Calculation of the SRI and implementation of potential flexibility measures for existing buildings

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May 29th 2024

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TEBE
TECHNOLOGY ENERGY BUILDING ENVIRONMENT

BAEDA Lab
BUILDING AUTOMATION ENERGY DATA ANALITYCS

EPBD context - Digitalization

- (23) Zero-emission buildings can contribute to **demand-side flexibility** for instance **through demand management, electrical storage, thermal storage and distributed renewable generation** to support a more reliable, sustainable and efficient energy system.
- *(49)[…]* ***Electric vehicles*** *are expected to play a crucial role in the* ***decarbonisation*** *and* ***efficiency*** *of the electricity system, namely through the provision of* ***flexibility****,* ***balancing*** *and* ***storage services****, especially through aggregation. […]*
- *(50)[…]* **Electric vehicles** constitute an important component of a clean energy transition on the basis of **energy efficiency measures**, alternative fuels, renewable energy and **innovative solutions for the management of energy flexibility**. […]
- *(54) […] The* ***digitalization of the energy system*** *is quickly changing the energy landscape, from the integration of renewables to* ***smart grids*** *and* ***smart-ready buildings****. In order to digitalize the building sector, the Union's connectivity targets and ambitions for the deployment of high-capacity* ***communication networks*** *are important for smart homes and well-connected communities. Targeted incentives should be provided* ***to promote smart-ready systems*** *and* ***digital solutions*** *in the built environment. This would offer* ***new opportunities*** *for energy savings, by providing consumers with more accurate information about their* ***consumption patterns****, and by enabling the system operator to manage the grid more effectively.* y. Member States should encourage the **use of digital technologies** for **analysis**, **simulation** and **management of buildings**, including with regard to deep renovations.
- *(55)* In order to facilitate a competitive and innovative market for **smart building services** that contributes to **efficient energy use** and **integration of renewable energy** in buildings and support investments in renovation, Member States should ensure **direct access to building systems' data** by interested parties. To avoid excessive administrative costs for third parties, Member States shall facilitate the **full interoperability of services** and of the **data exchange** within the Union.

DIRECTIVE (EU) 2024/1275 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 24 April 2024 on the energy performance of buildings (recast)

EPBD context - Digitalization

- *(56) 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 among 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. The smart readiness indicator is particularly beneficial for large buildings with high energy demand. For other buildings, the scheme for rating the smart readiness of buildings should be optional for Member States.*

- *(57) A **digital building twin** is an **interactive** and **dynamic simulation** that reflects the **real-time status and behaviour** of a physical building. By incorporating **real-time data** from sensors, smart meters and other sources, a digital building twin provides a holistic view of the building's performance, including energy consumption, temperature, humidity, occupancy levels, and more and can be used to monitor and manage the building's energy consumption. **Where a digital building twin is available, it should be taken into account, in particular for the smart readiness indicator**.*

- *(68) The **monitoring** of the building stock is facilitated by the **availability of data** collected by **digital tools**, thereby reducing administrative costs. Therefore, **national databases** for energy performance of buildings should be set up, and the information contained therein should be transferred to the EU Building Stock Observatory.*

DIRECTIVE (EU) 2024/1275 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 24 April 2024 on the energy performance of buildings (recast)

EPBD context – Digitalization

- Art. 13, par. 9: "Member States shall lay down requirements to ensure that […] **non-residential buildings** are **equipped with building automation and control systems**, as follows: (a) **by 31 December 2024**, non-residential buildings with an **effective rated output** for heating systems, air-conditioning systems, systems for combined space heating and ventilation, or systems for combined air conditioning and ventilation **of over 290 kW**; (b**) by 31 December 2029**, non-residential buildings with an **effective rated output** for heating systems, air-conditioning systems, systems for combined space heating and ventilation, or systems for combined air conditioning and ventilation **of over 70 kW**.";

- Art. 13, par. 10: "The **building automation and control systems** shall be **capable of**: (a**) continuously monitoring**, **logging**, **analysing** and allowing for **adjusting energy use**; (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; (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";

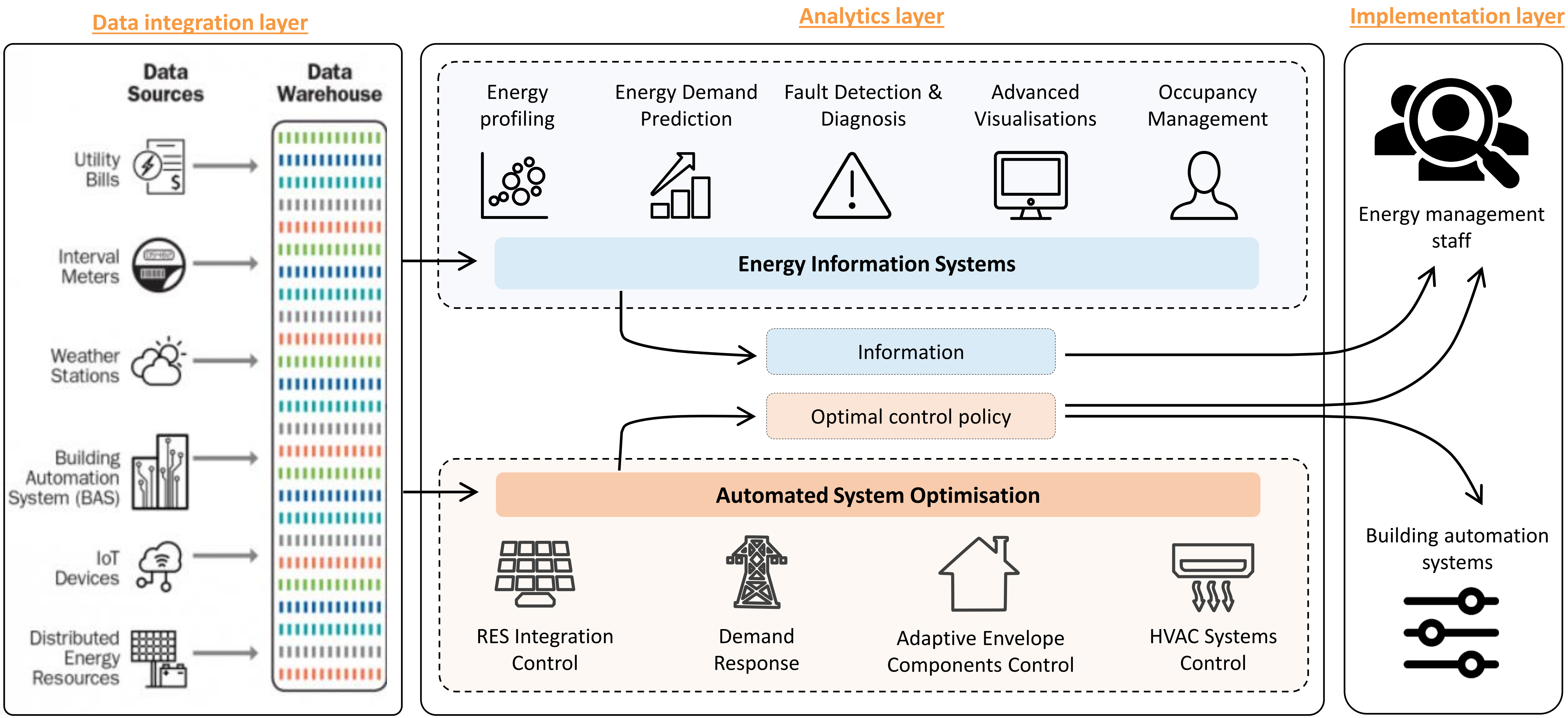
- Art. 13, par. 11: "Member States shall lay down requirements to ensure that [..] **from 29 May 2026**, **new residential buildings** and **residential buildings undergoing major renovations** are **equipped with** the following: (a) the functionality of **continuous electronic monitoring** that measures systems' efficiency and **informs building owners** or managers in the case of a significant variation and when system servicing is necessary; (b) effective control functionalities to **ensure optimum generation, distribution, storage, use of energy** and, where applicable, hydronic balance; (c) a **capacity to react to external signals** and **adjust the energy consumption**"

- Art. 15, par. 1: *"The Commission shall adopt delegated acts […] concerning 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**, in particular concerning **indoor environmental quality** and the **grid** and to **improve its energy efficiency** and overall performance.*

- Art. 15, par. 2: *[…]the Commission shall, **by 30 June 2027**, adopt a delegated act […] by **requiring the application of the common Union scheme for rating the smart readiness of buildings**, in accordance with Annex IV, **to non-residential buildings** with an **effective rated output** for heating systems, air-conditioning systems, systems for combined space heating and ventilation, or systems for combined air-conditioning and ventilation **of over 290 kW.***

DIRECTIVE (EU) 2024/1275 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 24 April 2024 on the energy performance of buildings (recast)

Next generation of Energy Management and Information Systems in Buildings leveraging AI

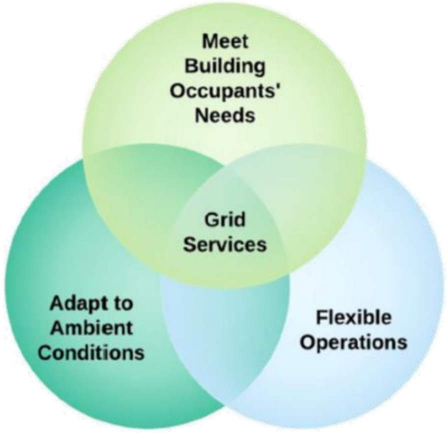


Source: https://betterbuildingssolutioncenter.energy.gov/beat-blog/smart-energy-analytics-are-key-building-energy-and-cost-savings

What is energy flexibility?

The widespread adoption of **renewable energy sources** poses challenges in managing power systems. A potential solution involves shifting from supply-side control to **demand-side management**.

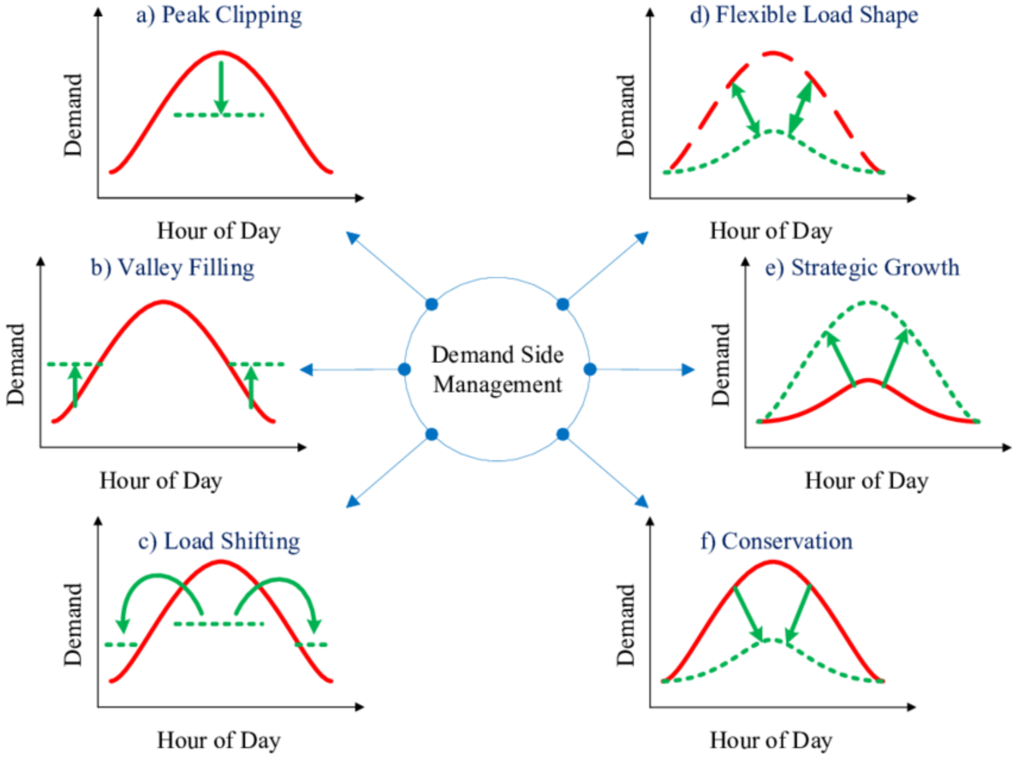
Demand-side flexibility *means the capacity of active customers to* ***react to external signals*** *and* ***adjust*** *their* ***energy generation*** *and* ***consumption****, individually or through aggregation, in a* ***dynamic time-dependent way****, which may be provided by smart, decentralized energy resources, including demand management, energy storage, and distributed renewable generation, to support a more reliable, sustainable and efficient energy system*



Source: H. Li, Z. Wang, T. Hong et al. (2021) [18]

Demand-side management strategies are critical for efficient energy consumption and grid optimization.

These approaches include **Demand Response** to **balance** supply and demand by shifting consumption during **peak** times enhancing grid **reliability**.



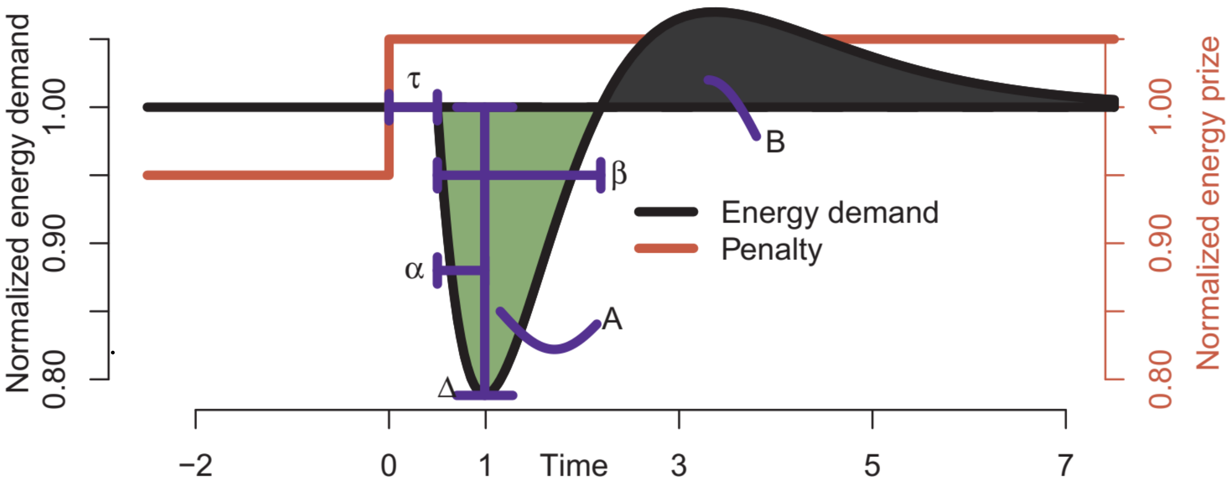
Source: Qurat-ul-Ain et al. (2019) [1]

The fingerprint of a flexibility strategy

A **methodology** for characterizing energy **flexibility** is established using the described **flexibility function**. This function explains how a particular **smart building**, or a **group** of smart buildings responds to a **penalty signal**.

The dynamic nature of the flexibility function enables it to be useful even when the system is not in steady state.

The **flexibility function** contains all information about the relationship between the **penalty signal** and the resulting **energy demand profile**.



Source: Junker, R.G. et al. (2021) [15]

Flexibility features

τ (Time): The time it takes for adjustments in energy pricing to have a noticeable effect on energy demand.

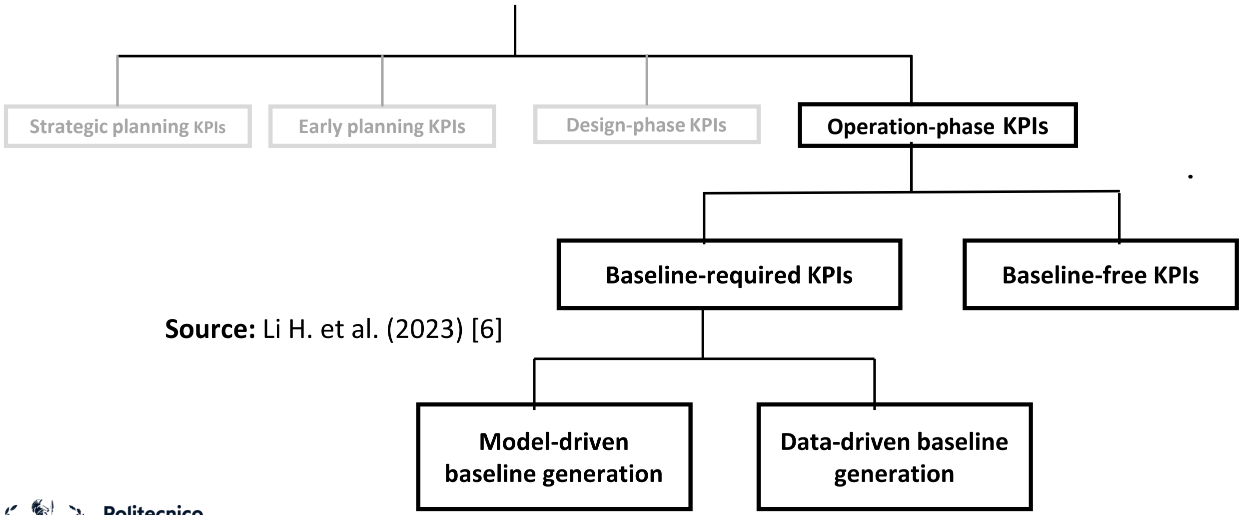
Δ (Power): The maximum change in demand that can occur following a change in penalties or pricing.

α (Time): The time it takes for the change in demand to reach its lowest level after the adjustment begins.

β (Time): The total duration during which energy demand remains decreased.

A (Energy): The total amount of decreased energy demand resulting from the changes.

B (Energy): B signifies the total amount of increased energy demand resulting from the changes.



Source: Li H. et al. (2023) [6]

The Smart Readiness Indicator. What is it?

- **Lack of awareness** about improvements in overall performance of buildings when implementing smart technologies
- SRI support the **smartness upgrade** of buildings
- It encourages the adoption of **energy flexibility solutions**
- It promote the adoption of **monitoring infrastructures** for buildings
- It measures the **potential smartness** of a building and **not its actual energy performance**
- SRI is based on:
  - ❑ The **readiness to** maintain **energy efficiency performance and operation** of the building through the adaptation of energy consumption
  - ❑ The **readiness to** adapt its operation mode in response to the **needs of the occupant**
  - ❑ The **readiness to** adapt its operation mode in response to the **needs of the energy grid** (energy demand flexibility)

SRI

Key functionalities

- Energy savings & operation
- Respond to users' needs
- Respond to the needs of the grid

Impact criteria

- Energy savings
- Maintenance & fault prediction
- Comfort
- Convenience
- Health & Well-being
- Information to occupants
- Energy flexibility & storage

Smart ready services

- Services per domain
- 27 for method A
- 54 for method B
- Method C (in-use) as possible future development
- Automation degree of each service
- From 0 (non-smart) to 4 (smart)

Domains

- Heating
- Cooling
- Domestic hot water
- Controlled ventilation
- Lighting
- Electricity
- Dynamic Envelope
- EV charging
- Monitoring & Control

Source: Final report on the technical support to the development of a smart readiness indicator for buildings

SRI calculation procedure. Triage Process

- The SRI is based on a **multi-criteria calculation method**
- The first criterion is the classification into **9 domains** of the services: **heating**, **cooling**, **DHW**, **controlled ventilation**, **lighting**, **dynamic building envelope**, **electricity**, **EV charging** and **monitoring & control**
- Each domain is characterized by a **set of services**
- For each service, a **level of functionality** needs to be expressed based on what the service provides (connected to ISO 52120)

Source: Final report on the technical support to the development of a smart readiness indicator for buildings

Heating	Heat emission control	Emission control for TABS (heating mode)	Storage and shifting of thermal energy	Control of distribution pumps in networks	Thermal Energy Storage (TES) for building heating (excluding TABS)
	Heat generator control (all except heat pumps)	Heat generator control (for heat pumps)	Sequencing in case of different heat generators	Report information regarding system performance	Flexibility and grid interaction

SRI calculation procedure. Triage Process

- Each **level of functionality** has **impact** on user well-being and building performance related impact criteria (e.g. set of scores associated)
- Set of **7 impact criteria** are defined: **energy savings**, **maintenance & fault prediction**, **comfort**, **convenience**, **health & well-being**, **information to occupants**, **energy flexibility & storage**
- For each functionality level is defined a **set of scores** that express the impact of that automation level on the 7 Impact criteria
- **Inventory of services** present in the building
- Level of functionality **assessment** real & max → **scoring**
- **Sum** of all the scores obtained per impact criterion under each domain

Domain X - Service n

	Energy savings	Maintenance and fault prediction	Comfort	Convenience	Health, well-being and accessibility	Information to occupants	Energy flexibility and storage
Level 0	0	0	0	0	0	0	0
Level 1	1	0	1	1	1	0	0
Level 2	1	0	2	2	2	0	0
Level 3	2	0	3	3	3	0	0
Level 4	3	0	3	3	3	0	0

Source: Final report on the technical support to the development of a smart readiness indicator for buildings

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SRI calculation procedure. Vertical & horizontal aggregation

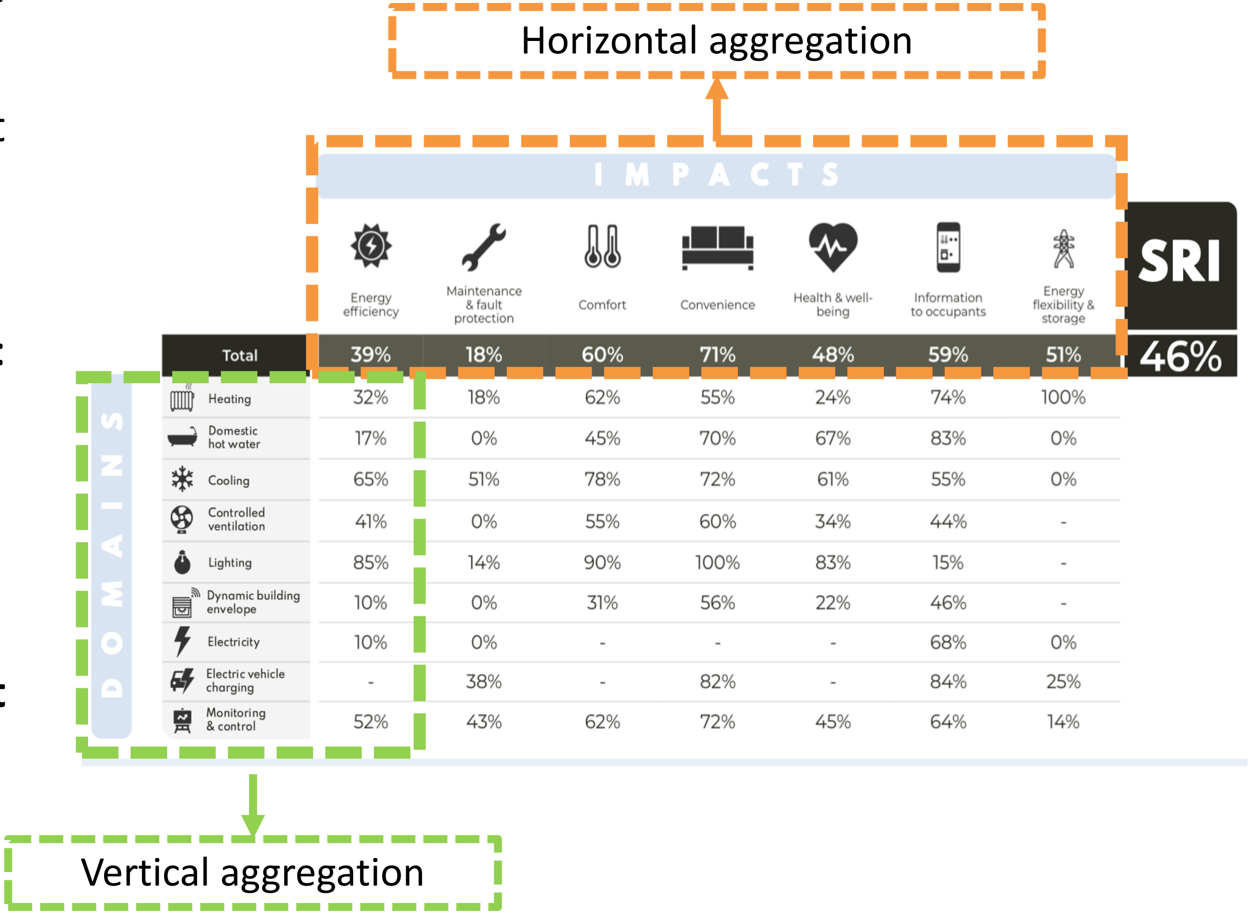
Vertical aggregation

- Domain scores (max & real) for each impact criterion are multiplied by **domain weighting factors**
- Domain weights express the relative importance of that domain with respect to the others for a given impact
- **3 weight types: energy-balance, equal, fixed**
- **Vertical summation** of weighted real and max scores: overall real and max scores

Horizontal aggregation

- Overall real & Maximum scores **multiplied** by **Impact weights**
- **Horizontal summation** of scores

$$\text{SRI} = \frac{\textit{Total Real Score}}{\textit{Total Maximum Score}}\ [\%]$$



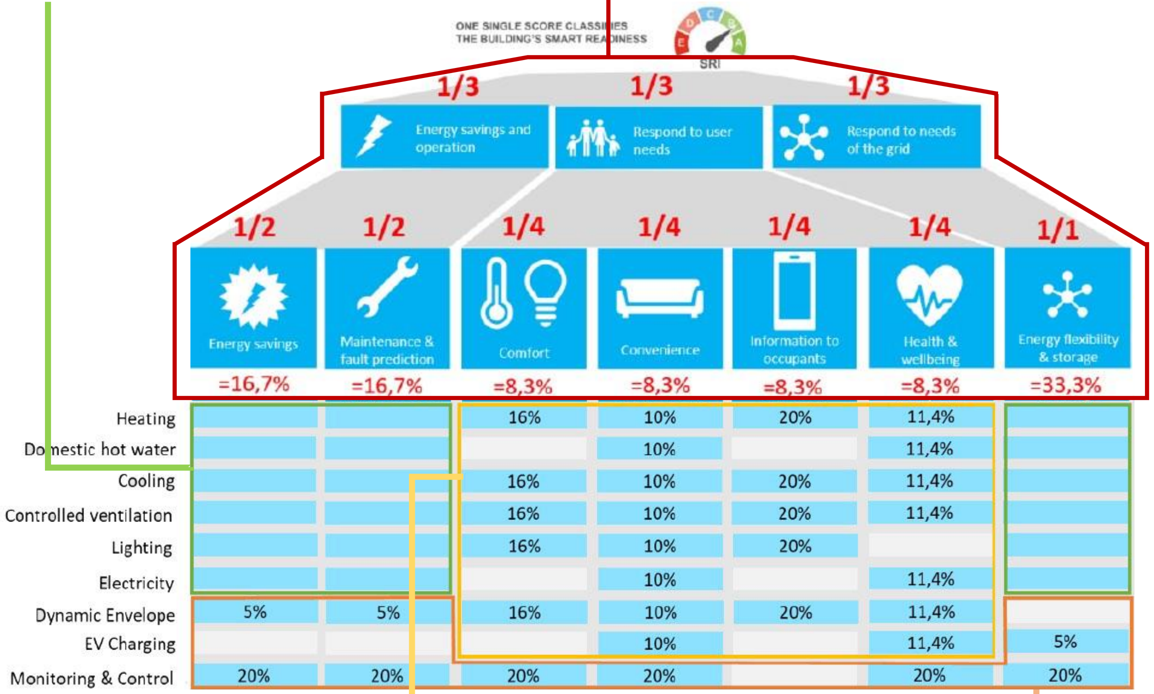
	Energy efficiency	Maintenance & fault protection	Comfort	Convenience	Health & well-being	Information to occupants	Energy flexibility & storage	SRI
Total	39%	18%	60%	71%	48%	59%	51%	46%
Heating	32%	18%	62%	55%	24%	74%	100%	
Domestic hot water	17%	0%	45%	70%	67%	83%	0%	
Cooling	65%	51%	78%	72%	61%	55%	0%	
Controlled ventilation	41%	0%	55%	60%	34%	44%	-	
Lighting	85%	14%	90%	100%	83%	15%	-	
Dynamic building envelope	10%	0%	31%	56%	22%	46%	-	
Electricity	10%	0%	-	-	-	68%	0%	
Electric vehicle charging	-	38%	-	82%	-	84%	25%	
Monitoring & control	52%	43%	62%	72%	45%	64%	14%	

Source: Final report on the technical support to the development of a smart readiness indicator for buildings

SRI weighting factors

Energy-balance weights:
- Based on primary energy usage
- Climate-dependent
- Based on building type

Horizontal weights:
- Equally distributed



	Energy savings	Maintenance & fault prediction	Comfort	Convenience	Information to occupants	Health & wellbeing	Energy flexibility & storage
Heating			16%	10%	20%	11,4%	
Domestic hot water				10%		11,4%	
Cooling			16%	10%	20%	11,4%	
Controlled ventilation			16%	10%	20%	11,4%	
Lighting			16%	10%	20%		
Electricity				10%		11,4%	
Dynamic Envelope	5%	5%	16%	10%	20%	11,4%	
EV Charging				10%		11,4%	5%
Monitoring & Control	20%	20%	20%	20%		20%	20%

Source: Final report on the technical support to the development of a smart readiness indicator for buildings

Equal weights

Fixed weights:
- non-changeable
- Estimated impact

Image from European Commission Final Report

SRI weighting factors: fixed weights

- Weighting factors for domains should be **derived from an energy balance whenever possible**
- **Fixed weights** are derived for domains where it is not possible to establish a **direct relationship with an energy balance operation** (e.g. monitoring and control or dynamic building envelope)
- Fixed weights are based on the **approach** of the **estimated impact** of a specific domain with respect to the others
- **20 % weighting** is assigned to the domain "**monitoring and control**“ for all impact criteria
- **5 % weighting** is assigned for the impact criteria **"Energy savings"**, **"maintenance and fault prediction"** and **"energy flexibility and storage"** to the domains **"electric vehicle charging"** and **"dynamic building envelope"**
- These values are **not dependent** on the **climate zone** or **building type**
- These **values cannot be changed** when using an alternative energy balance

Source: Final report on the technical support to the development of a smart readiness indicator for buildings

SRI weighting factors: equal weights

- **Equal weightings** are assigned to the impact criteria "comfort", "convenience", "health and wellbeing" and "information to occupants"

- Obtained by dividing the remaining weight for the given impact criteria for the number of domains that are relevant for the given impact criterion:

$$f_{domain,impact\ crit} = \frac{1 - \sum Fixed\ weights}{number\ of\ relevant\ domains}$$

- These values are not dependent on the climate zone or building type

- These values cannot be changed when using an alternative energy balance

Source: Final report on the technical support to the development of a smart readiness indicator for buildings

SRI weighting factors: energy-balance weights

- **Energy balance** weights are assigned to **impact criteria "energy savings", "maintenance and fault prediction" and "energy flexibility and storage“**
- Obtained by multiplying the remaining weight of the given impact criterion by the relative importance of the domain with respect to the others:

$$1-(\sum Fixed\ weights_{(impact\ crit)})*\alpha_{domain}$$

Energy balance weights - South Europe			
Domain	Energy efficiency	Energy flexibility and storage	Maintenance and fault prediction
Heating	0.32	0.38	0.33
DHW	0.10	0.12	0.10
Cooling	0.07	0.08	0.07
Ventilation	0.09	0.00	0.10
Lighting	0.03	0.00	0.00
Electricity	0.15	0.17	0.15

Example of pre-defined energy-balance weights for residential buildings.

Pre-defined α_{domain} values (%) for residential buildings in different European zones

WEIGHTINGS	North	West	South	North-East	South-East
Heating	39.9	45.3	42.2	40.5	27.5
DHW	12.4	10.2	13.3	18.6	7.7
Cooling	0.0	4.1	9.2	0.0	19.5
Ventilation	25.0	23.8	12.3	25.4	14.4
Lighting	4.9	2.0	3.6	0.8	1.2
Electricity	17.8	14.8	19.5	14.7	29.6

Pre-defined α_{domain} values (%) for non-residential buildings in different European zones

WEIGHTINGS	North	West	South	North-East	South-East
Heating	41.8	36.4	40.3	39.0	38.3
DHW	7.2	11.0	14.3	12.5	15.4
Cooling	12.5	16.9	15.7	11.2	9.9
Ventilation	26.2	19.1	11.7	24.4	20.1
Lighting	10.4	13.8	16.0	9.7	11.9
Electricity	2.0	2.8	2.1	3.1	4.4

- α_{domain} is the **relative importance of a domain** with respect to the others
- It represents the primary energy use of the given domain compared to the six primary energy usage.
- It is computed as follows:

$$\alpha_{domain}=Q_{domain}/Q_{total}$$

$$Q_{total}=Q_{heat}+Q_{DHW}+Q_{cool}+Q_{vent}+Q_{light}+Q_{\mathrm{renew}}$$

Source: Final report on the technical support to the development of a smart readiness indicator for buildings

SRI assessment: example

- **Residential building in Italy** (South Europe) with only **2 domains**: heating and DHW
- For heating are considered three services and only one for DHW
- The first two services of heating domain are present and mandatory, the third one is not present but mandatory
- The service for DHW is present and mandatory
- The levels of functionality are expressed in the table below and the **red one** are the **level of functionality present in the building**

Domain	Services	Is it Mandatory?	Is it present?	Does it affect the maximum	Level of functionality				
					Level 0	Level 1	Level 2	Level 3	Level 4
Heating	1) Heat emission control	Yes	Yes	Yes	No automatic control	Central automatic control (e.g. central thermostat)	Individual room control (e.g. thermostatic valves, or electronic controller)	Individual room control with communication between controllers and to BACS	Individual room control with communication and occupancy detection
	2) Control of distribution pumps in networks	Yes	Yes	Yes	No automatic control	On off control	Multi-Stage control	Variable speed pump control (pump unit (internal) estimations)	Variable speed pump control (external demand signal)
	3) Storage and shifting of thermal energy	Yes	No	Yes	None	HW storage vessels available	HW storage vessels controlled based on external signals (from BACS or grid)	0	0
DHW	1) Control of DHW storage charging (with direct electric heating or integrated electric heat pump)	Yes	Yes	Yes	Automatic control on / off	Automatic control on / off and scheduled charging enable	Automatic control on / off and scheduled charging enable and multi-sensor storage management	-	-

SRI assessment: example

- **Set of scores** associated to impact criteria
- Blue framed text is the level implemented within the building
- Yellow highlighted text is the maximum level

Heating - 1) Heat Emission Control

Functionality levels		Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
		IMPACTS						
level 0	No automatic control	0	0	0	0	0	0	0
level 1	Central automatic control (e.g. central thermostat)	1	0	1	1	1	0	0
level 2	Individual room control (e.g. thermostatic valves, or electronic controller)	2	0	2	2	2	0	0
level 3	Individual room control with communication between controllers and to BACS	2	0	2	3	2	1	0
level 4	Individual room control with communication and occupancy detection	3	0	2	3	2	1	0

Heating - 2) Control of distribution pumps in networks

Functionality levels		Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
		IMPACTS						
level 0	No automatic control	0	0	0	0	0	0	0
level 1	On off control	1	0	0	0	0	0	0
level 2	Multi-Stage control	2	0	0	0	0	0	0
level 3	Variable speed pump control (pump unit (internal) estimations)	2	0	0	0	0	0	0
level 4	Variable speed pump control (external demand signal)	2	0	0	0	0	0	0

Heating - 3) Storage and shifting of thermal energy

Functionality levels		Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
		IMPACTS						
level 0	None	0	0	0	0	0	0	0
level 1	HW storage vessels available	1	0	1	1	0	0	0
level 2	HW storage vessels controlled based on external signals (from BACS or grid)	2	0	1	1	0	0	0

DHW - 1) Control of DHW storage charging (with direct electric heating or integrated electric heat pump)

Functionality levels		Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
		IMPACTS						
level 0	Automatic control on / off	0	0	0	0	0	0	0
level 1	Automatic control on / off and scheduled charging enable	1	1	0	1	0	0	0
level 2	Automatic control on / off and scheduled charging enable and multi-sensor storage management	2	2	0	2	0	0	0

SRI assessment: example

- The next step is to calculate the **sum of both REAL SCORES and MAXIMUM SCORES for each domain**: the real score is the sum of the red value scores either maximum score is the sum of the yellow highlighted scores

REAL SCORE							
Impact criteria / Domain	Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
Heating	5	0	2	3	2	1	0
DHW	1	1	0	1	0	0	0

MAXIMUM SCORE							
Impact criteria / Domain	Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
Heating	7	0	3	4	2	1	0
DHW	2	2	0	2	0	0	0

SRI assessment: example

- **Real score and maximum score multiplied by the DOMAIN weightings** to obtain a new table with weighted values

REAL SCORE							
Impact criteria / Domain	Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
Heating	5	0	2	3	2	1	0
DHW	1	1	0	1	0	0	0

5 x 0,32 = 1,58

Real score x Domain Weightings = Real score - DW

Residential - South Europe - DOMAIN WEIGHTINGS							
Impact criteria / Domain	Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
Heating	0,32	0,38	0,16	0,10	0,20	0,33	0,11
DHW	0,10	0,12	0,00	0,10	0,00	0,10	0,11

REAL SCORE - DW							
Impact criteria / Domain	Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
Heating	1,58	0,00	0,32	0,30	0,40	0,33	0,00
DHW	0,10	0,12	0,00	0,10	0,00	0,00	0,00

SRI assessment: example

- **Sum of all domain scores for a given impact criterion** is performed (Vertical aggregation)

REAL SCORE - DW							
Impact criteria / Domain	Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
Heating	1,58	0,00	0,32	0,30	0,40	0,33	0,00
DHW	0,10	0,12	0,00	0,10	0,00	0,00	0,00
Vertical aggregation	**1,68**	**0,12**	**0,32**	**0,40**	**0,40**	**0,33**	**0,00**

1,58 + 0,10 = 1,68

MAXIMUM SCORE - DW							
Impact criteria / Domain	Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
Heating	2,22	0,00	0,48	0,40	0,40	0,33	0,00
DHW	0,20	0,24	0,00	0,20	0,00	0,00	0,00
Vertical aggregation	**2,42**	**0,24**	**0,48**	**0,60**	**0,40**	**0,33**	**0,00**

SRI assessment: example

- **Each Vertical aggregation score is multiplied by IMPACT Weighting factors**
- An example for the REAL SCORE – DW are provided below: a new line appear called Horizontal aggregation which represent the scores after the multiplication of REAL SCORE – DW by Impact Weighting (IW)

REAL SCORE - DW							
Impact criteria / Domain	Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
Heating	1,58	0,00	0,32	0,30	0,40	0,33	0,00
DHW	0,10	0,12	0,00	0,10	0,00	0,00	0,00
Vertical aggregation	$\boxed{1,68}$	0,12	0,32	0,40	0,40	0,33	0,00

1,68 x 0,17 = 0,28

Vertical aggregation x Impact Weightings

= Horizontal aggregation partial score

IMPACT WEIGHTINGS						
Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
$\boxed{0,17}$	0,33	0,08	0,08	0,08	0,17	0,08

REAL SCORE - DW							
Impact criteria / Domain	Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
	$\boxed{0,28}$	0,04	0,03	0,03	0,03	0,05	0,00

SRI assessment: example

- Weighted score obtained and ready for the next step: horizontal aggregation
- The horizontal is not yet performed in this tables

REAL SCORE - DW							
Domain \ Impact criteria	Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
Heating	1,58	0,00	0,32	0,30	0,40	0,33	0,00
DHW	0,10	0,12	0,00	0,10	0,00	0,00	0,00
Vertical aggregation	1,68	0,12	0,32	0,40	0,40	0,33	0,00
Horizontal aggregation	**0,28**	**0,04**	**0,03**	**0,03**	**0,03**	**0,05**	**0,00**

MAXIMUM SCORE - DW							
Domain \ Impact criteria	Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
Heating	2,22	0,00	0,48	0,40	0,40	0,33	0,00
DHW	0,20	0,24	0,00	0,20	0,00	0,00	0,00
Vertical aggregation	2,42	0,24	0,48	0,60	0,40	0,33	0,00
Horizontal aggregation	**0,40**	**0,08**	**0,04**	**0,05**	**0,03**	**0,05**	**0,00**

SRI assessment: example

- Sum of each impact criteria is performed in the column Total (horizontal aggregation step)
- **Ratio between Total Real score and Total Maximum score** is performed to obtain the SRI expressed as percentage

$$SRI = \frac{\textit{Total Real Score}}{\textit{Total Maximum Score}}$$

- Moreover, a ratio between the Real score – Horizontal aggregation and Maximum score – Horizontal aggregation impacts can be done, and this can give a percentage of **SRI relative score per impact criterion**

Impact criteria / Type of score	Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants	Total	SRI
REAL SCORE - Horizontal aggregation	0,28	+ 0,04	+ 0,03	+ 0,03	+ 0,03	+ 0,05	+ 0,00 =	0,47	71%
MAXIMUM SCORE - Horizontal aggregation	0,40	0,08	0,04	0,05	0,03	0,05	0,00	0,66	
Impacts %	70%	50%	67%	67%	100%	100%	0%	Class =	C

$$\frac{0,47}{0,66} * 100 = 71\%$$

$$\frac{0,28}{0,40} * 100 = 70\%$$

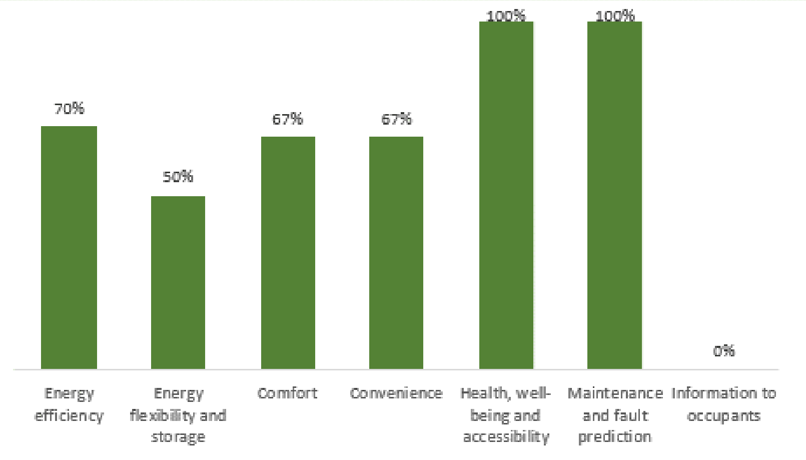
SRI assessment: example

- Based on the SRI and to the % assigned to every impact, the owner can easily understand how to improve his score
- In the example explained, the impact "Information to occupants" is 0%, so if the owner wants to improve his SRI must install services which provide information to occupants
- If SRI is coupled to an EPC the owner can easily have an overall framework about his building.

TOTAL SRI SCORE	71%	SRI CLASS	C

IMPACT SCORES

Energy efficiency	70%
Energy flexibility and storage	50%
Comfort	67%
Convenience	67%
Health, well-being and accessibility	100%
Maintenance and fault prediction	100%
Information to occupants	0%



SRI	Class
>90%	A
80 - 90%	B
65 - 80%	C
50 - 65%	D
35 - 50%	E
20 - 35%	F
< 20%	G

Heating/Cooling services

Functionality levels

Services	Level 0	Level 1	Level 2	Level 3	Level 4
Thermal Energy Storage (TES) for building heating (excluding TABS)	*Continuous storage operation*	*Time-scheduled storage operation*	*Load prediction based storage operation*	*Heat storage capable of flexible control through grid signals (e.g. DSM)*	-
Report information regarding HEATING system performance	*None*	*Central or remote reporting of current performance KPIs (e.g. temperatures, submetering energy usage)*	*Central or remote reporting of current performance KPIs and historical data*	*Central or remote reporting of performance evaluation including forecasting and/or benchmarking*	*Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection*
Flexibility and grid interaction	*No automatic control*	*Scheduled operation of heating system*	*Self-learning optimal control of heating system*	*Heating system capable of flexible control through grid signals (e.g. DSM)*	*Optimized control of heating system based on local predictions and grid signals (e.g. through model predictive control)*

Source: Final report on the technical support to the development of a smart readiness indicator for buildings

Electricity services

Functionality levels

Services	Level 0	Level 1	Level 2	Level 3	Level 4
Optimizing self-consumption of locally generated electricity	*None*	*Scheduling electricity consumption (plug loads, white goods, etc.)*	*Automated management of local electricity consumption based on current renewable energy availability*	*Automated management of local electricity consumption based on current and predicted energy needs and renewable energy availability*	-
Storage of (locally generated) electricity	*None*	*On site storage of electricity (e.g. electric battery)*	*On site storage of energy (e.g. electric battery or thermal storage) with controller based on grid signals*	*On site storage of energy (e.g. electric battery or thermal storage) with controller optimising the use of locally generated electricity*	*On site storage of energy (e.g. electric battery or thermal storage) with controller optimising the use of locally generated electricity and possibility to feed back into the grid*
Support of (micro)grid operation modes	*None*	Automated management of (building-level) electricity	*Automated management of (building-level) electricity consumption and electricity supply to neighbouring buildings (microgrid) or grid*	Automated management of (building-level) electricity consumption and supply, with potential to continue limited off-grid operation (island mode)	-

Source: Final report on the technical support to the development of a smart readiness indicator for buildings

EV charging and Monitoring & Control services

Functionality levels

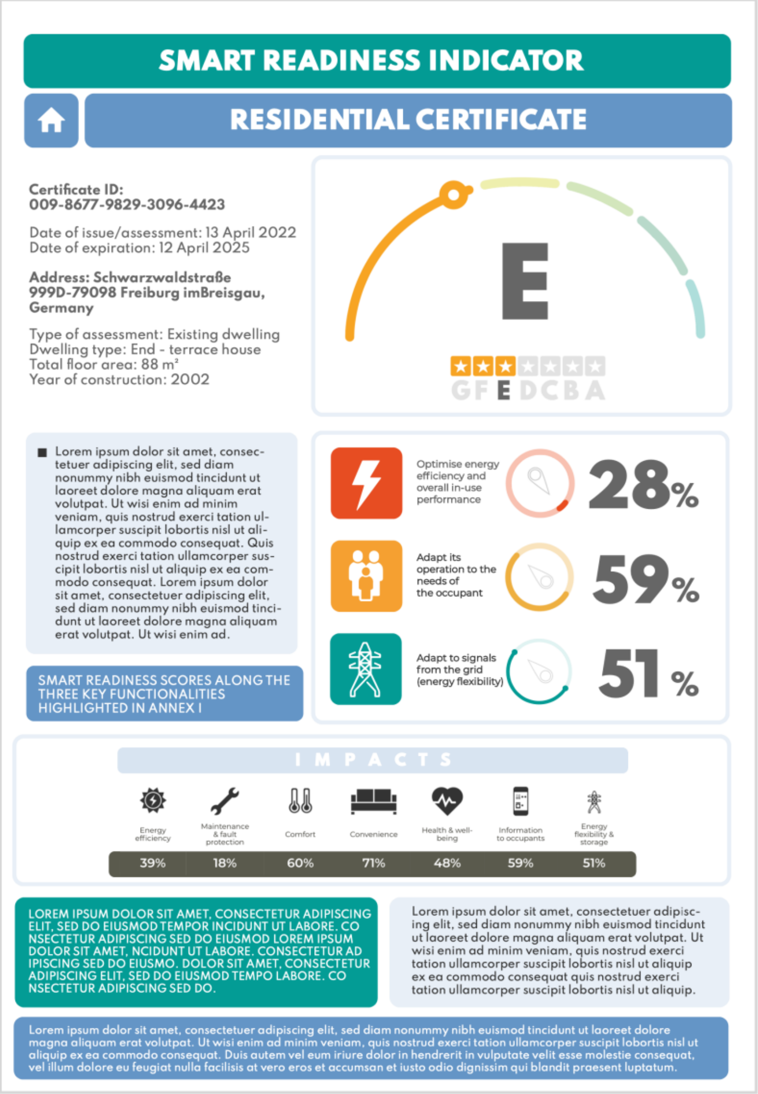
Monitoring & Control Services	Level 0	Level 1	Level 2	Level 3	Level 4
Detecting faults of technical building systems and providing support to the diagnosis of these faults	*No central indication of detected faults and alarms*	*With central indication of detected faults and alarms for at least 2 relevant TBS*	*With central indication of detected faults and alarms for all relevant TBS*	*With central indication of detected faults and alarms for all relevant TBS, including diagnosing functions*	-
Smart Grid Integration	*None - No harmonization between grid and TBS; building is operated independently from the grid load*	Demand side management possible for (some) individual TBS, but not coordinated over various domains	*Coordinated demand side management of multiple TBS*	-	-

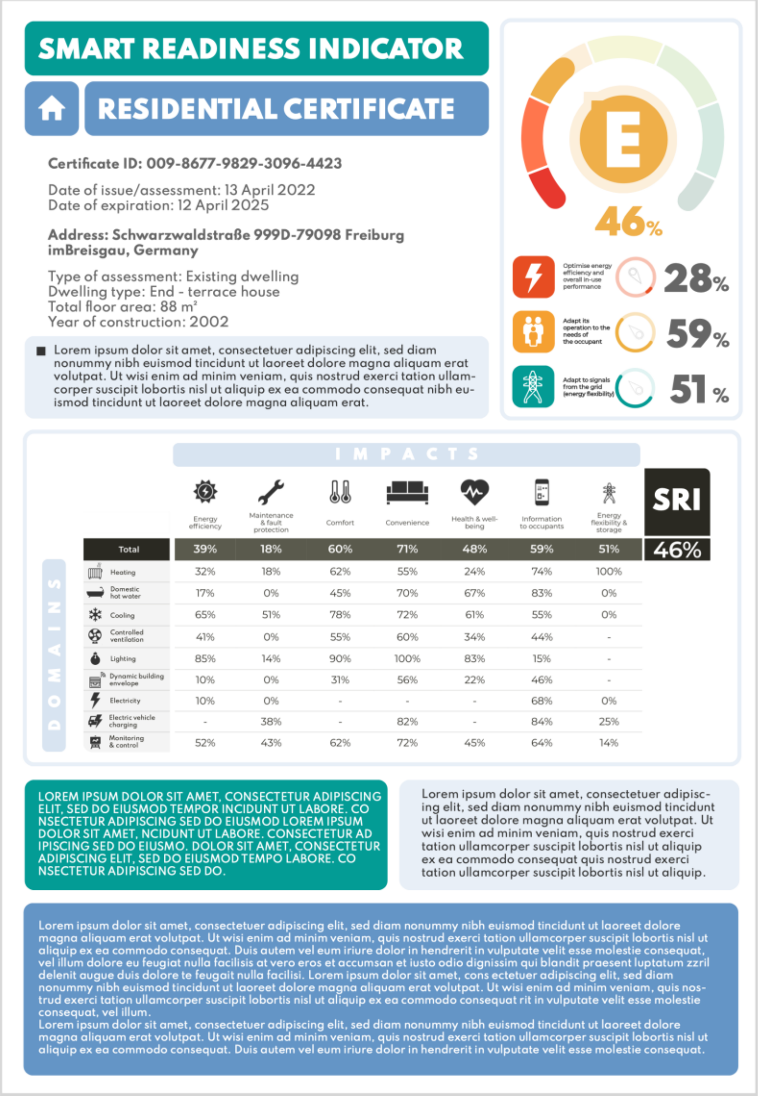
Functionality levels

EV charging Services	Level 0	Level 1	Level 2	Level 3	Level 4
EV Charging Grid balancing	*Not present (uncontrolled charging)*	*1-way controlled charging (e.g. including desired departure time and grid signals for optimization)*	*2-way controlled charging (e.g. including desired departure time and grid signals for optimization)*	-	-

Source: Final report on the technical support to the development of a smart readiness indicator for buildings

SRI possible certificates





	Energy efficiency	Maintenance & fault protection	Comfort	Convenience	Health & well-being	Information to occupants	Energy flexibility & storage
Total	39%	18%	60%	71%	48%	59%	51%
Heating	32%	18%	62%	55%	24%	74%	100%
Domestic 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%	-
Lighting	85%	14%	90%	100%	83%	15%	-
Dynamic building envelope	10%	0%	31%	56%	22%	46%	-
Electricity	10%	0%	-	-	-	68%	0%
Electric vehicle charging	-	38%	-	82%	-	84%	25%
Monitoring & control	52%	43%	62%	72%	45%	64%	14%

- **REHVA** launched an **online survey** to collect inputs for the development of an SRI certificate
- REHVA is The **Federation of European Heating, Ventilation and Air Conditioning associations**
- **2** main design options
- **Key information** about SRI are showed on the front side of the certificate (e.g. SRI class and partial scores)
- ***Additional information*** can be added on the reverse of the sheet or anywhere

Source: https://www.rehva.eu/news/article/smart-readiness-indicator-survey-on-certificate-design

SRI & possible connection with schemes

SRI & EPC

- SRI information should be integrated into an EPC
- Data from EPC to calculate **energy-related weighting factors**
- **To limit effort** and **cost** for assessment procedure (e.g. joint assessment)
- Potential to share **formed assessors** and **communication platforms**

SRI & Digital Logbook/BIM/SAREF ontology

- SRI information could be integrated into **Digital Logbook** procedure
- **Information** from Digital Logbook can be **useful for SRI assessment**
- The use of **BIM** can help in collect information about the building and its TBS/BEMS (e.g. triage)
- **SAREF ontology can help in the triage process** (e.g. interoperability)

SRI & Level(s)

- Level(s) and SRI may have some **overlap** for what concerns the **assessment** of **building energy performance** and **comfort/well-being**
- Limited effort and cost for assessment procedure (e.g. joint assessment)
- Potential **to share formed assessors**
- **Common KPIs** assessment for a future Method C in the SRI methodology

SRI & Building Renovation Passaport

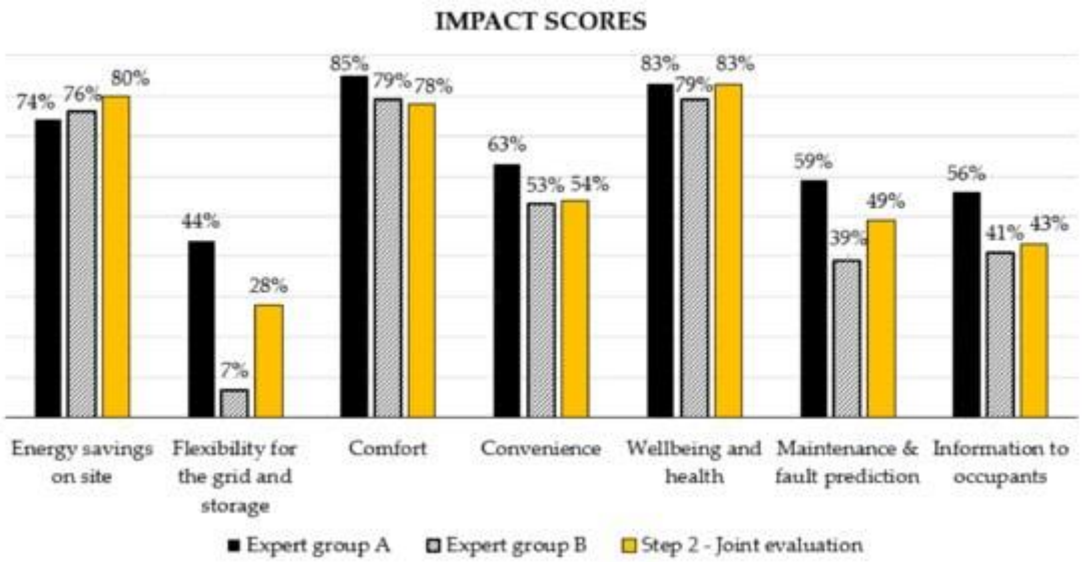
- SRI and Building Renovation Passports could share the same **documentation process**
- **SRI assessment could be integrated** within this process and potentially add value to BRP
- **Source of information** for SRI assessment

Source: Final report on the technical support to the development of a smart readiness indicator for buildings

SRI gaps & Challenges - Subjective component

- Test the SRI methodology (**subjective component** of the Triage);
- **2 assessment groups**: A composed by 2 researchers + energy manager, B composed by 2 researchers + provider of the building management and control system;
- Triage group A: 3 hours, information given by the energy manager and his knowledge of the test building;
- Triage group B: 5 hours, information from technical documentation;
- **Differences in the results**, more evident **for Information to occupants**, **energy flexibiliy**, **Maintenance & fault prediction**

Domain	Smart Ready Services	Functionality Levels Step 1 Expert Group A	Functionality Levels Step 1 Expert Group B	Step 2 Joint Evaluation
Electricity: renewables and storage	Reporting information regarding energy generation	2	2	2
	Storage of locally generated energy	0	0	0
	Optimizing self- consumption of locally generated energy	1	0	0
Electric vehicle (EV) charging	EV charging capacity	2	1	2
	EV charging grid balancing	0	0	0
	EV charging information and connectivity	0	0	0
Monitoring and control	Run time management of HVAC system	1	2	2
	Detecting faults of technical building systems and providing support to the diagnosis of these faults	1	1	1
	Occupancy detection: connected services	2	0	0
	Central reporting of technical building system performance and energy use	3	3	3
	Smart Grid integration	1	0	0
	Reporting information regarding Demand Side Management	1	0	0
	Override of Demand Side Management control	2	0	0



Source: Vigna I., Analysis of the Building Smart Readiness Indicator Calculation: A Comparative Case-Study with Two Panels of Experts, Energies, 13, 2796, (2020). https://doi.org/10.3390/en13112796

SRI gaps & Challenges

Source: P. A. Fokaides et al., How Are the Smart Readiness Indicators Expected to affect the Energy Performance of Buildings: First Evidence and Perspectives, Sustainability(2020). doi: https://doi.org/10.3390/su12229496

- **Test** the **SRI methodology** for different **building types**
- SRI methodology and proposed levels of functionalities need to be improved based on SRI results obtained from a significant sample of buildings
- Case of **small buildings with no BMS** that result worse compared to large buildings that have the ability to install BMS
- The SRI ignores a large category of buildings in which there are practical difficulties and general limitations (e.g. historical buildings)
- Around **25% of the building stock in Europe** was constructed before 1950 and is difficult to adapt some smart solutions in them
- Need to develop a **methodology for assessing the intelligence of historic buildings** and able to recognize practical difficulties in installing some smart solution in historic buildings
- Development of **sectoral SRIs** to recognize the variance in the building systems for **different building use**
- Requirements for the control and monitoring of building systems differ significantly based on the activity of the user of the building

Opportunities & future outlooks

SRI & ISO 52120-1:2022

- Most SRI services come from ISO 52120-1
- This standard presents a methodology to evaluate the impact of BACS and TBM functions with respect to the energy performance of the buildings
- **Standardized and exhaustive descriptions** of functionality levels can improve the SRI evaluation methodology
- **Better description of functionality levels to avoid approximations** and subjective decision during the Triage process
- Define what **set of variables and technologies enables specific functionality levels**

SRI & digital tools (DT, BIM, Ontologies)

- Digital tools support decision-making, increase efficiency and identify optimal solutions for managing buildings during operation
- **Ontologies** are digital tools that describe elements that characterize the building and the relationships between them
- Ontologies, digital twins and BIM can **help to collect information** about the building and its TBS
- Digital tools can **speed up the calculation procedure** of the SRI
- Digital tools **can limit the entire effort in collect information** for the assessment process

SRI Method C (data-driven approach)

- **Method C** is a development path for the SRI evaluation methodology
- It should enable **real-time SRI assessment** based on **actual building performance**
- **Quantitative method** instead of qualitative (methods A, B)
- **KPIs** to assess real indoor conditions, energy efficiency and energy flexibility
- **New methodology** can rely on **ontologies** to collect monitoring variables for KPIs computation

Position paper

Green Building Council Italia

Gestione energetica e automazione negli edifici: opportunità e sfide poste dal processo di transizione energetica e digitale dell'ambiente costruito

Mese anno

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Coming soon….

Calculation of the SRI and implementation of potential flexibility measures for existing buildings

Alfonso Capozzoli

May 29th 2024

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