White Paper

Task Force 3: Building interactions with the external environment

Topic C:

Data driven indicators for smart buildings

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Document information

Contributors

First name	Last name	Organisation/ relevant projects or initiatives
Co-Chairs		
Litiu	Andrei Vladimir	REHVA
Pozza	Cristian	EURAC
Task Force members		
Al Fakhri	Lama	Panasonic
Aranda Uson	Juan Antonio	CIRCE, frescO project
Bono	Flavio	JRC
Borràs	Mikel	IDP, SPHERE project
Brook	Boonie	Siemens
Boone	Wim	First Q Network working group smart buildings
Caliskan	Alper	Otis
Capozzoli	Alfonso	Politecnico di Torino
Chessa	Maria Rita	CEPI
Coujard	Clémentine	Dowel Innovation
David	Jenkins	Heriot-Watt University, CROSSCERT project
Deliyannis	Alexander	Sympraxis
Delvaeye	Ruben	BBRI
D'Herdt	Peter	BBRI
Dimitriadou	Ismini	Hypertech, ACCEPT project
Deliyannis	Alexander	Sympraxis, H2020 iBRoad & iBRoad2EPC projects
Fernández Boneta	Maria	CENER, ePANACEA project
Finocchi	Paolo	RINA, Auto-DAN project
Gabioud	Dominique	HES-SO Valais-Wallis, DOMOS project
Garzia	Federico	EURAC
Hogeling	Jaap	ISSO
Ismini	Dimitriadou	Hypertech on behalf of the ACCEPT project
Jenkins	David	Heriot-Watt University
Kachrimani	Louiza	UBITECH
Kazi	Sami	VTT
Kubicki	Sylvain	LIST
Leao Pirocchi	Jorge	IDP
Legazpi	Pablo Vicente	BDTA, SPHERE project
Litiu	Andrei Vladimir	REHVA
Mateus	Nuno	EDP, Smart2b project
Milardi	Martino	UNIRC
Mililli	Michele	RINA, Auto-DAN project
Perez Heras	Luis	CIRCE
Petit	Olivier	INGEROP

Petri	Ioan	Cardiff University
Pozza	Cristian	EURAC
Sainz	Fausto	COMET, SPHERE project
Schats	Bram	Avelution
Setién	Elisa	Eurolux
Striligás	Michael	Vertiliner
Tavaroli	Fabrizio	RINA, Auto-DAN project
Thorns	Peter	Zumtobel Group
Touggourti	Lounes	INGEROP
Uribe Cáceres	Daniel Antonio	LEITAT
Vavallo	Michele	SOLINTEL
Verbeke	Stijn	VITO
Willuhn	Wolfram	Plutinsus
Yilmaz	Levent	Auburn University
Zarli	Alain	ECTP
Zegginis	Dimitrios	ISZEB
Zeiler	Wim	TUE, IEA Annex 81 subtask C1; Brains for Buildings project
Reviewers		
Vandevelde	Birgit	VITO
Feedback from consultation		
Garzia	Federico	EURAC

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Executive summary

The SmartBuilt4EU project has set up four task forces investigating issues related to smart buildings: their objective is to identify the remaining challenges and barriers to smart building deployment, and the associated research and innovation gaps that should be addressed in the near future.

Task force 3 investigates how smart buildings can interact at best with their external environment. This topic C is focused on data-driven indicators related to the smart buildings. It addresses the following questions:

- **How to make the 'static' Smart Readiness Indicator evolve towards a dynamic indicator?** A 'dynamic SRI' could be defined as the regular update of the SRI score for a given building, and the 'live' verification that the referenced smart functionalities are operative. Ensuring this dynamic dimension implies that the data collection and SRI score calculation processes are automated, and that links to real-time building data are implemented.

- **How to position/connect at best the SRI with regards to other building performance indicators, that are evolving towards real-time data capturing?** In particular, energy performance certificates are meant to evolve in order to gain in accuracy and convergence in the way energy performance assessments are performed, also with the perspective of using real-time data.

In its first part, this paper provides a state of the art regarding the following issues, specific attention being paid to EC-funded projects:

- The smart readiness indicator: status and ongoing activities to automatise its calculation and link it to real-time building data
- The energy performance certificates: status and ongoing activities towards harmonisation of energy performance assessment and convergence with other indicators
- Other building performance indicators that are connected to building smartness.

A brainstorming process then enabled to identify some key barriers and drivers regarding the further development and implementation of data driven indicators. Figure 1 and Figure 3 provide an overview of the main barriers and drivers discussed.

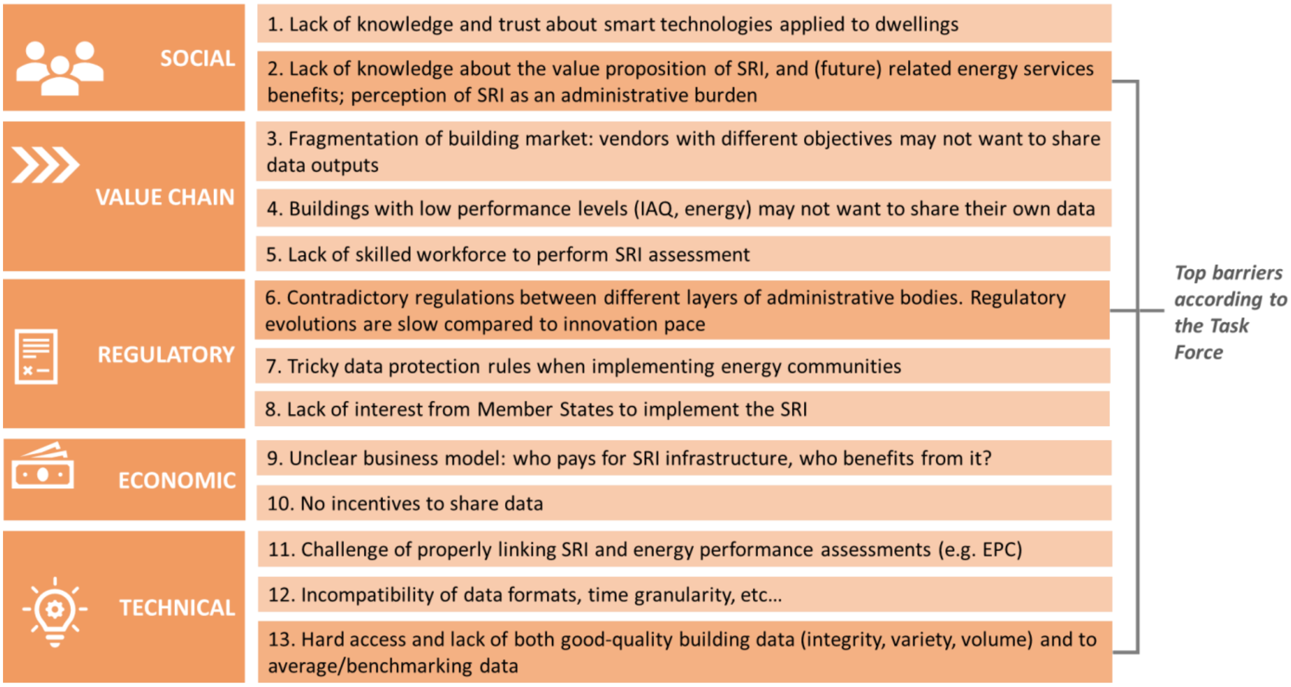

Figure 1: Overview of main barriers

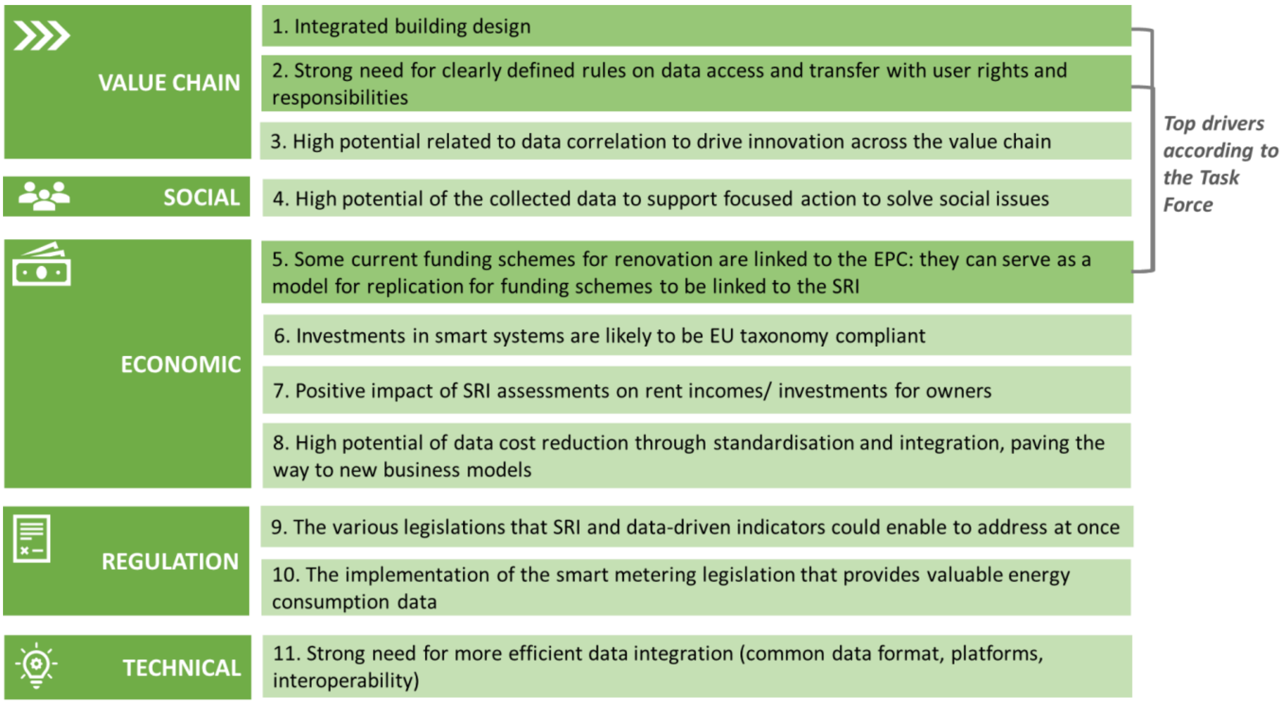

Figure 2: Overview of main drivers

Based on the State of the Art and the barriers and drivers, a number of research and innovation gaps were identified. They are synthetised in Figure 3 and Figure 4(the darker ones are those that were identified as priorities by the task force members).

These ‘gaps’ will feed the elaboration of the Strategic Research and Innovation Agenda on smart buildings that will be produced by the SmartBuilt4EU consortium by mid-2023, together with some recommendations targeting policy makers.

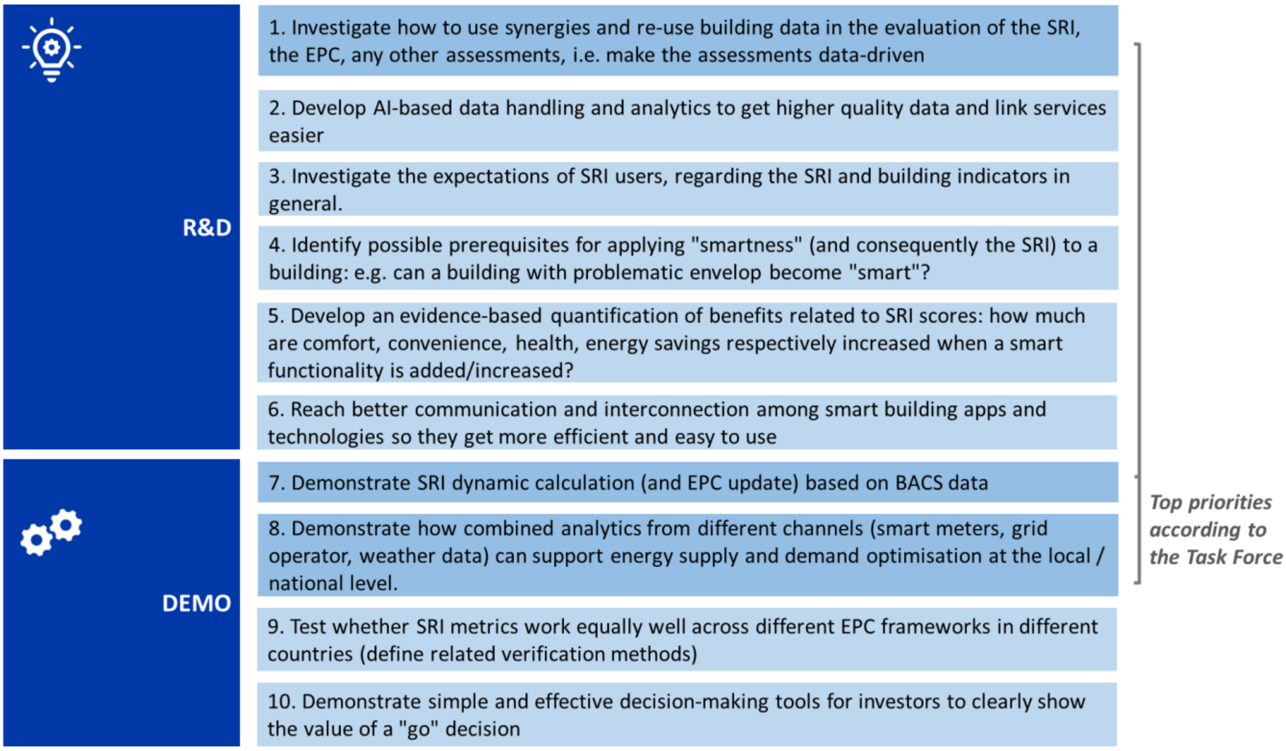

Figure 3: R&I gaps

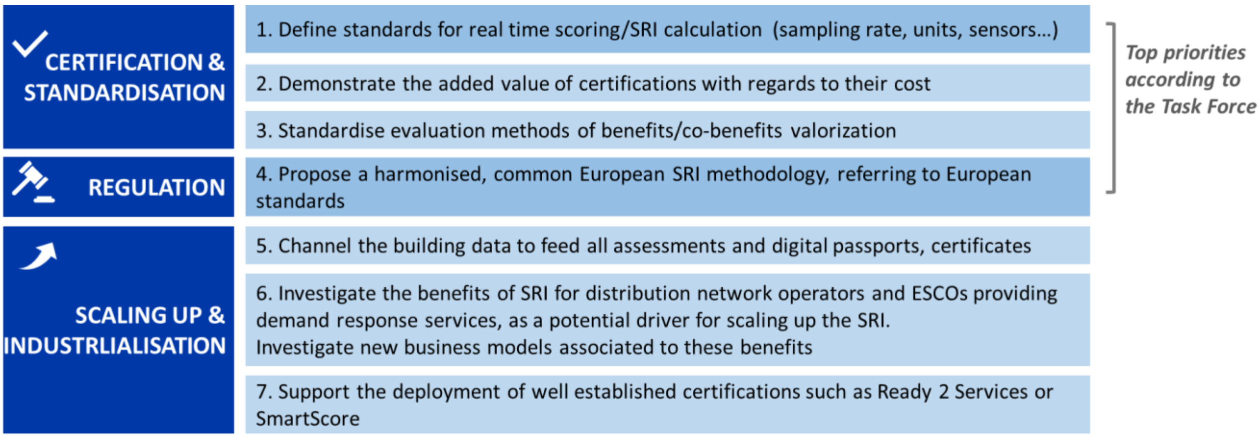

Figure 4: ’Go-to-market’ gaps

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List of abbreviations

AI	Artificial Intelligence
BACS	Building Automation and Control System
BCT	Blockchain Technologies
BDA	Big Data Analytics
BDT	Building Digital Twins
BE	Built Environment
BEMS	Building Energy Management Systems
BIM	Building Information Modelling
BMS	Building Management Systems
BREEAM	Building Research Establishment Environmental Assessment Method
BRP	Building Renovation Passport
CAPEX	Capital Expenditure
DBL	Digital Building Logbook
DT/DTwins	Digital Twins
DTE	Digital Twin Ecosystem
EC	European Commission
EEB	Energy Efficient Building
EMS	Energy Management Systems
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificates
GDPR	General Data Protection Regulation
GIS	Geographic Information Systems
HVAC	Heating Ventilation and Air Conditioning
ICT	Information and Communication Technologies
IEA	International Energy Agency
IEQ	Indoor Environmental Quality
IFC	Industry Foundation Classes
IoT	Internet of Things
KPI	Key Performance Indicator
LEED	Leadership in Energy and Environmental Design
ML	Machine Learning
nZEBs	Nearly Zero Energy Buildings
OPEX	Operational Expenditure
pTing	Real-time performance testing
R&I	Research and Innovation
SCAS	Smart, Connected Asset Systems
SRI	Smart Readiness Indicator
TF	Task Force

1. Introduction

This white paper is produced in the context of the SmartBuilt4EU project, a coordination and support action funded by the European Commission to bring together the research and innovation community on smart buildings.

The SmartBuilt4EU project has set up four task forces with volunteers across Europe, investigating topics related to smart buildings. They respectively address the interaction between building and end-user, efficient building operation, interactions between the building and the external environment, and cross cutting issues.

Figure 5: The four task forces set up by the SmartBuilt4EU project

SmartBuilt4EU task force 3 investigates how the smart building can interact with its external environment in a mutually beneficial way. The first line of investigation focused on smart buildings as providers of flexibility to the electricity grids[1]. The second line address the topics of new energy practices and communities.[2]

The present white paper focusses on the third topic, i.e. 'Data driven indicators for smart buildings' and presents the outcomes of a collective work, carried out with the members of the task force, in several steps:

- Agreement on the scope
- Review of the State of the Art and identification of the points to be investigated in particular
- Analysis of barriers and drivers
- Identification of R&I gaps
- Key conclusions on the topics and recommendations

2. Topic under investigation by the Task Force

2.1. Rationale

[1] SB4EU White Paper, task force 3 Topic A: Smart buildings as flexibility providers to the electricity grids. Final version, September2021

[2] SB4EU White Paper, task force 3 Topic C: Smart buildings as enablers of new energy practices and communities. Final version, May 2022

The smart readiness indicator (SRI) concept was introduced by the 2018 revision of the EPBD Directive to raise awareness about the benefits of smart building technologies. After a feasibility and scoping phase, an SRI rating scheme and calculation methodology were proposed and are currently being tested in some volunteering Members States.

Today, the smart readiness indicator enables to evaluate whether some specific smart functionalities can be activated in a given building. So far, the indicator is used to provide a one-time, 'static' picture of the building's smart capabilities. But its use could be pushed further to target other objectives, such as the regulator check of the smartness capabilities of the building (are they operative or not?) or its aggregation at larger geographical scale. Also, some synergies with other building indicators are still to be identified.

For buildings that do reach a high level of smartness, their daily operation implies the potential acquisition of high-volume, heterogeneous, but enriching data about the buildings' real-time performances. But such data will only provide actual value if it is processed and fed back to building users in an insightful and actionable manner.

This white paper therefore aims to provide an overview on what is known and what should be further investigated to answer the following questions:

- **How to make the 'static' smart readiness indicator (SRI) evolve towards a dynamic indicator?** A 'dynamic SRI' could be defined as the regular update of the SRI score for a given building, and the 'live' verification that the referenced smart functionalities are operative. Ensuring this dynamic dimension implies that the data collection and SRI score calculation processes are automated, and that links to real-time building data are implemented.

- **How to position/connect at best the SRI with regards to other building performance indicators, that are evolving towards real-time data capturing?** In particular, energy performance certificates (EPCs) are meant to evolve in order to gain in accuracy and convergence in the way energy performance assessments are performed, also with the perspective of using real-time data.

2.2. Scope

The following 'blocks of knowledge' were identified during the first meeting of the task force:

- The smart readiness indicator: status and ongoing activities to automatise its calculation and link it to real-time building data
- The energy performance certificates: status and ongoing activities towards harmonisation of energy performance assessment and convergence with other indicators
- Other building performance indicators that are connected to building smartness.

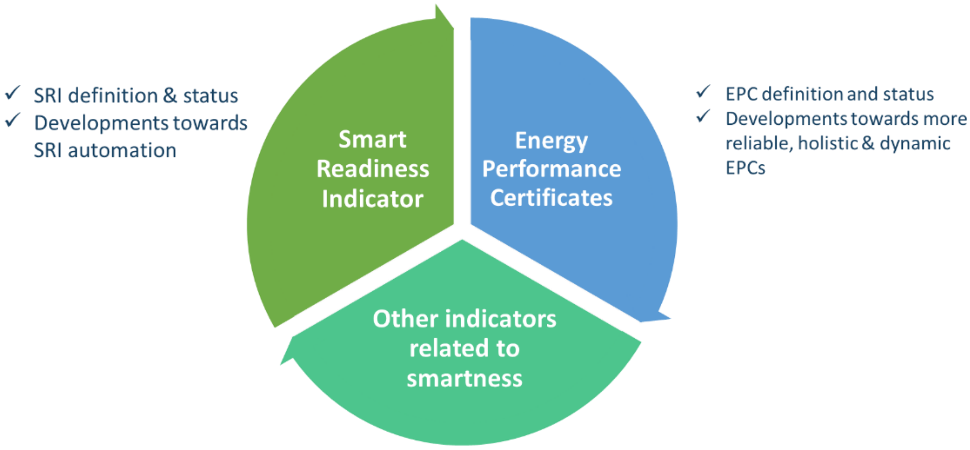

Figure 6: knowledge blocks for the State of the Art

3. State of the Art

3.1. Literature review

3.1.1. The smart readiness indicator

The smart readiness indicator (SRI) was introduced in 2018 by the Directive amending the Energy Performance of Buildings Directive, as a common EU scheme for rating the smart readiness of buildings. It aims to raise awareness on the benefits of smarter building technologies and make their added value more tangible for building users, owners, tenants, and smart service providers. The SRI rates buildings in their capability to perform 3 key functionalities:

- optimise energy efficiency and overall in-use performance
- adapt their operation to the needs of the occupant
- adapt to signals from the grid (for example energy flexibility)

The SRI scoring methodology is based on the following components:

- on one dimension, the three above-mentioned functionalities are further detailed in a set of impact criteria: e.g., energy efficiency, maintenance & fault prediction, comfort, information to occupants, etc.
- on the other dimension, an exhaustive catalogue of building's smart-ready services is defined, covering nine technical domains (e.g., heating, cooling, lighting, dynamic building envelope, eV charging). For each service, 4 progressive levels of functionality are defined.
- Crossing these two dimensions, a weighted assessment is performed per impact criteria and per technical domain, and then aggregated into a single SRI score.

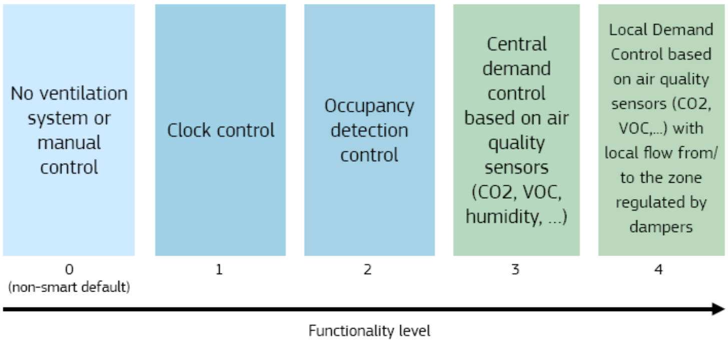

Figure 7: Example of progressive functionality levels defined for the assessment of the service 'supply air-flow control at room-level'

IMPACTS

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

Figure 8: Matrix showing SRI scores by domain and impact criterion, aggregate scores per impact criterion and the overall SRI score (SRI technical support studies).

Two assessment methods were proposed (A 'simplified' and B 'detailed'), requiring a different level of expertise to perform the assessment.

Status of implementation

After completion of a second technical study, a final report was officially published by the EC in September 2020. The Commission Delegated Regulation (EU) 2020/2155 established the definition of the SRI and a common methodology, by which it should be calculated. The Commission Implementing Regulation (EU) 2020/2156 detailed the technical modalities for effective implementation of the SRI. The SRI has now entered a testing phase, during which voluntary Members States conduct tests according to their own arrangements. The SRI is currently being tested in 6 EU countries: Austria, Czech Republic, Denmark, France, Finland and Croatia (details are provide in BUILDUP article here).

Many more research projects and organisations are carrying out tests, which are not part of an official testing programme initiated at MS level. At the end of the national test phases, countries shall assess the outcomes and decide whether they will implement the SRI.

An SRI Platform has been set up and three working groups (WG) were created in 2022 dealing with:

- WG1: Member State SRI test phase
- WG2: Maintenance and potential extension of the SRI calculation methodology
- WG3: SRI value proposition and supporting measures.

The working programmes of each WG should be released soon[3].

Ongoing European R&D about the automation of the SRI calculation

A number of European projects are currently exploring ways to automatise the data collection and score calculation for the SRI. We can cite here in particular:

- The ACCEPT project developed the D-SRI tool that undertakes the calculation of the SRI and applies it to pilot buildings. The tool collects the data from the relevant sources, manages to identify the technical systems in a pilot and infer the smartness levels of the activated technical building services, and calculates the SRI scores that are delivered to the end-user via a dedicated user interface. The tool paves the way to easily reproducible and up-to-date SRI scores delivered to the end-user.
- In smart2B, (semi-)automated assessment of selected SRI services and their functionality levels are planned, based on data and measurements (real time/historical, dynamic/static).
- DOMOS ambitions to contribute the definition of a digital SRI certificate containing ’hyperlinks‘ to monitoring and control points in the building.
- AUTO-DAN works to create a ’quasi-dynamic’ assessment of the SRI by putting together data from the building, the appliances and the external signals from the grid, based on a gamification process.
- fresco plans to include a smart readiness assessment it their smart retrofitting services.

Beyond EU projects, one should also mention:

- The study performed by Apostolopoulos et al. (2022) **applying the SRI methodology in two typologies of typical residential buildings in five EU countries to evaluate the retrofitting cost towards buildings smartification** and resulting SRI scores with different renovation scenarios. Results show that buildings constructed after the EPBD implementation can increase smartness with a relatively low cost compared to older buildings. Their initial overall SRI score however generally is in the 0–20% class, with buildings performing best in ’Health, well-being and accessibility‘ and ’Comfort‘ impact categories. The study also shows that smart-orientated retrofitting scenarios focusing on building automation and control measures can increase SRI scores towards to the 65–80% class, performing better in optimising energy efficiency when applying retrofits towards NZEB.
- Research by T. Märzinger and D. Österreicher (2020) from University of Vienna about **extending the application of the SRI to the load shifting potential at smart district scale.** The authors aim to address two limitations of the SRI approach: 1) the methodology is mainly focused on qualitative approaches based on the assessments of experts, and 2) it does not include the wider context of the districts.
- Research by Markoska et al. (2019) about **automatically estimating the minimum SRI level to perform real-time performance testing** (pTing) in buildings. In line with their pTing framework, they estimate a minimal SRI requirement of 23%, implying high applicability across a variety of buildings.

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[3] https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator/connecting-stakeholders_en

3.1.2. Energy performance certificates (EPC) and their potential of convergence with the SRI

EPCs were first introduced by the Energy Performance of Buildings Directive (EPBD) in 2002 with the aim to make the energy performance of individual buildings more transparent and were progressively reinforced through diverse amendments. All EU Member States have now implemented national EPC regimes. Different implementation approaches have led to a diverse set of instruments, varying in terms of scope and available information, resulting in some cases in limited reliability, compliance, market penetration and acceptance. Concerns are expressed about the quality and reliability of the data collected and the inferences made about final energy consumption. The energy performance gap between theoretical energy consumption estimated and real data is still a major and recurring issue.

Nevertheless, the EPC has a strong potential to raise public awareness about the need to make buildings more energy efficient, influence the building's property value, and give insights into the effectiveness of building policies.

The SRI features characteristics that are complementary to the EPC, providing added value and enlarging its scope. While a combined EPC-SRI approach could contribute to an increase in the use of EPCs and limits additional effort to make an SRI assessment, it also presents some practical challenges such as a the need for additional training for the assessors.

Data requirement similarities between EPC and SRI

The report published by the ePANACEA project in 2021 investigated the questions of the potential benefits and limits of a combined EPC-SRI assessment, building on the results of exercises performed with experts in Austria, Belgium, Germany, Greece, Finland and Spain. The report proposed an explorative approach to evaluate data similarities between the two schemes. The study concludes that there is a substantial degree of similarity between countries' EPC methodologies, however with differences depending on countries considered.

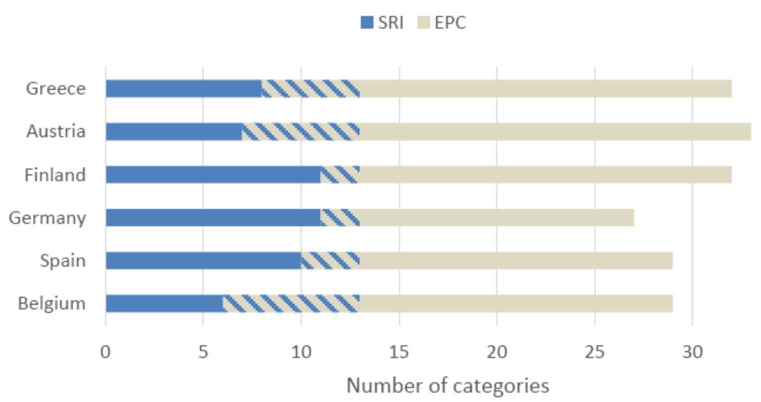

Figure 9: Overlap between EPC-SRI input data categories (indicated by the dashed-bar)[4]

The report provides some detailed guidelines for the EC and Member States to maximise the implementation of the combined EPC-SRI assessment.

Next-generation EPCs

A dozen of European projects are currently exploring various improvements to the EPCs, in particular:

[4] Source: ePANACEA guidelines on national EPC and SRI could be linked, 2021

- Evolve from a single, static certification process to more holistic and dynamic approaches capturing the building's real-time performances and dynamic behaviour (TIMEPAC, D2EPC, EDYCE projects)
- Integrate the building renovation passport into EPCs (iBRoad2EPC project) and EPCs with building digital LogBooks (EUBSuperHub)
- Cross-test EPC schemes in several EU countries and design generic frameworks to improve the accuracy, usability and harmonisation of EPCs (CrossCert, EUBSuperHub, EPCRecast).

3.1.3. Other building performance indicators connected to 'smartness'

To provide a larger overview on existing indicators related to building performances and their smartness, the table below lists some key building indicator schemes that are either directly targeting a smartness assessment, or that could benefit from smartness in the building data collection and processing.

Table 1: other building performance indicators and schemes related to smartness

Scheme	Short description
WiredScore	Global digital connectivity rating scheme (for offices and homes).
SmartScore	SmartScore scores the breadth and depth of the smart user stories (i.e. user functionality) implemented as well as assessing the technology, processes and procedures that support their implementation.
Ready2Services (R2S)	Label originated in France through a collaboration between the Smart Buildings Alliance, the alliance HQE, Green Building Council, Certivéa and Cerway.
WELL	Performance-based system for measuring and certifying features of buildings that impact human health and well-being, through air, water, nourishment, light, fitness, comfort and mind
FITWELL	Standard providing tailored scorecards for existing and new buildings and sites focused on occupants' health
BREEAM	Building Research Establishment Environmental Assessment Method. World's first sustainability rating scheme for the built environment, focuses on measuring and reducing the impacts of buildings
LEED	Leadership in Energy and Environmental Design. Another commercial Total Quality Assurance system from United States.

3.2. Lessons learnt from Horizon 2020 projects

3.2.1. Overview

Figure 10: Relevant H2020 projects identified by the Task Force members

Key lessons learnt or conclusions from some of these projects have already been presented in the state of the art. Lessons learnt from other recent projects are presented below.

3.2.1. Lessons learnt from the CrossCert project

The CrossCert project is attempting to 'cross-test' EPC methodologies across ten European countries for a sample of buildings, investigating the differences in methodology performance and outputs. In doing so, and through engaging with different user-groups, the project will identify a more harmonised approach to developing next-generation EPCs

SRI: The cross-test procedure will include the testing of prototype/new EPC output metrics through the crossCert sample building stock (147 buildings from residential and tertiary sectors in 10 countries). **SRI** is likely to be a key part of this, being a relatively mature next-generation EPC metric. The project will also be able to identify if the SRI metric, or similar next-generation metrics, performs differently when applied to different EPC methodologies.

Use of real-time performance data: a proportion of the sample buildings used in crossCert will also have **real energy consumption** recorded, to be compared to the modelled values of consumption emanating from the different EPC methodologies for each building. In doing so, the performance gap between measured and modelled energy consumption will be assessed, in a way that distinguishes between the different EPC methodologies used by different countries. This could potentially identify countries where real energy consumption data is more/less suitable for use with EPCs.

The difficulty in harmonising across quite different EPC methodologies is likely to be a key part of crossCert. Therefore, when identifying next steps for next-generation EPCs, it is important to distinguish between actions that are appropriate at, e.g., European Technical Committee level (and are, therefore, universally applied), and actions that have to be tailored to a specific approach of a country. By extension, we cannot assume that all new metrics will perform equally well for different countries. Furthermore, crossCert will add to the existing research on engagement with different user groups, using co-production techniques to identify information that different users actually need from EPCs – and whether such needs can be satisfied by existing and/or future EPC approaches.

3.2.2. Lessons learnt from the ePANACEA project

The ePANACEA project is mainly focused on the inclusion of actual energy use data (e.g., from utility bills, monitoring and/or smart meters) into energy modelling of buildings with the aim of reducing the performance gap and increasing accuracy, reliability, and acceptance of EPCs. Within ePANACEA project context, a key aspect for the successful implementation of the SRI scheme is its integration within existing schemes either official/mandatory like the EPC or other voluntary schemes like environmental labels.

ePANACEA explores how relevant aspects of the SRI could be best integrated within national EPC schemes across the six project countries (i.e., Austria, Belgium, Finland, Germany, Greece and Spain). The approach includes several opportunities such as: (i) a common use of data sources, (ii) inclusion of smartness related performance improvement in the energy performance calculation methods and (iii) the use of the energy balance from the EPC to improve default values within the SRI calculation. ePANACEA has also included the development of an inventory of smart and novel technologies and its prioritization with the objective of taking their impact on energy savings into account within the building energy assessment workflow. In this way, it could contribute to future developments regarding the SRI as well as to build the link between next generation of EPCs and the SRI.

Besides, the digitalisation of information using common data bases, easily accessible through web platforms is also part of the ePANACEA project. The SEPAP (Smart Energy Performance Assessment Platform) will integrate all energy related data for the building energy performance and SRI assessments. Thus, all related information for EPC and SRI assessments will be integrated in a common platform, allowing synergies and opportunities to carry out both assessments at the same time.

After a cross-analysis of EPC and SRI requirements through the 6 ePANACEA countries reported in the deliverable Guidelines on how national Energy Performance Certificates (EPCs) schemes and the Smart Readiness Indicator (SRI) could be linked | Zenodo, we can say that implementing a combined EPC-SRI assessment presents many opportunities but also some challenges.

We have identified a high complementary between the SRI and the national EPC schemes. Indeed, our analysis shows very little synergies between the input data included in the EPC assessment of the ePANACEA countries and the fields required to assess the SRI using Method A, although some countries appear to be better positioned to integrate the SRI methodology into their current EPC scheme.

However, it is important to highlight the fact that when information required differs, EPC and SRI data fields are obtained through the same building component. This means that acquiring the additional information to assess the SRI could be integrated in the EPC assessment in a time and cost-efficient manner. But on the other hand, the SRI cannot be calculated with the data stored from previous EPC assessments because specific SRI information is normally not gathered during on-site EPC visits.

Beyond the addition of valuable content, the information required to assess the SRI can be used to improve the quality and reliability of current EPC schemes. Indeed, the SRI could complement the current EPC approach by adding important assessment information in relation to fault detection, occupant's comfort and health as well as grid and RES integration. Also, this information could be used to complement tailored recommendations provided by the EPC report.

3.2.1. The frESCO project: dynamic SRI used as KPI

The frESCO project deals with new business models for innovative energy service bundles for residential consumers and develops the next generation of innovative pay-for-performance energy services that constitutes the next generation of EPC ins the residential sector based on real time data and AI algorithms. frESCO also develops innovative energy business models for ESCOs and demand-response aggregators to empower building residents to become active players in the energy market.

SRI: Dynamic SRI is one of the main KPIs of the frESCO platform. It is calculated in all the dwellings and buildings throughout the four pilot sites: a hotel in Greece, semidetached houses in Croatia, a block of apartments in Madrid and a social housing building in France.

Use of real-time performance data: a new data platform is developed enabling the ingestion, curation, storage and retrieval of building data. This data is captured and sent through a personalized multi-language gateway and a set of smart meters and sensors installed in premises that allow the monitoring, measurement and verification of savings and energy flexibility from a list of energy assets. Data is used by different analytics to provide energy and non-energy services to building residents.

3.2.2. Lessons learnt from the SPHERE project

SPHERE stands for 'Service Platform to Host and sharE REsidential data'. The project aims to provide a BIM-based Digital Twin Ecosystem (DTE) as a platform of platforms to optimise the building lifecycle, reduce costs, and improve energy efficiency in residential buildings. During any phase of the building's lifecycle, different stakeholders will be able to interact with this BIM Digital Twin model, based on the building's information and a scalable set of different software tools.

The SPHERE project provides stakeholders with a web-based and **BIM-based platform**/environment underpinned by the SPHERE application programming interface which enables a seamless integration of static data (geometry, BIM, etc.) and dynamic data (IoT) with multiple tools which, amongst others, help analyse and optimise the energy consumption, energy efficiency and environmental impact of the building overall throughout its entire lifecycle including, above all, operation and maintenance stage.

Real-time data is used by certain tools (algorithms) to analyse the buildings' real-time energy efficiency, consumption, and performance overall in order to alert end-users about any malfunction and/or strange/improvable behaviour, comparing actual data with historic baselines.

Some first recommendations from the development activities are to include libraries, models, etc. into the DTE in regards with alternative solutions (e.g., highly energy-efficient system, renewable-energy systems, etc.) which could be tested and compared against solutions used so far to improve decision-making of users, including a CAPex-OPex analysis.

3.2.3. Lessons learnt from the Smart2B project

Smart2B aims to create a smart building system, consisting of the Smart2B devices, platform and services, enabling smart buildings to interact with their occupants and the grid in real-time to untap energy efficiency and local flexibility. This approach will transform the existing building stock into an interconnected active element of the energy system by upgrading existing building equipment, individual buildings and entire building blocks to higher smartness levels.

The SRI assessment is embedded in the Smart2B platform, to assess current and improved smartness level of the pilots, and to generate smartness advice and the quantified impact on energy efficiency, comfort and flexibility. **(semi-)Automated assessment of selected SRI services** and their functionality levels are planned, based on data and measurements (real time/historical, dynamic/static).

Use of real-time performance data: a mapping and identification of the data/measurement's requirements will be performed for the selected SRI services and their functionality levels. Algorithms are developed to translate data/measurements to functionality levels of the selected SRI services.

Some first project findings are as follows:

- certain services and functionality levels are not detectable with data/measurements in the current service catalogue;
- certain services and functional levels are detectable but require the deployment of dedicated sensors and measurements which might not be foreseen in the project.

3.2.4. Lessons learnt from the ACCEPT project

The ACCEPT project aims to develop and deliver a digital toolbox to energy communities that will enable the provision of innovative digital services to their stakeholders. These services grant access to revenue streams that can financially support the communities' functions and ensure their longevity and well-functioning

The ACCEPT project adopts a specialised module called D-SRI that undertakes the calculation of the **SRI** and applies it on a multitude of pilot buildings. Implemented in a more developer-friendly environment, D-SRI is smoothly integrated in the ACCEPT's system architecture and interfaces with the relevant data sources. This way, the component collects the appropriate data that enables the calculation of the SRI per pilot building based solely on already existing information in the ACCEPTs repositories. The algorithms developed within D-SRI manage to identify the technical systems in a pilot and infer the smartness levels of the activated technical building services. A dedicated engine takes over the calculation of the SRI scores which are further delivered to the end-user via a UI offered in the project's application.

The D-SRI component extends the current methodology by automating the SRI assessment and eliminating the requirement of a separate smart audit expected by the building's stakeholders. It is further eligible for absorbing the updates in regards with the pilot equipment, as it is based on consolidated information extracted from the ACCEPT's repositories. This leads to easily reproducible and up-to-date SRI scores delivered to the end-user.

Based on the typology of the ACCEPT's pilot cases, the SRI's method A has been considered for both residential and small commercial buildings. As a result, a total amount of twenty-seven technical building services have been examined in order to define their level of smartness exclusively through available data sources. During this process several constraints have been faced in regards with the completeness of the existing information. To tackle this, a set of assumptions has been defined and applied taking strongly into consideration the enhanced smartness contributed by the ACCEPT's modules and solutions. This approach ultimately aims to deliver the SRI calculations of the pilot cases in a homogenous way.

In the first period of the D-SRI implementation, the module has been tested in one of the project's validation facilities with controlled environment. In the next period, as the development of other ACCEPT's system components is finalised, the module will be integrated in the system architecture and applied on the entirety of the ACCEPT's pilot buildings.

3.2.1. Lessons learnt from the domOS project

With the progress of digitalisation, more and more data that could be used to derive indicators become available. However, integrating these data in a coherent database with **uniform data and metadata** is still a challenge because access methods, security policies and message formats are still device/appliance specific.

In this context, the project domOS recognised this heterogeneity as a fact and elaborated an ecosystem allowing any data source to be normalised and associated to (also normalised) metadata. This approach rests upon machine-readable documents that describe the building energy topology and the interface to online devices and appliances.

SRI: The domOS approach aims at industrialising the smart building domain through the decoupling of the in-building infrastructure plane and of the application / service plane. As of today, the SRI is a static document referring to online services. The domOS approach could enable the definition of **a digital SRI certificate** containing "hyperlinks" to monitoring and control points in the building. Applications would then consume the digital certificate and start monitoring / control, if the required permissions are granted. domOS provides a lightweight, standard-based solution for this use case that fulfils cyber-security and privacy requirements.

3.2.1. Activities within the AUTO-DAN project

The Auto-DAN project will exploit the evolution of IoT and emerging technologies to capture data and create solutions that will enable the self-optimisation of the buildings' energy consumption. Auto-DAN pursues the aim of producing a cost-effective technological solution for the self-assessment of the actual energy performance of buildings and integrated appliances, providing building users with the awareness to proactively optimise their energy use.

Auto-DAN is working on the creation of an interactive dashboard which will be able to provide useful information to the user and increase the user awareness of energy efficiency both of the building and the appliances. Among the indicators that will be present on the dashboard, the Smart Readiness Indicator (SRI) will have a central role. The Auto-DAN partners are working jointly to **create a 'quasi-dynamic' assessment of the SRI** by putting together data from the building, the appliances and the external signals from the grid. This quasi-dynamic approach will be based on a gamification process, which will recommend changes to the building's system or appliances by promoting choices that will direct the user toward increasing building smartness**.** In parallel, a methodology is also being investigated to **link the SRI score with building energy savings and EPCs.**

Other important **data-driven indicators** that are being studied in Auto-DAN are the ones related to energy flexibility and demand-response. These themes are getting more and more important to reduce the stress on the electricity grid reducing the consumption during peak periods. The aim is to start from real, measured performance data coming from the energy meters and elaborate them to provide useful indicators to the user and promote demand-response strategies. These indicators will be calculated using the deferability characteristics of the appliances and the signals from the electricity grid and will be based on the typical load profile of the building.

3.3. Other initiatives related to data driven indicators

3.3.1. IEA Annex 81 on Data driven smart buildings

The International Energy Agency (IEA) Implementing Agreement on Energy in Buildings and Communities launched an Annex 81 on 'Data-driven Smart Buildings'. The overarching Annex' aim is to increase access to low cost high-quality data from buildings and support the development of data-driven energy efficiency applications' and analytics. This will enable real time building energy efficiency control optimisation and provide energy efficiency data and decision support for building facilities managers. Among the Annex objectives, are:

- provide the knowledge, standards, protocols and procedures for low-cost high-quality data capture, sharing and utilisation in buildings
- develop a control-oriented building modelling framework that enables testing, development, and assessment of the impact of alternative building HVAC control strategies in a digital environment

In June 2022, the Annex released a survey of metadata schemas for data-driven buildings.

3.3.2. Brains for Buildings (B4B)

B4B is a multi-year, multi-stakeholder project that started in 2021 and focuses on developing methods to harness big data from smart meters, building management systems and the Internet of Things devices, to reduce energy consumption, increase comfort, respond flexibly to user behaviour and local energy supply and demand, and save on installation maintenance costs. This will be done through the development of faster and more efficient machine learning and artificial intelligence models and algorithms. The project is geared to existing utility buildings such as commercial and institutional buildings.

4. Barriers and drivers

4.1. Barriers

Barriers to the further development and implementation of data driven indicators were listed and prioritised by the task force. The top barriers are highlighted below.

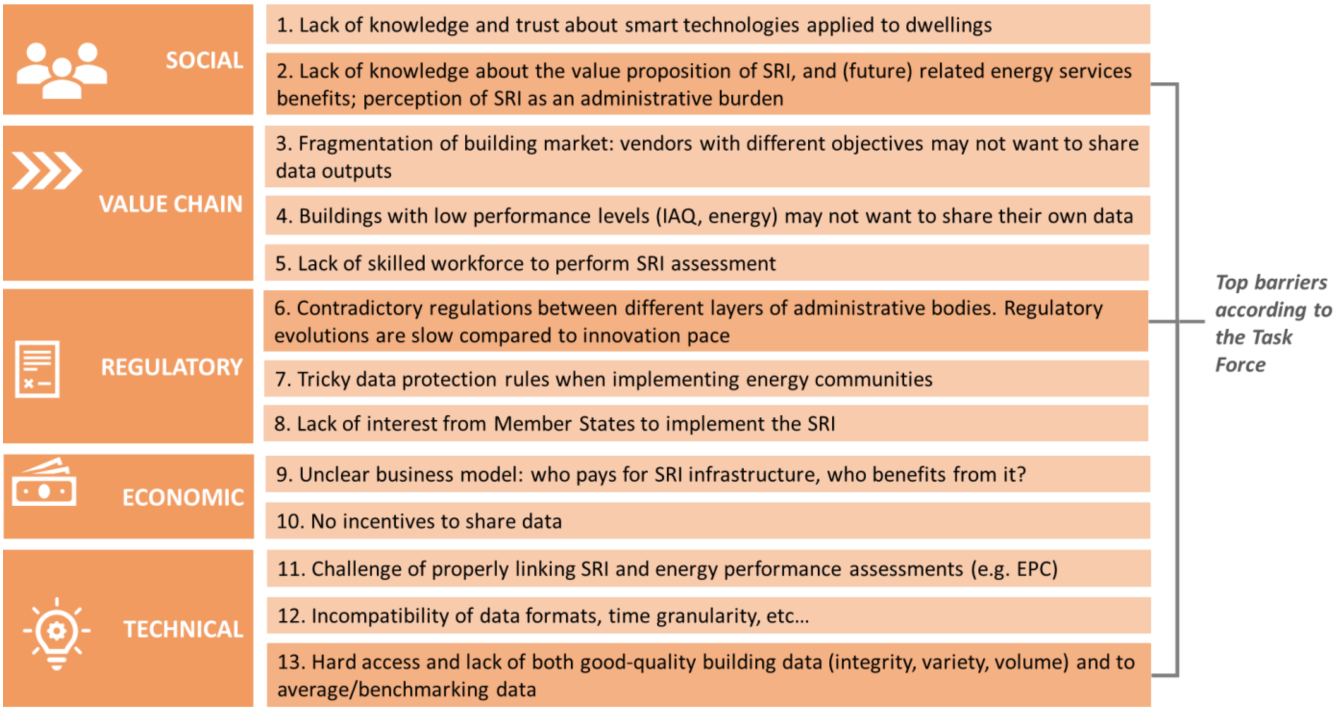

Figure 11: Barriers identified with task force members

4.2. Drivers

Drivers supporting the further development and implementation of data driven indicators were listed and prioritised by the task force. The top drivers are highlighted below.

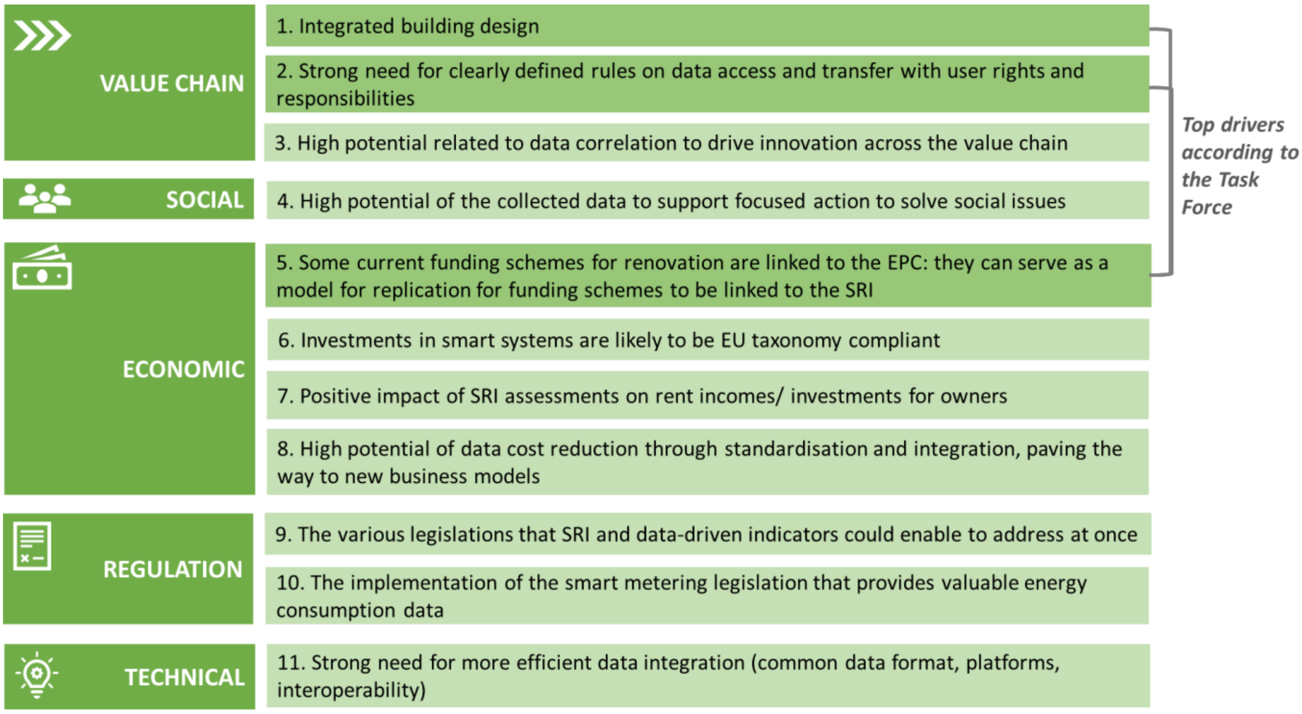

Figure 12: Drivers identified with task force members

As an outcome of the open consultation phase, an additional technical driver was proposed: leveraging current available smart infrastructure (sensors used for simple controls) to introduce additional smart technologies, mainly software, such as predictive control, advanced data analytics, etc. These can be enablers of further development and implementation of data driven indicators.

5. Gaps

Various activities required to overcome the barriers and leverage the drivers related to data driven indicators for smart buildings were suggested and prioritised by the task force members and are presented in Table 2. The priority ones according to the task force are in bold.

Table 2: Suggested R&I activities

Type of activity	Activities
R&I	- **Investigate how to use synergies and re-use building data in the evaluation of the SRI, the EPC, any other assessments, i.e. make the assessments data-driven** - Develop AI-based data handling and analytics to get higher quality data and link services easier - Investigate the expectations of SRI users, regarding the SRI and building indicators in general - Identify possible prerequisites for applying 'smartness' (and consequently the SRI) to a building: e.g. can a building with problematic envelop become 'smart'?

	- Develop an evidence-based quantification of benefits related to SRI scores: how much are comfort, convenience, health, energy savings respectively increased when a smart functionality is added/increased? - Reach better communication and interconnection among smart building apps and technologies so they get more efficient and easy to use
Demo	- **Demonstrate SRI dynamic calculation (and EPC update) based on BACS data** - **Demonstrate how combined analytics from different channels (smart meters, grid operator, weather data) can support energy supply and demand optimisation at the local/national level** - Test whether SRI metrics work equally well across different EPC frameworks in different countries (define related verification methods) - Demonstrate simple and effective decision-making tools for investors to clearly show the value of a 'go' decision
Regulation & legal framework	- **Propose a harmonised, common European SRI methodology, referring to European standards**
Certification & standardisation	- **Define standards for real time scoring/SRI calculation (sampling rate, units, sensors…)** - Demonstrate the added value of certifications with regards to their cost - Standardise evaluation methods of benefits/co-benefits valorisation
Scaling up & industrialisation	- Channel the building data to feed all assessments and digital passports, certificates - Investigate the benefits of SRI for distribution network operators and ESCOs providing demand-response services, as a potential driver for scaling up the SRI. - Investigate new business models associated to these benefits - Support the deployment of well-established certifications such as Ready 2 Services or SmartScore

6. Conclusion

This document formalises the collaborative work performed by the members of SmartBuilt4EU task force 3, on a voluntary basis, during the period May 2022 – October 2022. It also integrates the feedback collected during a peer review conducted by VITO in October 2022, and the open consultation process held during November 2022.
Based on an analysis of the state of the art and the identification of barriers and drivers, the main objective of this paper is to detect some research and innovation gaps that still need to be addressed in the coming years to support the further development and implementation of data driven indicators for smart buildings. This white paper will feed the elaboration of the strategic research and innovation agenda that the SmartBuilt4EU consortium will present to the European Commission.

To receive the updates on the SmartBuil4EU task forces, white papers and events, please register here: https://smartbuilt4eu.eu/join-our-community/

Contact point for task Force 3:
Clémentine COUJARD, DOWEL Innovation, clementine.coujard@dowel.eu

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Annex 1: list of H2020 projects reviewed

Table 3: list of relevant EU projects

Project	Status	Contact in TF	Weblink	Relevant inputs
SYNERGY SYNERGY		**VTT**	https://www.synergyh2020.eu	Development and demonstration of a Big Data platform powered by energy-related data
SRI support contract		**Stijn**	**https://smartreadinessindicator.eu/**	Contract to support awareness rausubg and testing of the SRI
iBRoad2EPC iBRoad2EPC		Coordinator Alexander Deliyannis	www.ibroad2epc.eu	The **iBRoad project developed the** Building Renovation Passport for single-family home-owners. iBRoad2EPC aims to **bridge** the Building Renovation Passport with the **EPC**, and **expand, improve** and **broaden** their format and joint scope to consider additional features, e.g., **indoor environment** and **smart technologies**, and become applicable also to **multi-family** and **public buildings**.
Auto-DAN Auto-DAN		Paolo Finocchi, RINA Consulting S.p.A)	https://www.autodan-project.eu/	Auto-DAN will produce a new dynamic self-assessment methodology that takes into account the actual energy performance of a building, the quality and operation of appliances/systems installed, user operational habits and the smart readiness indicator (SRI) of a building.
BuiltHub BuiltHub		**Cristian Pozza**	**https://builthub.eu/**	Dynamic EU building stock knowledge hub. Development of a web-based BuiltHub platform, and collection of aggregated data on building stock performance. Could potentially extend to SRI at building stock level.
MATRYCS **MATRYCS**			**https://matrycs.eu/**	Objective: define and deploy a Reference Architecture for Buildings Data exchange, management and real-time processing, and to translate this reference architecture into an Open, Cloud-based Data Analytics Toolbox. It will enable AI-based cross-sector analytics for smart energy-efficient buildings
BIGG **BIGG**			**https://www.bigg-project.eu/#about**	Demonstrating the application of big data technologies and data analytic techniques for the complete buildings life-cycle of more than 4000 buildings in 6 large-scale pilot test-beds.
ALDREN ALDREN	completed	Graziano Salvalai (poliMI)	https://aldren.eu/	provides **consistent sustainability metrics** to improve certification of energy and IEQ performance. Energy voluntary certificate EVC + Building Renovation Passport BRP

BEYOND	ongoing	John Avramidis	https://beyond-h2020.eu	BEYOND introduces a reference big data platform implementation for collecting, processing and analyzing building data, while transforming them into a tradeable commodity through the development of appropriate data sharing mechanisms for data sharing between different stakeholders.
DOMOS	ongoing	Dominique Gabioud	http://www.domos-project.eu/	Operating System for smart building: Any in-building infrastructure available for any monitoring / control / optimisation application, if permitted
Smart2B	ongoing	NUNO MATEUS	https://smart2b-project.eu/	SMART2B project will upgrade the capacity of existing buildings by developing non-intrusive IoT sensors and actuators to control equipment, while improving indoor comfort and energy efficiency. The project will allow for coordinated control of legacy equipment and smart appliances and integrate two existing cloud-based platforms into a single building management platform. **See D1.2 on Smart Performance Assessment & Advisor**
SPHERE	Ongoing	Pablo Vicente Fausto from COMET	https://sphere-project.eu/	**Provide a BIM-based Digital Twin Platform to optimise the building lifecycle, reduce costs, and improve energy efficiency in residential buildings.**
Next Gen EPCs cluster of projects				
	ongoing	María Fernández Boneta (Project Coordinator	ePANACEA Horizon 2020 project – Smart European Energy Performance Assessment & Certification)	ePANACEA develops a holistic methodology for energy performance assessment and certification of buildings. Its platform makes use of the most advanced techniques in dynamic and automated simulation modelling, big data analysis and machine learning, inverse modelling for the estimation of potential energy savings and economic viability check.
	ongoing	Graziano Salvalai (PoliMI)	https://epcrecast.wordpress.com/ https://epc-recast.eu/	New generation of EPCS. House owners' considerations about usefulness of the EPC are central as owners decide whether to implement energy conservation opportunities provided by the EPC. EPC RECAST is a decisive decision-supporting tool for tenants and potential buyers. It provides guidance on cost-optimal building renovation for building owners, covering as well IEQ, wellbeing and smartness.
	ongoing		https://edyce.eu/	Energy flexible DYnamic building Certification. It aims to create a technology-neutral methodology for dynamic labelling, based on maximizing the free running potential of the building and promoting the

				use of passive and low-cost solutions, instead of mechanical systems.
D2EPC	Ongoing	/	https://www.d2epc.eu/	Development of dynamic EPCs
frESCO	Ongoing	Juan Aranda / Project Technical Coordinator	https://www.fresco-project.eu/	Developing new innovative Pay for Performance energy service contracts and business models for ESCOs and demand-response Aggregators in the residential sector
crossCert	Ongoing	David Jenkins	https://www.crosscert.eu/	Cross test of EPCs is 10 countris. The procedure will include the testing of prototype/new EPC output metrics through the crossCert sample building stock. SRI is likely to be a key part of this, being a relatively mature next-generation EPC metric.