SUPPORT FOR SETTING UP A SMART READINESS INDICATOR FOR BUILDINGS AND RELATED IMPACT ASSESSMENT

EXECUTIVE SUMMARY of FINAL REPORT

Verbeke S., Waide P., Bettgenhäuser K., Uslar M.; Bogaert S. et al.

EXECUTIVE SUMMARY of the study accomplished under the authority
of the European Commission DG Energy

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Extensive summary of the final report

of the technical study

"Support for setting up a Smart Readiness Indicator for buildings and related impact assessment"[1]

Verbeke S., Waide P., Bettgenhäuser K., Uslar M.; Bogaert S. et al.

This document summarizes the main conclusions of the technical study commissioned and supervised by the European Commission services (DG ENERGY) towards the development of a smart readiness indicator for buildings[2]. The smart readiness indicator is part of the revised Energy Performance of Buildings Directive[3] (EPBD). A Smart Readiness Indicator (SRI) for buildings shall provide information on the technological readiness of buildings to interact with their occupants and the energy grids, and their capabilities for more efficient operation and better performance through ICT technologies. The SRI is expected to become a cost-effective measure which 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.

The technical study has explored the potential characteristics of the indicator via a transparent, open and interactive process, with the objective to support and inform the policy making process. This extensive summary complements the technical report with the aim to present the main concepts and outcomes of the study in a clear and concise format to interested stakeholders.

This summary, and the full report it is based on, solely presents the view of the consortium carrying out the study. The content of this report does not necessarily reflect the official opinion of the European Union. Beyond the scope of this preparatory study, the process for defining the indicator will further develop in the coming months under the supervision of the Commission services. To support this work, additional technical studies are planned and consultation with stakeholders will continue to be an essential part of the process towards the establishment of the SRI.

This document only presents a summary of the main outcomes of the study. The interested reader is referred to the full version of the final report for further details[1,2].

[1] Technical study carried out by VITO, Waide Strategic Efficiency, Ecofys and OFFIS for European Commission DG Energy.
Reference: Verbeke S., Waide P., Bettgenhäuser K., Uslar M.; Bogaert S. et al.; "Support for setting up a Smart Readiness Indicator for buildings and related impact assessment - final report"; August 2018; Brussels

[2] See https://smartreadinessindicator.eu for further information on the study.

[3] See press release of May 14th 2018: https://ec.europa.eu/info/news/commission-welcomes-council-adoption-new-energy-performance-buildings-directive-2018-may-14_en. The Energy Performance of Building Directive is part of the Clean Energy for All Europeans Package

CONCEPT - SMART READINESS INDICATOR – SRI

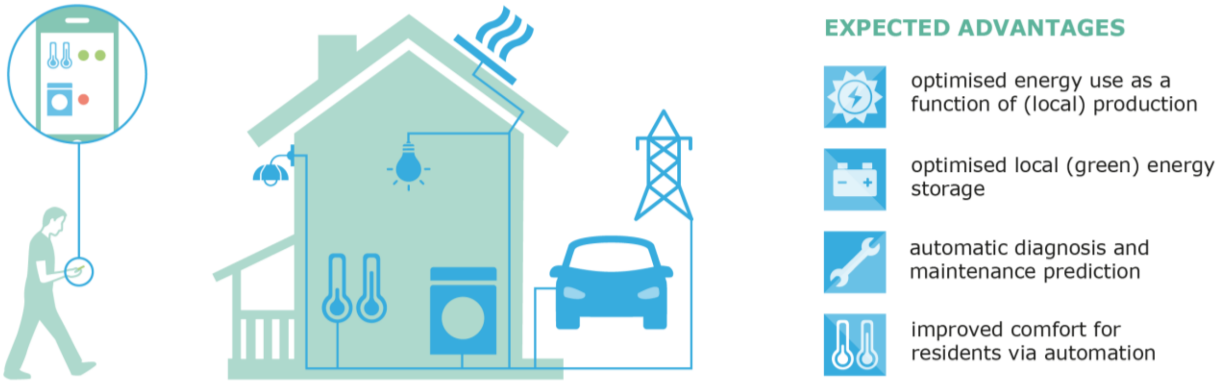

Figure 1 – Expected advantages of smart technologies in buildings

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 for controlling energy efficiency and energy flexibility as part of their daily operation. Such smart capabilities can effectively assist in creating healthier and more comfortable buildings, which adjust to the needs of the user and the energy grid while having a lower energy consumption and carbon impact.

A greater uptake of smart technologies is expected to lead to significant energy savings in a cost-effective way, while also helping to improve in-door 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. In the revised **Energy Performance of Buildings Directive** (EPBD) - which was published on 19 June 2018 - one of the focal points is to improve the realisation of this potential of Smart Ready Technologies (SRT) 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 at making the added value of building smartness more tangible for building users, owners, tenants and smart service providers. This technical study was commissioned to support to the development of this indicator.

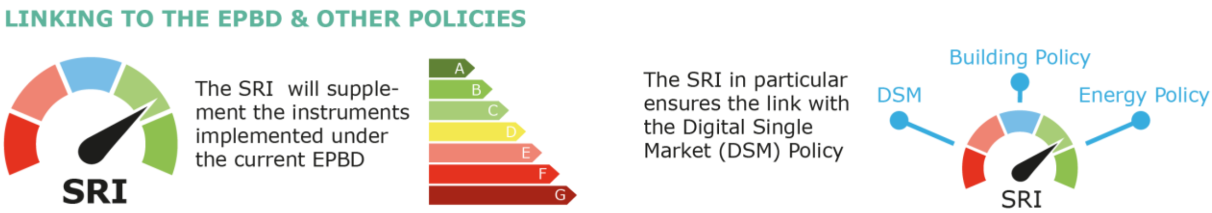

Figure 2 – Graphical representation of linkages of the SRI to other policy initiatives

The indicator is intended to **raise awareness** about the benefits of smart technologies and ICT in buildings (from an energy perspective, in particular), **motivate consumers** to accelerate investments in smart building technologies and **support the uptake of technology innovation** in the building sector. The indicator can also improve policy linkages between energy, buildings and other policy segments, in particular in the ICT area, and thereby contribute to the integration of the buildings sector into future energy systems and markets.

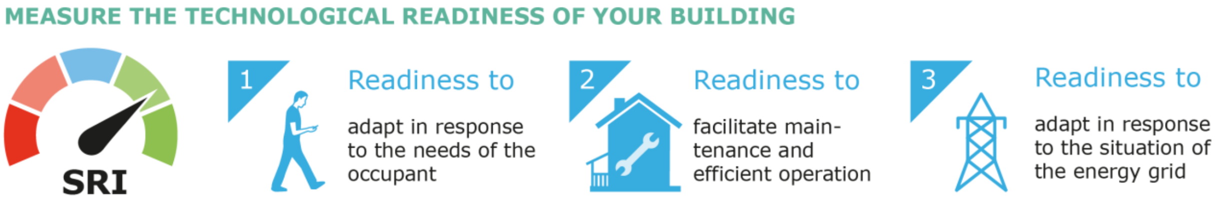

Figure 3 – Three key functionalities of smart readiness in buildings

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

For building occupants, owners and investors of both existing and new buildings, the SRI will provide information on the services the building can deliver. Credible information on the smartness of the building (and potential improvements to it) can steer their investment decisions. The shift towards 'smarter' buildings will bring about multiple benefits to the users of the buildings, including better energy efficiency, health and wellbeing, comfort and convenience.
Facility managers too will 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 various service providers, including network operators, manufacturers of technical building systems, design and engineering companies and many others. The SRI can help 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 boosting the market uptake of smart ready technologies through the establishment of a credible and integrated instrument.

Figure 4 – Target audience for the SRI

OBJECTIVES OF THE TECHNICAL SUPPORT STUDY

This study was commissioned and supervised by the European Commission services (DG ENERGY), with the aim of providing technical support to feed into the discussions on the definition and provision of a smart readiness indicator for buildings. In particular, this study proposes a methodological framework for the SRI and the definition of smart services that such an indicator can build upon. It is also provides a preliminary evaluation of potential impacts of the proposed indicator at the EU scale.

The study was conducted by a consortium of VITO, Waide Strategic Efficiency, Ecofys and OFFIS and finalised in August 2018. This document is distributed alongside the final report of the technical support study to provide a summary of the main outcomes.

GUIDING PRINCIPLES TO THE DEVELOPMENT OF THE SRI METHODOLOGY

The study has developed a prospective SRI methodology and scoring system. The following factors have explicitly been taken into account when deriving the methodology:

- The content, organisation and presentation of the SRI is to be salient and motivating towards the target audiences. Building occupiers, bill payers and owners are the primary target group, but ideally the SRI needs to resonate with all the key actors;
- The SRI must establish a clear value proposition towards key actors;
- The SRI should support the EU's energy policy agenda and satisfy the objectives stated in the revised EPBD. In a broader sense, the SRI will interface with many other policy domains and objectives, concerning resource efficiency, health, economic efficiency and employment, consumer rights and data protection, and digital technologies (e.g. cyber security) among others;
- The information that has to be conveyed in the SRI should satisfy the needs of the various target audiences;
- The information of the SRI should be communicated in a way that the target audience is receptive to it and is motivated to take positive action;
- The integrity and credibility of the SRI scheme will be crucial for its success;
- 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;
- Smart services may be constrained to reach their full potential, e.g. by other services or market boundaries. The methodology should recognise the distinction between smart readiness as opposed to operational smart capability;
- 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;
- The SRI methodology and scoring system needs to create a level playing field for market actors and aim for technology neutrality;
- The methodology should potentially allow for requesting qualifying preconditions which should be imposed before a building or specific services can be considered eligible for an SRI assessment;
- The methodology should have flexibility to interact with other policy instruments;
- An important consideration in deriving the SRI methodology will be to balance the desire of a sufficiently detailed assessment with the desire to keep the time and cost requirements limited;
- Buildings and building usage exhibit 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);
- In theory an SRI assessment could be conducted by a variety of different actors including: specialised third-party assessors, self-assessment by the building occupants or owners, facility managers, hired contractors, energy grid operators, IT service providers, building service engineers, ESCOs (Energy Service Companies), smart service providers, etc. The SRI methodology should be flexible enough to potentially allow for different types of implementation;
- The SRI should guarantee data protection by adhering to the provisions of the General Data Protection Directive (GDPR).

OVERALL CONCEPT OF THE SRI METHODOLOGY

The proposed SRI methodology is based on the inspection of 'smart ready services' which are present in a building. Such services are enabled by (a combination of) smart ready technologies, but are defined in a technology neutral way, e.g. the ability to "*control the power of artificial lighting*".

The SRI assessment procedure is based on an inventory of the smart ready services which are present in a building and an evaluation of the functionalities they can offer[4]. 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*". A potential implementation path is that of an SRI assessor who performs the assessment by indicating the implemented functionality levels for the relevant smart ready services using a simple **check-list approach**.

The services present in a building cover multiple **domains** (e.g. heating, lighting, electric vehicle charging, etc.) and can also bring about various **impacts** (energy savings, comfort improvements, flexibility towards the energy grid, etc.).

In order to cope with this multitude of domains and impact categories, a **multi-criteria assessment method** is proposed as the underlying methodology for calculating the smart readiness indicator. In this multi-criteria assessment, weightings can be attributed to domains and impact criteria to reflect their relative contributions to an aggregated overall impact score. Apart from the overall scores, sub-scores can be generated at both the domain level and the impact category level and these can also be communicated as part of the SRI. In the proposed methodology, the impact scores of the individual services are summed up using the above-mentioned weighting factors and then compared with the maximum impact score that the specific building could have obtained.

The methodology has the flexibility to be practically implemented in various ways, e.g. through on site-inspections by external SRI assessors, self-assessment by building owners, a blend of check-lists and self-reporting by intelligent equipment, etc. A working assumption is made that a likely implementation process will involve an inspection carried out by a competent third-party assessor. This may evolve over time into more sophisticated and less intrusive and costly assessment processes as the scheme becomes established and technology develops. In order 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.

The proposed methodology satisfies the guiding principles in that it:

- 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.);

[4] Multiple approaches can be envisioned to perform this assessment; e.g. an on-site visit by a certified external expert following a strict standardised assessment protocol, self-inspection by owners or inhabitants, updates of the SRI score by installers of technical building systems or even forms of declaration or measurement of the smart functionalities performed by the technical equipment itself.

- 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.

Figure 5 provides a graphical overview of the proposed SRI methodology, displaying how the multi-criteria assessment methods builds on the inspection of the individual services present in a building and finally aggregating to a weighted impact score.

The technical study investigated various components of the proposed SRI framework in detail. In this summary, the following main components of the SRI methodology are discussed:

- **The catalogue of smart ready services**
  This catalogue lists the various smart services that can be present in a building and are considered relevant to the SRI.
- **The impact criteria and scores**
  A smart ready service can provide several impacts to the users and the energy grid. A service implemented at a higher functionality level is expected to lead to greater impacts, which will eventually be weighted in the overall SRI score.
- **A streamlined set of services**
  Not all of the 112 services listed in the smart ready service catalogue are currently equally viable to be included in a practical SRI assessment. Therefore, a reduced set of 52 services is proposed, focussing on the services which can be practically assessed on site and which are expected to bring about the most important impacts.
- **Multi-criteria assessment method**
  Impact scores corresponding to the respective functionality levels are combined in a weighted sum, using a multi-criteria assessment method.
- **Normalisation of SRI score and triage process to select the applicable services**
  The nominal impact scores are normalised by comparing these to maximum possible impact scores that could be reasonably attained for the given building. Due to local and site-specific context some domains and services are either not relevant, not applicable, or not desirable. These are filtered out by performing a triage process.
- **Practical assessment, modularity and evolutionary aspects**
  The proposed modular framework allows flexibility to further specify and update the SRI method over time.

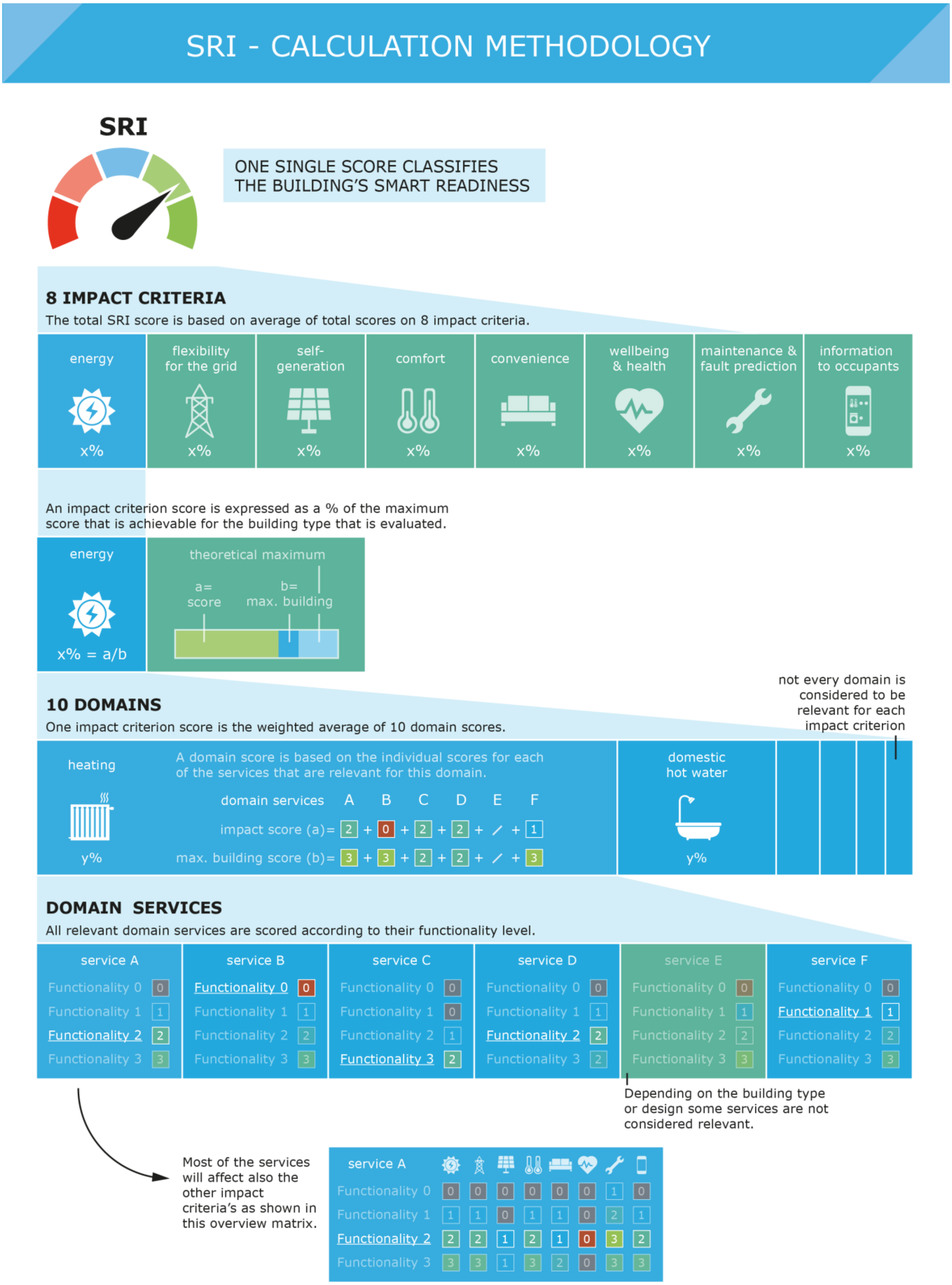

Figure 5 - Overview of the SRI methodological framework

THE CATALOGUE OF SMART READY SERVICES

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 the operation of technical building systems or the external environment (including energy grids) and to demands from building occupants."

The proposed SRI methodology 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, e.g. '*provision of temperature control in a room*'. To support this a catalogue of smart ready services has been developed with the benefit of substantial stakeholder feedback. This 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:

- **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 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 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.**

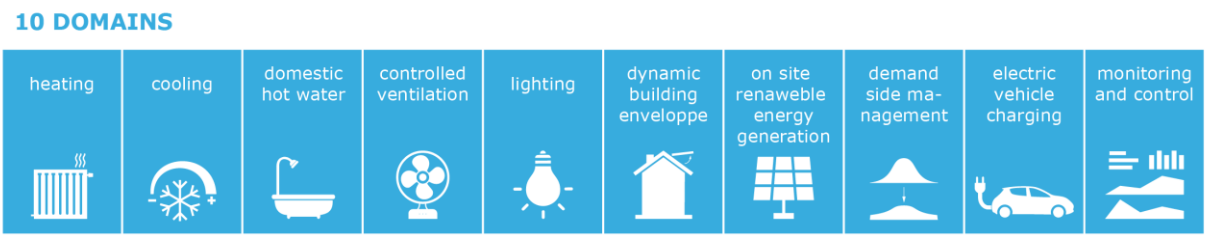

Figure 6 – Ten domains structuring the SRI catalogue

In the SRI service catalogue, services are structured within 10 **domains**: heating, cooling, domestic hot water, controlled ventilation, lighting, dynamic building envelope, on-site renewable energy generation, demand Side management, electric vehicle charging, monitoring and control. An additional domain 'various' contains services which are currently deemed out of scope or insufficiently mature to be included but might be considered in future iterations of the SRI methodology development.

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. The number of functionality levels varies from service to service, the maximum level can be as low as 2 or as high as 5. The functionality levels are expressed as ordinal numbers, implying that ranks cannot be readily compared quantitatively from one service to another.

In the process of compiling the catalogue, the following considerations have been taken into account:

- Services must be in the scope set by the terms of reference for this study and Annex 1a of the revised EPBD;
- Services must be described in a technology-neutral way;
- Services can have multiple impacts, e.g. on comfort, energy efficiency and user information;
- Services can be offered in multiple ways, with different levels of smartness;
- Some services might be mutually exclusive or conversely be mutually dependent (e.g. a service that requires smart metering to operate properly);
- The definition of a service must be unambiguous;
- The on-site assessment of services shall not require in-depth expertise or excessive inspection time;
- If services are already partially or completely defined in international technical standards, the catalogue shall align with these standards when possible;
- The service catalogue shall consider established and broadly marketed technologies and, where possible, emergent technologies;
- In order to limit the time spent on the assessment of services on-site, focus must be given to smart ready services with the highest expected impacts.

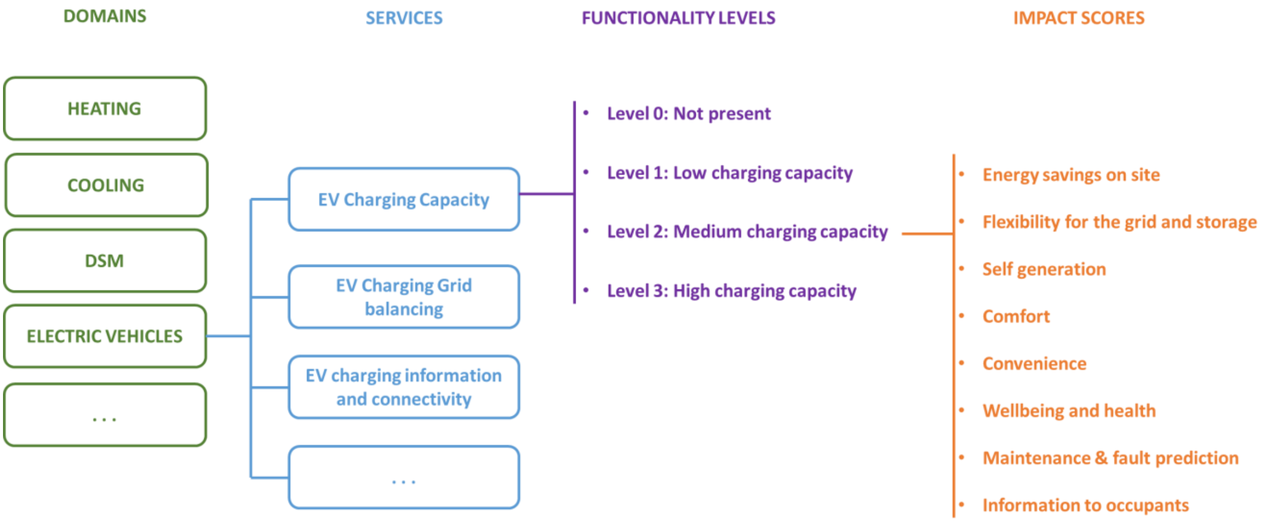

Figure 7 – Structure of the SRI service catalogue. Each service belongs to a given domain (e.g. 'heating') and can be provided with different functionality levels (the higher the level, the better the smartness). Services and functionality levels are then mapped to impact scores, which express their impact for the areas of interest (e.g. impact on comfort).

In total, the catalogue of smart services currently contains 112 services. Not all of them are equally viable or pertinent for inclusion in a practical SRI methodology. Therefore, a streamlined and more compact set of services has been built based on the full-fledged catalogue (see p.14).

IMPACT SCORES OF SMART READY SERVICES

A smart ready service can provide several impacts to the users and the energy grid. In the study, eight distinct impact categories have been considered. The impact criteria listed here may need to evolve further (e.g. to a more simplified set) to facilitate the implementation and communication of the SRI.

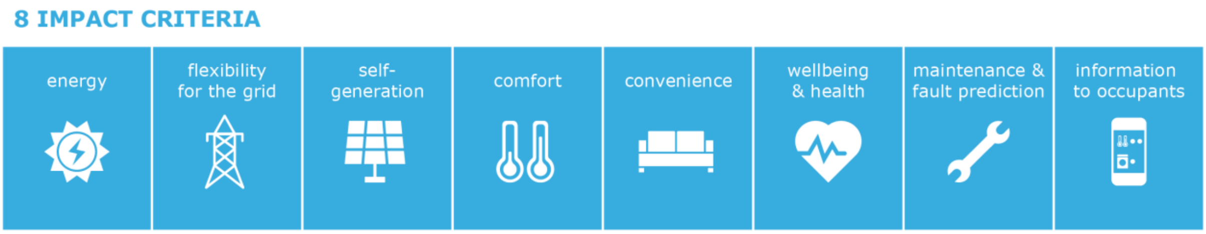

Figure 8 – Eight impact criteria defined in the study

- **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. energy savings resulting from better control of room temperature settings.
- **Flexibility for grid and storage**
  This impact category refers to the impacts of services on the energy flexibility potential of the building.
- **Self-generation**
  This impact category 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 of generated energy.
- **Comfort**
  This impact category refers to the impacts of services on occupants 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 the life easier” for the occupant, e.g. by requiring less manual interactions to control technical building systems.
- **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, detection and diagnosis**
  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.

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.

The provisional impacts in the current catalogue are based on expert assessment and, where possible, on applicable standards. At this stage, the impacts are not fully quantified and are solely used to support the development of the methodology. In subsequent stages of the development and implementation of the SRI, the impact scores will need to be further assessed prior to implementation. For some of the impact categories, it can be envisioned that it will be possible to move towards direct quantification (e.g. through dedicated simulations, or even on-site measurements) whereas for other impact categories (e.g. 'convenience') impacts should be defined based on a broad consensus. In any case, deriving scores for the more subjective impact categories should not be based on interpretation by individual SRI assessors, but be defined in the method to ensure a fully replicable SRI assessment.

In choosing the appropriate method for defining the impact scores of the smart ready services, the desire to have reliable and detailed results needs to be balanced with the expected time and effort required to perform a practical assessment.

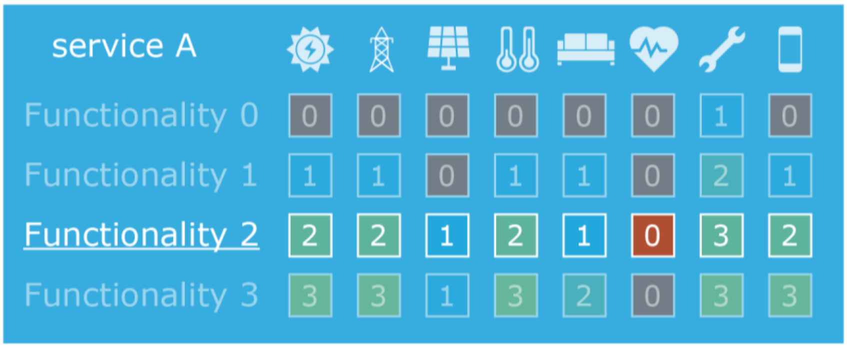

Figure 9 - Matrix displaying the impact scores for the eight impact categories of a fictitious "service A". Functionality level 2 is assumed to be present in the building, which has the following impact scores listed: "2" for energy savings on site, "2" for flexibility for grid and storage, "1" for self-generation, "2" for comfort, etc.

A STREAMLINED SET OF SERVICES FOR A PRACTICAL SRI ASSESSMENT

In total, the catalogue of smart services currently contains 112 services. Not all of these services are equally viable for inclusion in a practical SRI assessment.
To be able to implement an SRI it is necessary that:

- smart readiness service functionality is unambiguously defined and that impacts can be ascribed to the level of functionality delivered;
- it is technically feasible to assess services and functionalities;
- the time/cost of assessment (assuming that a site visit is performed) is acceptable;
- the information derived is assessable and understandable for the target audience.

For some of the services listed in the full-service catalogue, relevant standards and methodological frameworks are currently lacking. For others, it is technically difficult to conduct an assessment on site, e.g. because the impacts are sensitive to the nature of the control algorithms applied. Finally, for some services the impacts are perceived to be low and not commensurate with the assessment efforts needed. In consideration of these issues, the full list of 112 smart ready services has been streamlined to a reduced set of **52 actionable smart ready services** that are designed to ensure prioritisation of services with the highest expected benefits, maximum accordance with the EPBD scope and the highest potential for a viable practical assessment on-site.

A maximum of 52 smart services can therefore be inspected in the streamlined methodology. In practice, for any given building this number can be further reduced via a **triage process** (see p.16), since some of the services will not be relevant for a particular building depending on the context it exists in and the function its intended to fulfil.

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 from maximal smart readiness. The higher the percentage is, the smarter the building. The process to calculate this global score is quite straightforward (see Figure 5 for a graphical overview of the complete process).

1. It 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** in each of the eight impact criteria considered in the methodology (energy savings on site, flexibility for the grid and storage, self-generation, comfort, convenience, health & well-being, maintenance and fault prediction, information to occupants). See Figure 9 for an example of service impact scores.

2. Once all these individual services impact scores are known, an aggregated impact score is calculated for each of the 10 smart-ready domains considered in the methodology (see p.10 of this document). 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. See **Error! Reference source not found.** below.

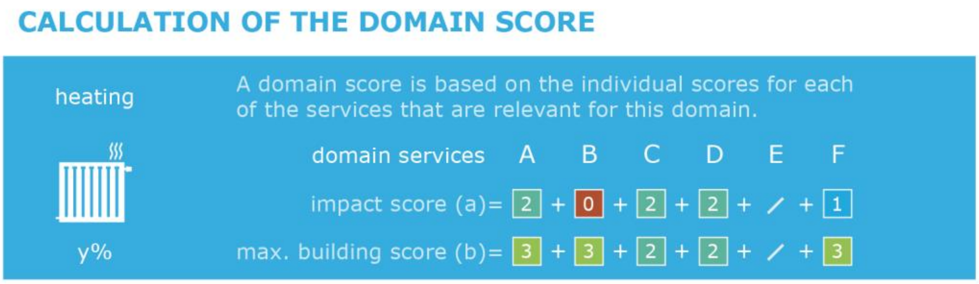

Figure 10 -Summing the scores of all relevant services in a domain for a specific impact category

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 considered impact. For instance, the weight of the 'heating' domain impact score will be higher than the weight of the 'domestic hot water' domain impact score in the calculation of the 'energy savings' total impact score.

4. The SRI score is then derived as a **weighted sum** of the **8 total impact scores**. Again, the weight allocated to each impact will depend on its relative importance for the smart readiness of the building.

<u>Notes:</u>

- For step 3 and 4, the weights used for in this study proposed by this study are tentative. They will be discussed and consolidated in subsequent steps.
- The proposed sequence is flexible, as it allows to derive scores at the level of each impact criterion (e.g. an SRI score specifically for energy flexibility).
- The methodology is described in further details in the report and illustrated by case studies.

The following section explains how the methodology can be further streamlined through the triage of smart-ready services.

NORMALISATION OF SRI SCORE AND TRIAGE PROCESS TO SELECT THE APPLICABLE SERVICES

The overall SRI score could be presented in various ways. In the technical study, it is 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 of the impacts of the 52 services listed in the streamlined SRI catalogue. It is very 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 don't need to be assessed during on-site inspections. Due to these different factors, in any real building, the amount of services to be inspected as part of an SRI assessment will be much lower than the 52 smart ready services listed in the streamlined catalogue.

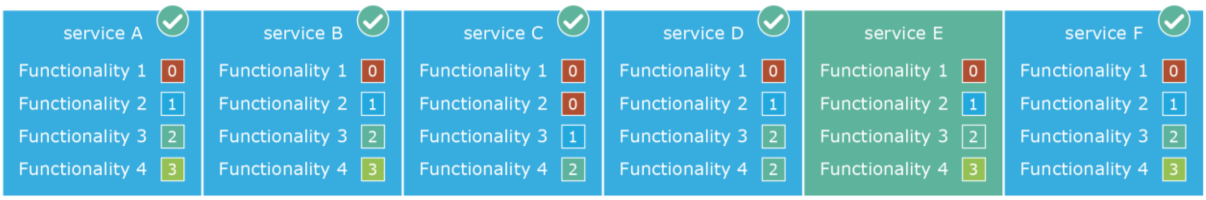

Figure 11 – Visualisation of triage process: for this specific example service E is not considered relevant for the building and thus is not inspected

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. Thus, the calculation of the score only takes 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.

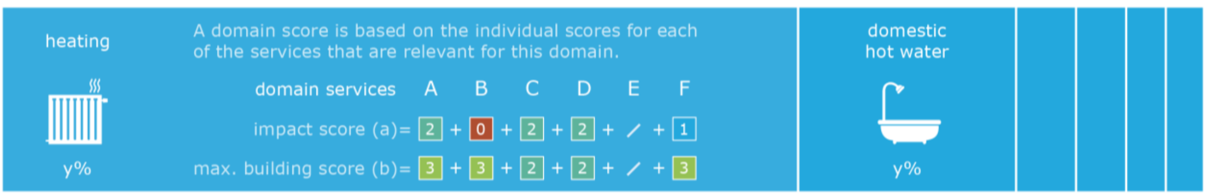

Figure 12 – Normalisation of the domain score. As a result of the triage process, service E is not considered and hence does not count towards the maximum score of the building (which is used to normalise the overall score)

Importantly, the final SRI score can be reported as a single aggregate score that is complemented by sub-scores per impact criterium and per domain. This flexibility allows users to be aware of how well specific domains score as well as the whole building and to see how well the building scores for the individual impact criteria. This could maximise the salience of the information to users, while facilitating their reflections on whether to improve the smartness of services for specific domains.

PRACTICAL SRI ASSESSMENT, MODULARITY AND EVOLUTIONARY ASPECTS

For the SRI **assessment procedure**, the current working assumption[5] is that a competent 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 - thus less costly - assessment processes as the scheme becomes established. Potential options for this could include the use of Building Information Models (BIM) to facilitate the assessment process and the emergence of some form of standardised labelling present 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. Topics discussed include:

- dealing with smart services which are only present in part of the building;
- complex buildings in which distinct and divergent activities are carried out in different parts of the building;
- differences in climate which impact the relative prevalence and importance of technical building systems;
- potential to implement the SRI progressively differentiating by type of building;
- using Building information modelling (BIM) as information source for SRI assessment;
- the degree of interoperability of smart systems and related technical building systems;
- the prevalence of broadband access and smart meters;
- potential linkages to industry and sector specific indicators which also apply to smart ready technologies;
- linkages with other building policy initiatives and in particular the energy performance certificates, the LEVEL(S) scheme and building renovation passports;
- differentiation and common aspects of SRI implementation across member states.

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 services are either not relevant, not applicable or not desirable and thus the SRI needs to be flexible enough to accommodate this. In the technical report examples are given of how to apply the methodology to address this variety of needs through either omitting and rescaling elements or by adapting the weightings within the common SRI framework.

The proposed modular framework allows **flexibility to further specify and update the SRI method over time**:

- The method may be adapted to include additional domains, services, functionality levels or impact categories. Therefore, a process will need to be implemented to allow the introduction of new services and functionality levels, update weightings and impact scores, based on the evolution of smart ready technologies available on the market. Transparent frameworks and procedures will have to be defined and set up to manage this process in close interaction with relevant stakeholders.
- The current methodology is based on ordinal scores ascribed to each service functionality level. The method is, however, flexible enough to be expanded to allow more differentiation in impact scores (e.g. differentiating by building type) or to also allow the use of cardinal impact scores derived from calculations, or even a blend of scoring mechanisms. It could also evolve to allow measured performance outcomes for some specific services and impact categories. If outcome-based assessments using dynamic metering become viable then it may no longer be necessary for the specific

[5] This working assumption does not exclude other pathways for implementation and the proposed methodology is flexible to eventually accommodate these. Other approaches will be further investigated, including the potential self-assessment by building owners or occupants.

service to be assessed manually but rather it could be done via a display interface to the user and/or assessor.
- The SRI assessment can be linked to other assessment schemes and voluntary labels, and for example also inform the user on the EC *broadband-ready label*[6] of a building. 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.

Transparent processes will be needed to support the evolution of the SRI once it is established. This framework should clarify the procedure to add or remove services and functionality levels, and to update impact scores.

FIELD TEST ON CASE STUDY BUILDINGS

The streamlined methodology was tested in two field case studies: a traditional single family house located in Manchester, UK (see
Figure 13) and the contemporary EnergyVille office building located in Genk, Belgium (see Figure 14).

Figure 13 - Single family house case study

Figure 14 - Office and laboratory case study building

In each assessment, the following steps were undertaken:

Step 1: Triage process to assess which services are relevant for a particular building. For the residential building this resulted in 23 relevant services. For the more intricate office building 44 services were to be assessed, also including services with respect to cooling, electric vehicle charging and shading control

Step 2: For each of the applicable services an assessment was made of the functionality level that was attained in the building. This was done based on information gathered from a visual inspection during a walk-through of the building, an interview with the building occupant or facility manager and the review of documentation of the technical building systems.

Step 3: For each of the relevant services, the functionality level is filled out in a calculation tool (currently a simple spreadsheet). This tool retrieves the impacts on each of the eight impact categories from a predefined dataset.

[6] See provisions in 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.

Step 4: The calculation tool aggregates all scores and weights them by domain and impact scores. In the case study examples, the domain weightings are different for the residential building and the office building to reflect a different importance of, for example, cooling and lighting in the distinct building types.

Step 5: The maximum obtainable weighted impact score was calculated by the calculation tool. This solely depends on services selected after the triage process.

Step 6: The overall SRI score is calculated as the ratio of the actual impact score (step 4) and the maximum attainable score (step 5).

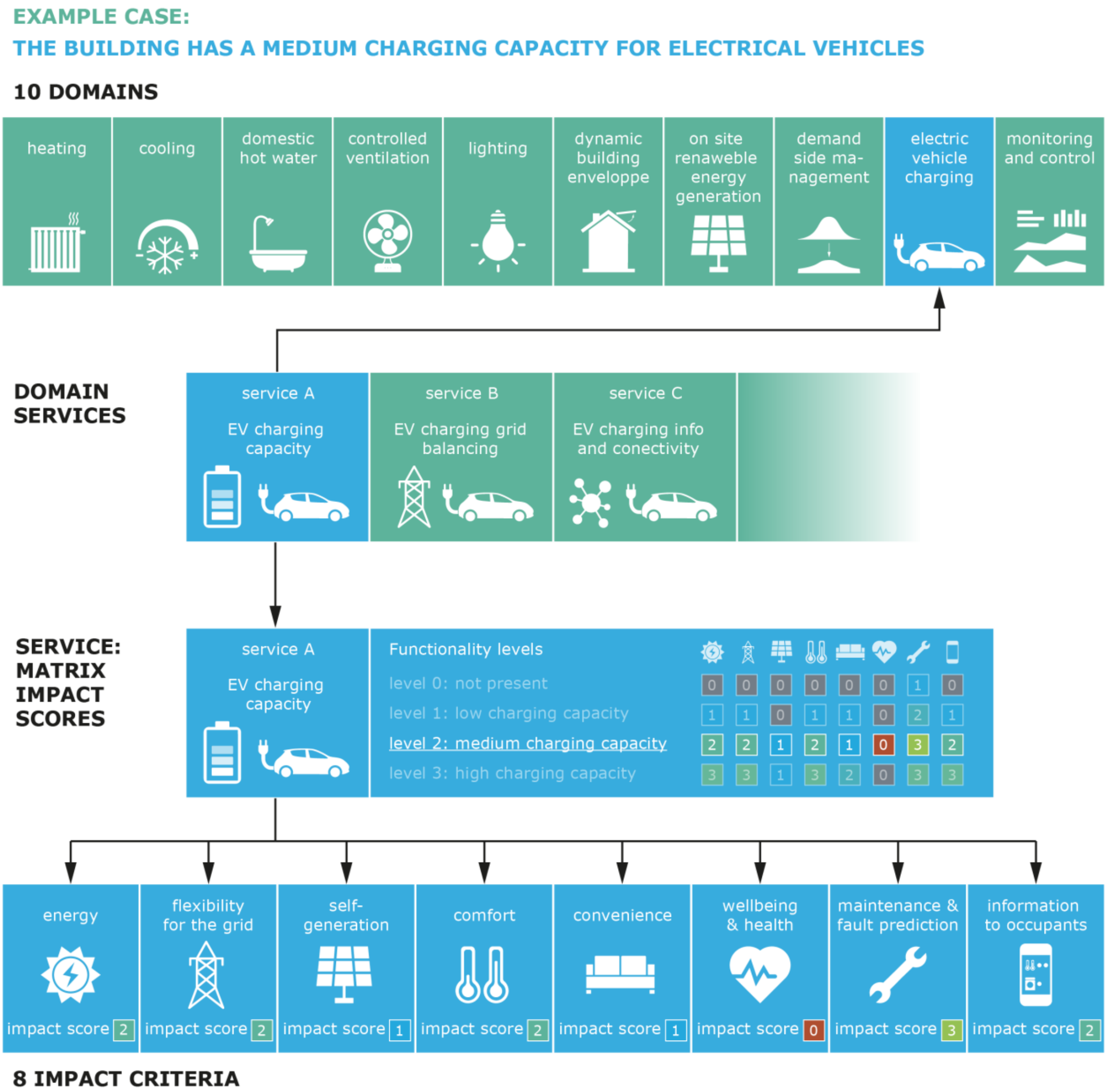

Figure 15 – Example of practical SRI assessment: the assessor lists the relevant services of a given domain and evaluates the functionality level of the implemented smart ready service. The predefined scores for the 8 impact criteria applicable to this functionality level are fed into the overall weighted score.

The **result of the SRI assessment** can be presented in various ways, e.g. as an overall single score, as a relative score (e.g. indicating that a building achieves 65% of its potential smartness impacts) or as a label classification (e.g. SRI label class 'B'). Sub-scores can also be presented (e.g. 72% on energy savings and 63% on comfort).

Preliminary findings suggest that presenting such sub-scores is valuable for end-users. Additionally, the impacts of an SRI can most likely be further increased if recommendations are also presented to the building occupant/owner/manager on the various options to increase the smartness of their building (e.g. to improve the score by reaching higher functionality levels on well targeted services).

With the streamlined list of services and the triage process in place, the time taken to conduct assessments is found to be similar to the time it takes to conduct energy performance certificate assessments in many countries. These practical case studies underpin that the methodology is straightforward and ready to be implemented in an acceptable time frame.

IMPACT ASSESSMENT METHODOLOGY

As part of the technical study, an **impact assessment** was performed to analyse the benefits and costs of implementing an SRI to support an increased uptake of smart ready technologies in buildings in the EU. It also aims to understand the impact of 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 (see Figure 16).

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 take into account new buildings, demolition of buildings and retrofits with regard to energy efficiency measures applied to the building shell and the heating, ventilation, and air-conditioning (HVAC) systems. The impact assessment relies on two building sector pathways: (i) The "*Agreed Amendments*" pathway, which corresponds to a scenario where the revision of the EPBD is implemented without additional measures and (ii) the "*Agreed Amendments + Ambitious Implementation*" pathway, which corresponds to a scenario where the revision of the EPBD is implemented in a more ambitious way.

In the second part of the impact assessment, the effects of an **uptake of smart ready technologies** (SRTs) and the SRI are modelled. The analysis is done in three different packages, dependent on whether a building has heating systems, cooling systems or both in place.
Furthermore, 3 distinct scenarios are considered in the analysis:

- **SRT_BAU:** No SRI, only existing incentives for smart ready technologies, thus representing the autonomous effects that can be observed in the market
- **SRT_Moderate implementation:** SRI voluntary, moderate accompanying measures and moderate implementation on member state level
- **SRT_High implementation:** SRI still voluntary, strong accompanying measures and considerable implementation on member state level

The working hypothesis is based on the following assumptions: the SRI will provide a common classification system across Europe such that technology and smart services and technology providers could position their service offerings in terms of the SRI levels. This will create a common structure within which smart services can compete and thus provide much needed transparency, leading to a lower risk and a higher adoption/uptake of smart ready technologies. This effect is partially dependent on the level of uptake of the SRI, since a very common usage of the SRI might lead to a clear positioning of the service providers towards the SRI.

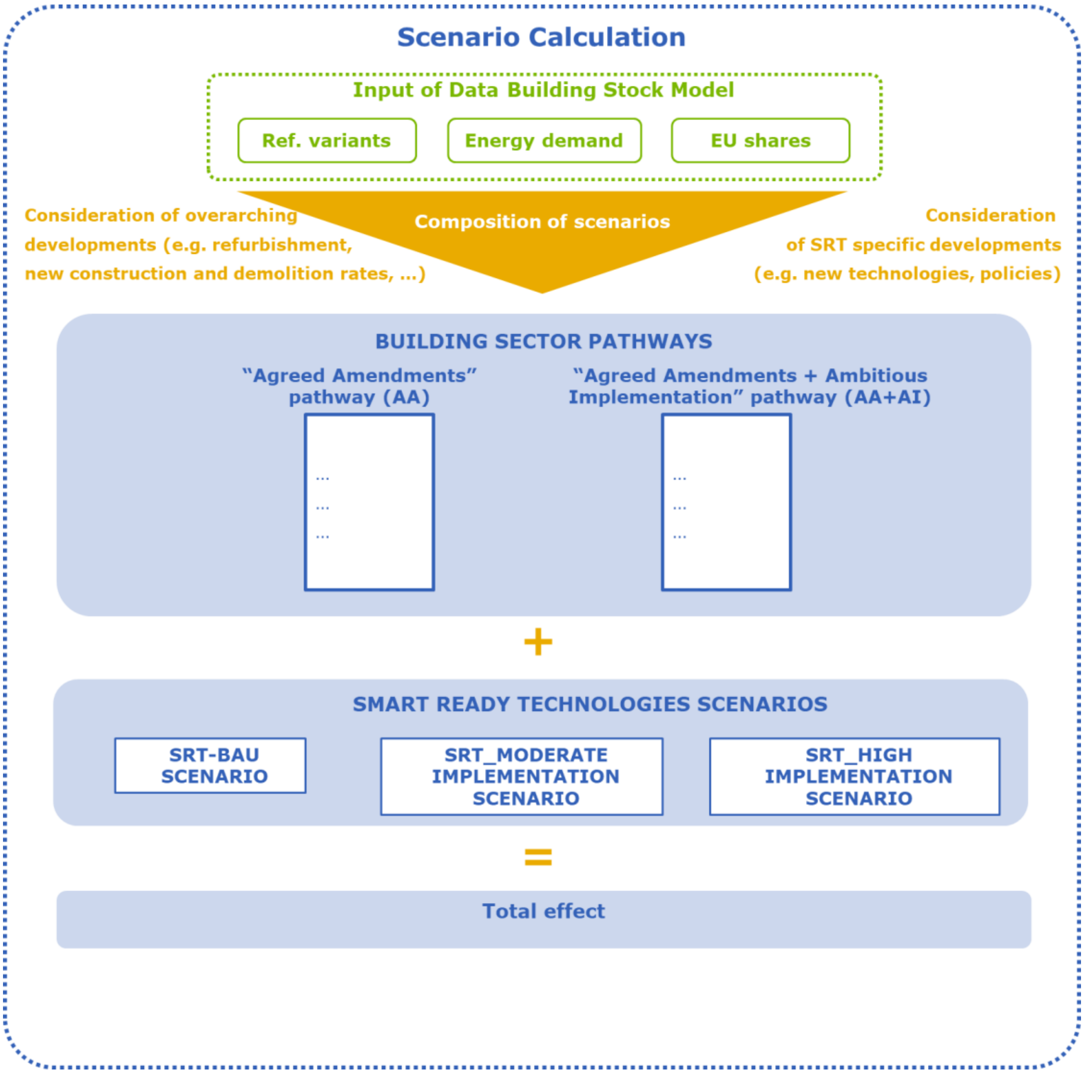

Figure 16 – Stepped approach in the impact assessment scenario calculation

The degree of specific supporting policies of member states will obviously have an influence on the adoption rates. Smart service adoption rates will also be strongly affected by the policy support measures which may be directly targeted towards them too (i.e. policies could be designed to both create incentives to have an SRI and to adopt certain smart services). The impact of the SRI on driving technology/service adoption will also be time dependent, such that the longer the SRI has been in place the more impact it will have because market actors become familiar with it.

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 – either thermal or electrical – due to the improved overall system performance. The final energy savings also lead to primary energy as well as CO_2-savings due to the improved energy efficiency of the buildings.

For each of the above described scenarios a yearly deployment rate of smart ready technologies is determined. For each of the improvement steps (i.e. I -> II or II -> IV) the relative saving potential for thermal and electrical energy (in % of the actual energy demand) is modelled as well as the investment costs per m^2 of floor area. The combination of deployment rate and improvement potential per SRI range gives the overall saving potential and investment costs (CAPEX) of the implementation of smart ready technologies in the building sector.

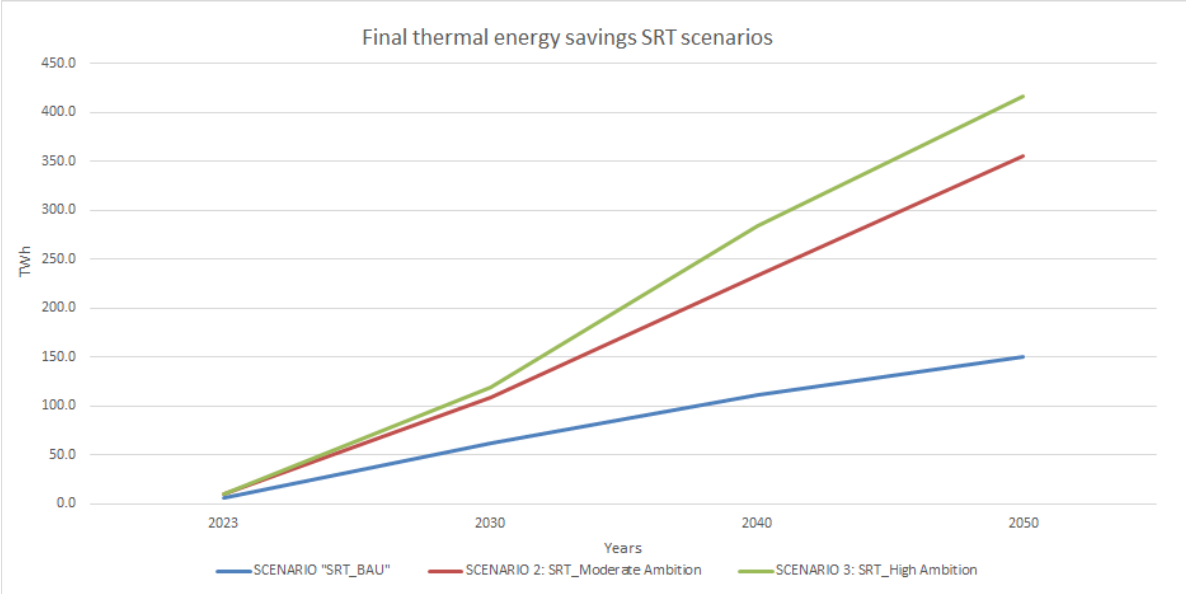

Figure 17 - Final thermal energy savings due to SRTs under each SRT scenario[7]

Building sector pathways

Under the baseline building stock pathway ("*Agreed Amendments*") and despite a slight increase in total building floor area, the final energy demand of the building stock across EU is expected to decrease by 53% from today until 2050 (58% in the "Agreed Amendments + Ambitious implementation" pathway). The main drivers are energy efficiency measures applied to the building envelope and the replacement of inefficient heating systems. The primary energy demand is reduced even more, since district heating and electricity are further decarbonized in the future. With regard to CO_2 emissions, a reduction of 61% from today's levels is attained by 2050 under the "*Agreed Amendments*" building sector pathway, while 67% are reached in the "Agreed Amendments + Ambitious Implementation" "pathway.

Smart ready technologies scenarios

Energy savings: Under the business-as-usual (SRT_BAU) scenario, which considers the development of smart ready technologies without the SRI, the total thermal energy savings in 2050 are about 150 TWh/a.
Under the SRT_Medium and SRT_High scenario, which take into account the influence of the SRI and accompanying measures, savings are approximately of 350 TWh/a and 420 TWh/a respectively. In addition, electrical energy savings increase from 8 TWh/a in the SRT_BAU scenario to 18 TWh/a and 20 TWh/a respectively in the SRT_Medium and SRT_High scenarios.

CO_2-emissions: the SRT_BAU scenario shows emission reduction by 26 Mt/a until 2050 compared to today's level, while the two other scenarios lead to significantly higher savings. For the SRT_High scenario the total CO_2-emission level can be lowered by 70 Mt/a until 2050.

Investments and economic impact: the SRT_BAU scenario leads to yearly investment of 3.5 billion Euro by 2050, while the SRT_High scenario leads to yearly investments of about 16.6 billion Euro by 2050. This leads to specific energy savings costs of about 0.02-0.04 Euro per kWh saved. These investments generate about 80,000 additional jobs in the SRT_Medium scenario and 140,000 additional jobs in the SRT_High scenario by

[7] The cumulated effects of all additional smart ready technologies from 2023 to 2050 are shown in this graph.

2030. By 2050 these numbers increase respectively to 170,000 and 210,000 additional jobs to be created and maintained.

Average payback of SRTs: The average payback of SRTs (in consideration of the yearly investments and savings outlined above) ranges from 2 to 6 years.

Sensitivity analysis: Only 20% of the energy savings achieved under the SRT scenarios would be obtained if the following limitations were applied to the implementation of the SRI: 1) introduction of the SRI only for buildings above a threshold of 1,000m² floor area: 2) Introduction of the SRI only for commercial buildings and units; 3) introduction of the SRI only for buildings that fall under the requirements of Article 14 and 15 of the revised EPBD on regular inspections of heating, ventilation and air-conditioning systems. This suggests that limitations on the scope of application of the SRI could have a significant influence on potential energy savings and related impacts.

STUDY DELIVERABLES AND PROCESS

The final report of the project is publicly available on the project website https://smartreadinessindicator.eu. Intermediate reports and presentations of stakeholder meetings can also be consulted on this webpage. The annexes to the final report include a spreadsheet with smart ready services and their properties.

The work has been carried out iteratively in close consultation with various stakeholders. As part of the consultation process, a first stakeholder meeting was organised in June 2017, a second meeting in December 2017 and a final one in May 2018. After each meeting, stakeholders were invited to provide written feedback to the reports and accompanying annexes. This feedback has led to important updates and amendments throughout the project.

The **catalogue** of smart ready services has been significantly amended in light of stakeholder comments. Multiple services were updated or added based on stakeholder suggestions. Furthermore, the need for a well-established process to review and regularly update the catalogue has been advocated and further discussed in the final report.

The **methodology** has been adapted and further streamlined to reflect the changes in the smart services catalogue. Based on growing insights and the feedback received, a streamlined SRI methodology is proposed that uses a consolidated set of services which are relevant in the scope of the EPBD, have significant impacts, are actionable now and can be assessed in practice. Further consideration has been given to how the SRI methodology can be tailored to address specific contexts and how it can link to other assessment procedures and initiatives. Significant attention has been given as to how a flexible structure can be set up that allows the SRI (methodology) to be adapted over time and to make use of data which may become available at that time (e.g. to make it possible to use quantified impact scores or actual measured data for specific impacts).

More details on the stakeholder interaction process and on the processing of stakeholder feedback are given in the full final report of the study.