083	39131

Table 56 - Incremental employment impacts of the SRI compared to the BAU for implementation pathway F1

	2023	2030	2040	2050
Manufacturing jobs	6225	8074	11562	14031
Installation jobs	5820	7550	10810	13119
Wholesale jobs	312	405	580	703
Retail jobs	1877	2435	3487	4232
Maintenance jobs	657	852	1221	1481
Assessment jobs (external)	1371	1455	2264	3342
Energy supply jobs	-1298	-4448	-7079	-11860
Net jobs	14965	16323	22845	25048

Table 57 - Incremental employment impacts of the SRI compared to the BAU for implementation pathway F2

	2023	2030	2040	2050
Manufacturing jobs	3592	5135	8080	10591
Installation jobs	3358	4801	7555	9903
Wholesale jobs	180	257	405	531
Retail jobs	1083	1549	2437	3194
Maintenance jobs	379	542	853	1118
Assessment jobs (external)	229	242	343	461
Energy supply jobs	-908	-3192	-4679	-8517
Net jobs	7913	9335	14994	17282

Table 58 - Incremental employment impacts of the SRI compared to the BAU for implementation pathway F3

	2023	2030	2040	2050
Manufacturing jobs	4906	6596	9774	12241
Installation jobs	4587	6167	9139	11446
Wholesale jobs	246	331	490	614
Retail jobs	1480	1989	2948	3692
Maintenance jobs	518	696	1032	1292
Assessment jobs (external)	1074	1138	1641	2295
Energy supply jobs	-1102	-3818	-5869	-10161
Net jobs	11708	13100	19155	21419

v. Material circularity

Table 59 - Estimated material related environmental impacts (from manufacture, distribution, EOL) compared to BAU for implementation pathway A1

Impact parameter	Units	2023	2030	2040	2050
Other resources & Waste					
Total Energy (GER)	PJ	20.1	23.2	24.3	21.4
of which, electricity (in primary MJ)	PJ	5.9	6.8	7.1	6.3
Water (process)	billion ltr	3.0	3.4	3.6	3.2
Water (cooling)	billion ltr	6.2	7.2	7.5	6.6
Waste, non-haz./ landfill	kt	172.3	198.9	208.3	183.5
Waste, hazardous/ incinerated	kt	32.4	37.4	39.2	34.5
Emissions Air					
Greenhouse Gases in GWP100	Mt CO2 eq.	1.1	1.3	1.3	1.2
ODP		0.0	0.0	0.0	0.0
Acidification, emissions	kt SO2 eq.	6.2	7.1	7.5	6.6
Volatile Organic Compounds (VOC)	kt	0.1	0.1	0.1	0.1
Persistent Organic Pollutants (POP)	ng i-Teq	1.2	1.3	1.4	1.2
Heavy Metals	t Ni eq.	1.7	2.0	2.1	1.8

PAHs	t Ni eq.	1.7	1.9	2.0	1.8
Particulate Matter (PM, dust)	t	9.2	10.6	11.1	9.8
Emissions water					
Heavy Metals	kg Hg/20	1280.6	1477.8	1547.8	1363.6
Eutrophication	kt PO4	78.8	90.9	95.2	83.9
POP ng-i-tec		0.0	0.0	0.0	0.0

Table 60 - Estimated material related environmental impacts (from manufacture, distribution, EOL) compared to BAU for implementation pathway A2

Impact parameter	Units	2023	2030	2040	2050
Other resources & Waste					
Total Energy (GER)	PJ	4.0	5.4	8.1	10.3
of which, electricity (in primary MJ)	PJ	1.2	1.6	2.4	3.0
Water (process)	billion ltr	0.6	0.8	1.2	1.5
Water (cooling)	billion ltr	1.2	1.7	2.5	3.2
Waste, non-haz./ landfill	kt	34.0	46.4	69.6	88.1
Waste, hazardous/ incinerated	kt	6.4	8.7	13.1	16.6
Emissions Air					
Greenhouse Gases in GWP100	Mt CO2 eq.	0.2	0.3	0.4	0.6
ODP		0.0	0.0	0.0	0.0
Acidification, emissions	kt SO2 eq.	1.2	1.7	2.5	3.2
Volatile Organic Compounds (VOC)	kt	0.0	0.0	0.0	0.0
Persistent Organic Pollutants (POP)	ng i-Teq	0.2	0.3	0.5	0.6
Heavy Metals	t Ni eq.	0.3	0.5	0.7	0.9
PAHs	t Ni eq.	0.3	0.4	0.7	0.8

Particulate Matter (PM, dust)	t	1.8	2.5	3.7	4.7
Emissions water					
Heavy Metals	kg Hg/20	252.4	344.5	516.8	655.0
Eutrophication	kt PO4	15.5	21.2	31.8	40.3
POP ng-i-tec		0.0	0.0	0.0	0.0

Table 61 - Estimated material related environmental impacts (from manufacture, distribution, EOL) compared to BAU for implementation pathway A3

Impact parameter	Units	2023	2030	2040	2050
Other resources & Waste					
Total Energy (GER)	PJ	11.3	14.1	17.1	17.0
of which, electricity (in primary MJ)	PJ	3.3	4.1	5.0	5.0
Water (process)	billion ltr	1.7	2.1	2.5	2.5
Water (cooling)	billion ltr	3.5	4.4	5.3	5.3
Waste, non-haz./ landfill	kt	96.7	121.2	146.2	145.8
Waste, hazardous/ incinerated	kt	18.2	22.8	27.5	27.4
Emissions Air					
Greenhouse Gases in GWP100	Mt CO2 eq.	0.6	0.8	0.9	0.9
ODP		0.0	0.0	0.0	0.0
Acidification, emissions	kt SO2 eq.	3.5	4.3	5.2	5.2
Volatile Organic Compounds (VOC)	kt	0.0	0.1	0.1	0.1
Persistent Organic Pollutants (POP)	ng i-Teq	0.6	0.8	1.0	1.0
Heavy Metals	t Ni eq.	1.0	1.2	1.4	1.4
PAHs	t Ni eq.	0.9	1.2	1.4	1.4

Particulate Matter (PM, dust)	t	5.2	6.5	7.8	7.8
Emissions water					
Heavy Metals	kg Hg/20	718.8	900.7	1086.1	1083.5
Eutrophication	kt PO4	44.2	55.4	66.8	66.7
POP ng-i-tec		0.0	0.0	0.0	0.0

Table 62 - Estimated material related environmental impacts (from manufacture, distribution, EOL) compared to BAU for implementation pathway B

Impact parameter	Units	2023	2030	2040	2050
Other resources & Waste					
Total Energy (GER)	PJ	7.6	9.5	13.1	14.4
of which, electricity (in primary MJ)	PJ	2.2	2.8	3.8	4.2
Water (process)	billion ltr	1.1	1.4	1.9	2.1
Water (cooling)	billion ltr	2.4	3.0	4.0	4.5
Waste, non-haz./ landfill	kt	65.1	81.6	111.9	123.6
Waste, hazardous/ incinerated	kt	12.2	15.4	21.0	23.3
Emissions Air					
Greenhouse Gases in GWP100	Mt CO2 eq.	0.4	0.5	0.7	0.8
ODP		0.0	0.0	0.0	0.0
Acidification, emissions	kt SO2 eq.	2.3	2.9	4.0	4.4
Volatile Organic Compounds (VOC)	kt	0.0	0.0	0.1	0.1
Persistent Organic Pollutants (POP)	ng i-Teq	0.4	0.5	0.7	0.8
Heavy Metals	t Ni eq.	0.6	0.8	1.1	1.2
PAHs	t Ni eq.	0.6	0.8	1.1	1.2
Particulate Matter (PM, dust)	t	3.5	4.3	6.0	6.6
Emissions water					
Heavy Metals	kg Hg/20	483.4	606.4	831.3	918.7
Eutrophication	kt PO4	29.7	37.3	51.1	56.5
POP ng-i-tec		0.0	0.0	0.0	0.0

Table 63 - Estimated material related environmental impacts (from manufacture, distribution, EOL) compared to BAU for implementation pathway C

Impact parameter	Units	2023	2030	2040	2050
Other resources & Waste					
Total Energy (GER)	PJ	3.1	4.5	7.0	9.2
of which, electricity (in primary MJ)	PJ	0.9	1.3	2.1	2.7
Water (process)	billion ltr	0.5	0.7	1.0	1.4
Water (cooling)	billion ltr	1.0	1.4	2.2	2.8
Waste, non-haz./ landfill	kt	26.7	38.2	60.1	78.8
Waste, hazardous/ incinerated	kt	5.0	7.2	11.3	14.8
Emissions Air					
Greenhouse Gases in GWP100	Mt CO2 eq.	0.2	0.2	0.4	0.5
ODP		0.0	0.0	0.0	0.0
Acidification, emissions	kt SO2 eq.	1.0	1.4	2.2	2.8
Volatile Organic Compounds (VOC)	kt	0.0	0.0	0.0	0.0
Persistent Organic Pollutants (POP)	ng i-Teq	0.2	0.3	0.4	0.5
Heavy Metals	t Ni eq.	0.3	0.4	0.6	0.8
PAHs	t Ni eq.	0.3	0.4	0.6	0.8
Particulate Matter (PM, dust)	t	1.4	2.0	3.2	4.2
Emissions water					
Heavy Metals	kg Hg/20	198.1	283.5	446.4	585.5
Eutrophication	kt PO4	12.2	17.4	27.5	36.0
POP ng-i-tec		0.0	0.0	0.0	0.0

Table 64 - Estimated material related environmental impacts (from manufacture, distribution, EOL) compared to BAU for implementation pathway D

Impact parameter	Units	2023	2030	2040	2050
Other resources & Waste					
Total Energy (GER)	PJ	11.0	14.3	17.9	17.8
of which, electricity (in primary MJ)	PJ	3.2	4.2	5.2	5.2
Water (process)	billion ltr	1.6	2.1	2.6	2.6
Water (cooling)	billion ltr	3.4	4.4	5.5	5.5
Waste, non-haz./ landfill	kt	94.3	122.8	153.0	152.3
Waste, hazardous/ incinerated	kt	17.7	23.1	28.8	28.7
Emissions Air					
Greenhouse Gases in GWP100	Mt CO2 eq.	0.6	0.8	1.0	1.0
ODP		0.0	0.0	0.0	0.0
Acidification, emissions	kt SO2 eq.	3.4	4.4	5.5	5.5
Volatile Organic Compounds (VOC)	kt	0.0	0.1	0.1	0.1
Persistent Organic Pollutants (POP)	ng i-Teq	0.6	0.8	1.0	1.0
Heavy Metals	t Ni eq.	0.9	1.2	1.5	1.5
PAHs	t Ni eq.	0.9	1.2	1.5	1.5
Particulate Matter (PM, dust)	t	5.0	6.5	8.2	8.1
Emissions water					
Heavy Metals	kg Hg/20	700.4	912.7	1137.1	1131.6
Eutrophication	kt PO4	43.1	56.1	70.0	69.6
POP ng-i-tec		0.0	0.0	0.0	0.0

Table 65 - Estimated material related environmental impacts (from manufacture, distribution, EOL) compared to BAU for implementation pathway E1

Impact parameter	Units	2023	2030	2040	2050
Other resources & Waste					
Total Energy (GER)	PJ	19.5	22.5	24.2	21.6
of which, electricity (in primary MJ)	PJ	5.7	6.6	7.1	6.3
Water (process)	billion ltr	2.9	3.3	3.6	3.2
Water (cooling)	billion ltr	6.0	7.0	7.5	6.7
Waste, non-haz./ landfill	kt	166.9	192.9	207.8	185.2
Waste, hazardous/ incinerated	kt	31.4	36.3	39.1	34.8
Emissions Air					
Greenhouse Gases in GWP100	Mt CO2 eq.	1.1	1.2	1.3	1.2
ODP		0.0	0.0	0.0	0.0
Acidification, emissions	kt SO2 eq.	6.0	6.9	7.4	6.6
Volatile Organic Compounds (VOC)	kt	0.1	0.1	0.1	0.1
Persistent Organic Pollutants (POP)	ng i-Teq	1.1	1.3	1.4	1.2
Heavy Metals	t Ni eq.	1.6	1.9	2.0	1.8
PAHs	t Ni eq.	1.6	1.9	2.0	1.8
Particulate Matter (PM, dust)	t	8.9	10.3	11.1	9.9
Emissions water					
Heavy Metals	kg Hg/20	1240.0	1433.6	1543.8	1376.0
Eutrophication	kt PO4	76.3	88.2	95.0	84.6
POP ng-i-tec		0.0	0.0	0.0	0.0

Table 66 - Estimated material related environmental impacts (from manufacture, distribution, EOL) compared to BAU for implementation pathway E2

Impact parameter	Units	2023	2030	2040	2050
Other resources & Waste					
Total Energy (GER)	PJ	3.2	4.5	7.1	9.3
of which, electricity (in primary MJ)	PJ	0.9	1.3	2.1	2.7
Water (process)	billion ltr	0.5	0.7	1.0	1.4
Water (cooling)	billion ltr	1.0	1.4	2.2	2.9
Waste, non-haz./ landfill	kt	27.4	39.0	61.0	79.7
Waste, hazardous/ incinerated	kt	5.2	7.3	11.5	15.0
Emissions Air					
Greenhouse Gases in GWP100	Mt CO2 eq.	0.2	0.3	0.4	0.5
ODP		0.0	0.0	0.0	0.0
Acidification, emissions	kt SO2 eq.	1.0	1.4	2.2	2.9
Volatile Organic Compounds (VOC)	kt	0.0	0.0	0.0	0.0
Persistent Organic Pollutants (POP)	ng i-Teq	0.2	0.3	0.4	0.5
Heavy Metals	t Ni eq.	0.3	0.4	0.6	0.8
PAHs	t Ni eq.	0.3	0.4	0.6	0.8
Particulate Matter (PM, dust)	t	1.5	2.1	3.3	4.2
Emissions water					
Heavy Metals	kg Hg/20	203.8	289.7	453.5	592.1
Eutrophication	kt PO4	12.5	17.8	27.9	36.4
POP ng-i-tec		0.0	0.0	0.0	0.0

Table 67 - Estimated material related environmental impacts (from manufacture, distribution, EOL) compared to BAU for implementation pathway E3

Impact parameter	Units	2023	2030	2040	2050
Other resources & Waste					
Total Energy (GER)	PJ	9.7	12.3	16.0	16.5
of which, electricity (in primary MJ)	PJ	2.8	3.6	4.7	4.8
Water (process)	billion ltr	1.4	1.8	2.4	2.4
Water (cooling)	billion ltr	3.0	3.8	5.0	5.1
Waste, non-haz./ landfill	kt	83.5	105.6	137.0	141.6
Waste, hazardous/ incinerated	kt	15.7	19.9	25.8	26.7
Emissions Air					
Greenhouse Gases in GWP100	Mt CO2 eq.	0.5	0.7	0.9	0.9
ODP		0.0	0.0	0.0	0.0
Acidification, emissions	kt SO2 eq.	3.0	3.8	4.9	5.1
Volatile Organic Compounds (VOC)	kt	0.0	0.1	0.1	0.1
Persistent Organic Pollutants (POP)	ng i-Teq	0.6	0.7	0.9	0.9
Heavy Metals	t Ni eq.	0.8	1.0	1.3	1.4
PAHs	t Ni eq.	0.8	1.0	1.3	1.4
Particulate Matter (PM, dust)	t	4.4	5.6	7.3	7.5
Emissions water					
Heavy Metals	kg Hg/20	620.1	784.4	1017.9	1052.5
Eutrophication	kt PO4	38.1	48.3	62.6	64.7
POP ng-i-tec		0.0	0.0	0.0	0.0

Table 68 - Estimated material related environmental impacts (from manufacture, distribution, EOL) compared to BAU for implementation pathway F1

Impact parameter	Units	2023	2030	2040	2050
Other resources & Waste					
Total Energy (GER)	PJ	5.4	7.0	10.0	12.2
of which, electricity (in primary MJ)	PJ	1.6	2.1	2.9	3.6
Water (process)	billion ltr	0.8	1.0	1.5	1.8
Water (cooling)	billion ltr	1.7	2.2	3.1	3.8
Waste, non-haz./ landfill	kt	46.4	60.2	86.1	104.5
Waste, hazardous/ incinerated	kt	8.7	11.3	16.2	19.7
Emissions Air					
Greenhouse Gases in GWP100	Mt CO2 eq.	0.3	0.4	0.6	0.7
ODP		0.0	0.0	0.0	0.0
Acidification, emissions	kt SO2 eq.	1.7	2.2	3.1	3.7
Volatile Organic Compounds (VOC)	kt	0.0	0.0	0.0	0.1
Persistent Organic Pollutants (POP)	ng i-Teq	0.3	0.4	0.6	0.7
Heavy Metals	t Ni eq.	0.5	0.6	0.8	1.0
PAHs	t Ni eq.	0.4	0.6	0.8	1.0
Particulate Matter (PM, dust)	t	2.5	3.2	4.6	5.6
Emissions water					
Heavy Metals	kg Hg/20	344.6	447.0	640.1	776.8
Eutrophication	kt PO4	21.2	27.5	39.4	47.8
POP ng-i-tec		0.0	0.0	0.0	0.0

Table 69 - Estimated material related environmental impacts (from manufacture, distribution, EOL) compared to BAU for implementation pathway F2

Impact parameter	Units	2023	2030	2040	2050
Other resources & Waste					
Total Energy (GER)	PJ	3.1	4.5	7.0	9.2
of which, electricity (in primary MJ)	PJ	0.9	1.3	2.1	2.7
Water (process)	billion ltr	0.5	0.7	1.0	1.4
Water (cooling)	billion ltr	1.0	1.4	2.2	2.9
Waste, non-haz./ landfill	kt	26.8	38.3	60.2	78.9
Waste, hazardous/ incinerated	kt	5.0	7.2	11.3	14.8
Emissions Air					
Greenhouse Gases in GWP100	Mt CO2 eq.	0.2	0.2	0.4	0.5
ODP		0.0	0.0	0.0	0.0
Acidification, emissions	kt SO2 eq.	1.0	1.4	2.2	2.8
Volatile Organic Compounds (VOC)	kt	0.0	0.0	0.0	0.0
Persistent Organic Pollutants (POP)	ng i-Teq	0.2	0.3	0.4	0.5
Heavy Metals	t Ni eq.	0.3	0.4	0.6	0.8
PAHs	t Ni eq.	0.3	0.4	0.6	0.8
Particulate Matter (PM, dust)	t	1.4	2.0	3.2	4.2
Emissions water					
Heavy Metals	kg Hg/20	198.8	284.3	447.4	586.4
Eutrophication	kt PO4	12.2	17.5	27.5	36.1
POP ng-i-tec		0.0	0.0	0.0	0.0

Table 70 - Estimated material related environmental impacts (from manufacture, distribution, EOL) compared to BAU for implementation pathway F3

Impact parameter	Units	2023	2030	2040	2050
Other resources & Waste					
Total Energy (GER)	PJ	4.3	5.7	8.5	10.6
of which, electricity (in primary MJ)	PJ	1.2	1.7	2.5	3.1
Water (process)	billion ltr	0.6	0.8	1.3	1.6
Water (cooling)	billion ltr	1.3	1.8	2.6	3.3
Waste, non-haz./ landfill	kt	36.6	49.1	72.8	91.2
Waste, hazardous/ incinerated	kt	6.9	9.2	13.7	17.2
Emissions Air					
Greenhouse Gases in GWP100	Mt CO2 eq.	0.2	0.3	0.5	0.6
ODP		0.0	0.0	0.0	0.0
Acidification, emissions	kt SO2 eq.	1.3	1.8	2.6	3.3
Volatile Organic Compounds (VOC)	kt	0.0	0.0	0.0	0.0
Persistent Organic Pollutants (POP)	ng i-Teq	0.2	0.3	0.5	0.6
Heavy Metals	t Ni eq.	0.4	0.5	0.7	0.9
PAHs	t Ni eq.	0.4	0.5	0.7	0.9
Particulate Matter (PM, dust)	t	1.9	2.6	3.9	4.9
Emissions water					
Heavy Metals	kg Hg/20	271.6	365.2	541.1	677.7
Eutrophication	kt PO4	16.7	22.5	33.3	41.7
POP ng-i-tec		0.0	0.0	0.0	0.0

ANNEX E. SRI METHOD A: SIMPLIFIED SERVICE CATALOGUE

Table 71 provides a summarising overview of the smart ready services and their functionality levels contained in this catalogue.

Table 71 – Summary of services and functionality levels of simplified service catalogue for method A

Domain	Smart ready service	Functionality level 0 (as non-smart default)	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 presence control
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 temperature set point)		
Heating	Heat generator control (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	Storage and shifting of thermal energy	None	HW storage vessels available	HW storage vessels controlled based on external		

Domain	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
				signals (from BACS or 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 benchmarking	Central or remote reporting of performance evaluation including forecasting and/or benchmarking ; also including predictive management and fault detection
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 on/off control, scheduled charging enable and demand-based supply temperature control or multi-sensor storage management		
Domestic hot water	Control of DHW storage charging	None	HW storage vessels available	Automatic charging control based on local availability of renewables or information from electricity grid (DR, DSM)	-	
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 benchmarking	Performance evaluation including forecasting and/or benchmarking ; also including predictive management

Domain	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
						and fault detection
Cooling	Cooling 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
Cooling	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 frequency control)	Variable control of cooling production capacity depending on the load AND external signals from grid	
Cooling	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)
Cooling	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 benchmarking	Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive

Domain	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
						management and fault detection
Controlled ventilation	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,...)	Local Demand Control based on air quality sensors (CO2, VOC,...) with local flow from/to the zone regulated by dampers
Controlled ventilation	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)	
Lighting	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)	

Domain	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
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	Reporting information regarding performance	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…)
Electricity	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
Electricity	Reporting information regarding electricity consumption	None	reporting on current electricity consumption on building level	real-time feedback or benchmarking on building level	real-time feedback or benchmarking on appliance level	real-time feedback or benchmarking on appliance level with automated personalized recommendations
Electricity	Reporting information regarding local electrcity generation	None	Current generation data available	Actual values and historical data	Performance evaluation including forecasting and/or benchmarking	Performance evaluation including forecasting and/or benchmarking; also including predictive management

Domain	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
						and fault detection
Electricity	Reporting information regarding energy storage	None	Current state of charge (SOC) data available	Actual values and historical data	Performance evaluation including forecasting and/or benchmarking	Performance evaluation including forecasting and/or benchmarking ; also including predictive management and fault detection
Electric vehicle charging	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
Electric vehicle charging	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)		
Electric vehicle charging	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)		

Domain	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
Monitoring and control	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	
Monitoring and control	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		
Monitoring and control	Central reporting of TBS performance and energy use	None	Central o rremote reporting of realtime energy use per energy carrier	Central o rremote reporting of realtime energy use per energy carrier, combining TBS of at least 2 domains in one interface	Central o rremote reporting of realtime energy use per energy carrier, combining TBS of all domains in one interface	

ANNEX F. SRI METHOD B: DETAILED SERVICE CATALOGUE

Table 72 provides a summarising overview of the smart ready services and their functionality levels contained in this catalogue.

Table 72 – Summary of services and functionality levels of detailed service catalogue for method B

Domain	Smart ready service	Functionality level 0 (as non-smart default)	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)	

Domain	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
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 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 benchmarking	Central or remote reporting of performance evaluation including forecasting and/or benchmarking; 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

Domain	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
						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 supplymentary heat generation)	Manual selected control of solar energy or heat generation	Automatic control of solar storage charge (Prio. 1) and supplementary 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)

Domain	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
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 benchmarking	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection
Cooling	Cooling emission control	No automatic control	Central automatic control	Individual room control	Individual room control with communication between controllers and to BACS	Individual room control with communication and occupancy detection
Cooling	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	
Cooling	Control of distribution network chilled water temperature (supply or return)	Constant temperature control	Outside temperature compensated control	Demand based control		
Cooling	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)
Cooling	Interlock: avoiding simultaneous heating and cooling in the same room	No interlock	Partial interlock (minimising risk of simultanieus heating and cooling e.g. by sliding setpoints)	Total interlock (control system ensures no simultaneous heating and cooling can take place)		
Cooling	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)	

Domain	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
Cooling	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 frequency control)	Variable control of cooling production capacity depending on the load AND external signals from grid	
Cooling	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
Cooling	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 benchmarking	Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection
Cooling	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)
Controlled ventilation	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

Domain	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
Controlled ventilation	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: Continuosly 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).
Controlled ventilation	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		
Controlled ventilation	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 compensation	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	
Controlled ventilation	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).	

Domain	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
Controlled ventilation	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)	
Lighting	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)	
Lighting	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 (during time intervals, dynamic and adapted lighting scenes are set, for example, in terms of illuminance level, different correlated colour temperature (CCT) and the possibility to change the light distribution within the space according to e. g. design, human needs, visual tasks)
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,	Manual operation or	Open/closed detection to shut down	Level 1 + Automised mechanical window opening	Level 2 + Centralized coordination of operable	

Domain	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
	combined with HVAC system	only fixed windows	heating or cooling systems	based on room sensor data	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…)
Electricity	Reporting information regarding local electricity generation	None	Current generation data available	Actual values and historical data	Performance evaluation including forecasting and/or benchmarking	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection
	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
Electricity	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	
Electricity	Control of combined heat and power plant (CHP)	CHP control based on scheduled runtime management and/or current heat energy demand	CHP runtime control influenced by the fluctuating availability of RES; overproduction will be fed into the grid	CHP runtime control influenced by the fluctuating availability of RES and grid signals; dynamic charging and runtime control		

Domain	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
				to optimise self-consumption of renewables		
Electricity	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 electricity 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)	
Electricity	Reporting information regarding energy storage	None	Current state of charge (SOC) data available	Actual values and historical data	Performance evaluation including forecasting and/or benchmarking	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection
Electricity	Reporting information regarding electricity consumption	None	reporting on current electricity consumption on building level	real-time feedback or benchmarking on building level	real-time feedback or benchmarking on appliance level	real-time feedback or benchmarking on appliance level with automated personalized recommendations
Electric vehicle charging	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
Electric vehicle charging	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)		

Domain	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
Electric vehicle charging	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 authorizition of the driver to the charging station (ISO 15118 compliant)		
Monitoring and control	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 based on building loads	Heating and cooling plant on/off control based on predictive control or grid signals	
Monitoring and control	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 diagn osing functions	
Monitoring and control	Occupancy detection: connected services	None	Occupancy detection for individual functions, e.g. lighting	Centralised occupant detect ion which feeds in to several TBS such as lighting and heating		
Monitoring and control	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	
Monitoring and control	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		

Domain	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
Monitoring and control	Reporting information regarding demand side management performance and operation	None	Reporting information on current DSM status, including mana ged energy flows	Reporting information on currenthistorical and predicted DSM status, including managed energy flows		
Monitoring and control	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
Monitoring and control	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	

ANNEX G. SRI ASSESSMENT PRACTICAL GUIDANCE

Note: this annex contains extracts from the guidance document which was delivered to stakeholders participating in the SRI testing phase. This document can serve as a starting point for deriving more detailed assessment guidelines and protocols.

a. Before you begin...

Select a building of your choice to perform an assessment. This can be a residential- or non-residential building, both newly constructed and existing.

To perform an assessment, start by selecting one of the two calculation sheets:

- Method A: simplified method
- Method B: detailed method *(default)*

Performing the SRI assessment will require the assessor to have a walk-through of the building with appropriate access to the technical building systems. Access to documentation or contact with the facility manager will likely also be of relevance.

b. The "Building information" tab

Start by filling out general building information.

i. Assessor information

Provide information on the assessor. The study team may use this information to contact you after the field trial to discuss your findings.

ii. General building information

Please fill out the fields as indicated.

Field: Building type

Choose from the following options:

- **Residential**
- **Non-residential**

Field: Building usage

In case of a residential building, please choose from the following options:

- **Single family house**

- **Small multi-family house: 10 residential units or less**
- **Large multi-family house: more than 10 residential units**
- **Other: student housing, carehomes,…**

In case of a non-residential building: please choose from the following options:

- **Offices**
- **Educational buildings**
- **Healthcare**
- **Other**

The selected building type and usage will be used to select the appropriate weighting factors. Note that in the current version, no differentiation has been made in the weighting factors within a building type. In other words, all non-residential buildings currently use the same weighting factors, regardless of their building usage.

Field: Building state

Please indicate the current state of the building:

- **Renovated**: applies to buildings that have undergone important energetic upgrades such as thermal insulation and/or upgrades to the technical building systems since the year of construction.
- **Original:** applies to building that have not undergone important energetic upgrades.

Field: Location

Please indicate the location (country) the building is located in. The appropriate climate zone will be determined automatically. 5 climate zones have been defined:

- **Northern Europe**: Denmark, Finland, Sweden, Norway, Iceland
- **Western Europe**: Austria, Belgium, France, Germany, Ireland, Luxembourg, Netherlands, United Kingdom, Liechtenstein, Switserland
- **Southern Europe**: Greece, Italy, Malta, Portugal, Spain, Cyprus
- **North-Eastern Europe:** Czechia, Estonia, Latvia, Lithuania, Poland, Slovakia
- **South-Eastern Europe**: Bulgaria, Croatia, Hungary, Romania, Slovenia

iii. Triage Process

The SRI calculation implements a triage process to identify which services should be taken into account for the final score. It is very likely that due to local and site-specific context some domains and services are not relevant, not applicable or not desirable.

In summary, the following approach has been implemented:

- for some services, an evaluation is only relevant in cases where the technical building systems it relates to are present (hence "smart ready"); this approach is appropriate when assessors cannot unambiguously determine the relevance of a domain. The service is excluded from the assessment

- some services may be mutually exclusive; if such services are not present, they can be excluded from the assessment
- some services might be absent but nonetheless desirable from a policy perspective (hence "smart possible"); this approach may provide stimuli for upgrading existing buildings with additional (smart) services. These services are included in the assessment. As a guiding principle, it could be considered that all services that are mandatory in a Member State's building code are mandatory in the SRI.

A number of inputs are required to perform the triage process as described above.

Triage process:

Please indicate for each of the technical building systems (TBS) whether they are present in the building or not. In some cases, if the TBS is not present, the user will be asked to indicate whether the TBS is mandatory in their country or region. This is the case for certain domains that may be desirable from a policy perspective, as described above (Controlled ventilation, Renewables and EV charging).

Please note that in the final version of the SRI the choice between mandatory and non-mandatory should not be made by the individual assessor, but by the implementing body.

iv. Heating

Field: Emission type

Please select from the options below:

- **TABS (Thermally Activated Building System):** this typically applies to embedded water-based surface heating and/or cooling systems, where pipes are embedded in the concrete core of a building's construction (floor slabs, walls). This does not include underfloor heating.
- **Other hydronic system (e.g. radiators):** this applies to systems that use a liquid heat transfer medium, typically water, glycol or mineral oil.
- **Non-hydronic system**: this applies to systems that do not use a liquid heat transfer medium, for instance, an all-air heating system.

Field: Thermal energy storage

Please select from the options below:

- **Storage present:** this applies to heating systems that include storage capabilities, e.g. under the form of a vessel or thermally activate building systems. This does not include underfloor heating.
- **No storage present:** this applies to heating systems without storage capabilities.

Field: Production type

Please select from the options below:

- **District heating**: this applies to buildings connected to a district heating system;
- **Heat pump**: this applies to heating systems that make use of a heat pump;

- **Central heating – combustion**: this applies to central heating systems using a combustion heat generator, such as oil or gas fired boilers;
- **Central heating – other**: this applies to other central heating systems;
- **Decentral heating (e.g. stoves)**: this applies to systems with individual heaters, such as stoves, electrical heaters or split-unit room air conditioning equipment.

Field: Multiple heat generators

Please select from the options below:

- **Single generator**: this applies to systems with a single generator;
- **Multiple generators**: this applies to systems with multiple generators. This applies both to multiple generators using the same energy source (e.g. two gas fired boiler) or to hybrid systems (e.g. heat pump and gas fired boiler). In this context, district heating is also considered as a heat generator.

v. Domestic Hot Water

Field: Production type

Please select from the options below:

- **Non-electric**: this applies to non-electric production of hot water, such as oil or gas fired boilers**;**
- **Electric:** this applies to electric hot water heaters.

Field: Storage present

Please select from the options below:

- **Storage present:** this applies to DHW systems that include a storage vessel;
- **No storage present:** this applies to DHW systems without storage capabilities.

Field: Solar collectors

Please select from the options below:

- **Solar collector present:** this applies to DHW systems that include a solar collector;
- **No solar collector present:** this applies to DHW systems without a solar collector.

vi. Cooling

Field: Emission type

Please select from the options below:

- **TABS (Thermally Activated Building System):** this typically applies to embedded water-based surface heating and/or cooling systems, where pipes are embedded in the concrete core of a building's construction (floor slabs, walls). This does not include underfloor heating.

- **Other hydronic system (e.g. radiators):** this applies to systems that use a liquid heat transfer medium, typically water, glycol or mineral oil.
- **Non-hydronic system**: this applies to systems that do not use a liquid heat transfer medium, for instance, an all-air heating system.

Field: Thermal energy storage present

Please select from the options below:

- **Storage present:** this applies to cooling systems that include storage capabilities, e.g. under the form of a vessel.
- **No storage present:** this applies to cooling systems without storage capabilities.

Field: Multiple heat generators

Please select from the options below:

- **Single generator**: this applies to systems with a single generator;
- **Multiple generators**: this applies to systems with multiple generators, mostly restricted to large buildings.

vii. *Controlled ventilation*

Field: System type

Please select from the options below:

- **Mechanical ventilation:** this applies to all mechanically driven ventilation systems, including balanced ventilation (mechanical exhaust and supply), mechanical exhaust, mechanical supply and hybrid ventilation.
- **Controlled natural ventilation:** this applies to controlled natural ventilation systems, e.g. automated opening of windows or other dedicated ventilation openings. Manual control of openings is not considered to be controlled natural ventilation. If manual control is needed, please indicate in the triage process that the TBS controlled ventilation is not present.

Field: Heat recovery

This field is only applicable in case of mechanical ventilation.

Please select from the options below:

- **Heat recovery**
- **No heat recovery**

Field: Space heating

This field is only applicable in case of mechanical ventilation.

Please select from the options below:

- **Used for space heating**
- **Not used for space heating**

Field: System sub-type

This field is only applicable in case of mechanical ventilation used for space heating.

Please select from the options below:

- **All-air:** this applies to ventilation systems which use air as a medium to transport energy from the ventilation unit to the conditioned space;
- **Combined Air-water**: this applies to systems where both air and water are used for providing the required conditions in the conditioned space. The air and water are cooled or heated in a central plant.

viii. Dynamic Envelope

Field: Movable shades, screens or blinds

Please select from the options below:

- **Present:** this applies both to devices providing solar protection (to avoid overheating) and devices avoiding glare;
- **Not present:** this is applicable when no devices are present providing solar protection (to avoid overheating) and devices avoiding glare.

ix. Electricity: renewables & storage

Field: On-site renewable electricity generation

Please select from the options below:

- **On-site renewable electricity generation**: this includes, but is not limited to photovoltaic cells, electricity from wind and CHP. Note that this field focuses on electricity, solar-thermal panels is covered under DHW;
- **No on-site renewable electricity generation:** this applies when no renewable electricity generation is present on-site.

Field: Storage of on-site generated renewable electricity

This field is only applicable in case on-site renewable electricity generation is present.

Please select from the options below:

- **Storage present:** this includes batteries and thermal energy storage (TES);
- **No storage present:** this is applicable when no battery and/or TES is present.

Field: CHP (Combined Heat and Power)

This field is only applicable in case on-site renewable electricity generation is present.

Please select from the options below:

- **CHP:** this is applicable when a combined heat and power plant is present on-site.
- **No CHP:** this is applicable when no combined heat and power plant is present on-site.

x. *Electric Vehicle Charging*

Field: On-site parking spots

Please select from the options below:

- **On-site parking:** this is applicable if parking is available on-site.
    - → For residential buildings, this may typically include a driveway, garage(s) or dedicated parking spot(s) in a (underground) car park.
    - → For non-residential buildings, this may typically include a garage(s), parking lots or dedicated parking spot(s) in a (underground) car park.
- **No on-site parking:** this applies when no parking is available, or in case of public parking.

Field: Electric vehicle charging spots

Please select from the options below:

- **EV charging:** this applies when at least one of the aforementioned on-site parking spots provides a recharge point;
- **No EV charging:** this applies when none of the aforementioned on-site parking spots provides a recharge point.

c. The "Calculation sheet" tab

The calculation sheet is where the actual assessment takes place. Every line in the sheet represents a service of the smart service catalogue.

Based on the triage process, the services that are not applicable to this particular building will be greyed out. No assessment is required for these services. The calculation sheet explicitly mentions whether a service is to be assessed (1 = to be assessed; 0 = not to be assessed).

For each service to be assessed, three fields may be completed:

- **Main functionality level**: please enter the functionality level of the service. A description of the different functionality levels is provided in columns G through K. Please note:
    - If the field is left blank, or the functionality level is not valid (e.g. higher than the maximum possible functionality level), a warning will be displayed in column F, and no SRI score will be calculated.
    - If the functionality level is valid, the chosen functionality level (column G-K) will turn orange, to facilitate visual validation.
- **Share of the functionality level**: this field enables to test partial compliance of a building to the main functionality level. If you do not wish to test partial compliance, please keep the default value of 100%. Else, indicate the percentage of net surface area of the building that complies with the main functionality level. For further instructions on partial compliance, refer to section e.
- **Optional: additional functionality level**: if the share of the functionality level (column F) is set to less than 100%, please provide the functionality level that applies to the remaining surface area.
- **Optional: assessor comments**

d. The "Results" tab

Three types of results are displayed in the "results" tab:

- **Total SRI score**: the total SRI score, taking into account domain weightings and impact weightings.
- **Impact scores**: the impact scores for each impact criterion, taking into account domain weightings.
- **Domain scores**: the domain scores for each domain, taking into account impact weightings.

e. Partial implementation of services

In some cases, a building will not comply fully with a given functionality level. For instance, control of artificial lighting power based on daylight levels may be installed in the open office space, but not in corridors. There are two ways to implement this in the SRI calculation:

- By default, it is assumed that the selected functionality level applies to the *entire building*. Therefore, the highest functionality level that applies to the entire surface area of the building should be selected. Alternatively, one might also indicate the functionality level that applies to the most relevant share of the building (e.g. a services present throughout a dwelling apart from the attic and corridors).

- Optionally, a split-up can be made, where up to two different functionality levels may be defined to include such partial compliance in the calculation.

The share of each functionality level is determined using the **net surface floor area.**

Note that at this moment the calculation only accommodates the definition of two functionality levels per service.

To illustrate the process of entering partial compliance, the example of daylight correction will be used. It is assumed that 60% of the building is equipped with automatic dimming (functionality level 3) and the remaining 40% is equipped with manual (central) controls (functionality level 0).

Please follow these steps in the tab "calculation sheet":

- In the field **"Main functionality level"** (column E), set the functionality level of the first zone of your building, in this case "3".
- In the field **"Share of the functionality level"** (column F), set the percentage of net surface floor area of the building that complies with the main functionality level, in this case 60%.
- In the field **"additional functionality level"** (column G), set the functionality level of the remaining surface area, in this case "0". The share of this functionality level will be calculated automatically, and is displayed in column H.

ANNEX H. SUMMARY OF DG ENERGY TARGETED PUBLIC CONSULTATION

a. Context

A targeted consultation was opened on the website of the Commission's DG Energy from 9 August 2019 to 11 October 2019. As stated on the survey's webpage[179], this consultation offered stakeholders the opportunity to contribute to the SRI development process and to provide relevant information in a structured way.

The consultation was open to all and sought in particular feedback from stakeholders from the fields of interest to the development of the SRI (e.g. product manufacturers, installers, building designers, building developers, contractors, etc.). The survey included 27 questions, articulated in five different sections:

- General information on the respondent,
- Questions about the audience and scope of the SRI,
- Questions on communication of the SRI[180],
- Questions on the implementation of the SRI,
- Additional, free comments.

The consultation allowed to collect detailed feedback from 93 respondents located in 21 Countries[181]. The main outcomes, articulated along the different topics addressed, are outlined in the following sections.

b. Respondents data

A total of 93 respondents from 21 different countries responded in the open public consultation. Belgium (30%), France (9%), Finland, Germany and Italy (8%) were the most represented countries. One out of two worked for a company or a business organisation and almost 20% for public authorities and non-governmental organisations. The most frequent expertise were manufacturers (36%) and suppliers (26%) of technical building systems and energy services and aggregators developers (24%). Not all respondents responded to all questions. Furthermore, the number of respondents in the open comment sections are often considerably lower than those answering to the related multiple-choice question.

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[179]The online survey was available at the following address: https://ec.europa.eu/energy/en/consultations/consultation-establishment-smart-readiness-indicator-buildings

[180] Here, communication refers to the way the information on smart readiness is communicated to end users.

[181] With a large representation of Belgium, as usual for such consultations, since many stakeholder associations are based on Brussels.

c. SRI target audience and scope

When asked about the target audience of the SRI, most of the respondents suggest to target first building owners and second building occupants, followed by facility managers, professional property developers and architectural and engineering offices. Informing building visitors or authorities was perceived least crucial. The majority of the respondents is in favour of targeting both residential and non-residential buildings in the SRI scope (60%).

Some respondents have commented that they suggest giving priority to large buildings and/or buildings with a high energy demand (whether commercial or residential), which are perceived to have a greater potential to benefit from smart technologies.

The majority of the respondents are in favour of addressing both new and old buildings (76%); whereas 24% of the answers suggest to focus solely on new constructions. In the comment section of the survey, 19 out of 93 respondents have made explicit reference to their perceived need to also include the existing building stock, given their large share on the market and the high expected gains from improved smartness. Some stakeholders suggest to only issue an SRI assessment for existing buildings in case of extensive building retrofits.

d. Adapting the SRI to context and future evolutions

A large majority of respondents (84%) are in favour of adapting the calculation methodology of the SRI to specific conditions and contexts. In their comments, the focus is primarily on climatic boundary conditions and the type of building. For the latter, some respondents argue that what it is intelligent in one building (e.g. a residential building) might not be it in another (e.g. a shopping mall or an office). One respondent suggests to also differentiate the methodology between new and existing buildings. Some stakeholders comment that the main audience can also differ between building types, thus suggesting a more simplified approach for residential buildings. Some of the stakeholders who voted in favor of adapting the SRI to local contexts nevertheless commented that "the variability of the methodology should be constrained" (…) "so as to guarantee consistency to the greatest possible extent across the EU during the implementation phase".

It is envisioned that the SRI methodology might need to be updated, in particular in relation to technological progress. The suggestions on the optimal update period are quite diverse: 1-3 years (17%), 3 years (28%), 5 years (31%), more than 5 years (11%) and 'other' (12%). In the comment section, some stakeholders relate the update of the methodological framework to the need for re-issuing and SRI assessment for a particular building.

e. SRI relations to other topics and schemes

Respondents were asked whether they think that other aspects of buildings (e.g. energy performance or broader life cycle aspects) should be expressed conjointly with the SRI. 73% answered in favour of this. 48 additional comments were received. 36 of these refer to linking the SRI to information on energy performance of the building (19 of these answers explicitly mention linking to Energy Performance Certificates (EPCs)). A broad range of other suggestions is received, including Life Cycle (impact) Assessment (6x), information on holistic sustainability (2x), information on indoor Environmental quality (2x), information on safety and security (2x), age of equipment, etc.

One stakeholder claims that only expressing the smartness of a building, without also communicating on the building's energy performance, can give a misleading picture, in light of the importance of thermal insulation for the flexibility of a building's overall electricity demand. One stakeholder warns that it is unclear what "expressed conjointly" implies. In some aspects, there might be a lack of consistent common assessment methodologies in the EU (e.g. smart ready accessibility services), thereby risking to jeopardise the consistency and congruence of the SRI itself.

When questioned on the need to also include smart ready accessibility services, 64% of the respondents answered in favour of this. Suggestions range from smart services for deaf or blind people, lighting controls for people with mobility problems and the shear accessibility of the building itself. In the comments, further nuances are sometimes added, e.g. suggesting to restrict this information to particular building types (e.g. hospitals), or to restrict this to future versions of the SRI. Some of the respondents who voted against the statement claim that this is out of scope of the Energy Performance of Buildings Directive or that accessibility should be mandatory in the building and thus not specifically evaluated.

f. SRI formatting

Respondents were also questioned on their preferences regarding the presentation of the SRI score(s): either as an overall smartness score, or sub-scores for each of the three key SRI functionalities highlighted in the EPBD [user needs, energy performance and demand side flexibility], or sub-scores by specific technical domains, or sub-scores by specific impacts. The largest group (32%) opted for communicating the sub-scores for each of the 3 key SRI functionalities separately, others preferred to report only one score (18%) or scores related to the technical domains (18%) or on the level of the more detailed impact criteria (16%). 17% of respondents filled out 'other', detailing various configurations of combining both aggregated scores and more detailed scores at the level of the three key functionalities, impacts or services.

A large majority of respondents suggest to include recommendations along with the SRI (89%). In the comments there is less agreement on how this should be implemented: some suggest generic recommendations while other favour case-specific information, some suggest to also include estimated costs for upgrades while a few other responses explicitly demand to not include cost estimates.

Questioned on the presentational format, 41% preferred a mnemonic scale (such as A to G, or 1 to 10 stars, etc.); and 17% preferred percentages (from 0% [no smart readiness] to 100% [maximum currently achievable smart readiness]). 30% opted for a combination of both. Those opting for the option 'other' suggest various alternatives, including physical benchmarks or quantitative data of relevance for utilities and flexibility aggregators.

Seventy-five percent of the respondents thought that SRI should prioritise an electronic presentation but they also suggest that it needs to be printable when addressed to persons with disabilities and older persons (94% considered this relevant).

g. SRI implementation and assessment

Respondents were asked whether they suggest that the SRI would operate independently, or whether it rather should be combined with existing schemes (e.g. energy performance certificates) or future schemes (e.g. life cycle performance of buildings, with the Level(s) tool)? 69% of respondents suggested to combine the SRI with other schemes.

In the comment section for this question, eight respondents refer to the multitude of existing information, schemes and data, and plead for a structured way to store and process all information, sometimes referring to building logbooks or building passports. This demand – e.g. "All information related to building performance must be put together in a structured framework, easily accessible and usable, and as well easy to be updated"- does, however, not necessarily imply a joint assessment process of the multiple schemes. Four respondents ask for a joint assessment with other schemes including Level(s) and other sustainability schemes. 23 respondents suggest a combined assessment with energy performance certificates (EPC). Arguments for this include the perceived need to tie the SRI introduction to a mandatory assessment to support market uptake and the reduced assessment costs and administrative burden by assessing both schemes jointly. Furthermore, some respondents add that they see a need to tie EPCs and the SRI together to avoid confusion and to be able to provide sound insights and investment suggestions. Some barriers to combining schemes are also voiced, e.g. the person assessing the energy performance is not necessarily capable of calculating the SRI. Three respondents comment that combinations could be pursued in the long term, but suggest that implementation would start independently from other schemes.

With regard to the implementation, 36% of the respondents considered that the responsibility for implementing the SRI should reside at the member state level, while 31% considered that it should be organised at both national and European level. 10% of the respondents are in favour of having a large role for the private sector in the implementation, although more than half of these express this should be in combination with either Member State or European Commission involvement.

While 42% state that the assessment of the SRI should be restricted to an independent inspection process, 11% are in favour of solely a self-assessment and 36% of a combination of both self-assessment and an independent inspection process. In the comments section, further nuances are added by some stakeholders, e.g. making this dependent on the type of assessment method (referring to method A and B described in the interim report of the SRI study), the business case of implementing the SRI or individual Member State preferences.

The technical study introduces the concept of potentially evolving to a remote SRI assessment process through remote measurement of the technical building systems. If this would become possible in the future, a large majority (91%) think this should be permitted. Some people pointed out that such an approach will also enable better commissioning of buildings, potentially in a continuous process. Some respondents doubt the feasibility or point out cyber-security concerns.

A question was raised on who should pay for the costs of the SRI assessment (noting that these costs are not yet known; however, the Impact Assessment accompanying the proposal for amending the Energy Performance of Buildings estimated these at a fraction of the costs of an energy performance certificate). 42% expressed that building owners and occupants should be the sole party to cover the costs of the SRI assessment, while an additional 29% foresees payments of owners and occupants in combination with other actors (Utilities, Smart services and technology industry, Member States).

Various other combinations of actors were suggested; 30% of them contained contributions from either utilities or the smart services and technology industry. 26% of the suggested combinations contained Member States amongst the contributing parties. Some also suggested that utility providers could help financing the process through Energy Efficiency Obligation Schemes when rolling out EPCs.

62% consider that supporting measures are needed for the implementation of the SRI. In order of preference, it is suggested that the implementation of the SRI be supported by "Awareness raising and promotional campaigns" (40%); "Integration with existing schemes (e.g. EPC)" (38%); "incentives" (38%); "Supporting policies targeting the uptake of specific smart technologies" (31%) and "Mandatory regulation at Member State level" (27%). Additional suggestions were raised including tax benefits and using the SRI scheme as an additional criterion for granting public funds and support schemes in housing and building renovation policies.

Finally, there was the opportunity to provide further comments at the end of the survey. 47 answers were received. Most of these provided further clarification to statements related to earlier questions, or referenced other statements or documents provided by the stakeholder in previous consultations of the technical support study. Comments on the technical specifications of the calculation methodology have been processed by the technical study team.

ANNEX I. GUIDING PRINCIPLES

As a precursor to the development of an SRI methodology it is important to consider the set of factors, or guiding principles, that were set out to guide SRI's methodological development. These were considered in the first technical study and the text reported then is reprised verbatim below.

a. The audience for the SRI

Prior to designing the SRI, it is essential to consider who it is to be aimed at and hence designed for. It is imperative that this is thought through if the content, organisation and presentation of the SRI is to be salient and motivating and hence to affect positive change.

In principle, the SRI will present smart readiness information with regard to both existing or new buildings and if it is to be an effective stimulus to action it will need to influence decisions regarding the smartness of these buildings. In principle, both building owners and occupiers can make smart building investment decisions and both can be affected by the degree of smartness attained; however, in general the owner will make the smart services investments and the occupier will be affected by them (the owner can be too but only indirectly so if they are not also the occupier and responsible for utility bills). Facility managers too will be an important audience for the SRI as they may operate the smart systems and may influence the investment decisions. In addition to the users and investors, the other important audience for the SRI will be the smart service providers. If an SRI resonates with them it can help organise and position their service offering by providing neutral and common framework wherein the capability of their smart services can be directly compared with those of their competitors including the incumbent non-smart services. This is likely to be critical to the schemes success because experience shows that service providers not only adjust their business models to position their services within the context of such schemes but can also strongly promote and amplify the schemes impact providing it is seen to be a viable and influential instrument. The potential service providers are very broad. They include: DSOs and TSOs, aggregators, micro-grid operators, heat network operators, gas and oil suppliers and service companies, RES and storage suppliers, TBS manufacturers and OEMs (Original equipment manufacturers), building service engineers and electro-mechanical contractors, facility managers, e-mobility service providers and equipment manufacturers, IT service providers and equipment suppliers, metering companies, building designers, building renovators, ESCOs and multi-utility service company providers, maintenance servicing companies, water utilities and service companies, third party assessors, health service providers, certification and accreditation agencies.

Ideally the SRI needs to resonate with all the key actors and needs to provide a framework that enables each party to find what they need regarding the articulation of smart services and capabilities within it. However, each of these parties is likely to have quite different needs and expectations and this implies that to the extent possible the SRI should be structured so that it can reflect and convey relevant information at the level each needs. Ultimately though it is the building occupiers, bill payers and owners who are the most important audience and thus their needs should take precedence.

b. The SRI value proposition

Establishing the value proposition of the SRI and considering how this affects its impact as a change vector is important for the SRI's success but also design. The key value propositions articulated in the Commissions call for tender are:

1) Readiness to adapt in response to the needs of the occupant (e.g. the heating system can be switched on or shifted to lower temperatures when there is nobody at home) and to empower building occupants by taking direct control of their energy consumption and/or generation (i.e. prosumer);

2) Readiness to facilitate maintenance and efficient operation of the building in a more automated and controlled manner (e.g. anticipate problems with clogged filters; use of CO_2 sensors to control the flow rate of ventilation systems); and

3) Readiness to adapt in response to the needs/situation of the grid (e.g. reduce consumption when there is not enough electricity in the grid system or switch on home appliances which could modulate peak electricity production - generally stemming from renewables).

The methodology also needs to be mindful of the desires of users of the SRI and that it is possible that building occupiers, service bill payers and owners might express their priorities differently. In the absence of doing market research to establish what the value proposition among these key audiences is, it is speculative to imagine what these may be. A priori it is likely to reflect a blend of desires regarding smart capabilities to minimise total expenditure on utilities and services, increasing comfort and convenience, providing health alerts and improving the health of indoor environments, provision of smart aesthetic experiences, and identification of faults and facilitation of maintenance. It may also address safety (e.g. fire) and security services but these are outside the scope of the current study as they are outside the scope of the EPBD. While facilitating e-mobility and helping reduce energy bills is likely to feature highly on people's priorities enhancing grid-flexibility is not except to the extent that it is a trigger to bill reduction (i.e. at best it is likely to be perceived as a means to an end and not an objective in its own right). This is likely to be a very important factor in how the SRI could be rolled out because if its value proposition to end customers is presented primarily in terms of grid flexibility engagement then engagement with the scheme and impact are likely to be low. More likely it would require careful packaging and presentation of the value propositions of which flexibility is one among many.

In addition, to be successful it will be necessary to structure the SRI so its value proposition is of greater value than its cost of implementation. Otherwise engagement with the SRI will not occur.

c. Policy objectives

The broad policy objectives for the SRI have been articulated in the Commission's tender document for the study and behind these is the intention that the SRI should support the EU's broad energy policy agenda by facilitating energy savings in buildings, improving grid balancing capability and thereby facilitating deeper penetration of intermittent RES, and facilitating the move towards low carbon transport via stimulating adoption of e-mobility solutions. In a higher-level sense these objectives equate to a desire to support the decarbonisation of the energy system, increase energy security and provide value for money to end-users and bill payers. Due to its wide scope and multifaceted nature the SRI will interface with many other policy domains and objectives, however. These concern health, economic efficiency and employment, consumer rights and data protection, and digital technologies (e.g. cyber security) among others. In principle, the SRI should comply with consumer rights, data protection and cyber security concerns and requirements.

It is important though to have clarity regarding the policy-related objectives stated in the EPBD to ensure the scheme is designed in a manner that best satisfies them:

"The smart readiness indicator should be used to measure the capacity of buildings to use information and communication technologies and electronic systems to adapt the operation of buildings to the needs of the occupants and the grid and to improve the energy efficiency and overall performance of buildings. The smart readiness indicator should raise awareness amongst building owners and occupants of the value behind building automation and electronic monitoring of technical building systems and should give confidence to occupants about the actual savings of those new enhanced-functionalities. Use of the scheme for rating the smart readiness of buildings should be optional for Member States"

This text clearly outlines the purpose of the SRI and this needs to be reflected in the methodology used to derive it.

d. The information to be conveyed

The preceding discussion of the audience, value proposition and policy objectives should inform the decisions about the information the SRI should convey. The art is to convey the information which will best stimulate change that supports the policy objectives without provoking unintended consequences. As the stimulation of this positive chance relies on the target audience being receptive to and motivated by the information they receive this requires the information to embrace the elements which can achieve this while retaining the required policy-related content. In the case of the SRI the target audience is very complex because the diverse set of smart service providers are also key actors and vectors of positive change. The great complexity of information which defines and describes the smart service capability cannot be ignored either.

The information needs of the end-user of the building (building occupier, owner, bill payer) are likely to be contradictory. On the one hand consumer research and behavioural science studies find that end-users decision-making is most influenced when information that informs the process is simple and limited (i.e. there is only a small amount of it). On the other hand, the same types of research will find that un-transparent information that does not relate to something tangible to the end-user is not accessible and is not utilised in their decision-making. The former observation would tend to drive the SRI in the direction of an aggregate indicator that pulls together scores across all the impacts of concern to (and hence motivating) to end-users. The latter observation would tend to mitigate against such simplified compound scores/rankings because the information they contain becomes muddled together and hence loses transparency and meaning. This is a particular problem for a smartness indicator because there is no common understanding of what smartness means and hence of what is being indicated when a compound indicator is used.

If one considers the issue from the perspective of service providers they are likely to want the information conveyed in the indicator to be able to clearly position the value propositions of their services against the rest of the market and incumbent (non-smart) services. As these services are inherently diverse this implies conveyance of information with a high degree of granularity. For some stakeholders such as DSO's, aggregators etc., additional quantified information such as energy consumption and flexibility metrics might be useful, alongside a compound score from the indicator. Furthermore, some audiences might want to receive additional information besides the scoring of the building in its present condition. To reach the policy objectives of spurring the uptake of smart services in the building stock, a valuable addition could be to provide tangible suggestions on the next steps to increase the smartness of a specific building.

e. Communication of the information

The form taken to communicate the information to the target audience will also affect its impact as positive change agent. In general research has proven that heuristic scales which convert underlying scores into more accessible rankings (such as A to G scales, 0 to 5 stars etc.) are more easily accessible by a non-technical audience than quantified numerical scores. Firstly, the heuristic scales clearly indicate all the end points and where the service offering lies upon it. Secondly, using a limited set of quantised levels makes it easier to process the information and act upon it. The decisionmaking process can be much more tractable with such scales because a service procurer could follow a simple horizontal rule e.g. nothing worse than a class B, rather than having to get lost in the technical details behind these rankings. Such information presentation can partly overcome the problems highlighted in the previous section. This can however only be successful if end-users feel that the scale reflects something they understand and care about. For other audiences, such as utility providers or contractors, quantified numeric scores could be preferred over heuristic scales.

The choice of media used to communicate the information is another aspect any SRI scheme would need to consider. For some intended audiences, secured (online) datasets might for example be preferred over a printed output. As far as the methodology is concerned though, this is a secondary issue, and can be settled upon at a later stage closer to implementation.

f. The integrity of the SRI

The integrity of the SRI will be crucial for its success. If the target audience does not believe the information it contains it will not make any positive impact in their procurement and utilisation decisions. The strength of belief in the schemes integrity will be clearly be affected by the integrity of the rating and assessment process and the perception of this.

g. The credibility of the SRI

The credibility of the SRI will also be crucial for its success. If the target audience does not believe the technical basis for the scoring is sound then it will undermine its impact. For some audiences a quantification in physical metrics (kWh,…) could increase the perceived credibility. This might however also entail additional risks towards credibility, in case the predicted values differ significantly from measured data in its actual operation.

h. Adaptability to context

The SRI methodology needs to avoid unintended perverse outcomes by being adaptable to relevant contextual factors. These can include variations by building type, by climate, by culture and the impact it has on the desire to have certain services. These in turn can lead to some smart services or even whole domains being inappropriate in some contexts. The scoring methodology deployed needs to be capable of adaptation to reflect this context and to avoid penalisation for the absence of irrelevant or impossible/impracticable services. It also needs to be adaptable to reflect divergence in priorities and implementation capabilities by jurisdiction. The implication of these concerns is that the methodology should be modular and flexible.

i. Smart ready and smart now

The distinction between the two concepts is potentially important in the design of an indicator. The term smart ready implies that the building itself is smart but its potential to realise the benefits from smart services may be constrained by limiting factors in the capability of the services it connects to at its boundary. This recognises the distinction between smart readiness as opposed to operational smart capability.

This is the spirit in which the methodology presented in the rest of the report aims to represent smart readiness.

j. Future proofing – allowing and encouraging innovation

The SRI and its methodology should not be inhibitors to innovation but rather should encourage it, thus, it is important that the methodology is such that positive innovations can be reflected and rewarded as early as possible. This means that the methodology should allow relevant new capabilities to be reflected as soon as possible and address future proofing needs by: allowing new solutions, recognising building smart readiness and avoiding negative lock-in effects, and recognising the distinction between smart readiness as opposed to operational smart capability. Furthermore, the impact of a rapidly changing landscape of policies and commercially available services can be incorporated by some extent by recognising a distinction between smart readiness as opposed to operational smart capability.

k. Fairness and a level playing field for market actors

The SRI methodology and scoring system needs to create a level playing field for market actors and aim for technology neutrality through the definition of functional capability rather than the prescription of certain technological solutions. The manner in which the smart readiness services were defined in the Task 1 catalogue reflects this principle.

l. The potential usage of qualifying preconditions

As the definition of what constitutes a smart building is open to interpretation some stakeholders have proposed that some preconditions should be imposed before a building is considered eligible to receive an SRI. For example, this was proposed in the first stakeholder meeting for the building energy performance. Others have suggested that certain services should satisfy minimum qualification thresholds for health or air quality before they become eligible. The methodology presented in this report is agnostic on this topic and is structured such that it could be used with or without such qualifying preconditions.

m. Interaction with other policy instruments

At present it is unclear how the SRI would interact, or operate in conjunction with, other policy relevant instruments - most notably EPCs. It is therefore important that the methodology set out permits any form of interaction deemed appropriate.

n. Treatment of fixed (static) versus transportable (mobile) smartness features

In principle there is a distinction between smart services that are embedded in the building and those that can be readily taken somewhere else. Capability for remote operation of smart building services by the occupant or their designated operative would need to stay with any future occupant/designated operative of that building for the SRI score to remain unchanged subsequent to a change in occupancy.

o. Time and cost requirements

Assessing the smartness of a building will require to inspect the building and its systems on site. The time and efforts needed for this will depend on multiple variables such as the number of services to be inspected, the detail of the assessment of each of the services, the size and accessibility of the building and the experience of the assessor. The costs for deriving an SRI will also be affected by the requested qualifications of the assessor and the additional efforts needed for operating any accompanying calculation software, in administrative tasks, travel time to the inspection site, etc. An important consideration in deriving the SRI methodology will thus be to balance the desire of a sufficiently detailed assessment with the desire to keep the time and cost requirements limited.

p. Building-specific features

Buildings and building usage display a great variety across the building stock. Ideally, an SRI reflects this complexity by encompassing some differentiation with regard to building usage typologies (e.g. residential, offices, educational buildings) and potentially also the age of a building (e.g. newly constructed versus existing building stock). Even within a single building differentiation can occur if it mixes different functions or if smart features are only present in specific parts of the building. The SRI methodology should be flexible to accommodate this large variation and for example allow for the roll-out of specific versions tailored towards a specific building type.

q. The SRI assessment process and aides to assessment

In theory an SRI assessment could be conducted by a variety of different actors including: specialised third-party assessors, the building occupants, facility managers, building owners, hired contractors, DSO/TSO operatives, IT service providers, building service engineers, ESCOs, smart service providers, etc. For the assessment to be reliable it is likely to necessitate that a competent and independent party should make the assessment (much as is the case for most EPCs). For the time being it is also expected that an assessor would need to have access to the building to be able to make an inspection on site. It is likely though, that as an SRI scheme matures that the assessment process would evolve to reflect on-going developments. Thus, as more and more of smart readiness features and associated service offerings become classified and standardised in accordance with the scope and definitions used in the scheme the means of making the assessment could evolve. Initially many service offerings and capabilities would require on-site visual assessment supported by access to relevant service documentation (either as hard copies or electronically). This process would be facilitated by the provision of clear markings on the products and documentation descriptions to indicate at a glance the service offerings the equipment provides with a one-to-one correspondence to the service and functionality level taxonomy used in the scheme. As the scheme matures it is conceivable that this information could be made available for packaged smart-ready products via some form of standardised signalling and reading/scanning process e.g. via QR codes or similar on the smart readiness equipment, documentation or associated web-sites. Equally, in principle smart- ready services installed as equipment systems by contractors (and not just supplied as packaged products that non-professional users can install and use) could also be subject to a smart readiness capability assessment by the contractor who then leaves on site smart readiness capability status information in a form that facilitates the assessment process. Again, this could be via QR codes or similar.

The process could be further facilitated were one central point to be established where this smart readiness status information would be deposited each time a new SRI service is added or an old one removed. Nor does this status information necessarily need to be stored and recorded on site. It could be loaded into a cloud-based server such that a SRI assessor would be granted access to this information to be able to make the assessment (either remotely or in conjunction with a site visit). Equally the systems could be provided with live remote status assessment capability to facilitate their remote and automated assessment.

Under such scenarios the assessor could be charged with making an aggregate assessment of the smart readiness service status information provided by packaged equipment suppliers, system installers and related service providers; each of whom could be held legally liable for the accuracy of the information they communicate into the system. Some kind of occasional sampling and verification process could then be established to support the integrity of this system. A self-assessment process wherein owners, occupiers or facility managers make the assessment and communicate it to the managing authority is also conceivable but may suffer from low engagement and lack of credibility.

Then a working assumption is made that a competent third-party assessor will make a site visit to the premises to conduct the SRI assessment and compute its score. This may evolve over time into more sophisticated and less intrusive and costly assessment processes as the scheme becomes established. It is important to appreciate that owners, facility managers and occupiers may affect access to a building to make an SRI assessment or equally may need to grant permission to access related data. This implies that they have to see the SRI as something they value in order for them to engage in and support the assessment process.

r. Data protection

With the advent of the General Data Protection Directive (GDPR) data protection will be a key requirement for the smart readiness indicator. This will not only affect smart services in buildings, but also the SRI certification itself. In particular, the building owner and occupant will need to consent to their data being used for any purpose and the data will need to be anonymised if it is to be used for statistical and research purposes. In addition, data owners will need to be granted access on request to any data that they own.

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