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

FINAL REPORT

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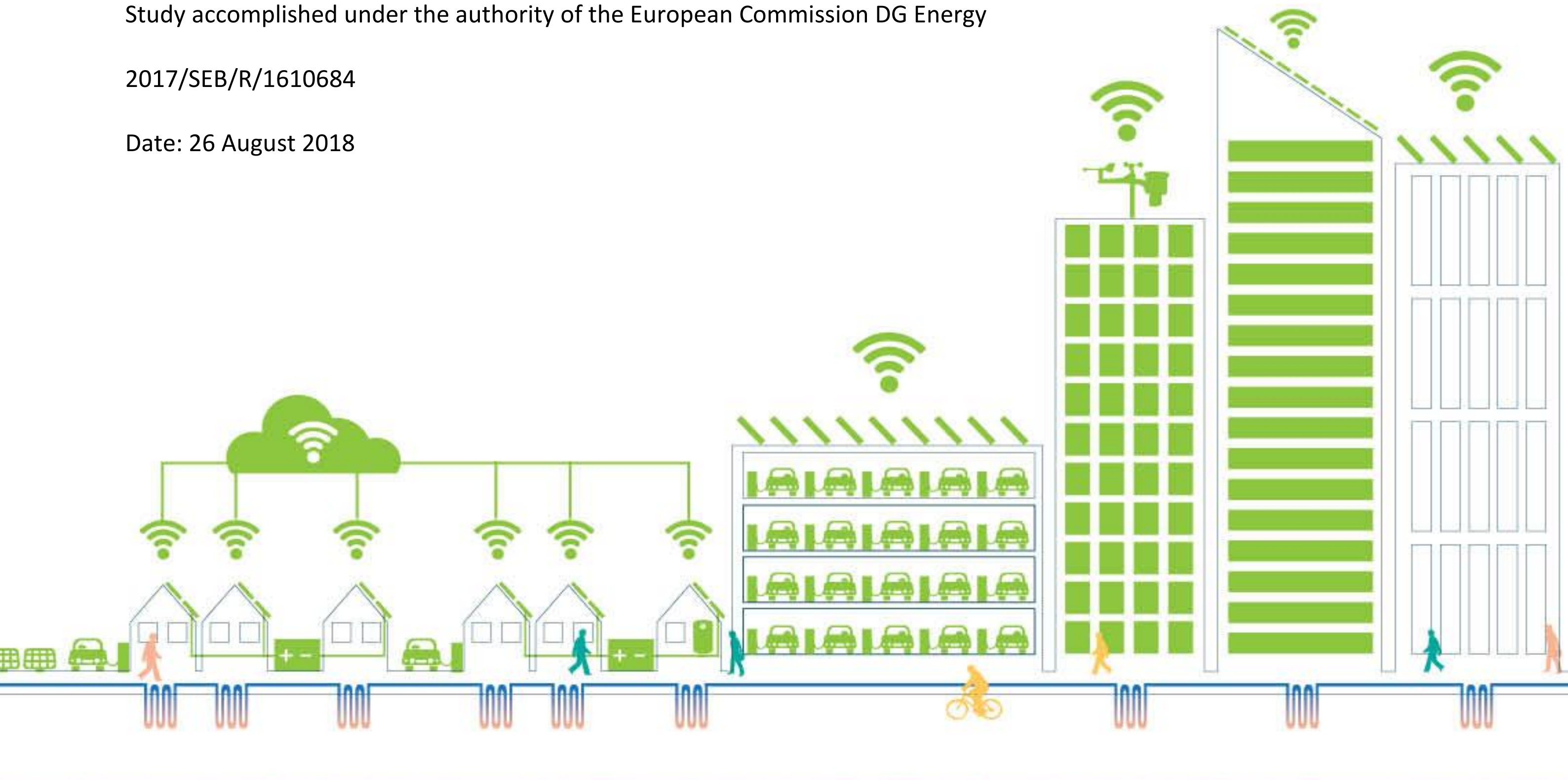

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LIST OF ACRONYMS

BACS	Building Automation and Control Systems
BAU	Business As Usual
BEMS	Building Energy Management System
CSR	Corporate Social Responsibility
DPC	Data Protection Class
DER	Distributed Energy Resource
DHW	Domestic Hot Water
DBE	Dynamic Building Envelope
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
EED	Energy Efficiency Directive
EPC	Energy Performance Certificate
EPBD	Energy Performance of Buildings Directive
EC	European Commission
HEMS	Home Energy Management System
ICT	Information and Communication Technologies
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
RES	Renewable Energy Systems
SFH	Single Family Home
SRI	Smart Readiness Indicator
SR	Smart Ready
SRT	Smart Ready Technologies
TBS	Technical Building Systems
TES	Thermal Energy Storage

EXECUTIVE SUMMARY

DEVELOPING A SMART READINESS INDICATOR FOR BUILDINGS

CONCEPT - SMART READINESS INDICATOR – SRI

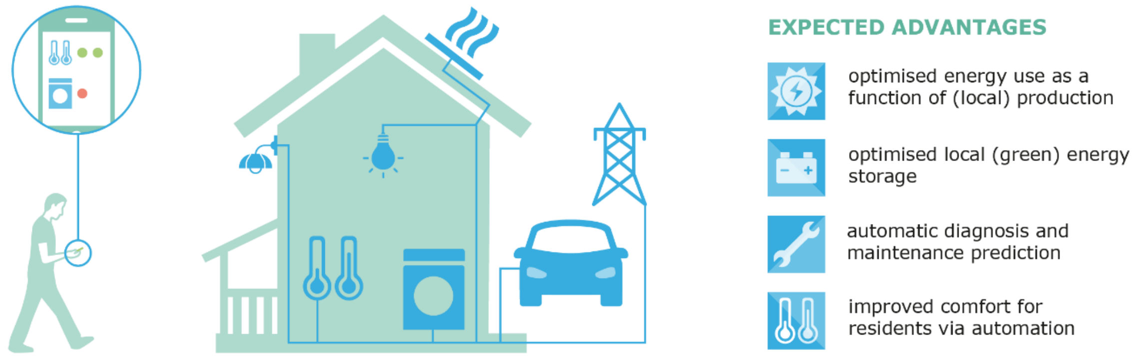

Figure 1 – Expected advantages of smart technologies in buildings

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.

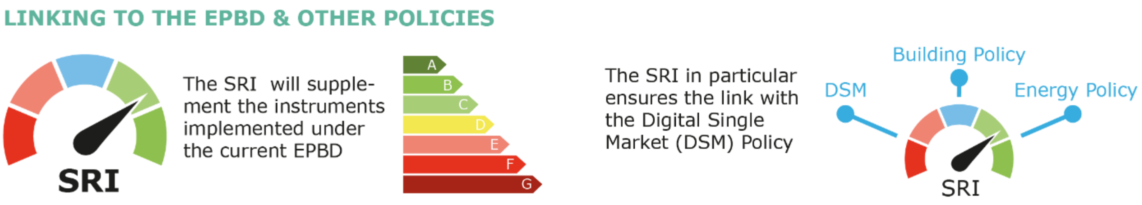

Figure 2 – Graphical representation of linkages of the SRI to other policy initiatives

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 executive summary provides an overview 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[1]. 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

[1] 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.

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.);
- 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.

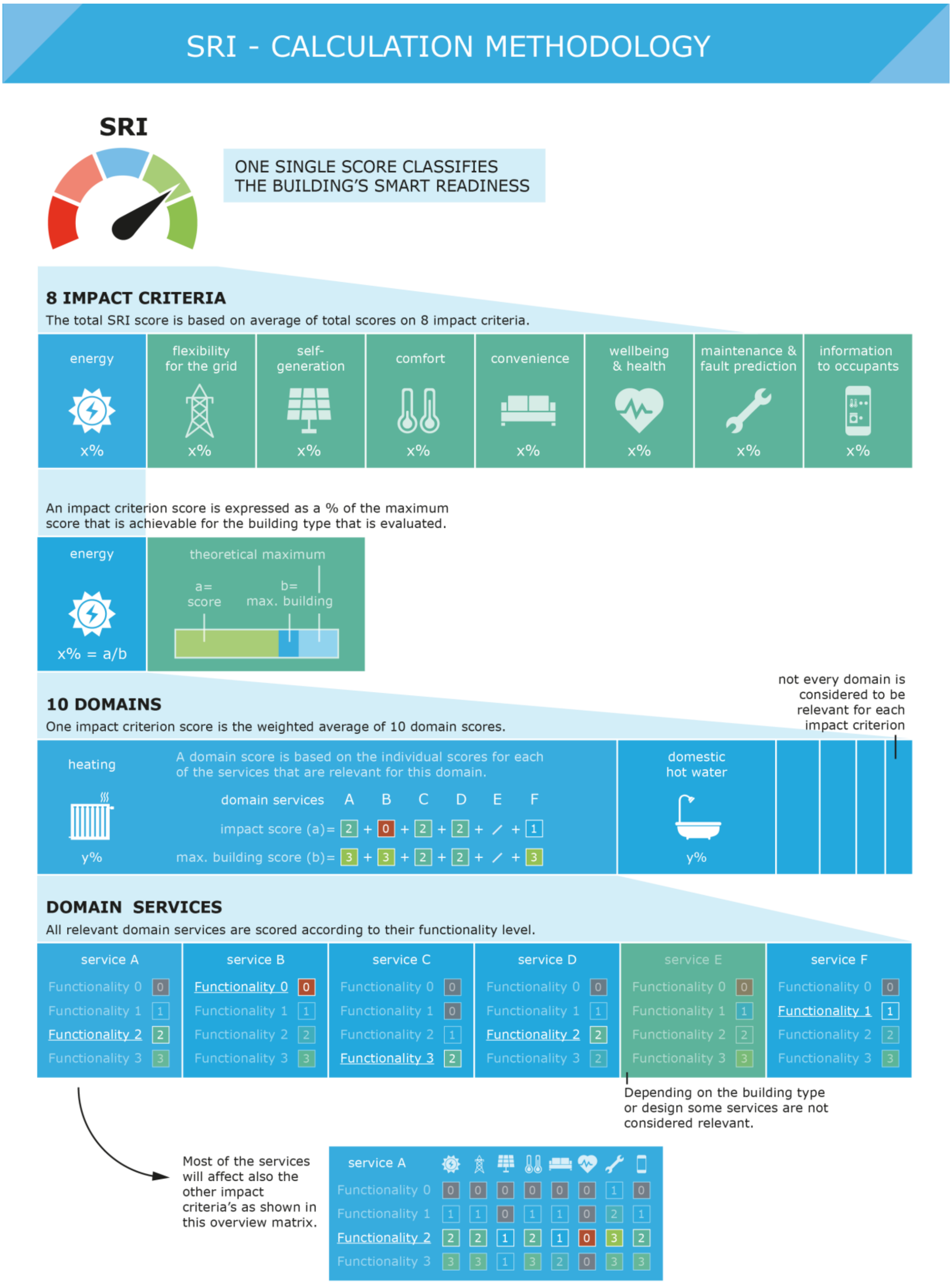

Figure 5 - Overview of the SRI methodological framework

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.**

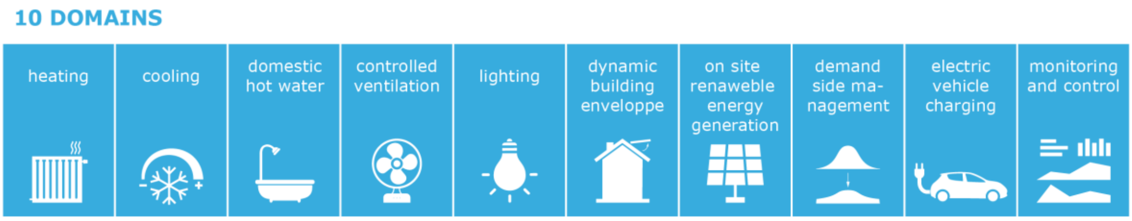

Figure 6 – Ten domains structuring the SRI catalogue

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.

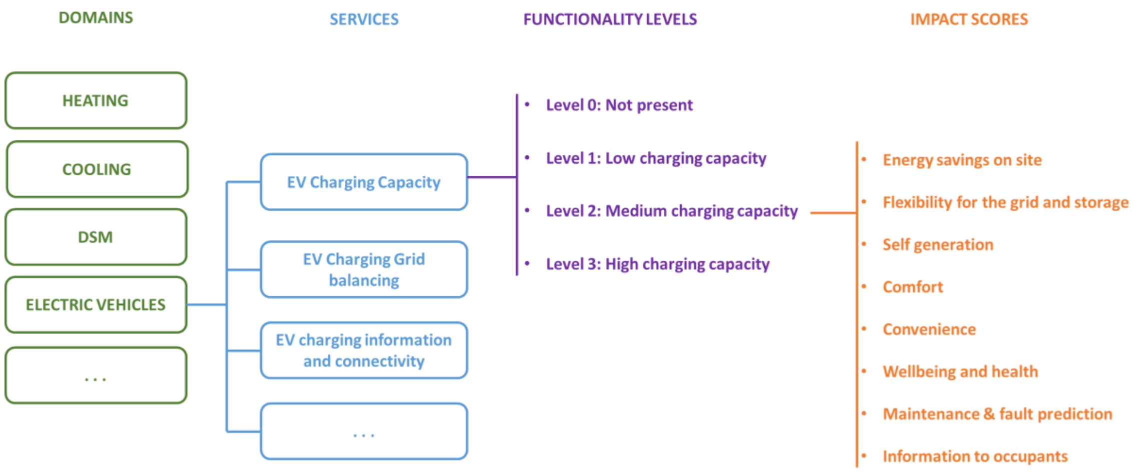

Figure 7 – Structure of the SRI service catalogue. Each service belongs to a given domain (e.g. 'heating') and can be provided with different functionality levels (the higher the level, the better the smartness). Services and functionality levels are then mapped to impact scores, which express their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

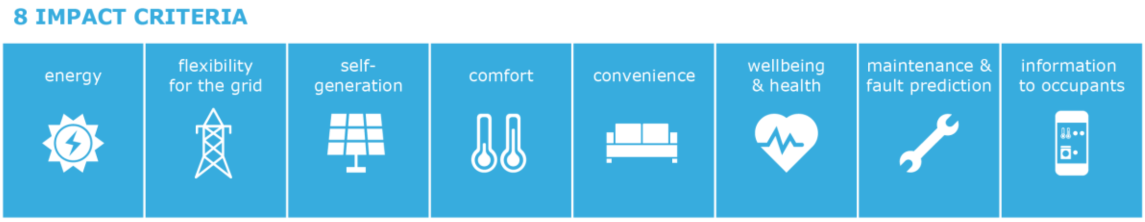

Figure 8 – Eight impact criteria defined in the study

- **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 fewer 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 nine-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.

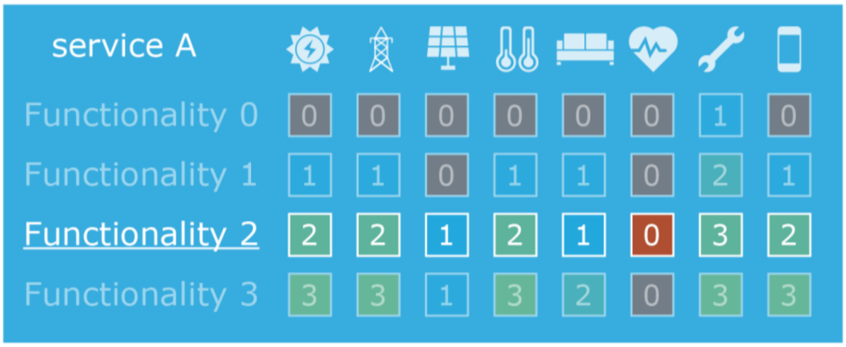

Figure 9 - Matrix displaying the impact scores for the eight impact categories of a fictitious "service A". Functionality level 2 is assumed to be present in the building, which has the following impact scores listed: "2" for energy savings on site, "2" for flexibility for grid and storage, "1" for self-generation, "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 Figure 10 below.

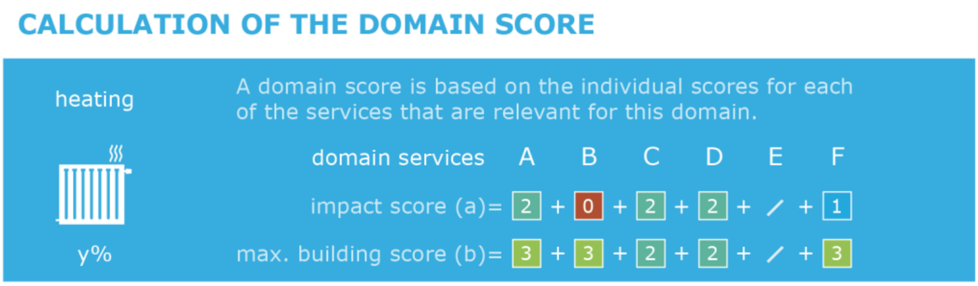

Figure 10 -Summing the scores of all relevant services in a domain for a specific impact category

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.

Notes:

- 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.

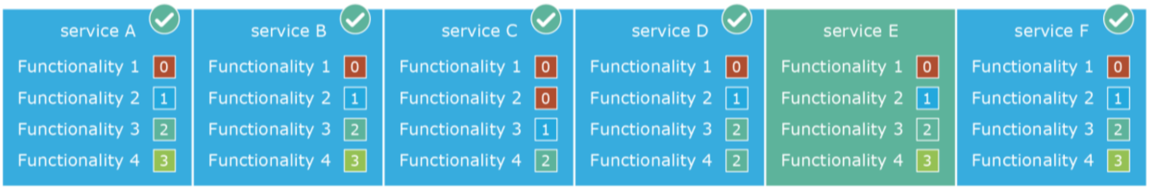

Figure 11 – Visualisation of triage process: for this specific example service E is not considered relevant for the building and thus is not inspected

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.

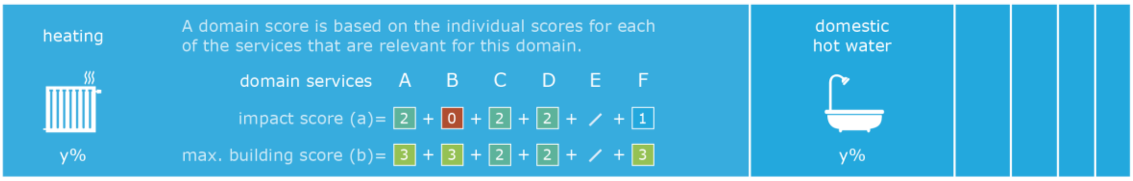

Figure 12 – Normalisation of the domain score. As a result of the triage process, service E is not considered and hence does not count towards the maximum score of the building (which is used to normalise the overall score)

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[2] 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.

[2] 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.

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 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*[3] 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.

[3] 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.

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.

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).

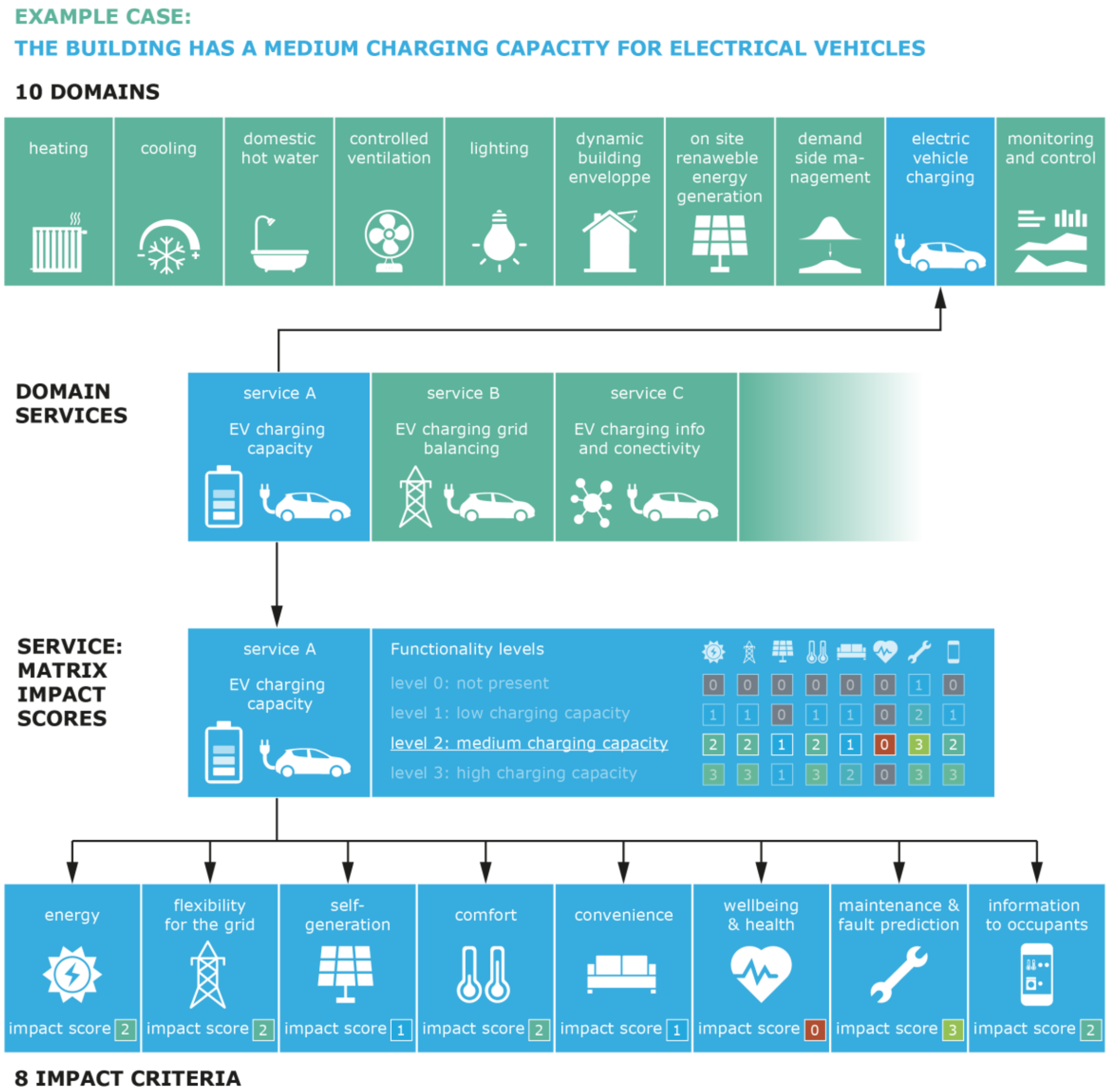

Figure 15 – Example of practical SRI assessment: the assessor lists the relevant services of a given domain and evaluates the functionality level of the implemented smart ready service. The predefined scores for the 8 impact criteria applicable to this functionality level are fed into the overall weighted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

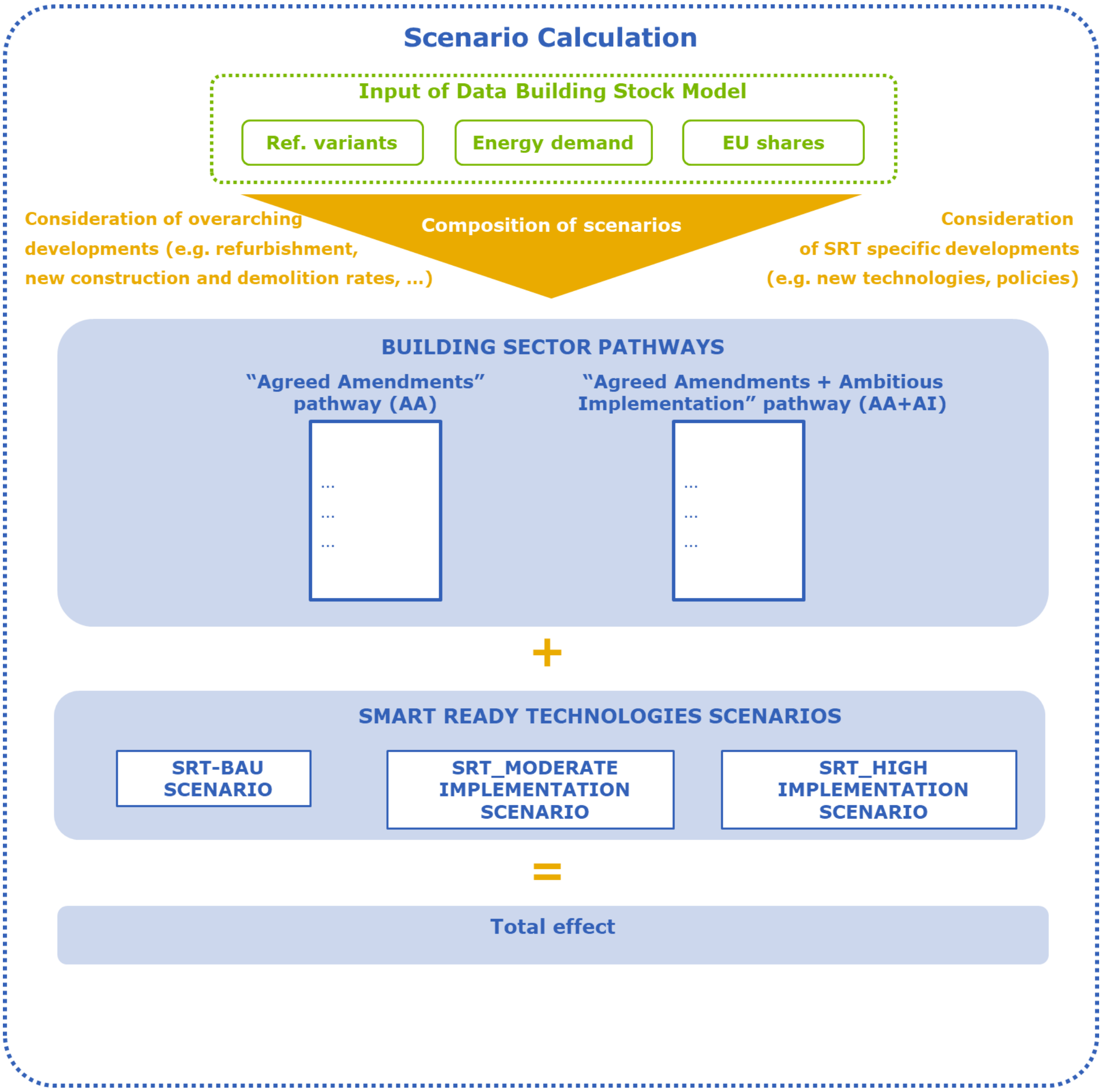

Figure 16 – Stepped approach in the impact assessment scenario calculation

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.

IMPACT ASSESSMENT RESULTS

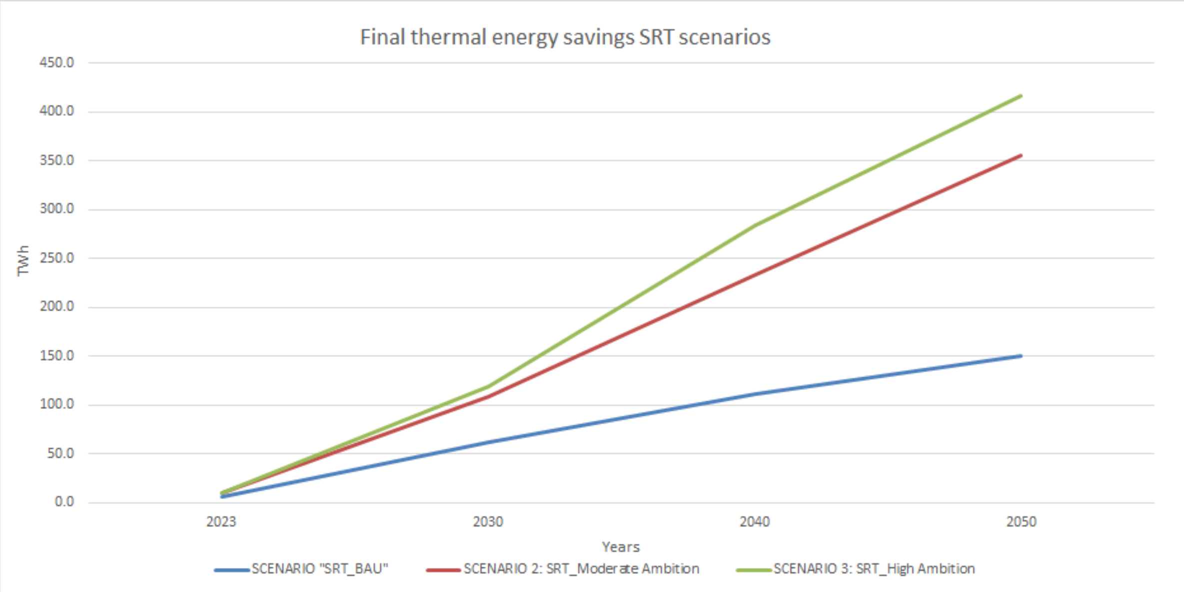

Figure 17 - Final thermal energy savings due to SRTs under each SRT scenario[4]

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

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

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 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.

CHAPTER 1 SCOPE AND OBJECTIVES OF THE STUDY

1.1. BACKGROUND

At the end of November 2016, the European Commission (EC) presented the “Clean Energy for All Europeans” package of proposals (EC, 2016) to amend and adapt several key directives in the field of energy efficiency, renewable energy, electricity market design, security of electricity supply and energy governance. In the scope of this package, buildings are treated as an essential driver of the energy transition. Buildings consume 40% of European Union (EU)’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 amended Energy Performance of Buildings Directive (EPBD) 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 it improves the comfort in the buildings and has the building adjusted to the needs of the user. Additionally, smart buildings have been identified and acknowledged as the key enablers of the future energy systems, in which there will be larger share of renewables, distributed supply and energy flexibility which is also managed on the demand side (e-mobility infrastructure, on-site electricity generation, energy storage). (EC, 2016)

The revised EPBD was approved by the European Parliament on 17 April 2018 and by the Council on 14 May 2018. While the current EPBD already considers Information and Communication Technologies (ICT) and smart systems to some extent[5], the revised EPBD aims to provide additional support by:

- introducing Building Automation and Control Systems (BACS) as an alternative to physical inspections;
- reinforcing building automation by introducing additional requirements on room temperature level 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 a SRI would raise awareness on 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 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 (RES).

[5] (1) the support to the introduction of intelligent metering systems and active control systems that aim to save energy, in line with Article 8; and (2) the possibility to use electronic monitoring and control systems as a partial replacement to inspections of heating and air conditioning systems, in line with Articles 14 and 15.

1.2. OBJECTIVES OF THE STUDY

This study is intended to provide technical support to the Directorate-General for Energy of the European Commission services in order to feed the discussions on the definition and provision of a smart readiness indicator for buildings. Such indicator was originally proposed in the Clean Energy for All Europeans package of proposals (EC, 2016). Parallel to this technical study a policy process has taken place, which led to the approval of the revised EPBD. The new provisions of the amended EPBD indeed require the establishment of an optional European Smart Readiness Indicator scheme for buildings.

This study provides technical support, and in particular focusses on proposing methods to define a smart readiness indicator and the definition of smart services such indicator can build upon. This work is carried out in close consultation with stakeholders. It is supplemented by an impact analysis to evaluate the expected impact of the proposed indicator at EU scale. This technical support study will finalise in August 2018.

The main objective of this study is thus to provides technical support to prepare the ground for the further establishment of the SRI. The revised EPBD stipulates that legal establishment will be done through two distinct legal acts. A delegated act will focus on the definition and calculation methodology of the SRI. An implementing act will specify the technical modalities of implementation. Both legal acts shall be adapoted by December 31st, 2019.

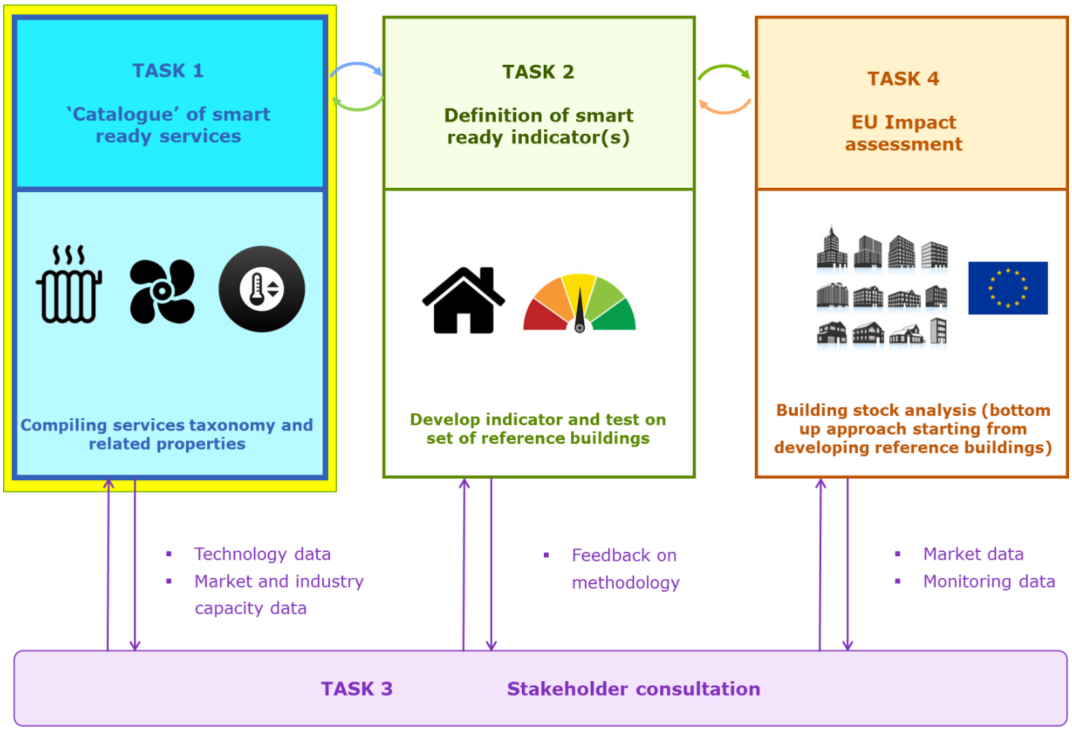

Figure 18- Overview of the project structure

1.3. This Final Report

This document covers the outcomes of the study 'Support for setting up a Smart Readiness Indicator for buildings and related impact assessment'.
This report is supplemented by an executive summary which also presents the main results.

The objective of **Task 1** is to identify and characterise the Smart Ready Technologies (SRT) together with the smart ready services (SRS) and functionalities that these technologies can provide to a building and its occupants. Under this task, suitable technologies are listed which fit the definition of smart-ready technologies that can be integrated into buildings and technical building systems to improve their operations and enhance energy efficiency.

A spreadsheet (Annex A), which is integral part of the Task 1 deliverables, presents the catalogue of smart ready services. It is structured in various tab sheets reflecting the distinct domains, and lists the smart ready services, their functionality levels and their impacts. This catalogue was updated to reflect feedback from the first two stakeholder workshops and subsequent stakeholder consultations.

Task 2 has taken the input from Task 1 deliverables and proposes methodological approaches to the calculation of the SRI. A streamlined SRI methodology is proposed that uses a consolidated set of services which are actionable now and are have reasonable confidence in their ability to be assessed and their attribution of impacts to functional levels. This report describes the development of such methodology and contains many updates based on growing insights and stakeholder feedback.

A stakeholder consultation process is ongoing as part of the dedicated **Task 3**. As part of these efforts a public website has been launched, and three stakeholder meetings have been organised. A first stakeholder meeting has been organised in June 2017, a second meeting in December 2017 and a third on May 28th 2018. After each stakeholder meeting, stakeholders were invited to give feedback to the reports and accompanying annexes[6]. A second progress report is distributed for public consultation in follow-up of the third stakeholder meeting. The progress in task 3 is reported in CHAPTER 4 of this document.

Task 4 presents **an EU impact assessment of the SRI.** It is based on the description of smart ready services from task 1 and the methodology to calculate the SRI in task 2. The core objective is the calculation of benefits from and costs for the uptake of smart ready services in relation to the implementation of the SRI. This analysis relies on a baseline projected evolution of the building stock (building sector pathway) in order to determine the additional saving potential from smart ready technologies and the SRI on top of that baseline. The impact analysis is reported in CHAPTER 5 of this document and features important updates compared to the second progress report.

[6] Consultation documents are available on https://smartreadinessindicator.eu/milestones-and-documents

CHAPTER 2 TASK 1 – SRT CHARACTERIZATION, MARKET ANALYSIS AND INDUSTRIAL CAPACITIES EVOLUTION IN EU

In this chapter, definitions are presented which provide both the scope and terminology for the project. Next, the structure of the services catalogue is presented. The concepts of domains, impacts and functionality levels of services are elaborated. Then the assumptions taken for the estimation of the impacts of smart ready services, in particular in relation to standards, are discussed.

2.1. TERMINOLOGY AND GLOSSARY

The full glossary defined in Task 1 can be found in Annex B of this document. The most important definitions are :

Definition of 'Smartness'

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 (Amirhosein et al., 2016). While it could be argued that the outcome of this project could lead to a definition stating '*a smart (ready) building is a building with a high SRI score*', this does not evade the need for defining smartness in the first place.

In this work, the following definition will be proposed:

"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 (see discussion on scope, section 2.2.1).

Definition of 'Smart Ready Service'

'Smart ready services' satisfy a need from the user (occupant/owner) of a building or the energy grid it is connected to.

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.

Definition of 'Smart Ready Technologies'

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 CO_2 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.

Definition of 'Technical Building System'

In the EPBD under Article 2(3), a 'technical building system' is defined as a technical equipment for the heating, cooling, ventilation, hot water, and lighting or for a combination thereof, of a building or building unit. In the amended EPBD, this definition is extended to building automation and control and on-site electricity generation. In the context of this study, this broader definition will be used.

Definition of 'Interoperability'

According to ISO/IEC 2382-01 on Information Technology Vocabulary, Fundamental Terms, interoperability is defined as follows[7]: "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".

Definition of 'Cybersecurity'

'Cyberspace 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.

[7] 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.

2.2. COMPILING THE SMART READY SERVICES CATALOGUE

One of the main objectives of Task 1 was to compile the full list (or catalogue) of smart ready services that can be found in buildings and that could be considered in the calculation of the SRI. This section presents the scope and structure of this catalogue.

2.2.1. SCOPE AND SELECTION CRITERIA

Three key functionalities of smartness in buildings have been taken into account when selecting the smart services for the 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**

And/or

> **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**

And/or

> **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.**

These three functionalities are in line with the Annex Ia of the revised EPBD.

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 Ia 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.

2.2.2. Structure of the Smart Ready Services catalogue

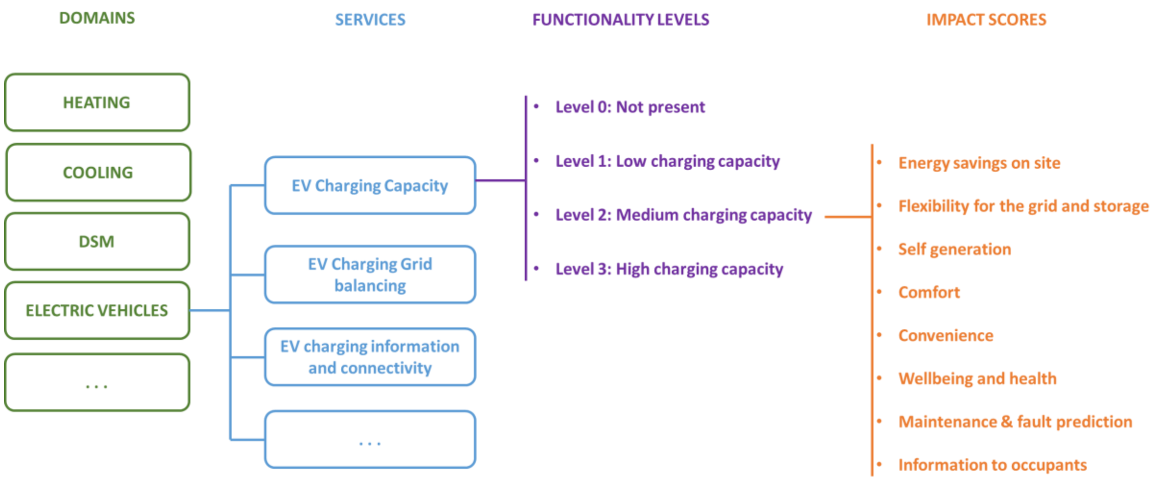

Figure 19 – Illustration of the structure of the SRI smart ready services catalogue

The SRI service catalogue is structured as shown in Figure 19. 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 along the the areas of interest (e.g. impact on comfort). More details are given in the following paragraphs.

Domains

In the SRI service catalogue, services are structured along 10 domains[8]: 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.

Smart Ready Services

The full catalogue currently lists 112 Smart Ready Services.
The reader is referred to Annex A of this document and the accompanying Excel spreadsheet for the full catalogue of services[9]. Figure 19 provides an excerpt of this catalogue, which illustrates the structure of the catalogue.

[8] Occupant comfort and health are currently not treated as service domains in the context of this study, but are considered in the impacts services can have.

[9] In comparison to previous versions of the catalogue (such as presented in the interim report of December 2017), the concept of "sub-services" is no longer being used. The numbering of the services has not been altered, and thus still reflects that some of the smart ready services are closely related. For example: smart ready services focusing on the demand side of heat control are numbered 1-a to 1-g, whereas those concerned with heat production are numbered 2-a to 2-e.

Functionality level

For each of the services several functionality levels are defined. A higher functionality level generally reflects a "smarter" service. 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 ordinal numbers, implying that ranks cannot be compared in between distinct services.

Impact criteria

The services translate into different impacts for buildings, building users and the energy grid: for example, enhancement of energy efficiency resulting from better control of TBS. One objective of the study was to select the most relevant impact categories to consider, taking into account the feedback from stakeholders. At this stage, the following eight impact categories are considered:

- **Energy savings on site:** 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. Potential overlaps with some national implementations of the energy performance certificates that reward BACS functionalities are discused in section 3.8.1.
- **Flexibility for grid and storage:** refers to the impacts of services on the energy flexibility potential of the building.
- **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 of the generated energy in order to provide more autonomy in terms of security-of-supply to the building.
- **Comfort:** 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. sufficient lighting levels without glare). Regarding the thermal aspects of human comfort, standard EN ISO 17772-1:2017 defines the design criteria for a building. SRTs can assist in ensuring the indoor environment meets these criteria during operation of the building, e.g. by controlling heat and cold delivery, controlling shading or window blinds, adjusting ventilation rates, etc.
- **Convenience:** 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 the technical building system.
- **Well-being and health**: refers to the impacts of services on the well-being and health of occupants. Not being harmful towards well-being and health of inhabitants is a strict boundary condition, which is required for all services included in the SRI assement. 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, 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 the TBS. It also has potential impacts on the energy performance of TBS by detecting and diagnosing inefficient operation.
- **Information to occupants:** this refers to the impacts of services on provision of information on building operation to occupants.

In the development of the calculation methodology, the services which have the highest impacts have been considered as most prioritary. The impact criteria listed here might need to further evolve (e.g. to a more simplified set) to facilitate the implementation and communication of the SRI.

Some of the impact categories of smart-ready services can also be relevant to other policy instruments and rating schemes. This is for example the case with energy savings and self-generation, in relation to the EPBD. This is also true for wellbeing, health and comfort in relation to building environmental assessment schemes such as Level(s)[10], BREEAM[11], HQE[12], or DGNB[13]. Section 3.8 of this report discusses linkages and potential overlaps between the SRI and other schemes in more detail.

Boundary conditions and supporting technologies and services

Some smart ready services may depend on pre-conditions and / or boundary conditions and supplementary services and technologies to be fully functional. Many of the smart services listed require supporting technologies and services to reach a desired functionality level, e.g. higher functionality levels of the services on heat generation or storage depend on other services (e.g. price signal information) delivered by other technologies (e.g. smart meters). The prevalence of supporting technologies such as the availability of broadband access or a smart metering device is not treated as separate smart service. Nevertheless, these technologies can be essential assets for some of the smart ready services. The supporting technologies are thus valued indirectly in the SRI when evaluating the smart ready services which depend on them.

Apart from technical boundary condition for specific services, other boundary conditions might have to be taken into account to prevent unintended side-effects of a greater uptake of smart technologies. This is specifically true for services with a potential impact on health and well-being of occupants, as well as thermal comfort.Recognising their important role, these potential impacts have been taken into account in the development of the catalogue of services in two ways. Firstly, services have been defined in such a way that higher functionality levels do not impede comfort, health and well-being, but rather enhance these. Furthermore, both physical comfort and well-being and health have been explicitly taken into account as impact factors in the proposed SRI method developed in Task 2 of the project.

Other boundary conditions include aspects such as interoperability or data protection and cyber-security. Interoperability is a prominent technical issue, translating into requirements for interfaces between systems. Dataprotection (in terms of privacy and technical robustness) is of highest importance for the occupant using the services. As regards cyber-security, the concept of security–by-design is nowadays a widely-accepted approach. Noting that the scope of this study is limited to the service level, and does not address the level of devices from individual vendors,, the issue of security is dealt with from a general security standards perspective. Section 2.4 of this report provides further information on these issues.

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[10] Level(s) is a voluntary reporting framework to improve the sustainability of buildings. Using existing standards, Level(s) provides a common EU approach to the assessment of environmental performance in the built environment.
http://ec.europa.eu/environment/eussd/buildings.htm

[11] https://www.breeam.com

[12] http://www.behqe.com

[13] http://www.dgnb.de

2.2.3. FORMAT OF THE SMART READY SERVICES CATALOGUE

The previous sections have given the theoretical and methodological foundations for Task 1 deliverables.

These deliverables (structured catalogue of smart ready services) are made available in the form of an Excel spreadsheet (Annex A), which is the key output form Task 1. It includes the following contents:

- In the spreadsheet file, the initial tab sheet covers the overall list of smart ready services as given in the Annex C of this document. For the purpose of easy reading the domains have been color-coded in the document. The structure of the tab sheet is in line with the structure presented in section 2.2.2. The columns show:
  - The domain of the service
  - The service code (that uniquely identifies the service)
  - The service group (e.g. controlling cooling demand)
  - The smart ready service name
  - Up to five functionality levels , which correspond to the different levels of smartness of a service
  - The standards from which the service was derived or to which the service is related – if applicable
  - An indication on whether the service is currently actionable
  - An indication on whether the service is considered in the proposed SRI methodology presented in CHAPTER 3
  - Preconditions to the assessment of a service, e.g. dependency on other services or building types (see more information on the triage process are in CHAPTER 3)
- In the additional tab sheets of the spreadsheet file, one tab sheet for each of the classifications domains from section 2.2.2 is given. For each of the services, the following information is displayed[14]:
  - The functionality levels of the service, ranging from level 0 up to level 4, depending on the service
  - The impacts of each of the functionality levels of the service, on a scale ranging from ----,---,--,-, 0, +, ++,+++ to ++++ for each the impact category.
  - The market uptake for both residential as well as commercial buildings
  - An estimation of the on-site inspection time needed to assess the service for each functionality level
  - Preconditions on other services (i.e. which other services are needed for the service to be made available)
  - Information sources / references used for the estimation of the impacts of the service, market uptake and inspection time
  - Relevant standards (e.g. for the assessment or the service)

The version of the catalogue provided with this report includes eleven domains, which cover 112 smart ready services. For each of those services, up to 5 functionality levels were assessed, with an average of 3 levels. For each level, 8 different impacts were assessed, two estimates of market uptake as well as the inspection time.

[14] The impacts, inspection time and market uptake were estimated by the project team based on expert assessment, relevant standards and stakeholder feedback. These estimations are provisional and should be considered as a discussion basis that will have to be further substantiated or better quantified in later phases.

The reader should be aware that this catalogue is the result of a thorough assessment of smart services but does not reflect the actual number of services used to calculate the indicator. The later is much lower (see CHAPTER 3).

The next section gives more details on each domain of the catalogue.

2.3. Selection and assessment of the services

2.3.1. Smart ready services domains

The study team identified the smart ready services based on a number of sources, including technical standards, policy and industry roadmaps and market analysis studies. The catalogue was further consolidated based on the feedback received from stakeholders.
This section summarizes the scope and contents of the smart ready services domains and related references. The reader is invited to refer to Annex A for a complete list and detailed description of smart ready services.

Heating

About 40% of EU's final energy is consumed in buildings, and space heating takes the largest share herein. Across EU 28, the total residential and service sector building heat market constitute an energy volume of approximately 13.1 EJ (STRATEGO, 2014-2016).

The reduction of the heating energy consumption and transition to renewable energy sources are important policy targets. Better design of buildings (increased insulation, optimal choice of glazing characteristics, proper use of the thermal capacity of the building structure, etc.) can reduce the heating need, while more efficient HVAC installations and renewable heat sources will reduce the environmental impact and primary energy demand for fulfilling this heat demand.

In the SRI Service catalogue, the "heating" domain lists smart services which enhance the operation of the heating systems (storage, generation, distribution and emission of heat).
These services are mainly related to the automation of the control of technical building systems for space heating, in accordance withtechnical standard EN 15232 and with some adaptations:

- Where relevant, simplification and aggregation of some services in order to ensure practical applicability and cost-effectiveness of the SRI.
- Where relevant, inclusion of additional services or functionality levels. For example service "Heating 2-b, Heat generator control for heat pumps", features an additional functionality level 3[15] which is not present in the EN 15232 standard. .

As standard EN 15232 does not quantify the energy efficiency gains resulting from heating system automation and control, and as these gains can depend on many factors such as building use, location, characteristics of the envelope, etc., the impacts given for this domain are only first order estimates which may need to be elaborated in follow-up work, e.g. by the inclusion of quantified scoring (see discussion in 3.6.1).

[15] controlling the heat generator capacity based on external signals from a smart electricity grid.

Cooling

This domain focuses on thermal storage, emission control systems, generators and energy consumption for space cooling.

The relative share of cooling energy consumption in the energy demand of a building will depend on climate and building usage, alongside the technical and geometrical properties of the building envelope, its technical installations and shading devices and the occupant behavior. Especially in Southern climates and specific typologies such as highly glazed office buildings, cooling can represent an important share of the overall energy demand of a building. Similarly to the heating domain, technical standard EN 15232 has been used as the main source in defining these services.

Domestic Hot Water

The domain of domestic hot water includes services dealing with the smarter control of generating, storing and distributing potable hot water in a building.

Especially in well-insulated residential buildings, provision of domestic hot water can represent an important share of the overall energy demand of a building. Similarly to the heating domain, technical standard EN 15232 has been used as the main source in defining these services.

Controlled Ventilation

This domain covers services for air flow control and indoor temperature control.
The ventilation rate and temperature control are important drivers for the energy demand of a building, and are equally important in relation to human health and thermal comfort. Smart controls can balance the contrasting demands, e.g. by regulating ventilation flow rates based on real-time measurement of indoor air quality parameters such as CO_2 concentrations. Similarly to the heating domain, technical standard EN 15232 has been used as the main source in defining these services[16].

While many of the services in technical standard EN 15232 are originally proposed for mechanical ventilation systems (and to a large extent also limited to non-residential buildings), they can also be applicable to residential systems and hybrid ventilation systems.

Lighting

This domain focuses on electric lighting managed/controlled by a lighting system based on, for instance, time, daylight, and occupancy.
Services for this domain are based on the initial CEN/CENELEC Smart House Roadmap[17] and extended by, e.g. the Ambient Assisted Living Roadmap of the German[18] DKE. The market data and analysis from the PPP Photonics 21[19] was also taken into account.

[16] The 'mechanical ventilation' section of EN15232 has been revised in the 2017 edition and these changes led to the rephrasing on some of the services in this domain compared to the previous interim report.
[17] CEN/CENELEC, Smart House Roadmap 2010
[18] DKE, German Standardization Roadmap AAL (Ambient Assisted Living) 2014
[19] PPP, Photonics 21 Initiative

Market uptake was assessed based on the structural analysis form the Gartner reports on Smart Lighting in the context of Smart Cities and smart home[20].

Dynamic Building Envelope

This domain focuses on the control of openings and sun shading systems. Commercially available energy management systems often focus on optimized control of lighting and HVAC systems. However, smarter operation of 'passive' building features such as operable shading and opening of windows can reduce the need for heating and/or cooling altogether and can have other impacts, such as on occupant thermal and visual comfort.

Services in this domain can affect the heating and cooling demand by controlling the amount of solar heat gains. They do however not directly control the heating or cooling systems in a building, and are therefore not part of the heating or cooling domain but introduced as a separate domain 'dynamic building envelope'.

The service on shading control is based on standard EN 15232, but expanded to include other types of shading. The services dealing with window opening control and window spectral properties are currently not mapped with international technical standards.

On-site Renewable Energy Generation

This domain incudes services that monitor, forecast and optimize the operation of decentralized power generation and control the storage or delivery of energy to the connected grid. Some of the services which relate to local energy generation have been subject to standardization efforts, specifically those within the 2010 IEC Smart Grid Standardization Roadmap (IEC, 2010). Many of these standards focus however mainly on the grid perspective and communication protocols. From a practical perspective, these aspects are difficult to assess on site. Furthermore, some of these features are assessed in the dedicated 'demand side management' domain of SRI. Therefore, the study team has suggested more aggregated services for the 'local energy generation' domain.

Demand Side Management

This domain focuses on the control of energy demand in response to implicit or explicit signals from thegrid (i.e. energy flexibility). The scope includes both explicit and implicit demand-response and both local smart grids (e.g. on a campus or urban level) and (supra)national grid.
The main focus of the services featuring in the smart ready service catalogue is on demand side management functionalities in electricity grids, which is in accordance with the text of EPBD Annex 1a. However, some of the services can be equally applicable to other types of energy grids, such as district heating and cooling grids. Further work can be done to assess how the scope could be broadened to include additional services excplicitly targeting district heating or cooling grids.

The definition of the series of this domain is based on both the IEC SMB Smart Grid Standardization Roadmap and consolidated information from the Preparatory Study on Smart

[20] Gartner, Hype Cycle for the Internet of Things, Hype Cycle for the Connected Home, Hype Cycle for Smart City Technologies and Solutions

Appliances[21] led in the scope of Ecodesign and energy labelling regulations. Some further adaptations were made; in particular streamlining and aggregation of some services, which can be difficult to assess on site or could require too much information.

The DSM domain overlaps to some extent the EV (Electric Vehicle) domain as EVs can provide storage and flexibility services for the electric grid.

Electric Vehicle Charging

This domain covers technical services provided by buildings to electric vehicles (EV) through recharging points, e.g. for electric consumption management and storage capabilities. In addition to the pure EV functionality, the electric storage from the EV can provide flexibility to the building and energy grid if properly controlled. Some of these services are derived from the IEC SG Standardization Roadmap which takes into account the results from the M/468 mandate[22]. Standards such as IEC 15118[23] provided information towards the definition of EV services in the SRI catalogue. This was supplemented by a few services which provide a more aggregated description of the EV charging capabilities. Still, as mentioned by stakeholder comments, some of the services in this domain are still emerging, with a lower market uptake compared to some services in other domains.

Monitoring and Control

This domain focuses on sensor data which can be provided by TBS in buildings and can be used by other services, and/or be combined into one overarching system such as a Home Energy Management System (HEMS). This for example includes occupancy detection functionalities, which can be used by multiple TBS such as heating, ventilation and lighting systems. This can also encompass services regarding the capability of the building occupants/managers to verify that the SRTs in place are operating as intended.

For ease of assessment, it was decided to structure services dealing with monitoring and control of one single domain under this respective domain of the catalogue. For example the service "*Report information regarding HEATING system performance*" is listed in the "heating" domain. Central reporting of all energy use per energy carrier (e.g. all gas use) is however part of the monitoring and control domain.

Various

During the course of Task 1 and based on suggestions by stakeholders, other smart ready services have been identified, which are not directly linked to any of the other domains and the scope set in the terms of reference of this study and Annex 1a of the revised EPBD. This for example includes services only focussing on security or health without any relation to technical building systems in the scope of the EPBD, such as services providing personal health monitoring of occupants or telemedicine services.

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[21] http://www.eco-smartappliances.eu

[22] http://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=450

[23] Communication between Electric Vehicles (EV), including Battery Electric Vehicles and Plug-In Hybrid Electric Vehicles, and the Electric Vehicle Supply Equipment

These suggested services are not part of the proposed SRI calculation methodology developed in Task 2 of this study. Nevertheless, these services are listed in the “Various” domain to serve as a reference and some of them might be considered for potential uptake if the scope of SRI would broaden up in future iterations of the indicator. For the services listed in the ‘various’ domain, no provisional impact scores have been defined.

2.3.2. PROVISIONAL IMPACT OF THE VARIOUS SERVICES

Impacts of smart ready services (and related functionality levels) are expressed on a nine-level ordinal scale: ----,---, --, -, 0, +, ++, +++,++++. While most of the impacts are positive, the scale also provides the opportunity to ascribe negative impacts[24]. Some services can result in benefits for several impact categories (e.g. energy flexibility) but negatively affect others (e.g. convenience or comfort of occupants might be slightly adversely affected by DSM).

The provisional impacts 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 Task 2. In later stages of the policy implementation of SRI, the impact scores will need to be further defined. For some of the impact categories, impact scores can explicitly be quantified, e.g. energy savings attributed to smart ready services. Multiple pathways can be envisioned to do so:

- Energy performance simulations carried out for a specific building (similar to the approach taken in energy performance certification of buildings)
- Impacts derived from measured performance characteristics of an in-use building[25]
- Predefined impact scores, calculated for a set of reference buildings (similar to the approach taken in the EU.bac certfification scheme). Potentially, such factors can be further differentiated according to climate, building type and other characteristics.

In choosing the appropriate method, the desire to have detailed results needs to be balanced with the time and efforts required to perform a practical assessment.

For several other impact categories, the quantification of the impacts requires to some extent a subjective judgement. This is for example the case for impact categories ‘convenience’ and ‘information to occupants’. Such subjective assessment is not to be done by the individual SRI assessor, but shall be defined as integral part of the SRI methodology. This can for example be defined by means of a dedicated expert group consisting of representatives of academia, policy experts and relevant industrial stakeholders. For illustration of the developed methodology in this preparatory study, the provisional impact scores have been proposed by the study team. Based on comments received through the stakeholder consultation carried out during the project, some modifications to these provisional impact scores have been applied. Nevertheless, the majority of the impact scores reported in Annex A currently represents a first rough assessment by the study

[24] In the current list of services, no services with vastly negative impacts on some of the impact criteria have been considered. An assymetric impact scale with 6 levels (-, 0, +, ++, +++,++++) would thus have been sufficient.

[25] A complicating factor in this method is the need for defining a representative ‘base case’ to which the savings of SRTs can be compared to. Furthermore, a method based on measured performance is not suitable for using during planning and design stage of a building.

team and these scores should not be considered as final outcomes on which there is a broad concensus.
In the smart ready service catalogue, the market uptake has also been provisionally assessed for each functionality level for all services, based on market analysis studies. The domains cover a broad variety of systems and technologies, some related to emerging technologies, some to connected home, some in to smart city technologies. The latest versions of the Gartner Hype Cycles 2017[26] has been the primary source for assessing the maturity of the services and functionality levels.

This catalogue is intended to support the development of the SRI methodology. Throughout the project it has evolved in an iterative way based on stakeholder inputs and growing insights. A transparent framework will have to be defined and set up to support and frame the evolution of the SRI once it is established. This framework should in particular clarify the procedure to add or remove services and functionality levels, and to update impact scores.

2.3.3. INSTALLING A PROCESS FOR UPDATING THE SMART SERVICE CATALOGUE

The catalogue of smart ready services has been developed in an iterative way throughout the complete study. It is expected that further updates will still be needed after the initial study and that an interative process of reviewing and updating the catalogue will have to be set in place once the SRI is established. The need for further updates originates from the following factors[27]:

- Many of the services are based on international standards. This increases the credibility and ease of assessment, but might in some cases also hamper innovation since the development and update of standards is often a lenghthy and intricate process. It might be needed to review the services and update or add the higher functionality levels to better take into account technological progress and innovation.
- All impacts of the services in the catalogue are currently highly provisional and need to be further substantiated. Some of these impacts are bound to evolve over time. Furthermore, some of the impacts could vary according to member countries, climatic zones, buildings types, etc.;
- The list of services considered in the current streamlined SRI methodology (see Task 2) could evolve due to changes in the scope of the SRI and the topic per se, advances in inspection methods and protocols, feedback from consumer tests, etc.;
- Feedback from field tests and large scale trials of the SRI in actual buildings could result in adaptations of the catalogue;
- Progress on inspection/assessment methods (such as the use of digital models of buildings, self-reporting from TBS, emergence of product-specific certification labels, etc.) could reduce the time and efforts needed for SRI assessment. This can shift the cost-benefit balance of the inspections, and generate the opportunity to consider more services in the future.

A robust process should be set up to regularly revise and update the smart services catalogue in close collaboration with all relevant stakeholders. This also implies agreeing on procedures and quality checks for updating impact scores; and potentially also extends to the development of agreed inspection protocols. In this process, care must be given to maintain a proper balance of assessment efforts versus impact of services to be included in the SRI, as well as the need for maintaining a

[26] Gartner, Hype Cycle for the Internet of Things, Hype Cycle for the Connected Home, Hype Cycle for Smart City Technologies and Solutions, 2017
[27] Also raised in the consultations by the stakeholders

reasonable balance amongst services and domains. A priori, such a process would preferably be organised at a European level to maintain a uniform approach and prevent market barriers.

A regular update of the service catalogue and impacts associated with the services, might also have consequences on how the SRI score is presented. SRI scores might become incomparable over time, or might need to be re-evaluated when an update of the SRI methodology is available.

2.4. DATA PROTECTION, CYBERSECURITY, INTEROPERABILITY AND STANDARDISATION

This section briefly introduces how the SRI links to the topics of data protection, privacy, cybersecurity, interoperability and related standardisation. Possible links to other building labelling and certificationschemes are further discussed in section 3.8 of this report.

2.4.1. DATA PROTECTION AND PRIVACY IN RELATION TO THE SRI

After four years of preparation, the EU General Data Protection Regulation (GDPR) was approved by the EU Parliament on 14 April 2016 and the official enforcement date was 25 May 2018. Those organizations in non-compliance may already face fines by the EC for not fulfilling the new requirements. The GDPR replaces the previous Data Protection Directive 95/46/EC and is designed to harmonize data privacy regulations across Europe, to protect and empower all EU citizens' data privacy and to re-shape the way organizations across the EC approach data privacy.

GPDR will apply to the processing of personal data by controllers and processors in the EU, regardless of whether the processing takes place in the EU or not. The GDPR will also apply to the processing of personal data of data subjects in the EU by a controller or processor NOT established in the EU, where the activities relate to, e.g. offering goods or services to EU citizens (irrespective of whether payment was required by the user) and the monitoring of behavior that takes place within the EU. Non-EU businesses processing the data of EU citizens will also have to appoint a representative in the EU in order to establish a link. Various data subjects must be adhered to according to the law:

- Breach Notifications
- Right to Access
- Data Erasure
- Data Portability
- Data Privacy by Design
- Data Protection Officers

Many of the smart services listed in the SRI catalogue have the potential to gather large amounts of personalized data. Even seemingly banal data sets such as indoor temperatures, energy consumption profiles or indoor air quality readings can potentially be put to wrong use to get insights in individuals' living patterns, holiday regimes, etc. For system vendors and OEMs (Original equipment manufacturer), integrators and (data) aggregators of smart building services, it is thus crucially important to implement proper data protection measures. The building owner or occupant should not undertake any action, since the GDPR assigns the responsibility for data protection to the system operator who actually processes and stores personal data.

In practice, it will not be feasible for an SRI assessor to have a full understanding of how data gathered by sensors in a building will be handled and how data protection is ensured. After all, this is mainly a matter of software and servers on a remote location. Furthermore, data privacy by design will be a prerequisite for all smart services on the EU market as of 25 May 2018 onwards. The approach taken therefore, is the assumption that all smart ready services present in a building are GDPR compliant and hence there is no need for a further detailed assessment of data protection of the smart services and technologies present in a particular building.

2.4.2. CYBER SECURITY IN THE CONTEXT OF THE SRI INDICATOR

Digital technologies are the backbone of smart ready services in buildings. They might also bring about new risks related to data theft, frauds and system hacking. Ensuring cybersecurity is therefore a key issue to foster trust in digital technologies.

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 European Union is an essential aspect of EU's Digital Agenda. The NIS (Network and Information Security) Directive on security of network and information systems was adopted by the European Parliament on 6th of July 2016 and entered into force in August 2016. Member States will have 21 months to transpose the Directive into their national laws, as well as 6 months more to identify operators of essential services.

In 2004 the EU set up ENISA[28]. The European Union Agency for Network and Information Security. ENISA works closely together with Members States and private sector in facing network and information security challenges, as well as delivering advice and solutions on cyber-security.

On 13 September 2017 the Commission issued a proposal for a so called cybersecurity package[29]. The 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 will ensure the trustworthiness of billion connected devices (in terms of IoT) 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 will provide EU-wide certification schemes as a comprehensive set of rules, technical requirements, standards and procedures[30]. This will be based on agreement at EU level for the evaluation of the security properties of a specific ICT-based product or service.

Cybersecurity will be an important prerequisite for public trust and greater uptake of smart ready technologies in the building sector. Preferably, the smart readiness indicator will align with the forthcoming EU cybersecurity certification framework, without the need for supplementary certification and assessment efforts. A straightforward solution could be the provision of an additional 'cybersecurity' indicator or symbol on the SRI label, if (- a subset of most relevant -) smart ready technologies present in the building adhere to the cybersecurity certification framework. Another potential solution to include this initiative in the SRI is the addition of extra service levels to already proposed services or the inclusion of new services dealing with cyber security. The current

[28] https://www.enisa.europa.eu/
[29] https://ec.europa.eu/info/law/better-regulation/initiatives/com-2017-477_en
[30] https://ec.europa.eu/digital-single-market/en/eu-cybersecurity-certification-framework

proposed methodology is flexible to deal with such expansions when the forthcoming EU cybersecurity certification framework becomes operational.

2.4.3. INTEROPERABILITY IN THE CONTEXT OF THE SRI INDICATOR

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 create more 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[31] and other properties have to be taken into account. Future interoperability will need pre-conditions to a building like broadband connectivity[32].

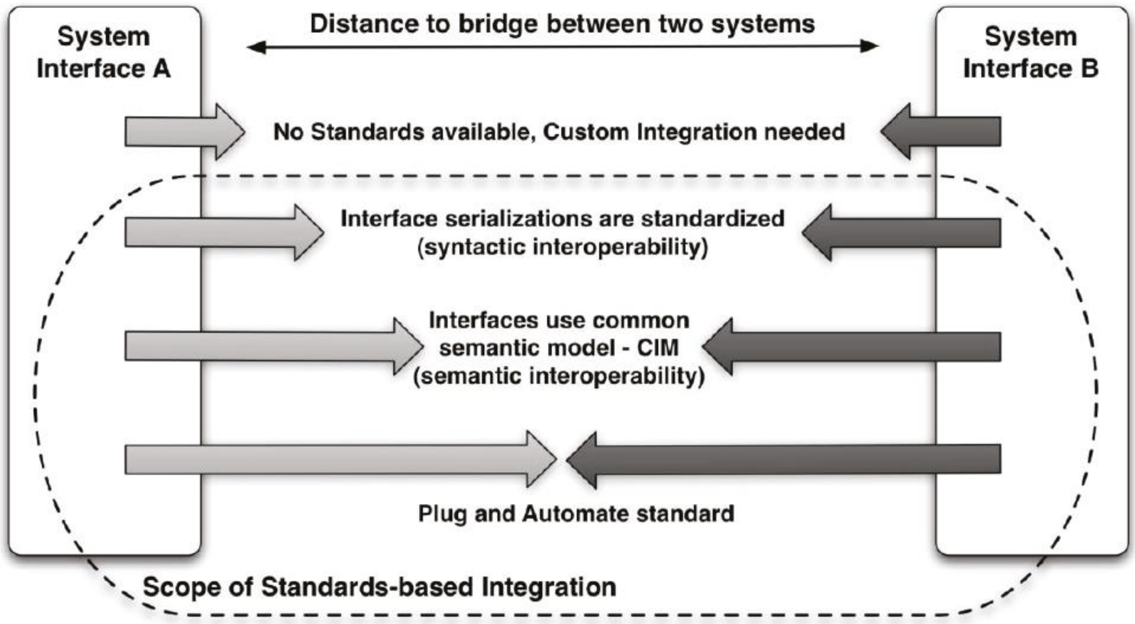

Figure 20 - Semantic integration distance for interoperability (source: Offis)

Figure 20 illustrates the different forms of interoperability; the integration distances range from customized 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 standardized in order to achieve a high interoperability, lower integration costs and better operational performance.

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

32 Directive 2014/61/EU

In the domain of smart appliances, the European Commission has boosted the development of a common ontology[33] for this domain, called SAREF (Smart Appliance Reference) and a standard based on it developed by ETSI[34]. These allow 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 communciation provide specifications for the energy domain[35] and the building domain[36]. Within the Ecodesign framework of the European Commission, further focus has been given to intereroperability in the product and service design of smart appliances[37] and BACS[38].

While such common framework is in place for some specific technologies such as smart appliances, this is not the case for all domains and technologies in scope of the SRI. Furthermore, these technical specifications are not applicable to legacy equipment already largely present in existing buildings.

Whilst interoperability is acknowledged as a very important concern[39] in relation to the SRI, an explicit evaluation of the interoperability of all equipment in a building would be difficult as it requires some in-depth information on an extreme borad range of technology and implemntations by various vendors that is often not readily available to an assessor, especially in case of legacy equipment. Furthermore, such assessment would need to be performed for many of the TBS present in a building, requiring large amounts of time and efforts which would have important repercussions on the cost of an SRI assessment. Annex C on Interoperability of this report provides more discussion on this topic.

Within the current proposal for an SRI assessment scheme, a different approach has thus been favored. Instead of evaluating various dimensions of interoperability for each of the TBS separately, technology neutral services have been introduced in the SRI catalogue[40]. Many of the services inherently require multiple sensors, actuators and controllers[41] to be interoperable to collectively deliver the specific service.

For example, a service such as “Building preheating control” requires an amount of temperature sensors installed, distribution pumps, heat generators, etc. to work together seamlessly[42] to deliver the requested service. Furthermore, specific services have been included in the service catalogue to express how TBS in different domains can work together. Inherently, some level of basic interoperability will be required to make such services actionable at all.

Examples include **“Cooling 1-f: Interlock between heating and cooling control”**, **“DE-2: Window open/closed control, combined with HVAC system”** and **“Central reporting of TBS performance and energy use”**.

[33] Defining semantics for technologies and functions

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

[35] 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

[36] 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

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

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

[39] Also raised in the consultation process

[40] Those are independent from vendor specific interoperability problems arising

[41] Mostly from different vendors and OEMs

[42] In terms of interfaces and sensor interpretation

If EU wide certification schemes or labels for indicating the interoperability of TBS emerge in the future[43], these could be introduced into the SRI methodology in future iterations (see further discussion in section 3.9.7).

2.4.4. TECHNICAL STANDARDS IDENTIFIED AND COVERED FOR THE SERVICE CATALOGUE

Standards can contribute to the development of an SRI by assisting in identifying or quantifying functionalities and services in a fast and harmonized way.

The ‘smart ready services’ in this study were to a large extent ourced from standards. 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 Building Automation and Controls Systems (BACS) on the energy consumption of the building. It is used within EPBD and contains a structured list of BACS and Technical Building Management (TBM) functions. Other examples 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.

[43] As recommended by stakeholders in the consultation process

CHAPTER 3 TASK 2 - ROBUST METHODOLOGY FOR THE HARMONISED CALCULATION AT EU LEVEL OF THE SRI FOR BUILDINGS

This chapter of the final report sets out the thinking behind the derivation of a generic methodology that could be applied to the calculation of a smart readiness indicator. It takes into account the comments received from the stakeholder consultation and includes the sections as detailed below.

Section 3.1 describes the factors that need to be considered in the derivation of an SRI. It includes a new sub-section on data protection.

Section 3.2 then sets out the development of a generic SRI methodology. It draws upon much wider experience in the derivation of multi-criteria decision making methodologies and applies this to the exposition of a generic SRI methodology. An illustration is then presented of how the generic methodology can be applied to a theoretical building using the array of smart readiness elements reported in the Task 1 catalogue. Note, this section has been updated to make use of the modified Task 1 services which were amended in light of stakeholder comments.

Section 3.3 introduces the reality checks that would need to be taken into account to implement an actual SRI and considers how these are likely to filter the smart readiness services that can be operationalised. It addresses the practical aspects that affect the ability to implement an SRI and includes a review of the maturity of the smart readiness elements reported in the Task 1 catalogue. This section has been updated to make use of the modified Task 1 services which were amended in light of stakeholder comments

Section 3.4 examines how the generic SRI based on the Task 1 catalogue can be streamlined to make a practically applicable smart readiness indicator. It reviews the Task 1 catalogue of smart readiness services and proposes some consolidation and restructuring. It then applies the proposed streamlined approach to two cases studies – one for a single family home and one for an office building. This section has been updated to make use of the modified Task 1 services which were amended in light of stakeholder comments

Section 3.5 considers how the SRI methodology can be tailored to address locally specific context and demonstrates its versatility and adaptability to different circumstances.

Section 3.6 is a new section that covers alternative methodological approaches including:

- Incorporating cardinal data assessment of impacts
- Using calculation software
- Using measured outcome based approaches
- Checklist based approaches
- Evolutionary hybrid approach

Section 3.7 addresses how the information in the SRI can be reported to the various users.

Section 3.8 is a new section that addresses linkages with other schemes and in particular with EPCs, Building renovation passports and the LEVELS scheme.

Section 3.9 is a new section that presents the findings from field trials of the streamlined SRI methodology on actual buildings.

Section 3.10 presents the provisional conclusions of the work in Task 2.

Annex F presents a review of the maturity of the smart readiness elements catalogued in Task 1 for use within an SRI methodology.

Annex G presents an actionable set of smart readiness elements drawn from the streamlined methodology.

3.1. FACTORS TO CONSIDER IN DERIVING AN SRI

This paragraph discusses the issues and principles one would want to include in an SRI and summarises how building smartness has been defined thus far in the project including the three main elements of buildings smartness requested by the Commission.

The Task 1 work has highlighted the array of smart readiness aspects and features that can be expressed in terms of the domains where they apply, the services and functions they offer. The domains articulate a taxonomy of the systems within which these smart readiness (SR) services are applied. For each of the services several "levels of functionality" are defined to differentiate between levels of smartness capability for a given functionality offered to the building occupant, owner or the grid. In addition, a set of eight higher-level impact criteria has been defined and the effect (expressed in terms of an ordinal ranking system) which each level of functionality is expected to have on these criteria has been estimated.

The prospective SRI methodology developed in this part of the report needs to take these inputs and use them to derive an output (or outputs) that provides an indicator of how "smart" a building is. In particular, it will (most likely) want to assess the effect these are expected to have on a set of designated impacts (e.g. the eight impact criteria) and award smart-readiness scores based on that.

Alternatively, another potential methodological approach for the SRI would be not to weigh the different impact scores, but rather structure the methodology along the different domains (e.g. 20% of the overall indicator is based on the smartness aspects related to heating, 15% to lighting, etc.). For the sake of clarity, only the approach based on weighting the impacts is further explored in this document.

The methodology chosen has to allow the impacts to be assessed and scored; however, at this stage of the indicator development process the policymaking community's views on the most important impacts and how they should be scored are unknown. Thus, the structure used in the methodology has to be adaptable to allow the policymaking process to establish a collective position on the choice of impacts to be addressed and their relative importance. In practice, it also needs to be developed in such a manner that will help to inform the discussion and facilitate the decision making process.

As a precursor to the development of an SRI methodology it is important to consider the set of factors that the SRI will need to address. These are now considered in turn.

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.

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.

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 multi-faceted 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 to ensure the scheme is designed in a manner that best satisfies them.

Moreover, since work started on this project an agreed text between the Parliament and Council for the revised EPBPD has been drafted which states that the objectives with regard to the SRI are as follows:

"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.

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.

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 decision making 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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

3.2. Development of a generic SRI methodology

This section sets out the development of the generic SRI methodology. It begins by briefly reviewing multi-criteria decision making methodologies in general and then leads from that to the exposition of the generic SRI methodology.

3.2.1. MULTI-CRITERIA DECISION-MAKING METHODS

This section discusses multi-criteria decision making (MCDM) methods that have been applied to energy/environmental decision-making including reviewing how they work and the compromises/value judgements they necessarily entail between different impact criteria, different areas of impact and different degrees of measurability i.e. cardinal, ordinal, qualitative metrics. It references and borrows from the DG GROW Points System for Complex Products study[44] (VITO & WSE 2017), where such an exercise was conducted. It then summarises the implications this has for the design of a generic SRI.

The derivation of a smart readiness indicator, which involves the assessment of numerous impact criteria related to building's smart service capability, is a manifestation of a multi-criteria decision-making process and like all multi-criteria assessment problems faces a challenge of how to determine preferred outcomes given the presence of more than one assessment criterion.

A more general understanding of the theory and principles involved in all such processes can be helpful to contextualise thinking on how methods to address these challenges could be derived and applied in the future. This section provides a very brief introduction to the theory MCDM and multi-criteria decision analysis (MCDA) that aims to position the SRI methodology framing in its broader context any thereby better understand the principles and theory behind the derivation and use of points-systems approaches for multi-criteria assessment.

In general, models that support MCDM are concerned with structuring and solving decision and planning problems involving multiple criteria. The rationale for creating such a structured framework is to support decision-makers confronting such problems. Usually there is no unique and unequivocally optimal solution to an MCDM problem that can be derived without incorporating preference information. Thus MCDM models are designed to provide a framework that will allow such preference information to be assessed in conjunction with deterministic or empirical information so that decisions which involve the assessment of multiple criteria can be reached within a structured framework.

MCDM has been an active area of research since the 1970s and draws upon knowledge in many fields including: mathematics, behavioural decision theory, economics, computer technology, software engineering and information systems. There are several MCDM-related organisations including the International Society on Multi-criteria Decision Making[45], Euro Working Group on MCDA (Euro working Group)[46], and INFORMS Section on MCDM (INFORMS)[47].

[44] https://points-system.eu/

[45] https://www.mcdmsociety.org/

[46] http://www.cs.put.poznan.pl/ewgmcda/

[47] http://connect.informs.org/multiple-criteria-decision-making/home

MCDM typologies

It should be noted that there are different classifications of MCDM problems and methods. A major distinction between MCDM problems is based on whether the solutions are explicitly or implicitly defined.

- *Multiple-criteria evaluation problems*: These problems consist of a finite, discrete number of alternatives, explicitly known in the beginning of the solution process. Each alternative is represented by its performance in multiple criteria. The problem may be defined as finding the best alternative for a decision-maker (DM), or finding a set of good alternatives. There may also be a need to sort or classify the alternatives. In this context sorting would be undertaken to place the alternatives into a set of preference-ordered classes (such as assigning star ratings to hotels). Classifying refers to assigning alternatives to non-ordered sets (such as diagnosing patients based on their symptoms).

- *Multiple-criteria design problems (multiple objective optimisation problems)*: In these problems, the alternatives are not explicitly known and an alternative (solution) may be found by solving a mathematical model. The number of alternatives may either be infinite (when some variables are continuous) or typically very large if the variables are countable (when all variables are discrete).

The SRI belongs to the set of multi-criteria evaluation problems which is reflected in the catalogue of smart readiness domains, services and functionalities presented in Task 1; however, regardless of whether the problem is of the evaluation or design type, preference information is required in order to differentiate between solutions in the decision model.

It is beyond the scope of this exercise to review all the potential MCDM methods (see Annex H for a list); however, the recently completed study on Ecodesign Points Systems for Complex products provides an extensive review of the application of points system methods to multi-criterion energy and environmental evaluation exercises as applied to technologies and other energy using or related systems, e.g. Task 2 report of Points System Study (VITO & WSE, 2017). The cases covered include many applied to the energy and environmental performance evaluation of buildings including the BREEAM, LEED and DGNB schemes. In so doing it considers the effectiveness, enforceability, transparency, and accuracy/reproducibility of these methods.

The key concept to understand is that because multi-criteria evaluation problems involve comparisons and judgements between inherently different criteria that they are necessarily subjective. There is no “right” answer to these evaluations but if good methodological practice is used the problem can be framed in a manner that allows judgements and preferences to be compared and treated within an organised framework, that maximises transparency, fairness of consideration and treatment and allows the designated decision makers to reach a collective position. The Analytic Hierarchy Process (AHP) is a good example of this. It is a MCDM tool that was first articulated in the 1970s and has the practical value of creating a framework that enables alternative choices across different assessment criteria sets to be compared and ranked against each other. In particular, it permits the assessment of sets of qualitative and quantitative criteria to be assessed within a common analytical structure in order to rank outcomes based on the preferences embedded in the model. The AHP does this by initially decomposing the decision problem into a hierarchy of sub-problems (much as the Task 1 smart services catalogue structure would imply). Then the decision-maker(s) evaluate the relative importance of its various elements by pairwise comparisons. The AHP converts these evaluations to numerical values (weights or priorities), which are used to calculate a score for each alternative. Decision situations to which the AHP can be applied include:

- Choice – The selection of one alternative from a given set of alternatives, usually where there are multiple decision criteria involved.
- Ranking – Putting a set of alternatives in order from most to least desirable
- Prioritisation – Determining the relative merit of members of a set of alternatives, as opposed to selecting a single one or merely ranking them
- Resource allocation – Apportioning resources among a set of alternatives
- Benchmarking
- Quality management – Dealing with the multidimensional aspects of quality and quality improvement
- Conflict resolution – Settling disputes between parties with apparently incompatible goals or positions.

The AHP does not determine a "correct" decision, but rather enables decision-makers to find one that best suits their objective and understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem, representing and quantifying its elements, relating those elements to overall goals and for evaluating alternative solutions.

There have been thousands of applications of AHP to complex decision-making situations. These encompass applications in a very diverse set of problems involving planning, resource allocation, priority setting and selection among alternatives, forecasting, total quality management, business process re-engineering, quality function deployment and balanced scorecards. It has particular application in group decision-making and is used around the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, shipbuilding and education. Commercial software to assist in applying AHP is available. Due to its intensive development nature the AHP is probably not best suited to the derivation of a multi-criterion public policy evaluation framework like the SRI, but aspects of its structuring of the MCDM problem that allow structured assessment of choice, ranking, prioritisation, resource allocation (e.g. assessment time & cost for the SRI) and benchmarking should be. These thoughts, and particularly how they have been applied to a points type evaluation framework inspire the development of the methodology set out below. In particular, the methodology set out in this Task is informed by the methodology developed and tested for the DG GROW Points System for Complex Products study (VITO & WSE, 2017).

3.2.2. DERIVATION OF A GENERIC SRI METHODOLOGY

This section describes the derivation of the generic SRI. It introduces a generic SRI scoring system and describes its elements, its modularity, and its flexibility.

The Task 1 work has highlighted the array of smart readiness aspects and features that can be expressed in terms of domains, services and functions. The domains articulate a taxonomy of the systems within which these smart readiness (SR) features are applied. For each of the services several "levels of functionality" are defined to differentiate between levels of implementation of smartness for a given functionality offered to the building occupant, owner or the grid. In addition, a set of eight higher-level impact criteria are defined and the effect (expressed in terms of an ordinal ranking system) that each level of functionality is expected to have on these criteria has been estimated.

The prospective SRI methodology needs to take these inputs and use them to derive an output (or outputs) that provides an indicator of how "smart" a building is. In particular, it will (most likely) want to assess the effect these are expected to have on a set of designated impacts (e.g. the eight impact criteria) and award smart-readiness scores based on this.

The methodology chosen has to allow the impacts to be assessed and scored; however, at this stage of the indicator development process the policymaking community's views with regard to the most important impacts and how they should be scored are not fully known. Thus, the structure used in the methodology has to be adaptable to allow the policymaking process to establish a collective position on the choice of impacts to be addressed and their relative importance. In practice, it also needs to be developed in such a manner that will help to inform the discussion and facilitate the decision making process.

An SRI methodology

It follows to consider what characteristics a general SRI methodology should have. Currently the envisioned methodology is that of a multi-criteria assessment based on the predicted impacts of the smart services present in a building. Prospective alternative approaches, such as assessing the 'level of smartness features implemented' (merely counting the features without taking into account their predicted impacts) or direct quantification or even measurement of physical characteristics, etc. are not pursued for now because in the former case they are likely to be too simplistic and lack credibility, whereas the latter approach implies a level of determinism that could result in practical difficulties for smart readiness assessments. Rather it aims to strike a balance between facility of implementation and the correct characterisation of impacts that best satisfies the considerations set out in Section 3.1.

In all multi-criteria assessment methodologies which result in a single score or indicator, the following approach is taken:

- identify the relevant impact criteria to be used in the assessment
- develop a methodology to determine the effect that sub-elements have on each impact criteria and thereby allow scoring per impact criteria
- develop a system of weightings to determine an overall score across the impact criteria.

If (for the sake of simplicity) it were to be assumed that there are just three relevant impact criteria (in fact the Task 1 report has identified eight[48]) and the indicator can be expressed as a simple weighted sum, then the overall score N becomes:

$$N = A \times a + B \times b + C \times c$$

Where a, b and c are the relative weightings given to the impact criteria scores A, B and C. Normally a, b and c would add up to 1 (to normalise the outcome) and A, B and C would be scored on a scale that corresponds to the final scale for N (e.g. it could be on a scale of 0 to 100, in which case A, B and C would also each be scored on a scale of 0 to 100). Such a system would give a final score for N of from 0 to 100 and this in turn could be transposed into a heuristic scale (such as A to G, or 1 to 5 stars) using a classification system that defines the grades in terms of the score N: noting that heuristic scales are valuable because they tend to be more accessible and memorable for users and hence easier to incorporate in their decision-making processes. Exactly this methodology can be applied for the SRI, even though the number and nature of impact criteria (A, B, C…X) and the weightings to be applied to them (a, b, c, …x where the sum of a to x is 1) remain to be consolidated in the policymaking process.

Under such a structure it would be possible to begin with the most tractable (important and viable) impact criteria and to add more in the future as they become sufficiently viable to assess. Each time a new impact criterion is added the weightings a, b, c, to x would need to be adjusted so that their

[48] Namely: energy savings on site, flexibility for the grid and storage, self-generation, comfort, convenience, health, maintenance & fault prediction, information to occupants.

sum still adds up to 1. It should be noted that the BPIE smartness indicator[49] intrinsically follows this approach but in that case there are 12 primary impact criteria (of which 3 are compound impact parameters made up of two sub-criteria) and these are implicitly each given a weighting of 1/12 to each of these i.e. it is implicitly assumed that each are of equal importance. This is essentially a special case of the methodology outlined above, but one that was developed by a project team without formally being informed by a representative public policy decision-making process to agree the impact criteria to be included and the relative weightings they should have.

Note, in principle, an initial set of impact criteria could be those highlighted in the tender document i.e. the readiness to: adapt in response to the needs of the occupant; facilitate maintenance and efficient operation; adapt in response to the needs/situation of the grid. Also, in principle these impacts could be further grouped based on their impact on a higher level impact criteria, such as greenhouse gas emissions, or energy security, and in this case analysis could be done to assess how much they are likely to contribute to these higher level impacts. Such a grouping process would require the introduction of an analytical step to determine the likely importance of each of these impact criteria on the higher level impacts. Alternatively, the method could simply assess each impact criterion separately and use weightings to reflect the importance they have on these higher level impacts.

How can each impact criterion be evaluated?

Deriving a score (A, B, C …X) for each impact criterion requires information on the impact each SR feature (i.e. service functionality level) has on the impact criterion and derivation of a rating system for the given parameter. The Task 1 work presented the study team's initial ordinal impact rankings for each SR service functionality level per impact criterion (or in some cases this is omitted when there is no information). In some instances, a standard exists that would allow an approximate quantitative impact value[50] to be estimated. In many cases there is currently no agreed system for determining the magnitudes of impacts. Annex F presents a partial review to clarify the state of knowledge on what is known about the impact of each SR feature on each of the eight designated impact criteria. Ultimately, if ordinal rankings (such as the scale ---, --, -, 0, +, ++, +++ used in Task 1) are to be meaningful then there will need to be a systematic and publicly legitimate effort to imagine the quantified limits of these scales and the intermediate values the ordinal rankings are most likely to correspond to.

Furthermore, and critically, the ordinal rankings by impact criterion in Task 1 are set at the domain level (e.g. heating, cooling, DHW, etc.) yet what matters is the overall impact across the domains on the impact criterion. To translate from domain level impacts to whole building impacts requires a mapping exercise for typical buildings. This will be elaborated further for certain key impact criteria in Task 4 but in the meantime use is made of some simple existing data to attempt this for some exemplar impact criteria, in order to demonstrate the principle.

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[49] Actually this is a "Smart-Ready Built Environment Indicator", which only rates the boundary conditions and not the buildings themselves.

[50] The underlying aim is to pinpoint features of a building which can augment its smartness. An exact quantification of the resulting effects of the smart features is therefore not necessarily needed. Calculating the energy savings or flexibility in terms of financial gains or kWh, or quantifying the healthier living environment in DALYs would be a very complicated undertaking, requiring highly complex calculation methodologies and extensive in-situ inspections. This is not considered at this step within the intended framework for the SRI. Rather simplified expressions representing average effects could be favoured as the basis of this calculation (e.g. in line with the methodology of 'classes' as reported in the EN15232 standard on energy savings from BACS).

Potential impact interactions between services

It should also be noted that theoretically there could be interactions between services that ideally should be taken into account. Whenever these could exist they should be identified and ideally the relationship between them established.

3.2.3. THEORETICAL APPLICATION OF TASK 1 ELEMENTS WITHIN THE GENERIC METHODOLOGY

This section shows how the generic methodology can be applied to a theoretical building using the array of Task 1 smart readiness catalogue elements. It shows how weighting the domains and/or impacts affects the outcomes. It also shows the degree to which organising the elements in terms of their impact progressively contributes to the final SRI score and thus helps clarify the potential trade-offs that can be envisaged from limiting the number of elements that are assessed in order to make a viable scheme.

The following sections present illustrations of the process of applying the generic methodology for the case where equal weightings are applied and also for the case where differentiated weightings are applied. They begin with an exposition of how the methodology could be applied to any building and then considers the specific case of a hypothetical single family home.

Equal weightings case study

In order to illustrate the generic SRI methodology it is applied here based on the distinctions made in the Task 1 analysis. In particular, it is assumed that the impact criteria to be addressed are the same as those identified in the Task 1 analysis, namely:

- Energy savings on site
- Flexibility for the grid
- Self-generation
- Comfort
- Convenience
- Well-being and health
- Maintenance & fault prediction, detection and diagnosis
- Information to occupants

Under this example, using the eight impact criteria provisionally proposed in the Task 1 report then the generic model set out before would become:

$$N = A \times a + B \times b + C \times c + D \times d + E \times e + F \times f + G \times g + H \times h$$

Where:
A = the impact score (from 0 – 100) for Energy Savings
B = the impact score (from 0 – 100) for Flexibility for the grid and storage
C = the impact score (from 0 – 100) for Self-generation
D = the impact score (from 0 – 100) for Comfort
E = the impact score (from 0 – 100) for Convenience
F = the impact score (from 0 – 100) for Health and well-being
G = the impact score (from 0 – 100) for Maintenance and fault prediction, detection and diagnosis
H = the impact score (from 0 – 100) for Information to occupants

And:

a = the impact weighting (from 0 – 100%) for Energy Savings
b = the impact weighting (from 0 – 100%) for Flexibility for the grid and storage
c = the impact weighting (from 0 – 100%) for Self-generation
d = the impact weighting (from 0 – 100%) for Comfort
e = the impact weighting (from 0 – 100%) for Convenience
f = the impact weighting (from 0 – 100%) for Health and well-being
g = the impact weighting (from 0 – 100%) for Maintenance and fault prediction, detection and diagnosis
h = the impact weighting (from 0 – 100%) for Information to occupants

and N is the total weightened score by domain.

In this first illustration of the generic method the impact criteria weightings are weighted equally i.e. at 12.5% each (i.e. at 100%/8 given that there are 8 impact criteria).
In practice, the impact of SR features on these criteria has to be assessed at the domain level where the SR features are applied. In this example the domains considered are also the same as in the Task 1 analysis, namely:

- Heating
- Domestic hot water
- Cooling
- Controlled ventilation
- Lighting
- Dynamic building envelope
- Energy generation
- Demand side management
- Electric vehicle charging
- Monitoring and control.

For each of these domains the same services as applied in the Task 1 analysis are assumed. E.g. in the case of heating the following 12 services are considered (see Table 1).

Table 1 - Heating services considered in Task 1

Heating services	
Heating-1 Heat control - demand side	
Heating-1a	Heat emission control
Heating-1b	Emission control for TABS (heating mode)
Heating-1c	Control of distribution network hot water temperature (supply or return) - Similar function can be applied to the control of direct electric heating networks
Heating-1d	Control of distribution pumps in networks
Heating-1e	Intermittent control of emission and/or distribution - One controller can control different rooms/zones having same occupancy patterns
Heating-1f	Thermal Energy Storage (TES) for building heating
Heating-1g	Building preheating control
Heating-2 Control heat production facilities	
Heating-2a	Heat generator control (for combustion and district heating)
Heating-2b	Heat generator control (for heat pumps)
Heating-2c	Sequencing of different heat generators
Heating-2d	Heat system control according to external signal (e.g. electricity tariff, gas pricing, load shedding signal etc.)
Heating-2e	Heat recovery control (e.g. excess heat from data centres)

Each service can be delivered with a varying level of SR functionality. In the Task 1 analysis these range from one to up to four functionality levels depending on the service considered (they can be as little as two functionality levels or as many as four levels). An example is the different functionality levels ascribed to the service of heat emission control (within the heating domain) which are defined in Task 1 as shown in Table 2.

Table 2 - Functionality levels for the heat emission control service from Task 1

Functionality level	Functionality description
0	No automatic control
1	Central automatic control (e.g. central thermostat)
2	Individual room control (e.g. thermostatic valves, or electronic controller)
3	Individual room control with communication between controllers and to BACS
4	Individual room control with communication and presence control

For each service Task 1 then ascribes an impact (functionality) rating (from 0 to ++++) for each impact criterion, as shown in Table 3 (for the example above).

Table 3 - Example of ordinal impact scores per functionality level from Task 1

Functionality levels		IMPACTS							
		Energy savings on site	Flexibility for the grid and storage	Self generation	Comfort	Convenience	Health and well-	maintenance & fault prediction	information to occupants
level 0	No automatic control	0	0	0	0	0	0	0	0
level 1	Central automatic control (e.g. central thermostat)	+	0	0	+	+	0	0	0
level 2	Individual room control (e.g. thermostatic valves, or electronic controller)	++	0	0	++	++	0	0	0
level 3	Individual room control with communication between controllers and to BACS	++	0	0	++	+++	0	+	0
level 4	Individual room control with communication and presence control	+++	0	0	++	+++	0	+	0

In this illustration of the generic SR methodology these Task 1 functionality rankings per service and impact criteria are assumed to be accurate[51]. Furthermore, a priori and for the sake of simplicity, it

[51] This is a working assumption to permit demonstration of the method. Many of the ordinal scores derived in Task 1 are the study team's own estimates aimed at indicating the relative importance of the (levels of) services on the impact categories and stimulating discussion on this. Some of these values will need to be further quantified in case these specific services are taken into account for an applied methodology.

is assumed that each functionality level grading is equivalent across services for any given impact criterion. Thus, if a functionality level is graded at +++ for two different services when considering a given impact criterion (e.g. energy savings) then the relative impact is provisionally considered to be the same (unless differentiated weightings are subsequently applied as discussed further below). This allows the ordinal rankings to be converted into the quasi numerical impact scores shown in Table 4.

Table 4 - Ordinal functionality level rankings mapped to nominal impact scores

Ordinal ranking	Nominal impact score
++++	4
+++	3
++	2
+	1
0	0
-	-1
--	-2
---	-3
----	-4

For any given service there is a maximum SR score it is possible to attain for the impact criterion in question. When aggregated across all the services these maxima can be used to derive a normalised score by dividing the sum of the nominal impact scores by the sum of the maximum possible nominal impact scores and multiplying by 100 to attain an overall percentage of the maximum score. This process, which produces an overall SRI score for a building, is illustrated in the single family house examples shown further below in section 3.2.3. In the current methodological example, the maximum is derived by simply summing the potential maximum score for all services. In the later section 3.4 which presents a more practical and streamlined version of the generic methodology, this approach is further refined, since based on technical considerations a maximum score on all criteria is very unlikely[52].

Broad approach

The generic SR methodology organises these elements into a multi-criteria hierarchical decision-making model to derive an overall SRI. It does this through a process which evaluates the effect that the level of functionality of the SR services have on the chosen impact criteria followed by aggregating these into a common score.

The methodological steps applied are as follows:

- Select the impact criteria to be used (for this illustration they are the same eight as those identified in the Task 1 report)
- Consider what weighting should be applied to the impact criteria to derive a final SRI (for this illustration they are all weighted equally)
- Consider the impact that each level of functionality of the SR services has on each chosen impact criterion (This illustration uses the gradings (i.e. ----, ---, --, -, 0, +, ++, +++, ++++) applied in the Task 1 report as the starting point for this. It then converts them into a corresponding numerical score (i.e. -4, -3, -2, -1, 0, 1, 2, 3, 4) and uses this to derive a % score

[52] As an example, the current list features some services which are specifically geared towards heating boilers, while others focus on heat pumps. In a small scale residential building it is highly uncommon that both systems will be present.

by dividing it by the maximum nominal impact score i.e. if the maximum ordinal score it is possible to attain for the service/impact criterion/domain combination in question is ++++ and the score attained by the particular building is + then then maximum nominal score is 4 and the actual score is 1 thus the normalised score is ¼ = 25%.

- A decision is then required regarding how to weight these scores within domains and across domains – in this illustration it is assumed a priori that the scores are directly comparable within a domain i.e. should have the same weight for each service considered. In the case of cross-domain weightings these are considered to be equal for all the impact criteria in this equal weightings case study, but is also reasonable to apply differentiated weightings as is considered in the next case study.

Weighting decisions

In general, decisions on weightings need to be made on:

- The impact criteria (initially eight in the Task 1 report and these are provisionally assumed to be equally weighted (i.e. equally important) in this illustration of the generic SR methodology)
- The domains (these are provisionally assumed to be equally weighted (i.e. equally important) in this illustration of the generic SR methodology; however, as this is known not to be the case depending on the impact criterion and building type in question a variant is shown further below in this section where impacts are weighted by the assumed importance of the domain to the impact criteria.
- The services considered (presently assumed to be the same as those set out in the Task 1 analysis and equally weighted)
- The functionality levels (presently assumed to be the same as those set out in the Task 1 analysis with the ordinal rankings also as set out in that report – for this illustration of the generic methodology it is assumed that the relative effect of identical service functionality grades is the same across different impact criteria, domains and services).

Single Family House – case study

For this example, a case study is examined of a hypothetical semi-smart single family house (SFH). The house is smart in that it has moderately sophisticated:

- heat demand control
- heat production control
- domestic hot water production control
- cooling demand control
- lighting occupancy control
- window open/closed control, combined with HVAC system
- monitoring & control of HVAC systems
- reporting information regarding historical energy consumption
- EV charging capabilities.

On the other hand, it is not so smart because it has no on-site distributed generation (and hence no smart control of this), no DSM capability, and no fault detection capability.

When equal weightings are applied (as discussed previously) this building scores 1.268 out of a maximum possible score of 3.513 and thus attains a normalised score of 35.2% = (100 × 1.238/3.513) % (see Table 5). Interestingly, while this system applies equal weightings some domains have a larger number of SR services than others (e.g. DSM has 17 SR services with a maximum total score of 1.188 while Lighting has four SR services with a maximum total score of 0.15). This implies that the simple process of accounting for the SR services also implies a set of preferences and hence there could be an argument for setting limits on the relative importance of the domains as well as the impact criteria.

Table 5 - Scores attained in equal-weighting single family house case study

Domain	Actual Scores	Max Possible Scores	Normalised Score
Heating	0.4125	0.6125	67%
DHW	0.1125	0.1125	100%
Cooling	0.1375	0.15	92%
MV	0	0.1	0%
Lighting	0.075	0.15	50%
Dynamic building envelope	0.125	0.175	71%
Energy generation	0	0.1125	0%
Demand side management	0	1.1875	0%
Electric vehicle charging	0.075	0.2125	35%
Monitoring and control	0.3	0.7	43%
Total SRI score	1.2375	3.5125	35.2%

Differentiated weightings case study

In the previous case study all aspects in the generic methodology as applied to the Task 1 analysis were weighted equally, however, this in itself implies a certain set of preferences. In this section a case study with differentiated weightings is investigated.

Table 6 shows an illustrative set of weightings to be applied at the domain level as a function of the impact criterion considered. These are not purely arbitrary but rather are selected based on certain notions and understanding. The weightings applied to energy savings on-site are intended to be fairly typical of the relative importance of each domain to an average existing European single family house, although it should be noted they are not typical of new-build and in reality will vary by climate, culture and other locally pertinent factors. Having noted this, they are presented here simply to illustrate how weightings can be applied and are in not intended to indicate the most appropriate values that should be applied. Equal weightings by domain are applied for those impact criteria where there is currently no information on the relative importance of different domains to the impact criterion in question. Where a domain is thought to have no importance for the impact criterion considered it's weighting is set to 0% and the other domain weightings adjusted accordingly so the total per impact criteria always adds up to 100%. Note, as the generic method is adapted towards a specific applied method it is expected that specific weightings would be derived as a function of building type and possibly climate (see section 3.5 on tailoring the SRI); however, it is equally possible for users of the system to develop their own weightings to reflect their priorities and locally pertinent factors.

Table 6 - Domain-level weightings per impact criteria assumed in weighted case study for a single family house

Domain	Impact criterion							
	Energy savings on site	Flexibility for the grid and storage	Self generation	Comfort	Convenience	Health and well-being	maintenance & fault prediction	information to occupants
Heating	66%	14%	0%	40%	10%	10%	10%	7%
Domestic hot water	18%	14%	0%	10%	10%	10%	10%	7%
Cooling	4%	14%	0%	15%	10%	10%	10%	7%
Controlled ventilation	3%	0%	0%	10%	10%	10%	10%	7%
Lighting	7%	0%	0%	10%	10%	10%	10%	7%
Dynamic building envelope	2%	0%	0%	5%	10%	10%	10%	7%
Energy generation	0%	14%	80%	0%	10%	10%	10%	7%
Demand side management	0%	14%	10%	5%	10%	10%	10%	7%
Electric vehicle charging	0%	14%	10%	0%	10%	10%	10%	7%
Monitoring and control	0%	14%	0%	5%	10%	10%	10%	40%
Total	100%	100%	100%	100%	100%	100%	100%	100%

Single Family House – case study

For this example a case study is examined of the same semi-smart single family house considered in section 3.2.3.

When the differentiated weightings of Table 6 are applied to this building it attains a total SR score of 2.554 out of a maximum possible score (for a fully smart ready building) of 5.347 and thus a normalised score of 47.8% = (100 × 2.554/5.347)% (see Table 7).

Interestingly, the application of differentiated weightings by domain can mitigate the impact of the equal weightings case study approach that could be said to favour domains with more SR services options. For example although DSM has 17 SR services in both the equal and differentiated weighting case studies the maximum total score of 0.984 is less for the differentiated weighting case study than the equal weighting cases study (where it is 1.188). On the other hand the importance of some domains, such as heating, has increased. Overall the total normalised SR score for this building is higher than for the equal weightings case which is indicative that the SR functions it has are better adapted to its needs than the equal weightings approach might imply.

Table 7 - Scores attained in differentiated-weighting single family house case study

Domain	Actual Scores	Max Possible Scores	Normalised Score
Heating	1.698333	2.360833	72%
DHW	0.157857	0.157857	100%
Cooling	0.13375	0.13875	96%
MV	0	0.0825	0%
Lighting	0.0675	0.13125	51%
Dynamic building envelope	0.098333	0.115833	85%
Energy generation	0	0.281548	0%
Demand side management	0	0.983929	0%
Electric vehicle charging	0.05119	0.142857	36%
Monitoring and control	0.347321	0.951786	36%
Total SRI score	2.554286	5.347143	47.8%

3.2.4. VIABILITY ANALYSIS

This section presents an initial analysis of factors pertinent to the viability of the generic methodology.

Number of SR service functions required to be assessed

The Task 1 analysis identified 99 (or 112 inlcuding the 'various' domain) SR services that in theory could have an effect on each impact criterion. It also identified 8 impact criteria which means in principle that there could be 8 x 99 = 792 individual service impacts to be assessed were a comprehensive SR assessment to be made. However, this accounting ignores that many of these service functions have no effect on specific impact criteria (i.e. they have a grading of 0 for the specific impact criterion considered regardless of the level of functionality they offer).

NOTE: Due to time contraints related to the revision of the model numbers mentioned in the remainder of this section have not been updated since the first progress report with the amended list of services, although this will be done for the subsequent version. The principles and conclusions they illustrate remain fully valid though.

Table 8 shows the number of non-zero services (see column headed "100% of the potential total impact") for each impact criterion. The impact criteria with the most number of non-zero (i.e. impactful) services are Comfort (which has 70) and the one with the least is Health and Well-being , which has 18. In total there are 377 non-zero (i.e. impactful) services across the 8 impact criteria in the Task 1 analysis. Nonetheless, not all of these non-zero services provide the same impact for any given impact criterion, thus they are not equally important in determining the overall SR impact per impact criterion. Figure 21 to Figure 28 show how the proportion of total SR impact varies as a function of the number of services assessed when the service impacts are ordered in sequence of those with the most impact to those with the least impact. Table 8 also indicates the number of services necessary to be assessed to attain 100%, 80% or 50% of the total impact per impact criterion.

This analysis is important because any practical SRI scheme will be constrained by time and resources and thus there is likely to need to be a basis for prioritising which SR services should be assessed in practice and which offer more marginal benefits. From this analysis it can be seen that were it required to determine 100% of the potential SR impact over the 8 impact criteria 377 services would need to be assessed, whereas the number falls to 246 and 13 respectively if 80% or 50% of the total impact is required. Alternatively, another means of reducing the number of services requiring assessment would be to omit certain impact criteria from the assessment. E.g. if only energy savings (to 80% of the potential total impact), flexibility for the grid (to 50% of the potential total impact), convenience (to 50% of the potential total impact) and information to occupants (to 50% of the potential total impact) to be included then the total number of services requiring assessment would fall to 74 (= 15+15+25+19). Of course there are other alternative approaches that could be applied to reduce the number of SR services to be assessed. These could include setting a maximum number of services to be assessed per impact criteria (e.g. the 10 with the highest impact per criterion) or applying differentiated impact criteria weightings and then ordering all the services to identify those that have the highest total impact across the impact criteria and selecting a given number of those to be assessed (e.g. the top 50). It is also expected that in practice this list would vary by building type. These issues are considered further in sections 3.3and 3.4.

Table 8- Sensitivity of the total impact score to the number of SR services assessed

Impact parameter	**No. of SR service functions required to be assessed to determine**		
	100% of the potential total impact	80% of the potential total impact	50% of the potential total impact
Energy savings	58	15	8
Flexibility for the grid	44	32	15
Self-generation	30	23	12
Comfort	70	48	25
Convenience	66	44	25
Health and Wellbeing	18	13	7
Maintenance & fault prediction	44	35	20
Information to occupants	47	36	19
All	377	246	131

Figure 21 - Share of energy savings impact attained as a function of the number of SR services assessed

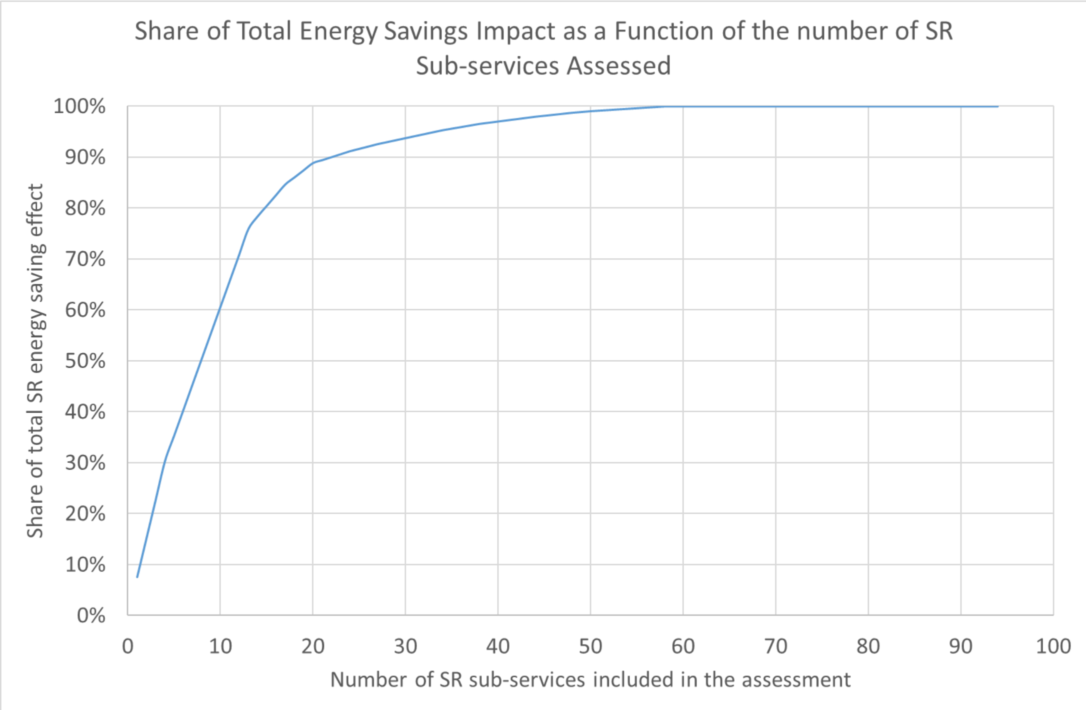


Figure 22 - Share of grid flexibility impact attained as a function of the number of SR services assessed

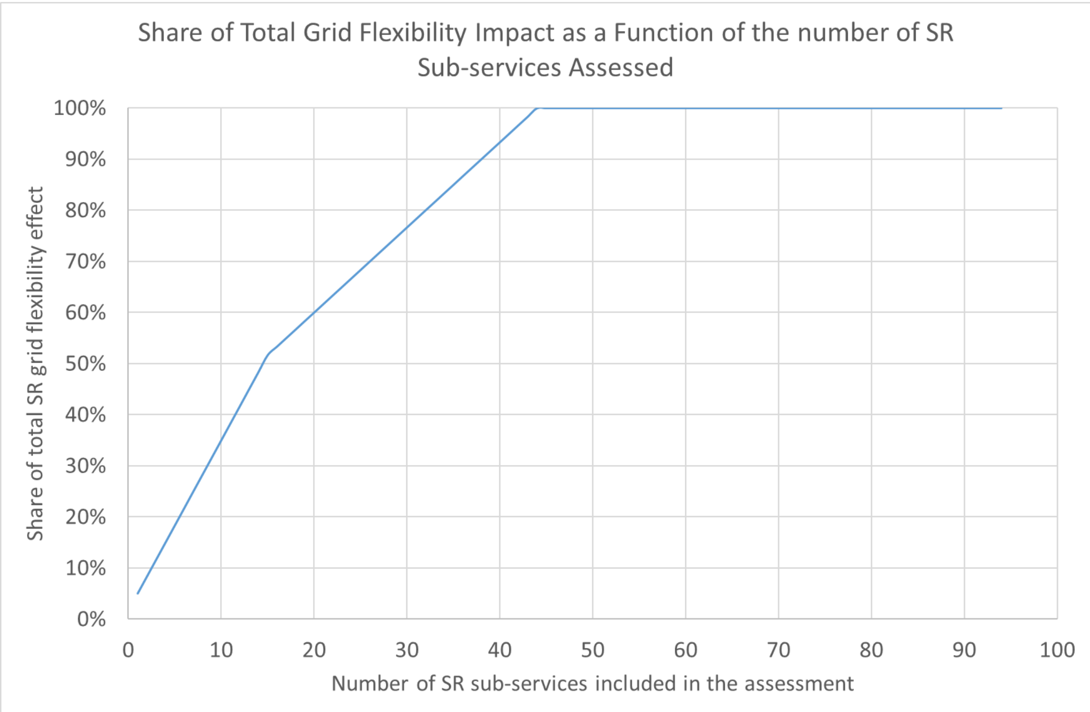


Figure 23 - Share of self-generation impact attained as a function of the number of SR services assessed

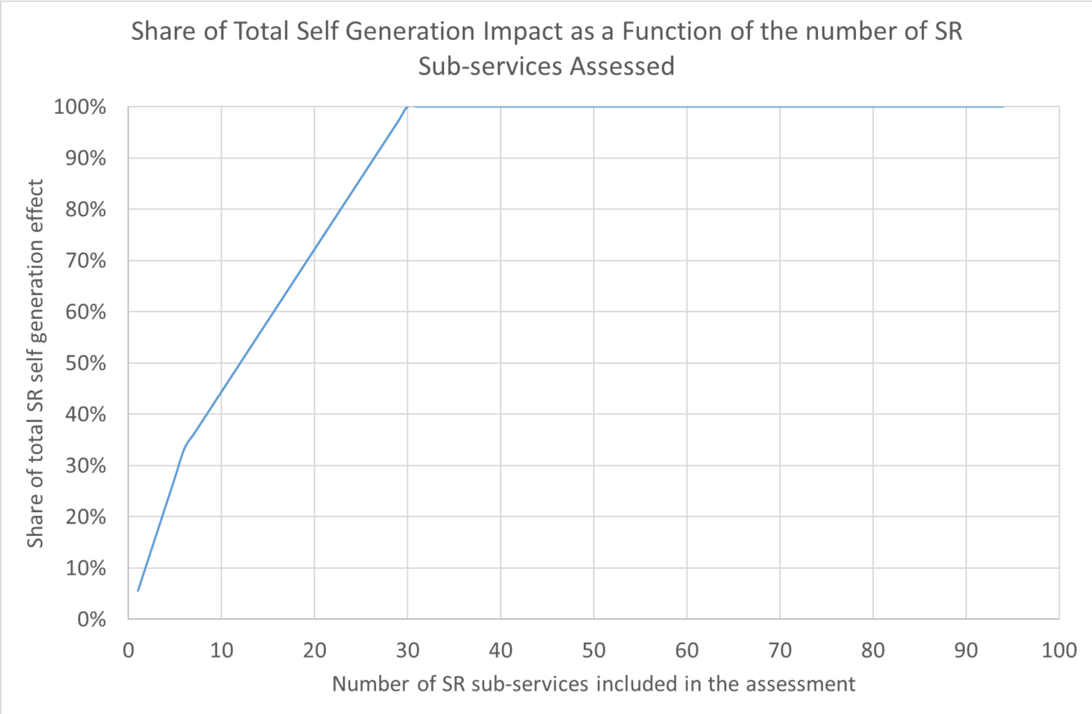


Figure 24 - Share of comfort impact attained as a function of the number of SR services assessed

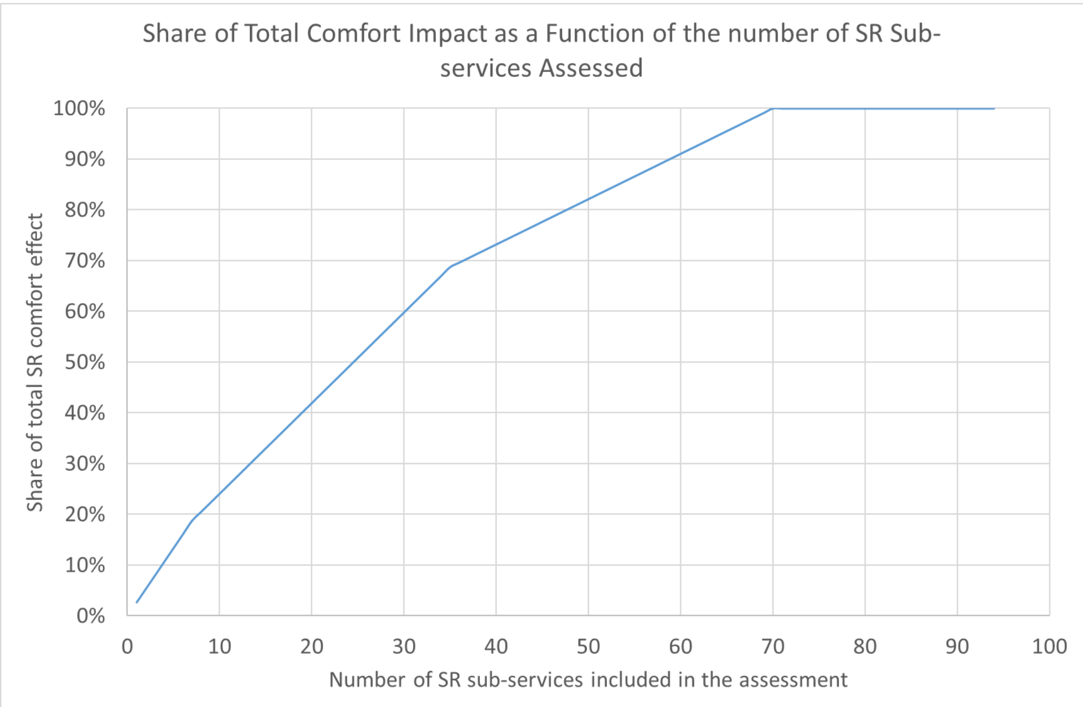


Figure 25 - Share of convenience impact attained as a function of the number of SR services assessed

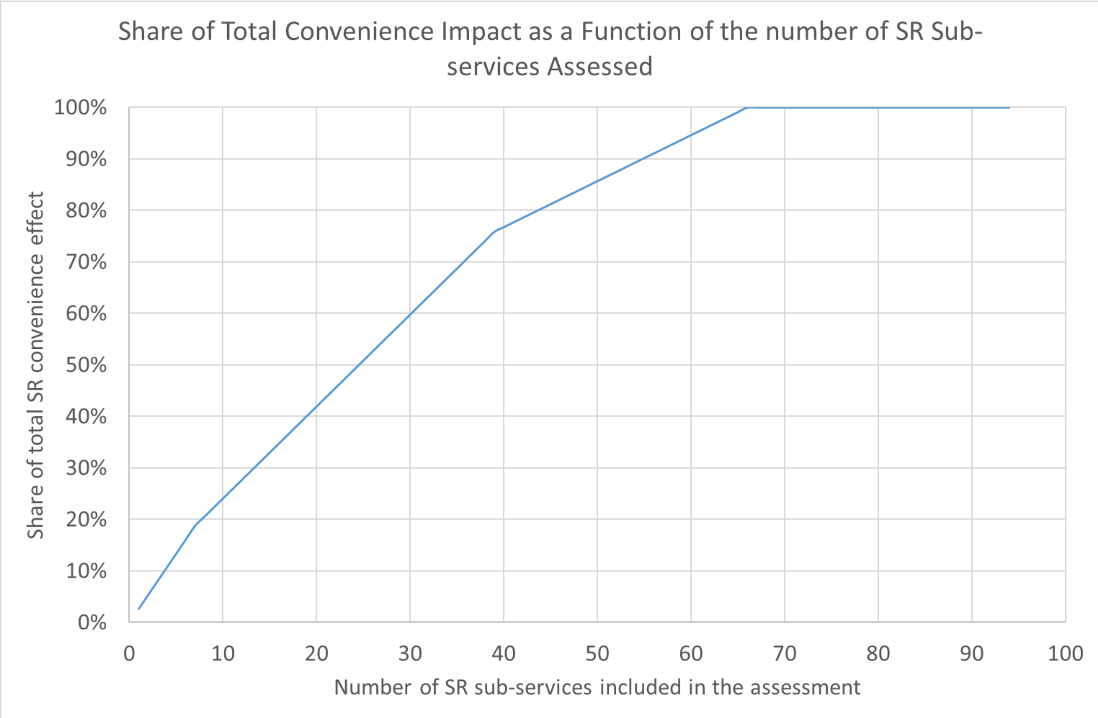


Figure 26 - Share of health and well-being impact attained as a function of the number of SR services assessed

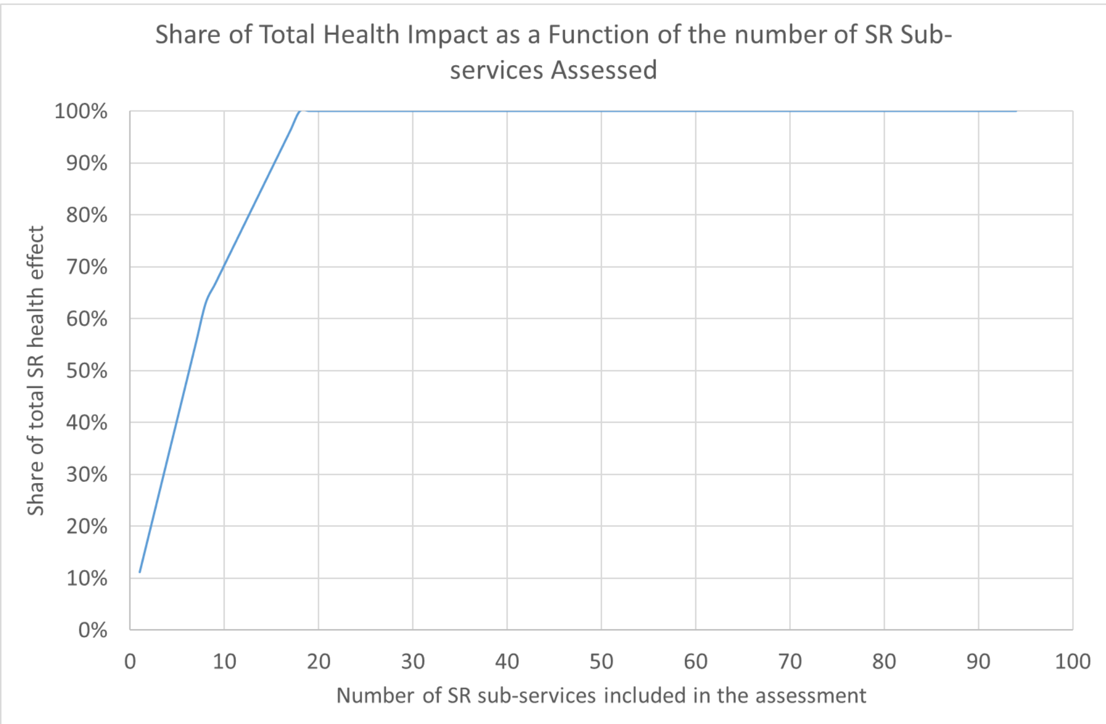


Figure 27 - Share of maintenance & fault prediction impact attained as a function of the number of SR services assessed

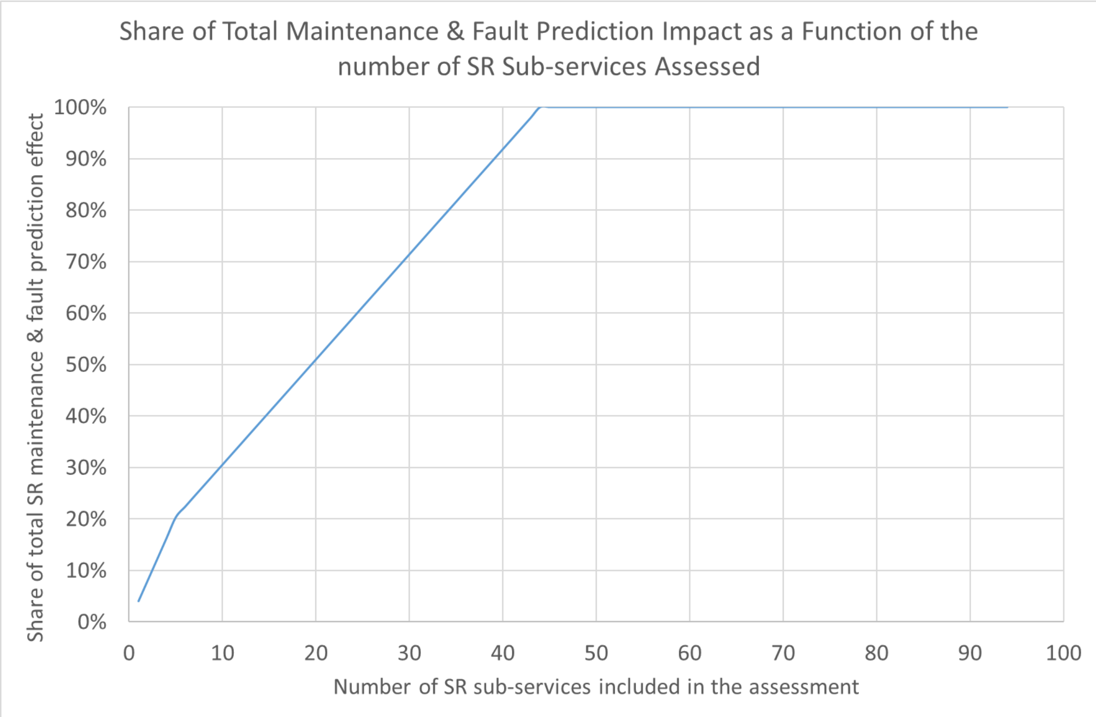
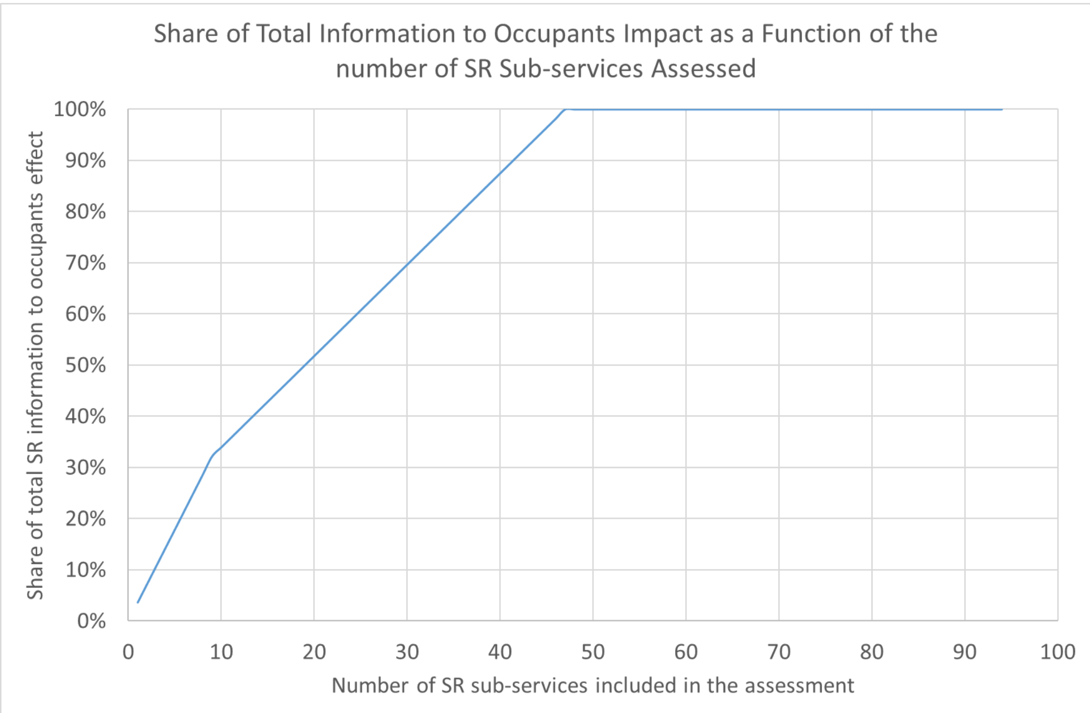


Figure 28 - Share of information to occupants' impact attained as a function of the number of SR services assessed



In aggregate, the same analysis can be done to see the sensitivity of the total SRI score to the number of services assessed, as is shown in Figure 29 and Figure 30 for the equal and differentiated weightings services respectively. For the equal weightings case 80% of the total SRI is captured by the top 63 most important SR services. For the differentiated weightings case it is by the top 62 most important SR services. The gentleness of the curve in both cases indicates that selection of the services to be assessed in order of their impact on the total SRI score only offers a modest potential to reduce the number of services requiring assessment for a given quality of SRI score i.e. the share of the total SRI score determined per tranche of services assessed is relatively constant; however, this is only the case when it is assumed that all of the services are pertinent and that there is no causality between them (both issues examined below).

For simpler buildings, such as residential buildings, this assumption is especially unlikely to be true and thus there is potentially much greater potential to reduce the number of SR services that need to be assessed. Figure 31 and Figure 32 show the equivalent data to Figure 29 and Figure 30 but for the explicit hypothetical single family house case study considered in section 3.2.3 respectively.

Figure 29 - Share of total SR impact attained as a function of the number of SR services assessed for the equal weightings case study

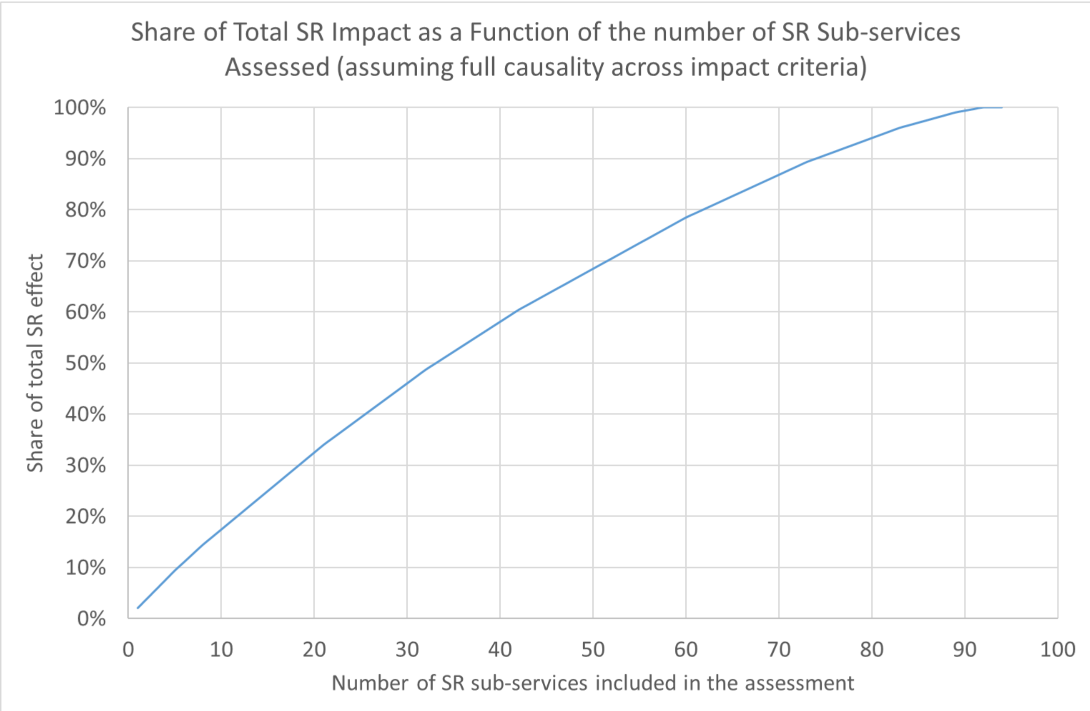
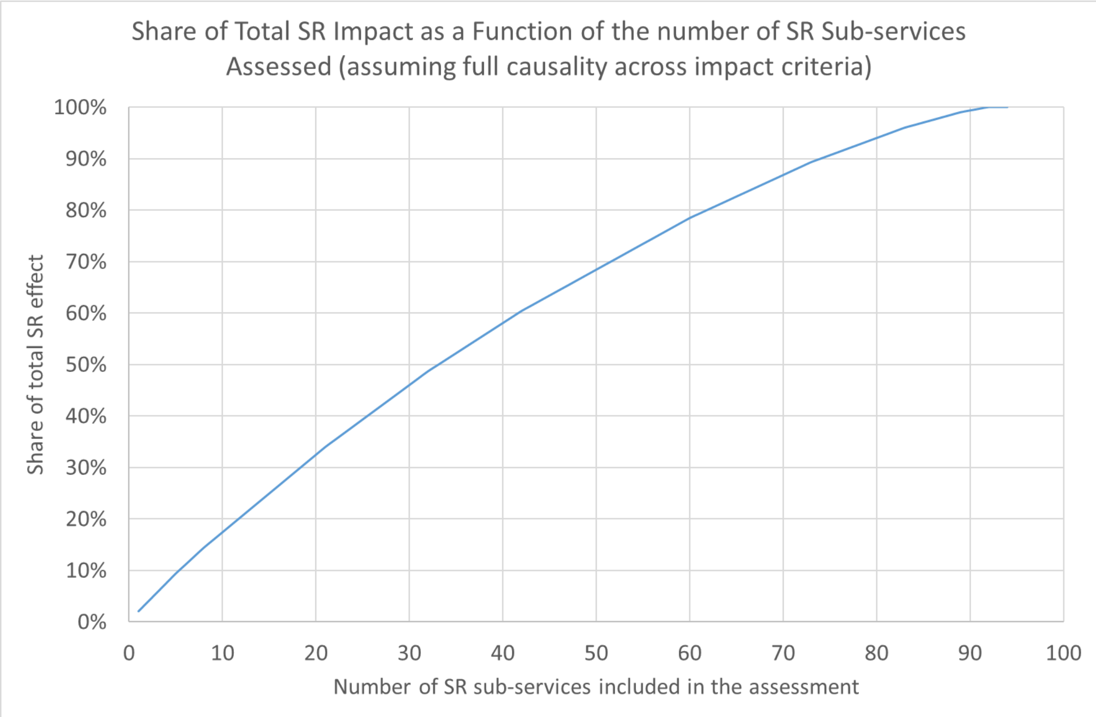


Figure 30 - Share of total SR impact attained as a function of the number of SR services assessed for the differentiated weightings case study



For both the equal and differentiated weightings single family home case studies respectively it is only necessary to assess 40 of the 92 possible services to attain the full SR impact for a fully smart home. This is because 52 of the comprehensive list of SR services are (provisionally) not considered to be pertinent to the typical single family home case and hence allow a considerable reduction in the expected assessment effort. Nonetheless, there is not much sensitivity to the priority given to the SR services assessed which indicates that further reduction in the number of SR services included in the assessment would entail a significant information loss for the SRI unless whole classes (e.g. whole domains) where to be excluded.

Figure 31 - Share of total SR impact attained as a function of the number of SR services assessed for the equal weightings case study

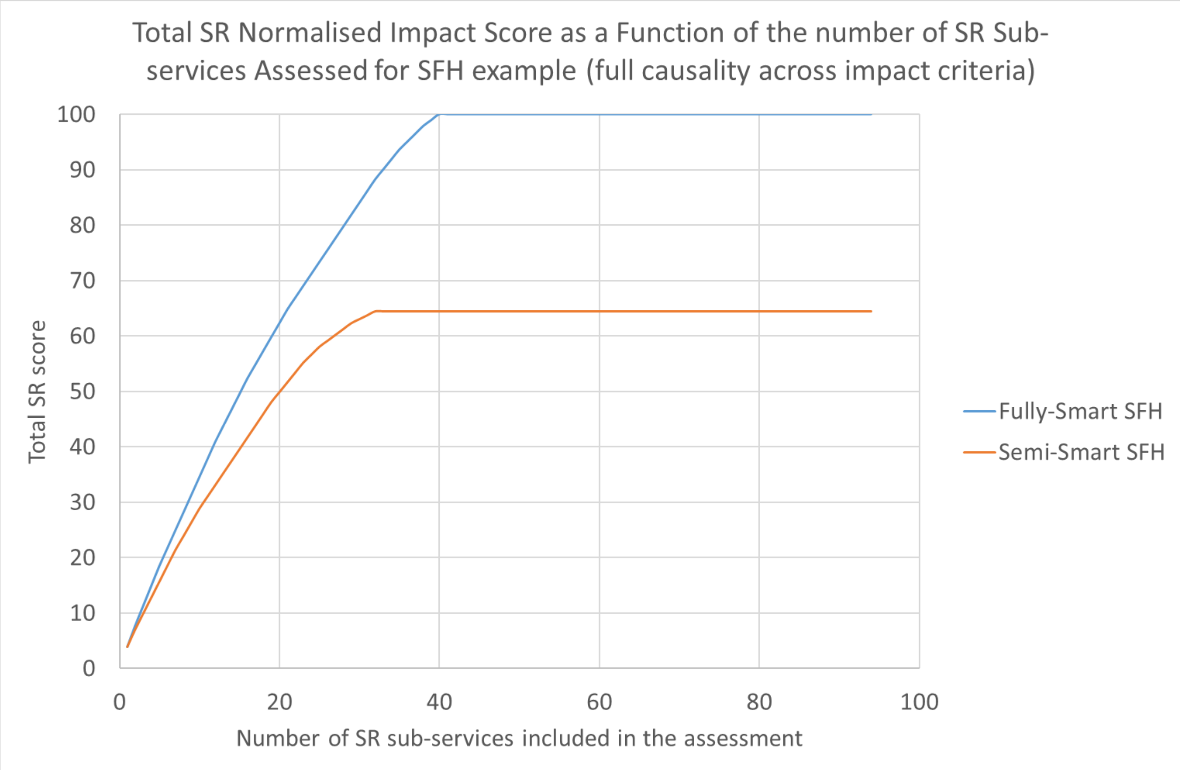
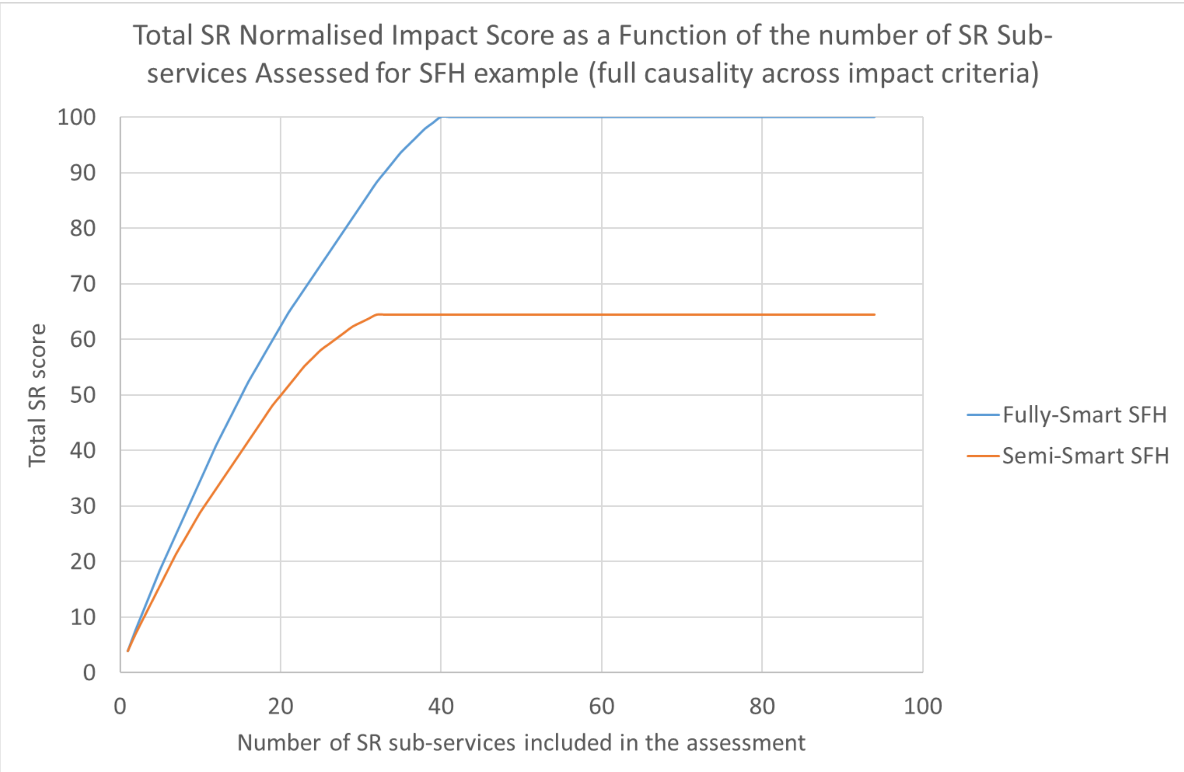


Figure 32 - Share of total SR impact attained as a function of the number of SR services assessed for the differentiated weightings case study



Causality between service functionality across impact criteria

The previous analysis assumed that service functionality levels are independent of each other from one impact criterion to another; however, this is not necessarily the case. In cases where it can be shown that providing a service functionality level with a specific impact rating for a given impact criterion automatically leads to a specific rating for a different impact criterion then an auto-completion scoring approach can be used for the second impact criterion (i.e. it is not necessary to do a separate and independent assessment). In principle, this could also apply to other impact criteria and could allow a significant economy in the total assessment time required to attain a given amount of SR impact information.

3.3. Practical Considerations

This section introduces the reality checks that would need to be taken into account to implement an actual SRI and how these are likely to filter the elements that can be operationalised.

3.3.1. Practical elements that affect the ability to implement an SRI

To be able to implement an SRI it is necessary that:

- smart readiness service functionality is defined and that impacts can be ascribed to the level of functionality delivered
- it is technically feasible to conduct an assessment
- the time/cost of assessment is acceptable
- the building occupants are willing to allow access for an assessment to be conducted
- the information derived is assessable and understandable for the target audience.

Ability to define functionality and ascribe impact outcomes to the function

If the SRI is to have solid technical foundations then it is essential that smart service functionality and functional levels can be defined and that impacts can be ascribed to those levels with a reasonable degree of confidence. Although the Task 1 smart readiness service catalogue defines a set of smart readiness services, functionality levels and impacts part of this is not founded on EU, international or national standards but rather is based on the study team's considered opinion. Wherever possible the functionality has been linked to definitions provided in standards but the reality is that many of the smart readiness services identified are not yet defined in standards anywhere. When they exist most standards will define services and functionalities but relatively ascribe performance levels and impacts to functionality. A notable exception, much used in this methodology, is EN15232-1:2017 *Energy performance of buildings. Impact of Building Automation, Controls and Building Management*. This standard not only defines services for BACS, but also defines functionality levels for each and presents a simplified method to ascribe energy savings impacts to those functionality levels (via the so-called BACS factor method) that is based on hundreds of TRANSYS building energy performance simulations. This is used in the methodology presented here to ascribe energy savings impacts to BACS related smart services and as such the impacts associated with this standard are the most reliable of all those reported in the Task 1 smart services catalogue. Note, the BACS factor method is not as reliable as the full impact assessment methods presented in the standard (which rely on detailed application of the suite of other building energy performance standards pertaining to each TBS) but the full methods are far too time consuming and involved to be imaginable for application in an SRI.

Technical feasibility of conducting an assessment

The technical capability to assess a smart readiness service and determine its level of functionality is key to being able to implement an SRI. If a service cannot be assessed it cannot be ranked and included in a scoring system. The experience is mixed with the smart readiness services reported in the Task1 catalogue. Many are not in standards and there is thus no documented experience of trying to assess them. Those which are defined in standards are more likely to have some practical experience of being assessed. This is the case for the BACS services defined in EN15232 and eu.bac[53] among others have developed a certification scheme based on these. In these cases there is good degree of confidence in the ability to conduct a technical assessment. For other smart services, which

[53] cert.eubac.org/

are not defined in standards, this has to be imagined and has not yet been put to the test. The findings in this regard are therefore somewhat speculative.

Time and cost of making an assessment

If it takes too long and hence is too costly and inconvenient for an SRI assessment to be made then the practical acceptability of the SRI will be insufficient and the benefit-reward ratio will be deemed unfavourable. There is relevant experience from EPCs and from the eu.bac voluntary certification scheme of the length of time it takes to conduct an assessment of technical building systems and BACS which has been leveraged for the estimates provided in the methodology discussions. In general, the assessment time needed for any given smart service will depend on how easy it is to locate and identify the smart service and then to determine its functional capabilities. This process can be facilitated by the availability of technical documentation and information indicated on the products or displays concerned. It will also depend on the expertise and competence of the assessor. While most smart services can be found in a single physical location (e.g. a control point, display panel or plant room) some are distributed throughout a building and require room-by-room inspection. These are likely to be more time consuming to assess although often they are also comparatively simple to inspect visually (e.g. lighting is controlled by presence detection or not). By contrast some of other services listed in the Task 1 catalogue will be very challenging to assess without some kind of facilitation.

Willingness to grant access

If assessments require physical inspection and on-site presence then it is necessary for inspectors to be granted access and the right to conduct an assessment by the building occupants. This can be one of the more challenging aspects and is especially the case when the assessment is not legally enshrined, as it is for the EPCs. The willingness of occupants to grant access may be partly conditional on the value added that they perceive the SRI to offer them. Thus inspection access is likely to be sensitive to this aspect. Retrieving access can be especially challenging in multi-tenant buildings for which communal TBS need to be assessed, e.g. heating installations in a technical room which is not directly accessible by all tenants.

Ability of the target audience to assess the SRI information

The degree to which the target audience can assess the SRI information it is presented will also affect the degree to which the SRI scheme is successful or not. If the information is not comprehensible and is meaningless to them then it will have a very limited motivational impact and be a weak change agent. Again there is experience of the extent to which users process the information in EPCs that can partly inform this determination, but it is likely that any prospective SRI would need to be pilot tested prior to full implementation to ensure it satisfies minimum comprehension and interpretation criteria.

3.3.2. Review of the maturity of the Task 1 elements

The maturity of each of the smart readiness services cited in the Task 1 catalogue is reviewed and reported in Annex F (see below). This review considers the factors which determine the degree to which these services are mature enough to be deployed within a practical SRI scheme. For each service the review considers:

- the degree to which the functionality of the service is described and defined in standards or a commonly adopted methodological framework, or is still nebulous and in need of definition

- the degree by which the impact can be ascribed to the functionality
- the basis by which the impacts associated with the functionality may be determined
- the degree to which the functionality can be determined by inspection.

In general it is found that the degree to which the functionality of the services are defined in standards or a commonly accepted methodological framework is high for the classic TBS domains (heating, DHW, cooling, controlled ventilation and lighting) and is low for the services in the other domains except for about half the services in the Monitoring & Control domain. There are almost no relevant standards and common methodological frameworks for the DSM services and only two partially applicable standards/frameworks for the Electric Vehicle (EV) domain.

This also strongly influences the degree of confidence that can be had in the estimation of the impacts associated with the functionality levels. With the exception of the energy savings on site impacts for the BACS defined in EN15232 almost all the other impacts are based on the provisional expert opinion of the study team. Clearly, more work would be needed for the level of confidence in the impacts ascribed to be increased. In this respect, feedback from stakeholders is also very much likely to help.

The degree to which the services can be assessed varies with the lower level (less smart) services being more straightforward to assess visually than some of the higher level services, which can be sensitive to the nature of the control algorithms applied. A general observation, stretching across all the smart readiness domains, is that when smartness depends on the capability associated with a control algorithm that it will not be straightforward to assess. As a result, many of the capabilities defined here will need classification and indication, or some smart signalling and reading device, to enable an inspector to assess their capability.

Considering these aspects it is evident that attempting to apply the SRI methodology to all the smart readiness services cited in the Task 1 catalogue is not currently viable for a practical scheme. Many of the smart readiness services cited are poorly defined and in a non-standardised/commonly agreed, manner. When this is the case the confidence with which their functionalities can defined is low and the confidence with which impacts can be ascribed to the functional levels is also low. The ambiguity surrounding these aspects also reduces the viability of making an assessment of these services and renders the time required to inspect them unacceptably high. As a consequence, it is necessary to streamline and rationalise the Task 1 smart readiness services in such a way that would allow them to be used in a viable scheme.

3.4. Streamlining the smart ready service catalogue

This section examines how the generic SRI can be streamlined to make a practical smart readiness indicator.

3.4.1. Streamlining the SRI elements

This paragraph applies the Annex F review findings on the Maturity of Task 1 elements reported in section 3.3.2 and proposes a reduced and restructured set of services that could be immediately viable (i.e. technically and feasibly actionable) within an SRI today. It conducts a screening process to make this assessment that is informed by the practicality considerations set out in section 3.3.1.

This reduced/amalgamated set of services that have been retained after this screening process are then applied in two building case studies presented in sections 3.3.2 to determine and illustrate their viability in terms of being able to be assessed, and the management of assessment time/costs/and site-access.

In principle, the methodology can be streamlined by the omission of services, the restructuring of services, and the application of logical triage processes. Services could be omitted if they are irrelevant or have a very modest impact. In addition, services whose attribution of impacts is not yet fully developed or confirmed could also be omitted. As this streamlined methodology is intended to be actionable at the present time then any service that is currently too poorly defined and too difficult to be assessed should be omitted until it is sufficiently mature to be included. Restructuring of services could be considered when the restructuring: improves the clarity regarding the service's functionality and impacts, when it helps to focus on the main impact and saves assessment time. Triage can be helpful in optimising the assessment process and thereby saving assessment time. With these thoughts, and the findings from the maturity review of section 3.3.2, in mind the remainder of this section proposes appropriate streamlining actions to be taken in to the streamlined SRI methodology.

Heating domain

Most of the heating services are actionable, defined in standards and have impacts (at least in terms of energy savings) that are attributable to their functionality levels. The exceptions are:

- Heating 2d -*Heat system control according to external signal*
- Heating 2e - *Heat recovery control (e.g. excess heat from data centres)*.
- Heating-3 - *Report information regarding heating system performance*

Were any to be omitted on the grounds of low relevance they would be:

- Heating-1b: Emission control for TABS (heating mode)
- Heating-1f: Thermal Energy Storage (TES) for building heating
- Heating-1d: Control of distribution pumps in networks
- Heating-2c: Sequencing of different heat generators
- Heating-2d: Heat system control according to external signal (e.g. electricity tariff, gas pricing, load shedding signal etc.)
- Heating-2e: Heat recovery control (e.g. excess heat from data centres)

However, the TABS, TES and heat recovery services are relevant if these systems are present and it is only because they are rare that they are less relevant to typical buildings today. Sequencing of heat generators is only relevant when multiple generators are present, which is often restricted to large buildings. Good control of distribution pumps can save a significant proportion of pumping energy but this is less important than the main heating loads.

Heating 2d - Heat system control according to external signal (e.g. electricity tariff, gas pricing, load shedding signal etc.). This is a partial DSM partial Monitoring & Control feature and hence should be viewed under these sections. For convenience it makes sense to move it to the M&C section; however, it should be noted that there is no standard or agreed protocol available to define this service.

Heating 2e - Heat recovery control (e.g. excess heat from data centres). Heat Recovery is addressed under EN15232 for Mechanical (Controlled) Ventilation and has been revised in the 2017 edition. Other specific heat recovery systems (such as heat recovery from data centres) only come into play for some specialised buildings and risk to overburden the assessment process. As a result, this service is simplified to only encompass ventilation heat recovery, and hence moved into the ventilation section and reformulated in line with EN15232:2017.

Heating-3 - *Report information regarding heating system performance* has been introduced since the first progress report. It links the information reporting function to the TBS in question (the same approach is done for DHW and cooling) but was previously partially covered in a non-TBS specific manner under Monitoring & Control. While there is no established standard or protocol addressing how this should be done the descriptions of the functionality are unambiguous and it should be straightforward to assess.

The other services (including 1b, 1d, 1f, and 2c) are clearly actionable so there is little reason to omit any of these from the streamlined methodology, providing sensible triage is deployed as now discussed.

→ **Triage**

Heating type
Is heating present? If not ignore the whole TBS. If it is assess if it is supplied by Combustion, District Heating, Electric Resistance, Heat Pump, Solar or a combination thereof?

- Assuming combustion ignore: Heating 2b
- Assuming heat pumps ignore: Heating 2a
- Assuming district heating ignore: Heating 2b
- Assuming electric resistance ignore: Heating 2a, Heating 2b
- Is there only one heat source? If so ignore Heating 2c

Estimated time required to make triage = 4 mins

TABS/TES
Is TABS present? If not ignore Heating 1b, Cooling 1b
Is TES present? If not ignore Heating 1f, Cooling 1g
Typical time required to make triage = 1 min

DHW domain

The first four (of six) DHW services all apply to storage based DHW systems thus a simple triage will avoid the need to assess them if storage is not present.

All the services except DHW-1c and DHW-3 are defined in standards, are actionable and have attributable impacts; however, determining capabilities without supporting documentation could be challenging.

DHW-1c - *Control DHW production facilities* is no longer included in the latest version of EN1532 and hence is not clear if this is still an actionable service.

DHW-3 - *Report information regarding domestic hot water performance* has been introduced since the first progress report. It links the information reporting function to the TBS in question (the same approach is done for heating and cooling) but was previously partially covered in a non-TBS specific manner under Monitoring & Control. While there is no established standard or protocol addressing how this should be done the descriptions of the functionality are unambiguous and it should be straightforward to assess.

DHW-2 - *Control of DHW circulation pump* is defined within EN15232 but is likely to be of limited relevance and difficult to assess therefore it is omitted from the streamlined method.

→ **Triage**

Is DHW storage present? If not ignore all DHW storage-related services (lines 16-20).
Typical time required to make triage = 1 min

Cooling domain

With the partial exception of Cooling-3 *Report information regarding cooling system performance* all the cooling services are actionable, defined in standards and have impacts (at least in terms of energy savings) that are attributable to their functionality levels. Were any to be omitted on the grounds of low relevance they would be:

- Cooling-1b: Emission control for TABS (cooling mode)
- Cooling-1g: Thermal Energy Storage (TES) for building cooling
- Cooling-1d: Control of distribution pumps in networks
- Cooling-2b: Sequencing of different cooling generators

However, the TABS, TES and heat recovery services are relevant if these systems are present and it is only because they are rare that they are less relevant to typical buildings today. Sequencing of cooling generators is only really found in very large buildings but is relevant when multiple generators are present. Good control of distribution pumps can save a significant proportion of pumping energy but this is less important than the main heating loads.

Cooling-3 - *Report information regarding cooling system performance* has been introduced since the first progress report. It links the information reporting function to the TBS in question (the same approach is done for heating and DHW) but was previously partially covered in a non-TBS specific manner under Monitoring & Control. While there is no established standard or protocol addressing how this should be done the descriptions of the functionality are unambiguous and it should be straightforward to assess.

All the services are clearly actionable so there is little reason to omit any of these from the streamlined methodology, providing sensible triage is deployed as now discussed.

→ **Triage**

Cooling type

Is cooling present? If not ignore all cooling services.
Time required to make triage = 1 min

Is there only one cooling generator? If so ignore Cooling 2b
Time required to make triage < 1 min

TABS/TES
Is TABS present? If not ignore Cooling 1b
Is TES present? If not ignore Cooling 1g
Typical time required to make triage = 1 min

Controlled ventilation

Most of the ventilation services are actionable, defined in standards and have impacts (at least in terms of energy savings) that are attributable to their functionality levels. None should evidently be omitted on the grounds of low relevance except potentially:

For Ventilation 1a *Air flow control* an additional functionality level 4 was suggested by stakeholders: 'Demand control ventilation based on biometric indicators'. In practice it might be hard to inspect this and there might be considerable overlap with the functionality level 3 'demand based control based on air quality sensors'. Therefore, this suggested additional functionality level 4 is not included in the streamlined set of SR services.

Ventilation 2b - *Room air temp. control (Combined air-water systems)* – which has modest impact and is likely to be difficult to assess (it concerns the levels of coordinated control within combined air-water systems)

Ventilation-5 for *Humidity control* and Ventilation-6 on *Reporting information regarding Indoor Air Quality* are services have been added to the Task 1 services catalogue since the first progress report. These two services are not yet defined in standards or any commonly available evaluation protocol. In the case of the humidy control the functional levels could be difficult to assess so for now is omitted from the streamlined methodology; however, the information reporting functional levels are unambiguous and hence can safely be retained. A stakholder has commented that the service of humidity control is especially relevant for healthcare facilities in order to reduce hospital-acquired infections. If dedicated SRI schemes for specific building typologies would emerge, it can be investigated whether humidity control should be part of the streamlined list of SR services in healthcare buildings.

Ventilation 4 – Heat recovery control: icing protection is defined in EN15232 but has rather modest impacts. It may therefore be a candidate for omission from the streamlined methodology.

→ **Triage**

Is controlled ventilation present (in any central form) if not ignore all CV services.
Typical time required to make triage = 1 min

Lighting

Lighting is a moderately important energy use in households but is important in non-residential buildings. If a walk-through inspection is required it could be somewhat time consuming so some may consider it is a moot issue whether lighting should be assessed in households. Nonetheless it is kept in the streamlined methodology for all building types. In part this is because it is certainly technically assessable. Note, the energy savings impacts ascribed to good lighting control solutions in EN15232 seem very conservative against those that can be derived from EN15393 and were reported in the Lot 37 Ecodesign Lighting Systems study. It is likely then that the impacts are greater than currently captured in the Task 1 catalogue and SRI methodology.

All of the three lighting services are actionable, defined in standards and have impacts (at least in terms of energy savings) that are attributable to their functionality levels. None should evidently be omitted on the grounds of low relevance although the impacts of the Lighting-1b *Mood and time based control of lighting in buildings* service are somewhat less than the others.

Lighting-1b *Mood and time based control of lighting in buildings* has been altered since the first progress report so that its impacts are framed in terms of the EN 15193-1, CEN-TR 16791 and EN 12464-1 standards. While these are helpful they do not avoid the need for a walkthrough assessment which could be deemed to be too high of an assessment burden for inclusion in the streamlined methodology.

→ **Triage**

Determine if any lighting has presence or daylight level detection.
Typical time required to make triage = uncertain (depends on availability of documentation and floor areas)
Note that this service can typically differ amongst rooms in a building. In principle, this can be dealt with by assessing the services on room level and eventually calculating a surface-weighted overall score. Such endeavour can however greatly affect the inspection time. Experience with EPC certification schemes have highlighted that measuring all floor surfaces or counting all lighting fixtures of a given type can require substantial amounts of time. It is therefore advisable that in the rollout of a SRI, inspection protocols define criteria to allow for inspecting only the main lighting types.

Dynamic building envelope

DE1- *Window solar shading control* is (mostly) defined in standards and has impacts (at least in terms of energy savings, comfort and health & wellbeing (avoidance of overheating and glare)) that are largely attributable to the functionality levels. However, this service has added a final functionality level of *Predictive blind control* which does not feature in EN15232 and hence, while in principle this should have the greatest impact on energy, comfort and convenience the increase in effect has not been simulated in the same way the other functionality level options have been.

The following two DBE services are not yet defined in any standards or commonly accepted protocols.

DE2- *Window open/closed control, combined with HVAC system*
DE3- *Changing window spectral properties*

It is thought feasible (albeit it needs to be verified) to inspect whether the windows open or close in response to the HVAC control and thus this service is added compared to the first progress report. Inspecting the spectral properties of windows may be too challenging and time consuming, however, and to this service is currently omitted from the streamlined SRI due to being difficult to action. Neither service should evidently be omitted on the grounds of low relevance.

→ **Triage**

If no DBE features (e.g. blinds, automated window opening or spectrally controlled windows) omit all DBE services.
Typical time required to make triage = 3 min

On-site renewable energy generation

If there is energy generation on site then unfortunately there are currently no set of standards or commonly used protocols applicable to address EG1 – EG5 (EG1- *Amount of on-site renewable energy generation*, EG2-*Local energy generation information*, EG3- *Storage of locally generated energy*, EG4- *Optimizing self-consumption of locally generated energy,* EG-5- *CHP control*) thus the assessment of these capabilities is currently challenging. The EG1 service simply quantifies how much RES is produced and hence is not really a smart service but a generation quantification service. EG2 concerning local energy generation information is important, essentially encompasses the service in EG1 and should be feasible to assess despite the lack of standrads or protocols, so it is proposed to include this within the streamlined service subject to its practicality being verified. For EG3 it should also be possible to assess if there is on site storage or not so this is also included. For EG4 and EG5 the assessment may be too challenging so these need further investigation before their status within the streamlined methodology is confirmed.

Note, in the case of EG4-*Optimizing self-consumption of locally generated energy* service assumes this is a goal whereas it could be argued that economic optimisation of EG in a way that optimises the proportion of generation used for self-consumption, self-storage and selling into the grid (locally or more widely) would be more indicative of user needs. Thus, the relevance of its inclusion may not be deemed sufficient by all parties.

Overall the number of energy generation services included since the first progress report has been expanded to provide more balance across the domains; however, there is a need to verify the actionability of some of these services before a definitive decision is made. If future standardisation efforts provide more sophisticated definitions and classification of self-generation smart services then these could be integrated into future versions of the streamlined SRI.

→ **Triage**

If no on-site energy generation (or storage thereof) capabilities omit all EG services.
Typical time required to make triage = 2 mins

Demand Side Management

From the current list of 21[54] separate DSM services defined within the revised Task 1 services catalogue, currently ony one of the services is supported by standards or an agreed assessment

[54] Note the services are listed from 1 to 22 but the service DSM-16 that was included in the first progress report has since been deleted

protocol. This means the services are weakly defined, very hard (if not impossible) to assess and have rather low confidence in the attribution of impacts to functionality levels. The only DSM capability within buildings that is currently standardised is from EN15232:2017 as follows:

Table 9 – Standardised DSM service

7.5	Smart Grid integration									
	0	No harmonization between grid and building energy systems; building is operated independently from the grid load								
	1	Building energy systems are managed and operated depending on grid load; demand side management is used for load shifting								

This simplified service has been incorporated into service DSM-18 on *Smart Grid Integration* although this is very aggregate and thus will not, by itself, capture much of the potential DSM functionality that is an important driver of grid flexibility. It does, however, capture the essential distinction of whether the building is capable of smart grid integration or not, although it does not distinguish which services can be integrated and to what degree. Thus it could be argued that the SRI should (or must) aim to capture the most pertinent DSM grid balancing capabilities, which would currently seem to pertain to DSM control of Heat Pumps, DHW and potentially smart appliances (DSM 4 and DSM 14). Note, while electric vehicles are also very important for grid-balancing they are discussed under that domain heading.

In the first progress report it was suggested that for DSM control of heat pumps the functionality could be defined as:
0: Simple control with fixed thermostat
1: Room thermostat with schedules
2: Heating control managed by input from apps, connected agenda's or presence detection
3: Optimisation of the heating demand inside the building
4: Optimisation taking into account external (price) signals

And that a similar list could also be made for DHW. An alternative approach was also suggested of adding the level four functionality (4: Optimisation taking into account external (price) signals) into the relevant services for heat pumps (in the heating and cooling domains) and the DHW domains although this risks diluting the current TBS specific services which are based on established standards. In the end a different approach is advocated as expounded in this section further below.

In the case of smart appliances, although much work is on-going it is yet to produce applicable results.

Note:
DSM7 *Fault location and detection* largely overlaps with MC 4 Fault Detection – and as the latter is based on EN15232:2017 the former (which has no supporting standard) can be omitted.

DSM-16 *Charging EV for a certain range* – is partially covered in the EV section and hence can be omitted.

DSM-5 *Power flows measurement and communications*, DSM-6 *Energy delivery KPI tracking and calculation*, DSM-11 *Demand prediction*, DSM-12 *Renewables generation prediction* and DSM-17 *Energy storage penetration prediction* have significant overlap with the Monitoring & Control

Feedback and reporting functions of MC 5-7 and hence could be merged into those within one aggregate assessment process – see M&C discussion below.

The other DSM functions cited are rather more niche and less central to the principal grid-balancing functionality in the Commission's tender document.

→ **DSM Conclusion**

For the streamlined SRI replace the original current Task 1 DSM service listing with the following four DSM services, numbers DSM 18, 19, 21 & 22 respectively, as shown in Table 10.

Table 10 - DSM services

Service	Level 0	Level 1	Level 2	Level 3	Level 4
Smart Grid Integration	No harmonization between grid and building energy systems; building is operated independently from the grid load	Building energy systems are managed and operated depending on grid load; demand side management is used for load shifting			
DSM control of equipment	Not present	Smart appliances and/or DHW subject to DSM control	Heating or cooling subject to DSM control	Heating and cooling subject to DSM control	Heating, cooling, DHW and appliances subject to DSM control
Reporting information regarding DSM	None	Reporting information on current DSM flows and controls	Reporting information on current, historical and predicted DSM flows and controls		
Override of DSM control	No occupant override	Manual override and reactivation	Scheduled override of DSM control and reactivation	Scheduled override of DSM control and reactivation with artificial intelligence	

Although the DSM control of equipment service is not supported by standards it should still be assessable and captures the main value proposition regarding the degree to which equipment that could have an impact on grid-balancing is able to do so. The attribution of impacts to these functionality levels remains arbitrary but they are correctly ordered in terms of their likely scale of grid-balancing capability for most building types. Note, since the first progress report this servce has been slightly amended to have a more logical progression of functionality and is included in the revised service catalogue as DSM-19 *DSM control of equipment*.

DSM-21 on *Information regarding DSM* and DSM-22 on *Override of DSM control* are thought to be highly relevant and should be feasible to assess in an unambiguous manner although this will need to be verified.

→ **Triage**

If no smart grid integration or DSM control of equipment are present omit all DSM services.
Typical time required to make triage = 1-4 minutes if documentation or building managers can be consulted.

Electric Vehicles

Like the DSM section the services listed for EVs are not defined in any standards or protocols. In principle, the key smart building service capabilities needed to support E-mobility are:

- charging capability (which is the product of the no. of assessable charge points and their charging speed)
- communication and control to enable the most economic charging (e.g. to support grid balancing via optimisation in response to network price signals)
- bi-directional communication and control to allow the EV batteries to sell power to the grid and be managed as part of an EV battery network to support grid balancing via optimisation in response to network price signals.

Even these functions are only partly defined in standards or protocols (e.g. charging modes (but not full capabilities) are defined in IEC 61851-1-2017 (3rd Edition, February 1, 2017): *Electric vehicle conductive charging system – Part 1: General requirements*. While communication capabilities of Electric Vehicles and Electric Vehicle Supply Equipment (EVSE) is set out in ISO/IEC/DIS 15118(E) *Road vehicles — Vehicle to grid communication interface — Part 1: General information and use-case definition* (which also details certain services).

Given that the principal goals are to promote E-mobility by facilitating convenient vehicle charging and to manage EV charging/storage in ways that support grid-balancing and RES penetration it is proposed to completely restructure the Task 1 EV services to reflect this as best as possible within the current state of the art by two simplified services as shown in the first two rows of Table 11:

Table 11 - EV services

Service	Level 0	Level 1	Level 2	Level 3
Charging	Not present	Low charging capacity	Medium charging capacity	High charging capacity
Grid balancing	Not present	1 way (controlled charging)	2 way (also EV to grid)	/
EV Charging - connectivity	EV charging information and connectivity	No information available	Reporting information on EV charging status to occupant	Communication with a back-office compliant to ISO 15118

Since the first progress report the first two services have been brought into the revised service catalogue as EV-15 and EV-16 respectively. The charging capacity referenced in EV-15 is yet to be fully defined but could be via the development of a simple algorithm reflecting the charging speed of the available sockets (which will partly correlate to the IEC 61851-1-2017 charge modes 1 to 4) and the number of available sockets (normalised to the building type or area). This capability really only has an impact on the Energy, Flexibility (as a necessary but insufficient condition) and Convenience impact factors.

The grid balancing capability of EV-16 (which would complete the grid-balancing impact of the charging service) is also not yet fully defined via standards and hence is kept very simple and aggregate here. Charging communication capability is defined in ISO/IEC/DIS 15118(E). Strictly speaking it could be argued that the grid balancing service is not yet sufficiently mature to be included in the streamlined methodology but it is quite likely that means of defining these simple functionality levels could be rapidly established and it represents the fastest track by which EV capability (as specified in the tender document) could be integrated into an actionable SRI. The same is true for the charging service but again if necessary implementers of the streamlined SRI could devise simple algorithms to classify the charging capability into the 4 levels expressed here.

Lastly, since the first progress report an additional service EV-17 on *EV Charging connectivity* has been added to reflect the value of reporting charging status information to occupants. This service is also not defined in standards but the functionality levels are reasonably unambiguous and hence it is thought they should be feasible to assess, although this needs verification.

→ **Triage**

If no EV charging points omit all EV services.
Typical time required to make triage = 1-4 minutes.

Monitoring and Control

Since the first progress report new user information services have been added at the domain level for heating, DHW, cooling, EG, DSM and EV. This has removed the need for some of the monitoring and control functions that were previously included in the monitoring and control section. Consequently, it has been deemed appropriate to retain the following services in the streamlined methodology:

MC-3 Run time management of HVAC systems
MC-4 Fault detection
MC-9 Occupancy detection: connected services
MC-13 Central reporting of TBS performance and energy use

The service MC-2 *Control of thermal exchanges*, which addresses energy (heat, cold) exchange/management among zones within one building or among different buildings will be inexistent in SFH and MFH and rare in any building type. Furthermore, it is not defined in any standard or protocol, therefore, MC-2 can be ignored as it is irrelevant or not currently assessable.

In practice the assessment of MC-1 *Heating and cooling set point management* & MC-3 *Run time management of HVAC systems* would be assessed at the same control point and at the same time to reduce the assessment time needed. And although MC-1 is now dropped from this section the same function is captured in the domain level checks and would be assessed in the same synergistic manner.

Of the original MC-5 – MC-7 services on feedback and reporting only MC-5 is defined within a standard (EN15232:2017). MC-6 and MC-7 are variants of this and would be assessed at the same instant and same point as MC-5. This significantly reduces the actual time required to conduct their assessment as the capability regarding present, historical, & predicted consumption (one set of capabilities) and presenting actual values, trending and predictive (another set of capabilities) can be assessed collectively. This means the additional time allocated to the assessment required for the MC-6 and MC-7 services can be ignored as the assessment time is already captured in MC-5. It should be noted that there is significant overlap between MC 5 – MC 7 and the services Heating-3, Cooling-3 and DH-3 which essentially report the same information but for the heating, cooling and DHW services specifically. It may often occur that the reporting of the TBS specific and building aggregate information is done at the same interface and so the assessment process would significantly overlap. For this reason the MC-5 to MC-7 services are now no longer necessary within the streamlined methodology.

The service MC-8 *Reporting information on IAQ* is now replaced by the new Ventilation-6 *Reporting information regarding IAQ* service and is treated in the ventilation domain.

Services MC-9 – MC-10 concern occupancy detection functionality and its use to control TBSs. The value of occupancy detection is mostly to be able to deactivate TBSs that are not needed and hence to save energy; however, some of this is already captured in functionality defined within the heating, cooling and lighting domains. The MC-9 and MC-10 services are not yet codified in standards or assessment protocols; however, MC-9 is more readily accessible and provides a distinct service from the domain level occupancy control functions. Therefore it is proposed to retain MC-9 in the streamlined methodology subject to its assesibility being verified but to omit MC-10.

Services MC-11 is concerned with the remote control of buildings so that absent users are able to adjust TBS/devices from a distance. It is not currently defined in any standards or protocols. Note, MC-11 was referred to as MC-9R in the previous versions of the report.

MC-12 is concerned with the ability to switch appliance of centrally within the home.

MC-13 is concerned with Central reporting of TBS performance and energy use. While this service overlaps with the Heating-3, DHW-3 and Cooling-3 services it is retained in the streamlined methodology to cover the instances where there is only reporting of the total (across TBS) energy consumption per energy carrier (as is common with less advanced smart meters without sub-metering at the TBS level).

→ **M&C Conclusions**

Include:

- MC-3 Run time management of HVAC systems
- MC-4 Fault detection
- MC-9 Occupancy detection: connected services
- MC-13 Central reporting of TBS performance and energy use

within the streamlined methodology.

Various domain

The services listed in the various domain are currently considered out of scope of the SRI methodology or not fully defined and are hence not part of the streamlined set of smart ready services.

Summary of changes

Once all these changes have been made the list of services that remains in the streamlined SRI methodology is as follows:

Table 12 – List of services: heating

Code	Service	Maximum functionality level
Heating-1a	Heat emission control	4
Heating-1b	Emission control for TABS (heating mode)	3
Heating-1c	Control of distribution network hot water temperature (supply or return) - Similar function can be applied to the control of direct electric heating networks	2
Heating-1d	Control of distribution pumps in networks	4
Heating-1e	Intermittent control of emission and/or distribution - One controller can control different rooms/zones having same occupancy patterns	3
Heating-1f	Thermal Energy Storage (TES) for building heating	2
Heating-1g	Building preheating control	2
Heating-2a	Heat generator control (for combustion and district heating)	2
Heating-2b	Heat generator control (for heat pumps)	3
Heating-2c	Sequencing of different heat generators	3
Heating-3	Report information regarding heating system performance	4

Table 13 - List of services: cooling

Code	Service	Maximum functionality level
Cooling-1a	Cooling emission control	4
Cooling-1b	Emission control for TABS (cooling mode)	3
Cooling-1c	Control of distribution network chilled water temperature (supply or return)	2
Cooling-1d	Control of distribution pumps in networks	4
Cooling-1e	Intermittent control of emission and/or distribution	3
Cooling-1f	Interlock between heating and cooling control of emission and/or distribution	2
Cooling-1g	Control of Thermal Energy Storage (TES) operation	2
Cooling-2a	Generator control for cooling	2
Cooling-2b	Sequencing of different cooling generators	3
Cooling-3	Report information regarding cooling system performance	4

Table 14 – List of services: DHW

Code	Service	Maximum functionality level
DHW-1a	Control of DHW storage charging (with direct electric heating or integrated electric heat pump)	2
DHW-1b	Control of DHW storage charging (using heat generation)	3
DHW-1d	Control of DHW storage charging (with solar collector and supplementary heat generation)	3
DHW-3	Report information regarding domestic hot water performance	4

Table 15 - List of services: CV

Code	Service	Maximum functionality level
CV-1a	Supply air flow control at the room level	3
CV-1b	Adjust the outdoor air flow rate	3
CV-1c	Air flow or pressure control at the air handler level	4
CV-2a	Room air temp. control (all-air systems)	2
CV-2c	Heat recovery control: prevention of overheating	1
CV-2d	Supply air temperature control	3
CV-3	Free cooling	3
CV-6	Reporting information regarding IAQ	3

Table 16 - List of services: lighting, DE, EG, DSM, EV and MC

Code	Service	Maximum functionality level
Lighting-1a	Occupancy control for indoor lighting	3
Lighting-2	Control artificial lighting power based on daylight levels	4
DE-1	Window solar shading control	4
DE-2	Window open/closed control, combined with HVAC system	3
EG-2	Local energy generation information	4
EG-3	Storage of locally generated energy	3
EG-4	Optimizing self-consumption of locally generated energy	2
EG-5	CHP control	1
DSM-18	Smart Grid Integration	1
DSM-19	DSM control of equipment	4
DSM-21	Reporting information regarding DSM	2
DSM-22	Override of DSM control	3
EV-15	EV charging capacity	3
EV-16	EV grid balancing	2
EV-17	EV charging information and connectivity	2
MC-3	Run time management of HVAC systems	3
MC-4	Detecting faults of technical building systems and providing support to the diagnosis of these faults	2
MC-9	Occupancy detection: connected services	2
MC-13	Feedback - Reporting information	3

In total there are at least 50 smart readiness services definitely included in this streamlined approach as opposed to 99 in the Task 1 catalogue. The number could be as high as 52 if the EG-4 and EG-5 services are found to be viable to assess.

Crucially, these 50 are the most actionable services in the sense that they are mostly defined in standards and should be feasible to assess via independent inspection. Furthermore, their impacts are more attributable to their functionality levels than is the case for those services that have been omitted from the Task 1 catalogue. Annex G lists the amalgamated subset of technically actionable services.

In the following sections, two case studies are applied to this streamlined methodology to explore how it could be applied for typical (i.e. representative) building types. Due to time contraints related to the revision of the model these case studies have not yet been updated since the first progress report with the amended list of full and streamlined services, although this will be done for the subsequent version. The principles and conclusions they illustrate remain fully valid though.

3.4.2. Case study 1 – A Single Family House

This section applies the streamlined methodology to a Single Family House case study and reports the outcomes in terms of the scores attained but also the aspects that affect feasibility including assessment time if done uniquely for the SRI or as part of an EPC process.

Table 17 - Single Family House case study

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

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

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

- heat demand control for heat emitters via TRVs and for the system via weather compensation and optimum stop/start
- heat production control includes variable temperature control depending on the load (depending on supply water temperature set point)
- monitoring & control of HVAC systems can be done by remote control (via smart phone) of the heating system
- reporting information regarding current and historical energy consumption
- basic (dumb) EV charging capabilities.

On the other hand it is not so smart because it has no on-site distributed generation (and hence no smart control of this), no DSM capability including no EV-related grid balancing capability, and no fault detection capability. As it has no cooling, hot water storage, controlled ventilation[55] or blinds these domains are excluded.

The full details from the SRI methodology spreadsheet are shown in the landscape table below.
Under the rationalised (streamlined) SRI methodology this building scores 53% out a maximum potential score for this building of 100% (Table 18). If relevant documentation were to be available it is (tentatively) estimated that a competent qualified inspector would require 30 minutes to do this

[55] Note small extractor fans in toilets and bathrooms and cooker hood extractor fans are not counted as "controlled ventilation" because their loads are too small and they only provide very localised extraction.

assessment once access to the premises has been granted. If documentation is not available the estimated inspection time increases to ~47 minutes. Were the same building to have no smart readiness services the inspection time is estimated to be 20 minutes and were it to have all possible smart readiness services and capabilities it is estimated to be 51 minutes with documentation and 90 minutes without. It should be noted that at the current time the large majority of single family buildings will have very few smart readiness features and thus the expected inspection times are in the 20 to 40 minutes range with an average probably of around half an hour.

Table 18 - Single Family House case study – SRI scores and assessment times

	Inspection time (mins)	**Inspection time (mins)**	**SRI**
Functionality level	SFH with documents	SFH without documents	
0	20	20	**0%**
Case Study	30	47	**53%**
4/Max	51	90	**100%**

Table 19 - Single Family House case study: SRI scores at service level

Code	Service	Case study functionality level	Functionality level	Maximum functionality level
Heating-1 Heat control on the demand side				
Heating-1a	Heat emission control	Individual room control (e.g. thermostatic valves, or electronic controller)	2	4
Heating-1b	Emission control for TABS (heating mode)	NA	0	0
Heating-1c	Control of distribution network hot water temperature (supply or return) - Similar function can be applied to the control of direct electric heating networks	Outside temperature compensated control	1	2
Heating-1d	Control of distribution pumps in networks	Variable speed pump control (pump unit (internal) estimations)	3	4
Heating-1e	Intermittent control of emission and/or distribution - One controller can control different rooms/zones having same occupancy patterns	Automatic control with optimum start/stop	2	3
Heating-1f	Thermal Energy Storage (TES) for building heating	NA	0	0
Heating-1g	Building preheating control	Program heating schedule in advance	1	2
Heating-2 Heat control on the supply side				
Heating-2a	Heat generator control (for combustion and district heating)	Variable temperature control depending on the load (depending on supply water temperature set point)	2	3
Heating-2b	Heat generator control (for heat pumps)	NA	0	3
Heating-2c	Sequencing of different heat generators	NA	0	3
Heating-3 Reporting information				
Heating-3	Report information regarding heating system performance	NA	1	4

Code	Service	Case study functionality level	Functionality level	Maximum functionality level
Lighting-1a	Occupancy control for indoor lighting	Manual on/off switch	1	3
Lighting-2	Control artificial lighting power based on daylight levels	Manual (per room / zone)	1	4
EG-2	Local energy generation information	None	0	4
EG-3	Storage of locally generated energy	None	0	3
DSM-18	Smart Grid Integration	None	0	1
DSM-19	DSM control of equipment	None	0	4
DSM-21	Reporting information regarding DSM	None	0	2
DSM-22	Override of DSM control	None	0	3
EV-15	EV charging capacity	Low charging capacity	1	3
EV-16	EV grid balancing	None	0	2
EV-17	EV charging information and connectivity	None	0	2
MC-3	Run time management of HVAC systems	Individual setting following a predefined time schedule including fixed preconditioning phases	1	3
MC-4	Detecting faults of technical building systems and providing support to the diagnosis of these faults	No central indication of detected faults and alarms	0	2
MC-9	Occupancy detection: connected services	Remote control of main TBS	1	3
MC-13	Central reporting of TBS performance and energy use	Real time indication of energy use per energy carrier	1	3

It is also pertinent to consider how the assessment time would change were all the TBS to be present (e.g. DHW, cooling, controlled ventilation and dynamic building envelope domains as well as those included in the case study). In this case the estimated inspection time would rise to 46 minutes for a building with no smart capabilities and to 125 minutes for one the maximum smart capabilities and supporting documentation, Table 20. In fact very few single family buildings have all possible TBS domains and thus this would be a-typical.

Table 20 - Single Family House with all domains – SRI scores and assessment times as a function of the smart functionality level

	Inspection time (mins)	**Inspection time (mins)**	**SRI**
Functionality level	SFH with documents	SFH without documents	
0	46	46	**0%**
1	85	170	**54%**
2/Max	119	236	**83%**
3/Max	124	255	**99%**
4/Max	125	256	**100%**

The weighting of impacts by domain applied in this analysis is as shown in Table 21, however, in principle any (including equal) weightings could be applied. Those used here are intended to better reflect the contribution smart functionalities make to the overall impacts as a function of the domain they apply to; however, many of the values applied are rather arbitrary and more work is required to establish any agreed recommended weightings. Note, when equal weightings per impact parameter are shown it simply indicates that the study team currently has no insight into what any recommended weightings could be and does not indicate that there is no rational to apply differentiated weightings for the impact parameter concerned.

Table 21 - Domain-level impact weightings used in the Single Family House case study

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

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

Underpinning the overall SRI score the case study building attains the ordinal impact scores by impact criterion as shown in Table 22. While energy has the largest potential for scoring (reflecting the wide array of smart services that influence energy consumption), there are potentially major contributions from flexibility, comfort, convenience and information to occupants. There is less for maintenance and fault prediction, health and well-being and self-generation. This could be because some existing smart services that address maintenance and fault prediction or health and well-being were not identified for the Task 1 catalogue or it may be that there are only limited smart services available for these impacts. In the case of self-generation it reflects the consolidation of the smart services into actionable measures made for this streamlined methodology. More could be added were the services more mature and better defined.

The *Maximum with all domains* row shows what could be scored were all possible services present and all domains. It is rather misleading though as this could never be the case as many of the smart services (and especially those that relate to the TBS) are effectively mutually exclusive e.g. a building would not have district heating, combustive heating, heat pumps, solar heating, TABS and Thermal Energy Storage, but most likely would just have a subset of these. As a result the apparent dominance of energy in this row is an artefact and would not be reflected in any actual building using this streamlined methodology.

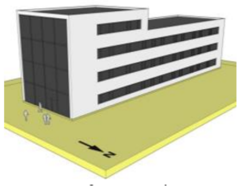
Table 22 - Ordinal impact scores for the Single Family House case study, the case study with maximum smart capability and for an equivalent building having with all possible domains and smart-services

	ORDINAL IMPACT SCORES							
	Energy	Flexibility	Self-gen	Comfort	Convenience	Health and well-being	Maintenance & fault prediction	Information to occupants
Case study	**20**	**4**	**0**	**19**	**15**	**6**	**0**	**8**
Case study Maximum	**42**	**22**	**2**	**28**	**33**	**7**	**3**	**14**
Maximum with all domains	**106**	**31**	**2**	**67**	**73**	**21**	**7**	**16**

3.4.3. Case study 2 – An office

This section applies the streamlined methodology to an office case study and reports the outcomes in terms of the scores attained but also the aspects that affect feasibility including assessment time.

Table 23 - Office case study: building characteristics

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

For this example a case study is examined of a hypothetical office building. This building is essentially the same as the High Performance office in the Ecofys/WSE technical building systems study. The building has a gas-fired boiler and hydronic heat distribution via radiator emitters. Space cooling is provided by a chiller that distributes coolth via a hydronic system using fan-coils. Domestic hot water is via localised instantaneous heaters and does not have storage. Controlled ventilation is supplied via an air handling unit but does not use heat recovery.

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

- heat demand control for heat emitters via eTRVs and for the system via weather compensation and optimum stop/start
- Individual room/zone demand driven control with communication between controllers and BACS and presence detection
- heat production control includes variable temperature control depending on the load (depending on supply water temperature set point)
- variable airflow and chiller capacity by means of variable speed drives on ventilation fans and the chiller compressor
- cooling circuit temperature (supply or return) with weather compensation, optimum start/stop and variable speed pump controls for network distribution pumps
- control of cooling emitters provided by individual room demand control with communication and presence detection
- air flow control at the room/zone level via demand control: wherein the system is controlled by sensors measuring indoor air parameters or adapted criteria (e.g. CO_2, mixed gas or VOC sensors)
- air flow or pressure control at the air handler level via automatic flow or pressure control with demand evaluation
- advanced air supply and humidity controls
- lighting control per task light source using occupancy and daylight responsive controls with dimming and daylight responsiveness for circulation lighting

- user-friendly BEMS system in place but with energy savings functions activated. Runs diagnostics, reports faults and provides informative displays of energy consumption, indoor conditions and possibilities for improvement
- basic (dumb) EV charging capabilities
- motorized operation of window blinds with manual control.

On the other hand it is not so smart because it has no on-site distributed generation (and hence no smart control of this) and no DSM capability including no EV-related grid balancing capability.

The full details from the SRI methodology spreadsheet are shown in the landscape table below.

Under the rationalised (streamlined) SRI methodology this building scores 64% out a maximum potential score for this building of 100% (Table 24). If relevant documentation were to be available it is (tentatively) estimated that a competent qualified inspector would require 2.5 hours to do this assessment once access to the premises has been granted. If documentation is not available the estimated inspection time increases to 4.3 hours. Were the same building to have no smart readiness services the inspection time is estimated to be 1.4 hours and were it to have all possible smart readiness services and capabilities it is estimated to be 4.3 hours with documentation and 8.8 hours without. It should be noted that at the current time the large majority of offices will have smart readiness capabilities of and below those shown in the case study.

Table 24 - Office case study: SRI scores and assessment times

	Inspection time (hrs)	Inspection time (hrs)	SRI
Functionality level	Office with documents	Office without documents	
0	1.4	1.5	**0%**
Case Study	2.5	4.3	**64%**
4/Max	4.3	8.8	**100%**

Table 25 – Office case study: SRI scores at the service level

Code	Service	Case study functionality level	Functionality level	Maximum functionality level
Heating-1 Heat control on the demand side				
Heating-1a	Heat emission control	Individual room control with communication and presence control	4	4
Heating-1b	Emission control for TABS (heating mode)	NA	0	0
Heating-1c	Control of distribution network hot water temperature (supply or return) - Similar function can be applied to the control of direct electric heating networks	Outside temperature compensated control	1	2
Heating-1d	Control of distribution pumps in networks	Variable speed pump control (pump unit (internal) estimations)	3	4
Heating-1e	Intermittent control of emission and/or distribution - One controller can control different rooms/zones having same occupancy patterns	Automatic control with optimum start/stop	2	3
Heating-1f	Thermal Energy Storage (TES) for building heating	NA	0	0
Heating-1g	Building preheating control	Thermostat self-learning user behaviour (presence, setpoint)	2	2
Heating-2 Heat control on the supply side				
Heating-2a	Heat generator control (for combustion and district heating)	Variable temperature control depending on the load (depending on supply water temperature set point)	2	3
Heating-2b	Heat generator control (for heat pumps)	NA	0	0
Heating-2c	Sequencing of different heat generators	NA	0	0
Heating-3 Reporting information				
Heating-3	Report information regarding heating system performance	Actual values and historical data	2	4

Code	Service	Case study functionality level	Functionality level	Maximum functionality level
Cooling-1 *Cooling control on the demand side*				
Cooling-1a	Cooling emission control	Individual room control with communication and presence control	4	4
Cooling-1b	Emission control for TABS (cooling mode)	NA	0	0
Cooling-1c	Control of distribution network chilled water temperature (supply or return)	Outside temperature compensated control	1	3
Cooling-1d	Control of distribution pumps in networks	Variable speed pump control (pump unit (internal) estimations)	3	4
Cooling-1e	Intermittent control of emission and/or distribution	Automatic control with optimum start/stop	2	3
Cooling-1f	Interlock between heating and cooling control of emission and/or distribution	Total interlock	2	2
Cooling-1g	Control of Thermal Energy Storage (TES) operation	NA	0	0
Cooling-2 *Cooling control on the supply side*				
Cooling-2a	Generator control for cooling	Variable temperature control depending on outdoor temperature	1	3
Cooling-2b	Sequencing of different cooling generators	NA	0	0
Cooling-3 *Reporting information*				
Cooling-3	Report information regarding Cooling system performance	Actual values and historical data	2	4

Code	Service	Case study functionality level	Functionality level	Maximum functionality level
DHW-1a	Control of DHW storage charging (with direct electric heating or integrated electric heat pump)	NA	0	0
DHW-1b	Control of DHW storage charging (using heat generation)	NA	0	0
DHW-1d	Control of DHW storage charging (with solar collector and supplementary heat generation)	NA	0	0
DHW-3	Report information regarding domestic hot water performance	NA	0	0

Code	Service	Case study functionality level	Functionality level	Maximum functionality level
CV-1 *Air Flow Control*				
CV-1a	Supply air flow control at the room level	NA	0	0
CV-1b	Adjust the outdoor air flow rate	NA	0	0
CV-1c	Air flow or pressure control at the air handler level	NA	0	0
CV-2 *Air Temperature Control*				
CV-2a	Room air temp. control (all-air systems)	NA	0	0
CV-2c	Heat recovery control: prevention of overheating	NA	0	0
CV-2d	Supply air temperature control	NA	0	0
CV-3	Free cooling	NA	0	3
CV-6 *Reporting information*				
CV-6	Reporting information regarding IAQ	NA	0	3

Code	Service	Case study functionality level	Functionality level	Maximum functionality level
Lighting-1a	Occupancy control for indoor lighting	Automatic detection (manual on / dimmed or auto off)	3	3
Lighting-2	Control artificial lighting power based on daylight levels	Automatic dimming	4	4
EG-2	Local energy generation information	None	0	4
EG-3	Storage of locally generated energy	None	0	3
DSM-18	Smart Grid Integration	None	0	1
DSM-19	DSM control of equipment	None	0	4
DSM-21	Reporting information regarding DSM	None	0	2
DSM-22	Override of DSM control	None	0	3
EV-15	EV charging capacity	Low charging capacity	1	3
EV-16	EV grid balancing	None	0	2
EV-17	EV charging information and connectivity	None	0	2
MC-3	Run time management of HVAC systems	Adaptation from a central room	2	3
MC-4	Detecting faults of technical building systems and providing support to the diagnosis of these faults	Individual setting following a predefined time schedule including fixed preconditioning phases	2	2
MC-9	Occupancy detection: connected services	None	0	3
MC-13	Central reporting of TBS performance and energy use	Real time indication of energy use per energy carrier	1	3

The weighting of impacts by domain applied in this analysis is as shown in Table 26, however, in principle any (including equal) weightings could be applied. Those used here are intended to better reflect the contribution smart functionalities make to the overall impacts as a function of the domain they apply to.

Table 26 - Domain-level impact weightings used in the Office case study

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

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

Underpinning the overall SRI score the case study building attains the ordinal impact scores by impact criterion as shown in Table 27. While energy has the largest potential for scoring (reflecting the wide array of smart services that influence energy consumption), there are potentially major contributions from flexibility, comfort, convenience and information to occupants. There is less for maintenance and fault prediction, health and well-being and self-generation. As mentioned for the single family home case study, this could be because some existing smart services that address maintenance and fault prediction or health and well-being were not identified for the Task 1 catalogue or it may be that there are only limited smart services available for these impacts. In the case of self-generation it reflects the consolidation of the smart services into actionable measures made for this streamlined methodology. More could be added were the services more mature and better defined.

Table 27 - Ordinal impact scores for the Office case study, the case study with maximum smart capability and for an equivalent building having with all possible domains and smart-services

	ORDINAL IMPACT SCORES							
	Energy	Flexibility	Self-generation	Comfort	Convenience	Health and well-being	Maintenance & fault prediction	Information to occupants
Case study	33	3	0	31	26	6	4	8
Case study Maximum	63	22	2	43	43	6	5	12

3.5. Tailoring the SRI

This chapter considers issues about how the applicability of the methodology is likely to vary depending on specific circumstances (building type, climate, site specific conditions, user preferences etc.). Local and site-specific context will mean that some domains and services are either not relevant, not applicable or not desirable and thus the SRI needs to be flexible enough to accommodate this. Equally depending on the local context SRI scheme operators may wish to elevate some aspects of the SRI (domains or impacts) and downgrade others – for example some operators of the SRI may be primarily concerned about promoting grid flexibility while others may be concerned about EV facilitation and on-site energy savings through enhanced control. 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.

3.5.1. Tailoring to take account of the buildings needs and context

Clearly, if a building has a technical building system or feature it should get a higher SRI score if that TBS/feature is smart than if it is not, but it is more subjective as to whether a building should be considered less smart if it doesn't have the TBS/feature in the first place.

Many of the smart readiness services catalogued in Task 1 are associated with technical building systems that are often not required or appropriate depending on the context in question. At the whole domain level, depending on the climate, internal loads, building function and overall building energy performance a building may not need:

- Heating (sometimes, but increasingly true in advanced passive buildings)
- Cooling (often)
- Controlled ventilation
- Controlled blinds or dynamic building envelope features.

It is inappropriate to give a building which doesn't need these TBSs a poorer SRI score than one which does simply because these TBS could be made to be comparatively smart compared to less smart options. This is for example the case if one considers the example of a highly advanced passive solar house using solar shades and ventilation or window opening control which eliminates the need for mechanical cooling, hence also doesn't need the TBS for controlling these.

Equally a building may not have or need:

- storage for domestic hot water or associated circulation pumps
- blinds or dynamic building envelope features
- on-site energy generation such as RES
- local storage, such as batteries
- parking facilities (and hence EV charging capabilities).

Therefore, any viable SRI methodology needs to be flexible enough to adapt to locally specific context. The methodology presented in this report is fully flexible in this regard because it allows the users to exclude any unnecessary TBS or service and re-normalise the SRI score so that the building is not penalised for its absence. Equally, whenever relevant, it would be possible to add new services (not mentioned in the report above) and adjust the scoring in a similar manner.

Not only can the methodology be tailored to take account of the presence or absence of TBSs and services, but it can also be tailored to take account of the relative priority to be placed on the ten distinct domains and the eight impacts. Sometimes this could be appropriate due to technical factors. For example, the climate in a specific location may alter the average importance of the different domains in a typical building-type for the on-site energy consumption and savings. An alternative example, could be that in a specific jurisdiction some flexibility options are made available by the DSOs whereas in another they are not – and this could provide a technical distinction in the relative importance of different DSM and EV charging services to the overall smart outcome of the building (notwithstanding the smart readiness versus smart capability now distinction). Equally, in different jurisdictions there are likely to be different priorities placed on the promotion of the various smart services and the importance of different impacts. This also means that for any given jurisdiction the SRI methodology could be applied in a manner which makes sense for the specificities of the building stock, climate, culture, service offerings and policy priorities that are present there. On the other hand, the SRI will be most effective if it retains a minimum level of harmonisation as discussed in section 3.9.9.

3.5.2. EXAMPLES OF HOW THE METHODOLOGY CAN BE TAILORED TO NEEDS AND CONTEXT

The methodological framework presented in this report is flexible enough to allow any of the types of contextual adjustments implied above. If a TBS or service is not present and not relevant then the methodology is applied in a way that discounts the absent TBS/service and renormalizes the scoring. It does this by setting the actual scores attained and the maximum scores that could be attained for the absent services to zero (the normalisation formulae will then set the maximum attainable score for a service to zero and ignore (discount) all normalisation ratios having a zero-value denominator).

In the SFH case study presented earlier this exact process is followed for the absent TBS domains of cooling, controlled ventilation and dynamic building envelope; but it is also applied for the absent services of:

- Emission control for TABS (heating mode)
- Thermal Energy Storage (TES) for building heating
- Control of DHW storage charging (with direct electric heating or integrated electric heat pump)
- Control of DHW storage charging (using heat generation)
- Control of DHW storage temperature, varying seasonally: with heat generation or integrated electric heating
- Control of DHW storage charging (with solar collector and supplementary heat generation)

- Control of DHW circulation pump

Note, that the TABS and TES services are discounted because the building does not use or need these. In the case of DHW it is different, because the building does have a DHW service but not one that utilises storage or circulation pumps.

Interestingly, the building does not have its own energy generation (i.e. RES) but the domain is retained and the building is set (and hence scored) at functionality level 0 out of a possible maximum functionality level of 2 on the Local energy production and renewable energies service. In this case the missing service is not discounted and thus the building's SRI score is lower than it would have been had a renormalisation process been applied. This is because it can be argued that the building would be a smarter building if it had this capability; however, this judgement is contestable and some users of the methodology might prefer to follow a discounting and renormalisation process in this instance too. However, to avoid such contestable judgement and any resulting arbitrariness, it is recommended that the second technical study develops clear guidance concerning this renormalisation process in order to eliminate variance in the rating given for the same building by different assessors.

In the Office case study presented above none of the domains are absent and hence no discounting and renormalisation process is applied at the whole domain level. Discounting and renormalisation is applied, however, for the following absent and unnecessary services:

- Emission control for TABS (heating mode)
- Thermal Energy Storage (TES) for building heating
- Heat generator control (for heat pumps)
- Sequencing of different heat generators
- Heat system control according to external signal (e.g. electricity tariff, load shedding signal etc.)
- Control of DHW storage charging (with direct electric heating or integrated electric heat pump)
- Control of DHW storage charging (using heat generation)
- Control of DHW storage temperature, varying seasonally: with heat generation or integrated electric heating
- Control of DHW storage charging (with solar collector and supplementary heat generation)
- Control of DHW circulation pump
- Emission control for TABS (cooling mode)
- Control of Thermal Energy Storage (TES) operation
- Sequencing of different cooling generators
- Controlled ventilation - Supply air flow control at the room level
- Controlled ventilation - Adjust the outdoor air flow rate
- Controlled ventilation - Air flow or pressure control at the air handler level
- Controlled ventilation - Room air temp. control (all-air systems)
- Controlled ventilation - Heat recovery control: prevention of overheating
- Controlled ventilation - Supply air temperature control

In all cases, this is because the service the smart services refer to is provided by another solution. For example as the building uses combustion based heating via a single boiler with hydronic distribution and emission via radiators the TABS, TES, heat-pump control, heat generator sequencing and external signal control smart services are unnecessary and inapplicable. The same is true of the TABS and TES cooling solutions, the DHW storage and distribution solution (as localised instantaneous water heating is used), and all the controlled ventilation smart services that are not applicable to the solution which is actually used (a combined air-water system).

The exclusion and renormalisation process described above is not the only means by which the methodology is adapted to contextual circumstances – the other method is by adjustment of the normalised weighting factors that are applied to the domains and/or to the impacts. In the two case studies presented in this report uneven (i.e. unequal) weighting factors are applied by domain for the following impacts (Energy savings on-site, Flexibility for the grid and storage, Self-generation, Comfort, Information to occupants) but even (equal) weightings by domain are applied for the impacts of Convenience, Health and well-being, and Maintenance & fault prediction. The rationale for this is that in the case of the unequally weighted impacts across domains some domains are thought to be more important to the overall impact than others. For example smart services in the heating, domestic hot water, cooling, controlled ventilation and lighting domains have no impact on self-generation so are weighted to zero for this impact. By contrast the importance of specific TBS to the energy-saving on-site varies depending on the building type (as well as other factors) and as a result the weightings applied to the TBS domains for the SFH and Office cases studies are not identical, but rather are adjusted to take account of the relative importance of each TBS to the buildings energy consumption (based on typical European buildings in this case). These examples are indicative of the application of a technical determination process that aims to ensure the overall SRI reflects the true impact of the potential smart readiness services on the impacts in question. As these can vary systematically according to context the methodology needs to be (and is) flexible enough to allow such contextual calibration to take place.

The other means of using the weightings capability is to apply differentiated weighting by impact type in the derivation of the overall SRI score. In the SFH and Office case studies presented above each of the eight impact criteria are treated (and hence weighted) equally, thus no impact criterion is considered to be more relevant than another. However, users of the methodology may have different perspectives on this issue and may wish to apply differential weightings by impact criterion. For example, if the scoring attributed to the discrete smart service functions or functionality levels is not considered to be sufficiently well-founded for some of the impact criteria these could be weighted downwards (or even to zero and hence discarded) compared to the remaining impact criteria.

It should be noted, that in all cases the methodology requires the weightings to sum to 100% across both the impact criteria and across the domains for each impact criteria. Thus adjusting the weighting for one element upwards requires that for another to be adjusted downwards to ensure the sum is always 100%.

3.6. EVOLUTIONARY METHODOLOGICAL APPROACHES

The methodology put forward above is not the only approach that could be used for the SRI. In principle the SRI could also be determined using methodologies based on:

- calculation based approaches i.e. using an algorithm and/or software
- measured outcome based solutions potentially including real time dynamic measurement data and a rated realtime indicator
- a checklist approach
- an evolutionary hybrid approach.

These options are examined in more depth below.

3.6.1. INCORPORATING CARDINAL DATA ASSESSMENT OF IMPACTS

The SRI methodology set out in the earlier sections of this report is based on applying ordinal rankings dependent on the SR capabilities present within a building. These rankings are derived by provisional expert evaluations of the study team with input from stakeholders and/or from exogenously derived rankings, such as those presented within standards (harmonised or otherwise). Were there to be a migration over time with an evolving maturity of the SRI towards the use of measured outcomes (see section 3.6.3) and/or calculated outcomes then cardinal impact data would become available which is intrinsically preferable to the use of less precise ordinal data.

This raises the question of how such cardinal data could be substituted for the ordinal rankings set out in the current method?

In fact the approach that could be followed is quite straightforward. The ordinal ranking methodology proposed for the SRI is already normalised against the eight overarching impact parameters such that for each impact parameter a building is awarded a score based on its relative attainment of the maximum possible score. Cardinal data can be similarly normalised and mapped onto this scale. By way of illustration consider the case of the EN15232 standard for BACS, which includes a simplified BACS factor method that ascribes progressively higher cardinal energy savings impacts to progressively more advanced BACS solutions for specific technical building systems. Under the current, even more simplified, SRI methodology these impacts, which are associated with BACS classes ranked from D to A within the standard, are mapped to the ordinal scores; however, it would be equally possible (and presumably preferable) to use the BACS factors directly in a cardinal impact score. The table below shows the EN 15232 BAC efficiency factors for thermal energy use for non-residential buildings. To calculate the (cardinal) impact the BACS class has on the building's thermal energy use the energy consumption of the TBS is multiplied by the BAC efficiency factor. Thus, in the case of an education building the thermal-energy TBS energy consumption would be multiplied by a factor 1.20 for a class D BACS and by 0.8 for a class A BACS thus the class A BACS would be expected to consume 0.8/1.20 = 66.7% of the class D BACS solution i.e. to use 33.3% less energy for an equivalent TBS service. As class A is the highest BACS service and class D the lowest they define the two end-points on the normalised scale. Under the ordinal ranking system the class A solution scores ++++ = 4 while the class D solution scores no + i.e. = 0. So in this case a score of 4 is equivalent to an energy saving of 33.3%, a class B score a saving of 26.7%, and a class C score to a saving of 16.7%.

There are two ways this cardinal information could be included within the scheme. The simplest approach would be to normalise it by the highest potential score. In this case this is a score of 4 for a 33.3% energy saving, so under the cardinal approach the highest score would remain 4, the next highest class B would become 3.2 = 4*26.7/33.3, the class C would be 2.0 = 4*16.7/33.3, and the class D would remain 0.

A more sophisticated approach would be to weight all the energy savings scores (whether ordinal or cardinal) by the expected energy consumption of each TBS as a proportion of the total building energy consumption (see weightings discussion) and to apply the savings estimates directly. Thus, if the given TBS being treated with cardinal data (from the example above) is expected to account for 40% of the total building energy consumption then the energy savings scores attained would be allocated for a class A solution leading to 33.3% energy savings for the TBS in question of 1.33 (= 0.4*0.333) of the maximum possible points awardable for on-site energy savings in the building.

Table 28 BAC efficiency factors for non-residential buildings as defined in EN 15232

Table A.1 — Overall BAC efficiency factors $f_{BAC,th}$ – Non-residential buildings

Non-residential building types	Overall BAC efficiency factors $f_{BAC,th}$			
	D	C Reference	B	A
	Non energy efficient	Standard	Advanced	High energy performance
Offices	1,51	1	0,80	0,70
Lecture hall	1,24	1	0,75	0,5 [a]
Education buildings (schools)	1,20	1	0,88	0,80
Hospital	1,31	1	0,91	0,86
Hotels	1,31	1	0,85	0,68
Restaurants	1,23	1	0,77	0,68
Wholesale and retail trade service buildings	1,56	1	0,73	0,6[a]
Other types - sport facilities - storage - industrial buildings - etc.		1		
[a] These values highly depend on heating/cooling demand for ventilation.				

Note, this example illustrates how it is possible to combine cardinal and ordinal data assessments within the SRI methodology and this means that as and when cardinal data is available for use it can be substituted for the simpler ordinal data without compromising the rest of the assessment framework. The modular nature of the SRI methodology enables this blended approach to be applied in an evolutionary manner.

3.6.2. USING CALCULATION SOFTWARE

In theory calculation-based approaches could be used to determine the SRI in place of metered outcomes (discussed in 3.6.3). These could use software or algorithms to award points based on a simulated set of outcomes based on the known behaviours and performance of smart readiness technologies and solutions. The software used by some MS to calculate building energy performance for EPCs is an example of this type of approach as applied specifically to building energy performance. There is a wide variety of current practice in the use of such calculation software and in reality it is understood that most EPC implementations do not currently capture the majority of energy savings that could be achieved via the deployment of smart energy savings technologies such as BACS, although they could be amended to do so.

In principle, calculation software could also be used to assess impact parameters other than energy savings on site. However, there appears to be less maturity in the development and deployment of calculation tools to address the other SRI impact parameters covered in the current methodology. Thus, the use of calculation tools is something that could be fostered and encouraged in the implementation of the SRI whenever such tools are available and viable. A next step could entail a detailed review of all available calculation tools and the documentation of their capabilities and suitability of use to derive specific SRI pertinent impacts. In the event that such tools are available for specific SR impacts or services it should be possible to integrate them within the SRI assessment methodology in place of, or as a supplement to, using the current methodology which is based on ascribing ordinal rankings linked to impact scores for specific smart readiness capabilities. An illustration of how this could be done is discussed in the previous section.

More generally, using calculation software to determine the SRI could be particularly relevant for design-time SRI assessments i.e. those based on building digital models.

3.6.3. USING MEASURED OUTCOME BASED APPROACHES

Some comments received on the previous versions of the report raised the issue of whether it might be viable to move towards an outcome-based approach rather than one based on assessing inputs. In an ideal situation an assessment based on measuring outcomes (in terms of energy performance, health, comfort etc.) is preferable because it is fully technologically neutral and could be structured to award scores that are proportional to the smart building outcomes which are achieved. The method put forward in the previous versions of the reports did not (so far) pursue this approach because an outcome-based approach is only possible when outcomes are measured and when there is a framework in place to normalise the outcomes that can be transposed to an SRI. Currently, building energy consumption can be measured when smart meters for each energy flow (e.g. electricity, gas, etc.) are in place and in theory this could be used to create a dynamic measure of building consumption that in turn could be normalised to produce an energy performance score that relates to the **energy savings on site** impact parameter. The normalisation process could take into account floor area (perhaps differentiated by the relative areas of internal spaces as a function of the activities conducted within them), building type, climate, and even occupancy (if this latter is also measured). In principle, measurements could also be done for the other seven impact parameters as follows

- **Flexibility for grid and storage:** could measure the magnitude of energy stored, of demand rescheduled from peak, and of the flow of stored energy from the building to the energy network on demand
- **Self-generation**: the amount of energy generated (perhaps expressed as a normalized ratio of the building energy consumption)
- **Comfort:** internal temperatures (when occupied) and the relative deviation from best practice set-points for occupied spaces
- **Convenience:** this impact category assesses the gains in terms of convenience in terms of “making the life easier” for the occupant, e.g. by requiring less manual interactions to control the technical building system
- **Health and well-being**: measurements of indoor air quality, light levels and light quality
- **Maintenance and fault prediction:** impacts from the point of view of the asset management or TBS perspective
- **Information to occupants**: a set of of most relevant measurable information could be identified and the extent to which this is provided gauged.

While this approach undoubtedly has merit it presents some practical problems at present. First, only parameters that can be measured can be accounted for and yet for the large majority of existing buildings only a few or none of the relevant parameters are currently metered. While increasing metering and intelligent diagnostics of building data is desirable and is an aspect of smartness, if the SRI is fully tied to the presence of this capability it would dramatically limit its scope (i.e. the proportion of existing buildings that could attain an SRI score and the proportion of impacts that could be assessed). In addition, requiring the inclusion of metering capability is likely to add costs that may also deter some building users from engaging with the SRI. Furthermore, smart metering capabilities are not harmonised across the EU and hence this could also be a driver of divergence. Finally, measured data can only be available for buildings that are already in operation. This would prohibit using the SRI methodology to inform decision making during the design stage for newly constructed or renovated buildings.

Conversely, metered data is more straightforward to assess remotely and were sufficient data to be available in this form it could remove the need for on-site inspection (i.e. enable either instantaneous and remote (if needed) assessment, and/or instantaneous automatic on-site evaluation and reporting) and could allow a real-time dynamic indicator of smartness to evolve. Thus, the presence of real time or short interval metering and/or measurement capability is a plus from a smart readiness perspective but any methodology that makes it a precondition of attaining a smart readiness rating risks excluding important aspects of smartness which are not contingent on having smart metering.

Consequently, it could be appropriate to aim to implement the scheme in such a way that it could migrate towards a measured outcomes approach in the future for those services where this makes sense. This would require sufficient metering capability to be place as well as the establishment of agreed normalised ranking systems for the services concerned so that these can be used to create normalised benchmarks and hence SRI scores (which could be a blend of the input based ordinal approach, calculated values and measured outcomes). This line of reasoning would also be consistent with awarding SRI bonuses to buildings that have greater metering (ideally dynamic metering) of smart readiness outcomes.

3.6.4. CHECKLIST BASED APPROACHES

At least one reviewer has proposed that a checklist approach be considered. In fact, the methodology proposed is based on a checklist method wherein a set of prospective smart services are assessed methodically and awarded points based on the degree of sophistication of the solution adopted. In addition to providing an overall SRI score the information assembled from the assessment process could be used to provide detailed information to the building user/owner on what was scored for each service against the potential score for each service, supported by ancillary information on what would be needed to score more highly for each service. Thus, there is no contradiction between the methodology proposed and the supply of checklist related information to the occupants and owners.

3.6.5. EVOLUTIONARY HYBRID APPROACH

Considering the elements reviewed above it seems sensible to envisage an SRI methodology that evolves from the initial quasi checklist-based score derived using manual on-site assessment to one that progressively replaces this by calculation, or ideally measured outcome-based assessment for specific smart services as these become viable. In the event that outcome-based assessments using dynamic metering become viable then it may no longer be necessary for the specific service to be assessed manually but rather it could be done via a display interface to the user and/or assessor.

In practice, calculation methods and/or look-up tables using cardinal data could be derived for the assessment of some of the smart services in the near-term and could be applied in preference to the less rigorous ordinal ranking assessment approach on a case by case basis. At this juncture a process could be imagined wherein implementers of the SRI are permitted to use on a smart service by smart service basis one of the following:

- the ordinal assessment method set out in this report
- an approved calculation-based method
- an approved metered (measured) outcomes-based method.

As such methods are developed as alternative more-rigorous approaches to the simplified ordinal method the authorities operating the SRI could grant the freedom to users and/or assessors to use the more robust approaches.

The modular approach put forward in the basic organisation and design of the SRI methodology allows this flexibility in the way the SRI is rolled-out. It means that trade-offs related to accuracy and the ease and speed of assessment can be adjusted based on the willingness of the building user/owner/manager to engage with the SRI, the resources available to make assessments and the desire for accuracy. Ordinal assessment can give way to cardinal impacts derived from calculations or preferably measured impacts as and when such approaches are developed and demonstrated to be viable for use. This approach ensures that a minimum rigour is always in place but that there is freedom to evolve and apply more accurate and dynamic assessments for specific services if these become available. It should be noted that this approach could also potentially allow engagement of voluntary schemes that go into greater depth for specific smart services.

3.7. ORGANISING AND REPORTING THE SRI

This section briefly considers how the SRI information could be organised and reported to determine if the methodology is flexible enough to accommodate presenting the SR information within any preferred reporting structure.

Section 3.1 listed the factors to consider in the SRI's development and highlighted the need for it to work for each of its key audiences. For it to work as an effective positive change agent it needs to inform and motivate these audiences to consider the adoption of beneficial smart readiness technologies within the buildings they have an influence over.

The most important audience is that which makes the capital equipment and services investment decisions for buildings which therefore brings into play the owners, occupants and facility managers. These audiences are likely to have a spectrum of needs from SR services and to have priorities that reflect these. They will need to feel the information presented to them is credible, reliable and informative but that it reflects their interests and priorities. Equally though the SRI is intended to work as a policy instrument that helps promote public policy objectives and thus it needs to encompass both sets of perspectives.

Good practice with the presentation of information to consumers and end-users is to "keep it simple", and to present numerical data via heuristic scales that aid and motivate the decision-making process without overloading it. The aggregate SRI scores produced in the streamlined methodology could be readily transposed into such a scale e.g. in Table 29.

Table 29 – Example of SRI scores and scale

SRI	Class
>86%	A
>72%	B
>58%	C
>44%	D
>30%	E
>16%	F
16% or less	G

Such an approach would present an easy way to summarise and communicate the overall SRI value proposition; however, it will certainly invite questions about what it really represents. What type of smartness is being considered within it? What kind of impacts are being assessed? Etc. If users feel they do not understand the rating it is less likely to resonate with them and less likely to impact their decision making. One way to address this could be to complement the overall heuristic classification with additional scoring data that explains more about what is contained within the overall ranking. This could comprise sub-scores or heuristic rankings by impact type, e.g. an A to G or 1 to 5 heuristic ranking for each of the eight impacts identified in the Task 1 work (or a reduced sub-set thereof). Alternatively or also sub-scores could be given by domain. This type of hybrid approach of combining a main ranking that would be emphasised in the presentational format with lower emphasis sub-scores or rankings, which are related to more tangible and hence explicable components, that feed the overall score could allow the users to get the main message at a glance while being able to probe deeper should they want more detail and/or reassurance about the nature of the elements feeding into the overall score. The choice of presentational format (which is not considered here) can also influence the most appropriate blend. Impacts could also be further aggregated into priority groups scores e.g. into energy, flexibility and e-mobility.

Happily the SRI methodology allows all sorts of additional scoring and ranking data to be presented in addition to the principal score and associated heuristic ranking class. In principle, data on scores could be presented by impact type, by domain type or even at each service level in whatever manner is found to be most effective with the target audience. Complementing the overall score with presentation of more granular data also has the benefit of enabling the distinct service offerings to better convey the impact of their services and this will be important in assisting their engagement with and use of the scheme. If service providers find the SRI and related information to be helpful in promoting their services they are likely to use it in their promotional material and to help communicate the value proposition to their customers. This can create an important amplifying effect that allows the scheme to gain traction faster and increase its effectiveness.

The decision regarding the most appropriate level of detail and formats by which the SR information should be presented should be tested through consumer and market research supplemented by stakeholder discussion; however, the key conclusion is that the streamlined methodology is capable of supplying the SR information in whatever level of aggregation or granularity is deemed most beneficial.

Lastly, if the SRI is to act as a stimulus to change efforts will be necessary to explain it and its sub-components to building occupants and owners. Some EPCs now include recommendations on how to best improve the energy performance of a property and the same approach could be implemented for the SRI, wherein recommendations on how best to raise specific aspects of the SRI score are provided. The provision of such information will help to empower occupant/owners in how they can benefit from improved SRTs and services.

3.8. Linkages with other schemes

The SRI does not act in a vacuum and thus it is legitimate to consider how it might interact with other building policy initiatives and in particular the EPCs, the LEVEL(S) scheme and the building renovation passports.

3.8.1. LINKAGE WITH EPCS

Energy performance certificates (EPCs) are mandated under the EPBD and must be produced and communicated to prospective purchasers and tenants whenever a building is due to change tenancy or ownership. Member States may base the EPC assessments on either calculated performance using standardised methodologies or on measured energy performance (usually based on historic energy bill data). While EPCs are mandatory the SRI is a voluntary initiative. According to the agreed text for the revision to the EPBD on a common general framework for rating the smart readiness of buildings:

> "10. The Commission shall, by 31 December 2019, adopt a delegated act in accordance with Article 23, supplementing this Directive by establishing an optional common Union scheme for rating the smart readiness of buildings. The rating shall be based on an assessment of the capabilities of a building or building unit to adapt its operation to the needs of the occupant and the grid and to improve its energy efficiency and overall performance.
> In accordance with Annex Ia, the optional common Union scheme for rating the smart readiness of buildings shall:
> (a) establish the definition of the smart readiness indicator; and
> (b) establish a methodology by which it is to be calculated.
>
> 11. The Commission shall, by 31 December 2019, and after having consulted the relevant stakeholders, adopt an implementing act detailing the technical modalities for the effective implementation of the scheme referred to in paragraph 10 of this Article, including a timeline for a non-committal test-phase at national level, and clarifying the complementary relation of the scheme to the energy performance certificates referred to in Article 11.
> That implementing act shall be adopted in accordance with the examination procedure referred to in Article 26(3)."
>
> And from Annex 1a:
>
> "1. The Commission shall establish the definition of the smart readiness indicator and a methodology by which it is to be calculated, in order to assess the capabilities of a building or building unit to adapt its operation to the needs of the occupant and of the grid and to improve its energy efficiency and overall performance.
> The smart readiness indicator shall cover features for enhanced energy savings, benchmarking and flexibility, enhanced functionalities and capabilities resulting from more interconnected and intelligent devices.
> The methodology shall take into account features such as smart meters, building automation and control systems, self-regulating devices for the regulation of indoor air temperature, built-in home appliances, recharging points for electric vehicles, energy storage and detailed functionalities and the interoperability of those features, as well as benefits for the indoor climate condition, energy efficiency, performance levels and enabled flexibility."

Thus in a formal sense the Delegated Act for the SRI to be prepared by the Commission will clarify the complementary relation of the SRI to the EPCs.

Without prejudice to the formal policymaking process a number of aspects would need to be taken into consideration, a non-exhaustive set of which includes:

Potential synergies between the SRI and the EPC including the possibility of a joint assessment process with the potential to considerably reduce overall assessment costs, a common logic with regard to the principal intervention moment with the greatest potential to stimulate upgrade in a

building's capabilities (i.e. when changing ownership or occupancy), the potential to share a communication platform (e.g. potentially SRI information could be integrated into an EPC)
Potential distinctions between the two including that: a) the voluntary nature of the SRI does not tie its assessment to a change in occupancy or ownership, b) upgrades in smart services may entail very minor physical interventions in a building and thus are less invasive/inconvenient to occupants than interventions to upgrade the physical fabric of a building, c) that SRI service offerings (perhaps provided by or supported by utilities or other service providers) may differ significantly from those related to the EPC and hence may have a different logic.

In addition to this, one of the main issues is to determine the clarity of distinction and/or overlap between the SRI and the EPC. The SRI is also concerned with building energy performance:

"The rating shall be based on an assessment of the capabilities of a building or building unit to adapt its operation to the needs of the occupant and the grid and to improve its energy efficiency and overall performance"

The methodology advanced in this report acknowledges this by including an impact parameter of energy savings on site and applies this to the BACS related aspects of the TBSs. This is because the energy savings from smarter operation and control of TBSs are considerable and because many of the current EPC implementations do little to capture this contribution in a manner that highlights the potential for improvement. As the EPCs are implemented at MS and/or regional level and thus more than 28 manifestations are currently in place it is recommended that further work be done to identify the degree of overlap between the energy savings captured in the EPC methodology implemented in each MS and those addressed in the draft SRI methodology presented in this report. This could be a main focus of a follow-up investigation. Such an assessment could help determine the extent of overlap in: scope, methodology and richness of information, so that more informed decisions could be made about the potential to use SRI information as an input into an EPC, or EPC information as an input into the SRI and also about the potential to share common assessment processes and communication platforms.

3.8.2. LINKAGE WITH BUILDING RENOVATION PASSPORTS

Some member states are currently trialling the rollout of building renovation passports that present a compilation of renovation activities conducted on a building and present owners and occupants with a continuous record of improvements that have been made. In theory the SRI could interface with this activity and potentially share some programmatic and content elements. Potentially for MS that are adopting such building renovation passports the SRI could be incorporated as an additional module within such documents, and/or the SRI and passports could share the same documentation process.

3.8.3. LINKAGE WITH LEVELS

LEVEL(S) is a voluntary building environmental impact assessment calculator developed by DG Environment. It promotes a lifecycle analysis assessment of a buildings environmental impact. The methodology applied involves the following stepwise approach to performance assessment and reporting:

Table 30 – LEVEL(S) stepwise approach to performance assessment and reporting

Step 1: Define the building to be reported on	✓ Part 3, section 1.1 should be followed in order to define the building, and the associated goal and scope of the performance assessment.
Step 2: Choose the level of performance assessment	✓ Based on the goal and scope of the performance assessment, the appropriate assessment level for the project should be selected from the three available options. ✓ Part 1, section 3.2 provides further guidance on the difference between the three levels.
Step 3: Follow the guidance and rules on how to carry out an assessment	✓ Part 2 provides a general introduction to each indicator. ✓ Part 3 should thereafter be consulted, where guidance is provided for each level on how to carry out a performance assessment. Rules are also laid down for reporting in the public domain. ✓ The Level 1 guidance forms the common basis for all assessments, and should be consulted before using Levels 2 and 3.
Step 4: Complete the reporting format	✓ In each set of technical guidance in Part 3, a format for reporting is provided.
Step 5: Determine the valuation influence and reliability of the assessment	✓ As an optional last step for each indicator, the potential influence on a property valuation and reliability of the data and calculation method may be rated and reported on. Part 3 provides a rating methodology for each indicator.

Three levels of assessment (See Step 2) are possible:

- Level 1 common performance assessment
- Level 2 comparative performance assessment
- Level 3 performance optimisation assessment

The method further defines the following array of macro objectives to be assessed:

- Macro-objective 1: Greenhouse gas emissions along a buildings life cycle
- Macro-objective 2: Resource efficient and circular material life cycles
- Macro-objective 3: Efficient use of water resources
- Macro-objective 4: healthy and comfortable spaces
- Macro-objective 5: Adaptation and resilience to climate change
- Macro-objective 6: Optimised life cycle cost and value

Conduct of the assessments entails evaluating the building's lifecycle impact against the macro-objectives selected.

In principle LEVEL(S) and the SRI may have some overlap in the degree to which they both entail assessment of the building energy performance (which contributes to the Macro-objective 1 for LEVELS) and the assessment of health/comfort (Macro-objective 4 for LEVELS).

For energy use LEVELS applies the following indicators expressed on a per m² of floor area basis:

1.1.1 Primary energy demand

1.1.2 Delivered energy demand (supporting indicator)

Both are expressed in units of kilowatt hours per square metre per year (kWh/m² /year).

In the case of Health/Comfort LEVELS entails assessing:

4.1 Indoor air quality

- 4.1.1 Good quality indoor air: Parameters for ventilation, CO2 and humidity
- 4.1.2 Target list of pollutants: Emissions from construction products and external air intake.

4.2 Time outside of thermal comfort range

- % of the time out of range of defined maximum and minimum temperatures during the heating and cooling seasons

In the case of energy for a common performance assessment, the following calculation methodology and reporting format shall be used. This requires reporting on the assessment type and the calculation method used, which shall be based on those required for building permitting and/or for issuing Energy Performance Certificates (EPCs) in each Member State in accordance with the Directive 2010/31/EU for the Energy Performance of Buildings (EPBD). Ostensibly LEVELS allows freedom for users to assess the building energy performance via either the method used in each national/local EPC implementation and/or via the method set out in the harmonised standards in support of the EPBD. This means that it has the same degree of overlap and distinction as the EPC methods do with the SRI with regards to energy performance.

In the case of comfort/health LEVELS entails an assessment of the IAQ. Even in the most basic Level 1 approach it entails a much more in-depth assessment than is implied by the SRI as follows:

Design stage 1: Simulation of the ventilation strategy

A design simulation of the building's ventilation strategy in accordance with EN 16798-7 shall be used to check the modelled performance of the ventilation rate, CO_2 levels and relative humidity levels.

Design stage 2: Use of product testing as a means of source control

Test results showing the emissions after 28 days shall be reported for each material or finish to be installed that falls within the identified scope. The determination of emissions shall be in conformance with CEN/TS 16516. Test data is therefore required from manufacturers/suppliers of the selected building products, as defined in the scope. All testing shall be on the as-finished product.

Design stage 3: Risk assessment to prevent mould

A risk assessment shall also be carried out on building designs. This shall focus on measures to control point sources of humidity and the avoidance of areas of cold bridging and air infiltration into the building envelope. The risk assessment shall be made in accordance with the following two standards:

o ISO 6946 calculation method for the thermal resistance and transmittance of building materials.

o ISO 13788 calculation method for the hydrothermal performance of building components and elements.

Thus it is apparent that the LEVELS approach has a different focus to the SRI but also in the areas where there is some overlap entails a more involved assessment process. The two schemes also have a different legal foundation. Considering this, there may be a potential for data from a LEVEL(S) assessment to be used to supply calculation inputs to aspects of an SRI assessment but there is less scope for an SRI assessment to inform a LEVEL(S) assessment.

3.9. OPTIONS FOR IMPLEMENTATION

In practice there are a variety of issues that the implementation of the SRI would need to be able to address. Some of the most important are considered below.

3.9.1. ACCOUNTING FOR SERVICES THAT ARE NOT PRESENT

There is a choice to be made when implementing the SRI as to how to address services which may not be present in a building but are included in the smart services catalogue. To decide on how to approach this the scheme needs to assess the service in question to consider the following:

a) could it be present? (if not then it should be excluded and the SRI re-normalised),
b) is it relevant? (if not then it should be excluded and the SRI re-normalised),
c) is it sufficiently important to justify the assessment effort?

If case a) applies, it is important that building SRI scores are not penalised when a smart service cannot reasonably be present e.g. for a building with no parking facilities it is not reasonable to expect these to be added to the building simply so smart EV charging can be included.

When considering case b) it is important that building SRI scores are not penalised for non inclusion of a service which is not relevant for that building. E.g. if a building doesn’t have parking facilities (because, for example, it is an upper story apartment in a building with no surrounding parking space) then it is reasonable to exclude the Electric Vehcile domain services from the SRI calculation and renormalize the score. The same could apply for other service domains such as cooling (e.g. for a passively cooled building or for buildings with negligible cooling loads), and dynamic building envelope (if adequate passive shading features are present on the building or if the building is shaded by other buildings or natural features).

Determining relevance at the domain level
It is less straightforward to decide how to treat a service that is not included in a building but that may be relevant. The logic to be applied to determine relevance is not always clear cut from a public policy perspective and nor is it always a straightforward technical judgement. A simple way to address the issue could be to base the implementation of the SRI on those *domains* that are present. Thus, if a whole domain is absent from a building then all its smart services would be ignored and the SRI renormalized following their exclusion. This approach might be deemed to be suitable for services such as HVAC which are dependent on climate and building design, but not for others where public policy seeks to promote the whole domain, such as DSM. This approach would essentially defer to the building owner’s judgement as to whether a services domain provided enough value to merit being included in their building.

Some service domains such as lighting and monitoring and control are always needed so they would invariably be included in the SRI calculation. DHW will almost always be needed but if it does not include storage and/or is not provided by electrical or solar power then none of the smart services listed in the current smart services catalogue apply. In this case a judgement will have to be made about whether it is considered appropriate to exclude the DHW services and renormalize for buildings that have DHW systems which are incompatible with the smart services or whether the SRI should be structure to promote DSM relevant DHW solutions to the extent that non-DSM compatible solutions are penalised in the SRI score (note, this is a policy determination issue). The energy generation domain is another where the SRI scoring may or may not be linked to its presence. If it is linked, buildings with no energy generation capability would achieve lower aggregate scores (all other factors being equal) than those that do. If it is not linked then the smart services that pertain to energy generation would be excluded from a renormalized SRI calculation if the building did not have energy generating capability.

Determining relevance at the sub-domain (i.e. services) level
If a domain is present it doesn't necessarily follow that a smart service applicable to that domain is always relevant. For example, heating will be present in most buildings but only a few will have thermally activated building systems (TABs) and so the service Heating-1b is only relevant for those which do. This is a similar issue to the case of DHW i.e. the service should be excluded when TABs are not present and the SRI calculation renormalized accordingly unless decided otherwise. However, this is not the case if the service would provide additional benefit for the overall functionality of the domain it applies to. If this is true then the service should be retained in the normalisation calculation process unless it is not deemed to be sufficiently important to justify the assessment effort (see the discussion of the streamlined method in section 3.4).

Relevancy – who decides and how is it presented?
Clearly the issue of whether a domain or service is deemed to be relevant will affect the aggregate SRI score for a building and thus there needs to be a common approach (at least within a given jurisdiction) of how this is determined. This means that it should not be left to the assessor to decide but rather that clear guidelines should be developed and issued by the body managing the scheme. This could be a topic for further investigation in follow-up work to this study.

It should also be noted that the manner in which the SRI score(s) are presented will affect the significance of whether or not a domain or service is included in the calculation. For example, if in addition to presenting an overall aggregate score, scores are also presented at the domain level then it would immediately become clear that a building has scored nothing for an absent domain at that level. Thus, at a minimum if certain domains are ignored from the aggregate score because they are not deemed relevant then the presentation of the score should make it clear these were ignored from the overall score calculation and that the building score is not comparable to a similar building that has these domains.

3.9.2. SMART SERVICES PRESENT IN DIFFERENT PARTS OF THE BUILDING

The impact of some smart services are sensitive to their spatial distribution within a building. This is the case for those smart services that apply to heat emission control, cooling emission control, ventilation zonal control, and lighting. It may also be the case for heating production, cooling production, DHW, ventilation control, and EV charging where different solutions are used in different parts of the building.

From a technical perspective the equitable approach to be applied to the SRI assessment process where spatially distinct solutions are applied in different parts of a building would be to apportion smart service scores on a pro rata basis of their delivery of the principal service. As a first order proxy floor area can be used to distinguish this. Thus if 60% of the building floor area is heated with a given solution and 40% with another then a pro-rata apportionment would be applied to the service assessment. This methodological approach is not new. Approaches which differentiate assessment as a function of building floor area served by a given service on are already adopted in many national building energy codes that, for example, set requirements for lighting levels and energy consumption or installed power differentiated by the type of function conducted in the various parts of a building. Many EPC calculation tools will also make such distinctions. However, bringing in distinctions by floor area will also complicate the assessment process and hence add to the assessment time and effort. Thus, there is a trade-off to be considered and managed.

3.9.3. Complex (multi-mode) buildings

Complex buildings are those where there are quite distinct and divergent activities carried out in different parts of the building. For example, a building which is a hospital that includes shopping outlets, or a large multi-family residence building that includes floor area used for commercial activities etc. Complex buildings may also include multiple tenancy or lease arrangements that could share common facilities and hence some technical building systems/smart service domains.

The same issue applies to the SRI assessment of such buildings as it does for EPCs and other building performance assessment tools, of how to delineate the boundaries that the SRI applies to within a building. In this case it is probably most practical to follow the property boundary delineation practices used in EPC assessments to the extent possible. This may often entail treating the internal building boundaries of the complex building based on the lease or tenancy arrangement, which will often result in a reasonably homogeneous activity mode occurring within the boundary the SRI would apply to. However, in some cases it may not and in these instances, if more than one modal activity is occurring within the same SRI rating boundary and the technical building systems are differentiated by activity mode then it may be sensible to derive a pro-rata SRI for the distinct sections of the building.

3.9.4. Climatic zones

Differences in climate, as represented by distinct climatic zones, will have an impact on the relative prevalence and importance of HVAC related TBS (heating, cooling, ventilation) and to a much less extent hot water energy demand (due to variations in the feed-in cold water temperature and hence the magnitude of temperature lift needed). Climate also has an impact on the importance of the dynamic building envelope with regard to solar shading and on the magnitude of energy generated per unit area of solar collectors/panels or by wind generators.

The importance of this variation for the application of the SRI methodology is that the differences in climate can result in some TBS/domains not being very prevalent in some climate zones and/or having a lesser relevance when they are present (e.g. the energy use may be significantly lower than for an equivalent building in a different climate). As previously discussed in section 3.9.1 if a TBS/domain is not present because it is not needed it implies that the SRI calculation should generally omit that service and be renormalized accordingly. In some cases, it might also be relevant to apply a climate adjusted weighting to the TBS/domain and then apply a filter for impact benefit against assessment effort to determine whether the service has a sufficient impact to justify its inclusion in the streamlined scheme.

By way of illustration, one can consider the (provisional) ordinal impacts allocated against each service and impact parameter by the study team (see the services catalogue). For a building with heating, cooling, DHW, controlled ventilation, a dynamic building envelope and energy generation and a typical set of eligible (i.e. not mutually exclusive) smart-services the share of eligible points by domain as a proportion of the total eligible points across all of these services and impact parameters is as follows (assuming equal weighting by domain):

- Heating = 25%
- Cooling = 17%

- DHW = 8%
- Controlled ventilation = 19%
- Dynamic building envelope = 9%
- Energy generation = 23%

According to the analysis in the Task 5 impact assessment for an average European office the ratio of heating to cooling primary energy consumption as a function of main climatic region and the year considered is projected to be as follows:

- Europe West = 10.3 in 2020; 4.8 in 2050
- Europe North = 7.5 in 2020; 2.6 in 2050
- Europe South = 1.6 in 2020; 1.0 in 2050

If the relative magnitude of energy is also taken to be a proxy for that for comfort and convenience then the relative importance of the heating and cooling domains could be weighted accordingly (there are much lesser contributions from these domains to the other impact parameters).
The impact of climate on the relative importance of the other domains mentioned (DHW, controlled ventilation, DBE and energy generation) is less apparent and hence it might be practical not to adjust their weightings based on climatic differences unless detailed evidence becomes available to establish clear correlations.

Thus as a first order proxy weightings applied to the heating and cooling domain scores could reflect their expected importance for the type of building considered. In principle, if building energy calculations are available by domain, this information could be used to derive the weightings but if not then regionally average figures could be applied. The regional average approach might also be used to decide whether it is sensible to include the domain at all e.g. if cooling is almost never present in a given locale and building type then the SRI assessment could simply omit it; or if it is present but its impact is very modest it could also be omitted to economise on assessment effort. The same approach can also be used to select or omit specific services instead of whole domains, e.g. for specific climatic regions the service “controlled ventilation 4 - icing protection control’ may not be relevant.

3.9.5. SHOULD DIFFERENT CATEGORIES OF BUILDINGS BE TARGETED?

One issue to be considered is whether the SRI should apply to all buildings or certain categories of buildings? In principle, it can apply to all buildings and as the methodological examples illustrate the methodology can be adapted to differentiate according to the type and complexity of building considered (albeit drawing from the same technical foundations). However, from an implementation perspective there could be a rationale to implement it progressively differentiating by type of building. If the SRI is implemented in a voluntary manner then it will make most sense to initially target it to the building types whose owners are most likely to be interested in having the SRI. However, it is not clear at this stage whether there will be a difference in interest and hence SRI adoption rates as a function of the building type. On the one hand commercial buildings have higher energy use per unit area and are more prone to sick-building issues than domestic buildings and hence it is possible that owners will wish to use the SRI to illustrate that their buildings are smart and to use this as part of the rationale underpinning the rental value. On the other hand, many householders are also likely to be interested in an evaluation of how smart ready their building is; especially if it is complemented by advice on what other options there could be to make it smarter.

Within the spectrum of commercial buildings it may be that owners of so-called class A buildings (i.e. those with higher rental values) may tend to have a greater interest in using a voluntary indicator to differentiate the quality of their buildings than owners of lower rental value buildings, but this is supposition that would need to be tested in the market. Furthermore, assuming the object of targeting the most promising (from a readiness to adopt the SRI perspective) building types is to progressively roll-out the SRI and gain momentum and impact in the market, then it may be best to begin with a sector that is most receptive to government policy initiatives. In particular, public sector buildings might provide a basis to pilot the scheme prior to rolling it out on a broader base of buildings.

3.9.6. Building Information Modelling

Building information modelling (BIM) is increasingly being used to share information between building professionals and their clients and to create an electronic log of the layout and systems installed in a building. It is used in the design stage to allow architects and building service engineers to agree on the functional arrangements so that an appropriate compromise between the different design needs of the building and the actors charged with delivering them can be addressed. The design BIM data can also help inform discussion and decisions between clients and building professionals prior to a final design being settled. Once the building is constructed the data files and software can be left with the client who can then request that future service providers also update the information every time they make an amendment to the building or its technical building systems. This has the potential to create a digital logbook for the building that tracks its initial conception and all subsequent additions and amendments. When BIMs are in place they constitute an obvious tool that could be used by an SRI assessor to help facilitate the SRI assessment. Should standard BIM protocols become the norm then SRI assessors could even request access to the data prior to a site visit and that way plan their inspection and/or pose pertinent questions ahead of the site visit.

3.9.7. Interoperability, broadband and smart meters

The degree of interoperability of smart systems and related technical building systems/domains is likely to be a critical issue for the smooth operation of smart systems; however, it is also a very challenging issue to address in practice and especially within the auspices of the SRI.

The quality of broadband access will be critical for many smart systems to function smoothly and especially those that require information exchange between systems within the building and agents or systems which are off-site. Articles 8 and 9 of the Directive on *measures to reduce the cost of deploying high-speed electronic communications networks* (2014/61/EU) ensure high-speed-ready, accessible in-building physical infrastructure in all newly constructed and majorly renovated buildings and introduce a voluntary *broadband ready* label at member state level. This could be provided as an additional or complementary piece of information to the SRI.[56]

Smart meters have been or are being rolled-out across a large proportion of EU buildings, with programmes being managed at the Member State or smaller regional level. Smart meters provide an important source of real-time utility consumption (energy or water) information to building occupants which can help them to optimise or adapt their usage to their needs and to variations in the tariff. They can also facilitate DSM services and metering of on-site energy generation. Consequently, smart metering related services are included in the smart readiness services catalogue. In particular in the monitoring and control services 5 to 7, and 13.

[56] https://ec.europa.eu/digital-single-market/en/building-infrastructure

While these services provide functionalities which are an important enabler of DSM services and of also feedback to users on their consumption/generation patterns, they are not a precondition to be able to attain a SRI score as not all smart services are contingent on this capability. However, they do feature prominently within the scoring system, and buildings with smart-meter related capacities will have incrementally higher SRI scores than those without.

3.9.8. Industry and sector specific indicators

Some industry and service sectors have developed or are in the process of developing smart service-specific indicators that apply to specific technology and service offerings. It is an open question of how these might work with the SRI. Potentially, these schemes could provide value to the SRI by:

- creating additional leverage and incentive for building owners to engage
- adding additional sophistication to the depth and integrity of the assessment for the services they address
- providing a common framework to assess a smart service that is not currently adequately covered within the SRI.

Nonetheless, a process would need to be determined to establish if and how they could be integrated within the SRI. Such a process would need to ensure they represent value for the public good and provide a level playing field for economic agents operating both within the service domain as well as in the other smart service domains. There are already a number of such industry or collaborative initiatives know to the study team which include at least the following:

- the eu.bac labelling scheme for BACS and BAC components
- a Lighting Europe initiative for smart lighting systems which is under development
- an IEA Annex 67 Technology Collaboration Programme initiative to develop an indicator for DSM services.

The nature of these initiatives are quite varied and so there is no fixed approach that be proposed regarding how their interaction with the SRI could be considered. The eu.bac scheme has been operational for a few years and is implemented on a voluntary basis. Their BACS labelling scheme is based on doing detailed audits of buildings against the provisions of the EN 15232 standard, and hence shares many aspects with the smart service definitions and performance levels proposed in this study for use with the SRI. Eu.bac have developed their own assessment tools to support their assessors and potentially some aspects of these could be suited to some aspects of the SRI assessment process.

3.9.9. Differentiation and commons aspects of SRI implementation

The agreed text of the revised EPBD ensures that the Commission is responsible for developing a common methodology for the SRI which Member States may then implement on a voluntary basis. Clearly, this means that Member States should find the SRI an attractive proposition that provides value added to building owners/occupiers, product & service providers and aligns with public policy objectives. The methodology set forward in this report is fundamentally flexible to needs. It has also highlighted a number of instances where it may not always be appropriate to include, or conversely exclude, a service due to differences in local circumstances such as climate, common practice and local constraints. A measure of local flexibility is desirable to allow these distinctions to be taken into account. However, on the other hand the benefits of following a common and inclusive approach, wherever this is not inconsistent with specific local circumstances, should not be ignored. Building owners are likely to find value in receiving information on the full panoply of smart services outlined in this report and an overly narrow implementation that excludes many services is more likely to be challenged for being partial and selective, which may undermine its integrity among stakeholders. Furthermore, a common approach across the EU allows relevant product and service offerings to be rolled out more easily and hence adds greater value to the SRI. It also reduces the risk of confusion among users, if they see that the SRI in neighbouring countries is essentially the same as in theirs.

3.10. APPLICATION OF THE STREAMLINED METHODOLOGY TO ACTUAL BUILDINGS

To test the streamlined methodology in reality it was field tested on two actual buildings. The first is a traditional single family house in the north of England and the second is a modern office in Flanders.

3.10.1. FIELD CASE STUDY – A TRADITIONAL SINGLE FAMILY HOUSE

Case study SFH: case study description

The house in question (Figure 33) is sited in Manchester (UK) and was built in 1902. It is a relatively large (~250 m^2 floor area), three story detached house with parking areas immediately adjacent to the property and with a garage that is used for storage rather than parking. While most of the property was from the original construction there were a number of parts which had been renovated. The back of property had a recently constructed conservatory/kitchen space and an adjacent office area (Figure 34). The walls had been insulated 15 years previously with insulation injected into the cavities between the interior and exterior brick layers, but more recently underfloor insulation had been added to the whole ground floor, and many rooms as well as all the top roof area of the house had had interior solid insulation applied. The windows were all renovated with modern double glazing made in keeping with the original window aesthetic. As a result the property is well insulated.

Figure 33 -Single family house assessed in field study – front view

Figure 34 -Single family house assessed in field study – rear view

Case study SFH: Assessment process and findings

The process followed was to make an appointment with the occupant to conduct the SRI assessment. Once the assessment began the assessor was invited into the kitchen/conservatory area to explain the purpose of the SRI and discuss the TBS and domains present in the building. The assessor was then invited to view all the rooms and to inspect the TBS's/domains at their leisure.

Following the introduction of the purpose of the SRI the assessor asked the occupant if they had any of all the domains treated under the SRI:

- Heating
- Cooling
- Hot Water
- Controlled ventilation
- Lighting
- Dynamic building envelope measures
- Self generation
- Demand Side Management
- Electric vehicle charging
- Monitoring and control

This served as a rapid triage process to establish which domains needed to be considered and which were absent. From the discussions which took about 5-7 minutes it quickly became clear that there was no cooling, self generation, or demand side management, but there was some doubt about the controlled ventilation and dynamic building enevelope measures. As would be expected for any property in this region heating, hot water, lighting, and monitoring and control domains were all present. For electric vehicle charging it soon became apparent there was an option to provide the most basic dumb charging capability but nothing more.

The discussion of these domains with the occupant was mostly straightforward. In the case of cooling there was no benefit from cooling in the local climate and so none of the households in the area have it. For self generation, the owners had conducted an assessment with a mind to install it but had concluded that the only viable location for PV panels was on the garage roof because the main orientation of the house is east-west, the front (east side) of the property is overshaded by a very large tree and the back has constrained roof spaces which are partially overshaded by large chimneys. PV had not yet been installed on the exterior garage because the whole building is in need of renovation; but this is reported to be planned in the future.

Potentially the most challenging issue would be to establish if any DSM services are in use. The general public is not familiar with the terminology nor the concept of DSM and thus it has to be approached obliquely. In principle, DSM is a service option for households in the UK and some aggregator services exist to cluster sites in order to create sufficient demand to satisfy the minimum eligibility requirements to bid into the capacity markets; however, these services are still very rare, have only recently been proposed on the market and are initially focused on non-residential users – thus, it would be very unusual to find a property benefitting from DSM services currently. The approach taken by the assessor to probe this topic was to ask about the tariff applied on the property, whether there was any smart metering and to see if it was a conventional tariff or had time of use or other significant DSM relevant characteristics. Then, to validate the response, to ask if the electricity utility was offering any tariff incentives to be able to externally control electrical equipment to avoid it being used in time of peak demand unless the user chose to pay a higher tariff.

From this it was rapidly established that the property was not currently using any DSM services. It was also apparent that the occupant had not been contacted by any provider of such services.
Once this triage process was complete the assessor visited each of the rooms with the occupant and conducted a visual inspection of the TBS/domains.

From this it became clear that:

- There was no controlled ventilation as defined within the streamlined methodology. Rather, there were manually operated extractor fans in each of the bathroom and toilets and within the kitchen hood over the hob (see Figure 35).

- Solar control was provided by manualy operated blinds, shutters and curtains – these were present in all relevant rooms and were certainly sufficient to address glare, thermal comfort and privacy needs (see Figure 36).

- Interestingly, the conservatory had an automatically dual sensor (interior temperature and external rain) controlled motorised top vent (Figure 37) that the user programmed to open as a function of the conservatory temperature (it shuts automatically if its rain). This is a smart ventilation/solar control technology, however, it does not feature in the streamlined methodology service list.

- The lighting (e.g. see Figure 38) was all manually controlled with either on-off switches or dimmer switches. The exception was one downstairs toilet that had a occupancy sensor which controlled the lighting (see Figure 39). The exterior of the property had motion sensor controlled security lighting with manual override. All the lighting in the property was energy efficient, with most being LED but a few fluorescent lights too.

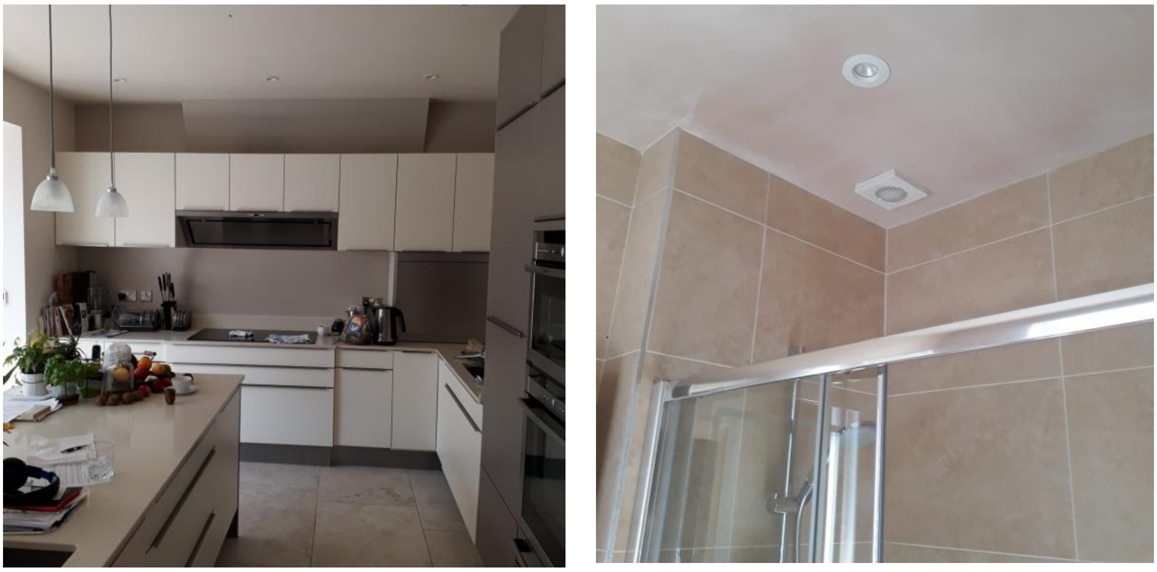


Figure 35 -Ventilation only via extractor fans

Figure 36 -Manual blinds/shutters for solar control and thermal comfort

Figure 37 - Automatic smart conservatory top vent

Figure 38 - Lighting – mostly LED and all manually controlled

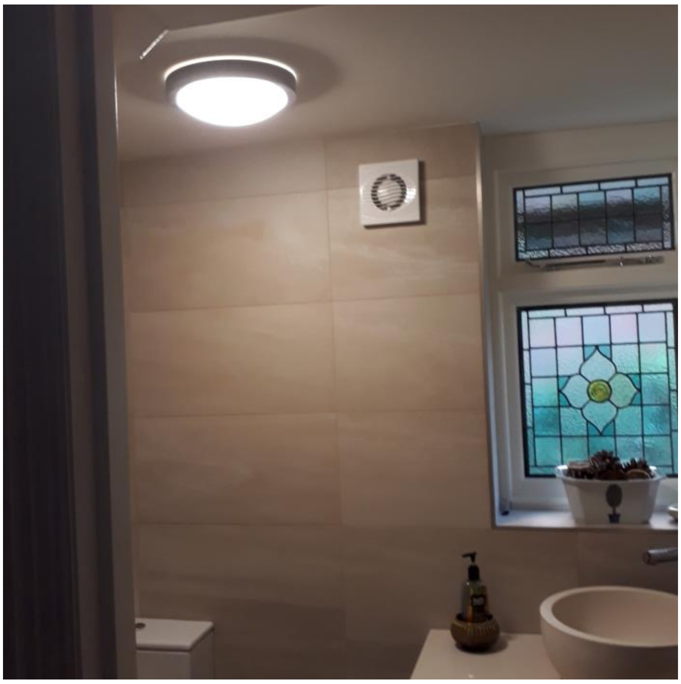


Figure 39 -Presence detection lighting via a motion sensor

The dominant source of energy consumption in the property are the heating and hot water domains. The heating was provided by two heat generators (one gas condensing combi-boiler and one gas system boiler) with the condensing boiler providing all the heating and hot water needs for the ground floor and one middle floor bathroom, and the system boiler providing the heating and hot water needs for the top floor and the rest of the middle floor.

On the ground floor the large kitchen/conservatory area (Figure 40) and the office are both heated by underfloor hydronic heating. The rest of the ground floor rooms (two reception rooms, a utility room, a toilet and hallway) and the middle floor bathroom are heated by radiators. Control of the heating is split into 3 zones (the kitchen/conservatory, office and rest of the ground floor) each with their own central thermostat and programming. The condensing boiler services these zones on separate hydronic loops, each operating at their own temperature and supplied through a manifold.

The system boiler is sited in the roof eves on the top floor and feeds a hot water storage tank and the upstairs heating circuit (Figure 41). In total it supplies heat to six bedrooms, two bathrooms and the stairwells and landings. All of the heating in these areas is via radiators.

Figure 40 - Kitchen/conservatory with underfloor heating

Figure 41 - System boiler and hot water storage tank

Degree of smartness in the space heating and hot water domains.
There are a number of smart features in the control and management of the heating and hot water in the property as follows (Figure 42).

- programmable temperatures scheduled by hour, day, and day of week/year in each of the 4 control zones
- weather compensation

- self-learning optimum stop/start
- TRVs on all emitters (excluding the underfloor heating)
- VSD controlled distribution pumps
- remote management of all heating and hot water via smart phone app
- occupant (smart-phone) presence detection option
- historical record and display of heating and hot-water consumption

The programmable temperature controls can be managed from either wall mounted control devices or via the smartphone app and in the latter case can be managed at a distance and optionally set to recognise when the occupants are not home (via smart home tracking) and hence switched to unoccupied defaults. The display of the heating and hot water consumption enables the user to keep track of their consumption and see the impact of technical or behavioural changes.

The TRVs on all the radiators ensure that the heat emitted from each emitter can be temperature limited, although they are not remotely programmable and nor are they linked to room temperature sensors or occupancy sensors. The VSD distribution pumps ensure the flow within each zone is fully adjustable and that the pump energy consumption is optimised. The weather compensation combined with the self-learning optimum start/stop functionality ensures that for each of the four zones the heating energy is provided optimally based on the thermal response rate of the zone, the dynamic interior-exterior temperature difference and the programmed set-points specified by the user. Once the self-learning system has determined the thermal response rate of the room (by a period of progressively more refined iterative heating to the set-point as a function of the interior to exterior temperature difference) the system learns when the heating needs to be activated at what temperature to achieve a given temperature lift within a given period. Critically, combined with the weather compensation system linked to local weather forecasting, this allows the smart controls to raise or decrease the temperature in an energetically optimal manner to meet the user comfort needs, and thus saves significant amounts of energy while optimising comfort.

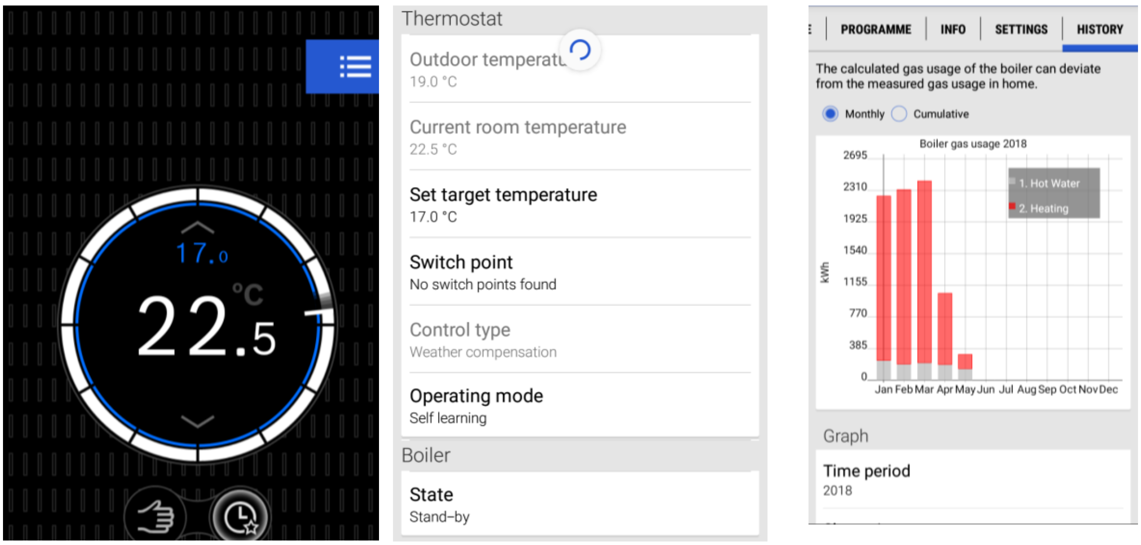


Figure 42 - Smart controls for the heating and hot water

Case study SFH: Assessment time and scoring

Prior to this exercise it had been estimated that for an average single family house of say 100 to 120 m^2 a typical SRI assessment would take between 32 and 41 minutes depending on the degree of documentation available. In fact this case study took 35 minutes to assess including the time spent discussing with the occupant and a further 5 minutes for data entry into a spreadsheet tool used to calculate the SRI score and sub-scores. As this is a large house – over 250 m^2, with six bedrooms, three bathrooms, an office, utility room, toilet, open-plan kitchen/conservatory area and two living rooms and one with comparatively complex TBSs (dual heat generators, multiple zones etc.) and a moderate degree of smartness – it is likely that this is the upper bound of the time it would take to conduct such surveys for more typical properties. However, for properties with all possible TBSs and full smart functionality (which will be very rare in practice) the time required would be longer.

Communicating the score to the occupant per impact field took about 5 minutes but explaining what could be done to attain a better score would take additional time and this is not accounted for in the assessment time presented above (in fact it was not possible to do in this case study as the occupant had to leave for another engagement).

Overall the property was given an SRI score of 45% under the streamlined methodology. However, the results are also reported by domain and by impact parameter (Table 31).

Table 31 - SRI scores for the single family house field study

	Energy	Flexibility	Self generation	Comfort	Convenience	Well-being and health	Maintenance & fault prediction	Information to occupants	SRI
Overall	**71%**	**0%**	**0%**	**77%**	**33%**	**17%**	**20%**	**19%**	**45%**
Heating	75%	0%	0%	85%	64%	0%	25%	75%	
DHW	100%	0%	0%	0%	0%	0%	50%	67%	
Cooling	0%	0%	0%	0%	0%	0%	0%	0%	
Ventilation	0%	0%	0%	0%	0%	0%	0%	0%	
Lighting	0%	0%	0%	0%	0%	0%	0%	0%	
Dynamic envelope	0%	0%	0%	0%	0%	0%	0%	0%	
Self generation	0%	0%	0%	0%	0%	0%	0%	0%	
DSM	0%	0%	0%	0%	0%	0%	0%	0%	
Electric Vehicles	0%	0%	0%	0%	20%	0%	0%	0%	
Monitoring & control	60%	100%	0%	67%	38%	33%	17%	14%	

In terms of impact parameters the property scored most highly for Energy Savings on Site and Comfort both of which were relatively well satisfied via a number of smart services of quite high functionality. As heating and hot water dominate the energy consumption the weightings applied to these services reflect this (in fact for simplicity the nominal EU building stock average values shown in Table 21 were used for these weightings; however, in principle progressively more accurate weightings could be used by applying UK average, local average, EPC calculated or actual measured TBS values for this kind of/or actual property). As there was no DSM capability the property scored 0% for the flexibility impact parameter and similarly 0% for self-generation.

At the domain level it scored 0% for the missing domains or the domains where there was no smart functionality recognised within the streamlined methodology i.e. for cooling, ventilation, dynamic building envelope, self generation, DSM, and electric vehicles.

In this example, the domains highlighted in grey were excluded from the calculation of the overall score for the reasons that: cooling offers no value in this location and building type; dynamic building features are not needed (i.e. bring negligible benefit) for this kind of property in the location it is in provided adequate manual shading systems are in place (which they were); similarly natural ventilation is adequate for such a property type; and self-generation was (for the reasons stated previously) not currently a viable option for the property concerned. All other domains did count towards the overall score. It should be noted that the methodology allows for the absent domains to be included or excluded from the overall score calculation as the governors of the scheme deem fit. Equally, in this example the absent domains of DSM and EV charging were included in the overall score as these are both central elements of the rationale for the SRI within the agreed EPBD text and it was deemed that these could be present and would bring benefits if they were. While the interpretation of what should or should not be included in the overall normalised score under what circumstances will doubtless require further discussion and refinement ahead of an SRI implementation, to ensure the right blend of consistency of approach and recognition of locally pertinent factors, it was interesting that this was very simple to communicate to the occupant, despite the occupant having no prior knowledge of the SRI. It was quickly explained that the greyed out domains did not contribute to the overall score and why, but also that the occupant/owners might still wish to add such services in the future. The matrix reporting approach with each sub-score seemed to assist considerably with the communication of the elements of the SRI and the domains and impacts which are being treated within it. The occupant seemed to understand and be comfortable with the summary provided when presented with this matrix. Thus, it would appear from this single case study that presenting the overall score and the sub-scores might greatly facilitate communication and avoid misunderstanding of the elements of the SRI. Further details of the calculation applied are presented in Annex I.

3.10.2. FIELD CASE STUDY – A CONTEMPORARY OFFICE BUILDING

Case study office building: case study description

The second case study building is a contemporary office building located in Genk; which is situated about 100 km east of Brussels in the Flemish region of Belgium. This 'EnergyVille 1' building was designed by Atelier Kempe Thill and inaugurated on 22 September 2016. It features offices, meeting rooms and laboratory facilities for 250 of the EnergyVille staff members. It is part of the 'Thor' science and business park[57] on a previously abandoned coal mine site.

The building is constructed to high energy efficiency standards (e.g. well insulated building envelope with triple pane glazing). The energy performance label according to Flemish EPBD regulations is E-level 23, which is lower than the nearly-zero energy building (NZEB) standard of E-level 40 for offices. This corresponds to an estimated primary energy demand for heating, cooling, ventilation and lighting of 53 kWh/m²/yr. The building is aiming to achieve the BREEAM Post Construction "excellent" label.

Being conceptualised as a 'living lab', the buildings contains many innovative technologies such as test ground for demand response, seasonal thermal energy storage, battery storage, fourth generation district heating, DC grid (±500 VDC, 35 kW), etc. More common TBS include ground sourced heat pumps and combustion boilers and a roof covered with 1070 photovoltaic panels. Throughout the building 350 sensors are installed to monitor comfort and meter the energy consumption.

By having such a wide array of TBS in this somewhat experimental building, the building is likely to have much more smart ready services to be assessed than more traditional office buildings.

[57] http://www.thorpark.be/en

Figure 43 -EnergyVille office building assessed in field study – front view

Figure 44 -EnergyVille office building assessed in field study - interior view

Figure 45 -EnergyVille office building assessed in field study - rear view

Case study office building: Assessment process and findings

Similar to the process described for the single family house, the inspection process starts with investigating which services are relevant for this particular building.

The building is actively heated and cooled, has a limited domestic hot water production, is equipped with moveable sun shading and features EV charging poles and locally generated renewable energy. Furthermore, the presence of two complementary heating systems (both heat pumps and combustion boilers) adds to the fact that most of the smart services in the streamlined catalogue can be assessed in this building. Of the 51 smart ready services present in the streamlined methodology, the triage process resulted in 44 services to be assessed for the EnergyVille I building. The few services which are not relevant include for example the control of solar hot water boilers and TABS (thermally activated building systems such as concrete core activation), since none of these TBS are present in the building.

A particular point of attention is the DSM domain. DSM services are currently very rarely offered for TBS in Belgian buildings. The EnergyVille I building nevertheless has some DSM capabilities which are used for testing and demonstration purposes. In the assessment of the case study, the DSM capabilities were assessed as if they were operational under true market conditions.

The assessment took place in close consultation with the building's facility manager. The triage process took place at the desk of the facility manager, with the building's as-built plans and technical documentation within reach. For some of the services, additional look-ups were needed, e.g. regarding the presence of a bypass of the heat recovery unit in the ventilation system to prevent overheating. For most of the services, the assessment of the functionality levels could already tentatively take place while performing the initial screening.

After the initial assessment at the facility manager's desk, a walk-through of the building was organized to confirm the functionality levels of the various smart ready services.
To save on inspection time, the walk-through was limited to the utility rooms and some representative rooms (e.g. an office space and a meeting room). If in these representative rooms a

specific functionality was present, it was assumed this is the case for the whole building. For example, in both the office and meeting room, the service Lighting 2: "Control artificial lighting power based on daylight levels" was implemented with functionality level 3 = "automatic dimming". It is thus assumed that this is true for the remainder of the building as well, which was also confirmed by the facility manager.

For some of the services, there was currently still a need for interpretation by the SRI assessor, e.g. to map the EV charging capacity indicated on the charging pole to the proposed functionality levels. Further substantiation of the method and the development of inspection protocols will reduce the need for interpretations and result in more uniform inspection results.

Figure 46 -EnergyVille office building: EV charging equipment

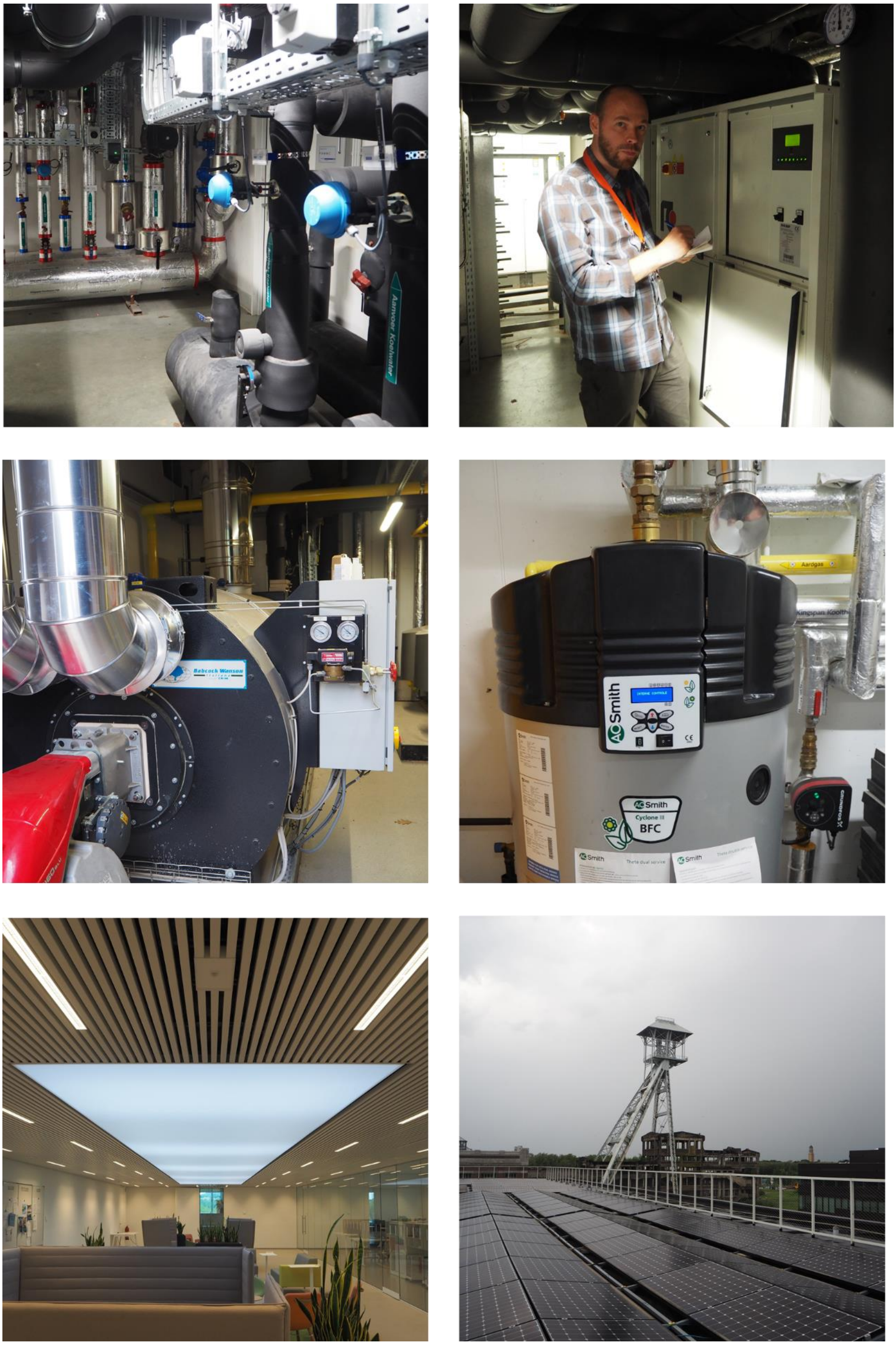


Figure 47 -EnergyVille office building: heating and cooling ductwork, heat pump, combustion boiler, DHW storage vessel, presence and luminance detection, roof-mounted PV

For many of the services, a visual inspection was sufficient to determine the functionality level. For some other services - especially those implemented at higher functionality levels - additional information was required. This was retrieved either by interviewing the facility manager, either by investigating the technical documentation of the installed equipment.

For example, it was visually confirmed that both a combustion boiler and heat pump are present and thus service Heating 2c: “Sequencing of different heat generators” is of relevance for this building. The exact sequencing control can however not be visually assessed, especially because the inspection was carried out during a warm day during which the building did not require space heating. The facility manager confirmed that priority was given to the heat pump, which results in functionality level 2 for this particular service.

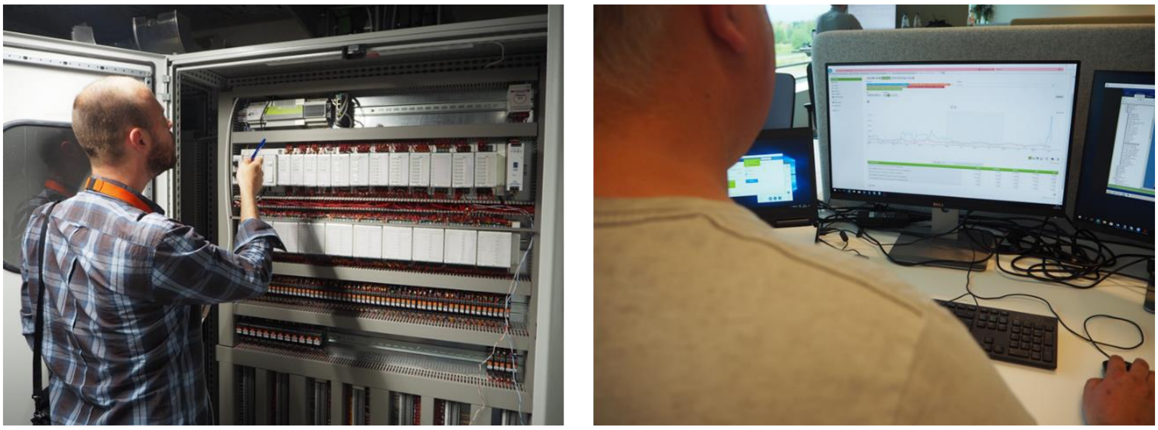


Figure 48 -EnergyVille office building: building energy management system

Case study office building: Assessment time and scoring

The overall inspection time for this building amounted to 65 minutes. The assistance of the facility manager greatly helped to confine the inspection time, since he could provide direct access to all technical facilities and was well aware of how the TBS were organized. Being a recently constructed building, most of the technical documentation was also readily available in the as-built archive.

Most of the assessment has been performed based on visual inspection and an interview with the facility manager. This implies that for many of the services no formal proof has been gathered, e.g. it was not attempted to retrieve written documentation on the exact control logic of the sequenced space heating generators. Furthermore, for many services the inspection was restricted to a few representative rooms. A complete walkthrough of the building, including inspection of each luminary or shading device, would have added significantly to the total inspection time.

It is noted again that this building features a large amount of smart services; an average office building will probably require less than 44 services to be assessed. Furthermore, an increased practical experience with SRI assessment and the availability of inspection protocols can also help to limit the inspection time.

Table 32 – SRI scores for the EnergyVille I office building field study

	Energy	Flexibility	Self-generation	Comfort	Convenience	Wellbeing and Health	Maintenance & fault prediction	Information to occupants
Ordinal impact score case study building	**54**	**18**	**5**	**34**	**42**	**13**	**16**	**20**
Maximum obtainable score for the case study building	**73**	**25**	**5**	**45**	**61**	**19**	**23**	**30**
Relative score	**74%**	**72%**	**100%**	**76%**	**69%**	**68%**	**70%**	**67%**

Overall, the building achieved an SRI score of 77% under the streamlined methodology. This means that 77% of the (weighted) potential smartness impacts for this building can be achieved by the services present. Table 32 reports the scores by impact criterion.

For this field case study, different domain weightings were used than for the residential case study. These adapted figures reflect that domains such as cooling and lighting are relatively more important in office buildings than residential buildings. Furthermore, the weightings for the impact criterium 'Energy savings on site' were set in such a way that they represent the expected energy consumption breakdown of this specific building. These values thus differ from those used earlier in section 3.4.3 on in the case study 2 office, which used more generic figures (presented in Table 26). This illustrates that the methodology could allow to finetune the domain weightings tailored to the energy profile of a specific building, or to define multiple classes (e.g. by building type and climatic zones). As was previously the case, the eight impact criteria were weighted equally. This implicitly gives all impact criteria equal importance in the overall SRI score, but from a methodological perspective it is also possible to alter these weightings to give more prominence to some of the eight impact criteria.

Table 33 - Domain-level impact weightings used in the EnergyVille I field case study

Domain	**Energy savings on site**	**Flexibility for the grid and storage**	**Self generation**	**Comfort**	**Convenience**	**Health and Wellbeing**	**maintenance & fault prediction**	**information to occupants**
Heating	30%	2.5%	0%	40%	10%	10%	10%	7%
Domestic hot water	4%	2.5%	0%	10%	10%	10%	10%	7%
Cooling	30%	2.5%	0%	15%	10%	10%	10%	7%
Controlled ventilation	7%	2.5%	0%	10%	10%	10%	10%	7%
Lighting	15%	2.5%	0%	10%	10%	10%	10%	7%
Dynamic building envelope	6%	0.0%	0%	5%	10%	10%	10%	7%
Energy generation	0%	2.5%	80%	0%	10%	10%	10%	7%
Demand side management	0%	40%	10%	5%	10%	10%	10%	7%
Electric vehicle charging	0%	40%	10%	0%	10%	10%	10%	7%
Monitoring and control	8%	5%	0%	5%	10%	10%	10%	40%
Total	100%	100%	100%	100%	100%	100%	100%	100%

The building features a wide array of smart technologies and was thus initially expected to achieve a very high SRI score. The obtained score of 77% shows that there is nevertheless still some room for improvement for this building and also underpins that the methodology and service catalogue are forward-looking. To the facility manager, this assessment provided insights in future upgrade potential. Overall, the impact criterion 'information to occupants' had the lowest score for this case study building. The building is equipped with many sensors and currently provides a lot of information to the facility manager. To achieve a higher score on this criterion, information on energy use, energy generation and IAQ should also be presented to the other building occupants besides the facility manager. Based on the outcome of the assessment, the facility manager is investigating to implement this feature as a 'quick win' to improve the SRI score.

In general, it is expected that no building will realistically achieve the 100% smartness score, especially since the service catalogue will further evolve over time as new services become available. With a score of 77%, this case study building is probably one of the top performers concerning smart readiness. Many of the buildings in the existing building stock will likely have a much lower score with an order of magnitude of 0 to 20%. The SRI score should be communicated in such a way that it encourages the uptake of smart features in a building, but equally doesn't discourage well performing buildings to proudly display the SRI score. Instead of a score presented as a percentage, other representations such as star ratings or alphanumeric labels (A,B,C…) could also be suitable to present the SRI score of a building. In that case, the thresholds can be set in such a way that the highest scores are practically obtainable without implementing the highest possible functionality levels for all of the smart services in a building.

3.11. PROVISIONAL CONCLUSIONS OF TASK 2

The SRI methodology set out in Task 2 aims to address the key factors and principles to be considered as were articulated in Section 3.1. In addition, it aims to be as practical to implement as possible without jettisoning the features that give it value to end-users and that support the policy imperatives which underpin it. The resulting approach, as set out in the streamlined methodology and demonstrated via two in-field case studies, follows a simple checklist process that is straightforward and ready to implement currently.

The SRI methodology developed (especially the streamlined version) responds to all the imperatives with regard to:

- The audience for the SRI
- The SRI value proposition
- Policy objectives
- The information to be conveyed
- Communication of the information
- The integrity of the SRI
- The credibility of the SRI
- The interpretation of smart ready versus smart now
- Future proofing – allowing and encouraging innovation
- Fairness and a level playing field for market actors
- The potential usage of qualifying preconditions
- Interaction with other policy instruments
- Treatment of fixed (static) versus transportable (mobile) smartness features
- The SRI assessment process and aides to assessment

The method is modular and can easily be tailored to specific needs and contexts. It is also as flexible as possible with regard to permitting innovative services to be included within it. For example, should a service provider develop an innovative offering that raises the maximum functionality level attainable within any give service then the innovative service offering could immediately be scored at a higher functionality level even without a formal renormalisation of the maximum denominator for that service. The benefit would still carry into the overall SRI score. Periodically the whole scheme could be recalibrated and the maximum denominators adjusted. Similarly, if an entirely new type of SR service is developed that could be recognised and incorporated within each periodic revision of the scheme.

The SRI methodology is flexible enough to allow the information to be reported in whatever type and level of aggregation is deemed to be most beneficial. The optimum choice can be informed by consumer and stakeholder research but may also be dependent on local context and hence need to be settled at a national or smaller level.

The streamlined SRI methodology is estimated to be assessable in timespans that are not dissimilar to those required e.g. for EPCs. The experience from the two field case studies suggest that this a reasonable assumption.

It has also been established that several of the Task 1 services are not sufficiently mature to be implemented or require too much time and efforts to allow for a practical assessment on-site. This is especially the case for some of the DSM and EV services. As a result, a set of actionable solutions have been proposed to address this in the streamlined methodology. Even in the case of the streamlined services some of the solutions proposed require further development to be unambiguous in their implementation.

The methodology chosen allows the impacts to be assessed and scored. At this stage of the indicator development process the policymaking community's views with regard to the most important impacts have been partially clarified via the agreed amendment to the EPBD; however, more guidance on policymaker's imperatives and priorities will be needed to fully crystalise the scoring. Nonetheless, the structure used in the methodology is completely adaptable to allow the policymaking process to establish a collective position on the final choice of impacts to be addressed and their relative importance. In recognition of locally specific contexts it is flexible enough to allow this process to be followed at the local level too and thereby allow local preferences regarding impacts, domains, services and reporting to be implemented within the same common framework.

Furthermore, and importantly, the proposed methodological framework is structured such that the current input driven ordinal ranking via manual on site assessment approach can evolve as and when cardinal information (from calculation or measurement) and appropriate methodologies become available to incorporate an evolution towards a more accurate, output based, dynamic evaluation that could potentially be done automatically or remotely.

These conclusions reflect the following observations:

- Maturity is a precondition of being implementable, thus services whose functionality is not yet adequately defined or determinable to be included in the scheme will necessarily be excluded until these issues are addressed;
- To be successful (i.e. if it is to be adopted in practice) it is necessary to structure the SRI so its value proposition to its target audience is of greater value than its cost of implementation;
- To be relevant the SRI methodology has to be able to manage local and site-specific factors and thus needs to be sufficiently flexible to manage variations in such circumstances;

- A common methodological template such as that described in this report allows maximisation of harmonisation while also being adaptable to implementation that fully respects this local context.

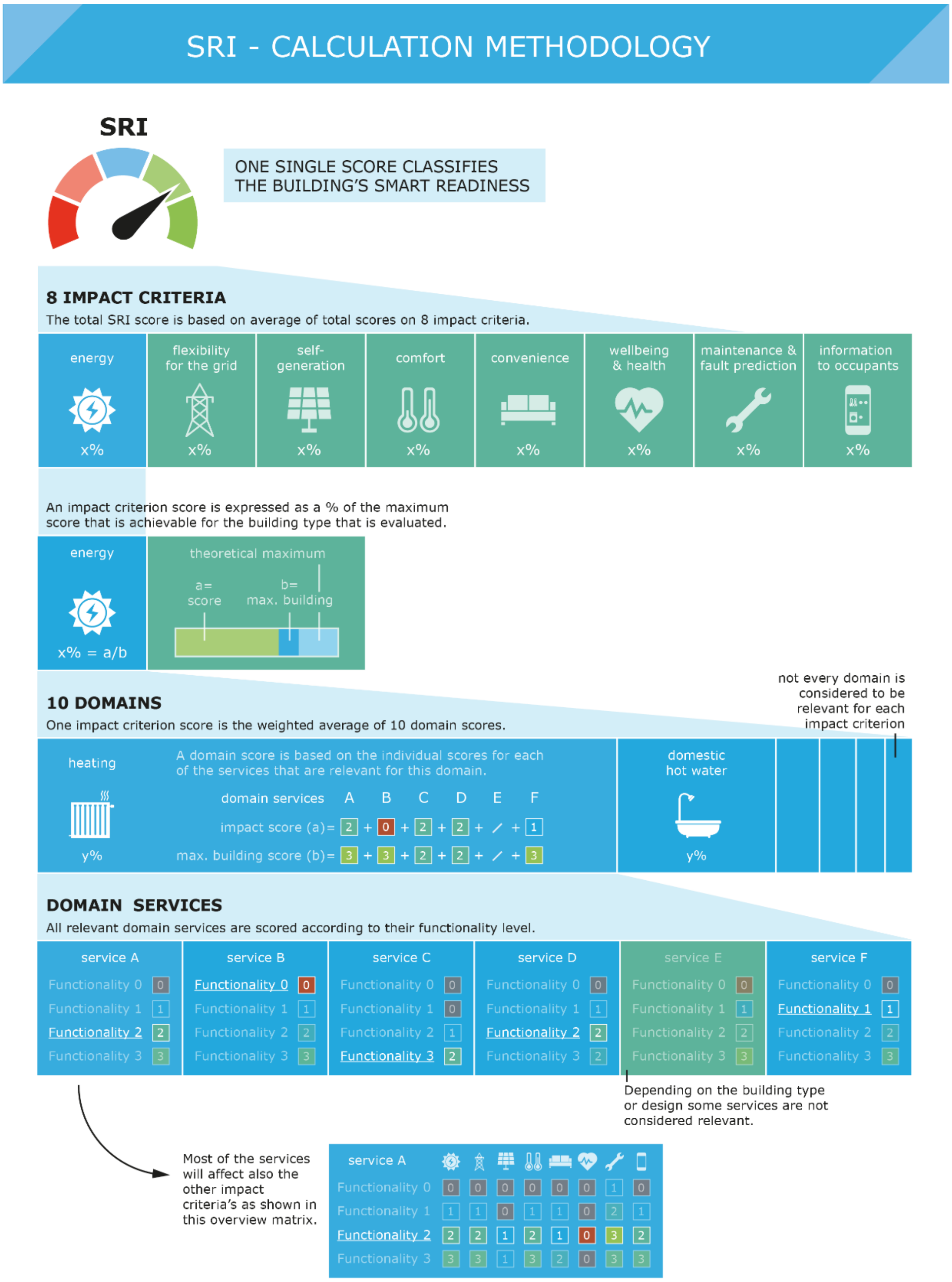


Figure 49 – SRI calculation methodology overview

CHAPTER 4 TASK 3: STAKEHOLDER CONSULTATION

Interactions with stakeholders are an essential part of the process towards a SRI. At multiple occasions, stakeholders have had the opportunity to provide input to this study, thereby creating a transparent and open process. These interactions have supported the substantiation of the content in the technical tasks of this study, but were also beneficial to generate a broader awareness of the potential of an SRI as well as identify opportunities and challenges for the further steps towards implementation.

Several actions have been undertaken to strengthen the interaction with stakeholders, including the launch of a public website and three stakeholder meetings in Brussels with subsequent opportunities for written feedback.

Public website

The project website (https://smartreadinessindicator.eu) aims at informing the general public on the goals of this study. Furthermore, visitors could register through the website to be added to the list of stakeholders. During the study, technical working documents and interim reports were available on the website for public consultation, together with a feedback form. The meeting minutes of each stakeholder meeting are also available on the project website.

First stakeholder meeting and subsequent feedback

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.

The feedback given by the initial and extended deadlines for commenting was consolidated by the team and stored in an Excel spreadsheet along the following categories:

- General remarks were consolidated and taken into account writing this report, focusing on wording, stakeholders, limitations as well as focal areas for the project.
- The feedback from the questionnaire in relation to the Task 1 was taken into account, mostly dealing with the service catalogue and its content, structure and possible ways to assess the services.
- New services (around 10) which were suggested were reviewed and added to the Service Catalogue and Excel spreadsheet.

On 12th September 2017, a first progress report was shared with registered stakeholders comprising the next iteration of the report and the service catalogue, taking into account the feedback as well as further insights. Stakeholders were invited to provide feedback on the new version by mid-October. Further details on the composition of the stakeholder comments can be found in Annex J.

Second stakeholder meeting and subsequent feedback

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. Further details on the composition of the stakeholder comments can be found in Annex J.

Third stakeholder meeting

In consultation with DG Energy, it was decided to organise a third stakeholder meeting within the scope of this 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 second progress report is distributed for formal feedback after the stakeholder meeting. Further details on the composition of the stakeholder comments can be found in Annex J.

Overview of main stakeholder comments on the second progress report

Table 34 provides an overview of the main comments provided by stakeholders on the second progress report, and it lists the main comments that have been raised by multiple stakeholders and clarifies the position of the technical study team in response to those comments. The consortium received nearly 200 comments. Many of the comments received have led to direct modifications of the report and its annexes, such as the smart ready service catalogue.

Table 34 - Overview of the main stakeholder comments

Comment (aggregated)	Response of the technical study team
Some stakeholders express the concerns that weighting factors will cause subjectivity in the SRI assessment.	The weighting factors are inherently subjective, since they aim to group multiple domains and impacts which are mutually not directly comparable. This is a classic problem in any multi-criteria assessment scheme and many methods exist to obtain a balanced consensus. By also visualizing the (unweighted) sub-scores by impact category or domain, the underlying information is also presented to the use. It is important to note that the weighting factors are not to be 'made up' by the individual assessors, but will be defined as part of the methodology, e.g. differentiated by climate and type of building. This will ensure replicability of the assessment.
The triage process is generally well supported, but there are also questions/concerns that the exclusion of absent services may lead to the fact that buildings are not comparable or that manufacturers cannot advertise the benefits of specific products and services towards the SRI score.	In case a building does not have a need for specific services (e.g. as a result of absence of domestic hot water production, no heat pumps, no cooling needs hence no cooling equipment,…) such services are indeed not evaluated. Another approach to this kind of absent services would heavily bias the assessment. As a result, care should be given in comparing SRI scores: a building is compared to 'a virtual twin with the maximum of available services implemented for that specific building design'. This concept is also used in energy performance certification schemes and known as the 'notional building approach' (Pérez-Lombard et al., 2009). Apart from the 'triage' process, potentially different weighting factors (by climate, building type,…) also prohibit direct comparison of scores amongst vastly different buildings. Nevertheless, the method builds on the functionality levels of the smart services. These are defined in a common way, and can be used as a marketing instrument across the EU.
Many stakeholders express the need to further test the method on different types of buildings.	The study team acknowledges this. This is however beyond the scope and timeframe of the current technical study, but can be taken up in follow-up studies and further steps towards the implementation phase.

Some stakeholders express their concerns that a low SRI assessment cost might result in poor quality of the assessment and therefore jeopardize the credibility of SRI. Given the complexity of many contemporary buildings, a high level expertise (hence training) will have to be expected from SRI assessors.	The study team has not proposed a specific cost for the SRI assessment, although a previous EPBD impact assessment study[58] indeed proposed relatively low assessment costs. The proposed methodology allows multiple ways of SRI assessment; e.g. ranging from simple online self-assessment by individual consumers to on-site inspection by qualified assessors. Potentially, the SRI assessment methods can be differentiated by building type, since more expertise is likely to be needed in contemporary non-residential buildings. The proposed method is flexible to allow such different implementation scenarios which are to be investigated in follow-up studies and policy preparation efforts.
Conflicting views are formulated on whether or not to rely on international standards for defining services and impacts, and how to follow the standards, amendments or standard development. Some stakeholders prefer following standards for all services since this is a well-established process with good representation of many industrial stakeholders. Others comment that many standards are lagging behind and relying on standards would slow down the integration of new technologies and related services in the SRI.	The study team acknowledges that multiple views exist on this matter. The rate of updates and general uptake of international standard can also differ by industry. Further discussions will be needed to set up a generally accepted framework for estabilishing and updating the SRI service catalogue. A potential solution is the set-up of working groups (including industry representatives) dedicated to a specific domain or set of domains. These working groups can define a framework which consists of a blend of standards and other initiatives relevant to that specific sector.
Some stakeholders suggested additional services to be included, such as 'energy efficiency of the electrical installation' according to IEC/EN 60364-8-1 or 'energy efficiency of lifts and elevators'.	The energy efficiency in itself is not part of the scope of SRI, since this would cause too much overlap with existing policy instruments such as EPCs and Energy labels. Nevertheless, the 'smart control' of such equipment could be part of the SRI (for comparison: ventilation heat recovery efficiency is not part of SRI, but the control of the ventilation rate – e.g. based on CO_2 sensors – is part of SRI)
Some stakeholder suggest to broaden the scope of smart services included in the SRI assessment, e.g. including access control, fire alarm, security systems, lifts and elevators.	The study team acknowledges that many of the suggested services can provide smart functionalities to the building and its users. They are however not part of the scope of the SRI set by the EPBD mandate and hence are not withheld in the proposed streamlined methodology. Many of these suggested services have been listed in the domain 'various' for future reference. For some of the suggested services, the technical study team reckons it can be worthwile investigating future inclusion in the SRI. Some of these smart features might resonate with a general public's notion of 'smart buildings'. Even though not in line with the current scope of the EPBD, inclusion of some of these services might spur the public interest and uptake of the SRI, and thus support the policy goals of the EPBD.

[58] Commission staff working document - impact assessment accompanying the document proposal for a directive of the european parliament and of the council amending 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

Stakeholders have commented on the inclusion of district heating networks which are not explicitly reflected in the service list.	District heating is not explicitly mentioned in the scope of Annex1a of the amended EPBD. Nevertheless, many of the currently listed smart services dealing with the control of the heating systems are equally applicable to district heating networks (and equally so for DHW and cooling). In follow-up work, it could be investigated whether it is relevant to include additional services which are specifically focused on district heating or cooling. It this case, it might be considered to also assess whether the connected district grid is able to adapt its operation, e.g. by mixing various energy sources and giving preference to low-carbon heat or cold generation when possible thanks to the DSM efforts. Such approach would however require assessing technical features beyond the scope of the individual building, which brings about extra challenges to the practical assessment of such services.
Some stakeholders explicitly welcome the services which were included after the last round of stakeholder consultation. Some further amendments are proposed by stakeholders, mainly to adjust some of the current services, their functionality levels and scores.	The study team has adjusted the service list where the request is deemed relevant and sufficiently underpinned by factual information. In any case, the services catalogue and its features are still provisional, and a framework will need to be established to have a consensus on the final catalogue and a future update process.
A stakeholder suggested to give more attention to basic infrastructure (such as wiring and cabling)	The approach of rating 'services' as opposed to 'technologies' had the advantage of creating a technological neutral position of the SRI. For some of the services, basis infrastructure (such as a smart meter) can be needed as a precondition for higher fuctionality levels, and is thus indirectly rewarded in the SRI. Nevertheless, it can be argued that a building with some basic infrastructure present is more 'smart ready' than a building without; even if the services which build on top of this infrastructure are not present. Future work can review the current approach, and for example introduce additional functionality levels to award the presence of infrastructure, without having the services present in the building. A potential drawback of this approach is a greater deviation of the definition of services which already feature in technical standards such as EN ISO 15232.
Some comments were received pointing towards the relevance of services which are listed in the catalogue, but not retained as part of the streamlined set of services.	Multiple criteria have been used to select which services should be retained in a restricted streamlined methodology. Exclusion of some services does not necessary allude to a low relevance, but is often a result of other factors such as the lack of applicable standards or the complexity of on-site assessment. The streamlined list of services is used to illustrate the method, but can (and presumably will) be amended in follow-up work. Stakeholders are invited to provide further proposals on definitions and inspection guidelines for specific services, preferably based on a broad consensus within an industry sector.

A few stakeholders (re)iterate their preference of an output based / quantified indicator.	The current methodology is flexible to allow quantified scores (e.g. from simulations or measurements) for specific impact categories. For other impact categories (e.g. comfort, convenience, information to occupants) direct quantification is deemed very intricate or even impossible. In further steps towards implementation or later updates of the SRI, an appropriate blend of ordinal rankings and quantified scores can be established, potentially differentiating by building type.
Some stakeholders comment that having services tied to specific technologies (e.g. DHW storage, heat pumps,…) breaches the 'level-playing field'.	The study team acknowledges that the SRI should allow a level-playing field for smart ready technologies and has therefore aimed to define the services in a technology neutral way. However, some of the services are by nature only applicable to specific technologies (e.g. DHW storage vessels or heat pumps). In the proposed methodology, these services are only assessed if such technology is or should be present (see 'triage process'). By comparing the score of the building with a hypothetical variant with maximum smart functionalities for the same set of technologies, the building is not 'punished' in its SRI score when a specific technology is not available in the building. In conclusion, the SRI method does not favor any specific technology.
Some stakeholders comment on the estimates of the current market uptake of smart ready services.	The numbers on estimated market uptake refer to the full building stock - not only the newly constructed buildings - and across the EU. Although SRTs such as automated shading control are relatively common in newly constructed (especially in warmer climates), their average market uptake is estimated low in the overall stock of residential buildings. Stakeholders are invited to provide additional data to follow-up studies.
Some stakeholders comment that a 'smart' building does not equal a 'good' building. It is argued that passive measures can be as good or better than active controls, and that adding (too) much controls might even create more possibility for bad control.	The study team agrees that 'smart' does not necessary equal 'good performing', nor 'sustainable', 'comfortable' or 'fully energy efficient'. Other indicators and policy instruments exist for assessing these specific aspects of a building. Of course, a high SRI score can often be an important step towards a well performing building, as smart services can provide the means to better understand a building's behavior and perform controls in an optimized way. The communication towards end-users should be clear on what the SRI label entails and what it doesn't. For some of the building services, passive solutions (e.g. overhangs to exclude excessive solar gains) can indeed be preferred over smart controls (e.g. smarter control of a cooling system). This is dealt with in the triage process: if no cooling is present (e.g. as a result of good building design), this is not evaluated in the SRI assessment. In follow-up work it can be further refined which services should always be part of the SRI assessment, even though not present in building (hence evaluated at functionality level 0).
Some stakeholders raised comments on how the SRI should be implemented by member states, by whom the assessment should take place, etc.	The topic of SRI implementation is out of scope of the preparatory technical study, but will be covered in future studies and policy preparation efforts.

Other interactions with stakeholders

The study team and representatives of the EC's services have engaged in further bilateral discussions with specific groups of stakeholders. This includes email conversations, teleconferences, bilateral meetings and presentations at conferences or study days.

On 25th October 2017 during the EPBD Concerted Action meeting in Bucharest, a double session took place with discussions about the features of smart buildings and other topics from this SRI study.

CHAPTER 5 TASK 4: IMPACT ASSESSMENT

This chapter describes the approach and important results of the impact assessment (IA) for smart ready technologies (SRT) and the implementation of the Smart Readiness Indicator (SRI) in the EU. It shows the possible bandwidth for the uptake of SRTs and provides key conclusions.

After a brief overview on the general setting, sope and goal of the impact assessment in section 5.1, the main results concerning benefits and costs for SRTs and the SRI are described in section 5.2 together with a general outlook on the energy demand and CO_2-emissions of the EU building sector. Beside the quantitative analysis of energy, emissions and economic parameters, a mostly qualitative analysis of wider benefits such as health, indoor environment, comfort and life-cycle aspects is conducted. In addition, a sensitivity analysis regarding the most important uncertainties is given here as well as a description of current and future policy measures supporting the uptake of SRTs. Section 5.3. gives a high-level overview on the methodology and the approach, while overall conclusions are summarized in section 5.4. Details on the models can be found in the Annex K-M in this report.

5.1. SCOPE AND GOAL OF THE IMPACT ASSESSMENT

The objective of the impact assessment is to analyse the benefits and costs of implementing a Smart Readiness Indicator in buildings regarding an uptake of smart ready technology implementation in the EU buildings sector. It also aims to understand the impact of accompanying policies to enhance the impact of the SRI.

A cost benefit analysis is carried out for snapshots at 2023[59], 2030, 2040 and 2050 and considers a range of benefits and effects, while concentrating on assessing the benefits in monetary, energy (final and primary) and emissions units on a cumulative and yearly basis, for the different building segments. Furthermore, a qualitative analysis is conducted to elaborate on the effects regarding health, indoor air quality, comfort and life-cycle effects. The cost-benefits analysis is based on the modelling of the effects of the uptake of smart ready technologies in the building stock and the impact the SRI can have on the latter. For this study smart ready technologies cover building automation and control systems (BACS), electromobility charging infrastructure in buildings and demand side management (DSM), see task 2 (CHAPTER 3) of this report.

The impacts of an uptake of electromobility charging infrastructure in buildings focuses on the installation of chargers in or next the buildings and considers the effects of electromobility on demand response together with a possible active participation of the user in the grid/energy markets.

The methodology for quantifying benefits and costs of smart ready technologies includes two steps, as depicted in Figure 50.

The first step is the calculation of **building sector pathways** within the framework of the revised EPBD. These pathways describe the general development of the building sector taking into account new buildings, demolition of buildings and retrofits regarding energy efficiency measures to the

[59] We assume that the SRI will be implemented from 2020 but that there will be a transitional period of 2-3 years before it is effective in the EU; hence the choice of 2023 for the first snapshot and not 2020.

building envelope and the HVAC systems. The pathways provide the underlaying energy consumptions of the building stock and therefore determine the potential savings for SRTs.
Based on the definition of reference buildings, the calculation of energy demands and the aggregation to the EU building stock, the following building sector pathways for the EU28 building sector (including the current SRTs in the market) are calculated in five geographic zones across the EU:

- **"Agreed Amendments" pathway (AA):** Baseline development considering the agreed amendments of the revised EPBD
- **"Agreed Amendments + Ambitious Implementation" pathway (AA+AI):** Baseline development considering the agreed amendments of the revised EPBD, but with an ambitious implementation (i.e. additional supporting measures) on MS level

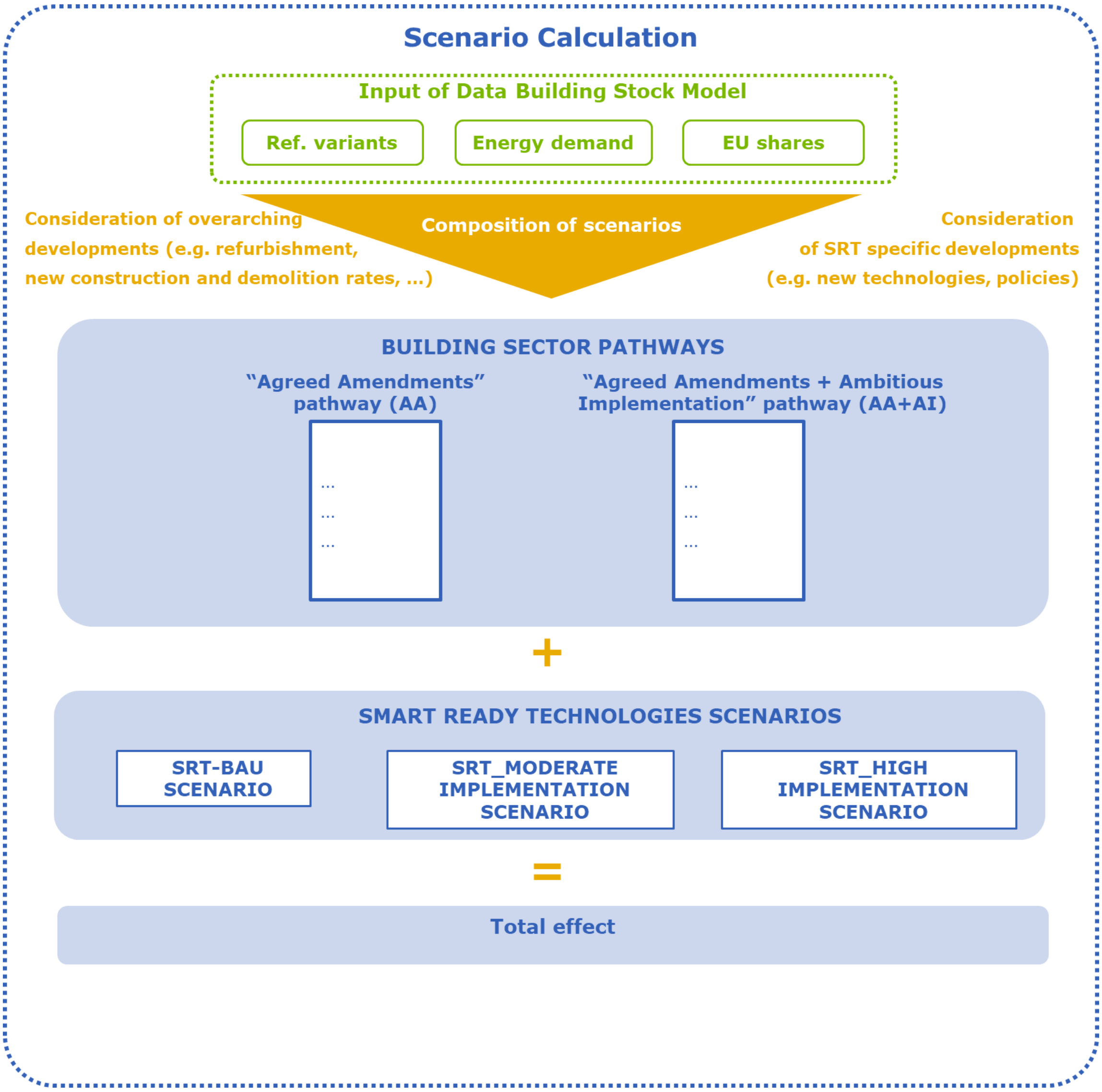


Figure 50 - Overview of scenario calculations

The second step is the calculation of the **Smart Ready Technologies effects** on top of the building sector pathways described above, taking into account the effects of the SRI. The following set of SRT scenarios are considered in the analysis:

- **SRT_BAU:** No SRI, only existing incentives for Smart Ready Technologies
- **SRT_Moderate implementation:** SRI voluntary, moderate accompanying measures and moderate implementation on MS level
- **SRT_High implementation:** SRI still voluntary, strong accompanying measures and considerable implementation on MS level

5.2. Overview of methodology and approach

The methodology for the evaluation of impacts is split into two steps, see Figure 50. The *first part* is the modelling of the underlying building sector pathways for the evolution of the EU building stock, taking into account the policy framework given by the revised EBPD. They describe the general development of the building sector taking into account new buildings, demolition of buildings and retrofits that include energy efficiency measures which have an impact on building envelope and HVAC systems. These pathways are modelled with the Built-Environment-Analysis Model (BEAM) [60], a bottom-up building sector model used by Ecofys. 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* the additional impacts (as compared to the baseline given by the building sector pathways) of an increased uptake of SRTs are modelled. Again, several scenarios for the uptake of SRTs are differentiated: (i) the "*SRT_BAU scenario*" corresponds to the case where the SRI is not introduced - only existing incentives for SRTs apply; (ii) the "*SRT_Moderate implementation scenario*" corresponds to the case where the SRI is introduced as a voluntary scheme, with limited supporting measures and limited implementation in MS; (iii) the "*SRT_High implementation scenario*" corresponds to the case where the SRI is introduced as a voluntary scheme, with strong supporting measures and ambitious implementation in MS.

5.2.1. Building sector scenarios methodology

The building sector pathways are modelled with the Built-Environment-Analysis Model[61] BEAM, a bottom-up building sector model proprietary to Ecofys.
The first step for the building sector modelling process is the definition of reference buildings. A reference building is a building that represents a typical building (type, geometry, thermal quality, HVAC- and BAC-system) of the building stock. This enables the analysis of an entire building stock by analysing the stock from bottom-up, based on a different set of reference buildings. Typical residential reference buildings are, e.g. detached or semi-detached single and multi-family houses of different sizes and/or age classes (construction periods). Typical non-residential building types are, e.g. office buildings, schools, hotels, hospitals, and retail facilities.
In this study we define a single family (SFH), a small multi-family (SMFH) and a large multi-family (LMFH) as reference buildings for the residential building stock and an office building and retail[62] building for non-residential buildings[63].

[60] See Annex A for a description of the BEAM-Model
[61] See Annex A for a description of the BEAM-Model
[62] Office and retail buildings are considered as typical non-res buildings with the largest SRT saving potentials.
[63] According to the proposal.

After having defined the adequate set of reference buildings, the next step is to determine the energy demands - and thereby the saving potentials of the reference buildings. Note that the building sector pathways do not take into account the additional savings from SRTs, which will be done in the SRT scenarios.
The results of the determination of the energy demands and potentials of the reference building variants are aggregated to represent the EU building stock and its future development. For this step the EU28 building sector is split into five geographical zones (in compliance with the approach followed for the EPBD impact assessment).

The outputs of the building sector pathway calculation with the BEAM model are the floor area development per building type, final and primary energy demand, and related CO_2-emissions, and energy costs, see an illustrative example for Single Family Houses (SFH) in Figure 51 For the target years 2023, 2030, 2040 and 2050 the outputs regarding floor area development – split up by retrofit level – final energy demand by system as well as primary energy demand and CO_2-emissions are shown. The overall floor area is increasing, while the energy demand is decreasing mainly due to the introduction of energy efficiency measures on the building shells and the replacement of inefficient HVAC systems.

EU-West						
	Floor area [m2]		2023	2030	2040	2050
		not renovated	7.40E+09	5.29E+09	2.81E+09	2.05E+08
		already renovated	6.54E+09	6.54E+09	6.54E+09	6.54E+09
		retrofit (<=2025)	4.38E+08	1.31E+09	1.31E+09	1.31E+09
		retrofit (>2025)	0.00E+00	1.04E+09	3.32E+09	5.71E+09
		new (<=2025)	4.16E+08	9.18E+08	9.18E+08	9.18E+08
		new (>2025)	0.00E+00	4.78E+08	1.44E+09	2.44E+09
	Final energy consumption [TWh/a]					
		total	1437	1233	986	726
thermal		heating	1206	991	728	454
thermal		hot water	212	220	233	244
electrical		cooling	0.3	0.3	0.4	0.4
electrical		lighting	0	0	0	0
electrical		auxiliary energy (el)	18	22	25	28
	Primary energy consumption [TWh/a]					
		total	1638	1333	1011	699
		heating	1360	1063	745	439
		hot water	239	236	238	236
		cooling	1	1	0	0
		lighting	0	0	0	0
		auxiliary energy (el)	39	34	28	23
	CO2-Emissions [Mt/a]					
		total	275	226	174	123
		heating	231	182	130	79
		hot water	41	40	41	42
		cooling	0	0	0	0
		lighting	0	0	0	0
		auxiliary energy (el)	4	3	2	2
	average PE factor [-]		1.14	1.08	1.03	0.96
	average CO2-factor [kg/kWh]		0.191	0.183	0.176	0.169

Figure 51 - Exemplary output of the building pathway calculation for single family houses (SFH) in the geographical region EU-West

The parameters and assumptions for the building sector pathways are set based on the report and modelling work by Ecofys for the EC study *"Ex-ante evaluation and assessment of policy options for* *the EPBD"*[64] of April 2016. These are adjusted in accordance with agreed amendments under the revised EPBD (see ANNEX L – Building sector Scenarios – Assumptions and detailed results).

The outputs of the building sector pathway calculation with the BEAM model are the floor area development per building type, final and primary energy demand, related CO_2-emissions and energy costs. The outputs are calculated for five geographical regions (EU-West, EU-North, EU-North-East, EU-South, EU-South-East).

5.2.2. SRT SCENARIOS METHODOLOGY

The smart ready technology (SRT) scenarios quantify the effects of the uptake of SRTs in addition to the building sector pathways. These effects are calculated with an Excel based model for the three scenarios described above. The autonomous effects of SRTs due to replacement of systems and systems in new buildings that can be observed today continue in the "SRT_BAU" scenario. They are also included in the building sector pathways and are quantified here. In addition to the autonomous effects, the "SRT_Moderate implementation" and "SRT_High implementation" scenarios assume an uptake of SRTs due to the introduction of the SRI. The different effects are described in the following sections.

As described in task 2 (chapter 4) of this study, the SRI is expressed as a score taking into account a weighting across the different domains and functional levels. For the purpose of this IA, the smart readiness of buildings is expressed as ranges of SRI scores. SRI range I (or smart readiness level I) covers all SRIs below 26%, SRI range II all SRIs between 26% - 50%, SRI range III all SRIs between 51% - 75% and SRI range IV all those above 75%. The higher the range, the smarter the building.

For the automation and control (BACS) domains such as heating, DHW, cooling, controlled ventilation, lighting, dynamic building envelope, energy generation, and monitoring/control the SRI ranges I to IV reflect the categorization A-D of the European BACS standard EN 15232. Hereby the BACS category D relates to SRI range I and BACS category A to SRI range IV.

All possible improvement over the SRI ranges are taken into account, such as SRI range I -> II, I -> III, I -> IV, II -> III, II -> IV and III -> IV. If a building undergoes improvement steps as indicated above, the final energy savings – either thermal or electrical – can be realized due to the improved overall system performance. The final energy savings also lead to primary energy as well as CO2-savings due to the improved energy efficiency of the buildings.

Furthermore, the SRT model distinguishes between buildings with heating only, buildings with cooling only and buildings with both heating and cooling systems for all geographical zones in order not to penalize buildings for systems that are not in place. The SRT scenarios are calculated for three geographical regions, EU-North, EU-West and EU-South individually.

The approach for quantifying the effects of smart ready technologies can be described as follows. For each of the above described scenarios a yearly deployment rate is determined for the different automation and control domains as the main input. This rate is split into SRI-range improvement steps (i.e. I -> II or II -> IV). For each of the improvement steps the relative saving potential for thermal and electrical energy (in % of the actual energy demand) is given in the model as well as the investment costs per m^2 of floor area. The combination of deployment rate and improvement

[64] Ecofys 2016: Ex-ante evaluation and assessment of policy options for the EPBD, Final report for EC DG-ENER

potential per SRI range gives the overall saving potential and investment costs (CAPEX) of the implementation of SRTs.

Combining the steps described above leads to thermal and electrical energy savings, primary energy and CO_2-savings, energy cost savings and total investments per year. These outputs are given for each of the above described scenarios per reference building type and geographical zone.

The Demand-Side-Management (DSM) potential for electricity demand has also been considered, but only based on existing studies and literature, and without conducting scenarios analysis. The main opportunities for DSM are heat pumps, direct electrical heating, EV charging as well as cooling and ventilation in buildings, as they account for the largest share of electricity demand.
In order to determine the DSM realistic potential that is incorporated in the building stock, the relevant electricity demand is considered as a theoretical maximum DSM potential. Based on additional data, the realistic balancing potential is determined in the second step.

Furthermore, the effects of the uptake of Electric Vehicle (EV) charging infrastructure need to be considered within the EPBD scope. However, the largest effect of the installation of EV charging infrastructure is clearly the “driver/enabler” function that is a prerequisite for the uptake of EVs in general. Without any charging infrastructure in the built environment, the attractivity of EVs will be limited. Apart from this, EVs can provide storage and flexibility to the building in case of charging or discharging – in case the charger and the battery allow two-way charging.
In order to show the potential impact of the EV charging infrastructure in general, possible EV-uptake scenarios (i.e. min and max) are discussed qualitatively and also in a quantitative way (i.e. the current and expected number and capacity of chargers).

Baseline scenario for SRT uptake

The baseline scenario for SRT uptake is the SRT_BAU scenario. Based on a recent study by Ecofys and Paul Waide[65] this baseline scenario assumes a yearly deployment rate of SRTs of 1.2%. In this scenario, smart readiness of buildings improves gradually, which means that buildings cannot improve smart readiness by more than one level (e.g. from SRI range I to SRI range II) at a time.

Additional uptake of SRTs due to SRI

Our 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 SRTs. This effect is not independent of the level of uptake of the SRI (a very common usage of the SRI might lead to a clear positioning of the service providers regarding the SRI), but a certain critical mass of SRIs will be needed until the above described process leads to an uptake of SRTs. If the critical mass of the SRI in the building stock is attained, the uptake will most likely not be a linear development, but could be described with an S-curve function and adoption/implementation rates (saturation curve).

The degree of MS-specific supporting policies of course will have an influence on the adoption rates. Smart service adoption rates will also be strongly affected by the policy support measures which may

[65] 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

be directly targeted towards them too (i.e. policies could be designed to both create incentives to have an SRI and also 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.

In order to translate this mechanism into the SRT model, we set the following assumptions in order to define to SRT-scenarios.

The "**High implementation**" scenario assumes a maximum possible uptake regarding the issuing of SRIs. The assumption here is, that MS put significant financial incentives into place (i.e. the costs of issuing the SRI is covered by incentives but also there are significant incentives to adopt SRTs - especially energy saving BACS, EV charging and flexibility technologies).

- SRI issuing rate of **30%** per year (with ramping up in the beginning)
- 50% of SRIs issued lead to investments to improve smart readiness (which equals to **15%** per year)
    - This leads to limited improvements in 75% of these cases, which do not lead to a change regarding the SRI ranges I, II, III or IV.
    - Only 25% of these measures lead to an improvement of the SRI range (which corresponds to a **3.75%** yearly rate)
        - The share of SRTs measures that result in major improvements (upgrades in technical building or HVAC systems) along all measures is increasing over time due to a market uptake.
        - All other smaller measures lead to an improvement by one SRI range

For the "**Medium implementation**" scenario the following assumptions are taken.

- SRI issuing rate of **15%** per year (with ramping up in the beginning)
- 50% of SRIs issued lead to investments to improve smart readiness (which equals to **7.5%** per year)
    - Little improvements are done in 50% of these cases, which do not lead to a change regarding the SRI ranges I, II, III or IV.
    - 50% of these measures lead to an improvement of the SRI range (which corresponds to a **3.75%** yearly rate)

In addition, the rate of ownership transition could also be considered as an upper limit for the deployment of the SRI. Each time a tenant or owner of a building changes, the incentive to issue an SRI could be considered to be comparable with the incentive to issue an EPC.

5.3. IMPACT ASSESSMENT RESULTS

This chapter gives an overview of the results regarding the underlying building sector pathways and the smart ready technologies scenarios (SRT scenarios).

5.3.1. UNDERLYING BUILDING SECTOR PATHWAYS

As described in the overall approach, the first part of the process for quantifying the benefits and costs of smart ready technologies and the Smart Readiness Indicator is the calculation of building sector pathways. They describe the general development of the building sector considering new buildings, demolition of buildings and retrofits regarding energy efficiency measures to the building shell and the 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. Both pathways are based on the parameters and assumptions for the building sector pathways which were defined in the report and modelling work by Ecofys for the EC study *"Ex-ante evaluation and assessment of policy options for the EPBD"* , see section 5.2.1.

Figure 52 shows the evolvement of final energy demand for space heating in the EU until 2050. The overall demand in 2020 of 3050 TWh/a is reduced by 53% to 1400 TWh/a by 2050 in the "Agreed Amendments" scenario, while the "Agreed Amendments + Ambitious implementation" reduces the final energy demand for heating by about 58%. The main drivers behind this development are energy efficiency measures applied to the building envelopes and the replacement of old heating, hot water and cooling systems across EU. At the same time the floor area is steadily increasing due to the construction of new buildings and extensions to existing buildings not being fully offset by the level of demolitions. The total floor area is therefore estimated to increase by approx. 15% from 2020 until 2050.

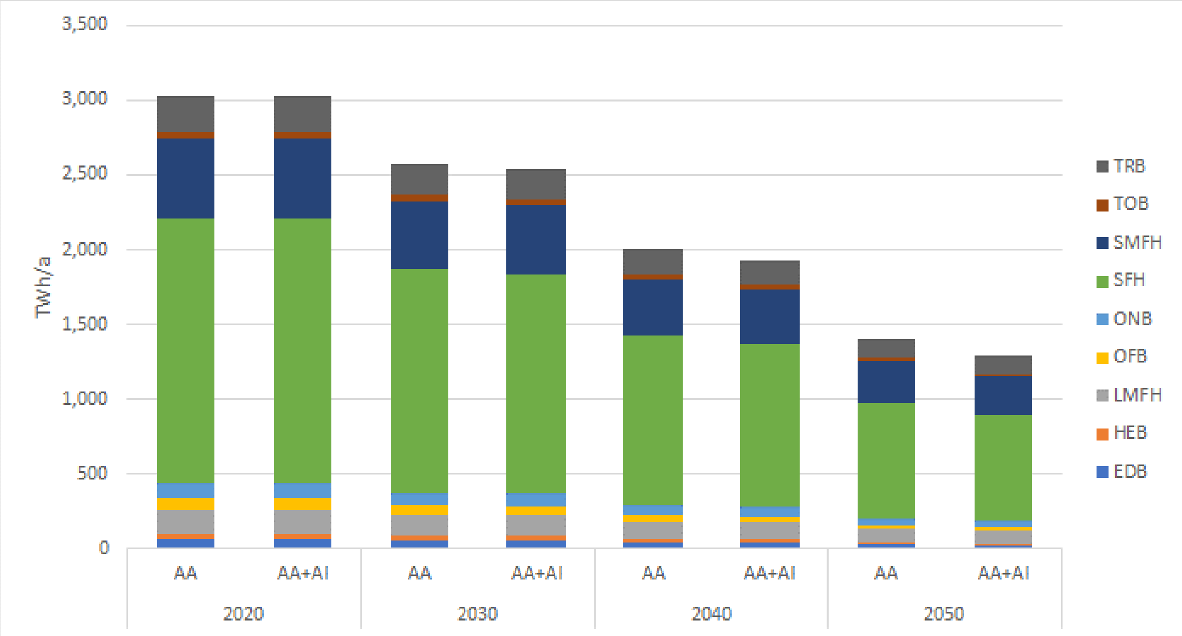


Figure 52 - EU total final heating energy consumption per type of heating system[66]

In terms of primary energy, the reduction is even more pronounced since fuel switching in the case of heating system replacement not only leads to efficiency improvements, but also to a further decrease in the consumption of primary energy. Where heat pumps are introduced, the higher efficiency of heat pumps leads to overall lower primary energy demands. In addition, the primary energy factor (PEF) for electricity and district heating is expected to improve over time.

Similar causes lead to a decrease of 61% in CO_2-emissions for heating in the "Agreed Amendments" scenario until 2050, as CO_2-factors are improving over time and a switch to less carbon-intensive energy carriers further supports the decarbonisation effect, see Figure 53. For the "Agreed Amendments + Ambitious Implementation" scenario the decrease in CO_2-emissions is even larger with 67%.

[66] Abbreviations in the figures: VS: Ventilation sytsem, HR: Heat recovery, c: condensing system, nc, non-condensing system, HP: Heat pump, DH: District heat, EL: Electricity.

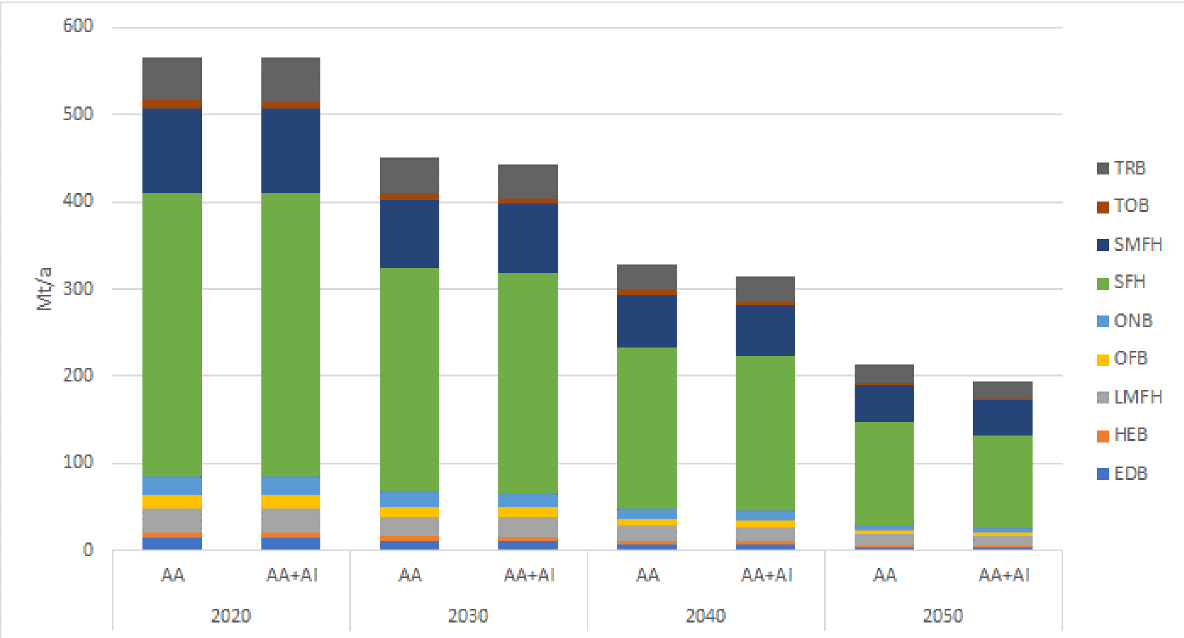


Figure 53 - Total EU CO_2 emissions from heating per reference building[67]

Finally, the energy costs for heating increase until 2030 (see Annex L). The main driver behind this effect is increasing energy prices until 2030, while an assumed constant level of energy prices from 2030 onwards in combination with decreasing final energy demands leads to decreasing energy costs from 2030 to 2050.

Only the heating-related results are shown in this section, because they are most relevant. However, the domains of hot water, cooling, lighting and auxiliary energy are also covered by the model and their results are reported in the Annex L.

5.3.2. SRT SCENARIOS

The smart ready technology (SRT) scenarios quantify the effects of the uptake of SRTs in addition to the building sector pathways, with a focus on monetary, energy and CO_2-emissions. Furthermore a qualitative analysis describes co-benefits of energy efficiency measures and smart ready technologies (SRTs) regarding health, wellbeing, indoor environment and thermal comfort and also addresses effects from a life-cycle analysis (LCA) perspective..

Quantitative analysis of benefits and costs

The benefits and costs of SRTs are calculated with an Excel based model for the three scenarios described above. The buisiness-as-usual development of SRTs is modelled in the “SRT_BAU” scenario. In addition to this baseline, the “SRT_Moderate implementation” and “SRT_High implementation” scenarios assume an uptake of SRTs due to the introduction of the SRI.

[67] Abbreviations in the figures: Office Building (OFB), Trade and Retail Building (TRB), Education Building (EDB), Touristic Buildings (TOB), Health Buildings (HEB), Other non-residential buildings (ONB).

The “SRT_BAU” scenario takes only existing incentives for the uptake of SRTs into account and assumes that the SRI is not implemented, while the other two scenarios (SRT_Moderate implementation and SRT_High implementation) assume a voluntary SRI is implemented with medium or strong accompanying measures respectively at the MS level. The uptake of SRTs is modelled from 2023. The main parameters of the scenarios are described in section 5.2.2.

Figure 54 gives an overview of the savings regarding final thermal energy, which can be realized by the different scenarios until 2050 due to the introduction and uptake of SRTs for all building types and all geographical regions. The numbers are cumulative, which means that the 2050 numbers represent all effects in the year 2050 of SRTs which were implementation between 2023 and 2050 compared to today. All future effects are considered. The total thermal energy savings in 2050 are about 150 TWh/a for the SRT_BAU scenario, while the SRT_Medium and SRT_High implementation scenarios show significantly higher savings with approx. 350 TWh/a respectively 420 TWh. While the SRT_BAU scenario assumes constant implementation rates at current level over time, the SRT_Medium and SRT_High implementation scenario show a rather progressive pathway due to a ramping-up period in the beginning where implementation rates are increased and trust in the SRI is built.

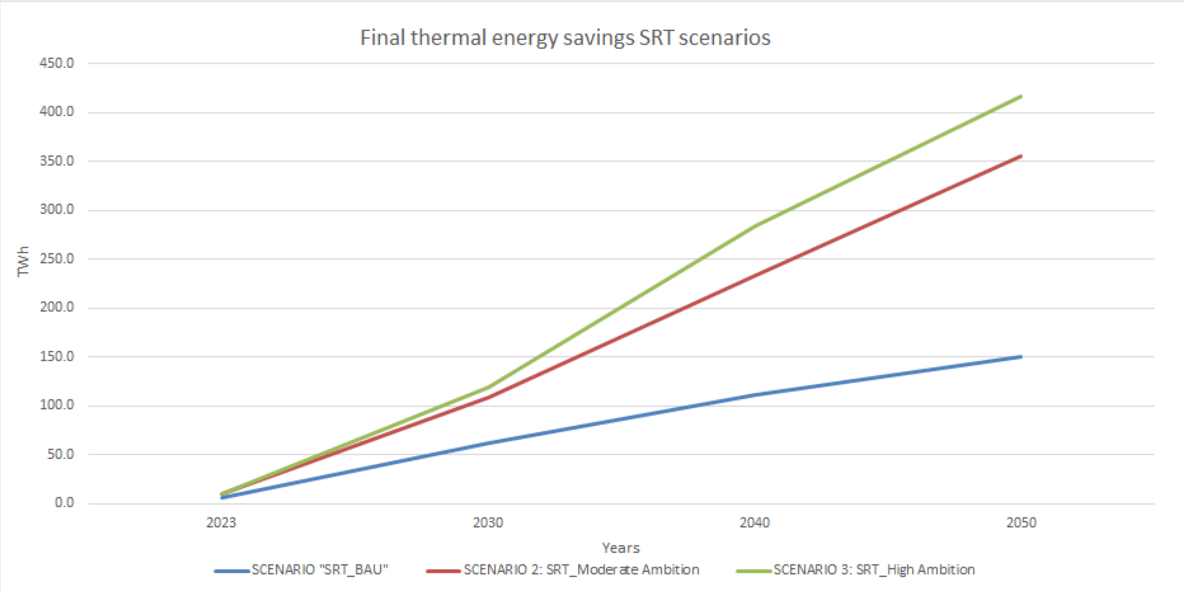


Figure 54 - Final thermal energy savings SRT scenarios[68]

Figure 55 shows the additional effects of the SRT_Medium and SRT_High scenarios compared with the SRT_BAU development. The total final energy demand for (extracted from the buildings sector pathways[69]) is added to the graph in order to put savings into perspective. The SRT_Medium scenarios show additional savings of 200 TWh/a by 2050 compared to today’s level[70], while the SRT_High scenario leads towards 260 TWh/a of final thermal energy savings by 2050, which is about 19% of the demand for final energy for heating in 2050.

[68] The cumulated effects of all additional SRTs from 2023 to 2050 are shown in this table.
[69] The “Agreed Amendments” pathway is shown here.
[70] The total energy savings until 2050 is represented by the area under the curves.

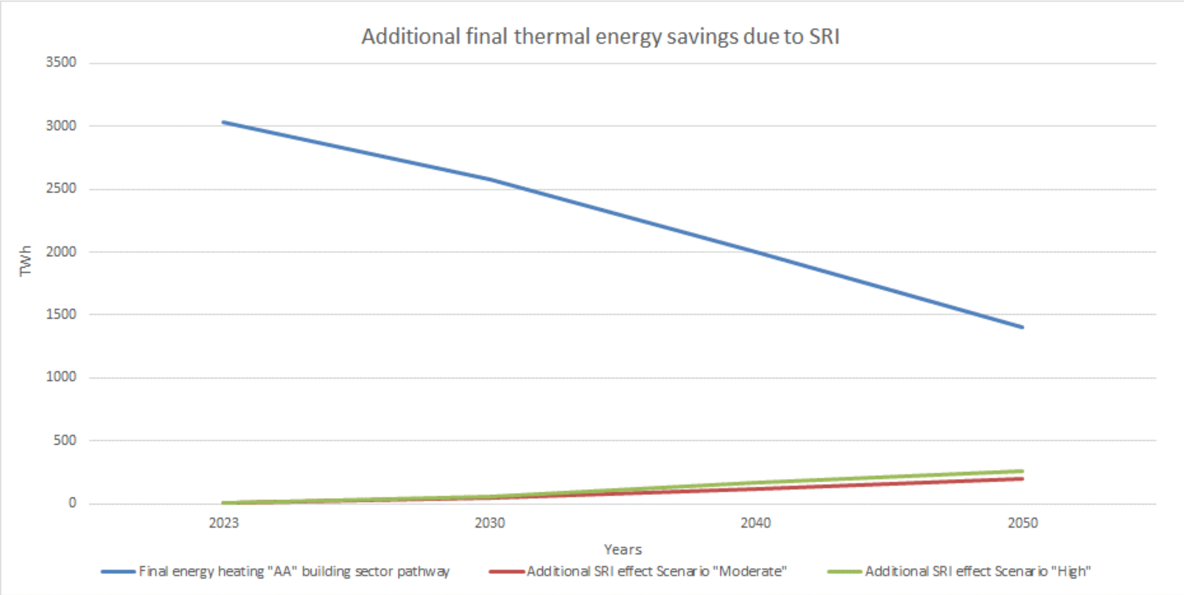


Figure 55 - Additional final thermal energy savings due to SRI in comparison with final energy heating development in the EU building sector by 2050[71]

In addition to thermal energy savings the model also calculates the electrical savings for auxiliary energy, cooling and also lighting in non-residential buildings. These savings increase up to 8 TWh/a by 2050 in the SRT_BAU Scenario and 18TWh/a respectively 20TWh/a in the SRT_Medium and SRT_High scenarios.[72]

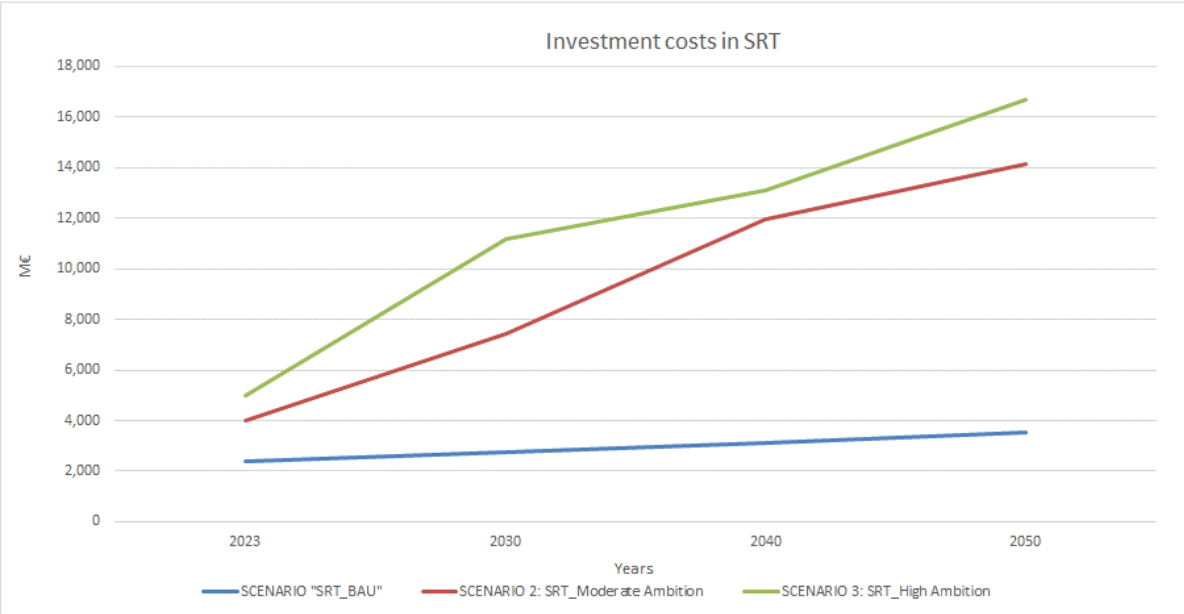


Figure 56 - Investments per year in SRTs by 2050

[71] The cumulated effects of all additional SRTs from 2023 to 2050 are shown in this table.

[72] The electricity savings are based on realistic, increasing implementation rates and on the savings given in EN15232 standard. Since the implementation rate on the one hand and the saving potential per measure on the other hand might not be as ambitious as it is for the Ecodesign "Lot 37" (lighting systems) study, it might explain a certain difference in saving potential compared to studies led in the Ecodesign area.

Figure 56 gives an overview of the yearly investments in SRTs required to achieve the energy savings outlined above. While the SRT_BAU scenario shows a slightly increasing investment level towards 3.5 billion Euro per year by 2050, the SRT_High scenario shows yearly investments of about 16.6 billion Euro by 2050. This leads to specific energy savings costs (based on investments and energy savings) of about 0,02-0,04 Euro per kWh saved[73].

In the scope of this study social-economic effects are addressed as well. Therefore, the link between investments in SRTs and new jobs is established. Additional investments lead to additional jobs for the installation of SRTs (direct effects) and the production of the components (indirect effects). In order to quantify these effects, Olivera et. al (2014)[74] and Ürge-Vorsatz et al. (2010)[75] analyse the additional jobs created per 1 million Euro additional investments for the construction sector. Both studies conclude with a range of 16-17 additional jobs created per 1 M€ additional investments for both direct and indirect effects. In terms of the SRT scenarios does it mean, that by 2030 80,000 additional jobs are created and maintained for the SRT_Medium scenario and 140,000 additional jobs for the SRT_High scenario. By 2050 these numbers increase to 170,000 respectively 210,000 additional new jobs (which is approx. a factor 3-4 of the jobs in the BAU sector).

Figure 57 shows the yearly savings on energy costs from SRTs for thermal and electrical energy (without DSM/flexibility measures). For the SRT_BAU scenario, the yearly cost savings decrease from about 460 to 270 million Euro per year. Since the energy efficiency of the building stock is assumed to improve over time, the cost savings from SRTs decline due to decreasing efficiency improvement potentials. For the SRT_Moderate and SRT_High scenario, energy cost savings range between 800 and 1,200 Million Euro per year. Compared to the yearly investments from Figure 56, a static payback period between 3-6 years can be calculated.

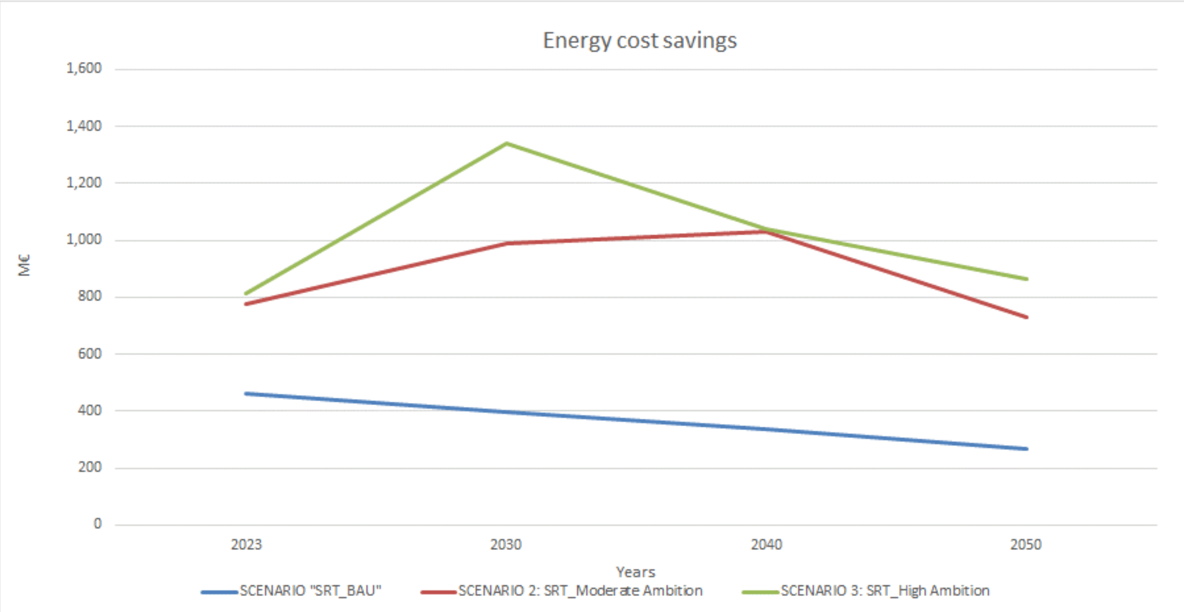


Figure 57 - Energy cost savings by SRTs until 2050

[73] Assumption: SRT lifetime 20 years and static calculation (based on German standard VDI 2067)
[74] Olivera et. al 2014: "A prospective analysis of the employment impacts of energy efficiencyretrofit investment in the Portuguese building stock by 2020". International Journal of Sustainable Energy Planning and Management Vol. 02 2014 81-92
[75] Ürge-Vorsatz et al. 2010: "Employment Impacts of a Large-Scale Deep Building Energy Retrofit Programme in Hungary"

Regarding CO_2-emissions, the following savings could be realized (see *Figure* 58): for the SRT_BAU an emission reduction by 26 Mt/a until 2050 compared to today's level can reached, while the two other scenarios lead to significantly higher savings. For the SRT_High scenario the total CO_2-emission level can be lower by 70 Mt/a until 2050.

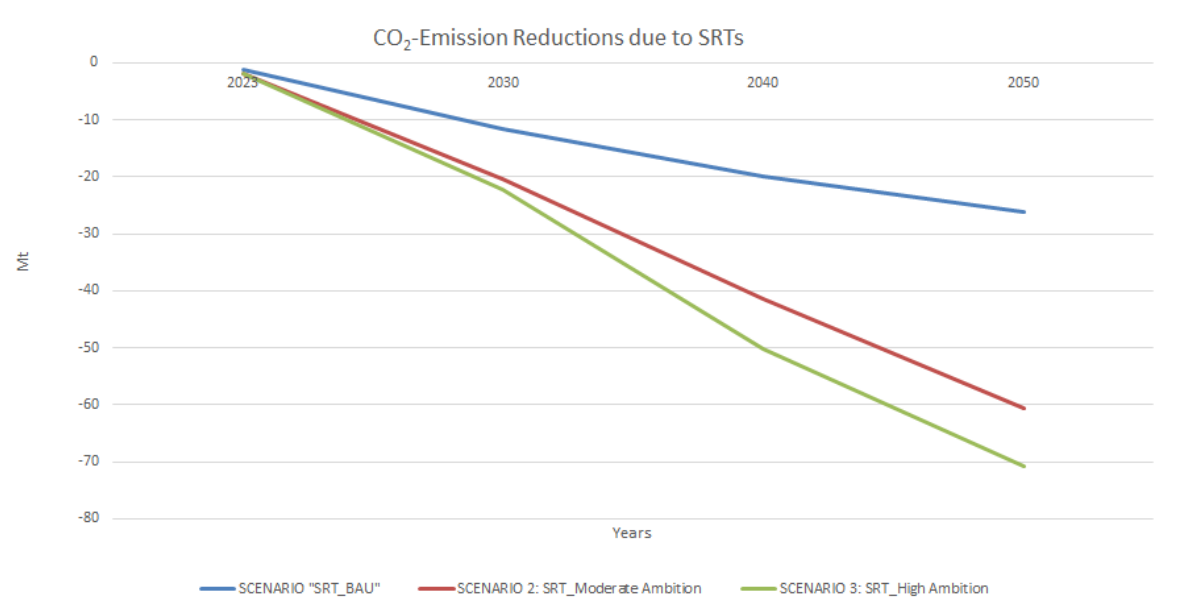


Figure 58 - *CO_2-Emission Reductions due to SRTs by 2050*[76]

The uptake of SRTs also impacts the Demand-Side-Management (DSM) potential. The main opportunities for DSM are EV charging, heat pumps and direct electrical heating (also for hot water) as well as cooling and ventilation in buildings, since they are responsible for most of electricity demand within buildings. This potential has been determined based on the results of recent studies.[77]

The starting point for assessing the DSM potential is an overview of the relevant electricity demand. Table 35 summarizes the total electricity demand of the relevant domains from the building sector pathways for the target years 2023, 2030, 2040 and 2050. As gas-condensing boilers are the main heating systems for replacement in the "Agreed Amendments" building sector pathway, the electricity demand for heating is significantly decreasing, while the electricity for hot water is stable (due to increasing efficiencies of heating systems on the one hand side and at the same time increasing floor areas in the building stock), and cooling and auxiliary electricity is increasing over time. Due to more efficient lighting technologies, the electricity demand for lighting is slightly decreasing over time.

[76] The cumulated effects of all additional SRTs from 2023 to 2050 are shown in this table.
[77] As a total for all buildings types.

Table 35 - Total Electricity demand ("Agreed Amendments" building sector pathway)[78]

TWh/a	2020	2030	2040	2050
heating	233	191	140	88
hot water	47	47	46	44
cooling	38	43	45	47
Aux. El	76	92	96	101
Lighting n-res	258	201	211	221
sum	651	574	539	501

In a next step, this theoretical potential is put into perspective by considering the findings of studies that have analyzed the available DSM potential. An Ecofys study on the "Role of energy efficient buildings in the EUs future power system" [79] determines the increased flexibility potential from using heat pumps in a high efficiency 2050 EU building sector to be about 60 GW. This analysis has been done based on heat-pump control together with a thermal water-storage to optimize the heat-pump usage according to DSM requirements.

Another study for DG ENER by COWI, Ecofys, VITO and Thema[80] gives figures on demand side management potential in all sectors across the EU (Industry, commercial and residential buildings). By 2020 it estimates the total theoretical demand response potential across the EU is 120 GW. If this potential could be fully used for 1h per day it would mean approx. 43 TWh/a of balancing potential, which equates to 6.5% of all electricity demand in buildings by 2020. For 2030 the same study estimates the theoretical potential to be 160GW, which is a factor 1.3 higher than for 2020. The current baseline of DSM potential used is about 23 GW in 2020, which is about 19% of the theoretical potential.

Qualitative aspects regarding health, thermal comfort and life-cycle

This section elaborates on the co-benefits of energy efficiency measures and smart ready technologies (SRTs) regarding health, wellbeing, indoor environment and thermal comfort in a qualitative way. Furthermore, the effects from a life-cycle analysis (LCA) perspective for such measures are discussed and explained in a case-study.
However, given the scope of the project and the stage of development of the SRI, this study concentrates on assessing the benefits in monetary, energy (final and primary) and emissions units. Therefore LCA aspects are not an integral part of this impact assessment modelling and detailed life cycle assessment calculations have not been conducted.

Thermal and indoor environmental comfort

While the comfort aspect is most relevant for all buildings, sub-optimal room temperatures have a direct impact on performance and productivity – which is in the first place relevant for non-residential buildings. Kalz and Pfafferott (2014)[81] describes the thermal comfort requirements and classes of ISO 7730:2005-10. a: "Thermal Comfort and Energy-Efficient Cooling of Nonresidential Buildings".

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[78] Abbreviations: Aux. el = auxiliary electricity (i.e. pumps, fans etc.), n-res = non-residential buildings
[79] Ecofys study "The role of energy efficient buildings in the EUs future power system" for Eurima, 2015.
[80] COWI, Ecofys, VITO and Thema (2016): IMPACT ASSESSMENT STUDY ON DOWNSTREAM FLEXIBILITY, PRICE FLEXIBILITY, DEMAND RESPONSE & SMART METERING.
[81] Springer Briefs in applied sciences and technology, 2014.

Energy efficiency measures and the introduction of SRTs have not only a positive impact on energy and GHG-emission savings, but also contain multiple co-benefits such as improved thermal comfort and indoor environment. The requirements are based on a heat-balance approach and are distinguished into a summer and winter season. Following the ISO 7730 approach, an ideal temperature of 24.5 °C is applicable for the summer season and 22.0 °C for the winter season. The criterion for thermal comfort is stipulated as an average operative room temperature with a tolerance range depending on the percentage of dissatisfied occupants: +/- 1.0, +/- 1.5 and +/- 2.5 °C – representing the comfort classes I, II and III.

In addition to the definition of comfort classes, Zhang el al. (2011)[82] describes the direct correlation between indoor temperature and productivity, see Figure 59. Based on a variety of studies (such as by Wyon), a decrease in performance can be observed above an average room temperature of 26-27°C and below 21°C. Energy efficiency measures but especially smart ready technologies as part of technical buildings systems and building automation and control systems pay an important role in order to keep the indoor temperature within the optimal bandwidth and therefore avoid a decrease in thermal comfort, performance and productivity.

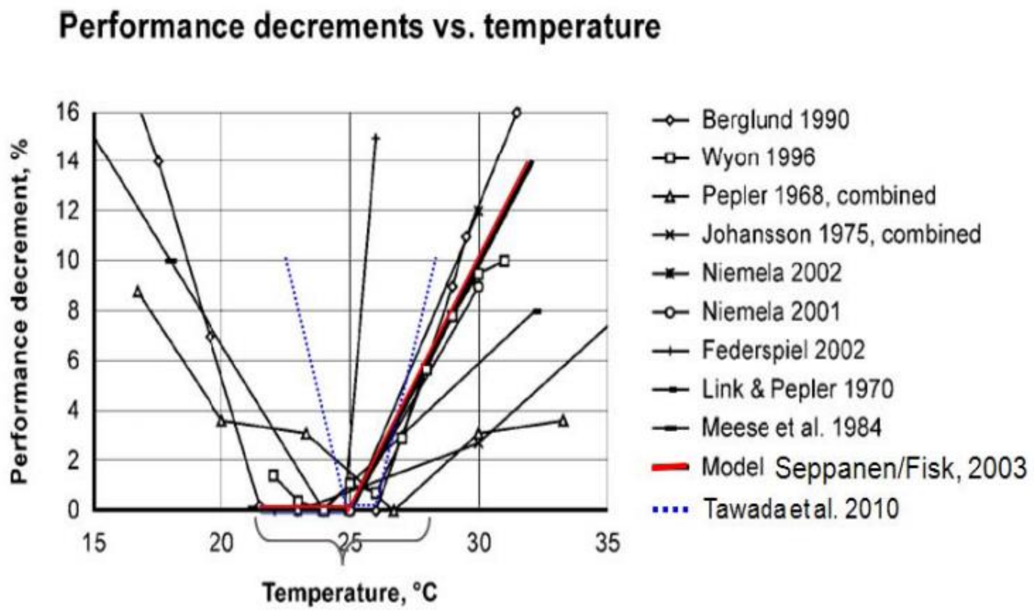


Figure 59 - Summary of studies on the effect of room temperature on decrement of performance and productivity. Source: Zhang el al. 2011: "Air temperature thresholds for indoor comfort and perceived air quality", Building Research & Information (2011) 39(2), 134-144.

[82] "Air temperature thresholds for indoor comfort and perceived air quality". Building Research & Information (2011) 39(2), 134-144.

Life-cycle aspects

This section addresses key questions related to life cycle aspects in the context of this project based on the study "*eco efficiency of heating and storage systems*".[83] As far as possible points of intersection of life cycle aspects and smart buildings are derived. Annex M briefly gives an overall overview and summarizes the importance of life cycle aspects in the context of the building and construction sector.

The consideration of life cycle aspects is important in the context of the smart readiness of buildings. The building sector and related sectors (e.g. construction materials and manufacturing of technical building systems) have a strong impact on the environment. Before, during and after the useful life of a building numerous processes exist in which resources (including energy) are needed.[84]

Worldwide about 40 % of resources and energy consumption, 25% of water consumption and about one third of the global GHG emissions can be allocated to buildings and the construction sector.[85] With the production of about 30% of all anthropogenic solid waste buildings are considered to be one of the biggest causes of waste worldwide.[86] These values stress the relevance of the building and construction sector in relation to environmental pollution worldwide.

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. An increasing improvement of the energy-efficiency of the building and the energy system technologies combined with an increased use of renewable energy sources, will have an effect on the total environmental impacts of buildings: the impact of the building construction and technical building systems will increase in relative terms while the impacts of the operational energy use will decrease.[87]

The above mentioned study analyses life cycle aspects and cost-benefits of heating systems which have been derived from an examination about the eco efficiency of heating and storage systems for the Bavarian Ministry of Environment[88]. The primary objective of the study was to compare environmental and economic performance of various heating and storage systems with eco-efficiency analysis for new and (partly) refurbished buildings. The simplified and holistic evaluation of different heating and storage systems by 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 programs.

The study focuses on a comprehensive view of the various systems over their entire life cycle (i.e., consideration of 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. The influence of the following parameters on the results have been examined:

- the energy performance of the building
- differing levels of hot water consumption
- technology lifetimes

[83] Ecofys, Thinkstep 2017: Eco efficiency analysis
[84] Püschel; Teller; Abramjuk: Umweltgerechte Baustoffe (2013), p. 13
[85] United Nations Enviornment Programme: Sustainable Buildings and Climate Initiative (SBCI) (2016)
[86] Cf. Blumberg: Technische Gebäudeausrüstung (TGA) für Nachhaltige Bauten (2015)

- 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 high eco-efficient technologies respective determine 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 greenhouse gases, other environmental categories such as acidification, eutrophication, particulate matter, toxicity and resource consumption are also included and aggregated via a weighting key (single-score indicator) to allow direct comparability of technologies across all environmental categories.

The results of the study show that during lifetime of a heating system the environmental impact of the utilisation phase is the highest (as illustrated in the graph below). In a new building in passive house standard the utilisation phase of a gas condensing boiler including solar thermal has a share of 71% of CO_2-equivalents (20 years lifetime). For heat pumps this share is even higher and lies between 80-95% (including losses of refrigerant). Based on this it can be derived that smart ready technologies for HVAC systems, such as control and feedback systems, positively affect the impact on the environment by raising energy efficiency based on e.g. 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 of the utilisation phase increases and consequently the impact of smart ready technologies is higher. For partly refurbished (heating system exchange and partly refurbished envelope) and for not refurbished buildings (only heating system exchange) the share of CO_2-equivalents of gas condensing boiler including solar thermal is up to 90%.
However, in terms of smart technologies a right balance between controlling systems and resulting energy consumption need to be found considering various aspects, such as quality of building envelope and heating system but also behavioural aspects of residents.

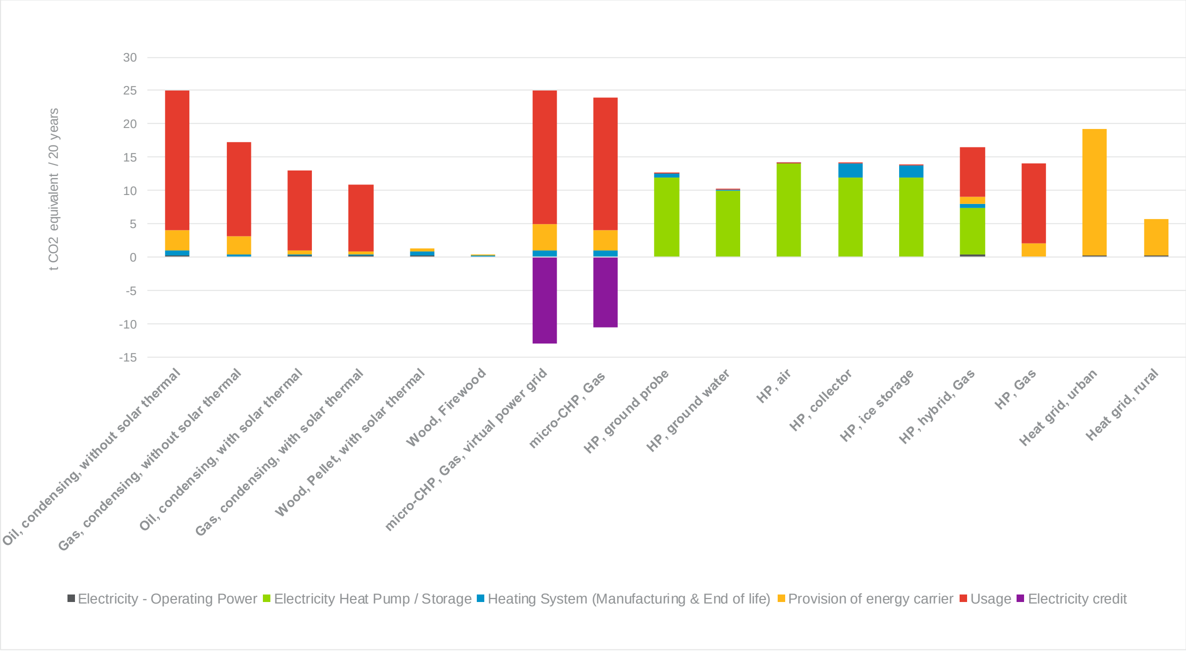


Figure 60 - New Building, comparison of heating systems, GHG excluding domestic electricity. Source: Ecofys, Thinkstep 2017: Eco efficiency analysis

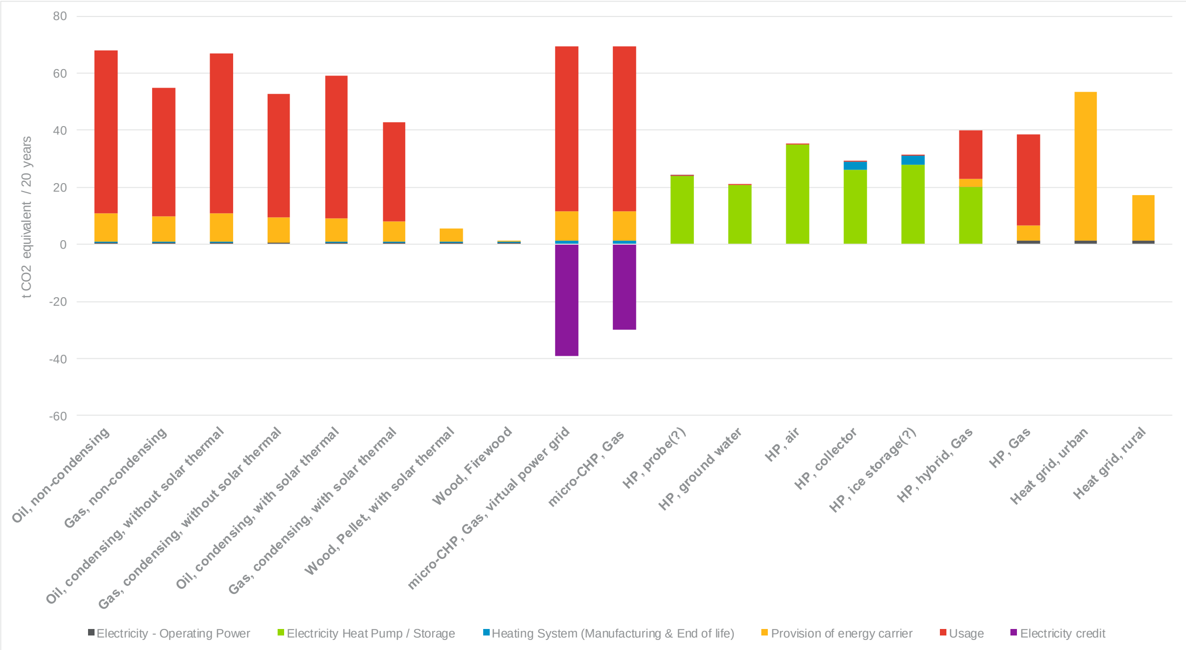


Figure 61 - Partly refurbished buildings, comparison of heating systems, GHG including domestic electricity. Source: Ecofys, Thinkstep 2017: Eco efficiency analysis

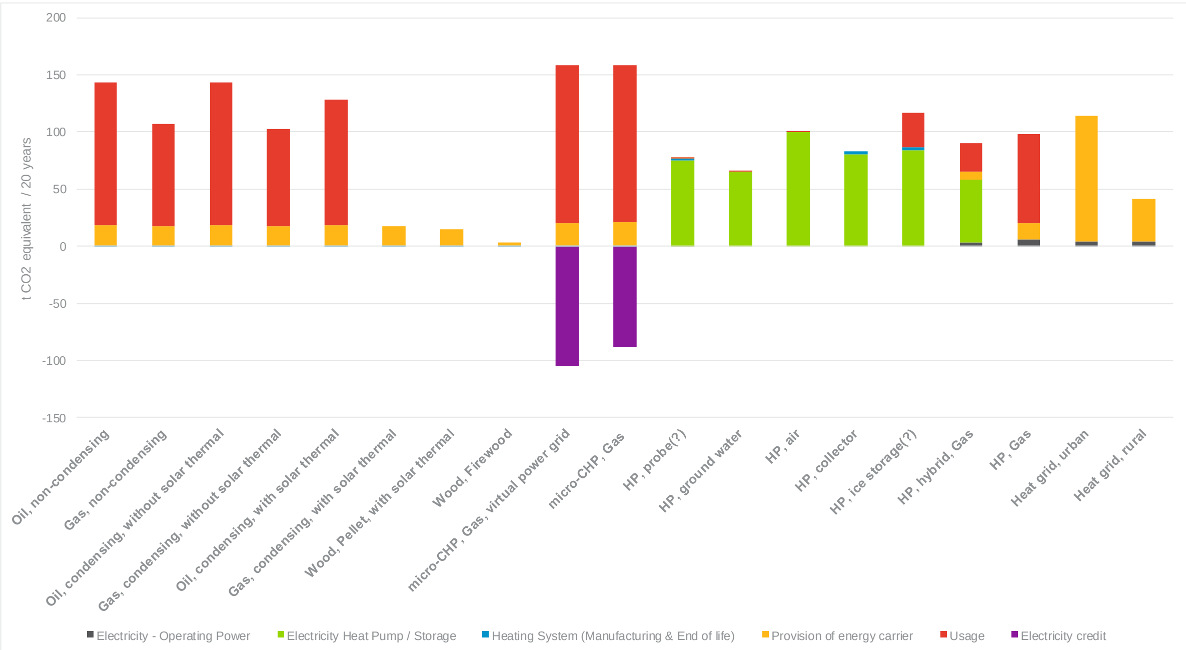


Figure 62 - not refurbished buildings, comparison of heating systems, GHG including domestic electricity. Source: Ecofys, Thinkstep 2017: Eco efficiency analysis

Health aspects

Around 508 million European citizens spend about 90% of their time indoors[89] (living and working). Therefore Europe's buildings have a major impact on Europeans' health.
Studies[90] show that the probability of poor health increases when living in a building with structural/ functional deficiencies such as having indoor temperatures during summer or winter that are too cold or too warm. The results described here also show statistically significant interdependencies between the quality of buildings and general health.

The following graph illustrates that the probability of health issues across EU28 increases 1.7 times when living in buildings with bad thermal comfort in winter. When perceiving overheating during summer the probability increases by 1.4 times. Overall around 22 million Europeans (ca. 4.4%) suffer from bad thermal comfort in winter or summer. By taking into account other deficiencies such as a lack of daylight, dampness, etc. the share increases to nearly 17%, i.e. one out of six European reports living in unhealthy buildings. In some countries, that number is as high as one out of three.[91]

Furthermore, a survey from 2015 and 2016[92] examines several characteristics of a healthy home and the importance for healthy living. In this context, participant were asked to score health categories from 1 to 7 (1 is "not important" and 7 is "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 smart ready technologies contribute to decrease probability of poor health caused by functional deficiencies of the HVAC system or structural deficiencies of the building. In addition it can contribute occupants specific needs to fulfil characteristics of healthy homes. This can be achieved by increasing the level of controllability/ automatization by using indoor environmental quality sensors (regulate temperature, humidity, ventilation, lighting and CO2) to maintain healthy indoor climate conditions and thermal comfort level[93].

[89] Klepeis et al., 2001; NEST, 2004
[90] A. Hermelink & A. John (Ecofys), 2017: The relation between quality of dwelling, socio-economic status and health in EU28 and its Member States; Velux, 2017: Healthy Home Barometer 2017.
[91] ibidem
[92] Healthy Home Barometer 2016 (Velux)
[93] See also case study from S. Chen & J. Huang, 2012: A Smart Green Building: An Envirionmental Health Control Design. Energies, 1648-1663, 2012.

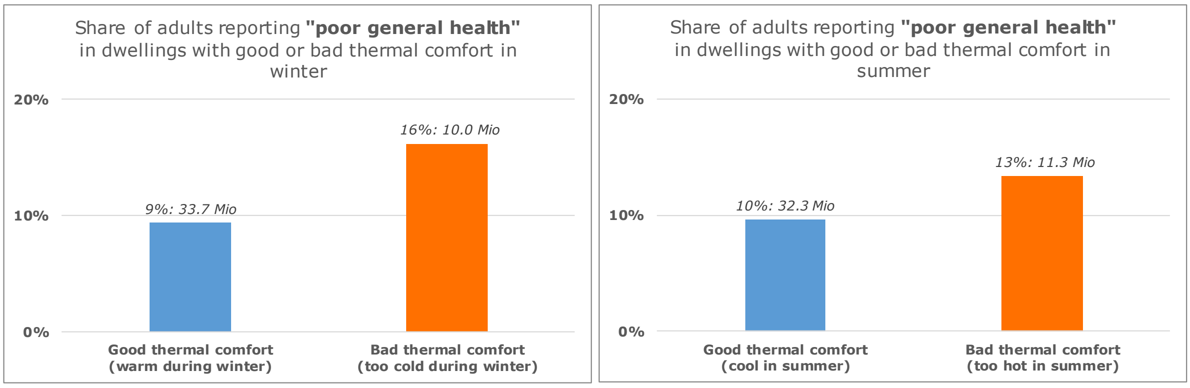


Figure 63 (left) - Share of adults in EU reporting "poor general" when perceiving good or bad thermal comfort in winter. (right) - Share of adults in EU reporting "poor general" when perceiving good or bad thermal comfort in summer. Source: Hermelink & John, 2017 (Ecofys)

5.3.3. SENSITIVITY ANALYSIS AND SRI OPTIONS

This section provides a limited sensitivity analysis regarding the most sensitive parameters like costs of SRTs and their saving potential, but also some specific scenario variations where the SRI is only introduced for a part of the building sector. For this purpose, in option 1 the SRI is only introduced for building above a threshold for the floor area of 1,000 m², while option 2 covers commercial buildings/units only. Option 3 introduces the SRI only in case a mandatory inspection under Art. 14 or 15 of the EPBD is required. Finally, the sensitivity of benefits and costs are addressed with a bandwidth of the underlaying assumptions.

Option 1: Introduction of the SRI for buildings above a 1,000m² floor area threshold only

In case the SRI is only introduced for buildings above 1,000 m² floor area, the scenarios are applied to the respective share of the building stock. In the residential sector only the multi-family houses (MFH) have larger floor areas per building than the threshold. The share of MFH larger than 1,000 m² can be determined form the EPBD Impact Assessment[94] with 31%[95]. Furthermore, the study "Panorama of the European non-residential construction sector"[96] gives the information that 32% of all non-residential buildings are larger than 1,000m², which can be translated into approx. 60% of the non-residential floor area. Taking this share of buildings into account, the final thermal energy savings account to 80 TWh/a by 2050 only in the SRT_Moderate scenario and to 90 TWh/a by 2050 in the SRT_High scenario, while the savings on electricity are about 9 TWh/a in the same timeframe for the SRT_Moderate and 10 TWh/a for the SRT_High scenario, see Figure 64. This leads to the final conclusion, that 3% additional savings in relation to total final energy for heating in 2050 can be realized in the SRT_Moderate scenario and 4% additional savings in the SRT_High scenario.

[94] Ecofys 2016: Ex-ante evaluation and assessment of policy options for the EPBD, Final report for EC DG-ENER
[95] Regarding floor area
[96] "Panorama of the European non-residential construction sector" 2011, Figure 24.

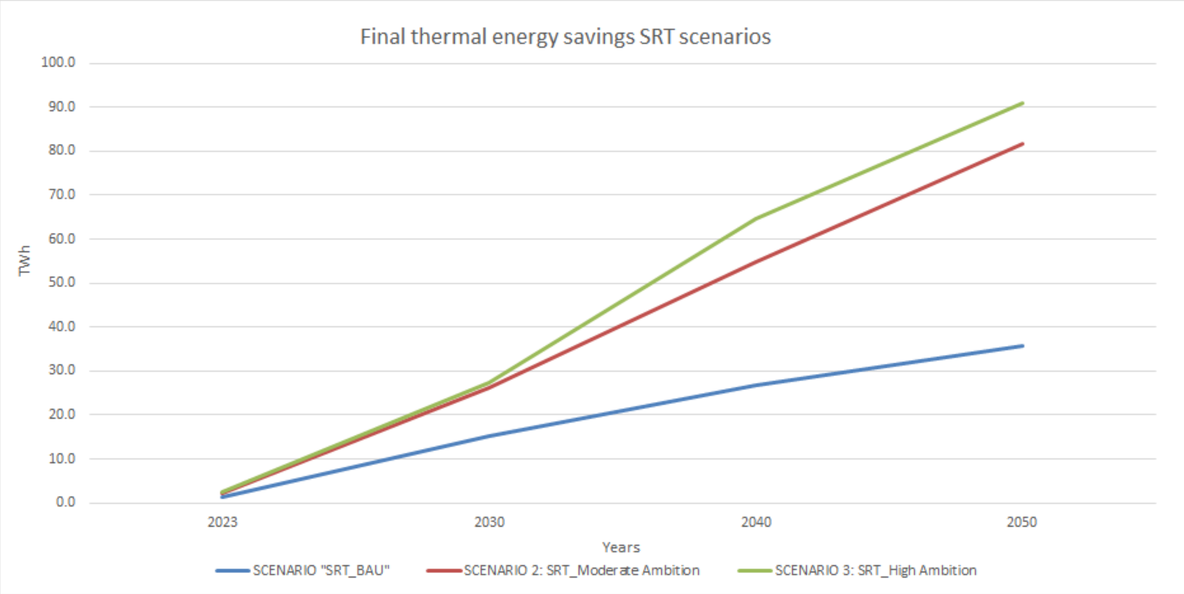


Figure 64 - Final thermal energy savings for buildings with floor area above threshold[97]

Option 2: Introduction of a mandatory SRI for commercial buildings/ units only

Another variation of the SRI is that it is only introduced for commercial buildings and commercial units in mixed-use buildings (residential and non-residential). For this analysis the share of commercial buildings floor area (non-residential buildings without public and educational buildings) is determined by the study "Panorama of the European non-residential construction sector"[98] to 79.2% of the non-residential buildings. Figure 65 shows the SRT effects for that share of buildings only regarding final thermal energy savings. For the SRT_Medium scenario 75 TWh/a are saved on thermal energy and 11 TWh/a on electrical energy, while the SRT_High scenario saves 81 TWh/a on thermal and 12 TWh/a on electrical energy by 2050. In both cases this leads to about 3% additional savings in relation to total final energy for heating in 2050.

[97] The cumulated effects of all additional SRTs from 2023 to 2050 are shown in this table.
[98] "Panorama of the European non-residential construction sector" 2011, Table 14.

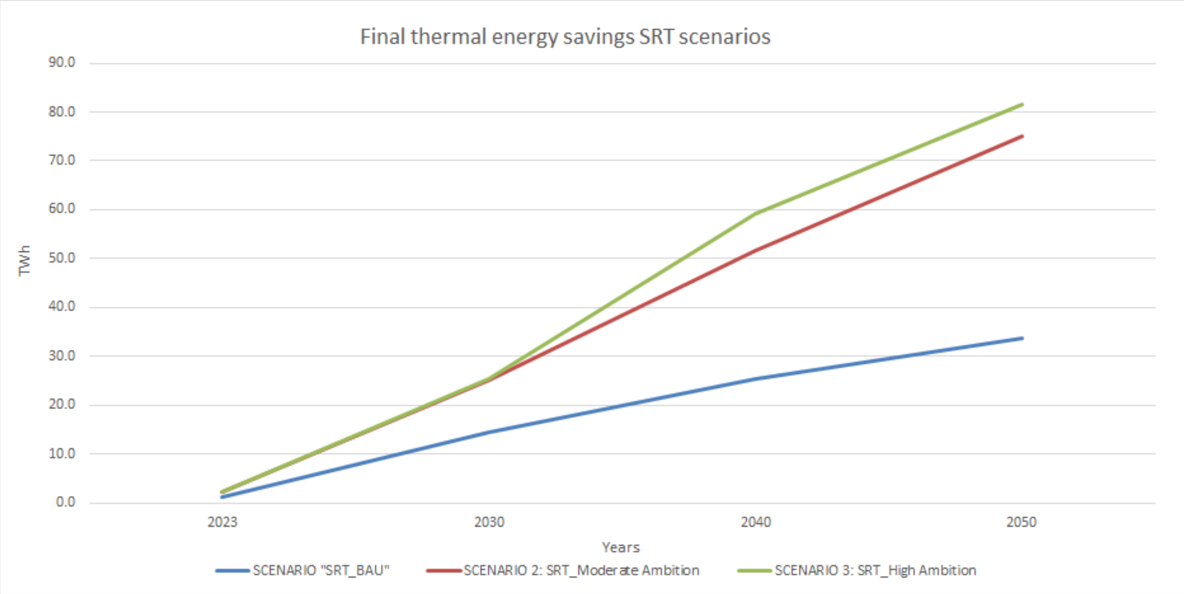


Figure 65 - Final thermal energy savings for commercial buildings and units[99]

Option 3: Introduction of a mandatory SRI for buildings which are subjected to mandatory inspections under Art. 14-15 EPBD

Articles 14 and 15 of the revised EPBD require mandatory regular inspections for heating and ventilation/cooling systems in buildings, if the installed capacity is greater than 70 kW. The analysis of the building types and thermal building systems (TBS) show, that 80% of the large multi-family houses (LMFH) have systems >70 kW in place. Since 31% of all residential floor area is covered by LMFH, in total 25% of residential buildings floor area has systems >70 kW installed. 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. Taking this limitations into account, the SRI has the following effect regarding energy savings, see Figure 66 for final thermal energy savings. In the SRT_Moderate scenario 71 TWh/a on thermal energy and 8 TWh/a on electrical energy can be saved by 2050, while 80 TWh/a on thermal energy and 9 TWh/a on electrical energy can be saved by the SRT_High scenario.

[99] The cumulated effects of all additional SRTs from 2023 to 2050 are shown in this table.

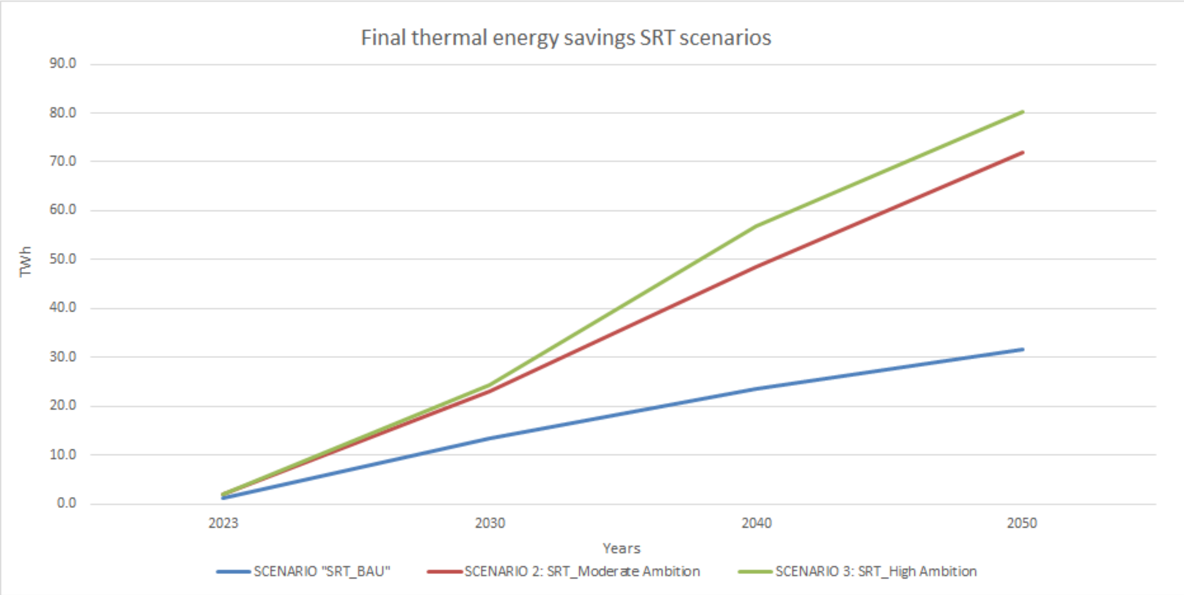


Figure 66 - Final thermal energy savings for buildings with mandatory inspections under Art. 14-15 EPBD [100]

The investment costs of SRTs and the SRT savings are the two most important parameters in the SRT model. Therefore, a sensitivity analysis regarding these parameters is conducted.

Sensitivity 1: Investment costs of SRTs

In order to show the impact of the assumptions on investment costs for SRTs, the following sensitivities to this parameter are applied.

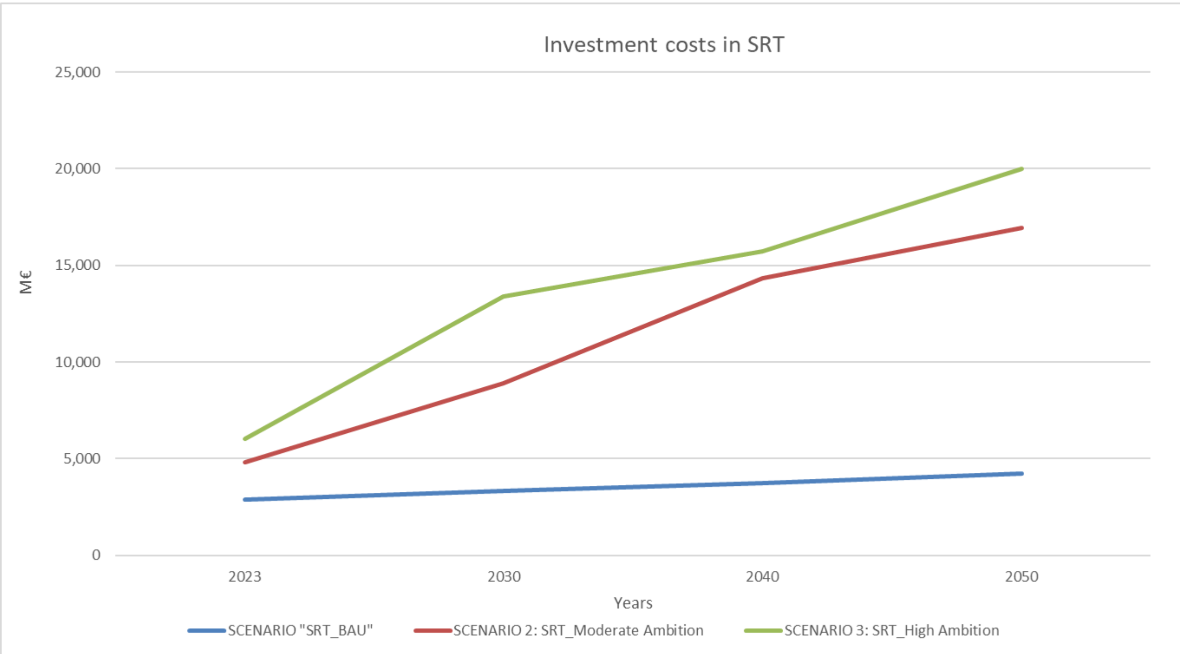


Figure 67 - Investments in SRTs per year for all buildings with a cost increase of 20%

[100] The cumulated effects of all additional SRTs from 2023 to 2050 are shown in this table.

Since the specific investment costs are assumed to be constant in the model, no learning curves and economy of scale effects are included. To show the effect of potentially much lower prices for SRT in the future, the investment costs are decreased by 50% in a first step. Since costs are significantly lower at the same SRT saving potential, the main effect is the decrease of payback times for SRTs.
If on the other hand investment costs are 20% higher than assumed in the main scenarios (in order to show higher costs in the SRT technologies), the total investments increase to a 20% higher level (see Figure 67).

Sensitivity 2: Energy saving potential of SRTs

Apart from investment costs, the findings are very sensitive to the assumptions of the energy savings potentials of SRTs. As higher savings potentials than the default values (which are mostly based on the EU BACS standard EN 15232) are considered to be unlikely, under this sensitivity analysis the savings are decreased by 20% in order to show the potential effects of lower savings per SRT adopted. As a direct effect the final thermal and electricity savings go down by the same proportion, see Figure 68. Furthermore the energy costs savings and CO_2-reductions decrease as well, because they are directly related to the energy savings. Apart from this the indicator €/kWh saved increases to approximately 0.03 €/kWh saved from the default level.

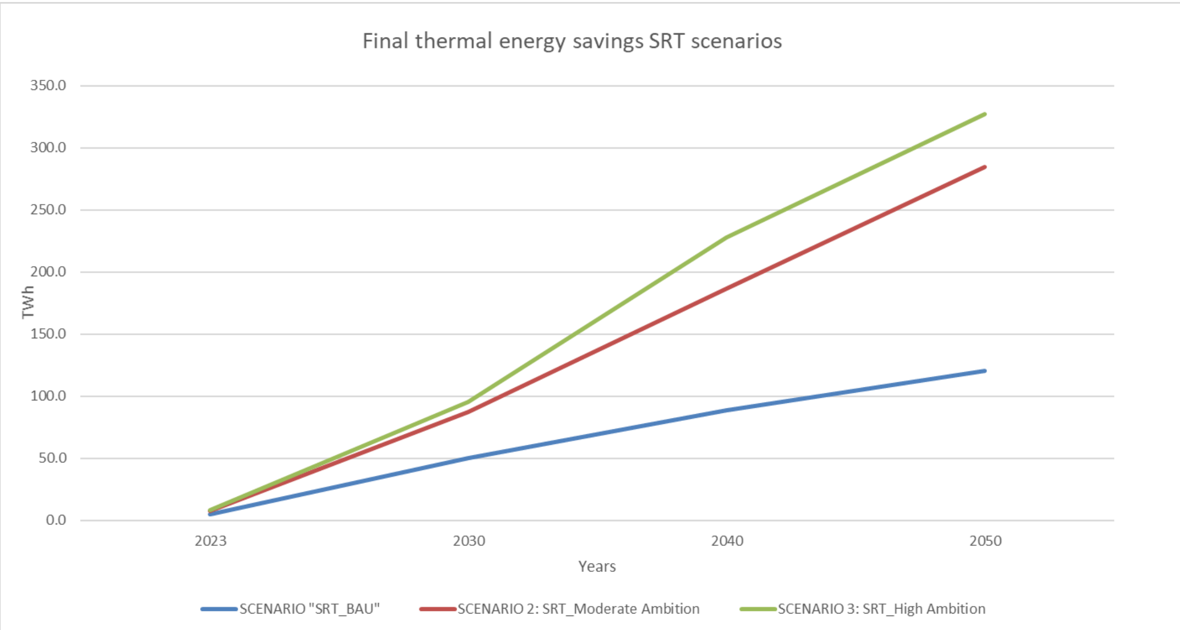


Figure 68 - Final thermal energy savings for all buildings with a decrease in SRT savings of 20% [101]

5.3.4. Policy measures

Public policies, incentives and information campaigns can influence and promote the adoption of energy management and SRTs. The effect of policies could be both on the overall demand for SRTs and on the magnitude of energy savings per SRT adopted. The European legislation in place can already support the deployment of SRT. The effect of the current EU legislation regarding the EPBD is considered under the "business as usual (SRT-BAU)" scenario. Additionally, further measures and

[101] The cumulated effects of all additional SRTs from 2023 to 2050 are shown in this table.

policies can play a levering role for increasing the uptake of SRTs. This second set of measures are considered under the "moderate implementation" and "high implementation" scenarios. The following sections give an overview of the existing policies that may influence the implementation of SRT today and also considers the potential future accompanying measures and policies that could increase demand for SRTs and the magnitude of energy savings per SRT adopted.

Regarding additional policy measures, MS have a number of options to support the implementation and strengthen the impact of the SRI. First, they can promote its adoption by any combination of information and publicity campaigns aimed at building owners and occupants, working with the Technical building systems TBS/smart services domain supply chain to explain the value added of the SRI for their businesses and to encourage the promotion of products and services within its framework, etc. Second, they can provide incentives to support its implementation including training assessors and financially supporting the cost of assessment and any related certification efforts. Third, they can support its integrity by such measures as providing accreditation of service providers, certification of SRI ratings and conducting supporting ex and post ante impact assessments derived from real impact data. Fourth, they can directly stimulate the adoption of SRI ratings through: the provision of incentives to have an SRI assessment; by creating captive demand among certain sectors (e.g. by requiring public buildings to have an SRI assessment, or by promoting its inclusion within Corporate Social Responsibility (CSR) initiatives, etc.); or by making it mandatory (potentially by directly linking it to EPCs). Fifth, they can create incentives to support improvements in SRI ratings which could be aimed at elevated smart service functionalities that align with public policy objectives such as energy and emissions savings. Such incentives could be targeted generally (i.e. as incentives to increase or attain a given SRI score), or they could be aimed at supporting deployment of the most promising SRTs and services, or they could be linked to improved performance for specific SRI domains (e.g. DSM or electric vehicle charging)[102]. Several EU-level policy mechanisms already exist which could be used to promote the SRI including the energy savings and energy efficiency obligations within the EED Article 7 provisions (i.e. if saving obligations are fulfilled using SRTs in the framework of the SRI) or the various articles within the EPBD including those addressing financial support, but also those addressing setting provisions for new TBSs under Article 8.

Similarly, the private sector also has a large role to play in promoting the success of and impact of the SRI. Technology and service providers could position their offerings within its framework and create supply chain alliances that create a critical mass within the market such that the SRI becomes a common language for building smartness. This can help to demystify smart services and products for the public and create a common value and assessment framework that allows offerings to compete on a transparent and equal basis. Such a structure should help consumers/procurers to better understand and value the offers they are being presented with and thereby mitigate a significant barrier to technology uptake and the development of the market. On the demand side – businesses that procure and use smart technologies and services to improve their building stock, productivity and operations can apply the SRI to facilitate their decisions about which smart services/technologies to procure. As mentioned previously it could be interwoven with CSR (Corporate Social Responsibility) objectives but it can also be used to add value to real estate. Among technology and service providers working within specific SRI domains and TBSs there could be agreement to engage with and support the technical specifications within the SRI to ensure it reflects the current state of the art and captures key value propositions. Ideally, the private sector, public

[102] Note, such incentives could be structured more generally but allow the SRI to be a means of demonstrating attainment. They could also be structured in all the traditionally established ways to support technology deployment such as grants, rebates, soft loans, fiscal incentives, pay as you save schemes, etc. Note, MS could choose to fund such incentives and support schemes from general taxation or could create obligations on service providers (such as utilities) to support such schemes.

sector and civil society would work cooperatively to promote and support the SRI so it is a highly effective vehicle to deliver the broad policy objectives. The strength of this cooperation and engagement at the MS and sub-MS level, as well as at the wider EU level, will clearly be a determining factor in its success.

The bandwidth of possible implementations on MS level is shown in the SRT scenarios of this IA. A more detailed description about current but also potential future policy measures is available in Annex N.

5.4. Conclusions of the impact assessment

This chapter summarizes the main findings from the impact assessment on the uptake of Smart Ready Technologies and the Smart Readiness Indicator.

Regarding the underlying EU building sector pathways the final energy demand for heating – as the main indicator for the energy efficiency improvements on building shells and heating systems – is decreasing by 53% in the "*Agreed Amendments*" building sector pathway and 58% in the "Agreed Amendments + Ambitious implementation" pathway from today until 2050, despite a slight increase in total building floor area. 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.

For the Smart Ready Technologies (SRT) scenarios a business-as-usual (SRT_BAU) setup is assumed with constant implementation of SRTs at current level and without the implementation of an SRI. Furthermore, a SRT_Medium and SRT_High scenario are defined, which in addition address the uptake of SRTs due to the implementation of the SRI.

The total thermal energy savings in 2050 are about 150 TWh/a for the SRT_BAU scenario, while the SRT_Medium and SRT_High implementation scenarios show significantly higher savings with approx. 350 TWh/a respectively 420 TWh/a. In addition to that the electrical energy savings increase up to 8 TWh/a by 2050 in the SRT_BAU Scenario and 18 TWh/a respectively 20 TWh/a in the SRT_Medium and SRT_High scenarios. Regarding the investments in SRTs, the SRT_BAU scenario shows a slightly increasing investment level towards 3.5 billion Euro by 2050, the SRT_High scenario shows yearly investments of about 16.6 billion Euro by 2050. In relation to the energy savings obtained with the SRTs lead this to specific energy savings costs of about 0,02-0,04 Euro per kWh saved[103]. These additional investments lead to additional jobs of about 80,000 by 2030 for the SRT_Medium scenario and 140,000 additional jobs for the SRT_High scenario. By 2050 these numbers increase to 170,000 respectively 210,000 additional new jobs. The energy cost savings for the SRT_BAU scenario decline from about 460 to 270 million Euro per year due to decreasing efficiency potentials, while the SRT_Moderate an SRT_High scenario rank between 800 and 1,200 Million Euro energy cost savings per year. Compared to the yearly investments from above, a static payback period between 2-6 years can be calculated. Regarding CO_2-emissions, the SRT_BAU scenario shows emission reduction by 26 Mt/a until 2050 compared to today's level, while the two other scenarios lead to significantly higher savings. For the SRT_High scenario the total CO_2-emission level can be lower by 70 Mt/a until 2050.

A sensitivity analysis shows, that approx. 20% of the energy savings could be obtained only if the SRI would be introduced for buildings above a threshold of 1,000m² floor area. Roughly the same effect would occur, if the SRI would be introduced for commercial buildings and units only, or if it would be applicable for buildings only that need to conduct mandatory regular inspections of heating and ventilation/cooling systems under Article 14 an 15 of the revised EPBD.

This analysis clearly shows, that the SRI would have a much higher impact if all buildings would be addressed and not only a certain share.

[103] Assumption: SRT lifetime 20 years and static calculation (reference: German standard VDI 2067)

The sensitivity analysis furthermore shows, that the impact of the assumptions made on investment costs for SRTs is significant.

For DSM measures the effect in the market is derived from other studies. The increased flexibility potential of running heat pumps in a high efficiency 2050 EU building sector is estimated to be about 60 GW[104], while another study[105] estimates the total theoretical demand response potential in 2020 (including buildings and industry) to be 120 GW. If this potential could be fully used for 1h per day it would mean approx. 43 TWh/a balancing potential, which equates to 6.5% of all electricity demand in buildings in 2020. For 2030 the same study estimates the theoretical potential at 160GW, which is a factor of 1.3 higher than for 2020.

[104] Ecofys study “The role of energy efficient buildings in the EUs future power system” for Eurima, 2015.
[105] Table 5-1 from “IMPACT ASSESSMENT STUDY ON DOWNSTREAM FLEXIBILITY, PRICE FLEXIBILITY, DEMAND RESPONSE & SMART METERING, EC DG-ENER July 2016

CHAPTER 6 CONCLUSIONS

This final report provides an overview of the work carried out in the project that supports EC DG Energy in setting up a Smart Readiness Indicator for buildings.

Task 1 has provided definitions and a taxonomy to define smart ready services and their impacts. This led to the development of a catalogue of smart ready services for buildings. These services are focusing on optimization, interaction with occupants and interoperability and interaction with the energy grid. In the taxonomy, the services are grouped into 11 main domains. The identified domains cover Heating, Cooling, Domestic Hot Water, Mechanical Ventilation, Lighting, Dynamic Building Envelope, Local Energy Generation, Demand Side Management, Electric Vehicle Charging, Monitoring and Control, and Various.
For each of the services in the catalogue, one or more functionality levels are defined and an indicative assessment of their impacts have been made. The impacts that are assessed cover energy savings on site, flexibility for the energy grid and storage, self-generation of energy, comfort, convenience, well-being and health, maintenance and fault prediction, and information provided to the occupant. The indicative impacts of each of the functionality levels of the smart ready services are assessed on a seven-level scale, based on either information from standards, stakeholders and market knowledge. The catalogue has been developed in an interative way and was updated for this final report to reflect comments from stakeholders and evolving insights.

Task 2 has developed a harmonized methodology to calculate the smart readiness indicator. The generic methodology is found to work well on a theoretical level and to meet all the requirements for the methodology. However, using the full Task 1 catalogue of services would require too many services to be assessed to be viable in practice and many services are both challenging to assess and would have low credibility. Therefore, options to streamline the methodology by rationalising the services have been examined. This leads to the derivation of a streamlined SRI methodology that uses a consolidated set of 52 services which are actionable now and are have reasonable confidence in their ability to be assessed and their attribution of impacts to functional levels. This streamlined methodology is tested against two building cases studies – a single family home and an office.
The time taken to conduct assessments using the streamlined method is found to be similar to the time it takes to conduct EPC assessments in many countries. The methodology is modular and flexible which means it can be tailored to local and building specific contexts. It can also be used in ways that accommodate innovation in service offerings and functionalities. The method is informed by many considerations including the target audience and the information to be reported and is shown to be able to reflect their priorities and needs. The flexibility of the methodology permits variation in implementation according to the local needs and circumstances; however, it still applies a harmonised framework.

Task 3 deals with the interaction with stakeholders. A public website and various meetings have been set up to provide information and source valuable feedback. This feedback has fed the development of the other tasks in this project.

The **task 4** impact assessment analysed the benefits and costs of implementing a Smart Readiness Indicator (SRI) in buildings to support an increased uptake of Smart Ready Technologies (SRTs) in buildings in the EU. It also aimed to understand the impact of accompanying policies to enhance the impact of the SRI. The methodology in the framework of this study is split into two steps. The first part focuses on the modelling of the evolution of the EU building stock within the framework of the revised EPBD: the 'building sector pathways'. In the second part the effects of an uptake of smart Ready Technologies (SRTs) and the SRI are modelled: the 'SRT uptake scenarios'.
As conclusions for the Smart Ready Technologies (SRT) scenarios a business-as-usual (SRT_BAU) setup is assumed with constant implementation of SRTs at current level and without the implementation of an SRI. Furthermore, a SRT_Medium and SRT_High scenario are defined, which in addition address the uptake of SRTs due to the implementation of the SRI. The total thermal energy savings in 2050 are about 150 TWh/a for the SRT_BAU scenario, while the SRT_Medium and SRT_High implementation scenarios show significantly higher savings with approx. 350 TWh/a respectively 420 TWh/a. In addition to that the electrical energy savings increase up to 8 TWh/a by 2050 in the SRT_BAU Scenario and 18 TWh/a respectively 20 TWh/a in the SRT_Medium and SRT_High scenarios. Regarding the investments in SRTs, the SRT_BAU scenario shows a slightly increasing investment level towards 3.5 billion Euro by 2050, the SRT_High scenario shows yearly investments of about 16.6 billion Euro by 2050. In relation to the energy savings obtained with the SRTs lead this to specific energy savings costs of about 0,02-0,04 Euro per kWh saved[106]. These additional investments lead to additional jobs of about 80,000 by 2030 for the SRT_Medium scenario and 140,000 additional jobs for the SRT_High scenario. By 2050 these numbers increase to 170,000 respectively 210,000 additional new jobs. The energy cost savings for the SRT_BAU scenario decline from about 460 to 270 million Euro per year due to decreasing efficiency potentials, while the SRT_Moderate an SRT_High scenario rank between 800 and 1,200 Million Euro energy cost savings per year. Regarding CO_2-emissions, the SRT_BAU scenario shows emission reduction by 26 Mt/a until 2050 compared to today's level, while the two other scenarios lead to significantly higher savings. For the SRT_High scenario the total CO_2-emission level can be lower by 70 Mt/a until 2050.

[106] Assumption: SRT lifetime 20 years and static calculation (reference: German standard VDI 2067)

CHAPTER 7 ANNEXES

- Annex A: Smart Ready Services catalogue (Excel file)
- Annex B: Glossary
- Annex C: Interoperability of smart ready technologies
- Annex D: Standardisation related to smart buildings
- Annex E: Hype Cycles to assess maturity of services
- Annex F: Review of applicability of services for inclusion in SRI
- Annex G: An Actionable Subset of Smart Readiness Elements (Excel file)
- Annex H: Multi criteria decision making methods
- Annex I: Calculation process details for the in-field Single Family Home case study
- Annex J: Summary of stakeholder main comments
- Annex K: The built-environment-analysis-model $BEAM^2$
- Annex L: Building sector scenarios – assumptions and detailed results
- Annex M: SRT Scenarios – Detailed Assumptions
- Annex N: Current and additional accompanying policies
- Annex O: Reference list

ANNEX A - THE SMART READY SERVICES CATALOGUE

For reasons of readability as well as complexity, the service catalogue is distributed as accompanying Excel spreadsheet.

The table below provides an excerpt of the smart ready services catalogue with the domains, service coding and names and indication whether the services are part of the proposed simplified SRI methodology.

Table A 1 - Excerpt of the smart ready services catalogue

Domain	Code	Smart ready service	Part of the proposed simplified indicator
Heating	Heating-1a	Heat emission control	yes
Heating	Heating-1b	Emission control for TABS (heating mode)	yes
Heating	Heating-1c	Control of distribution fluid temperature (supply or return air flow or water flow) - Similar function can be applied to the control of direct electric heating networks	yes
Heating	Heating-1d	Control of distribution pumps in networks	yes
Heating	Heating-1e	Intermittent control of emission and/or distribution - One controller can control different rooms/zones having same occupancy patterns	yes
Heating	Heating-1f	Thermal Energy Storage (TES) for building heating (excluding TABS)	yes
Heating	Heating-1g	Building preheating control	yes
Heating	Heating-2a	Heat generator control (for combustion and district heating)	yes
Heating	Heating-2b	Heat generator control (for heat pumps)	yes
Heating	Heating-2c	Sequencing of different heat generators	yes
Heating	Heating-2d	Heat system control according to external signal (e.g. electricity tariff, gas pricing, load shedding signal etc.)	no
Heating	Heating-2e	Control of on-site waste heat recovery fed into the heating system (e.g. excess heat from data centers)	no
Heating	Heating-3	Report information regarding HEATING system performance	yes
Domestic hot water	DHW-1a	Control of DHW storage charging (with direct electric heating or integrated electric heat pump)	yes
Domestic hot water	DHW-1b	Control of DHW storage charging (using hot water generation)	yes
Domestic hot water	DHW-1c	Control of DHW storage temperature, varying seasonally: with heat generation or integrated electric heating	no

Domestic hot water	DHW-1d	Control of DHW storage charging (with solar collector and supplymentary heat generation)	yes
Domestic hot water	DHW-2	Control of DHW circulation pump	no
Domestic hot water	DHW-3	Report information regarding domestic hot water performance	yes
Cooling	Cooling-1a	Cooling emission control	yes
Cooling	Cooling-1b	Emission control for TABS (cooling mode)	yes
Cooling	Cooling-1c	Control of distribution network chilled water temperature (supply or return)	yes
Cooling	Cooling-1d	Control of distribution pumps in networks	yes
Cooling	Cooling-1e	Intermittent control of emission and/or distribution	yes
Cooling	Cooling-1f	Interlock between heating and cooling control of emission and/or distribution	yes
Cooling	Cooling-1g	Control of Thermal Energy Storage (TES) operation	yes
Cooling	Cooling-2a	Generator control for cooling	yes
Cooling	Cooling-2b	Sequencing of different cooling generators	yes
Cooling	Cooling-3	Report information regarding cooling system performance	Yes
Controlled ventilation	Ventilation-1a	Supply air flow control at the room level	yes
Controlled ventilation	Ventilation-1b	Adjust the outdoor air flow rate	yes
Controlled ventilation	Ventilation-1c	Air flow or pressure control at the air handler level	yes
Controlled ventilation	Ventilation-2a	Room air temp. control (all-air systems)	yes
Controlled ventilation	Ventilation-2b	Room air temp. control (Combined air-water systems)	no
Controlled ventilation	Ventilation-2c	Heat recovery control: prevention of overheating	yes
Controlled ventilation	Ventilation-2d	Supply air temperature control	yes
Controlled ventilation	Ventilation-3	Free cooling with mechanical ventilation system	yes
Controlled ventilation	Ventilation-4	Heat recovery control: icing protection	no
Controlled ventilation	Ventilation-5	Humidity control	no
Controlled ventilation	Ventilation-6	Reporting information regarding IAQ	yes
Lighting	Lighting-1a	Occupancy control for indoor lighting	yes
LIghting	Lighting-1b	Mood and time based control of lighting in buildings	no
Lighting	Lighting-2	Control artificial lighting power based on daylight levels	yes
Dynamic building envelope	DE-1	Window solar shading control	yes
Dynamic building envelope	DE-2	Window open/closed control, combined with HVAC system	yes
Dynamic building envelope	DE-3	Changing window spectral properties	no
Energy generation	EG-1	Amount of on-site renewable energy generation	no

Energy generation	EG-2	Reporting information regarding energy generation	yes
Energy generation	EG-3	Storage of locally generated energy	yes
Energy generation	EG-4	Optimizing self-consumption of locally generated energy	yes
Energy generation	EG-5	CHP control	yes
Demand side management	DSM-1	Services for integration of renewables into the building energy portfolio	no
Demand side management	DSM-2	Services for integrating battery storage systems into energy portfolio	no
Demand side management	DSM-3	Support of microgrid operation modes	no
Demand side management	DSM-4	Integration of smart appliances	no
Demand side management	DSM-5	Power flows measurement and communications	no
Demand side management	DSM-6	Energy delivery KPI tracking and calculation	no
Demand side management	DSM-7	Fault location and detection	no
Demand side management	DSM-8	Fault prevention and risk assessment	no
Demand side management	DSM-9	Fraud detection and losses calculation	no
Demand side management	DSM-10	Neighbourhood energy efficiency calculation	no
Demand side management	DSM-11	Demand prediction	no
Demand side management	DSM-12	Information exchange on renewables generation prediction	no
Demand side management	DSM-13	Heat management for a multi-tenant house by aggregator	no
Demand side management	DSM-14	Flexible start and switch off of home appliances	no
Demand side management	DSM-15	DSM control of a device by an aggregator	no
Demand side management	DSM-17	Energy storage penetration prediction	no
Demand side management	DSM-18	Smart Grid Integration	yes
Demand side management	DSM-19	DSM control of equipment	yes
Demand side management	DSM-20	Connecting PV to DSO grid	no
Demand side management	DSM-21	Reporting information regarding DSM	yes
Demand side management	DSM-22	Override of DSM control	yes
Electric vehicle charging	EV-1	Charging whenever needed at the charging pole of the building ("dumb charging service")	no
Electric vehicle charging	EV-3	Charging with local, building system based control (price signal based charging)	no

Electric vehicle charging	EV-4	Charging with aggregated control (EV responsible party as VPP balancing responsible party)	no
Electric vehicle charging	EV-5	Charging with aggregated control (EV resposible party under a balance responsible party)	no
Electric vehicle charging	EV-7	Grid connected heating for EV in winter time	no
Electric vehicle charging	EV-8	Providing system services to DSO operations	no
Electric vehicle charging	EV-9	Charging for optimisation of the EV battery life-cycle	no
Electric vehicle charging	EV-10	Charging at a commercial building site - roaming	no
Electric vehicle charging	EV-11	Charging based on DSO price tags - " local wind storage"	no
Electric vehicle charging	EV-12	Providing the state-of-charge to home display	no
Electric vehicle charging	EV-13	Fast charging services - mode 4	no
Electric vehicle charging	EV-14	Vehicle to grid operation and control	no
Electric vehicle charging	EV-15	EV Charging Capacity	yes
Electric vehicle charging	EV-16	EV Charging Grid balancing	yes
Electric vehicle charging	EV-17	EV charging information and connectivity	yes
Monitoring and control	MC-1	Heating and cooling set point management	no
Monitoring and control	MC-2	Control of thermal exchanges	no
Monitoring and control	MC-3	Run time management of HVAC systems	yes
Monitoring and control	MC-4	Detecting faults of technical building systems and providing support to the diagnosis of these faults	yes
Monitoring and control	MC-5	Reporting information regarding current energy consumption	no
Monitoring and control	MC-6	Reporting information regarding historical energy consumption	no
Monitoring and control	MC-7	Reporting information regarding predicted energy consumption	no
Monitoring and control	MC-9	Occupancy detection: connected services	yes
Monitoring and control	MC-10	Occupancy detection: space and activity	no
Monitoring and control	MC-11	Remote surveillance of building behaviour	no
Monitoring and control	MC-12	Central off-switch for appliances at home	no
Monitoring and control	MC-13	Central reporting of TBS performance and energy use	yes
Various	VA-1	Coming home - leaving home functions	no

Various	VA-2	Inactivity recognition services	no
Various	VA-3	Multi-tenant access control for buildings without keys	no
Various	VA-4	Occupants Wellbeing and health status monitoring services	no
Various	VA-5	Dementia monitoring	no
Various	VA-8	Rain water Collection	no
Various	VA-9	Smoke detection	no
Various	VA-10	Water leakage detection	no
Various	VA-11	Carbon Monoxide detecion	no
Various	VA-12	Emergency notification services	no
Various	VA-13	Smart testing of emergency lighting	no
Various	VA-14	Intelligent alerting on building events	no
Various	VA-18	Energy Cost Allocation for heating, cooling and water	no
Various	VA-19	Lifts and elevators: Control and dispatching	no
Various	VA-20	Lift and elevator monitoring and maintenance	no
Various	VA-21	Lift and elevator energy recovery management	no

ANNEX B – 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.

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 Climate, heating, lighting, DSM, DER 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.

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 refers to the capability of a building or its systems to sense, interpret, communicate and actively respond in an efficient manner to the changing conditions, which are introduced by demands of the building occupant, the operation of technical building systems or the external environment (including energy grids).

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. Regarding the term smart, we consider certain capabilities as smart – focusing on optimization, interaction with occupants and being interoperable and adaptive.

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.

An example would be the following: Using an application, e.g. on a mobile phone, the user invokes the activation of a wireless protocol-based controlled light-bulb as a comfort function. This is either a micro service or a single function. In order to activate one or more light bulbs when arriving at home, the user can use the mobile in order to get the perimeter trigger of e.g. the front door, which then activates the predefined light scene. This can be considered a service since it is based on individual, more atomic functions which are composed to a service which provides more added value.

Another example dealing with the EV Charger at a home would be a service dealing with the charging of a car. The user needs to go 20 km to work the next day starting at 6AM and arrive at home at 7PM and connects the car to the charging station. The service calculates the optimum charging process, schedule and pricing and charges the vehicle according to the boundary conditions set by the user.

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 under Article 2(3), a 'technical building system' is defined as a technical equipment for the heating, cooling, ventilation, hot water, lighting or for a combination thereof, of a building or building unit. In the proposal for amending the EPBD, this definition is extended to building automation and control, on-site electricity generation and on-site infrastructure for electro-mobility. In this study this definition is extended to a broader scope, taking the connection of the building to the other infrastructures like electricity, water, waste water, etc. more into account.

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 C – INTEROPERABILITY OF SMART READY TECHNOLOGIES

As discussed in section 2.4.3, interoperability of smart ready technologies is crucial for many of the smart services in a building and to prevent vendor-lock-in effects. Interoperability requires the establishment of a common shared information model that is to be used throughout many applications and systems.

Typically, one has to distinguish between various levels of interoperability which will be discussed in the next paragraphs. Assessing interoperability by metrics is not completely new in the context of the Smart Readiness Indicator. As early as in the 1980s, this has been defined as a problem by the EC[107]. First, this was only treated as a problem from the perspective of team working on code for a common software or system towards a common goal (e.g. shared functionality). The focus was on easily integrating parts and components. Later, it became apparent that systems from various vendors with no common development unit would have to interact [2]. Typically, interoperability is defined as the ability of one or more systems or elements to exchange information and to use the information that has been exchanged. One has typically to distinguish between four high level requirements for interoperability:

- Technical interoperability
- Syntactic interoperability
- Semantic interoperability
- Organizational interoperability

Technical interoperability in the context of the SRI would focus on the hardware as well as software, plug-ins being compatible, the same protocols being used, platforms for M2M communications with back-end systems.
As the system on a building is assessed at run-time this can typically be taken as given, since the system is operational at that time being. Nevertheless, technical interoperability might still be critical if the TBS are to be expanded, especially in case this is done with components form another vendor.

Syntactic interoperability focuses on the data formats, while CSV based or XML based data still has the same format, parts may be missing in a payload or be optional. For the SRI, there might be information missing on some aspects of controls to be deployed. This shall not occur for a given, running system but the extension this will be a problem.

The dimension of **semantic interoperability** focuses on the interpretation of the data, meaning the same signal triggers a correct event or the data is interpreted the same by systems from different vendors. A common understanding is needed, therefore, it is hard to actually assess this at the SRI inspection time. However, this aspect was taken into account when creating the basic structure of the service catalogue. The service catalogue is based to large parts on harmonized, existing taxonomies as already presented in the task 1 section. One specific taxonomy, which was taken into account, was SAREF. The SAREF ontology presents a controlled vocabulary and concepts, which define semantics. For this study, we have taken into account the main SAREF ontology as well as the Smart Appliances and SEP2 ontology[108].

[107] https://ec.europa.eu/isa2/eif_en, [4]
[108] https://sites.google.com/site/smartappliancesproject/ontologies/reference-ontology

The last dimension, **organizational interoperability** deals cross company, cross region and culture interpretation of the data, mostly, e.g. in the same context. Given the time before the GDPR, different organizations had different right and laws to treat personal data (e.g. with a data center in the US). This harmonization of the system context leads to a better organizational interoperability in long term [Rezaei et al., 2013].

In the scope of SRI, many of there factors are too hard to be measured at inspection time by a non-system savvy technician from a third party. If interoperability metrics were to be introduced in SRI, a focus should therefore primarily be on the dimensions of technical and syntactical interoperability. A hypothetical analysis of such interoperability would require investigating multiple factors, such as: [Kasuni, 2001]:

- Standards explicitness
- Standards maturity
- Standards vendors supporting
- Standards feature coverage
- Standards profiles implemented
- Profile explicitness
- Profile coverage
- Profile extensions
- Profile documentation
- Products available supporting
- Product performance
- Supported platforms
- Conformance testing in place
- Product -2- Product Interoperability tests

As it is obvious from the extensive list presented here, assessing the interoperability of systems in a building environment requires an elaborate assessment procedure in itself. Typically, we assume this was done at engineering or construction time of a building, taking into account most factors from the previous list. After all, this contributes to a maintainable technical solution with better lifecycle costs.

For a very quick assessment at inspection time, the focus should be on long-term support and standardization, thus, the factors:

- Standards explicitness
- Standards maturity
- Profile extensions
- Products available supporting
- Conformance testing

Those five categories could be a base for a (very simple) interoperability indicator to assess solutions in the context of the Smart readiness indicator. In the context of the European Interoperability Framework (EIF) which deals with government to government and government to citizen data interoperability, the very same categories were taken into account by the European commission [Section 3.3 to 3.6, European Interoperability Framework EIF, 2017]. Nevertheless, even such simplified interoperability indicator would require significant time and effort, especially in existing buildings with poorly documented TBS. Therefore, it was opted to not explicitly assess the interoperability of smart ready technologies, but rather take this into account in some specific services of the proposed SRI (see section 2.4.3 of this report).

ANNEX D – STANDARDISATION RELATED TO SMART BUILDINGS

D.1. 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. At the time that this report was first written (July 2017), 35 different national and regional methodologies to calculate the energy performance of buildings were available. 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.

The new/reviewed EPBD standards within M/480 became available recently (July 2017), complementary to these standards is an online tool that guides the user through the set of standards (CEN, 2017). For the reader it is also important to understand that a modular EPBD EN standard system has been introduced and some EN standards were renumbered at ISO level, as a consequence some EN standards may have new references as of 2017 and not necessarily all possible modules are already covered by a standard. Also EN EPBD standards use numbers 15xxx and ISO 52xxx. For example, former standard EN 13790-1:2003 is replaced by EN ISO 52016-1.

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.

At the current state of the project it is not decided to what extent the SRI will be making a connection to the EPBD, and especially EPCs (Energy Performance Certificates). If such a connection is deemed relevant, several approaches can be envisioned to deal with this current diversity amongst member states. This will be further explored as part of the work undertaken in Task 2 of this project.

D.2. 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[109] will build upon those results.

D.3. 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.4. 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 are:

- 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.

[109] http://www.etip-snet.eu/

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[110].

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.

An overview of relevant Technical Committees within CEN, CENELEC and ETSI is included in TBD.
A National Standard at Member State level, A DIN-EN or AFNOR-EN, etc. is a national standard. It is published as each country in Europe adopts the EN document.

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

D.5. A SELECTION OF THE MOST RELEVANT STANDARDS FOR SRI

D.5.1. 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

[110] http://www.etsi.org/technologies-clusters/technologies/575-smart-grids

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[111].

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 D1.

[111] https://isolutions.iso.org/ecom/public/nen/Livelink/open/35102456

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													

Table D1 - Summary of the main modular structure of the EPB Standards

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.

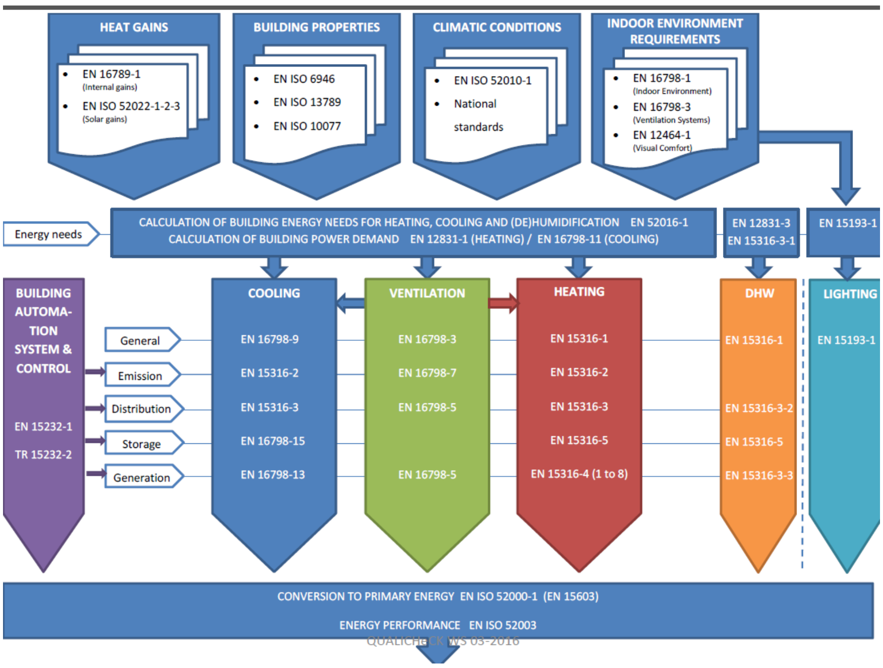


Figure D1 - Overview of applicable standards in the ongoing review of EPB (Jaap, 2016)

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 1 — *(concluded)*

		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								

Figure D2 - Table 1 on lighting controls defined in EN 15232

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[112].

EN 16947-1:2017 Building Management System - Module M10-12
This is a new European Standard to address the TBM/BMS functions. This new 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.

[112] https://isolutions.iso.org/ecom/public/nen/Livelink/open/35102456

- 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.
- 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. Nevertheless, an SRI could consider this and attempt to model impact based on sensitivity analysis on these user parameters, *but up to our knowledge a data set for this is not available.*

D.5.2. Examples of implementation of EPBD calculation methods at Member State level

As mentioned before, the implementation of EPBD calculation methods is still very different per 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.

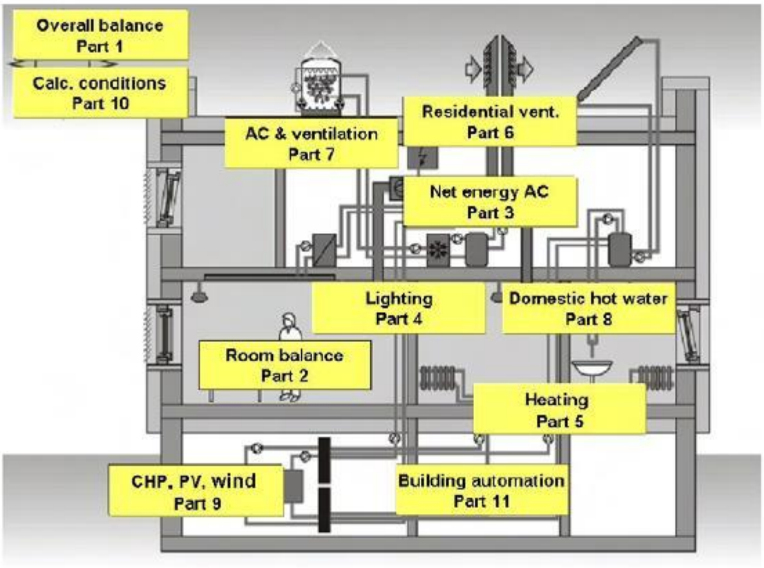


Figure D3 - Structure of German EPBD calculation standard DIN V 18599 Important EN product and/or smart building system standards

D.5.3. 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 new 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.

D.5.4. 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.

D.5.5. 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 E – HYPE CYCLES TO ASSESS MATURITY OF SERVICES

In order to choose the initial domains for integration in the catalogue and assess the maturity (TRL) of the service levels, the latest versions of the Gartner Hype Cycles 2017 were taken into account. Those hype cycles analyze form a view of the markets the expectations and shares of a technology and highlight their future market share and define uncertainties. The hype cycle from Gartner is a branded graphical presentation developed and used by the American research, advisory and information technology firm Gartner, for representing the maturity, adoption and social application of specific technologies. The hype cycle provides a graphical and conceptual presentation of the maturity of emerging technologies through five phases. The phases are usually defined as follows:

Each hype cycle drills down into the five key phases of a technology's life cycle.

No.	Phase	Description
1	Technology Trigger	A potential technology breakthrough kicks things off. Early proof-of-concept stories and media interest trigger significant publicity. Often no usable products exist and commercial viability is unproven. (TRL 1 and 2)
2	Peak of Inflated Expectations	Early publicity produces a number of success stories—often accompanied by scores of failures. Some companies take action; most don't. (TRL 3 to 5)
3	Trough of Disillusionment	Interest wanes as experiments and implementations fail to deliver. Producers of the technology shake out or fail. Investment continues only if the surviving providers improve their products to the satisfaction of early adopters. (TRL 6)
4	Slope of Enlightenment	More instances of how the technology can benefit the enterprise start to crystallize and become more widely understood. Second- and third-generation products appear from technology providers. More enterprises fund pilots; conservative companies remain cautious. (TRL 7)
5	Plateau of Productivity	Mainstream adoption starts to take off. Criteria for assessing provider viability are more clearly defined. The technology's broad market applicability and relevance are clearly paying off. (TRL 8)

Table E1 - five key phases of a technology's life cycle

A mapping onto the TRL levels, like they are used in the H2020 program, e.g. by the commission, is possible:

Technology Readiness Level	Description
TRL 1.	basic principles observed
TRL 2.	technology concept formulated
TRL 3.	experimental proof of concept
TRL 4.	technology validated in lab
TRL 5.	technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 6.	technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 7.	system prototype demonstration in operational environment
TRL 8.	system complete and qualified
TRL 9.	actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Table E2 - TRL levels

As Gartner has a very wide and broad coverage of technologies for their individual hype cycles, we chose to use the following three current version to assess the future uptake and shares of technologies to the services. It has to be kept in mind that the hype cycles sometimes cover basic technologies and services build upon those technologies. This has been taken into account in the assessment.
The following three studies have been taken as basic assessment material according to the five phases of the hype cycle:

- Hype Cycle for Smart City Technologies and Solutions, 2017
- Hype Cycle for Internet of Things, 2017
- Hype Cycle for Connected Home, 2017

In addition, we addressed the suitability of this approach by looking into the individual dimensions and definitions of the terms covered in the hype cycle. It has to be kept in mind that the hype cycle does not perfectly fit to the concept of TRL (technology readiness level).

Technology readiness levels (TRL) are a method of estimating technology maturity of Critical Technology Elements (CTE) of a program during the acquisition process. They are determined during a Technology Readiness Assessment (TRA) that examines program concepts, technology requirements, and demonstrated technology capabilities. TRL are based on a scale from 1 to 9 with 9 being the most mature technology.

However, as during this task 1 phase a lot of technologies had to be assessed based on service and not technology level, the approach to take into account products like Gartner is proposing proved useful as it covered a broad variety of services in scope of this project.

According to Gartner, a connected home is networked to enable the interconnection and interoperability of multiple devices, services and apps, ranging from communications and entertainment to healthcare, security and home automation. These services and apps are delivered over multiple interlinked and integrated devices, sensors, tools and platforms. Connected, real-time, smart and contextual experiences are provided for the household inhabitants, and individuals are enabled to control and monitor the home remotely as well as within it.

The technologies behind the connected home can be grouped in the following categories according to Gartner (Source Gartner IT definitions) :

Networking: Familiar home networking technologies (high bandwidth/high power consumption), such as Multimedia over Coax Alliance (MoCA), Ethernet, Wi-Fi, Bluetooth, as well as 3G and Long Term Evolution (LTE), are complemented with low-power consumption networking standards for devices and sensors that require low bandwidth and consume very little power, such as thermostats.

Media and Entertainment: This category, which covers integrated entertainment systems within the household and includes accessing and sharing digital content across different devices, has proved to be the most prolific and contains some of the most mature technologies in the connected home.

Home Security/Monitoring and Home Automation: The technologies in this category cover a variety of services that focus on monitoring and protecting the home as well as the remote and automated control of doors, windows, blinds and locks, heating/air conditioning, lighting and home appliances, and more.

Energy Management: This category is tightly linked to smart cities and government initiatives, yet consumer services and devices/apps are being introduced at mass-market prices that allow people to track, control and monitor their gas/electricity consumption.

Healthcare, Fitness and Wellness: Solutions and services around healthcare have proven slow to take off, because they have to be positioned within a health plan and sold to hospitals and health insurance companies. The fitness and wellness segment has strong and quickly developed ecosystems that range from devices to sports wares to apps, which integrate seamlessly with each other to create a strong customer experience.

The Gartner Hype Cycle for Smart City Technologies has the following Structure and classification for the year 2017:

On the Rise

- Data Marketplace
- City Operations Center
- Civic and Community Development
- Digital Ethics

At the Peak

- Digital Security
- Sustainability and COP21
- **Smart Monitoring for Public Infrastructures**
- Greenfield Smart City Framework
- **IoT Platform**
- Blockchain in Government
- Smart Parking Strategies
- **Connected Home**
- **Internet of Things**
- LPWA

- Smart City Framework
- **Smart Transportation**

Sliding Into the Trough

- Water Management
- Car-Sharing Services
- **Building Controls and Management**
- **Microgrids**
- Vehicle-to-Vehicle Communications
- **Distributed Generation**
- **Smart Lighting**
- Intelligent Lamppost
- Big Data
- **Health Information Exchange**

In addition to this Hype Cycle on Smart Cities which already covered a lot of classifications relevant to this study (in **bold**), the sub study on Smart Home is of interest. When reading, it is obvious that connected home is, form the perspective of smart city, itself a topic and can be dealt with in more detail. Thus, this hype cycle covers much more variety in terms of basic services and technologies as well as phases.

On the Rise

- Smart Dust
- Microsupercapacitor Batteries
- Midrange Wireless Power Charging
- Smart Mirrors
- **802.11ax**
- Bluetooth 5
- Chatbots
- Pet Monitors
- Bots
- Robotic Vacuum Cleaner
- **VPA-Enabled Wireless Speakers**

At the Peak

- Smart Robots
- Gesture Control Devices
- Virtual Assistants in Utilities
- **Virtual Assistants**
- **Connected Home**
- **Home Automation**
- LPWA
- Personal Health-Tracking Devices
- **Predictive Analytics**

Sliding Into the Trough

- **Home Energy Management**
- **802.11ad**
- **Consumer Smart Appliances**
- 802.11ac Wave 2
- Wearables
- Customer Gateways
- **Smart Locks**
- **Smart Thermostats**
- **Smart Lighting**
- **Remote Medical Monitoring**

Climbing the Slope

- Home Wireless Music Systems
- Personal Cloud
- 802.15.4
- **ZigBee**
- **TV Companion Screen Apps**

Entering the Plateau

- **Connected TVs**
- **OTT STBs**
- Internet Video

In addition, the aspect of IoT devices is of higher importance to the CRE buildings (commercial real estate). Therefore, the hype cycle for IoT has been used for the overall assessment process but has less importance to the SRI study than the other two which focus on the core technologies in the context of ICT in buildings.

On the Rise

- Licensing and Entitlement Management
- **IoT-Enabled Product as a Service**
- **Infonomics**
- Hardware Security
- Digital Twin
- **Managed IoT Services**
- IoT Business Solutions
- IoT Edge Analytics
- Digital Ethics
- IoT-Enabled ERP

At the Peak

- **IoT Security**
- IoT Platform
- IoT Services
- IoT Edge Architecture
- **Machine Learning**

- Autonomous Vehicles
- Event Stream Processing
- Connected Car Platforms
- **Internet of Things**
- LPWA
- Enterprise Information Management Programs

Sliding Into the Trough

- Low-Cost Development Boards
- **Intelligent Building Automation Systems**
- IoT Integration
- **IT/OT Alignment**
- **Managed Machine-to-Machine Services**
- **Asset Performance Management**
- **Smart Lighting**

Climbing the Slope

- **Cloud MOM Services (momPaaS)**
- Message Queue Telemetry Transport
- MDM of Product Data

Based on those studies, expert consultation as well as the expertise of the team, the initial service catalogue was created and further refined during the process and stakeholder consultations.

ANNEX F – REVIEW OF APPLICABILITY OF SERVICES FOR INCLUSION IN SRI

This annex reviews the services and functionality levels in the Task 1 report and considers their ability to be applied in an operational SRI currently. For each service this considers:

- the degree to which the functionality of the service is described and defined in standards, or is still nebulous and in need of definition
- the basis by which the impacts associated with the functionality can be determined
- the degree by which the impact can be ascribed to the functionality
- the degree to which the functionality can be determined by inspection.

The text below summarises the findings but the detailed service by service assessment is delivered in the form of an Excel table which accompanies this report.

F.1. SERVICES WITHIN THE HEATING DOMAIN

The remaining Task 1 heating services are all specified in the standard EN15232:2017 with the exception of the services:

- Heating 1g – *Building preheating control*
- Heating 2d - *Heat system control according to external signal (e.g. electricity tariff, gas pricing, load shedding signal etc.)*
- Heating 2e - *Control of on-site waste heat recovery fed into the heating system (e.g. excess heat from data centers)*
- Heating 3 - *Report information regarding heating system performance*

For all the services listed in EN15232 their functionality is clearly related to average impacts (for on-site energy consumption) based on numerous TRNSYS simulations and expressed via the BACS factors cited in the standard. Other impacts are based on the consortium team's judgement and are not corroborated through standards.

All the remaining services have a high or medium impact on on-site energy use (reflecting significant savings opportunities associated with smart control) and the dominance of heating in most EU buildings (this observation is clearly climate sensitive).

An initial screening assessment process will be appropriate to determine which services might be eligible for inclusion and which dropped. If the dropped services do not bring specific smart benefits that the retained services cannot provide then this should certainly lead to their exclusion from any normalisation process; however, in some cases this may require some judgment by the scheme organisers. For example, use of heat pumps, if integrated into smart grid control, would bring grid-flexibility advantages compared to alternative heat sources but does this mean they should score better under an SRI than a building using non-electric based heating?

Some services such as Thermo-Active Building Systems (TABS) and Thermal Energy Storage (TES) are rare and hence will not currently feature in the vast majority of the building stock. Also sequencing of heat sources only becomes a control issue when more than one heat source is available. This is usually only the case in large buildings and hence can be screened out of most assessments.

The "inspectability" of the services varies with the lower level (less smart) services being more straightforward to assess visually than some of the higher level services, which can be sensitive to the nature of the control algorithms applied. A general observation, stretching across all the smart readiness domains, is that when smartness depends on the capability associated with a control algorithm that it will not be straightforward to assess. As a result many of the capabilities defined here will need classification and indication, or some smart signalling and reading device, to enable an inspector to assess their capability. Inspection can take place at the plant room except for the heat emission inspection which requires a walk-through the building to be verified, however, as this is one of the major potential sources of energy savings it is likely worth the effort.

F.2. Services within the DHW domain

All the DHW services except:

DHW-1c *Control of DHW storage temperature, varying seasonally: with heat generation or integrated electric heating*

DHW-3 *Report information regarding domestic hot water performance*

are supported by European standards. DHW 1c is not assessable through any standard. DHW 1a to 1d only pertain to storage water heater systems and hence are not applicable to combi-systems and other instantaneous heating systems. It is a debatable point as to whether having storage capability (which takes space and is associated with losses) should be advantaged within an SRI due to having the potential for DSM storage or smart-charging control, or should be penalised due to the storage losses (note the balance of distribution losses should also be factored into any holistic assessment).

For all the services listed in EN15232 their functionality is clearly related to average impacts (for on-site energy consumption) based on numerous TRNSYS simulations and expressed via the BACS factors cited in the standard. Other impacts are based on the consortium team's judgement and are not corroborated through standards.

Potentially the biggest DHW impact is associated with flexibility but this is addressed elsewhere.

As is the case for heating many of the DHW smartness capabilities depend on the capabilities associated with a control algorithm that it is not straightforward to assess. As a result many of the capabilities defined here will need classification and indication, or some kind of smart signalling and reading device, to enable an inspector to assess their capability.

Inspection can take place at the plant room (or where the storage water heater and pumps are).

F.3. Services within the cooling domain

The Cooling 1 and 2 services listed in the Task 1 catalogue presented in the first progress report are not real services but are summaries of the sub-services listed under them. They can therefore be ignored.

The remaining Task 1 cooling services are all specified in the standard EN15232:2017 except the newly introduced:

Cooling-3 *Report information regarding cooling system performance*

For all the services listed in EN15232 their functionality is clearly related to average impacts (for on-site energy consumption) based on numerous TRNSYS simulations and expressed via the BACS factors cited in the standard. Other impacts are based on the consortium team's judgement and are not corroborated through standards.

All the remaining services have a high or medium impact on on-site energy use (reflecting significant savings opportunities associated with smart control) and the dominance of heating in most EU buildings (this observation is clearly climate sensitive).

An initial screening assessment process will be appropriate to determine which services might be eligible for inclusion and which dropped. If the dropped services do not bring specific smart benefits that the retained services cannot provide then this should certainly lead to their exclusion from any normalisation process; however, in some cases this may require some judgment by the scheme organisers. For example, use of control of distribution network chilled water temperature (supply or return) (supplied by a central chiller(s)) and control of distribution pumps is one cooling strategy, but is not inherently smarter than using individual heat pumps, chilled beams or air-based central cooling systems; thus, non-relevant options need to be dropped from the assessment on a non-prejudicial basis.

Some services such as Thermo-Active Building Systems (TABS) and Thermal Energy Storage (TES) are rare and hence will not currently feature in the vast majority of the building stock. Also sequencing of different cooling generators only becomes an issue when more than one generator is available and operational within a centrally manged cooling system. This is usually only the case in some large buildings and hence can be screened out of most assessments.

The "inspectability" of the services varies with the lower level (less smart) services being more straightforward to assess visually than some of the higher level services, which can be sensitive to the nature of the control algorithms applied. A general observation, stretching across all the smart readiness domains, is that when smartness depends on the capability associated with a control algorithm that it will not be straightforward to assess. As a result many of the capabilities defined here will need classification and indication, or some smart signalling and reading device, to enable an inspector to assess their capability.

Inspection can take place at the plant room except for the heat emission inspection which requires a walk-through the building to be verified, however, as this is one of the major potential sources of energy savings it is likely worth the effort.

F.4. SERVICES WITHIN THE VENTILATION DOMAIN

The ventilation services in Task 1 are all based on EN15232 with the exception of the newly introduced service:

Ventilation-6 *Reporting information regarding IAQ*

For all the services listed in EN15232 their functionality is clearly related to average impacts (for on-site energy consumption) based on numerous TRNSYS simulations and expressed via the BACS factors cited in the standard. Other impacts are based on the consortium team's judgement and are not corroborated through standards.

The "inspectability" of the services varies with the lower level (less smart) services being more straightforward to assess visually than some of the higher level services, which can be sensitive to the nature of the control algorithms applied. A general observation, stretching across all the smart readiness domains, is that when smartness depends on the capability associated with a control algorithm that it will not be straightforward to assess. As a result many of the capabilities defined here will need classification and indication, or some smart signalling and reading device, to enable an inspector to assess their capability.

Inspection can take place at the plant room for all centralised cooling systems.

F.5. SERVICES WITHIN THE LIGHTING DOMAIN

The lighting services in Task 1 are all based on EN15232 with the exception of Lighting 1b *Mood and time based control of lighting in buildings* which is now revised to be based upon elements within EN 15393, CEN-TR 16791 and EN 12464.

For all the services listed in EN15232 their functionality is clearly related to average impacts (for on-site energy consumption) based on numerous TRNSYS simulations and expressed via the BACS factors cited in the standard and this is the advantage of using the EN15232 simplified method in place of the more accurate but much more time consuming assessment that would be possible via EN15193 *Energy performance of buildings. Energy requirements for lighting*. Other impacts are based on the consortium team's judgement and are not corroborated through standards.

The "inspectability" of the services varies with the lower level (less smart) services being more straightforward to assess than the higher level services, which can be sensitive to the nature of the control algorithms applied. A general observation, stretching across all the smart readiness domains, is that when smartness depends on the capability associated with a control algorithm that it will not be straightforward to assess. As a result many of the capabilities defined here will need classification and indication, or some smart signalling and reading device, to enable an inspector to assess their capability.

Inspection requires a walk through the building and in principle should apply some space-function weighted process (i.e. to take account of the prevalence of different lighting solutions by room/floor-area) to be verified; however, in the case of lighting this walk-through should provide an unambiguous appraisal.

F.6. SERVICES WITHIN THE DYNAMIC BUILDING ENVELOPE DOMAIN

Of the three dynamic building envelope services cited in Task 1 only DE-1 *window solar shading control* is based on an existing standard (EN15232) but even then it includes an additional functionality level (*predictive blind control*). The other two services (*Window open/closed control, combined with HVAC system* and *Changing window spectral properties*) are not supported by standards. As a result only the DE-1 service has impacts that can be clearly attributed to functionality levels whereas the remainder are unsubstantiated (though likely to be relevant in principle). This means they are less actionable currently. Nonetheless, DE-2 Window open/closed control, combined with HVAC system is important and probably more straightforward to inspect tha the spectral properties service.

As with other services, blinds and hence dynamic blind control, are not present in all buildings. It is thus a moot point whether buildings without blinds should be considered less smart for not having an option to manage the blind control.

Inspection (at least for verification) requires a walk through the building and in principle should apply some space-function weighted process (i.e. to take account of the prevalence of different lighting solutions by room/floor-area) to be verified; however, this walk-through should provide an unambiguous appraisal.

F.7. Services within the energy generation domain

None of the five energy generation services cited in Task 1 are based on an existing standard or protocol and thus their functional levels are rather subjective and the relation between their functional levels and the impacts reported are unsubstantiated. Nonetheless, this is an important domain and thus it is necessary to identify relevant services to the extent they are actionable in practice.

It could be argued the first service EG-1 *On site renewable energy generation* is a simple quantification of the amount of RES available (or produced) and as such is not really "smart" at all. For that reason it is currently not included in the streamlined SRI method. From a policy perspective there might be a desire to encourage on site renewable energy generation, and therefore include this service nonetheless.
Services EG-3 to EG-5 dealing with storage, optimisation and CHP control are also somewhat arbitrary and weakly attributed. It therefore seems evident that clearer standardisation is needed to support smart serviced classification in this domain. Nonetheless, the newly proposed EG-2 service on *Reporting information regarding energy generation*, while not being defined within any standard, would appear to be self-evident, highly relevant and follow a logical impact attribution.

As with many other services, RES is not present in all buildings and it is a moot point whether buildings without RES should be considered to be less smart for not having an option to manage RES.

Visual inspection is partly possible (e.g. presence of RES or storage) but quantification and assessment of control/communication/magnitude related capability may require additional support and facilitation.

F.8. Services within the demand side management domain

None of the DSM services cited in Task 1 are based on an existing standard, except DSM-18 *Smart Grid Integration* and thus their functionality and functional levels are subjective while the relation between their functional levels and the impacts reported are unsubstantiated.

Grid flexibility is the principal benefit of DSM and the main reason why it would be/is encouraged and incentivised; however, not all buildings are equally equipped to provide flexibility due to the nature of the technical building systems they use (which may or may not be inherently controllable and utilisable for DSM-grid balancing purposes). It is thus a moot point whether a building that is less inherently able to store electrical energy is less “smart” than one that has higher inherent storage capability. What is less contestable is the degree to which the inherent storage capacity is “smart” enough to be able to provide DSM capability.

Most of services cited refer fully or in part to grid-balancing relevant capabilities, some focus on storage, some on communication and control, some on the level or scale of the service.

The lack of maturity in DSM service classification within Task 1 reflects the current absence of standards and common agreement on how to classify and attribute DSM capability. Nonetheless, the importance of the topic is such that 4 DSM services are proposed within the streamlined methodology with the expectation that they are actionable, even though they are not currently defined in standards or assessment protocols.

Visual inspection is only of limited value to verify DSM capability so quantification and assessment of control/communication/magnitude related capability will require additional support and facilitation.

F.9. Services within the electric vehicle charging domain

None of the fourteen EV services cited in Task 1 are directly based on an existing standard although many have some aspects of their functionality defined within either IEC 61851-1-2017 *Electric vehicle conductive charging system – Part 1: General requirements* (which has a simple but only partially applicable classification of EV charging-point modes) or ISO/IEC/DIS 15118E *Road vehicles — Vehicle to grid communication interface — Part 1: General information and use-case definition* (which addresses communication and control issues). However, as these standards are not really established to support smart charging and the services cited in Task 1 only partially relate to these then their functionality and functional levels are subjective while the relation between their functional levels and the impacts reported are unsubstantiated.

The principal benefits of smart e-mobility services are ease and speed of charging (which facilitates adoption of EVs in place of hydrocarbon vehicles and thereby saves energy – albeit not really on-site - GHG emissions and local air pollution emissions) and the extra-grid flexibility that EVs can offer (especially if charging off peak or if equipped with the ability to sell electricity back to the grid on peak). It is not evident that the catalogue of services cited in Task 1 capture these capabilities in a clear manner with the exception of the newly introduced EV-15, 16 and 17 services, which while in need of further work (e.g. to define what is meant by low, medium and high charging capacity) are otherwise relatively self-evident.

The lack of maturity in EV smart service classification within Task 1 reflects the current absence of standards and common agreement on how to classify and attribute this capability. The development of such standards should therefore be examined as a priority.

Visual inspection is only of limited value to verify EV smart service capability so quantification and assessment of control/communication/magnitude related capability will require additional support and facilitation. Many of the capabilities defined here would need classification and indication, perhaps complemented by some smart signalling and reading device, to enable an inspector to assess their capability.

F.10. SERVICES WITHIN THE MONITORING AND CONTROL DOMAIN

Several of the Task 1 monitoring and control domain services are specified in the standard EN15232:2017 and thus their impacts with regard to on-site energy use are readily attributable via the BACS factor methodology derived from extensive building simulation results.

The exceptions to this are:

MC-2 *Control of thermal exchanges*
MC-6 *Reporting information regarding historical energy consumption*
MC-7 *Reporting information regarding predicted energy consumption*
MC-9 *Occupancy detection: connected services*
MC-10 *Occupancy detection: space and activity*
MC-11 *Remote surveillance of building behaviour*
MC-12 *Central off-switch for appliances at home*
MC-13 *Central reporting of TBS performance and energy use*

The impact of these other services are based on the consortium team's judgement and are not corroborated through standards. Monitoring and control smart services have a significant user information impact and can all be assessed at the central control point or points within a building or on associated mobile devices. Screening for which services are present and which not is often not possible by a quick visual scan but requires working with the control devices (especially the display devices) and associated documentation/facilitating information.

As a result many of the capabilities defined here would need classification and indication, or some smart signalling and reading capability, to enable an inspector to make an assessment.

ANNEX G - AN ACTIONABLE SUBSET OF SMART READINESS ELEMENTS

This annex provides an extract from the Task 1 smart ready services catalogue which is currently deamed actionable for inclusion in the SRI methodology.

Table G 1 - Excerpt of the smart ready services catalogue

Domain	Code	Smart ready service
Heating	Heating-1a	Heat control - demand side
Heating	Heating-1b	Heat control - demand side
Heating	Heating-1c	Heat control - demand side
Heating	Heating-1d	Heat control - demand side
Heating	Heating-1e	Heat control - demand side
Heating	Heating-1f	Heat control - demand side
Heating	Heating-1g	Heat control - demand side
Heating	Heating-2a	Control heat production facilities
Heating	Heating-2b	Control heat production facilities
Heating	Heating-2c	Control heat production facilities
Heating	Heating-3	Information to occupants and facility managers
Domestic hot water	DHW-1a	Control DHW production facilities
Domestic hot water	DHW-1b	Control DHW production facilities
Domestic hot water	DHW-1d	Control DHW production facilities
Domestic hot water	DHW-3	Information to occupants and facility managers
Cooling	Cooling-1a	Cooling control - demand side
Cooling	Cooling-1b	Cooling control - demand side
Cooling	Cooling-1c	Cooling control - demand side
Cooling	Cooling-1d	Cooling control - demand side
Cooling	Cooling-1e	Cooling control - demand side
Cooling	Cooling-1f	Cooling control - demand side
Cooling	Cooling-1g	Cooling control - demand side
Cooling	Cooling-2a	Control cooling production facilities
Cooling	Cooling-2b	Control cooling production facilities
Cooling	Cooling-3	Information to occupants and facility managers
Controlled ventilation	Ventilation-1a	Air flow control
Controlled ventilation	Ventilation-1b	Air flow control
Controlled ventilation	Ventilation-1c	Air flow control
Controlled ventilation	Ventilation-2a	Air temperature control
Controlled ventilation	Ventilation-2c	Air temperature control
Controlled ventilation	Ventilation-2d	Air temperature control
Controlled ventilation	Ventilation-3	Free cooling
Controlled ventilation	Ventilation-6	Feedback - Reporting information
Lighting	Lighting-1a	Artificial lighting control
Lighting	Lighting-2	Control artificial lighting power based on daylight levels

Dynamic building envelope	DE-1	Window control
Dynamic building envelope	DE-2	Window control
Energy generation	EG-2	Feedback - Reporting information
Energy generation	EG-3	DER - Storage
Energy generation	EG-4	DER- Optimization
Energy generation	EG-5	DER - Generation Control
Demand side management	DSM-18	Smart Grid Integration
Demand side management	DSM-19	DSM control of equipment
Demand side management	DSM-21	Feedback - Reporting information
Demand side management	DSM-22	Override control
Electric vehicle charging	EV-15	EV Charging
Electric vehicle charging	EV-16	EV Charging - Grid
Electric vehicle charging	EV-17	EV Charging - connectivity
Monitoring and control	MC-3	HVAC interaction control
Monitoring and control	MC-4	Fault detection
Monitoring and control	MC-9	TBS interaction control
Monitoring and control	MC-13	Feedback - Reporting information

ANNEX H - MULTI CRITERIA DECISION MAKING METHODS

The following MCDM methods are available, many of which are implemented by specialised decision-making software:

- Aggregated Indices Randomisation Method (AIRM)
- Analytic hierarchy process (AHP)
- Analytic network process (ANP)
- Best worst method (BWM)
- Characteristic Objects METhod (COMET)
- Choosing By Advantages (CBA)
- Data envelopment analysis
- Decision EXpert (DEX)
- Disaggregation – Aggregation Approaches (UTA, UTAII, UTADIS)
- Dominance-based rough set approach (DRSA)
- ELECTRE (Outranking)
- Evidential reasoning approach (ER)
- Goal programming (GP)
- Grey relational analysis (GRA)
- Inner product of vectors (IPV)
- Measuring Attractiveness by a categorical Based Evaluation Technique (MACBETH)
- Multi-Attribute Global Inference of Quality (MAGIQ)
- Multi-attribute utility theory (MAUT)
- Multi-attribute value theory (MAVT)
- New Approach to Appraisal (NATA)
- Nonstructural Fuzzy Decision Support System (NSFDSS)
- Potentially all pairwise rankings of all possible alternatives (PAPRIKA)
- PROMETHEE (Outranking)
- Stochastic Multicriteria Acceptability Analysis (SMAA)
- Superiority and inferiority ranking method (SIR method)
- Technique for the Order of Prioritisation by Similarity to Ideal Solution (TOPSIS)
- Value analysis (VA)
- Value engineering (VE)
- VIKOR method
- Fuzzy VIKOR method
- Weighted product model (WPM)
- Weighted sum model (WSM)
- Rembrandt method.

ANNEX I - CALCULATION PROCESS DETAILS FOR THE IN-FIELD SINGLE FAMILY HOME CASE STUDY

This annex reports the specific assessment and calculation applied in the in-field SFH case study reported in section 3.10.1. It begins with reporting the inputs to the assessment by domain and then discusses the calculations which produce the sub-scores and aggregate SRI score reported in Table 31.

The following domains were absent and hence all scored zero:

- Cooling
- Controlled ventilation
- Dynamic Building Envelope
- Self generation
- DSM
- EV (only dumb charging)

In the case of Lighting while there was energy efficient lighting throughout the property there was only one small internal space (a toilet) which used smart lighting controls and hence it too scores zero (technically it could have been just above zero but the space was probably only ~1/90th of the total floor area of the property). The external security lighting used motion sensors but the streamlined methodology is currently focused on internal lighting.

I.1. Space heating

In the case of space heating the building scored the values indicated in Table I2 below. The ordinal impact scores are produced by defining the functionality level for the service as set out in the services catalogue. Only the services retained in the streamlined methodology are eligible for consideration, however, depending on the heating solution adopted not all of these will be relevant for the building in question. In the case of this building the TABS and Thermal Energy Storage solutions are not part of the solutions applied and hence are zeroed-out and do not contribute to the overall scores. Nonetheless, this leaves 9 eligible smart heating services of the 11 potentially eligible services.

In Table I2a the ordinal impact scores for the building are shown but in Table I2b the maximum possible ordinal impact scores for any building are also shown. The process of deriving the service level smart readiness scores for the building in question is to normalise its scores by dividing them by the maximum possible scores.

I.2. Hot Water

The equivalent data is reported for domestic hot water in Table I3a and Table I3b. Given that the hot water is gas-fired the only applicable service is DHW-3 concerning the reporting of information of the domestic hot water performance.

I.3. Lighting, DSM and Monitoring & Control

The equivalent data for lighting, DSM and Monitoring & Control is reported in Table I4a and Table I4b. For lighting and DSM the building essentially has no smart service capability so it scores 0 on these services. It does rather better on the Monitoring and Control MC3 and MC13 services.

I.4. Aggregation

The aggregated scores are shown in Table I1 (identical to Table 31). While the scores per domain are the simple sum of the normalised service-level scores discussed above the aggregate overall score is determined after the domain and impact parameter weighting factors shown in Table 21 have been applied. As mentioned in the discussion in section 4.10 these weightings are currently far from imperfect – they are reasonably representative of an EU average building for energy consumption but for other impact parameters they need more work to establish appropriate values. Even for energy, more accurate approaches can be used even down to the specific energy balance for the building in question if sub-metering data or EPC calculations are available. Thus, for the time being these weightings are simply applied to illustrate the methodological principle and are not intended to be reflective of an optimal or truly representative set of data.

Aside from the weightings the other issue is which domains are applied to derive the overall normalised score. This is discussed in section 3.10.1.

Table I1 – SRI scores for the in-field single family home case study

	Energy	Flexibility	Self generation	Comfort	Convenience	Well-being and health	Maintenance & fault prediction	Information to occupants	SRI
Overall	**71%**	**0%**	**0%**	**77%**	**33%**	**17%**	**20%**	**19%**	**45%**
Heating	75%	0%	0%	85%	64%	0%	25%	75%	
DHW	100%	0%	0%	0%	0%	0%	50%	67%	
Cooling	0%	0%	0%	0%	0%	0%	0%	0%	
Ventilation	0%	0%	0%	0%	0%	0%	0%	0%	
Lighting	0%	0%	0%	0%	0%	0%	0%	0%	
Dynamic envelope	0%	0%	0%	0%	0%	0%	0%	0%	
Self generation	0%	0%	0%	0%	0%	0%	0%	0%	
DSM	0%	0%	0%	0%	0%	0%	0%	0%	
Electric Vehicles	0%	0%	0%	0%	20%	0%	0%	0%	
Monitoring & control	60%	100%	0%	67%	38%	33%	17%	14%	

Table I2a. Heating service scores for the in-field SFH case study

SR fields						ORDINAL IMPACT SCORES							
Domain	Code	Service	Functionality level for this building	Max possible functionality level	Max functionality level in this building	Energy	Flexibility	Self-gen	Comfort	Convenience	Health	Maintenance & fault prediction	Information to occupants
Heating	Heating-1a	Heat emission control	2	4	4	2	0	0	2	2	0	0	0
Heating	Heating-1b	Emission control for TABS (heating mode)	0	3	0	0	0	0	0	0	0	0	0
Heating	Heating-1c	Control of distribution network hot water temperature (supply or return) - Similar function can be applied to the control of direct electric heating networks	1	2	2	1	0	0	1	1	0	0	0
Heating	Heating-1d	Control of distribution pumps in networks	3	4	4	3	0	0	3	0	0	0	0
Heating	Heating-1e	Intermittent control of emission and/or distribution - One controller can control different rooms/zones having same occupancy patterns	2	3	3	2	0	0	2	2	0	0	0
Heating	Heating-1f	Thermal Energy Storage (TES) for building heating	0	2	0	0	0	0	0	0	0	0	0
Heating	Heating-1g	Building preheating control	2	2	2	2	0	0	2	2	0	0	1
Heating	Heating-2a	Heat generator control (for combustion and district heating)	1	2	2	1	0	0	1	0	0	0	0
Heating	Heating-2b	Heat generator control (for heat pumps)	0	3	0	0	0	0	0	0	0	0	0
Heating	Heating-2c	Sequencing of different heat generators	0	3	0	0	0	0	0	0	0	0	0
Heating	Heating-3	Report information regarding HEATING system performance	2	4	4	1	0	0	0	0	0	1	2

Table I2b. Heating service scores for the in-field SFH case study

SR fields			ORDINAL IMPACT SCORES								MAXIMUM POSSIBLE ORDINAL IMPACT SCORES							
Domain	Code	Service	Energy	Flexibility	Self-gen	Comfort	Convenience	Health	Maintenance & fault prediction	Information to occupants	Energy	Flexibility	Self-gen	Comfort	Convenience	Health	Maintenance & fault prediction	Information to occupants
Heating	Heating-1a	Heat emission control	2	0	0	2	2	0	0	0	3	0	0	2	3	0	1	0
Heating	Heating-1b	Emission control for TABS (heating mode)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heating	Heating-1c	Control of distribution network hot water temperature (supply or return) - Similar function can be applied to the control of direct electric heating networks	1	0	0	1	1	0	0	0	2	0	0	1	2	0	1	0
Heating	Heating-1d	Control of distribution pumps in networks	3	0	0	3	0	0	0	0	3	0	0	3	0	0	0	0
Heating	Heating-1e	Intermittent control of emission and/or distribution - One controller can control different rooms/zones having same occupancy patterns	2	0	0	2	2	0	0	0	3	0	0	3	3	0	0	0
Heating	Heating-1f	Thermal Energy Storage (TES) for building heating	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heating	Heating-1g	Building preheating control	2	0	0	2	2	0	0	1	2	0	0	2	2	0	0	1
Heating	Heating-2a	Heat generator control (for combustion and district heating)	1	0	0	1	0	0	0	0	2	0	0	2	0	0	0	0
Heating	Heating-2b	Heat generator control (for heat pumps)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heating	Heating-2c	Sequencing of different heat generators	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heating	Heating-3	Report information regarding HEATING system performance	1	0	0	0	0	0	1	2	1	0	0	0	1	0	2	3

Table I3a. DHW service scores for the in-field SFH case study

SR fields						ORDINAL IMPACT SCORES							
Domain	Code	Service	Functionality level for this building	Max possible functionality level	Max functionality level in this building	Energy	Flexibility	Self-gen	Comfort	Convenience	Health	Maintenance & fault prediction	Information to occupants
Domestic hot water	DHW-1a	Control of DHW storage charging (with direct electric heating or integrated electric heat pump)	0	3	0	0	0	0	0	0	0	0	0
Domestic hot water	DHW-1b	Control of DHW storage charging (using heat generation)	0	3	0	0	0	0	0	0	0	0	0
Domestic hot water	DHW-1d	Control of DHW storage charging (with solar collector and supplymentary heat generation)	0	3	0	0	0	0	0	0	0	0	0
	DHW-3	Report information regarding domestic hot water performance	2	4	4	1	0	0	0	0	0	1	2

Table I3b. DHW service scores for the in-field SFH case study

SR fields			ORDINAL IMPACT SCORES								MAXIMUM POSSIBLE ORDINAL IMPACT SCORES							
Domain	Code	Service	Energy	Flexibility	Self-gen	Comfort	Convenience	Health	Maintenance & fault prediction	Information to occupants	Energy	Flexibility	Self-gen	Comfort	Convenience	Health	Maintenance & fault prediction	Information to occupants
Domestic hot water	DHW-1a	Control of DHW storage charging (with direct electric heating or integrated electric heat pump)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic hot water	DHW-1b	Control of DHW storage charging (using heat generation)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic hot water	DHW-1d	Control of DHW storage charging (with solar collector and supplymentary heat generation)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	DHW-3	Report information regarding domestic hot water performance	1	0	0	0	0	0	1	2	1	0	0	0	1	0	2	3

Table I4a. Lighting, DSM and Monitoring & Control service scores for the in-field SFH case study

SR fields						ORDINAL IMPACT SCORES							
Domain	Code	Service	Functionality level for this building	Max possible functionality level	Max functionality level in this building	Energy	Flexibility	Self-gen	Comfort	Convenience	Health	Maintenance & fault prediction	Information to occupants
Lighting	Lighting-1a	Occupancy control for indoor lighting	0	3	3	0	0	0	0	0	0	0	0
Lighting	Lighting-2	Control artificial lighting power based on daylight levels	0	4	4	0	0	0	0	0	0	0	0
Demand side management	DSM-18	Smart Grid Integration	0	1	1	0	0	0	0	0	0	0	0
Demand side management	DSM-19	DSM control of equipment	0	4	4	0	0	0	0	0	0	0	0
	DSM-21	Reporting information regarding DSM	0	2	2	0	0	0	0	0	0	0	0
	DSM-22	Override of DSM control	0	3	3	0	0	0	0	0	0	0	0
Monitoring and control	MC-3	Run time management of HVAC systems	2	3	3	2	1	0	2	2	1	0	0
Monitoring and control	MC-4	Detecting faults of technical building systems and providing support to the diagnosis of these faults	0	2	2	0	0	0	0	0	0	0	0
Monitoring and control	MC-9	Occupancy detection: connected services	0	2	2	0	0	0	0	0	0	0	0
	MC-13	Central reporting of TBS performance and energy use	1	3	3	1	0	0	0	1	0	1	1

Table I4b. Lighting, DSM and Monitoring & Control service scores for the in-field SFH case study

SR fields			ORDINAL IMPACT SCORES								MAXIMUM POSSIBLE ORDINAL IMPACT SCORES							
Domain	Code	Service	Energy	Flexibility	Self-gen	Comfort	Convenience	Health	Maintenance & fault prediction	Information to occupants	Energy	Flexibility	Self-gen	Comfort	Convenience	Health	Maintenance & fault prediction	Information to occupants
Lighting	Lighting-1a	Occupancy control for indoor lighting	0	0	0	0	0	0	0	0	2	0	0	2	2	0	0	0
Lighting	Lighting-2	Control artificial lighting power based on daylight levels	0	0	0	0	0	0	0	0	3	0	0	3	3	3	0	0
Demand side management	DSM-18	Smart Grid Integration	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Demand side management	DSM-19	DSM control of equipment	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
	DSM-21	Reporting information regarding DSM	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	3
	DSM-22	Override of DSM control	0	0	0	0	0	0	0	0	0	2	0	0	3	0	2	2
Monitoring and control	MC-3	Run time management of HVAC systems	2	1	0	2	2	1	0	0	3	1	0	2	3	1	0	1
Monitoring and control	MC-4	Detecting faults of technical building systems and providing support to the diagnosis of these faults	0	0	0	0	0	0	0	0	0	0	0	0	2	2	3	2
Monitoring and control	MC-9	Occupancy detection: connected services	0	0	0	0	0	0	0	0	1	0	0	1	1	0	2	1
	MC-13	Central reporting of TBS performance and energy use	1	0	0	0	1	0	1	1	1	0	0	0	2	0	1	3

ANNEX J – OVERVIEW OF STAKEHOLDER ATTENDANCE

This section summarizes the attendance of three SRI stakeholder meetings and gives an overview of the stakeholder comments that the consortium received after each stakeholder meeting.

J.1. 1ST STAKEHOLDER MEETING

More than 65 representatives from a broad variety of stakeholder organisations attended the first stakeholer meeting. From mid September to mid October 2017, stakeholders were invited to provide feedback on the first progress report of the SRI study and the service catalogue. The consortium received more than 150 comments on the report, together with 70 comments on the service catalogue list. These were sent in by 25 different stakeholders of which:

- 21 sector organizations/associations
- 2 Member States
- 2 NGOs

J.2. 2ND STAKEHOLDER MEETING

More than 85 representatives attended the second stakeholder meeting. From mid January to mid February 2018, stakeholders were invited to provide written feedback to the interim report of the SRI study and the service catalogue (shared with them on 16 January 2018). The consortium received more than 260 comments on the interim report and more than 100 comments on the service list. A significant increase from the 150 and 70 comments respectively received during the second round of stakeholder comments. The comments came from about 28 stakeholders of which:

- 23 sector organizations/associations
- 2 companies
- 1 NGO
- 1 Member State and 1 region representative

The comments provided consist of a mix of statements, questions and suggestions. The study team has assessed the relevance and applicability of all comments received, which led to significant adaptations of the service catalogue and proposed methodology. Furthermore, the report was expanded with additional sections, e.g. with regard to linkages to other assessment schemes for the building sector.

J.3. 3RD STAKEHOLDER MEETING

More than 70 representatives from a broad variety of stakeholder organisations were present in the last stakeholder meeting. After the meeting, the consortium received nearly 200 comments on the interim report, and these comments came from 28 stakeholders (with 4 stakeholders representing 2 organizations), of which:

- 22 sector organizations/associations
- 5 industrial companies
- 1 Member State

ANNEX K - THE BUILT-ENVIRONMENT-ANALYSIS-MODEL BEAM²

This section gives an overview on the methodology used for the ex-ante assessment of policy option, which is the BEAM² model.

K.1. Terms and Definitions

As the **Built Environment Analysis Model BEAM²** model is set up in the framework of the European Energy Performance of Buildings Directive (EPBD), the general terms and definitions are aligned with it. The relevant document in that context is the umbrella document for all European standards within the EPBD, which is the Technical Report (TR): Explanation of the general relationship between various CEN standards and the Energy Performance of Buildings Directive (EPBD), see (CEN/TR 15615)[113]. They are also valid for the energy demand calculations for space heating and cooling from (DIN EN ISO 13790)[114], which are also referred to.

K.2. Scope

The scope of the model is described in this section. General references for the energy-related calculations are (CEN/TR 15615) and report by Boermans et al.[115].

The calculation methodology follows the framework set out in the Annex to the EPBD. For useful heating and cooling demand calculations the methodology in EN ISO 13790 (DIN EN ISO 13790) allows a simplified monthly calculation based on building characteristics. It is not dependent on heating and cooling equipment (except heat recovery) and results in the heating energy that is required to maintain the temperature level of the building. It can either be provided by the heating/cooling system or be recovered from the exhaust air stream. The calculations are based on specified boundary conditions of indoor climate and external climate, which are also given on monthly basis. Furthermore information on the internal and solar heat gains as well as transmission and ventilation heat losses are required. Based that energy demand the delivered energy (final energy) for heating, cooling, hot water, ventilation and lighting if applicable are calculated per fuel type. It takes account of heat emission, distribution, storage and generation and includes the auxiliary energy demand from building-related components like fans and pumps.

In a last step the overall energy performance in terms of primary energy and CO_2 emissions is calculated. An overview of the calculation process is given in Figure K 1, based on the umbrella document (CEN/TR 15615). It involves following the energy flows from the left to the right.

The three steps of the energy performance calculation are always done for reference buildings for a sector, age group, retrofit level and HVAC systems. Subsequently the energy costs per year and the investment costs in case of a new buildings or retrofit are calculated.

113 CEN/TR 15615. Technical Report - Explanation of the general relationship between various European standards and the Energy Performance of Buildings Directive (EPBD) - Umbrella Document, CEN April 2008 (English).

114 DIN EN ISO 13790. Energy performance of buildings - Calculation of energy use for space heating and cooling (ISO 13790:2008), Beuth Verlag Berlin 1999 (German version EN ISO 13790:2008).

115 Boermans, Thomas, Kjell Bettgenhäuser, Andreas Hermelink, and Sven Schimschar. May 2011. Cost optimal building performance requirements - Calculation methodology for reporting on national energy performance requirements on the basis of cost optimality within the framework of the EPBD, Final Report, European Council for an Energy Efficient Economy eceee, Stockholm (English).

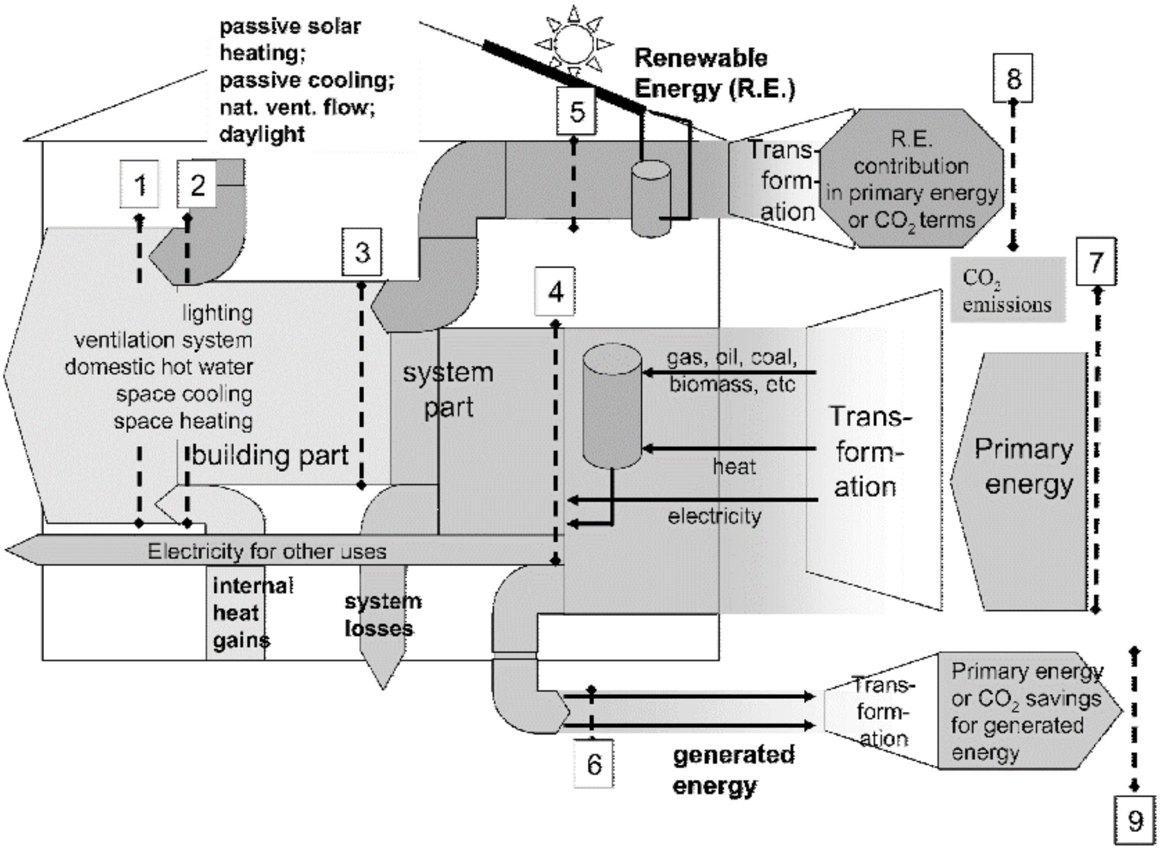


Figure K 1 - Schematic Illustration of the scope for the newly developed Built-Environment-Analysis-Model BEAM2, Source:(CEN/TR 15615)[116]

Key for Figure K 1

(1) represents the energy needed to fulfil the users requirements for heating, cooling, lighting etc, according to levels that are specified for the purposes of the calculation.
(2) represents the "natural" energy gains - passive solar heating, passive cooling, natural ventilation, daylighting ˝U together with internal gains (occupants, lighting, electrical equipment, etc)
(3) represents the 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 CO2 emissions associated with the building.

K.3. Structure and Methodology

The basic model setup and calculation process is shown in Figure K 2. It is based on the energy demand calculations for space heating and cooling from the ISO Standard 13790:2008 (DIN EN ISO 13790). As all calculations are executed for a highly disaggregated building stock with all its

[116] 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. Renewable energy wares like biomass are included in [7], but are distinguished from non-renewable energy wares by low *CO*22 emissions. In the case of cooling, the direction of energy flow is from the building to the system.

characteristics, the following description of the methodology and calculation process applies for all sub-segments of the building sector within the model.

Basic input to the model are data on the building stock such as building types, floor area, age groups, retrofit levels, HVAC systems in stock and population. Furthermore the climate data such as temperature and irradiation is required. Based on this data a status-quo inventory of the building stock can be constructed.

For the scenario analysis as central part of the model, additional input data with respect to population forecast, GDP development, new building, demolition and retrofit activities, thermal insulation standards, heating, ventilation and air conditioning equipment, renewable energy systems and energy efficiency measures is required. Furthermore energy costs, cost for energy efficiency measures at the building envelope and costs for heating, cooling and ventilation systems and renewable energy systems together with increase rates and discount rates are processed. With respect to the overall energy performance the greenhouse gas emissions factors and primary energy factors are required per fuel type and embodied energy and GHG emissions for energy efficiency and HVAC systems.

The calculation process over the scenario time frame is organized as follows. Based on the initial floor area distribution along the reference buildings (RB), age groups (AG), retrofit levels (RL), heating systems (HS)117, hot water systems (DHW)118 and cooling systems (CS) a forecast for the floor area is done taking into account new building, demolition and retrofit programs for all or parts of these combinations.

All activities in year i have an effect starting in year i+1.
The useful energy demand for heating and cooling is derived from an integrated calculation algorithm based on (DIN EN ISO 13790). The energy demands for hot water, auxiliary energy and electrical appliances if applicable are also derived. The final energy is calculated based on the parameters of the HVAC systems[119]. The aggregated final energy for heating can be compared to top-down data. In this case a calibration factor is calculated, which can be applied to the final energy for heating.

The delivered energy together with the primary energy and GHG emission factors are combined to the overall primary energy and GHG emissions. For the economic assessment heating and cooling loads per single building type are derived, which are relevant to the systems sizes and investment costs. The economic evaluation takes beside the investment costs also the energy costs into consideration. In addition to the above described output the embodied energy and primary energy for all energy-related components (efficiency and HVAC systems) are quantified in the model based on the total volumes of insulation, area of windows and number and power of HVAC equipment.

[117] Heating systems (HS) also include ventilation systems (VS) and solar thermal systems (STS) for HS support if applicable.
[118] Hot water systems (DHW) also include solar thermal systems (STS) for hot water if applicable.
[119] The final energy is equal to the delivered energy plus energy produced in or on the building by solar or wind systems.

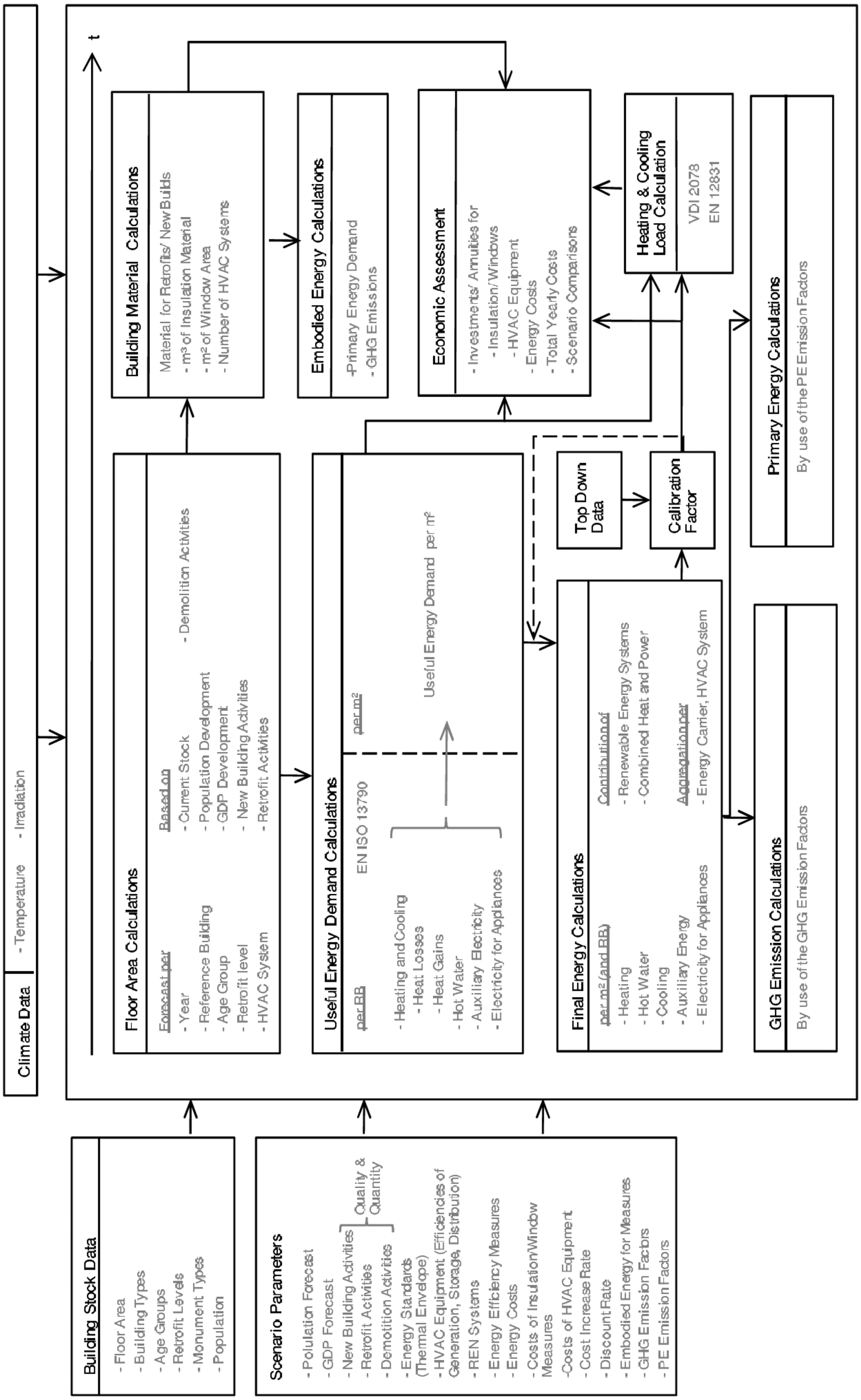


Figure K 2 - General Structure of the Built-Environment-Analysis-Model BEAM[2]

K.4. Scenario Results

Main outputs of the model are the floor area developments for RB, AG, RL, HS, DHW and CS in the first place. Next step is the calculation of the useful energy demands for heating, cooling and hot water. From this the final energy/ delivered energy for heating, cooling, hot water, ventilation and auxiliary energy is derived. For the overall energy performance the greenhouse gas emissions and primary energy is being calculated. Furthermore the embodied primary energy and greenhouse gas emissions of the energy related components for new buildings and retrofits are considered.

For the economic evaluation energy costs per year are provided as well as investment costs in new buildings and retrofits. In order to compare yearly costs the investments are broken down along the lifetime of components to yearly costs by use of annuities.
All results are given in specific units (e.g. per m^2) and for the overall building stock in the respective scenario.

K.5. Input Data

Input data to the model describes the current building stock as status-quo. This is e.g. the floor area distribution and the definition and specifications of reference buildings (RB), age groups (AG), retrofit levels (RL) and HVAC systems such as heating (HS), hot water (DHW), solar thermal systems (STS), ventilation systems (VS) and cooling systems (CS).

A more detailed description of the BEAM² model is available in the dissertation by Bettgenhaeuser[120].

[120] Bettgenhäuser, K. (2013). Integrated Assessment Modelling for Building Stocks - A Technical, Economical and Ecological Analysis. Dissertation TU Darmstadt D17, Ingenieurwissenschaftlicher Verlag 2013.

ANNEX L – BUILDING SECTOR SCENARIOS – ASSUMPTIONS AND DETAILED RESULTS

L.1. PATHWAY DEFINITIONS AND PARAMETERS

This Annex describes the main set of parameters for the underlying building sector scenarios. As described, the values are derived from a comparison of the set of parameters that has been used for the EPBD Impact Assessment.

L.1.1. Building sector scenario parameters - Agreed Amendments pathway

Based on the EPBD IA parameter dataset and the adaptions, the following main parameters are defined:

- Thermal qualities
  - New buildings:
    - 2017-2020: Cost optimal U-values according to MS reports
    - 2021-2025: introduction of NZEBs (approx. 12.5 % improvement)
    - 2026-2030: 7.5% improvement due to new cost optimality values
  - Existing buildings that undergo thermal renovation:
    - 2018-2025: Cost optimal U-values from MS reports
    - 2023-2027: 5 % improvement[121] compared to 2018-2022
    - 2028-2030: 5 % improvement[122] compared to 2023-2027
- Retrofit rates (equivalent full thermal renovation rate[123])
  - Residential:
    - Up to 2025: 0.56-1.22%
    - 2026-2050: 1.29-1.4%
  - Non-residential:
    - Up to 2025: 0.65-1.32%
    - 2026-2050: 1.36-1.50%
- New Building rates

[121] update cost optimality calculations, average improvement 2020-2030

[122] update cost optimality calculations, average improvement 2020-2030

[123] The full thermal renovation rate reflects the amount of buildings that undergo a renovation and upgrade of the total building envelope (roof, external walls, windows and ground floor) developed as an equivalent rate of renovations that include all or only parts of these different components. The full thermal renovation rate is therefore an indicator that describes the number and scope of renovations of the building envelope, while not describing the ambition level (e.g. thickness of insulation) of the single measures.

Table L 1 - New building rates in the "Agreed Amendments" pathway

Sector	Period	North	West	North-East	South	South-East
Residential	Up to 2025	1.02-1.06%	0.66-0.59%	1.01-0.62%	0.69-0.57%	0.39-0.33%
	2026-2050	1.07-1.09%	0.58-0.54%	0.57-0.38%	0.56-0.50%	0.33-0.30%
Non-Residential	Up to 2025	1.23-1.29%	0.90-0.80%	1.44-1.02%	0.97-0.85%	0.74-0.68%
	2026-2050	1.30-1.33%	0.79-0.75%	0.96-0.75%	0.83-0.78%	0.67-0.64%

- Demolition rates
    - Residential: 0.1%
    - Non-Residential: 0.2%

L.1.2. Building sector scenario parameters – Agreed Amendments + Ambitious Implementation pathway

Scenario "Agreed Amendments + Ambitious Implementation" will follow later, but will be part of the presentation during the stakeholder meeting.
The main difference to the above described "Agreed Amendments" pathway is in average an earlier adaption of high energy efficiency standards for the building shells, especially for the renovation of buildings and higher shares of renewable heating systems.

L.2. Detailed Model inputs

L.2.1. Agreed Amendments to the EPBD

The following Table L 2 gives on overview of the agreed amendments to the EPBD, based on the communication of 2018-01-25.

Table L 2 - Overview of Agreed Amendments of the EPBD Trialogue Process

EPBD Amendments (2018-01-25)	
Art.	**Content**
2	Clarification on **Definitions**
2A	NEW: **Long-term renovation strategy (from EED)** - Roadmap with polocies and actions - Mobilization of investments - Public consultation
6	**New Buildings** - List with high efficient alternative systems (to be considered) removed
7	**Existing Buildings** - Minor additions (health and indoor climate)
8	**Technical Building systems** - Minor additions (self-regulating devices) - **EV charging points** (at least one in five) for more than 10 parking spaces (if car park in the building or physically adjacent) for N-RES and **ducting infrastructure** only for RES buildings o Not mandatory for small/ medium enterprises o limiting factors (i.e. costs) - **EPCs**: Energy performance need to be assessed when technical building systems are installed(/replaced - **SRI**: Optinal EU-wide scheme for rating the smart readyness of buildings => NEW Annex Ia
10	**Financial Incentives** - More deteils on how financial incentives shall be linked to energy performance improvements - EPCs database shall gather data
14	**Inspection of Heating systems** - Threshold for regular inspections moved from 20kW to 70 kW - Alternative measures with equivalent impact still allowed - N-RES: BACS mandatory from systems >290kW from 2025 onwards - RES: Voluntary introduction of electronic monitoring
15	**Inspection of AirCon systems** - Threshold for regular inspections moved from 12kW to 70 kW - Alternative measures with equivalent impact still allowed - N-RES: BACS mandatory from systems >290kW from 2025 onwards - RES: Voluntary introduction of electronic monitoring
19	**Review** - District: Spatial context instead of single building introduced
20	**Information** - MS duty to inormation owners and tenants rephrased
23-26	**Admin**
Annex I	**Calculation of energy performance** - The “energy performance” indicator has been romoved (adressing the efficiency of the building shell), on Primary Energy required
Annex Ia	NEW: **Smart Readiness of buildings** - The EC shall develop a methodology for the SRI that takes the following points into account: o Maintain energy efficiency performance o Adapt to the needs of the occupant o Flexibility in relation to the grid

L.2.2. Adjustments to the EPBD IA parameters

Based on the list of agreed amendments to the EPBD from above, this section gives on overview of how the new policy setup in the EPBD would correlate with the "*Option II: Enhanced implementation, including targeted amendments for strengthening of current provisions*" scenario from the EPBD Impact Assessment and how the underlaying parameter dataset needs to be adapted.

We propose to take the *"Option II: Enhanced implementation, including targeted amendments for strengthening of current provisions"* as a starting parameter set for the BAU building sector scenarios, as it is to a large extend in line with the agreed amendments of the EPBD from the Trialogue Process. To fully align the scenario assumptions with the agreed amendments, we propose to adjust the following parameters:

- Renovation quality (building shell)
- Renovation rate
- Improvement/ replacement rates of TBS (heating, cooling)
- Heating system implementation mix

The following four scenarios were defined in the framework of the EPBD-IA, see Table L 3.

Table L 3 - Overview of NEW policy options and corresponding measures[124]

Option 0: No-change option	
0B.	Continuation of the energy efficiency obligation scheme after 2020
0C.	Project development assistance
0D.	Continuation of the cohesion policy funds post-2020 (Baseline)
0F.	Building related products under eco-design and energy labelling
0G.	Horizon 2020 post 2020
Option I: Enhanced implementation and soft law, including clarification and simplification of the current Directive	
6A	Guidance on EED Article 4
3A	Guidance for clarification of the current provisions on calculation methodologies
5A	Additional supporting guidance on implementation of cost-optimal levels of minimum performance requirements
Option II: Enhanced implementation, including targeted amendments for strengthening of current provisions	
6B	Long term target set by Member states
3B	Increase the transparency and comparability of energy performance calculation methodologies
4A	Improved EPC quality and data availability
2A	Initial commissioning of new/upgraded technical buildings systems
2B	Continuous commissioning of technical building systems in non-residential buildings
2C	Continuous commissioning of technical building systems in apartment buildings with central heating and/or air conditioning systems
8A	Long term renovation plans
8B	Link between public financing and renovation depth
8C	Disclosure of actual energy consumptions
Option III: Enhanced implementation and increased harmonization, while introducing substantial changes	
3C	Full harmonisation of energy performance calculation methodologies
5B	Include the co-benefits that flow from improved energy performance in the cost-optimal framework methodology
7C	Beyond nearly zero-energy buildings
4B	Self-pre-assessment platform for residential building units
0E.	Reinforced policy funds post-2020

[124] Source: "Ex-ante evaluation and assessment of policy options for the EPBD - Final report", Ecofys for DG-ENER, April 2016

A detailed comparison of the EPBA-IA scenario *"Option II: Enhanced implementation, including targeted amendments for strengthening of current provisions"* with the list of Agreed Amendments to the EPBD from above shows the following match:

Table L 4 - Comparison of EPBD Agreed Amendments with corresponding measures in the EPBD IA 2016

EPBD Agreed Amendments	Corresponding measure in EPBD IA 2016
2: Clarification on Definitions	3A: Guidance for clarification of the current provisions on calculation methodologies
2A: NEW: Long-term renovation strategy (from EED) - Roadmap with polocies and actions - Mobilization of investments - Public consultation	8A: Long term renovation plans 6A: Guidance on EED Article 4
6: New Buildings - List with high efficient alternative systems (to be considered) removed	No direct impact
7: Existing Buildings - Minor additions (health and indoor climate)	Little direct impact, does refer to 5B: Include the co-benefits that flow from improved energy performance in the cost-optimal framework methodology

8: Technical Building systems
- Minor additions (self-regulating devices)
- EV charging points (at least one in five) for more than 10 parking spaces (if car park in the building or physically adjacent) for N-RES and ducting infrastructure only for RES buildings
  o Not mandatory for small/ medium enterprises
  o limiting factors (i.e. costs)
- EPCs: Energy performance need to be assessed when technical building systems are installed(/replaced
SRI: Optinal EU-wide scheme for rating the smart readyness of buildings => NEW Annex Ia
	4A: Improved EPC quality and data availability
	2A: Initial commissioning of new/upgraded technical buildings systems
	2B: Continuous commissioning of technical building systems in non-residential buildings
	2C: Continuous commissioning of technical building systems in apartment buildings with central heating and/or air conditioning systems
	- SRI to a large extend covered by TBS measues
	- Charging points not covered by EPBD IA

10: Financial Incentives - More deteils on how financial incentives shall be linked to energy performance improvements - EPCs database shall gather data	Does refer partly to 8B: Link between public financing and renovation depth
14: Inspection of Heating systems - Threshold for regular inspections moved from 20kW to 70 kW - Alternative measures with equivalent impact still allowed - N-RES: BACS mandatory from systems >290kW from 2025 onwards - RES: Voluntary introduction of electronic monitoring 15: Inspection of AirCon systems - Threshold for regular inspections moved from 12kW to 70 kW - Alternative measures with equivalent impact still allowed - N-RES: BACS mandatory from systems >290kW from 2025 onwards	2B: Continuous commissioning of technical building systems in non-residential buildings 2C: Continuous commissioning of technical building systems in apartment buildings with central heating and/or air conditioning systems

- RES: Voluntary introduction of electronic monitoring	
19: Review - District: Spatial context instead of single building introduced	Does partly refer to 7C: Beyond nearly zero-energy buildings
20: Information - MS duty to inormation owners and tenants rephrased	Does partly refer to 3A: Guidance for clarification of the current provisions on calculation methodologies
Annex I: Calculation of energy performance - The "energy performance" indicator has been romoved (adressing the efficiency of the building shell), on Primary Energy required	Does partly refer to 3B: Increase the transparency and comparability of energy performance calculation methodologies
Annex Ia: NEW: Smart Readiness of buildings - The EC shall develop a methodology for the SRI that takes the following points into account: ○ Maintain energy efficiency performance ○ Adapt to the needs of the occupant ○ Flexibility in relation to the grid	- Not covered

As a result of the comparison, the following policy options from the Option II (including Option I) for the EPBD IA are ***NOT covered*** by the Agreed Amendments of the EPBD:

Table L 5 - Policy options of the EPBD IA that are not covered by the Agreed Amendments to the EPBD

5A	Additional supporting guidance on implementation of cost-optimal levels of minimum performance requirements
6B	Long term target set by Member states
8C	Disclosure of actual energy consumptions

➔ Option 5A refers to 3a (66%) of original policies

Option 3a: Accelerate the implementation of cost optimal levels	All buildings	stock/ new bldgs.	Earlier implementation of CO values in comparison to S1	Retrofit	
				Full thermal renovation rate:	No effect
				HVAC system exchange rate:	No effect
				Quality building envelope:	Apply CO levels for existing buildings from MS reports in 2017 instead of 2018, and 5% improvement in 2021 instead of 2023 and again 5% improvement in 2026 instead of 2028
				HVAC systems:	
				New buildings	
				Quality building envelope:	Small effect (included in system mix development)
				HVAC systems:	No effect for new buildings Small effect (included in system mix development)

➔ 6B Long term targets set by MS (8A) ➔ Effect assessed at 2/3 of effect attributed to option 8A (long term renovation plans) ➔ Option 8A refers to 3b (100%) of original policies

Option 3b: Increase rate of renovation by promoting voluntary long-term renovation plan linked to financing schemes	All buildings	Stock	Higher renovation rate	Retrofit Full thermal renovation rate: HVAC system exchange rate: Quality building envelope: HVAC systems: New buildings Quality building envelope: HVAC systems:	 0.15% increase 0.05% increase No effect No effect No effect No effect

➔ Option 8C refers to 4d (100%) of original policies

Option 4d: Voluntary Disclosure of Operational Energy Consumption in public buildings	Binding for public buildings, voluntary for non-residential buildings	stock	Increase of renovation rate. Higher quality of building envelope retrofit	Retrofit Full thermal renovation rate: HVAC system exchange rate: Quality building envelope: HVAC systems: New buildings Quality building envelope: HVAC systems:	 0.05% increase 0.02% increase Small effect (10% of bldgs. perform 10% better than CO levels = 1% increase of ambition level) No effect No effect No effect

In ***addition we have partly covered*** the following policies from the Option III by the Agreed Amendments of the EPBD

Table L 6 - Policy options of the EPBD IA that are additional to the Agreed Amendments to the EPBD

5B	Include the co-benefits that flow from improved energy performance in the cost-optimal framework methodology
7C	Beyond nearly zero-energy buildings

➔ Option 5B refers to 3C (100%) of original policies

Option 3c: Set ambitious requirements for new and existing buildings by 2030 and 2050 (beyond cost-optimal)	All buildings	stock/ new bldgs.		Retrofit Full thermal renovation rate: HVAC system exchange rate: Quality building envelope: HVAC systems: New buildings Quality building envelope: HVAC systems:	 No effect No effect 10% improvement of Cost-optimal levels from 2021 for new bldgs. and renovations due to including co-benefits Use of higher performing systems (effect included in system mix development) No effect No effect

➔ Option 7C: Effect assessed at 20% of effect attributed to option 5B (Include the co-benefits that flow from improved energy performance in the cost-optimal framework methodology) ➔ Option refers to 3C (100%) of original policies.

As a **summary** of the comparison from above the adaption of the parameter dataset of "*Option II: Enhanced implementation, including targeted amendments for strengthening of current provisions"* is as follows:

<u>Retrofit parameters:</u>

- **Full thermal renovation rate**: -2/3*0,15%-0,05% ➔ **-0,15%**
- **HVAC system exchange rate**: -2/3*0,05%-0,02% ➔ **-0,05%**
- **Quality building envelope**: not included: cost optimal levels two years earlier (2021 instead of 2023 and 2026 instead of 2028), 1% increase of ambition level of CO; in addition: CO levels 10% better from 2021 onwards (120% of this effect), ➔ **10% better CO levels**
- **HVAC systems**: not included: ; in addition: cost optimal levels two years earlier (2021 instead of 2023 and 2026 instead of 2028), Use of higher performing systems (effect included in system mix development) ➔ **CO levels two years earlier**

<u>New building parameters:</u>

- No effects

L.3. Building stock disaggregation

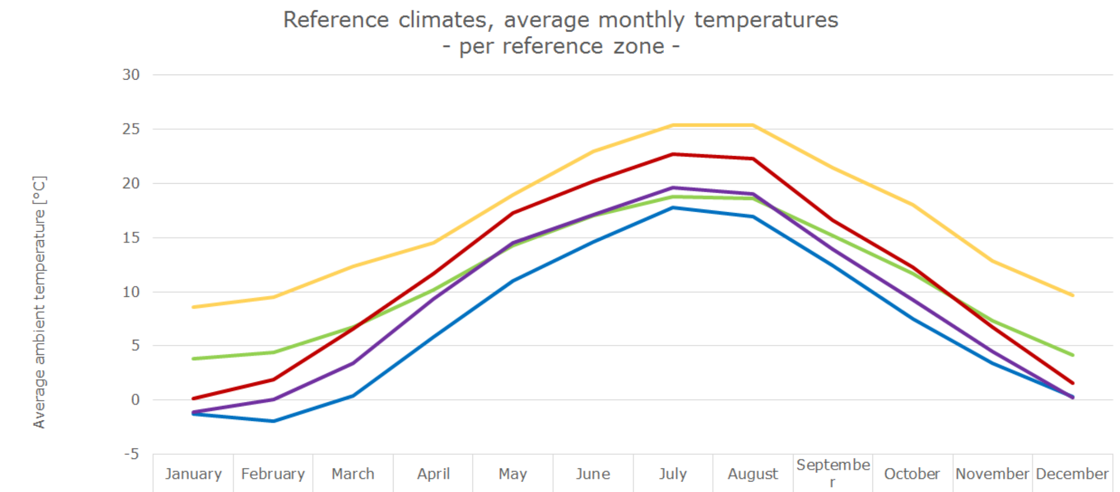
L.3.1. Reference zones and climates

The building stock is divided into five climate zones for Europe. The countries within the respective reference zones are shown in Figure L 1.

Figure L 1 - Geographical regions for Europe

All countries are assigned to one of the reference zones concerning the criteria of (i) climate conditions, (ii) building stock characteristics and (iii) cost structures and level of investment costs/energy costs.

Figure L 2 shows the reference climate conditions in terms of weighted average ambient temperatures of the reference zones.



	January	February	March	April	May	June	July	August	September	October	November	December
Northern	-1	-2	0	6	11	15	18	17	12	8	3	0
Western	4	4	7	10	14	17	19	19	15	12	7	4
North-Eastern	-1	0	3	9	15	17	20	19	14	9	4	0
South-Eastern	0	2	7	12	17	20	23	22	17	12	7	2
South	9	10	12	15	19	23	25	25	22	18	13	10

Figure L 2 - Average ambient temperatures of the reference zones per month (Source: [Meteotest, 2012])

L.3.2. Reference Buildings

The model requires the definition of reference buildings as representative average building types for all buildings in stock. Reference buildings are typical representatives with regard to the geometry of a building.

Residential

Reference buildings from (iNSPIRe, 2014) are used, which are:

- Single Family House (SFH)
- Small Multi Family House (SMFH)
- Large Multi Family House (LMFH)

The parameters and geometries for the chosen reference buildings are shown in Table L 7, Table L 8 and Table L 9.

Table L 7 - Parameters for Single Family House (SFH) (Source: [iNSPIRe, 2014])

Parameter	Values	Unit
Total floor area	96	m^2
A/V ratio	0.90	1/m
Average room height	2.5	m
Exterior building volume	281	m^3
Exterior walls	128	m^2
Windows	26	m^2
Cellar ceiling	52	m^2
Roof / upper ceiling	52	m^2

Table L 8 - Parameters for Small Multi Family House (SMFH) (Source: [iNSPIRe, 2014])

Parameter	Values	Unit
Total floor area	500	m^2
A/V ratio	0.5	1/m
Average room height	2.5	m
Exterior building volume	1,672	m^3
Exterior walls	513	m^2
Windows	128	m^2
Cellar ceiling	124	m^2
Roof / upper ceiling	124	m^2

Table L 9 - Parameters for Large Multi Family House (LMFH) (Source: [iNSPIRe, 2014])

Parameter	Values	Unit
Total floor area	2,340	m^2
A/V ratio	0.3	1/m
Average room height	2.5	m
Exterior building volume	7,484	m^3
Exterior walls	699	m^2
Windows	699	m^2
Cellar ceiling	462	m^2
Roof / upper ceiling	462	m^2

Non-residential

The reference buildings for non-residential buildings are defined along the Annex I.5 of the EPBD[125]. The geometries are based on data from European Copper Institute (ECI) for the study "Panorama of the European non-residential construction sector" (2011):

- Office Building (OFB)
- Trade and Retail Building (TRB)
- Education Building (EDB)
- Touristic Buildings (TOB)
- Health Buildings (HEB)
- Other non-residential buildings (ONB)

125 Hospitals are listed under health buildings and hotels and restaurants under touristic buildings. Sport facilities are addressed with other non-res buildings.

The parameters and geometries for the chosen reference buildings are shown in Table L 10, Table L 11, Table L 12, Table L 13, Table L 14 and Table L 15.

Table L 10 - Parameters for Office Buildings (OFB) (Source: [ECOFYS, 2011b])

Parameter	Values	Unit
Total floor area	1,801	m²
A/V ratio	0.25	1/m
Average room height	2.6	m
Exterior building volume	4,683	m³
Exterior walls	277	m²
Windows	150	m²
Cellar ceiling	360	m²
Roof / upper ceiling	360	m²

Table L 11 - Parameters for Trade and Retail Building (TRB) (Source: [ECOFYS, 2011b])

Parameter	Values	Unit
Total floor area	1,448	m²
A/V ratio	0.36	1/m
Average room height	3.6	m
Exterior building volume	5,214	m³
Exterior walls	302	m²
Windows	130	m²
Cellar ceiling	724	m²
Roof / upper ceiling	724	m²

Table L 12 - Parameters for Education Building (EDB) (Source: [ECOFYS, 2011b])

Parameter	Values	Unit
Total floor area	2,552	m²
A/V ratio	0.45	1/m
Average room height	2.6	m
Exterior building volume	6,556	m³
Exterior walls	318	m²
Windows	106	m²
Cellar ceiling	1.216	m²
Roof / upper ceiling	1.216	m²

Table L 13 - Parameters for Touristic Buildings (TOB) (Source: [ECOFYS, 2011b])

Parameter	Values	Unit
Total floor area	968	m²
A/V ratio	0.40	1/m
Average room height	3.00	m
Exterior building volume	2,904	m³
Exterior walls	385	m²
Windows	127	m²
Cellar ceiling	323	m²
Roof / upper ceiling	323	m²

Table L 14 - Parameters for Health Buildings (HEB) (Source: [ECOFYS, 2011b])

Parameter	Values	Unit
Total floor area	6,420	m²
A/V ratio	0.27	1/m
Average room height	2.60	m
Exterior building volume	16,692	m³
Exterior walls	997	m²
Windows	330	m²
Cellar ceiling	1,605	m²
Roof / upper ceiling	1,605	m²

Table L 15 - Parameters for Other non-residential buildings (ONB) (Source: [ECOFYS, 2011b])

Parameter	Values	Unit
Total floor area	2,434	m²
A/V ratio	0.39	1/m
Average room height	3.00	m
Exterior building volume	9,500	m³
Exterior walls	682	m²
Windows	2,014	m²
Cellar ceiling	507	m²
Roof / upper ceiling	507	m²

L.3.3. Age groups

The definition of age groups in stock is required to distinguish between different construction periods of buildings. The chosen age groups are:

- Pre 1945
- 1945-1970
- 1971-1990
- 1991-2014
- from 2015

L.3.4. Retrofit Levels

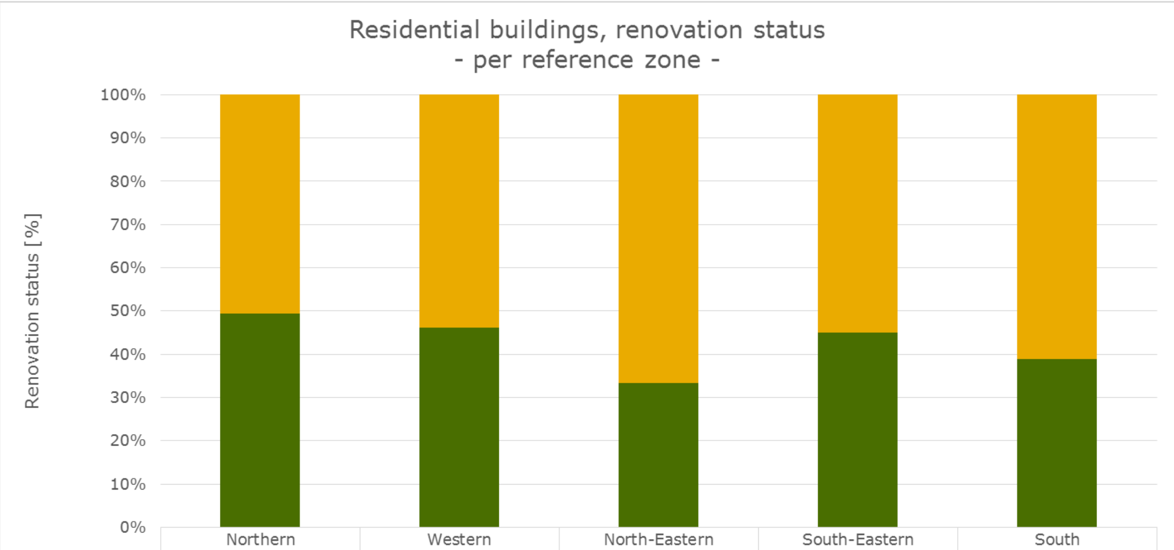
The stock is further disaggregated into two sub-groups, considering the thermal characteristics:

- "Renovated",
- "Not-revovated".

This disaggregation enables the establishment of two levels of thermal characteristics for the considered segment.
Already renovated buildings are not excluded from renovation by the model, but the not renovated buildings undergo renovation first.

In the scenario calculation for both, residential and non-residential buildings and for each reference zone, one retrofit level (major renovation) will be 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 residential and non-residential buildings of the "renovated" and "not renovated" cases are defined in section J.3.5.

Residential
Figure L 3 shows the share of already retrofitted 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 L 3 - Considered share of already retrofitted residential buildings [%] (Source: own calculation based on [ECOFYS, 2012], based on [Euroconstruct, 2005] with further updates and assumptions for period 2005-2013.)

Non-Residential

Figure L 4 shows the share of already retrofitted non-residential buildings per reference zone.

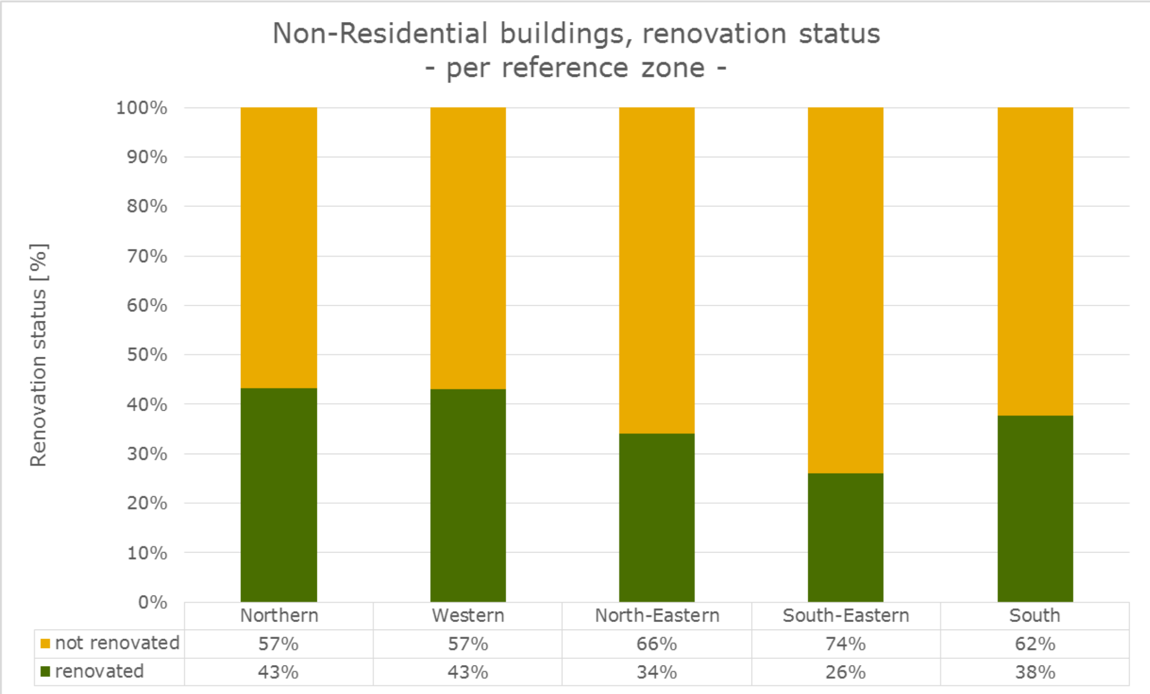


Figure L 4 - Considered share of already retrofitted non-residential buildings [%] (Source: own calculations for 2014 based on [Euroconstruct, 2005])

L.3.5. Floor Areas

The following figures give an overview on the floor area distribution along the reference zones of the study:

- Residential:
  - per reference buildings (Figure L 5 and Figure L 6),
  - per age group (Figure L 7),
- Non-residential:
  - per reference buildings (Figure L 8 and Figure L 9),
  - per age group (Figure L 10).

Residential

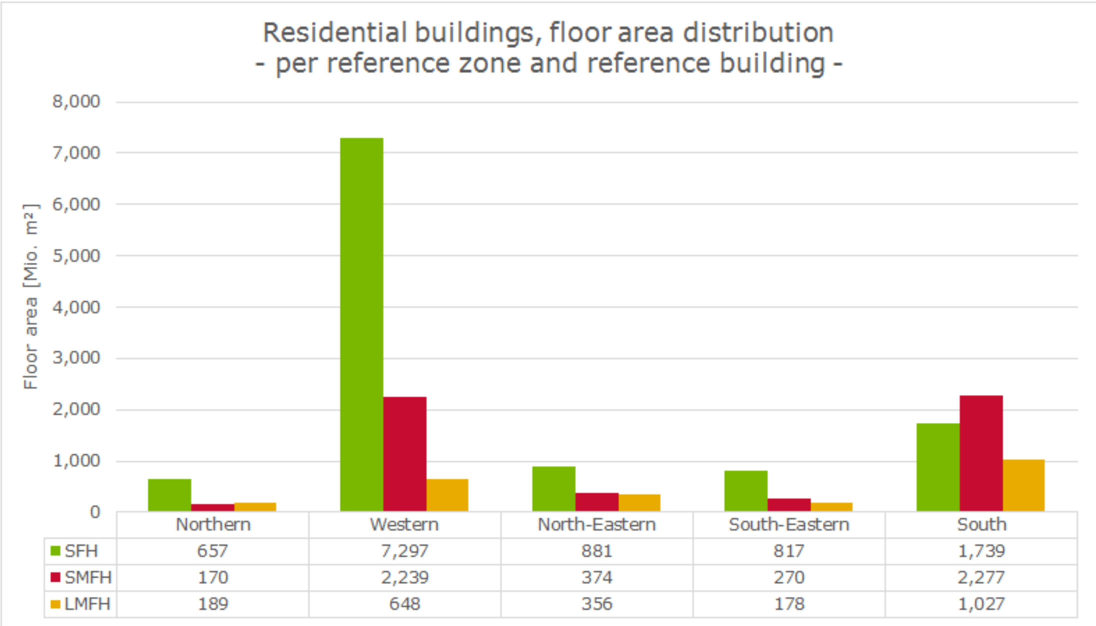


Figure L 5 - Floor area distribution in residential buildings, per zone and reference building [Mio. m²] (Source: own calculation based on [iNSPIRe, 2014], [IWU, 2015], [ENERDATA, 2013-2015], [BPIE, 2015] and [Schimschar, 2015])

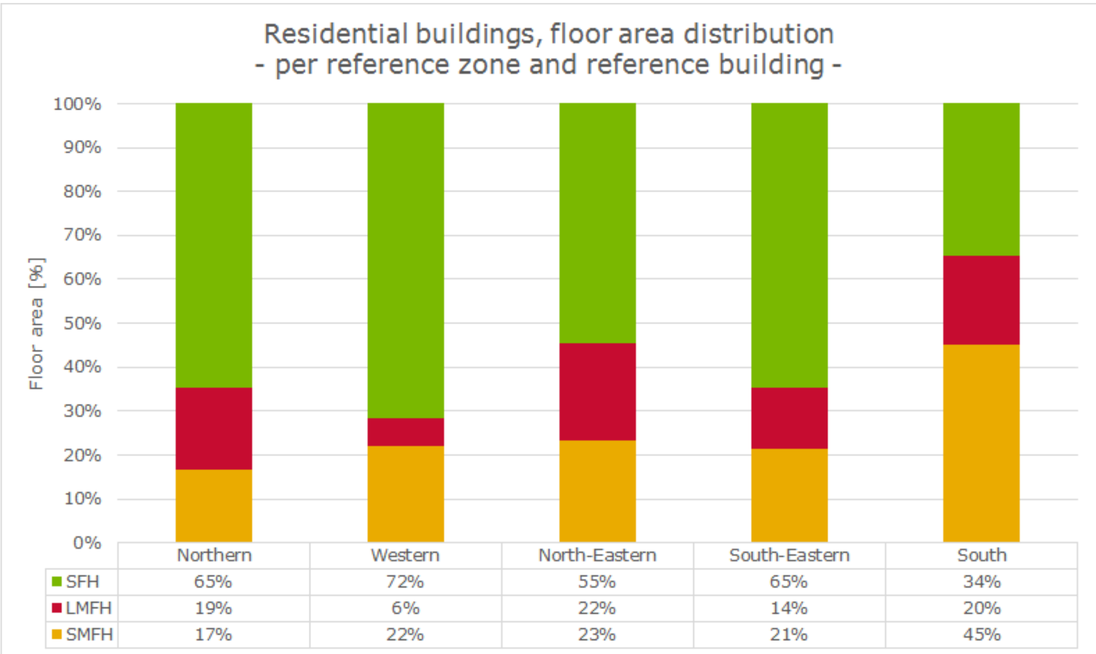


Figure L 6 - Floor area distribution in residential buildings, per zone and reference building [%] (Source: own calculation based on [iNSPIRe, 2014], [IWU, 2015], [ENERDATA, 2013-2015], [BPIE, 2015] and [Schimschar, 2015])

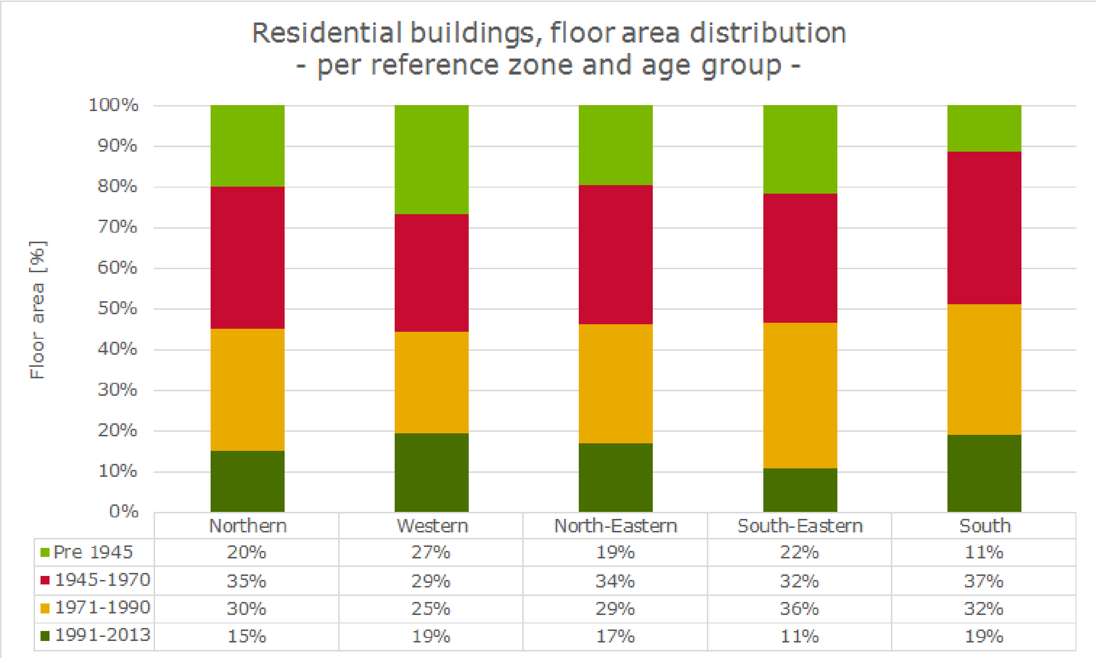


Figure L 7 - Floor area distribution in residential buildings, per zone and age group [%] (Source: own calculation based on [iNSPIRe, 2014], [IWU, 2015], [ENERDATA, 2013-2015], [BPIE, 2015] and [Schimschar, 2015])

Non-Residential

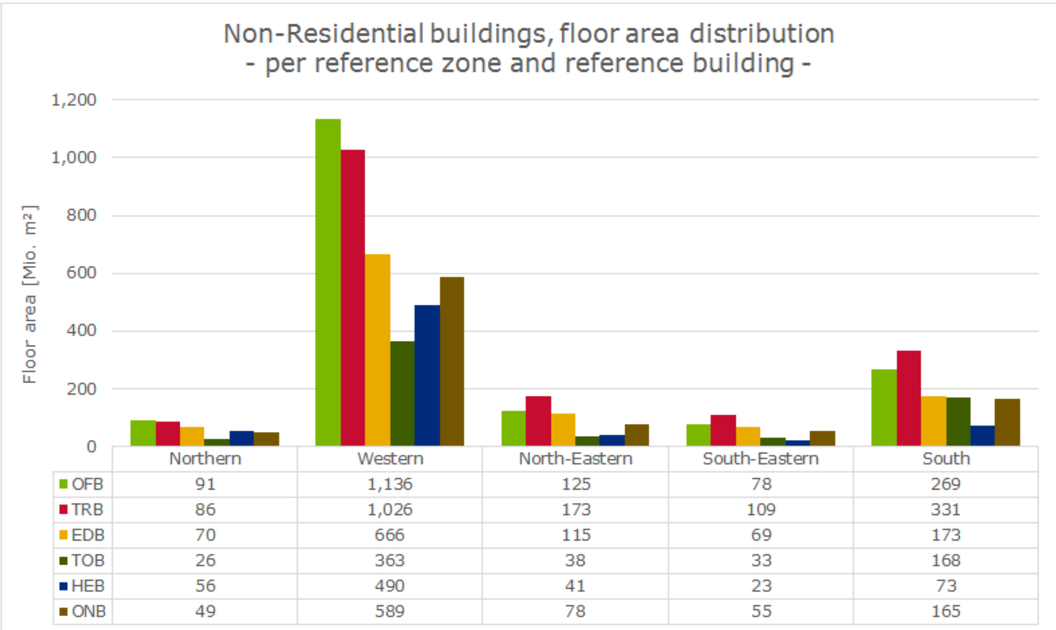
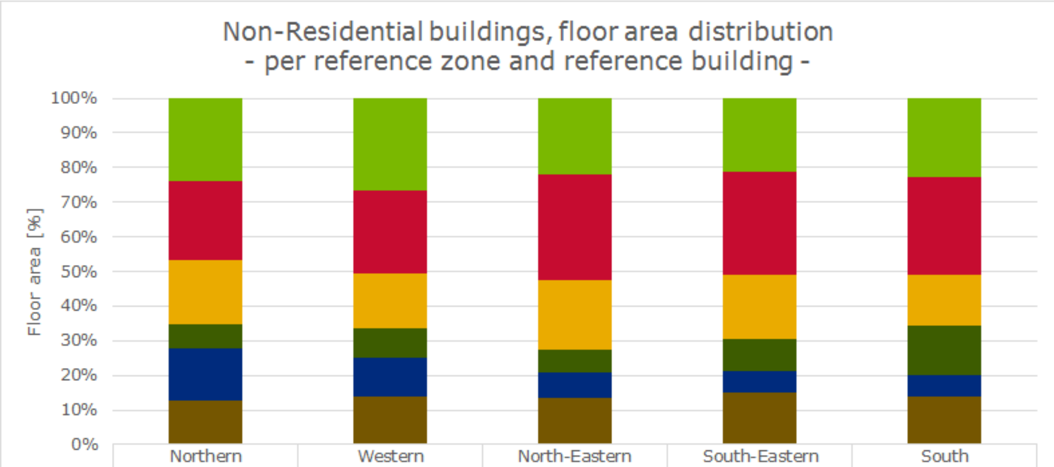
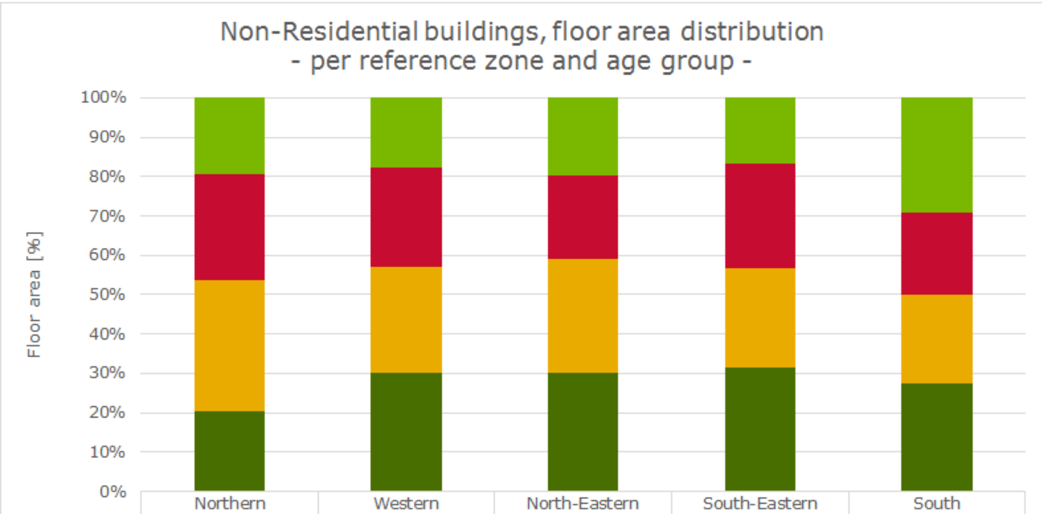


Figure L 8 - Floor area distribution in non-residential buildings, per zone and reference building [Mio. m²] (Source: own calculation based on [iNSPIRe, 2014], [IWU, 2015], [ENERDATA, 2013-2015], [BPIE, 2015] and [Schimschar, 2015])



	Northern	Western	North-Eastern	South-Eastern	South
OFB	24%	27%	22%	21%	23%
TRB	23%	24%	30%	30%	28%
EDB	18%	16%	20%	19%	15%
TOB	7%	9%	7%	9%	14%
HEB	15%	11%	7%	6%	6%
ONB	13%	14%	14%	15%	14%

Figure L 9 - Floor area distribution in non-residential buildings, per zone and reference building [%] (Source: own calculation based on [iNSPIRe, 2014], [IWU, 2015], [ENERDATA, 2013-2015], [BPIE, 2015] and [Schimschar, 2015])



	Northern	Western	North-Eastern	South-Eastern	South
Pre 1945	19%	18%	20%	17%	29%
1945-1970	27%	26%	21%	26%	21%
1971-1990	33%	27%	29%	25%	23%
1991-2013	20%	30%	30%	31%	28%

Figure L 10 - Floor area distribution in residential buildings, per zone and age group, [%] (Source: own calculation based on [iNSPIRe, 2014], [IWU, 2015], [ENERDATA, 2013-2015], [BPIE, 2015] and [Schimschar, 2015])

L.4. Detailed building sector Pathways

This section gives an overview of the results for the building sector pathways.

L.4.1. AGREED AMENDMENTS PATHWAY

European Union

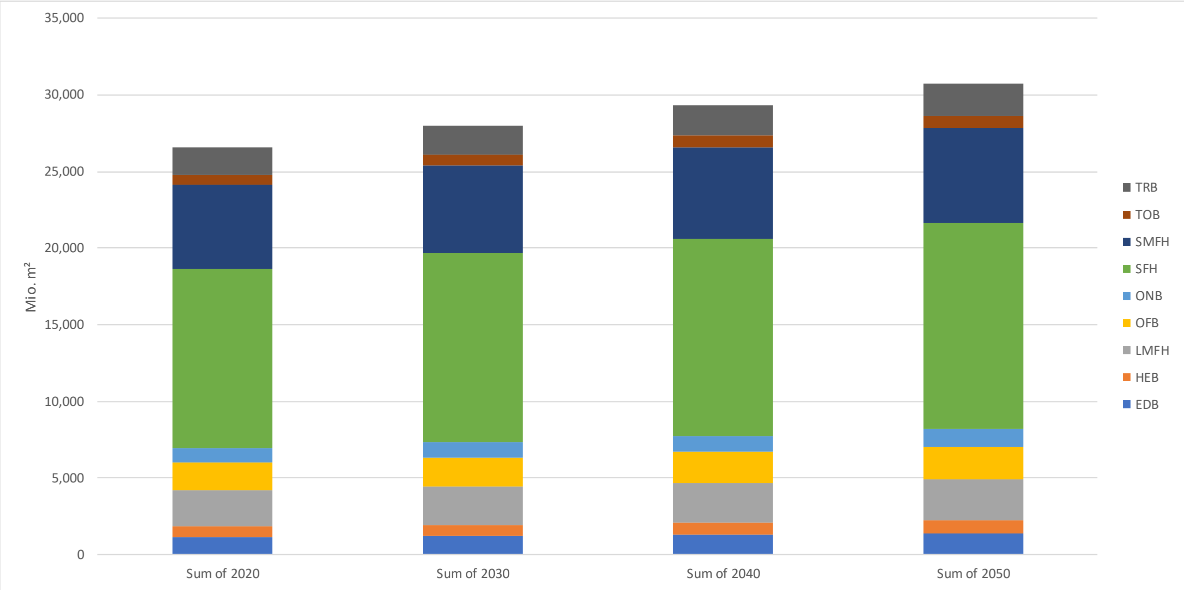


Figure L 11 - Floor area per reference building – EU

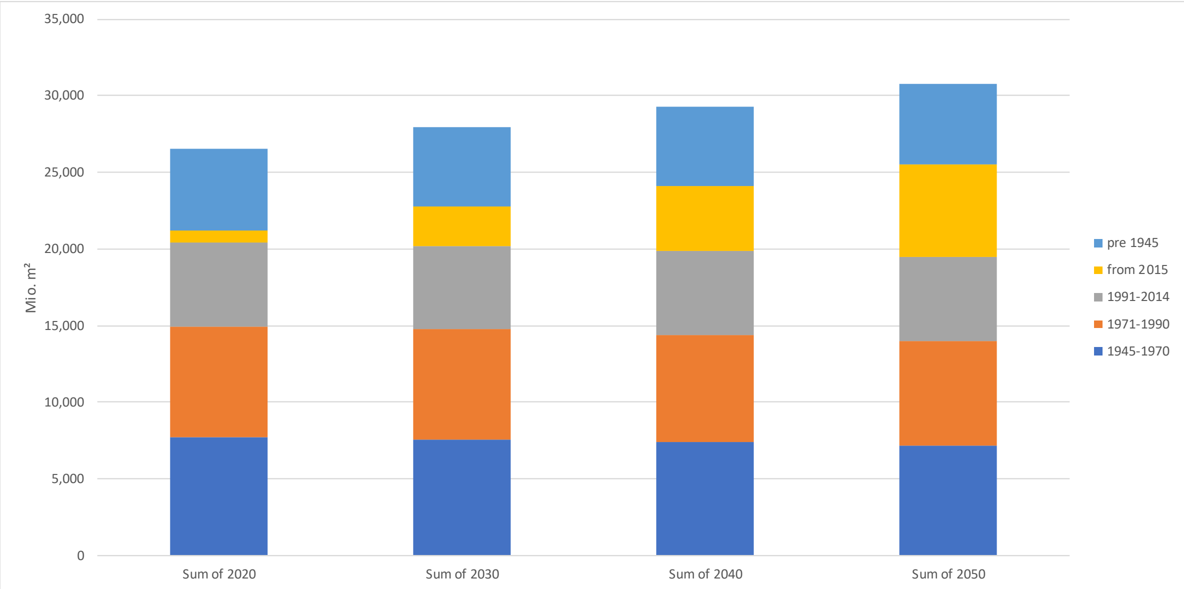


Figure L 12 - EU total floor area development per buildings' age group

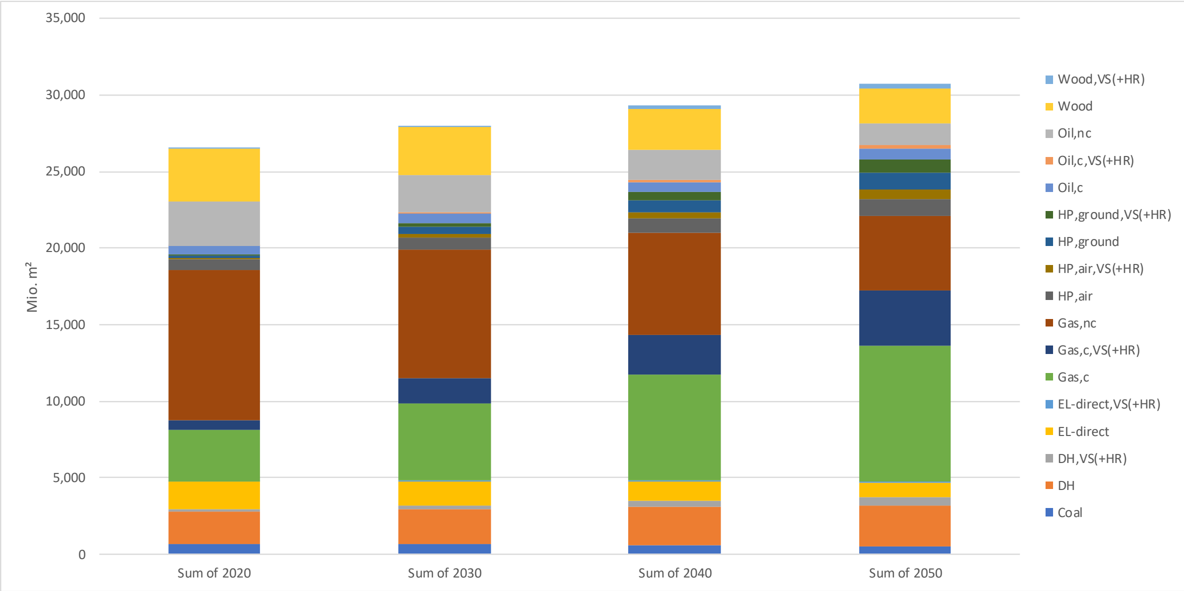


Figure L 13 - Floor area per heating system – EU

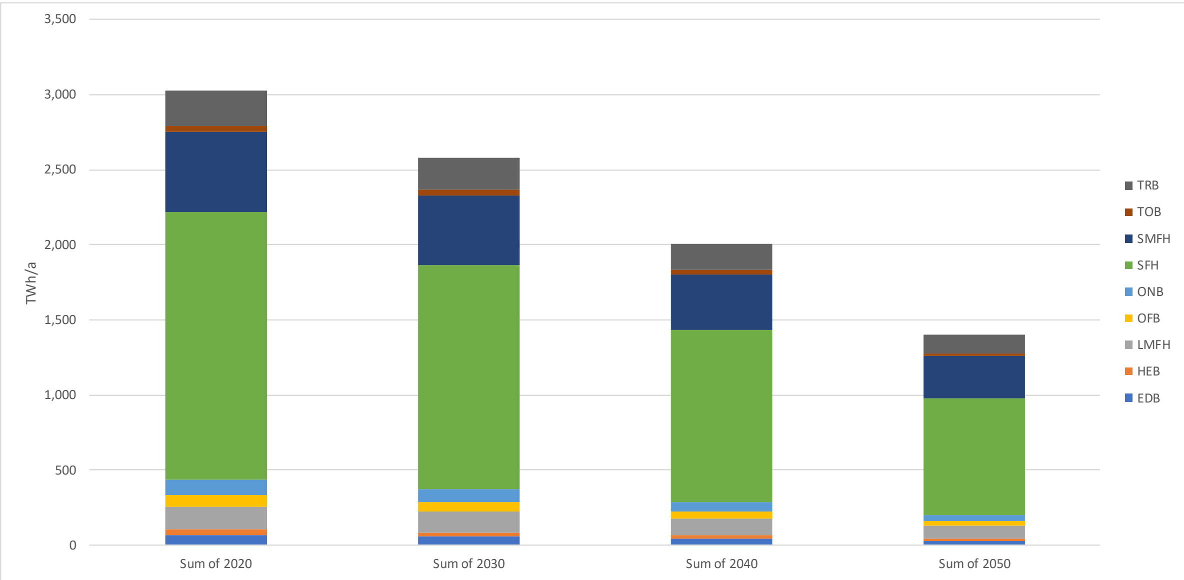


Figure L 14 - Final Energy heating per reference buildings – EU

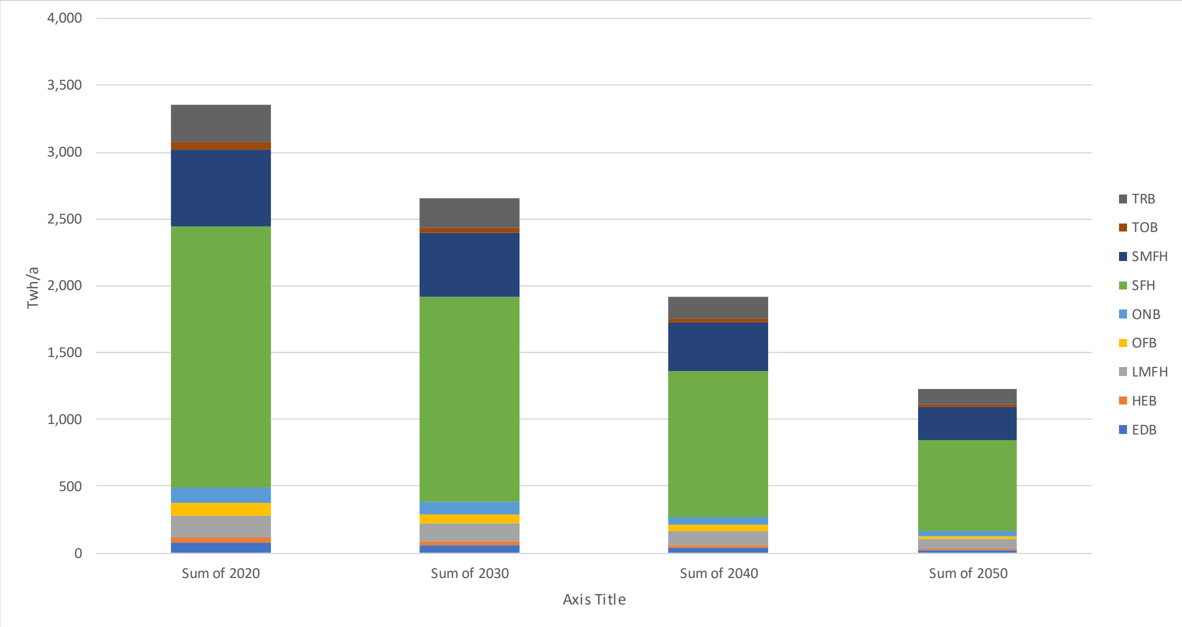


Figure L 15 - Primary Energy heating per reference building – EU

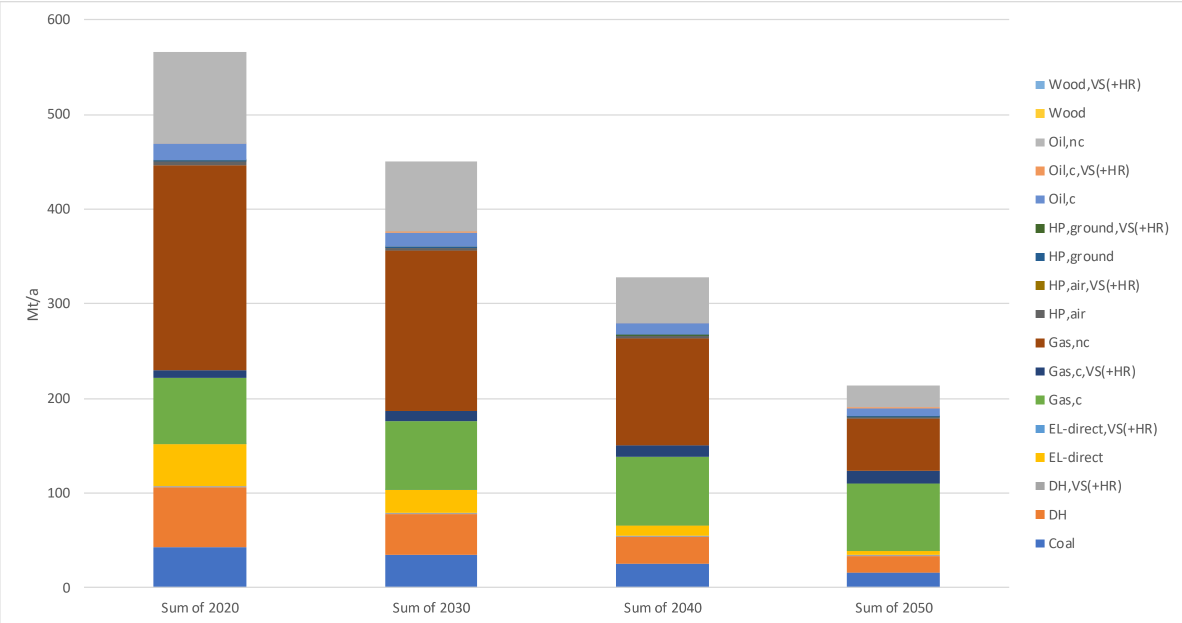


Figure L 16 - CO_2 emissions heating per heating system – EU

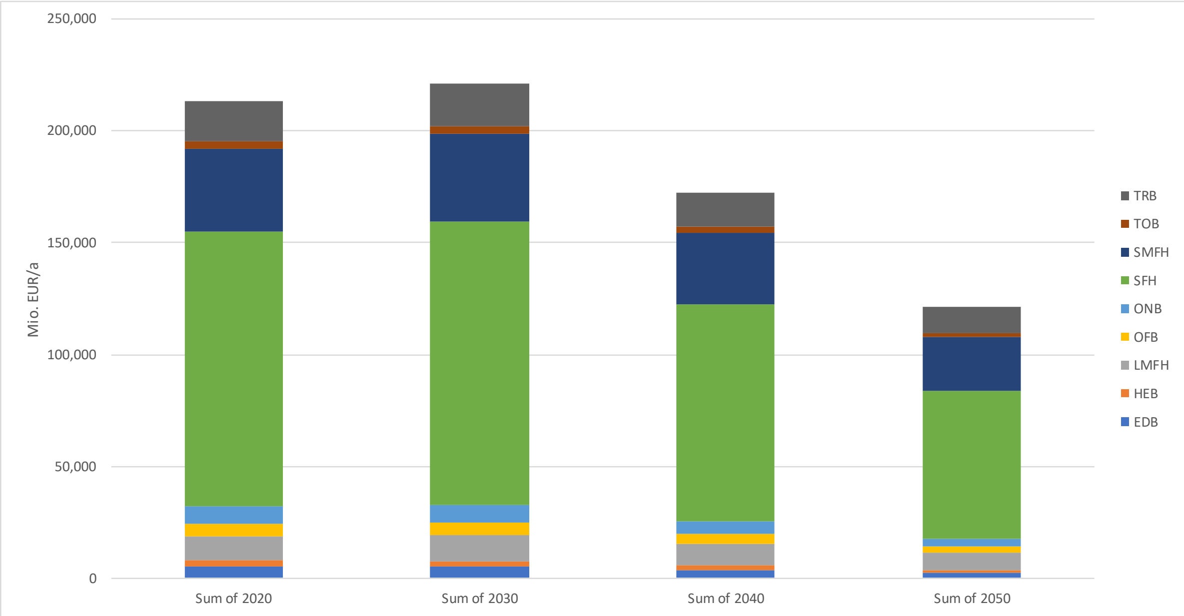


Figure L 17 - Energy Costs heating per reference building – EU

L.4.2. Agreed Amendments + Ambitious Implementation Pathway

European Union

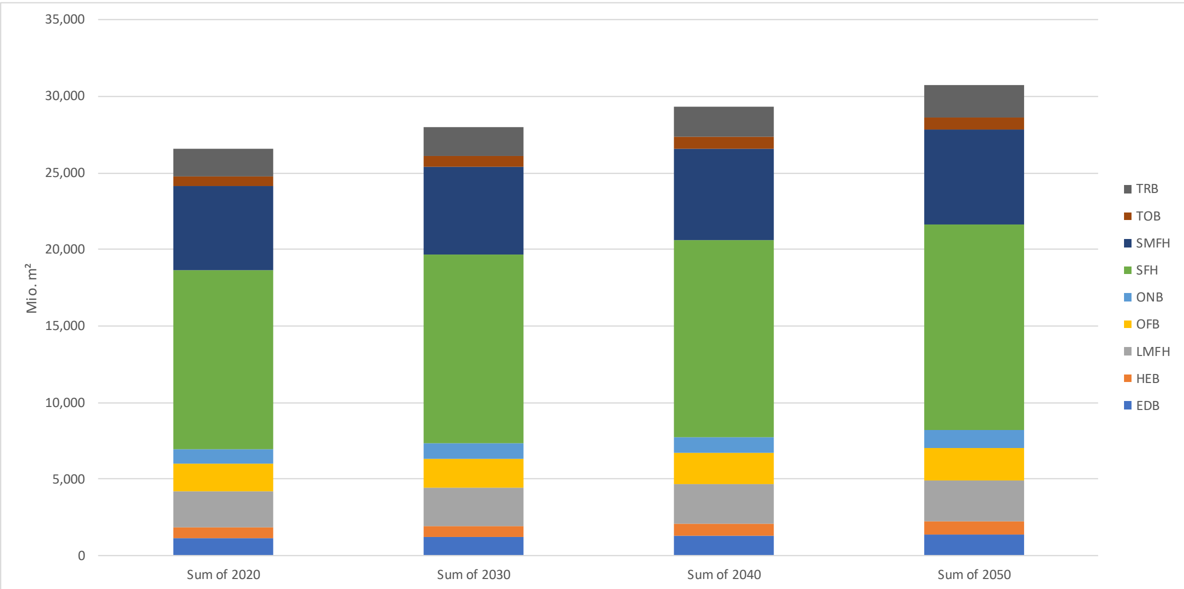


Figure L 18 - Floor area per reference building – EU

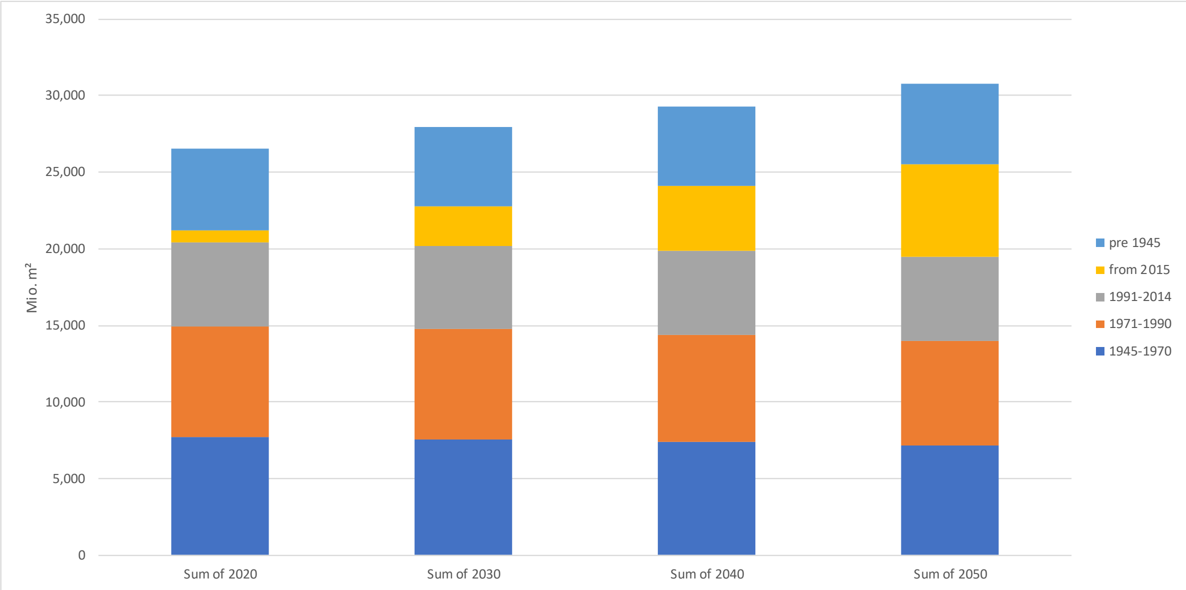


Figure L 19 - EU total floor area development per buildings' age group

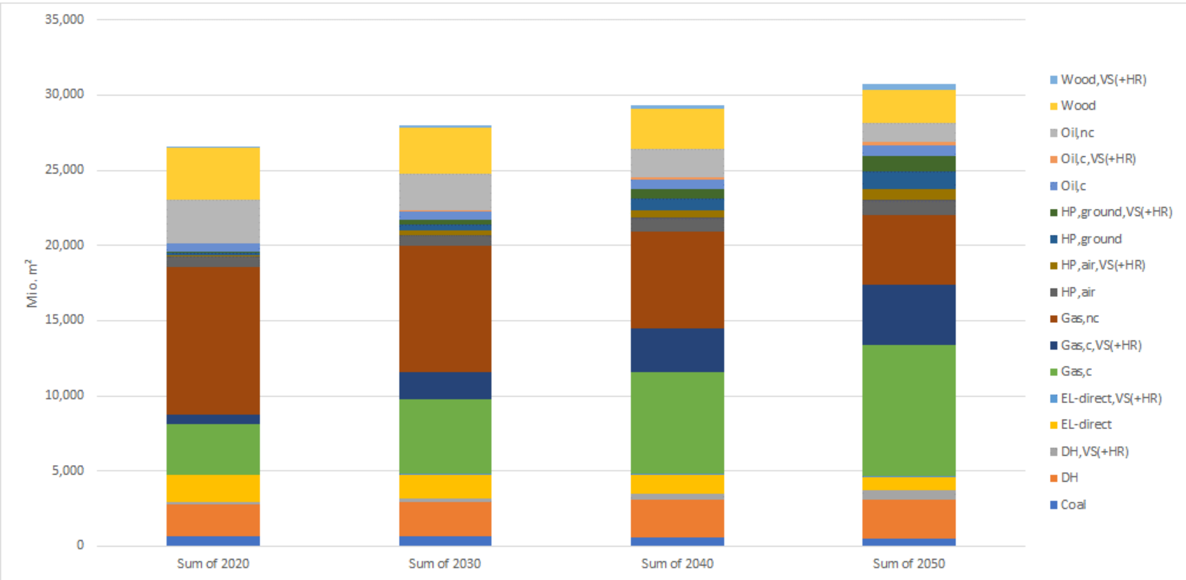


Figure L 20 - Floor area per heating system – EU

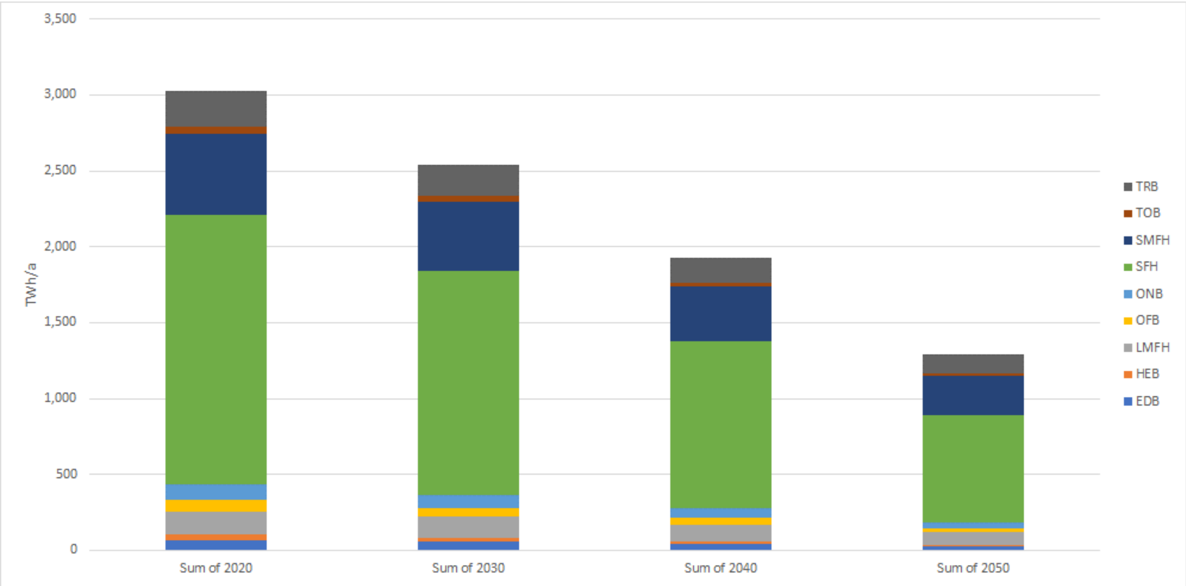


Figure L 21 - Final Energy heating per reference buildings – EU

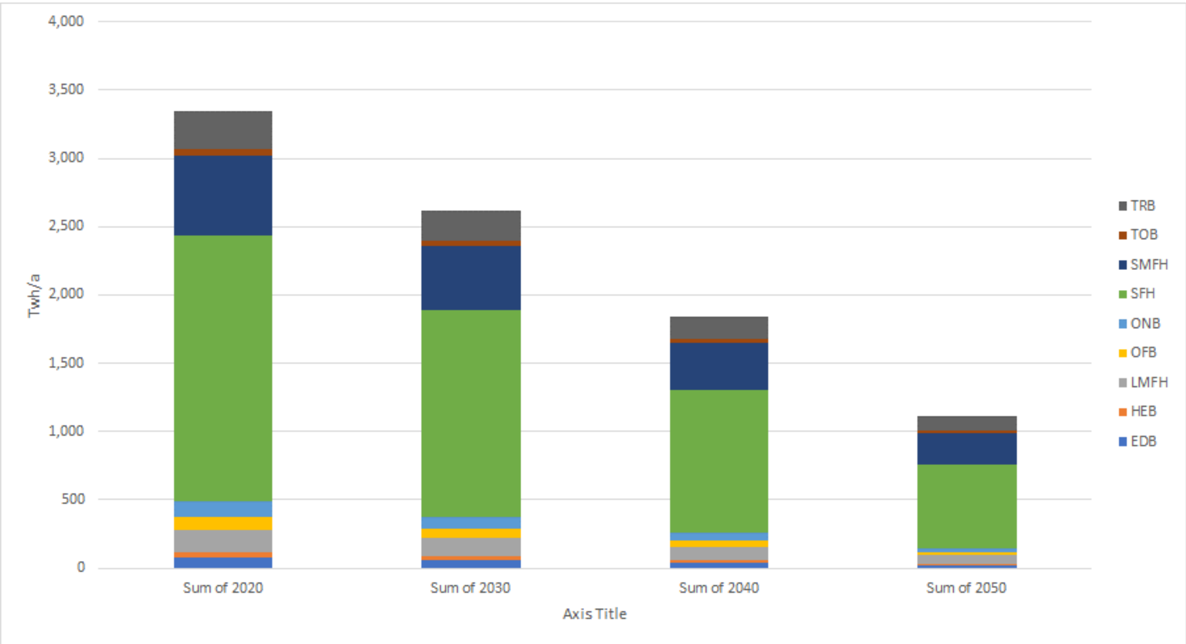


Figure L 22 - Primary Energy heating per reference building – EU

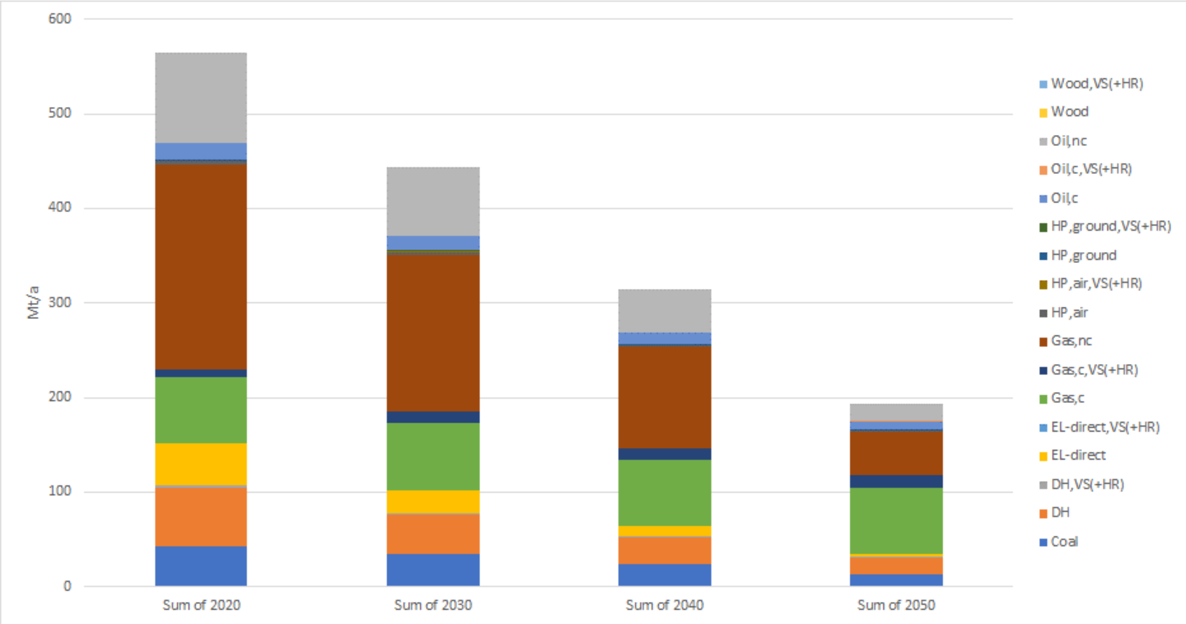


Figure L 23 - CO_2 emissions heating per heating system – EU

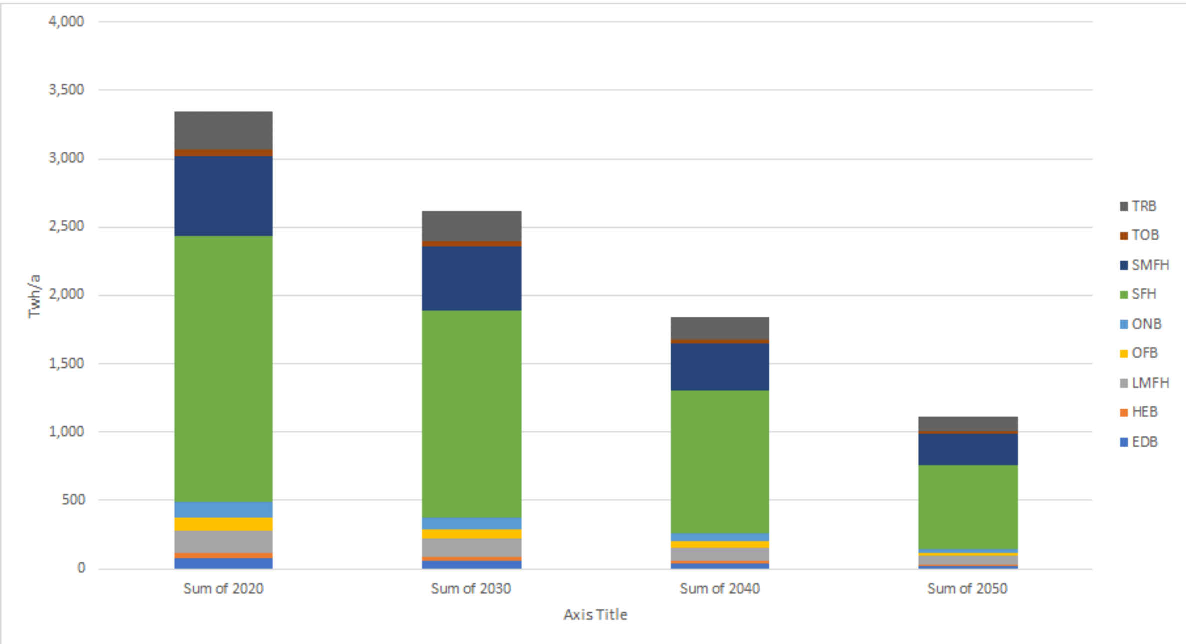


Figure L 24 - Energy Costs heating per reference building – EU

ANNEX M – SRT SCENARIOS – DETAILED ASSUMPTIONS

M.1. Smart ready technologies and smart readiness indicator scenarios

M.1.1. General smart ready technology scenario definitions and parameters

This annex summarizes the general SRT scenario parameters. Table M 1 gives an overview of heated and cooled floor area for residential and non-residential buildings in Europe, while Table M 2 summarizes the current status of SRI ranges in the EU building stock.

The proportions of heated and/or cooled floor areas are mainly based on EU data from the Stratego Heat Roadmap Europe project and on a study for Germany on energetic inspection. As the table shows, the by far largest share of the residential building stock is with heating only. A significant share of heated and cooled floor area is present in Southern Europe only. For non-residential buildings the picture is different, as more buildings have cooling systems installed, especially in Southern Europe again.

	Heating only	Heating + Cooling	Cooling only
Residential			
EU-North	99%	1%	0%
EU-West	97%	3%	0%
EU-South	90%	9%	1%
Non-residential			
EU-North	90%	10%	0%
EU-West	80%	20%	0%
EU-South	35%	64%	1%

Table M 1 - Share of heated, cooled and heated+cooled floor area[126]

The other important starting point is the distribution of SRI ranges in the building stock today, as it defines and limits the possible improvement steps. In Western Europe the share of better SRI-ranges (III and IV) is generally higher than in Northern or Southern Europe, but also on a relatively low level. For residential buildings across Europe, more than 80% are assigned the SRI ranges I and II with quite some improvement potential. Non-residential buildings are more often equipped with BACS, since the HVAC systems in non-residential buildings usually have a higher complexity and a more relevant role than that in residential buildings. For those buildings more than 50% are within SRI ranges I and II, which also represents a high improvement potential.

[126] Sources: Ecofys "Energetic inspection report" for Germany, Stratego Heat Roadmap Europe: "Quantifying the Heating and Cooling Demand in Europe" Work Package 2 Background Report 4

Table M 2 – Status quo of SRI ranges in the EU building stock[127]

Northern-EU

	SFH, SMFH	LMFH	Office	Retail
SRI range I	25%	30%	35%	25%
SRI range II	70%	60%	55%	45%
SRI range III	4%	8%	8%	15%
SRI range IV	1%	2%	2%	15%

Western-EU

	SFH, SMFH	LMFH	Office	Retail
SRI range I	20%	25%	30%	20%
SRI range II	70%	60%	55%	40%
SRI range III	8%	11%	11%	20%
SRI range IV	2%	4%	4%	20%

Southern-EU

	SFH, SMFH	LMFH	Office	Retail
SRI range I	15%	20%	25%	15%
SRI range II	80%	70%	65%	55%
SRI range III	5%	9%	9%	20%
SRI range IV	0%	1%	1%	10%

Another central set of parameters is the energy savings for improving the SRI range and the associated investments for this step. Both parameters are summarized in M.2. Data sources on costs and benefits, differentiated by geographical zone and building type.

M.1.2. Life-cycle aspects

Life cycle phases of a building

The lifecycle of a building is composed of various phases (see following graphic). Depending on literature there are different approaches for the categorization of the phases. The following modular approach is presented in the DIN EN 15978.[128]

Modules A1 to A3 represent the product stage which includes all raw materials needed to produce the construction products (including transportation of them). Technical building systems run through similar modules as construction products but normally these products are produced with much more individual resources or sub products. The construction products have to be transported to the construction site of the newly constructed building (A4) and are being installed in the building during the construction process (A5).

Often the use stage (B1 to B7) and more specifically the operational energy use (B6) has the highest impact on the environment. Energy which is consumed for heating, hot water, cooling, lighting during the operational phase causes significant impacts on the environment[129]. Also repair (B3) and

[127] Source: Expert assumption based on EN15232 BACS level descriptions A-D, "Smart homes and buildings" presentation from BSRIA and Input data to the Leonardo Energy study "The potential for energy savings from energy management in the EU – findings from a comprehensive assessment" by Paul Waide

[128] Deutsches Institut für Normung e.V., DIN EN 15978: Nachhaltigkeit von Bauwerken –Bewertung der umweltbezogenen Qualität von Gebäuden – Berechnungsmethode (2012), p. 19 ff.

[129] Deutsche Energie-Agentur GmbH: Der dena-Gebäudereport (2015), p. 12

maintenance (B2) are counted within the operational phase and represent a significant amount of energy consumption.

As soon as the building has reached its end of life cycle stage (C1-C4) it is often demolished (or substantially renovated – C1) and the demolition waste is disposed. This implies transport to the end of life waste treatment facilities (C2), waste processing and treatment (C3). The following figure illustrates this cycle:

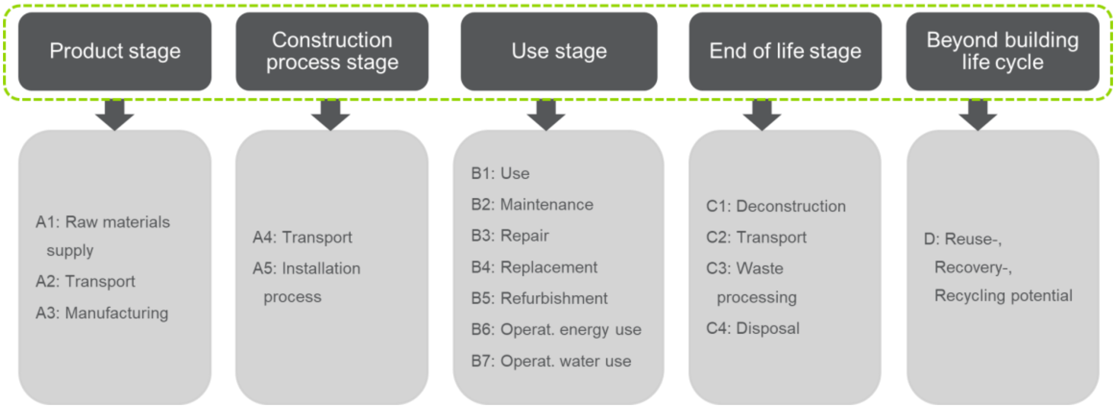


Figure M 1 - Life cycle phases of construction products and buildings according to the CEN norm - family for sustainable buildings.[130]

A higher penetration of smart appliances requires other (sometimes more rare) resources for their production. In consequence the (negative) impacts on the environment are subject to change while implementing smart appliances. Further research is required here.

Method of approach of a life cycle

A suitable method to assess the complex environmental impacts of construction products and buildings is the life cycle assessment (LCA). The LCA assesses the complete life cycle of a product or process and provides a detailed picture of all potential environmental impacts over the complete life cycle, from cradle to grave. A life cycle assessment can assess all environmental impacts both at the level of single construction products as well as at the building level. Life cycle assessment in the building industry is - besides for the optimization of production processes of construction materials and products – increasingly used for a holistic analysis of the whole building.[131] The results of such LCA assessments can be used for various purposes: e.g. for the selection of environmentally friendly building materials or products, or to select technical systems with a low environmental impact. In that sense LCA can be a key planning tool to illustrate potential environmental impacts of certain building component in the overall building system.

LCA allows to make assessments for different stages of the building or building components. The following figure illustrates the three different approaches: “Cradle to gate”, “Cradle to grave” and “Cradle to cradle”.

[130] Adapted from bauforumstahl – sustainable buildings
[131] Graubner; Hüske: Nachhaltigkeit im Bauwesen (2003), p. 111

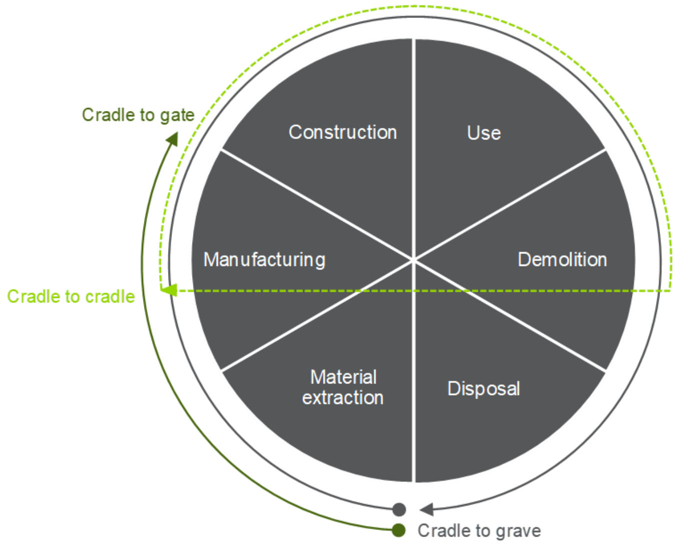


Figure M 2 - Method of approach of a life cycle.[132]

A cradle to gate LCA is defined as an analysis of the product stage from the primary resource extraction, transportation to the production facilities and the production processes itself. For a building assessment it includes all building components that are needed to construct the building (including technical installations). **A cradle to grave LCA** includes all life cycle phases: product stage (primary resource extraction, transport to manufacturing site and production processes), construction process stage (transport to construction site and construction process), use stage of the building and the end-of-life stage (demolition of the building, transport to end-of-waste treatment options and the end-of-waste treatment itself, including disposal and recycling[133]). The **cradle to cradle** approach has been developed in 2002 and describes the life cycle without defining an end of life. It considers all products being able to be recycled (no down recycling) and re-used again). In cradle to cradle inspired buildings only materials are used that can be recycled (no down recycling) or re-used again as resources. By doing so the environmental impact and the impact on human beings is positive.[134]

Difficulties in performing LCAs to smart buildings and appliances

Research is recommended on the further insights on the characteristics of raw materials. The increase in smart appliances drives the demand for raw materials. An analysis of future technologies and required raw materials to produce future technologies for smart appliances would allow profound conclusions to be drawn about the interplay between technical change and the type of raw materials needed for innovative smart appliance technologies.[135] The execution of an LCA may be difficult because there might be a lack of inventoried emissions for the extraction and use of raw materials outside Europe, such as for greenhouse gases[136] or most relevant emissions that will have an effect on categories like acidification or photochemical ozone formation potential[137]. Many raw materials are mined outside the EU, but imported and consumed in the EU. Especially for the impact categories "fossil and mineral resource consumption", there could be a distortion due to a lack of information available on the emissions that have an influence on these impact categories.

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[132] Adapted from Isabell Passig, ina Planungsgesellschaft mbH
[133] Lambertz: Green Building Engineering (2014)
[134] Zanatta: Cradle to Cradle inspirierte Gebäude (2016)
[135] Ecofys, Thinkstep 2017: Ecofys efficiency analysis
[136] UNFCCC 2016
[137] CEIP 2016

Cost-benefits and life cycle aspects of battery- and thermal storages

This chapter summarizes mainly the information on cost-benefits and life cycle aspects of battery- and thermal storages which have been derived from an actual examination about the eco efficiency of heating and storage systems for the Bavarian Ministry of Environment. The primary objective of the study was to compare environmental and economic performance of various heating and storage systems with eco-efficiency analysis. The simplified and holistic evaluation of different heating and storage systems by the eco-efficiency analysis opens up a fact-based and application-specific selection of heating and storage systems for house and apartment owners in Bavaria, taking into account the existing support measures and programs.

The eco-efficiency analysis in this study contrasts the total cost over the whole life cycle of a technology with its environmental impacts to identify high eco-efficient technologies respective determine 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 greenhouse gases, other environmental categories such as acidification, eutrophication, particulate matter, toxicity and resource consumption are also included and aggregated via a weighting key (single-score indicator) to allow direct comparability of technologies across all environmental categories.

The study focuses on a comprehensive view of the various systems over their entire life cycle (i.e., consideration of 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. The influence of the following parameters on the results have been examined:

- Energy standard of the building
- Different hot water consumption
- Lifetime of technologies
- Energy price increases
- Heat pump efficiencies

The study made clear that there is no scientific, objective method for weighting environmental categories into an aggregated result. Weighting should therefore be understood primarily as an attempt to identify shifts from environmental problems to other environmental categories, in particular for climate protection purposes, and, where possible, to provide recommendations for action to reduce environmental impacts in other environmental categories.

In addition to the aggregated results of the eco-efficiency analysis, the study first presents in detail the economic results of the heating and storage systems, shows exemplarily selected environmental categories as well as results from the above-mentioned parameters, as well as results for the greenhouse gases and the weighted results of the ecological analysis. in the ecological assessment the study looked into other environmental topics such as such as acidification, eutrophication or toxicity and summarized by means of a weighting key to a value (single score) in the eco-efficiency analysis.

The economic analysis showed that the system with the lowest investments cost are often the most economic systems (in the considered circumstances). Heat pumps are dependent from the ratio of electricity to the other energy costs and from the quality of the system and its optimisation. Also hot water demand has a significant impact on the energy costs and should be considered. Despite financial incentives battery storage is still not economical (up to 12 kWh). However, since there has been observed a strong price decrease it can be assumed that *Li-Ionen batteries will soon be economic.*

The ecological analysis showed that independent from energy carrier the reduction of the useful energy demand has a decisive contribution to the reduction of negative impact on environment. In new buildings with passive house standard this kind of heating system plays a less important role.

It is important to consider that the weighted results of all environmental categories are dependent from the weighting and may differ according to weighting preferences. On top there a high and different uncertainties in the impact categories (of the environmental topics) relating to characterization method, standardization factor and emissions itself that are aggregated. In general is the robustness of the results of GHG emissions or other air pollutants that have impact on acidification and eutrophication high to very high and in contrast the robustness with toxicity or resource indicators rather low.

Regarding storage systems the study found out, that when excluding the resource indicator, the use of batteries as system storage can be advantageous. However due to weakness in the applied ILCD method the study does not give a final conclusion about this topic but rather states that the eco-efficiency strongly depends on future cost development of batteries.

The study found also out that in general some systems as e.g. heat pump has a better ecological assessment than the reference case (gas boiler) but due to higher costs the eco-efficiency is mostly worse. In conclusion this implies that with a reduction of negative impact on environment goes hand in hand with higher costs. Heat generators with gas normally have a relative good eco efficiency (due to little air pollutants, however in the context of the climate goals this can be considered critical as long as gas is not substituted in significant shares with biomethane or synthetic gas (power to gas).

M.2. Data sources on costs and benefits

The following section gives an overview of the so far investigated data sources for costs and benefits for SRTs. We are still working on this list and scan all studies/data sources that were mentioned in the proposal and are available in the consortium. In addition to that the BACS-Standard EN15232 is an important starting point for the saving of the 8 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 smart appliances market from technical, economic, and societal aspects. The focus of this study is on the smart appliances and the potential 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 Business as usual (BAU) and 100% scenarios.

The data is available on theoretical monetary benefits from providing flexibility per smart appliance per year per scenario per year as well as on an aggregated level for EU-28. The study considers and presents cost elements from end-user perspective such as the initial investment costs for the appliance and the recurrent operational costs and additionally the expected increase in the retail price of devices by adding a Demand Response interface.

Preparatory study on lighting systems (Lot 37), 2016
The final report of Preparatory Study on Smart Appliances (Lot 37) provides information on the markets, users, technologies of lighting systems and an analysis considering their development with

technical, economic, and environmental aspects. The focus of this study is on the indoor and road lighting systems. The study 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 by considering three scenarios.

The data is available on specific capital expenditure for acquisition and installation of LED-luminaires, optimising design and addition of controls as well as a summary of EU 28 savings due to lighting system improvements, in terms of annul electricity saving, GHG emission reductions, annual energy cost savings, annual user expense saving per scenario.

The added value of smart energy management in the low-energy homes of the future, 2016

The core aim of the SMART HOME project was to understand the role of smart energy management technologies can pay in nZEB homes, and the quantification of energy and energy cost savings that would relate. The study is based on modelling a sample home. The report present information on estimated total energy consumption and annual energy costs per three scenarios reflecting different levels of use of energy management systems (EMS); no EMS, EMS that integrates all energy management functions, and EMS that also controls the energy demand based on a variable electricity price. The data was available for the purpose of this study is energy savings for detached house with floor area of 187 m² for cooling and ventilation.

The scope for energy and CO2 savings in the EU through the use of building automation technology, 2014

The report presents the findings of an analysis that examines the potential of building energy controls to accelerate energy savings. The data is available on estimated building automation technology (BAT)/building energy management systems (BEMS) sales by residential building and service sector building type in Europe as well as costs to procure, install and commission BAT and BEMs per building type and estimated average savings per building type and projected BAT penetration.

The scope for energy savings from energy management, 2016

The report outlines the potentials of energy management system (EMS) with respect to energy savings, and an assessment of the status of the EMS technology in Europe The available data in this report includes 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 sectors buildings and industry).

Chancen der Energetischen Inspektion für Gesetzgeber, Anlagenbetreiber und die Branche

This report provides data on energy cost savings due to optimisation of systems and further more when additionally installing more efficient components for ventilation and cooling equipment.

Technische Optimierung und Energieeinsparung

The report presents data on final energy savings based on measured data before and after optimisation of the heating system per residential building type.

Table M 3 - Thermal and electrical energy savings and investments per building type and region [138]

	North		West		Süd	
	SFH SMFH LMFH	Office Retail	SFH SMFH LMFH	Office Retail	SFH SMFH LMFH	Office Retail
thermal savings						
buildings SRI range I -> II	5%	23%	10%	30%	15%	38%
buildings SRI range I -> III	11%	41%	22%	55%	33%	69%
buildings SRI range I -> IV	15%	45%	29%	60%	44%	75%
buildings SRI range II -> III	6%	19%	12%	25%	18%	31%
buildings SRI range II -> IV	10%	23%	19%	30%	29%	38%
buildings SRI range III -> IV	4%	4%	7%	5%	11%	6%
electrical savings						
buildings SRI range I -> II	8%	8%	8%	8%	8%	8%
buildings SRI range I -> III	14%	14%	14%	14%	14%	14%
buildings SRI range I -> IV	16%	16%	16%	16%	16%	16%
buildings SRI range II -> III	6%	6%	6%	6%	6%	6%
buildings SRI range II -> IV	8%	8%	8%	8%	8%	8%
buildings SRI range III -> IV	2%	2%	2%	2%	2%	2%
CAPEX (€/m2)						
buildings SRI range I -> II	4.8	3.6	4.0	3.0	3.2	2.4
buildings SRI range I -> III	9.6	18.0	8.0	15.0	6.4	12.0
buildings SRI range I -> IV	16.8	36.0	14.0	30.0	11.2	24.0
buildings SRI range II -> III	6.6	18.0	5.5	15.0	4.4	12.0
buildings SRI range II -> IV	14.4	30.0	12.0	25.0	9.6	20.0
buildings SRI range III -> IV	9.6	24.0	8.0	20.0	6.4	16.0

[138] Source: Ecofys/Waide study for Danfoss on Article 8, Waide studies, expert assumptions based on EN15232 BACS level descriptions.

ANNEX N – CURRENT AND ADDITIONAL ACCOMPANYING POLICIES

Public policies, incentives and information campaigns influence and can promote adoption of energy management and SRT. The effect of policies could be on the demand for SRT and increase in the reliability of energy savings. There are already several initiatives in European policy and legislation today that can support the deployment of SRT. The effect of current related EU legislation is considered under “business as usual (SRT-BAU)” scenario. Additionally, further measures and policies can play a levering role for increased update of SRT. This second set of tools are considered under “moderate” and “increased uptake” scenarios. The following sections give an overview over existing policies that influence the implementation of SRT today and shows possible future accompanying measures and policies considering both increase in demand and increase in reliability of energy savings.

This lists some of the key policies on SRTs in the area of regulatory law, information measures from MS, incentives and others.

N.1. The Energy Performance of Buildings Directive (EPPB)

One of the most important regulations dealing with energy efficiency in EU is the EPBD. The core of EPBD is to increase and ensure the energy efficiency of building stock by cost effective means. This study runned in parallel to the review of this Directive. On 30 November 2016 the Commission proposed an update to the EPBD to help promote the use of smart technology in buildings, to streamline existing rules and accelerate building renovation. This resulted in a new Directive (EU) 2018/844 which ammends Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency that was published on june 19th 2018.

It is worth noting that the prior Article 8 is replaced by a new Article 8 on Technical building systems, electromobility and the Smart Readiness Indicator(SRI).

Herein in point (10) and (11) it says on SRI that:

(10) The Commission shall, by 31 December 2019, adopt a delegated act in accordance with Article 23, supplementing this Directive by establishing an optional common Union scheme for rating the smart readiness of buildings. The rating shall be based on an assessment of the capabilities of a building or building unit to adapt its operation to the needs of the occupant and the grid and to improve its energy efficiency and overall performance.

In accordance with Annex Ia, the optional common Union scheme for rating the smart readiness of buildings shall:

> *(a) establish the definition of the smart readiness indicator; and*
>
> *(b) establish a methodology by which it is to be calculated.*

(11) The Commission shall, by 31 December 2019, and after having consulted the relevant stakeholders, adopt an implementing act detailing the technical modalities for the effective implementation of the scheme referred to in paragraph 10 of this Article, including a timeline for a non-committal test-phase at national level, and clarifying the complementary relation of the scheme to the energy performance certificates referred to in Article 11.

Note that also other articles in the EPBD can have impacts on the uptake of SRTs, and more generally the condition of the building stock as a whole, e.g. the provisions related to renovation and inspection of heating systems.

In the revision of EPBD, **Article 2** is amended to include "Long term renovation strategy". This requires Member States to establish a long-term strategy to support the renovation of the national stock of residential and non-residential buildings, both public and private, into a highly energy efficient and decarbonised building stock by 2050. Among the requirements of the provision, it is mentioned that an overview of national initiatives to promote smart technologies and well-connected buildings and communities, as well as skills and education in the construction and energy efficiency sectors is needed. If applied appropriately this provision would increase deployment of SRT.

Article 8 is amended to take into account the revised definition of technical building systems and new paragraphs. Additional paragraphs are as follows;

> Article 8 new paragraph 5 "Member States shall ensure that, when a technical building system is installed, replaced or upgraded, the overall energy performance of the complete altered system is assessed, documented and passed on to the building owner, so that it remains available for the verification of compliance with the minimum requirements set pursuant to paragraph 1 and the issue of energy performance certificates. Without prejudice to Article 12, Member States shall decide whether to require the issue of a new energy performance certificate."
>
> Article 8 new paragraph 6 "The Commission shall, by 31 December 2019, adopt a delegated act in accordance with Article 23, supplementing this Directive by establishing an optional common European Union scheme for rating the smart readiness of buildings. The rating shall be based on an assessment of the capabilities of a building or building unit to adapt its operation to the needs of the occupant and the grid and to improve its energy efficiency and overall performance."
>
> The recitals strongly emphasize the emerging importance of digital solutions, and update of the proposed EPBD articles introduce implementation of potentially higher rate of Deployment of SRT.

The amendment of EPBD also includes the following provisions on inspection of heating and air-conditioning systems. **Article 14** is replaced with following paragraphs:

> "Member States shall lay down the necessary measures to establish regular inspection of the accessible parts of systems with an effective rated output for space heating or for combined space heating and ventilation purposes of over 70 kW, such as the heat generator, control system and circulation pump(s) used for heating buildings. The inspection shall include an assessment of the heat generator efficiency and the heat generator sizing compared with the heating requirements of the building and considering, where relevant, the capabilities of the heating system to optimize its performance at typical or average operating conditions.
>
> Where no changes have been made to the heating system or as regards the heating requirements of the building since an inspection pursuant to this paragraph was carried out, Member States may choose not to require the assessment of the heat generator sizing to be repeated.

1a. As an alternative to paragraph 1, Member States may opt to take measures to ensure the provision of advice to users concerning the replacement of heat generators, other modifications to the heating system and alternative solutions to assess the efficiency and appropriate size of the heating system or combined heating and ventilation system. The overall impact of such an approach shall be equivalent to that arising from the provisions set out in paragraph 1.

Before Member States apply the measures referred to in the first subparagraph, they shall, by submitting a report to the Commission, document the equivalence of the effect of those measures to the measures referred to in paragraph 1.

Such report shall furthermore be included in the national climate and energy plans according to applicable reporting obligations [i.e. Governance Regulation].

2. Member States shall set the requirements to ensure that non-residential buildings with an effective rated heating or combined heating and ventilation system output of over 290kW, where technically and economically feasible, are equipped with building automation and control systems by 2025.

The building automation and control systems shall be capable of:

(a) continuously monitoring, logging, analysing and allowing for adjusting energy usage;
(b) benchmarking the building's energy efficiency, detecting losses in efficiency of technical building systems, and informing the person responsible for the facilities or technical building management about opportunities for energy efficiency improvement; and
(c) allowing communication with connected technical building systems and other appliances inside the building, and being interoperable with technical building systems across different types of proprietary technologies, devices and manufacturers.

3. Member States may set requirements to ensure that residential buildings are equipped with:

(a) the functionality of continuous electronic monitoring that measures systems' efficiency and inform building owners or managers when it has fallen significantly and when system servicing is necessary, and
(b) effective control functionalities to ensure optimum generation, distribution, storage and use of energy.

3a. Buildings that comply with paragraphs 2 or 3 shall be exempt from the requirements laid down in paragraph 1.

3b. Technical building systems explicitly covered by an agreed energy performance criterion or a contractual arrangement specifying an agreed level of energy efficiency improvement, such as energy performance contracting as defined in point (27) of Article 2 of Directive 2012/27/EU or that are operated by a utility or network operator and therefore subject to performance monitoring measures on the system side, shall be exempt from the requirements laid down in paragraph 1, provided that the overall impact of such an approach is equivalent to that arising from the provisions set out in paragraph 1.

Article 15 is replaced with following paragraphs

"1. Member States shall lay down the necessary measures to establish a regular inspection of the accessible parts of air-conditioning systems or of combined air-conditioning and ventilation systems, with an effective rated output of over 70 kW. The inspection shall include an assessment of the air-conditioning efficiency and the sizing compared to the cooling requirements of the building and considering, where relevant, the capabilities of the air-conditioning or of the combined air-conditioning and ventilation system to optimize its performance at typical or average operating conditions.

Where no changes have been made to the air-conditioning system or to the combined air-conditioning and ventilation system or to the requirements for cooling of the building since an inspection pursuant to this paragraph was carried out, Member States may choose not to require the assessment of the sizing to be repeated.
Member States that maintain more stringent requirements pursuant to Article 1(3) shall be exempted from the obligation to notify them to the Commission.

1a. As an alternative to paragraph 1, Member States may opt to take measures to ensure the provision of advice to users concerning the replacement of air-conditioning systems or combined air-conditioning and ventilation systems, other modifications to the air-conditioning system or combined air-conditioning and ventilation system and alternative solutions to assess the efficiency and appropriate size of these systems. The overall impact of such an approach shall be equivalent to that arising from the provisions set out in paragraph 1.

Before Member States apply the measures referred to in the first subparagraph, they shall, by submitting a report to the Commission, document the equivalence of the effect of those measures to the measures referred to in paragraph 1.

Such report shall furthermore be included in the national climate and energy plans according to applicable reporting obligations [i.e. Governance Regulation].

2. Member States shall set the requirements to ensure that non-residential buildings with an effective rated output for systems for air-conditioning or systems for combined air-conditioning and ventilation of over 290kW, where technically and economically feasible, are equipped with building automation and control systems by 2025.

The building automation and control systems shall be capable of:

(a) continuously monitoring, logging, analysing and allowing for adjusting energy usage;
(b) benchmarking the building's energy efficiency, detecting losses in efficiency of technical building systems, and informing the person responsible for the facilities or technical building management about opportunities for energy efficiency improvement; and

3. Member States may set requirements to ensure that residential buildings are equipped with:

(a) the functionality of continuous electronic monitoring that measures systems' efficiency and inform building owners or managers when it has fallen significantly and when system servicing is necessary, and

(b) effective control functionalities to ensure optimum generation, distribution, storage and use of energy.

3a. Buildings that comply with paragraph 2 or 3 shall be exempt from the requirements laid down in paragraph 1.

3b. Technical building systems explicitly covered by an agreed energy performance criterion or a contractual arrangement specifying an agreed level of energy efficiency improvement, such as energy performance contracting as defined in point (27) of Article 2 of Directive 2012/27/EU or that are operated by a utility or network operator and therefore subject to performance monitoring measures on the system side, shall be exempt from the requirements laid down in paragraph 1, provided that the overall impact of such an approach is equivalent to that arising from the provisions set out in paragraph 1. ”

Both Articles clearly emphasizes the use of building automation and control systems where technically and economically feasible. This creates a direct incentive for high SRT deployment rate across Europe.

N.2. The Energy Efficiency Directive

The Energy Efficiency Directive, (EED) (2012/27/EU) adopted on 25 October 2012, requires the Member States to set indicative national energy efficiency targets ensuring that the EU reaches its headline target of saving 20 % of primary and final energy consumption by 2020 compared to business-as-usual projections. In its Implementation report on the Energy Efficiency Directive, adopted on 23 June 2016, Parliament concluded that the existing directive, while offering a framework for reducing energy demand, was being implemented poorly. On 30 November 2016, the European Commission presented the ‘Clean Energy for All Europeans’ package of proposals, including a revised Energy Efficiency Directive amending the current directive. The revision is still ongoing.

N.3. Other policy Incentives

EPBD: Smart finance for smart buildings initiative

The commission has launched the Smart Finance for Smart Buildings (SFSB) initiative, as part of the 'Clean Energy for All Europeans' package. This initiative includes practical solutions to mobilize more private financing for energy efficiency and renewable energy sources in buildings. It follows a threefold objective; using public funds more effectively: project development assistance; changing the risk perception of financers and investors.

These incentives have clear potential to help increase the number and effectiveness of energy saving measures in buildings by increasing he availability of financial resources and acceptance of available technology. In this context the initiative could create strategic opportunity to support deployment of SRT and controls for energy management, where technically and economically feasible.

Incentives in the framework of the renovation roadmaps

Roadmaps need to address all relevant aspects of the buildings and construction sectors, including technologies, construction materials. Inclusion of financial support and organisational support is one of the main pillars of successful renovation roadmaps. For example France has Finance law creating the 0% green loan with banks, Germany has subsidies and loans that are available for energy efficient renovations that meet certain ambition level.

They can provide investment in consumer education and outreach so that they are made aware of need for renovations, possibiliies and technologies in market. For example in the Netherlands the office responsible for the implementation of the renovation plan coordinates activities that brings together different stakeholders in events supporting the energy saving pilot projects and communication activates.

National roadmaps integrate plans that provide logistical support for homeowner for the required professional skills for decision making and planning. To make innovative solutions more accessible to homeowners.

Mentioned features are examples of national renovation roadmaps and their opportunity to combine various support instruments for creating a greater momentum for use of SRT and energy management in renovation activities.

ANNEX O - REFERENCE LIST

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