Smart2B

Smartness to existing Buildings

UPGRADING SMARTNESS OF EXISTING BUILDINGS THROUGH INNOVATIONS FOR LEGACY EQUIPMENT

Deliverable 1.2

Functional Requirements of the Smart Performance Assessment & Advisor

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Abbreviations and acronyms

Abbreviation	Definition
ADR	Active Demand Response
AI	Artificial Intelligence
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BACS	Building Automation and Control Systems
CARP	Comfort Asset Rating Procedure
CORDIS	Community Research and Development Information Service
CORP	Comfort Operational Rating Procedure
EPBD	Energy Performance of Buildings Directive
FF	Flexibility Function
HVAC	Heating, Ventilation and Air Conditioning
ICT	Information and communications technology
IEA EBC	International Energy Agency Energy in Buildings and Communities
IEQ	Indoor Environmental Quality
KPI	Key Performance Indicator
PAQ	Perceived Air Quality
PDD	Predicted Percentage of Dissatisfied
PMV	Predicted Mean Vote
RES	Renewable Energy Sources
SPA&A	Smart Performance Assessor and Advisor
SRI	Smart Readiness Indicator
TBS	Technical Building Systems

Revision history

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DISCLAIMER

Executive Summary

The deliverable D1.2 is associated with task T1.2 "Functional Requirements of the Smart Performance Assessment & Advisor" in WP1 "Specifications and Requirements for Smart2B Concept".

The objective of this deliverable is to explore and define the functional requirements of the Smart Performance Assessment & Advisor (SPA&A) prior to its further implementation in WP4. In this context, this deliverable is mainly focused on gathering the insights on the state-of-the-art approaches that: identify benchmarks that can be used to measure the performance in each impact area according to the smart readiness indicator (SRI); identify methodologies that can be used to communicate the impact to the end-users; define the system performance thresholds that trigger occupant feedback; and define the type of feedback that will be provided.

This deliverable consists of a general methodology introduction, an introduction of SRI and SPA&A in the context of Smart2B, a state-of-the-art literature review, the results of four expert interview sessions and the results of the survey participated by eighteen experts. The conducted research works jointly define and detail the functional requirements of the Smart Performance Assessment & Advisor.

1. Introduction

The aim of Task 1.2 is to explore and define the functional requirements of the Smart Performance Assessment & Advisor (SPA&A) prior to its further implementation. In this context, this deliverable is mainly focused on gathering the insights on the state-of-the-art approaches that:

(i) Identify benchmarks that can be used to measure the performance in each impact area according to the smart readiness indicator (SRI);

(ii) Identify methodologies that can be used to communicate the impact to the end-users;

(iii) Define the system performance thresholds that trigger occupant feedback; and

(iv) Define the type of feedback that will be provided.

The content of this deliverable is based on the four pillars presented previously, and presents a preliminary exploration of the current state-of-the-art relevant for the definition of the functional requirements and the selection of approaches for the correspondent implementation in the development of the SPA&A.

1.1. Methodology and relation to other project activities

A background literature review, a set of expert interviews and an online survey have been carried out in a stepwise manner.

First and foremost, a thorough background literature review helps the study team to quickly grasp the broader aspects that should be covered in defining the requirements. As a second step, by interviewing the targeted experts, the study team can further enrich the knowledge on dedicated aspects leveraging from real-life past experience that is not (or rarely) addressed in the literature. Last but not least, the conducted surveys bridge the gaps between general SRI and User Advising concepts and specific operational requirements for Smart2B project, hence and ultimately, allow to identify and define the requirements of SPA&A in detail.

The outcome of this deliverable will be further considered for the development of the relevant SPA&A Smart2B service foreseen in WP4 framework, as well as the implementation of the interactive application and user interface in WP5. Figure 1 depicts the relation between these work packages within the Smart2B iterative implementation approach.

1.2. Structure of the deliverable

This deliverable consists of the general methodology definition, the introduction of SRI and SPA&A, the relevant literature review, the results of the expert interview and from the survey, which jointly allow to define and detail the functional requirements of the Smart Performance Assessment & Advisor. The requirements will be used to further develop the SPA&A in Task 4.2.5, Smart2B services framework integration in T4.3 and the interactive user-interface applications in WP5.

This deliverable is divided in five main chapters and a final conclusion chapter as follow:

- <u>Chapter 2 – SRI and SPA&A in Smart2B: an introduction of the SRI scheme and the envisioned SPA&A service in the context of Smart2B.</u>

- Chapter 3 – State-of-the-art review: the state-of-the-art review covers four key pillars.
- Chapter 4 - Expert Interviews: the framework, the questions and the key findings of four expert interview sessions.
- Chapter 5 – Survey: the framework, the questions and the key findings of the survey that includes the inputs from 15 experts.
- Chapter 6 - Conclusion: the defined functional requirements of SPA&A.

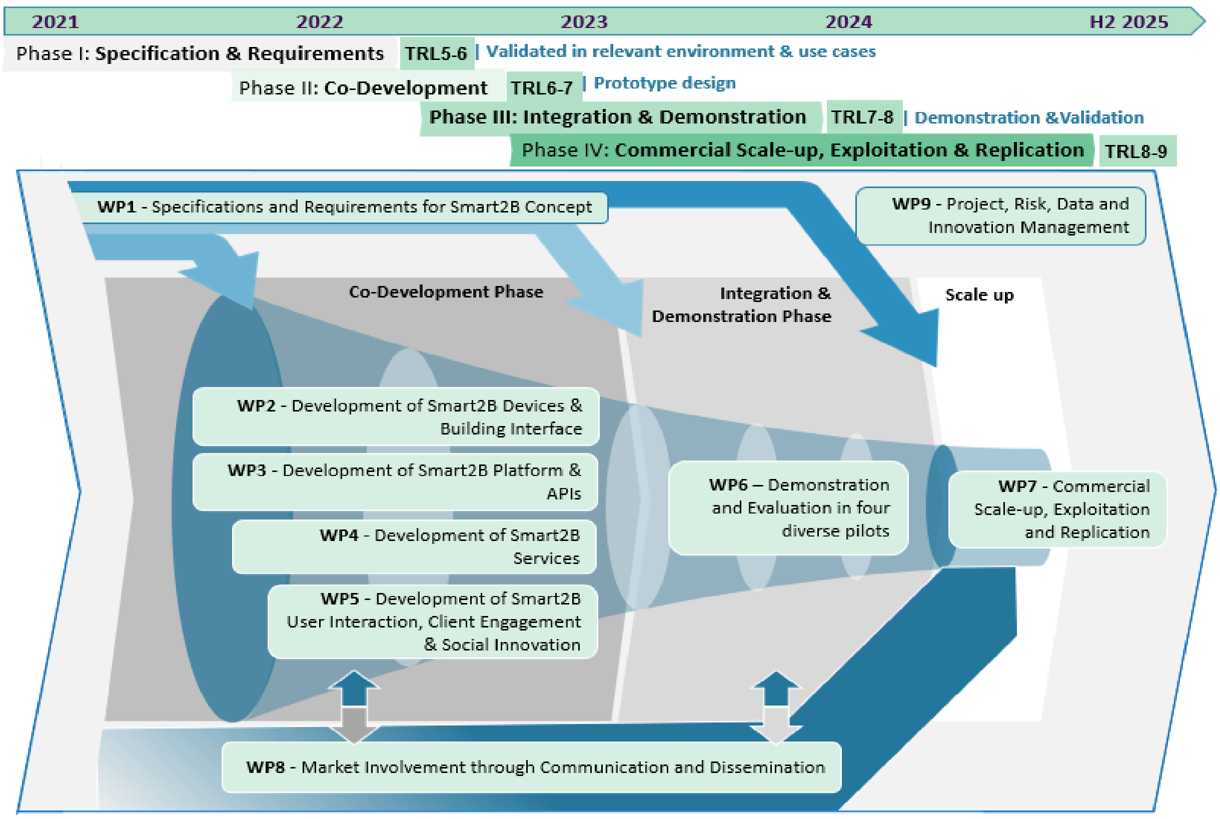


Figure 1: Relationship of the work packages directly served by task 1.2 within the Smart2B iterative implementation approach.

2. SRI and SPA&A in Smart2B

2.1. SRI methodology

Smart technologies enable and facilitate the decarbonization of the building sector. SRI, an indicator for rating the smart readiness of buildings, was introduced by the European Commission in the revised Energy Performance of Buildings Directive (EPBD) and its subsequent regulations (EC, 2020). The proposed SRI aims to establish a common framework for quantifying the added value of building smartness for building users, owners, tenants, and smart service providers. The SRI rates the smartness of the building in their capability to perform **three key smart readiness functionalities**:

- Optimise energy efficiency and overall in-use performance;
- Adapt their operation to the needs of the occupant;
- Adapt to signals from the grid (energy flexibility).

The three key functionalities are further detailed into a total set of **seven impact criteria**, including: energy efficiency, energy flexibility and storage, comfort, convenience, health, maintenance and fault prediction, and information to occupants.

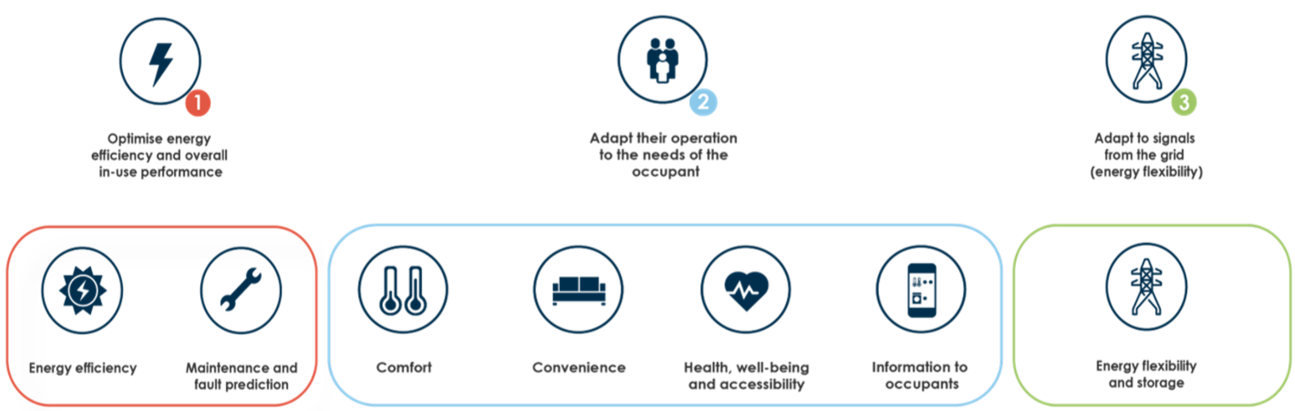


Figure 2: SRI impact criteria

Nine technical domains are used as basis in the SRI methodology, including: heating, cooling, domestic hot water, ventilation, lighting, dynamic building envelope, electricity, electric vehicle charging, monitoring and control.

SRI methodology is a flexible and modular multi-criteria assessment method which builds on assessing the smart ready services of these domains present in a building. The SRI score is calculated based on a weighted sum of the seven total impact scores. An impact criterion score is calculated as the maximum score that is achievable for the building. One impact criterion score is the weighted average of the 9 domain scores. In each domain, several services are included and for each of the services, several functionality levels are defined. The domain services are scored according to their functionality level. A smart service catalogue covers both a simplified method (A) and a detailed assessment method (B). Certain domains and services may not be considered relevant, depending on the building type or the assessment method and should be omitted.

Current SRI methodology consists of a manual on-site checklist-based assessment resulting in a score that represents the smartness associated with the technologies that are present in the building, but it does not address the actual in-use performance. In the long run, Technical Building Systems (TBS) and Building Automation and Control Systems (BACS) might be able to self-report the functionality levels of certain smart ready services in a building, that can directly serve to substitute inputs for Methods A and B.

Moreover, the future version of SRI (method C) goes beyond this and quantifies the actual performance of in-use buildings, and it is foreseen to evolve towards a fully performance-based methodology which can provide measurable results, yet it is currently considered to be a potential future evolution of a certification approach for a commissioned building, going beyond the currently envisaged scope of the SRI.

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

Figure 3: The proposed three assessment method options in SRI study

In Smart2B, the study team will explore this through formulating the concept and developing the service - Smart Performance Assessment and Advisor.

2.2. Smart Performance Assessment & Advisor

Smart performance assessment & Advisor will provide the building users with data-driven insights in the current smartness of the building, suggest improvement actions to increase the potential upgrading of the building in line with the SRI definition, and show their economic and environmental impacts. The insights raise awareness and nudge occupants towards energy efficient behaviour and smart digital renovation direction; to ultimately support informed investments in smart and energy-efficient technologies. Moreover, the SRI assessment will be based on WP3 developments which gathers monitored data on the performance of the applied Information and communications technology (ICT) services and technologies in each building to validate from an asset rating to a real and dynamic building performance assessment. SPA&A service is foreseen to assess the building's smartness by the principle of SRI calculation method B. However, instead of on-site expert inspection on all the domains and services, SPA&A automates this inspection partially by linking the monitoring data with one or more specific services and their functionality levels, for instance, SPA&A should be able to evaluate whether the smart ready service - heat emission control - is central control (functionality level 1) or individual room control (functional level 2) by analysing the temperature profiles of individual rooms in combination of the control signal. Yet, this will not be implemented in all the domains and all the services, but only a restricted set of domains and services which are appliable in the demo site(s). In addition, SPA&A is foreseen to provide qualitative smartness advice and explore the feasibility to quantify the impact of the increased smartness in the three key functionalities of SRI. For those dedicated smart ready services where data flows are available, SPA&A is foreseen to perform a fully automated smartness assessment, which will assist to minimize the inspection effort by an SRI assessor or even eliminate the requirement of an on-site inspection by the assessor. The rest of the services might still need the expert inspection by the traditional checklist approach.

Hence, the SPA&A service will perform two important tasks. First, by leveraging on data from the Smart2B platform and knowledge graph (WP3), it will provide data-driven insights on the current smartness of the building through the application and user interfaces developed in WP5. Second, it will suggest upgrading actions to increase the potential smartness of the building and provide economic and environmental impact information for building users (occupants, owners, etc). The inputs which can be used for the smartness assessment of the building will be derived automatically. Through the post-processing of monitored data, the functionality levels of relevant smart ready services and the associated impacts including energy savings, information to occupants, and grid flexibility will be considered, in line with the definition of the three SRI key functionalities.

SPA&A will self-assess building smartness performance according to the principles of the Smart Readiness Indicator. These principles will be extended with automated performance assessments and users' engagement through the community. The ability to provide data-driven insights on the smart operation of the building will contribute to reduce the total energy consumption, increase energy efficiency and flexibility potential. Insights in actual smartness performance – rather than theoretical smartness performance – will support informed investments in smart technologies.

In summary the SPA&A is foreseen to feature the following five functionalities:

1. A fully automated data-driven dynamic self-assessment of current actual building smartness performance according to the principles of the SRI. Through the post-processing of the monitored data, the functionality levels of various smart ready services are considered, in line with the definition of the three SRI key functionalities i) Energy performance and operation; ii) Response to the needs of the occupants and iii) Energy flexibility.
2. Generation of suggested actions to improve the potential smartness performance of the building in line with the definition of the same three SRI key functionalities.
3. Determination of economic and environmental impacts of suggested smartness performance improvements.

4. Implementation of services within an integrated framework including a data platform and an application with graphical user interfaces to provide easy access to the above-mentioned information for the building users (occupants, facility managers, etc.). A user-centric design approach is employed in the development process to ensure user preferences are sufficiently addressed.
5. Interactive communication stimulating awareness raising, activation of user engagement in the building smart performance and instigation of building user behaviour change in relation to the building smartness performance.

With the afore-defined methodology in chapter 1.1, the specific functional requirements of SPA&A are further investigated in detail and the corresponding results are presented in the following chapters.

3. State-of-the-art review

In this chapter the main state-of-the-art approaches related to the four pillars as defined in the introduction are referenced and briefly described. It is not intended to provide a full overview, but to gather the main state-of-the-art approaches considered potentially suitable and feasible candidates for implementation in the SPA&A in the frame of the Smart2B project. A lot of relevant information has been found on aspects related to multiple of the four pillars in the SmartBuilt4EU project deliverables.

The SmartBuilt4EU is a 30-month project (October 2020-April 2023) funded by the H2020 program that has objectives – amongst others – to reference and promote key innovators and innovations in smart buildings and to identify barriers, opportunities and best practices for the further uptake of smart buildings. Co-benefit key performance indicators are identified (SmartBuilt4EU, 2021) and in more detail specifically on state-of-the-art on the topic flexibility in a report by a dedicated task force (SmartBuilt4EU TF3, 2021), both of which the main indicators are briefly covered in the chapter 3.1. Also a dedicated task force (SmartBuilt4EU TF1, 2021) investigates how interactions between any smart building and its users can be facilitated and improved. A first white paper presents the topics related to acceptance and attractiveness of smart building solutions for the end users and also covers aspects related to feedback (SmartBuilt4EU TF1, 2021). In it, smartness requirements are defined for maximum attractiveness and acceptance of smart buildings to end-users, also relevant in view of defining the requirements for the SPA&A are shown in Figure 4.

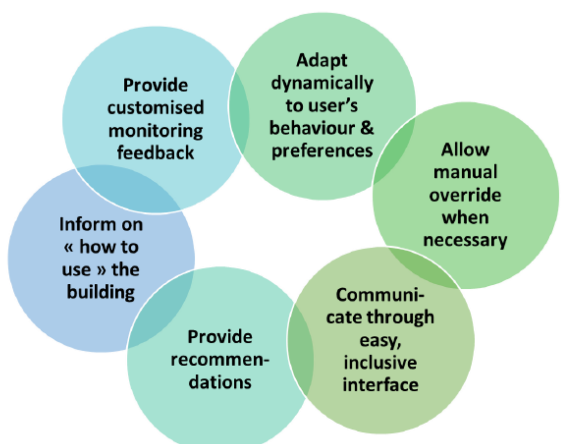


Figure 4: Smartness requirements for the attractiveness of smart buildings to end users (SmartBuilt4EU TF1; 2021).

The state of knowledge, good practices and lessons learnt are described and categorized in three main blocks; knowledge of end-users, workflows and communication and technical solutions to raise acceptance and attractiveness of smart building solutions. Key barriers and drivers are discussed. Specific state-of-the-art approaches relevant for one of the four pillars are described in the following chapters. It is noteworthy to mention is that there are two next rounds of white papers planned for future publication, expected to be published in April 2022 and October 2022.

Additional scientific publications are reviewed when certain aspects are not addressed in SmartBuilt4EU.

3.1. Pillar 1 - Identify benchmarks that can be used to measure the performance in each impact area according to the SRI

A study of mapping co-benefits indicators with 7 impact criteria was carried out in SmartBuilt4EU (SmartBuilt4EU, 2021). A set of 18 main co-benefit key performance indicators (KPIs) are identified to be potentially coupled with the SRI impact criteria, and eight main indicators are further selected after a dedicated expert group consultation, being: primary energy, energy demand and consumption, operative temperature, indoor relative humidity, CO_2 concentration, ventilation rate, load matching index, grid interaction index. The impact criteria of the three key functionalities of SRI are addressed by these indicators. The study of SmartBuilt4EU concludes that the specified impact criteria of SRI are already widely investigated, including energy efficiency, comfort, energy flexibility and storage. Therefore, the KPIs related to these impact criteria can be quantified easily or measured straightforwardly, whereas for other impact criteria, it is difficult to identify easily measurable KPIs to quantify those benefits, including maintenance and fault detection and convenience. A brief overview of the selected KPIs that address the quantifiable impact criteria is listed in the following subchapters.

3.1.1 KPI - energy performance and operation

- ***Primary energy***

  Primary energy is defined in the EPBD recast as energy from renewable and non-renewable sources which has not undergone any conversion or transformation process (EC, 2021), and the corresponding primary energy factors are required to convert the energy related to the different carriers to primary energy.

- ***Energy demand and consumption***

  Energy demand and consumption refer to all the energy delivered in a specific period. Demand refers to the theoretically calculated or simulated while consumption refers to the monitored or measured.

- ***Share of renewable energy***

  This indicator quantifies the ratio of energy generated from on-site RES and the energy use, either thermal or electrical energy.

3.1.2 KPI - response to the needs of the occupants

- ***Predicted Mean Vote (PMV) & Predicted Percentage of Dissatisfied (PPD)***

  PMV is an index that aims to predict the mean value of the votes of a large group of persons on a 7 points thermal sensation Likert scale (from -3 to +3) based on the heat balance of the human body. Within the index, +3 translates as hot, while -3 as cold.

  PPD is an index that establishes a quantitative prediction of the percentage of occupants that would indicate not being satisfied in relation to their thermal environment. PPD indicates the predicted percentage of people stating to be dissatisfied with thermal conditions.

  When subjectively measured, it is resulting from personal acceptability votes (yes/no) or derived from subjective PMV scores (derived from a sufficient amount of actual sensation votes); those outside a specific range, related to average acceptability with thermal conditions.

PPD is a function of PMV for given thermal conditions, but the percentage of dissatisfied may be higher as a result of local discomfort.

- ***Percentage of time within or outside thermal comfort range***

  The percentage of time that the temperature is within or outside a specified range defined according to the comfort model. Ideally this is by use of the operative temperature, but for practical reasons often is based on air temperature alone. This needs to be specified in the method. Similarly, (weighted) excess hours methods can be implemented on other indoor environmental quality performance indicators or a set of those.

- ***Operative temperature***

  The operative temperature is the uniform temperature of an imaginary black enclosure in which an occupant would exchange the same amount of heat by radiation and convection as in the actual non-uniform environment (ISO 7730). It can be measured or calculated as the average of the air temperature and the mean radiant temperature weighted according to the convective and radiative heat transfer coefficients respectively. It often is approximated as the average of air temperature and the mean radiant temperature. Operative temperature is for instance used to define quality levels of thermal indoor environmental conditions in adaptive thermal comfort method.

- ***Indoor relative humidity***

  Indoor relative humidity represents the amount of water vapor that indoor air contains, in relation to the maximum amount of water vapor that indoor air could contain under the same condition.

- ***Daylight factor***

  Daylight factor is defined as the ratio between outside and inside light level, which reflects the quality of indoor visual comfort.

- ***CO_2 concentration***

  Amount of CO_2 in the air expressed in parts per million (ppm). The CO_2 concentration is a commonly used indicator to determine general indoor air quality for spaces in which CO_2 air pollution is mainly related to human occupancy and not any other exogenous sources. CO_2 concentration is considered a marker for all air pollution contaminants induced by humans. If important emissions from sources other than humans are expected, such as from activities or processes, building components or furniture, or local outdoor air pollutants (other than CO_2), the CO_2 concentration as an indicator is likely to overestimate the overall quality of indoor air.

- ***Ventilation rate***

  The ventilation rate is the rate at which external fresh air replaces specific volumes of indoor (saturated) air and is delivered into the building, closely linked to CO_2 concentration for spaces in which air pollution is mainly related to human occupancy, is commonly used as an indicator for indoor air quality as well. Requirements in terms of ventilation rates usually are formulated as function of the size of the building, the (anticipated) occupancy rate and the type of building (related to the expected activities, processes and component emissions).

3.1.3 KPI - energy flexibility

For key functionality aspect on energy flexibility, there are plenty of indicators available that are more or less suitable depending on the specific needs of the assessed project/case study. An overview can be found in the literature (Vigna I. et al., 2018). In addition, five frequently used energy flexibility metrics are summarized by (Li. H et al., 2021), including peak power reduction, flexibility factor, self-sufficiency/self-consumption, capacity of active demand response (ADR)/efficiency of ADR, and flexibility index. Most noteworthy and compliant to the requirements of being general and easy to calculate (SmartBuilt4EU, 2021) are the Annual Mismatch Ratio, Load Matching Index and Grid Interaction Index and especially also the indicator for energy flexibility developed in Annex 67 (Jensen S.Ø. et al., 2019).

- ***Peak power reduction***

  It refers to the (percentage of) reduced power demand during the peak hour due to the flexibility operation, can be expressed either in power or %.

- ***Self-sufficiency/self-consumption***

  Self-sufficiency is the degree to which the on-site electricity generation is sufficient to fill the energy needs of the building, while self-consumption is defined as the amount of locally generated and consumed electricity with respect to the total local electricity generation.

- ***Annual Mismatch Ratio***

  The annual mismatch ratio (Vigna I. et al., 2018; Ala-Juusela M. et al., 2014) is defined as the annual average of the hourly difference between the energy demand and energy supply from local renewable energy sources for each energy type and counted only when the demand exceeds the supply from renewable energy sources (RES). It can be interpreted as the share of energy that is imported for each energy type.

- ***Load Matching Index***

  The load matching index (Vigna I. et al., 2018; Voss et al., 2010) indicates the amount of energy that can be generated by on-site renewable sources and stored in batteries in comparison to the load. In addition, it gives indications to the amount of exported energy in comparison to on-site generation.

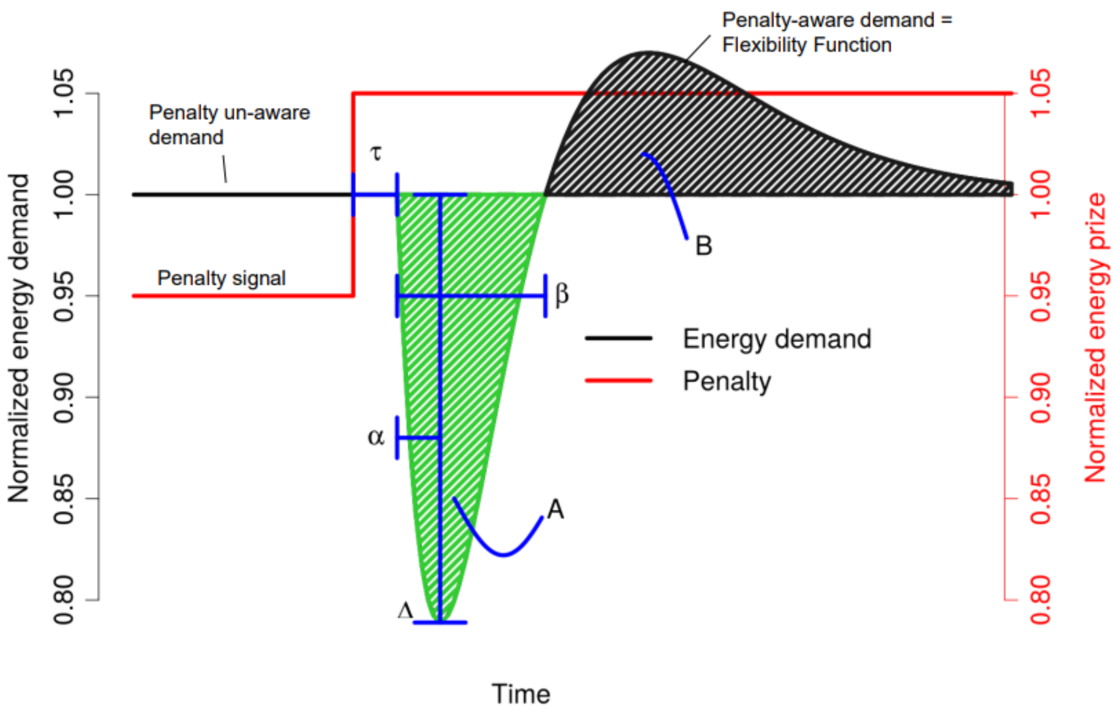
  The load matching index can be interpreted as a factor expressing the coincidence between the generation of energy from on-site renewable sources and the load for a specific time interval which is positively affected by the presence of storage. A high value (with a maximum of 1) indicates a high coincidence between load and on-site generation.

- ***Grid Interaction Index***

  The grid interaction index (Vigna I. et al., 2018; Voss et al., 2010) is the ratio of the net grid metering over a given period compared to the maximum/minimum value within an annual cycle. A positive value indicates the building is net exporting on-site generated energy.

- ***Energy flexibility of buildings and districts according to IEA EBC Annex 67***

  A harmonised approach to determine an indicator for energy flexibility of buildings and districts (demand side) is proposed in the IEA EBC Annex 67 (Jensen S.Ø. et al., 2019), taking into account also the perspective from the supply side. The methodology to characterise the energy flexibility available in buildings and districts (Pernetti R. et al., 2019) is based on the ability of energy flexible buildings to adjust their demand with the main objective of reducing a chosen cumulative penalty (e.g. energy cost or CO_2 emissions) while respecting the needs of the building users.



- τ (Time): Delay from step increase (or a decrease) to initial response.
- Δ (Power): Maximum change in response.
- α (Time): The time it takes from the start of the response to the maximum response.
- β (Time): The total amount of time during which the consumption is reduced.
- A (Energy): The total decrease in the amount of energy demand during the response.
- B (Energy): The total increase in the amount of energy consumption – also called rebound.

Figure 5: The expected response of some energy flexible buildings (without any prior knowledge regarding changes in the penalty signal) exposed to a step increase in the penalty signal, termed as the Flexibility Function, adopted from (Pernetti R. et al.; 2019).

A flexibility function (FF), of which the general shape is graphically represented in Figure 5, describes the relation between a penalty signal and demand response and is used for the assessment and labelling of energy flexibility in buildings and districts. Also a harmonised visualization and communication tool is proposed.

The KPIs are the Expected Flexibility Saving Index and the Flexibility Index, which represent the ability of building(s) to respond to the requirements of the energy networks seen from the building and network side respectively.

3.2. Pillar 2 - Identify methodologies that can be used to communicate the impact to the end-users

Acceptance of smartness in buildings from its users doesn't depend solely on the technological solutions implemented but it strongly depends on the users' ability to interact, communicate their needs to the system and adapt its operation according to their individual perspective of well-being and comfort living. Therefore, it is crucial to identify these needs and build a communication system accordingly.

3.2.1 More attractive and digitally accessible buildings

The users' needs can be classified to **two distinct categories**: a) their physical and psychological needs. The physical needs refer to the essential necessities for an individual to survive; usually standardized and quantified through scientific methodologies, and b) while the psychological needs depend on the individual's perception of well-being and can be influenced by his/her moral, ethics code, economic status.

Without any doubt, the **physical needs** of the occupants alter as they *age*. Ageing people have lower acceptance of new technologies and less patience when it comes to learning how to operate a new system. In addition, ageing occupants have usually poorer eyesight, reduced muscle mass, reduced hearing capacity and diminished mobility and agility. The aforementioned needs must be taken under consideration during the designing process of a user interface, to accommodate the user's requirements and ensure attractiveness of the system and long-term engagement.

Certain *health conditions* may also define the ideal living conditions of the occupants, and therefore must be taken under consideration during the designing process of the communication system. For example, it is prohibited to patients with myasthenia gravis to live in a high temperature environment, as this might deteriorate the condition. In addition, inevitably ageing users are more susceptible to common colds as their immune system weakens with age, and therefore they need to remain in warmer indoor conditions. As a result, it is essential for any smart building to be able to take the appropriate decisions to adapt the temperature of the building accordingly and to ensure the well-being of the individuals.

Furthermore, the design process should also consider occupants with *special needs* and provide solutions that are easy to use, easy to provide feedback to accommodate their special needs. The control system of the smart building ought to ensure accessibility in a multitude of ways to limit the unnecessary movements of disabled individuals and provide a voice communication system, accommodating blind individuals.

Apart from physical needs, the technology acceptance and behaviour of users can be influenced by an individual's **psychological needs**, which can determine their *ethical values* and *economic status*. Ethical values may include environmental concerns and moral use of data and resources, while economic status usually determines the intention to use a system. As a result, the users of the smart building shall have access to accurate statistics of the energy efficiency, consumption, and energy savings of the building at any point in time and make use of gamification techniques to attract and challenge the occupant's intention of use.

Attractiveness and engagement are also related to the type of and usage of the smart building, as it results in different technical requirements. Certain indoor conditions may improve the productivity and reduce sick leaves in an office building while others may improve quality of sleep, which is essential in a residential building. Therefore, a smart system needs the be able to adapt accordingly.

3.2.2 Technical approaches to enable raising acceptance and awareness

As mentioned above the acceptance of a smart system depends on its ability to adapt according to the user's needs. User acceptance can increase if users participate in the design stages of the system (user-cantered design) and take initiatives in the deployment of smart systems in already existing buildings. There are also technical solutions that can foster the interest of end-users in smart building features, such as human user interface and gamification.

Human user interface is vital for ensuring the communication between the user and the system and can increase the volume and quality of the interactions with the users if designed accordingly. To increase attractiveness, a human-user interface should be inclusive, simple, easy to use and provide detailed instructions of use.

Attractiveness can be increased when the interface is designed according to the specific needs of the individuals, therefore it should be able to adapt according to their age, health conditions and disabilities. Some useful features would be providing larger fonts and high contrast for users with poor eyesight and voice commands for sightless individuals and elderly people that usually find it difficult to operate smart devices manually.

It is also crucial that the interface adapts to the user's native language to ensure effortless and smooth communication with monolingual users.

The interface shall also be accessible from multiple devices. This can assist the users with moving disabilities to interact with the system from multiple locations and provide the ability of the occupants to be informed and control the indoor conditions of the smart building remotely.

Several gamification techniques can also be used to increase communication and engagement of the user with the system. *Gamification strategies* refer to the process of using gaming techniques to motivate consistent participation and long-term engagement. Gamification techniques would be meaningful to be designed according to the behavioral characteristics and values of the users. A possible technique can be to socially compare the energy savings for users that are environmentally concerned, to unlock extra features and provide rewards to the users that are high in rank. Another possible technique is to inform the health-concerned users about the quality of air in the building, compared to non-smart buildings or outdoor conditions.

3.2.3 State-of-the-art review

One of the main obstacles' innovative technologies (especially artificial intelligence - AI) are called to address is user acceptance and adoption (Brounen et al., 2013; Chadwick et al., 2022; Kahma et al., 2017). The role of end-users in decision-making is central in the success of intelligent management (Goulden et al., 2014). Societal perception, social inclusiveness, behavioral change and active engagement of end-users is one of the main pillars for a coherent future (Ponce et al., 2016). Usually, this kind of technology is considered as an additional functional layer over existing front-end frameworks. As a result, individually exploited commercial solutions, available in the market, are quite limited.

Contrary to the above, many work pieces and methodological studies have become available as primary research results. Narrowing the application spectrum down to energy transition in smart grid applications, several EU-funded projects have already successfully demonstrated relevant results, addressing this issue at different scale levels and context. The main contextual categories can be listed as follows:

- **Informative Energy Awareness:** *eTEACHER*, *Cultural-E*, *GAIA*, *MOBISTYLE*, *ChArGED*, *COOLTORISE*
  The associated frameworks implement straight-forward solutions for direct communication of the user's usage and decisions impact on energy efficiency, utilizing data analysis and profiling tools in the back-end.
- **Mitigating Energy Poverty:** *ENPOR*, *SocialWatt*
  The associated frameworks focus on specific social target groups, emphasizing on economically vulnerable end-users, to tackle energy poverty. These frameworks focus on reshaping energy usage of socially weaker groups which potentially are less familiar / convenient with new handheld and AI technologies. The ultimate goal is to address poor living comfort conditions caused by high energy prices.
- **Gamified End-Users Engagement:** *Tribe*, *EnerGAware*, *enCOMPASS*
  The associated frameworks focus on incentivizing energy consumers who are less engaged in energy efficient usage policies. Gamifying usually complies with technology-literate user groups where certain tokenized prizes are foreseen in targeted competitions and challenges.
- **Flexibility-Driven Consumers and Communities:** *SCORE*, *BRIGHT*, *ACCEPT*, *HESTIA*
  The associated frameworks abstract the application of targeted engagement measures at a microgrid / district level. The transformation of the European energy mix, gradually increasing the RES share, inevitably suggests for incentivizing flexible consumption at the demand-side. The goal is to familiarize prosumers and flexibility-providing consumers with incentivized demand shaping enabling demand response schemes.
- **Citizen Co-creation for Energy Transition Technologies:** *SENDER*, *GreenPlay*, *IRIS*, *POCITYF*, *SMART TOGETHER*
  The associated frameworks abstract the application of targeted engagement measures at a neighbourhood / city level. To ensure social inclusiveness, regulatory cohesion and technology acceptance, specific citizen groups (representatives) are called to actively engage in the definition of functional requirements on smart-grid topics. Co-creation strategies for mutually developed energy transition schemes in wide-scale city (energy network) areas are achieved through engaging webinars, social communication platforms and media, local-authority-driven open days, etc.

3.3. Pillar 3 - Define the system performance thresholds that trigger occupant feedback

KPIs that could be used to measure system performance have been primarily identified in chapter 3.1. Yet these KPIs have limited value unless they can be compared with benchmarks. Such benchmarks can be defined as ratings or individual thresholds. Feedback communication can be triggered at a specific position KPIs in relation to their benchmarks. The actual KPIs mostly expressed as indicators or technical parameters of the system (e.g. heating system efficiency) are often hard for the end users to interpret. Most literatures found are mainly focused on **comfort, health and wellbeing** thresholds. These thresholds can be defined by referring to the design values defined in the standards and building performance assessment and certification systems. As the relevant indicators are usually based on observations obtained from a large group of people, they should be interpreted as mean values. Large individual variation may exist, and user feedback is essential in defining and finetuning these thresholds. For instance, temperature thresholds provide temperature boundaries below/above which the occupants perceive discomfort as being too cold/warm. A user interaction with the setpoints indicates a current discomfort of the user, so the smart control should also learn how to minimize the user interactions.

Air temperature thresholds are investigated and proposed for acceptable comfort in air-conditioned buildings (Zhang et al., 2011). The researchers used the ASHRAE database of field studies in which acceptability votes were obtained from real occupants, and the results showed that within the thresholds, the acceptability is indistinguishable. Therefore, there is little gain from conditioning spaces to an “optimum” air temperature and a significant energy savings. However, beyond the thresholds, there is a significant drop-off in acceptability.

The equally-acceptable range between the thresholds is 8 – 10 K wide in both of airconditioned and natural ventilated buildings. It is possible that a perception of reduced air quality in warm environments could impose an upper temperature threshold. Perceived air quality (PAQ) is seen to be closely correlated to thermal comfort rather than temperature; as long as thermal comfort is maintained by the air movement, PAQ will be acceptable.

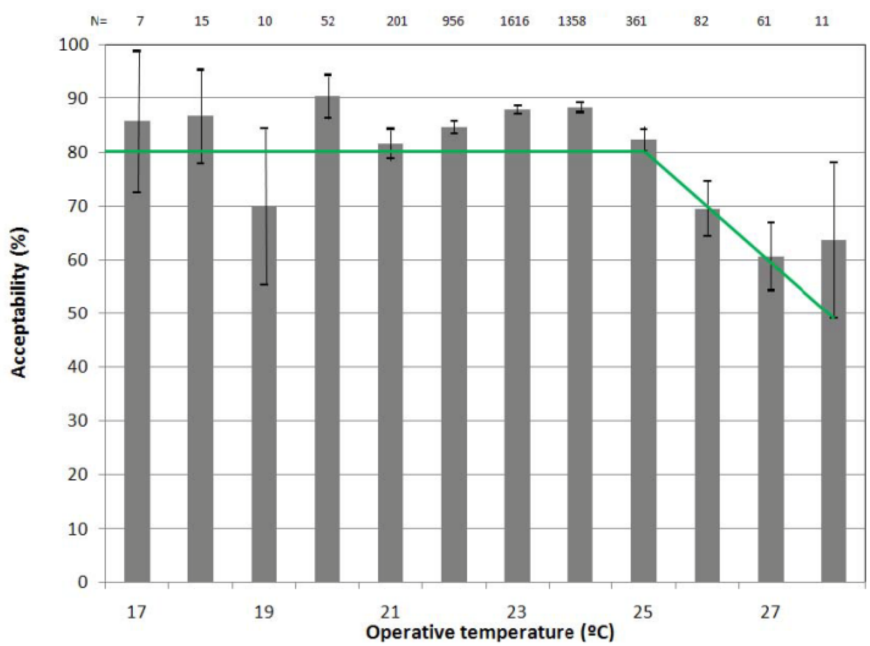


Figure 6: Acceptability against temperature at the workstation, winter and summer.

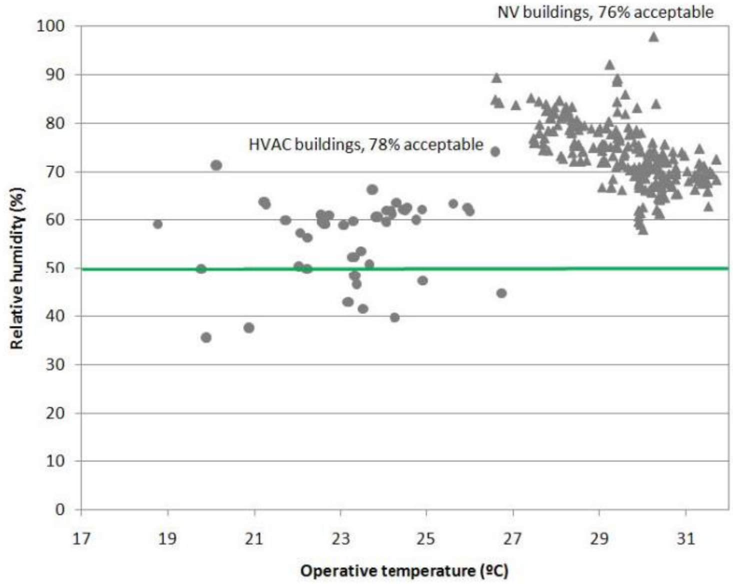


Figure 7: Acceptable rate for very different indoor thermal environments in HVAC (dots) and naturally ventilated (triangles) buildings in Singapore.

It is concluded that by broadening the interior temperature thresholds in HVAC buildings, each 1K broadening corresponds to about 7 – 15% energy saving (Hoyt et al. 2009). The actual savings strongly depend on the local external climatic conditions.

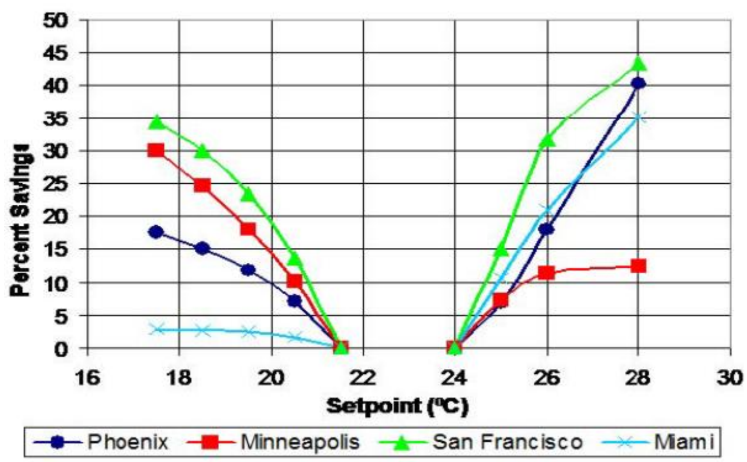


Figure 8: HVAC energy savings for widened air temperature setpoints relative to conventional setpoint range in San Francisco, Miami, Phoenix, and Minneapolis (Hoyt et al. 2009).

Extensive field studies revealed non-universality of the applicability of traditional thermal comfort theory based on laboratory experiments indicating important influence of the opportunity of building users to adapt to thermal environmental conditions. Adaptive thermal comfort theory has rivetted its position in thermal comfort standards such as ASHRAE STD 55 (ASHRAE, 2020) and EN 16798-1 (CEN, 2019) and is solely applicable for warm locations or periods to buildings without mechanical cooling systems with operable windows, etc. It allows a broader range for indoor acceptable environments as function of external thermal conditions.

Indoor CO_2 concentration can be measured and checked if it is consistent with the given thresholds which reflects the operation of the ventilation system or the opening of operable windows.

Table B.12 — Default design CO_2 concentrations above outdoor concentration assuming a standard CO_2 emission of 20 L/(h/person)

Category	Corresponding CO_2 concentration above outdoors in PPM for non-adapted persons
I	550 (10)
II	800 (7)
III	1 350 (4)
IV	1 350 (4)
NOTE The above values correspond to the equilibrium concentration when the air flow rate is 10, 7 and 4 l/s per person for cat. I, II, and III, IV, respectively, and the CO_2 emission is 20 l /h per person.	

Figure 9: Categories of CO_2 concentration level in the EN16798-2.

A direct relationship between parameters and indicators describing indoor environmental quality and health is much less straightforward and mainly covers influencing aspects of indoor air quality and phenomena addressed in relation to what is usually referred to as sick building syndrome. Exemplary is the ASHRAE handbook of fundamentals that contains a chapter dedicated to the topic of indoor environmental health (ASHRAE, 2021) including a description of the many determining factors.

The circumstances and timing of triggering occupant feedback aiming at behaviour change in view of improving the building performance can be based on one or more parameters or indicators in relation to their benchmarks. In addition, also external parameters such as market aspects also determine the decision logic for triggering feedback for maximum effect.

With respect to energy efficiency and energy flexibility, historical profiles of end users and the comparison with peers, such as energy consumption, PV generation that is locally consumed (self-consumption), can be used to define the thresholds. A few examples are further elaborated in the following chapter.

3.4. Pillar 4 - Define the type of feedback that will be provided

With the afore-defined KPIs, the thresholds and the monitoring data flows respectively, the next step is to define the feedbacks for turning data into meaningful smartness advice. For instance, if the data meets the threshold criteria that could infer humidity, what actions could be taken to prevent a negative impact to the property or occupant wellbeing.

The topic of "acceptance and attractiveness of smart building solutions to the end-users" was addressed in SmartBuilt4EU (SmartBuilt4EU TF1, 2021). It has been summarized that, smart building solutions should provide monitoring feedback to end users and this feedback should be communicated through simple, user friendly interfaces, that are inclusive to all population at any time in life.

The feedback provided should be transmitted as customised information on how the building operates, how the operational conditions are perceived by the occupants, and how occupants behaviours can impact the building performance. The feedback can be in different forms, for instance, simple visualisation of data monitoring, historical trend analysis, specific widgets, videos or ad hoc suggestions, and should also include quantitative indicators where possible.

The literature review performed allow to identify several success cases that should be considered when defining the type of feedback that will be provided by Smart2B. For example, the MOBISTYLE dashboard (Figure 10) allows the visualization of historical energy usage and CO_2 concentration. Different actors can interact with the dashboard according to their role. In eTEACHER, an application (Figure 11) is developed to teach users to save energy in different building types. This app gives tailored recommendations based on user's energy behaviours, meanwhile the gamification and benchmarking approaches maximumly engage the users to stay active. In UtilitEE, the interface (Figure 12) was designed to exchange personalized information to the end users, including historical energy data, performance ratings and analytics and energy clock breaking down the 24h energy consumption profile indicating the peak and non-peak hours, which motivate the end users to become more conscious about their energy consumption patterns towards more sustainable behaviours. In FEEdBACk, a behaviour predictor app (Figure 13) is developed to predict the energy saving opportunities based on the previous behaviours. The InBetween app (Figure 14) consists of 5 main features, including sensing and energy management, real-time notification centre, energy efficiency performance and benchmarking, energy efficiency tips repository and weather forecast.[1]

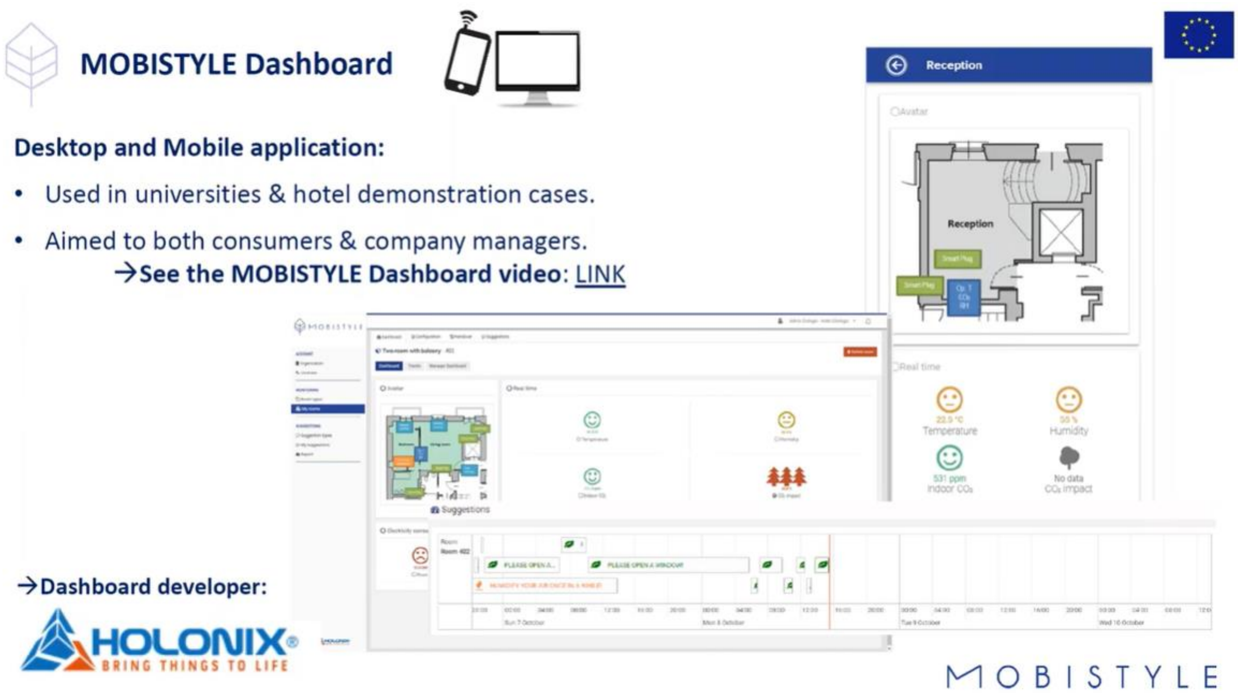


Figure 10: MOBISTYLE Dashboard for two non-residential buildings.

[1] The figures are screenshots taken from BUILDUP webinar.

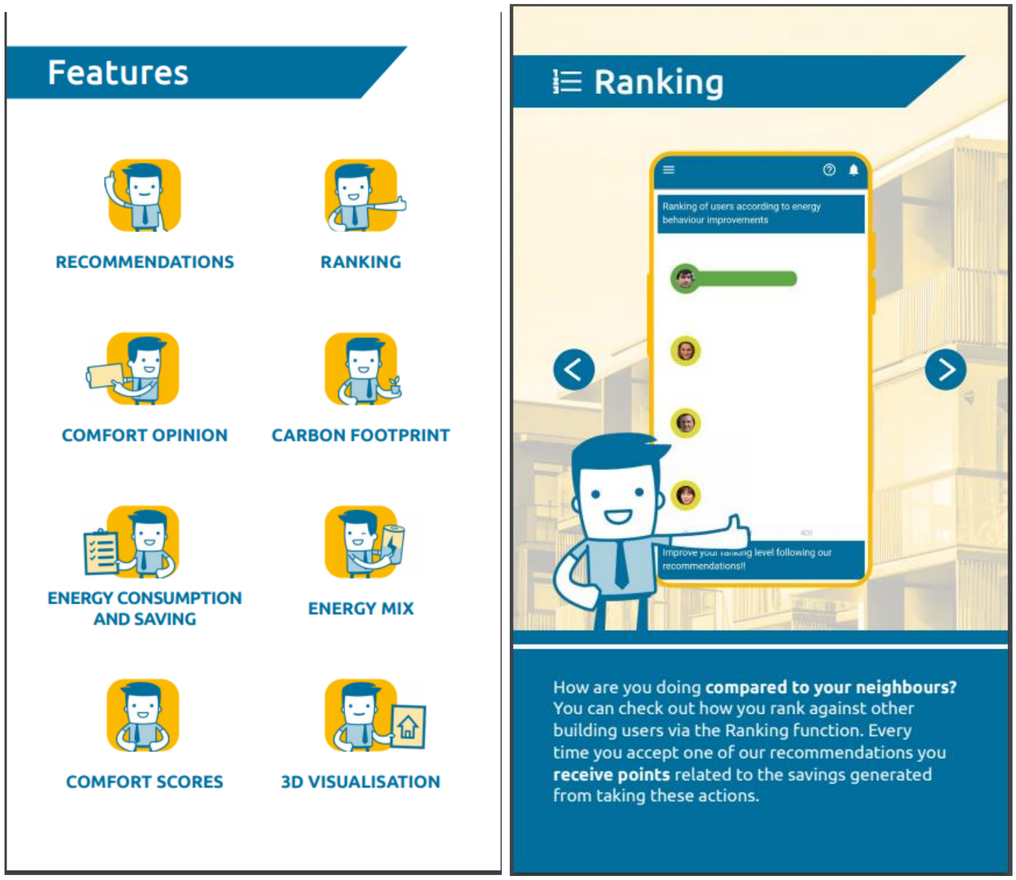


Figure 11: eTEACHER application features.

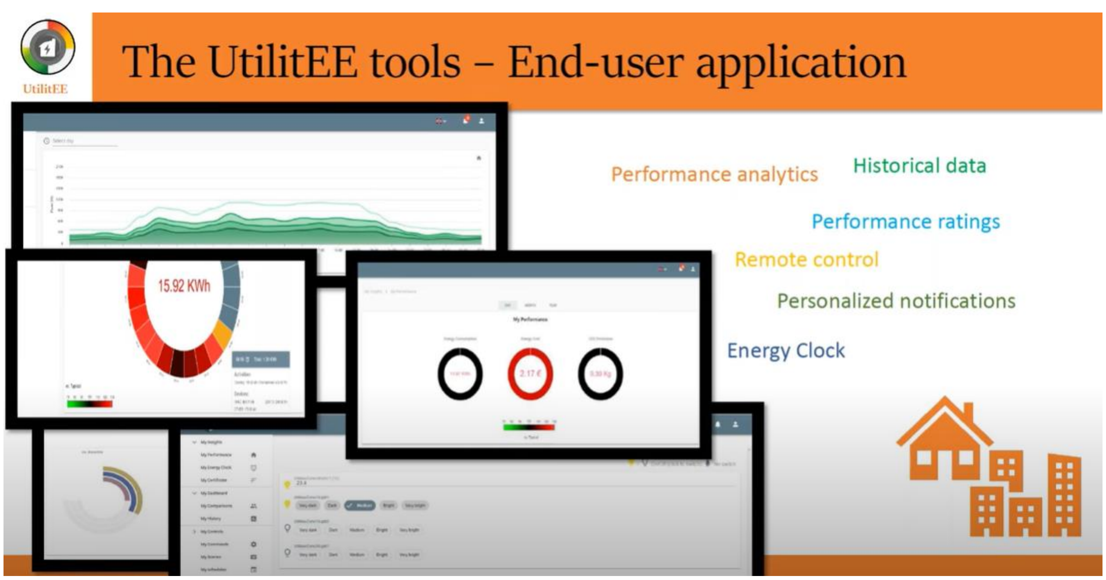


Figure 12: UtilitEE end user application.

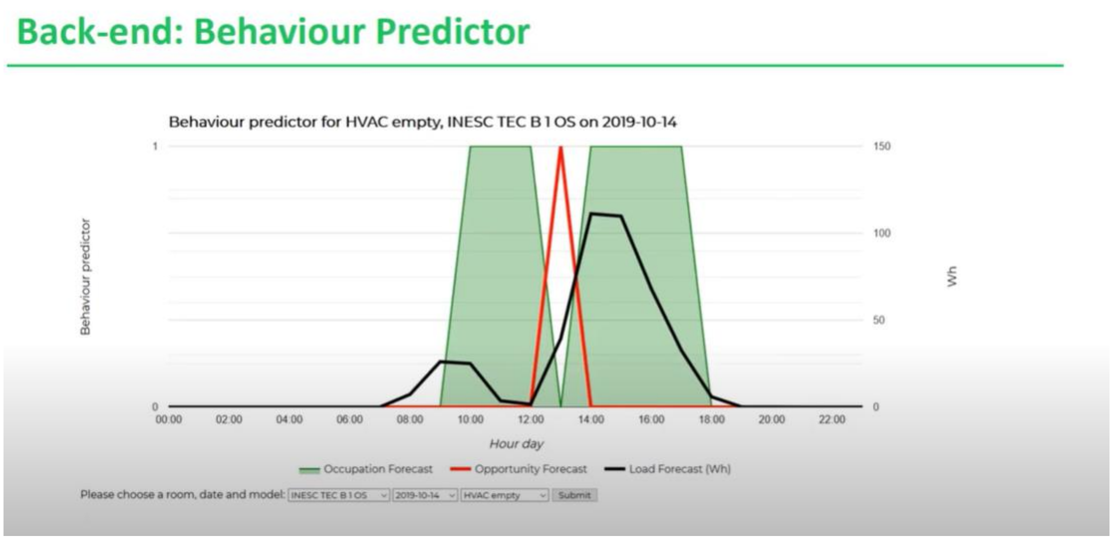


Figure 13: FEEdBACk interface.

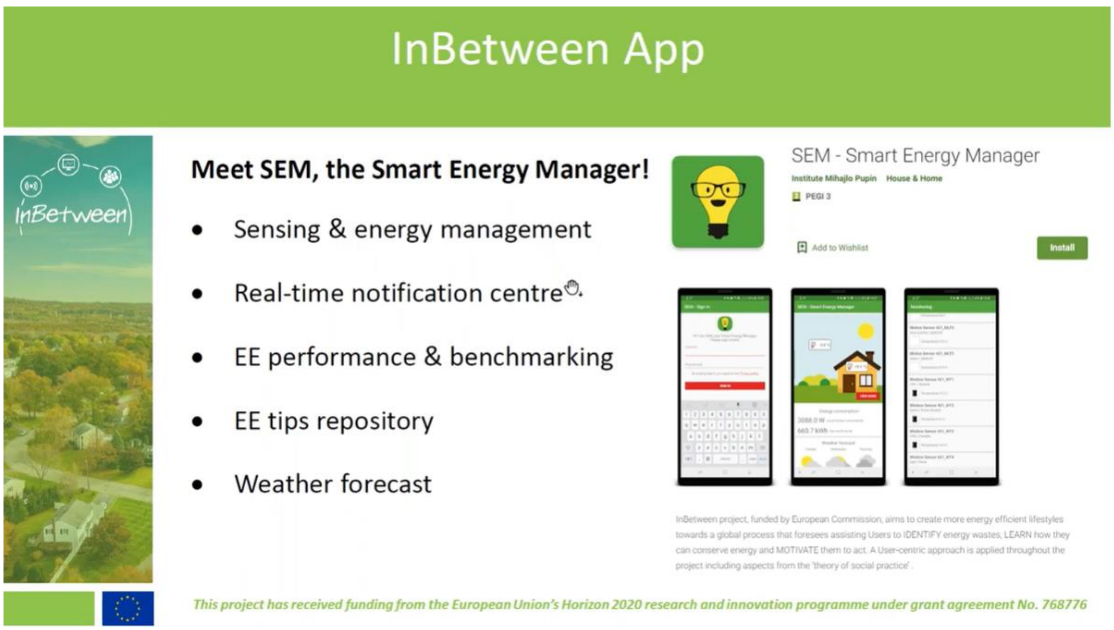


Figure 14: InBetween app and its core features.

For expert user groups with more knowledge and expertise, the feedback could stay at complex level and contain sufficient amount of technical details. In [Cultural-E] project, a data visualization library was developed to display a detailed list of both energy and indoor environmental parameters that can be selectively used for the expert users such as building designers, including:

- the energy balance of the building;
- the energy consumption related to each energy use of the house;
- the hourly frequency of heating and/or cooling load needed to maintain ideal indoor conditions;
- the share of renewable energy in case a photovoltaic system has been installed in the building;

- hourly mapping of internal temperatures, useful to identify any areas of thermal discomfort;
- the distribution of the simulated/monitored indoor temperature and relative humidity on the psychrometric graph;
- the percentage of time in which CO_2 concentration and indoor relative humidity within occupied time fall within the four indoor environmental quality (IEQ) categories identified in standard EN 16798-1: 2019 for each thermal zone;
- the number of hours in which the shadings are activated;
- the number of hours in which the windows are opened in order to assess if the action of natural ventilation alone can guarantee an acceptable level of internal comfort, whether it affects the energy consumption of the building as well as giving indications on how the occupants interact with the building.

4. Expert interviews

4.1. Interview framework

Four expert interview sessions were organized in December 2021 in order for the task team to quickly define and grasp the main questions and narrow down the options for answers for the survey.

In these four sessions, eight experts relevant for the domain of knowledge from five European knowledge institutions were interviewed. The list of the questions used for the interviews is included in chapter 4.2. This list of questions was provided to the interviewees upfront in preparation of the actual interview.

All sessions were recorded for internal consultation, only for reporting purpose. Questions were answered depending on the domain of expertise of the respective experts, meaning that not all questions are answered by all experts, but all answers represent expertise insights.

The interview questions related to methodologies and benchmarks are structured according to the 3 key smart readiness functionalities of the SRI methodologies (European Commission, 2020):

- Optimise energy efficiency and overall in-use performance (energy efficiency);
- Adapt their operation to the needs of the occupant (comfort, health and information to the occupants);
- Adapt to signals from the grid (energy flexibility).

In addition to the indicators and benchmarks of the key functionalities, aggregation into a main smartness performance indicator was also covered.

It was brought to the attention of the interviewees beforehand that potential candidate approaches should be selected in relation to the extent to which the methods are suitable and feasible for implementation in the SPA&A in the frame of the Smart2B project.

The detailed results of the interviews are summarized in the following chapters.

4.2. Interview questions

Main questions for interview are organized in line with the proposed 4 pillars, in order to gather expert insights on those aspects as much as possible. The questions are listed below:

Questions on identifying benchmarks that can be used to measure the performance in each impact area according to the SRI:

1) Which state-of-the-art indicators with benchmarks are available to quantify and evaluate performance of use for smart performance assessment and advisor (SPA&A) for each of the impact domains?
2) Which indicators would you recommend to be best suitable for direct implementation in the SPA&A for each of the 3 impact domains or as an overall indicator? Briefly explain why.

Questions on identifying methodologies that can be used to communicate the impact to the end-users:

3) Which state-of-the-art methodologies are available that can be used to communicate the smartness impact to end-users in view of awareness raising and behaviour change instigation (Best available technologies)? (user interface (available in different devices?), gamification approach?)
4) Which one(s) would you recommend to be best suitable for use in the SPA&A? Briefly explain why.
5) What categories of end users need to be defined to differentiate communication in line with the main requirements and expectations? (facility manager, building occupants, etc.) Briefly explain what different approaches would be suitable if so.

Questions on defining the system performance thresholds that trigger occupant feedback:

6) What approach would you recommend to define thresholds of performance that trigger occupant feedback or what levels of thresholds would you use for the SPA&A for the impact domains?
7) Is there a need to differentiate feedback depending on the level of potential improvement to trigger feedback? (e.g. if potential for improvement is high, only include most important feedback elements.)

Questions on defining the type of feedback that will be provided:

8) What type of feedback would you recommend to minimally include in the SPA&A? List aspects and briefly explain? (monitored data/indicators, historical trends with benchmarking targets; information on smartness aspects and recommendations for improvements)
9) What aspects related to the form of the communication would you recommend (e.g. aspects related to technology, format, graphical representation/visualization, frequency and timing of feedback, etc…)? Briefly explain why.
10) Is there a need to differentiate between target audiences? If so, which categories are minimally required?
11) Is there a further need to customize/personalize communication within target audiences? Briefly explain why this would be beneficial and how it should be approached.

Additional questions on methods are available to determine economic and environmental impact of building smartness aspects:

12) Which state-of-the-art methods are available to determine economic impact of changes in building smartness aspects?
13) Which state-of-the-art methods are available to determine environmental impact of changes in building smartness aspects?

Additional questions on methods that would be best suitable for direct implementation in the SPA&A:

14) What aspects do you think are minimally required and feasible to include in the SPA&A for each of the following impact domains and or overall impact;

15) Do you have recommendations or important aspects that you would like to add related to the requirements of the SPA&A (that were not mentioned earlier during this interview)?

16) To conclude, an open question on additional topics, general aspects or aspects forgotten complements the list for completeness was made.

4.3. Key findings

In this chapter, main findings from the expert interviews are described, thematically structured in the following subchapters:

- Smartness performance methods and indicators with benchmarks
  - For key functionality aspect comfort
  - For key functionality aspect energy efficiency
  - For key functionality aspect energy flexibility
  - For determination of economic impact of building smartness aspects
  - For determination of environmental impact of building smartness aspects
- Communication to end-users

Findings from the interviews related to the smartness performance methods and indicators with benchmarks Several methods and performance indicators with benchmarks that are considered as candidate for use in the SPA&A were mentioned by the interviewees.
A brief description of the methods and indicators that were brought to the attention by the interviewees is included in Chapter 3.

For the purpose of overall smartness performance indication, the SRI method (European Commission, 2020) was mentioned as potentially the best suited candidate. Also for part performance indication on one or more of the key functionalities; comfort, energy savings and/or grid flexibility, the SRI -method is a potential candidate suitable for implementation in the SPA&A. The SRI already is officially adopted by Delegated Regulation and Implementing Regulation as an optional common EU scheme. Furthermore, the SRI is developed to exclusively capture the impact related to smartness characteristics of the building and its technical equipment.
Furthermore, it was suggested to investigate the possibilities to define functionality levels based on processing of automated monitoring data instead of based on inspection. The SRI method (both method A and B) and similarly the BAC factor method of EN 15232 (CEN, 2017c) consists of a checklist approach in which descriptive information on the presence of technology defines the potential service levels that form the basis of the determination of the performance level. The self-assessment of a certain functionality level of a specific service on the basis of a related event-occurrence e.g., presence detection; or other data monitoring, is an example of such an approach to replace on-site surveyed information from checklists. Following such approaches, the SRI methodology and more specifically method B, could be followed in which input information could as much as feasible be substituted by information automatically derived from monitoring and the remainder of the SRI inputs would be completed by inspection. Another approach could be to develop a fully automated method to determine the

smart readiness which is a surrogate of the SRI method diverging from it at distinct aspects that may be case-specific; e.g. depending on the specific building and the availability of data. Several methods and indicators were mentioned to take into consideration for the envisioned implementation of the SPA&A to determine smartness related performance in one of the 3 key functionality aspects as defined in the SRI methodology. The choice of the best suitable candidate for direct implementation in the SPA&A is very much depending on the monitored / pilot-surveyed data that is expected to become available and with a preference for the simple indicators that are easy to implement. Hence, the task team should further align with the other relevant tasks in WP1 to streamline these KPIs.

For key functionality aspect comfort, several approaches were mentioned with some distinct characteristics worth looking into when considering application within SPA&A.
One such distinction concerns the objective versus subjective measurements. Subjective measurements refer to the acquisition of information by means of questionnaires to be answered by usually multiple building users, while objective measurements refer to the acquisition and postprocessing of information obtained from one or more measurement sensors and or other objective information sources. Some approaches combine both to some extent. For example, the Horizon 2020 project X-tendo comfort feature consists of two methods, the Comfort Operational Rating Procedure (CORP) (Sheikh Z. et al., 2021a) applicable to operational buildings and the Comfort Asset Rating Procedure (CARP) (Sheikh Z. et al., 2021b), applicable to unoccupied buildings, such as new buildings.
For comfort it was suggested that minimally indicators for thermal comfort and CO_2 should certainly be included. For thermal comfort, full PMV/PPD analysis (EN 16798-1 (CEN, 2019), ISO EN 7730 or ASHRAE STD 55) could provide indicators useful to supplement the SRI comfort indicator based on a checklist approach and potentially also useful to quantify the benefits of increased smartness in that respect. Adaptive thermal comfort (also part of EN 16798-1 (CEN, 2019)) was also mentioned as a good candidate since there would be no strict requirement to collect inputs such as clothing insulation levels and activity of building users as is the case in PMV/PPD calculation. Application of the adaptive thermal comfort model is however limited to specific types of buildings, excluding for instance fully air-conditioned buildings. Ventilation is also indicated as also indicated as a relevant parameter that should be considered. Furthermore, it was referred that the parameter relative humidity may be very important to include, especially in naturally ventilated buildings. ASHRAE 55 methods were also referred to with the distinct advantage of the availability of thermal comfort library in Python.

For key functionality aspect energy efficiency, the interviewees hinted at maximising the automation of acquisition and processing of information, indicating a preference for data-driven methods, which may also be beneficial to the accuracy of the resulting indicators. At the same time, it was indicated that a fully automated approach for the SPA&A would be very ambitious, but a hybrid approach would be feasible in which automated data-driven approaches are combined with checklists possibly requiring on-site acquisition of information to fill the gaps. Several of the approaches that were mentioned include the requirement of on-site inspections to some extent or information to be obtained from other sources than remote metering infrastructure (meters, sensors, actuators or controllers). It was also suggested to consider an approach of measured energy performance, such as the methods developed within Horizon 2020 projects X-tendo or ePANACEA (Verheyen J. et al., 2022). Disaggregation algorithms, however, are not accurate and require additional information on the type of devices that are installed. Similarly, the use of benchmarks of actual energy use (such as obtained from monitoring or billing information) is favoured over calculated energy performance for the reason that the latter requires building thermophysical properties and characteristics of the technical installations related to their efficiency, information that is less difficult to capture from automated measurements. It was also highlighted that the rebound effect should be taken into account. Furthermore, the preference for automated acquisition and processing of information over the (on-site) ad hoc gathering of inputs may also be applicable to the other key functionality aspects: Comfort and Grid flexibility.

For key functionality aspect energy flexibility, there are plenty of indicators available, but a selection is not so easy and depending on the aim of the project. The indicator developed in the IEA EBC Annex 67 (Jensen S.Ø. et al., 2019) is mentioned as potentially a good candidate.

For determination of economic impact of building smartness aspects, cost-benefit analysis for indication of revenue on investments comparing investment costs with energy cost savings via total cost of ownership, return on investment or payback time are mentioned.

For determination of environmental impact of building smartness aspects, operational primary energy use or CO_2 emissions in relation to long-term objectives (near-zero energy buildings or zero-emission building respectively) are mentioned. These methods only cover environmental impact related to the operational phase. The inclusion of more broad environmental analysis is recommended to also include co-benefits. Also life cycle costing (LCC) is indicated as an interesting candidate to quantify environmental impact.

Findings from the interviews related to communication to end-users

The following technologies, brands or projects were mentioned by the interviewees related to the communication of the smartness impact to the end-users in view of awareness raising and behaviour change instigation; Energy dashboards, such as Emoncms, preference for non-intrusive load mapping (such as implemented in Smappee), Flukso, Netatmo, VITO CO_2-house, PEAKapp, Mobistyle, Circusol(Triggering ad-hoc initiation of electrical appliances (demand response) based on colour indication in the house indicating excess on-site energy generation from renewable sources), HOLISDER (on user acceptance), Gamification with competition (Waterville) (Calculus gateway), keep the fish alive, light in shower to indicate shower time), SRI project (European Commission, 2020) (user expectations).

Related with the **type of advice**, it is recommended to distinguish between advice with focus on performance improvements with behaviour change instigation (try to alter the habits of building users) and advice regarding maintenance and operation (try to prevent operational problems and optimize building operation). The approach related to the timing of the provision of information is different for real time information and long-term monitoring information. Timescale for real-time information is indicated to be monthly (or daily) rather than hourly in the basic view. The choice to provide long-term information (for instance in the format of a report) on request or actively pushed by the system is to be determined by user preference

and also by the appropriate timing in view of maximising the desired effect in terms of user action.
A graphical user interface in the form of a dashboard is minimally required, including chart visualisation with baseline, applications use (disaggregated electrical energy use), potential energy savings and advice of flexibility of appliance usage. One suggestion is to include one indicator for energy (cost) and one for smartness performance. Recommendations should not be limited to visualisation of monitoring data. They should include textual information and may also be provided in the form of videos. It is strongly encouraged to use colours in the dashboard to maximise nudging effects and to engage user-experience centred design experts in the design process of the dashboard development. The acquisition of information such as preferences inserted by the building user is also referred as an important functionality that should be included in the SPA&A.

Two distinct target audiences should be minimally included: building users and facility managers. Building users can subsequently be further categorised into user groups with basic profiles of energy consumption based on statistical information. These may be region specific. For comfort, time blocks may be defined in accordance with user profiles, taking into account for instance presence (in the building/zone or not) and activity of users (for instance sleeping or not).

Content and lay-out of the graphical user interface can be tailored to these two groups. Building users graphical interface should be easily comprehensible information on the general building level. SRI studies have shown that also building users like to have access to detailed information but offered in layers; from aggregated in the main view to more detailed information in underlying levels. Furthermore, users should also be able to further tailor the interface to their preferences, also in relation to recommendations. The highest level of detail (both the type of information and the timescale) should be accessible for the facility managers, but not in their main view. The user interface for the facility managers may also have more focus on maintenance and operational control of the building and should ideally also allow for insight in all data (e.g. via download for their own analysis).

Multiple applications running on several different devices can be elaborated but could be limited to minimally an app or a website. Those are found to be most suitable as most people have a smartphone and know how to use it, making the information readily accessible. Furthermore, these are also compatible with the implementation of gamification approaches.

Providing information directly in the building (via dedicated hardware) is preferred over online information, because the latter is more easily forgotten. There may however be reluctancy towards such in-building communication hardware as these may be perceived as somewhat aggressively intrusive technologies.

It is emphasized that user trust is essential to achieve maintained user engagement. Aspects of concern include privacy, data security and operational resilience. Therefore, it is recommended to give a brief comprehensive explanation of the purpose and functionalities of the SPA&A to the user. The use of anonymised data, pre-training of models external of the test buildings and edge computing, decentralised operation without access to data at all time, are mentioned as best practices. Furthermore, the number of on-site technical interventions to get SP&A properly functioning should be minimised. Thorough preparation and testing of the technology are thus required not only from technical point of view but also to maximise user engagement and motivation.

Maintained action is required to acquire prolonged motivation of SPA&A users. In case no action is taken it is shown that motivation and the interaction of the user with the application halts. Rewards for positive interactions by users such as giving feedback, watching recommendation videos or even for simply logging in are considered helpful to increase engagement and motivation.

Behaviour change instigation works better when notifications are given after the action and when impact prediction is given together with the recommendations. It is considered beneficial to show potential energy savings during activities as people tend to use more energy during activities.

It is advised to consider implementing gamification aspects with competition and rewards.

Feedback should be prioritised according to the estimated potential impact and considering user preference or relevance. It is recommended to include a user control functionality in the SPA&A for ranking information that is to be presented in the graphical user interface according to his/her preference or relevance. SPA&A Users should be able to select or prioritize the feedback aspects or directly intervene with the prioritisation ranking. Information with highest ranking (e.g. as function of the estimated impact ranking and user preference ranking) may be presented at higher frequency and more predominantly positioned in the graphical user interface. It is advices to avoid too much repetition and to limit the number of feedback messages over time. Frequently repeated recommendations on subjects that are perceived not or no longer interesting by users may become counterproductive and may even cause users to abandon use of the application. Include possibility to provide feedback by users on SPA&A functionalities, for instance regarding specific recommendations.

Threshold levels that trigger feedback to the SPA&A user are dependent on the key performance indicators. Indoor environmental quality performance feedback may be initially predefined based on standards or good practices and in relation to the actual outdoor environmental conditions. The system could enable tailored definition of system performance threshold levels that trigger occupant feedback based on user inputs. Based on such feedback by the user, the system can be trained to adjust settings depending on the user's preferences. For instance, at distinct combination of indoor environmental conditions, the SPA&A could inquire the building users in relation to discomfort or simply ask users to press button at every occasion in which they feel discomfort in relation to indoor environmental conditions.

For energy savings system performance indicator threshold values to trigger feedback can be based on historical benchmarks and/or peer comparison (in distinct user group profiles) with notification in case of a specified deviation from the central tendency of the specific benchmarking group reference. Opportunities to save energy can be identified and monitored including ranking when the building user takes action. Monitoring and presentation of progress of achieved energy savings is considered good practice for motivation of building users and instigation of behaviour change. Savings should be presented in a comprehensible way, for instance via virtually planted trees.

For energy flexibility, the feedback can be based on the dynamic pricing of the energy carriers from the data platform, allowing control decisions based on tariff differences between the energy carriers. In essence, the consumer needs to know the predicted amount of energy (cost) savings associated with the recommended actions such as activating a specific appliance at the recommended moment in time.

Such principles can in general be implemented for all key functionality aspects of building smartness. Together with short term forecasting, signals can be derived to indicate appropriate timing to activate appliances or HVAC systems. User in the loop actuators can be included in the SPA&A system, in which building users are encouraged to control building technical systems based on SPA&A feedback messages serving as signals for system control operated by humans.

5. Survey

5.1. Survey framework

As a next step, based on the gathered inputs from the targeted expert interviews, a list of refined closed-ended questions is proposed for this survey. The survey questions are formulated considering the outcomes of the targeted expert interviews and the main part of the background literature research. A total of 18 respondents completed this survey, from both the consortium members (15 respondents) and the advisory board (3 respondents). A list of questions used for the survey is included in chapter 5.2. The full results can be found in detail in Annex 1.

5.2. Survey questions

The survey includes 31 questions articulated into the afore-defined four pillars.

Survey questions on identifying benchmarks that can be used to measure the performance in each impact area according to the SRI:

1) What type of indicator would you recommend to use to quantify smartness performance on the following impact domain – thermal comfort?
2) For main impact domain on comfort, which aspects would you recommend to be included in the SPA&A (Multiple answering options possible);
3) In general, do you think data-driven indicators or checklist (asset rating) approaches to be best suitable for use in the SPA&A?
4) Do you think economic aspects (e.g. investment costs, incentives about data collection/automated energy efficiency with zero human intervention/user teleoperation, convenience/low installation disruption) of smartness improvement measures should be included in the SPA&A?
5) Would you agree to use CO_2 saving to communicate environmental impact in the SPA&A?
6) Would you agree to use payback time to communicate economic/financial impact in the SPA&A?
7) Which category of indicators should/could/to be included in SPA&A?
8) Which comfort related indicators should/could/to be included in SPA&A?
9) Which energy flexibility related indicators should/could/to be included in SPA&A?
10) Which energy efficiency related indicators should/could/to be included in SPA&A?
11) Which additional information should/could/to be included in SPA&A?

Survey questions on identifying methodologies that can be used to communicate the impact to the end-users:

1) What type of communication approach(es) do you think are useful to include in the SPA&A to regularly notify users on changes (by taking into account the implementation difficulty)?
2) SPA&A dashboard should be working on below device(s):
3) Do you agree to include a gamification approach with competition elements in the SPA&A, in order to trigger user interaction and feedback?
4) To what level do you think the communication (e.g. approach, content and format) needs to be diversified for various user groups?

5) Would you agree to send customized information to the end user?

Survey questions on defining the system performance thresholds that trigger occupant feedback:

1) What would be the threshold for the energy efficiency related indicators?
2) What would be the threshold for the comfort related indicators?
3) What would be the threshold for the energy flexibility related indicators?
4) What should be the reference baseline scenario?
5) Would you agree to ask users to rank on importance of aspects/topics to obtain feedback on?
6) Would you agree to take user inputs into account while defining the system performance threshold?

Survey questions on defining the type of feedback that will be provided:

1) Would you think that co-design process is necessary in terms of collecting inputs from end users?
2) Do you think additional impact domain(s) to account for co-benefits should be included in the SPA&A?
3) Would you agree to have benchmarking functionalities (historical or peer) in the SPA&A?
4) Would you like to see colour codes that indicate the quality of the performance level?
5) Would you agree to have descriptive feedback on smartness related aspects of the building in SPA&A?
6) Which type of recommendation would you like to have with regard to the estimated smartness impact?
7) How often would you prefer to have an overview report?
8) Would you recommend to ask the user on his/her preference to include specific recommendations or feedback options?
9) Do you think that the content, occurrence and frequency of the feedback should be as much as possible automatically generated from the data?

5.3. Key findings

First of all, the collected responses reflect the notion that the proposed survey questions in four pillars well address the key aspects that should be taken into account while defining the functional requirements of SPA&A. The key findings are summarized below.

Survey results on the methodology and the benchmarks:

13 respondents support that the SPA&A should be a purely data-driven approach, whereas 4 choose to have a checklist approach. The hybrid approach is less supported.

More specifically, to define the benchmarks and the indicators to be included in the SPA&A, it is generally supported by the respondents to include the smart readiness indicator overall and sub-domain scores. Besides, where possible, appropriate indicators that quantifies the three key functionalities of SRI should be included as well, and more specifically, the impact criteria of energy efficiency, thermal comfort, health and energy flexibility should also be given with priority. An overview of the respondents' preferences of indicators can be found in Figure 15, Figure 16 and Figure 17. Most respondents support to primarily use the impact scores of SRI as indicators. With respect to comfort and health, relative humidity, CO_2 concentration and temperature are top three most voted indicators. For energy flexibility, self-consumption and peak power reduction percentage are mostly voted indicators. The energy efficiency indicators - energy use, specific energy use as well as share of renewable energy - are well supported. The specific indicators in each impact criteria should be carefully selected based on the availability of the data input of each demo site.

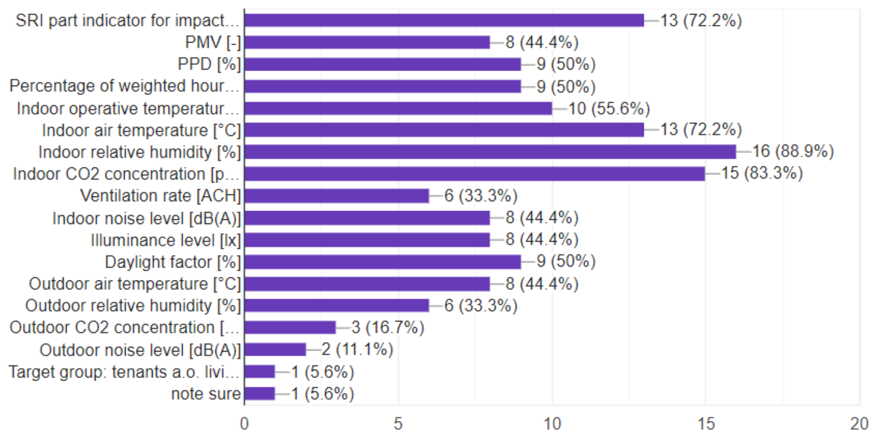


Figure 15: survey results on occupant comfort and health related indicators.

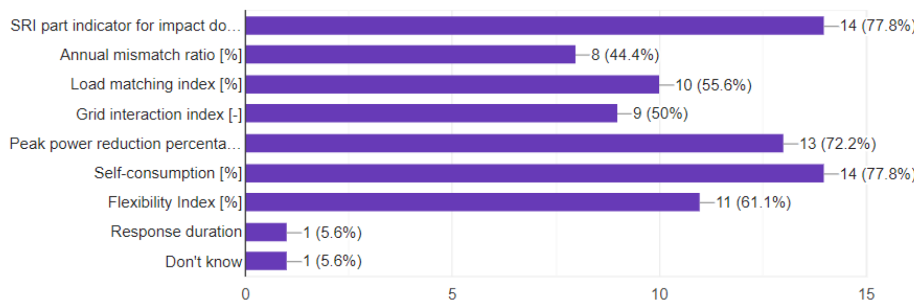


Figure 16: survey results on energy flexibility related indicators

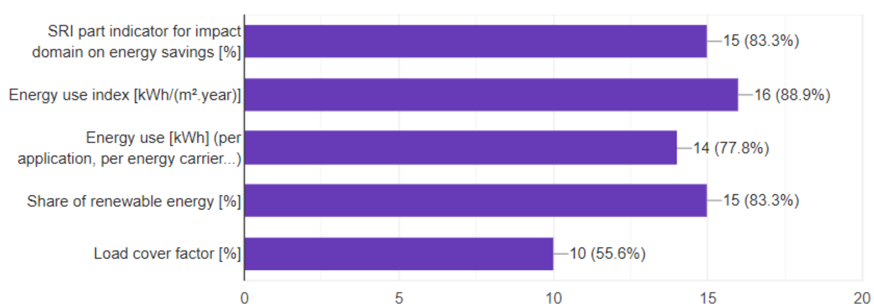


Figure 17: survey results on energy efficiency related indicators.

16 respondents agree to include both subjective and objective indicators to properly quantify thermal comfort. Most respondents support to include thermal comfort and indoor air quality

in the tool and include visual and acoustic comfort where possible. In addition, 17 respondents agree to include economic and environmental indicators, yet they should be presented as understandable as possible to the end-users.

Survey results on the methodologies to communicate the impact to the end-users:

Furthermore, the survey results shows that the impact and the information should be communicated to the end users in an interactive, accessible and understandable way. The majority of the respondents agrees that the SPA&A dashboard should be accessible via different devices (mainly smartphone, PC, etc.), and the end users should be notified regularly with emails and notifications from the dashboard. 16 respondents support to embed a gamification approach in the dashboard for the end users, which can potentially facilitate the communication, tigger more user feedback and make it more interactive. Yet one valid remark states the gamification approach might jeopardise the interest of the advanced users of using the dashboard and the SPA&A service. Hence, it is of great essence to distinguish between user groups (occupants and facility managers) and deliver customized information to the targeted end users.

Survey results on the system performance thresholds that trigger occupant feedback:

Moreover, in the survey, 16 respondents consider that the historical profiles should be primarily used as baseline for further benchmarking purposes, and 10 of 18 also think the peer profiles could be used to define the baseline scenario. 10% deviation from the baseline scenario is considered by the majority of the respondents as the common threshold, which is the tightest margin amongst all options.

All respondents agree to give the end-users the chance to rank on the importance of the aspects or topics to obtain feedback on, additionally, they also support to consult with end-users and ask for their inputs for defining the system performance threshold. Therefore, a co-design process might be of necessity to collect such feedback so that the user needs can be clearly understood while designing this service.

Survey results on the type of feedback that will be provided:

Regarding the type of feedback to the end-users, all respondents support to have benchmarking functionality in the SPA&A, and they would like to see colour codes to indicate the quality of the performance level. Furthermore, it is also well supported to have descriptive feedback on smartness related aspects of the building in SPA&A.

13 respondents agree that it is important to give the smartness feedback both on the technologies and the operational performance of the buildings, which in fact suggests that a hybrid assessment approach might be needed. The frequency of reporting and delivering the information to the end users should be user specific.

6. Conclusion

To explore and define the functional requirements of the SPA&A, a literature review including the analysis of the SRI technical study, more than five H2020 projects and fifteen research papers were performed. The research work also includes four interview sessions of eight experts and a survey consisting of fifteen respondents from Smart2B consortium and three respondents from the advisory board of Smart2B.

As result of the literature review performed, the expert interview and the survey conducted, following are identified and summarized the key functional requirements of Smart Performance Assessment & Advisor:

- SPA&A should integrate data flows and based on its type, quality and quantity, the functionality level of specific smart ready service(s) can be automatically derived and continuously updated, which reflects the performance based dynamic smartness, instead of a purely theoretical smartness.
- SPA&A will only address restricted set of domains and services according to the principles of the SRI, but will **not** be able to cover all the domains and services of the SRI methodology. Depending on the data availability, SPA&A should be able to self-report the functionality level of specific smart ready service(s) and quantify the associated impact with appropriate KPI(s) that cover one or more SRI impact criteria. The assessment can thus be fully automated for the selected smart ready services where sufficient data is available for assessing the functionality level; For the rest of the smart ready services in the SRI list, manual inspection might still be required.
- The KPIs in the SPA&A that can be used to quantify the impact in the smartness assessment are case specific and should be selected in line with the demo cases, based on the availability of the data input.
- 10% deviation from the baseline scenario is considered as the common system performance threshold that can trigger the user feedback. End-users should be able to adapt or adjust the threshold or at least give feedback in defining the system performance threshold.
- SPA&A should be able to benchmark the performance, depending on the availability of end user’s own historical data and the data from peers, potentially to be grouped according to distinct user profiles.
- SPA&A should be able to display the theoretically calculated SRI results, and dynamically update the performance-based SRI and the functionality levels of the specific services deployed in the demo sites. The recommendations of improving smartness in SPA&A should cover both technologies of the building as well as building’s operation and activation of appliances. The recommendations should be given together

with their predicted impact. Achieved improvements can be displayed for motivational purposes. Colour codes can be of help to visually deliver information to end users in an appealing way.

- The content and the interface of SPA&A service should be tailored to different targeted user groups (occupants and facility managers) and their specific needs. Both should have access to more detailed information but offered in layers. Gamification (rewards, competition) can help to deliver the complex technical terms in an understandable manner, hence is considered as the approach to facilitate the general users to get on board, stay active and stimulate interaction on the SPA&A service. Whereas the advanced users or experts might appreciate access to sufficient amount of detailed information of their buildings.
- SPA&A dashboard should be accessible via different types of devices and inform the end users regularly with emails directly and notifications via the dashboard.
- Feedback should be prioritised according to the estimated potential impact and taking into account user preference or relevance. End users of SPA&A should be able to adjust the frequency of reporting and information.
- SPA&A should be GDPR compliant when collecting personal data from end-users and anonymize personal information in benchmarking functionality.
- Installation and maintenance of SPA&A should require only limited number of on-site interventions and should be introduced and supported with sufficient explanation to the end-user to ensure user acceptance of SPA&A.

7. References

CEN; 2019; EN 16798-1: Energy performance of buildings - Ventilation for buildings - Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics - Module M1-6; European Committee for Standardization (CEN); Brussels, Belgium; 2019 May;

CEN; 2017a; EN ISO 52000-1: Energy performance of buildings – Overarching EPB assessment –Part 1: General framework and procedures; European Committee for Standardization (CEN); Brussels, Belgium; 2017 July;

CEN; 2017b; EN ISO 52016-1: Energy performance of buildings - Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads - Part 1: Calculation procedures; European Committee for Standardization (CEN); Brussels, Belgium; 2017 July;

CEN; 2017c; EN 15232-1: Energy Performance of Buildings - Energy performance of buildings - Part 1: Impact of Building Automation, Controls and Building Management - Modules M10-4,5,6,7,8,9,10; European Committee for Standardization (CEN); Brussels, Belgium; 2017 May;

CEN 16798-2:2019 Energy performance of buildings - Ventilation for buildings - Part 2: Interpretation of the requirements in EN 16798-1 - Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics (Module M1-6)

European Commission, 2021; DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the energy performance of buildings (recast);

Verbeke, S., Aerts, D., Reynders, G., Ma, Y., Waide, P.; 2020; Final report on the technical support to the development of a smart readiness indicator for buildings: final report, Publications Office, Brussels, Belgium; 2020;

European Commission, 2020; Regulation (EU) 2020/2155 for the Delegated Act – establishing an optional common European scheme (definition and calculation methodology);

European Commission, 2020; Regulation (EU) 2020/2156 for the Implementing Act – detailing the different technical implementation modalities;

ASHRAE, 2020; ANSI/ASHRAE Standard 55: Thermal Environmental Conditions for Human Occupancy;

ISO, 2005; ISO 7730: Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria;

Jensen, S.Ø. et al.; 2019; Summary report; International Energy Agency (IEA), Energy in Buildings and Communities Programme (EBC) Annex 67 Energy flexible buildings; Danish Technological Institut (DTI); 2019 Dec;

Pernetti R., Knotzer A., Jensen, S.Ø.(eds.) et al.; 2019; Characterization of Energy Flexibility in Buildings; International Energy Agency (IEA), Energy in Buildings and Communities Programme (EBC) Annex 67 Energy flexible buildings; Danish Technological Institut (DTI); 2019 Dec;

Sheikh Z. et al.; 2021a; H2020 project X-tendo Feature 2: Comfort Operational Rating Procedure (CORP) – user-guide (Beta-version 1.2); Building Performance Institute Europe (BPIE); Brussels, Belgium; 2021 Aug;

Sheikh Z. et al.; 2021a; H2020 project X-tendo Feature 2: Comfort Asset Rating Procedure (CARP) – user-guide (Beta-version 1.2); Building Performance Institute Europe (BPIE); Brussels, Belgium; 2021 Aug;

SmartBuilt4EU, 2021; H2020 project SmartBuilt4EU: D3.1: Co-benefit indicators of Smart Buildings for business case development; EURAC; Bolzano, Italy; 2021 Sept 27;

SmartBuilt4EU, Whitepaper Task Force 1: Interactions with users - Topic A: Acceptance and attractiveness of smart building solutions to the end-users; Final version; 2021 Sep;

SmartBuilt4EU, White Paper Task Force 3: Interactions with the external environment: Topic A: Smart buildings as flexibility providers to the electricity grids; Final version; 2021 Sep;

Han Li, Zhe Wang, Tianzhen Hong, Mary Ann Piette; Energy flexibility of residential buildings: A systematic review of characterization and quantification methods and applications, 2021;

Verheyen J. et al.; 2022; Next generation energy performance assessment methods for EPCs using measured energy data; Proceedings of the CLIMA 2022 conference; Rotterdam, the Netherlands; 2022;

Vigna I., Pernetti R., Pasut W., Lollini R.; 2018; New domain for promoting energy efficiency: Energy Flexible Building Cluster; Sustainable Cities and Society 38; 2018 Apr; pp. 526-33;

Voss K., Sartori I., Napolitano A., Geier S., Gonzalves H., Hall M., Heiselberg P., Widén J., Candanedo J. A., Musall E., Karlsson B., Torcellini P.; 2010; Load matching and grid interaction of net zero energy buildings; 8th EuroSun conference; Graz, Austria; 2010 Sep-Oct;

Wargocki P., Mandin C., Wei W.; 2019; H2020 project Aldren deliverable D2.4 – ALDREN Methodology note on addressing health and wellbeing; 2019 Apr 30;

Wu J., Lian Z., Zheng Z. Zhang H.; 2020; A method to evaluate building energy consumption based on energy use index of different functional sectors; Sustainable Cities and Society; 2020 February;

Serrenho, T., Bertoldi, P., Smart home and appliances: State of the art - Energy, Communications, Protocols, Standards, EUR 29750 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-03657-9, doi:10.2760/453301, JRC113988;

Dirk Brounen, Nils Kok John M.Quigley, 2013; Energy literacy, awareness, and conservation behavior of residential households;

Kevin Chadwick, Rebekah Russell-Bennett, Nicholas Biddle, 2022. The role of human influences on adoption and rejection of energy technology: A systematised critical review of the literature on household energy transitions;

Nina Kahma, Kaisa Matschoss, 2017. The rejection of innovations? Rethinking technology diffusion and the non-use of smart energy services in Finland;

Murray Goulden, Ben Bedwell, Stefan Rennick-Egglestone, Tom Rodden, 2014. Smart grids, smart users? The role of the user in demand side management;

Pedro Ponce, Kenneth Polasko, Arturo Molina, 2016. End user perceptions toward smart grid technology: Acceptance, adoption, risks, and trust;

Hui Zhang, Edward Arens, Wilmer Pasut, 2011; Air temperature thresholds for indoor comfort and perceived air quality Building Research & Information (2011) 39(2), 134-144

Hoyt, T., Kwang, H.L., Zhang, H., Arens, E. And Webster, T., 2009; Energy savings from extended air temperature setpoints and reductions in room air mixing. International Conference on Environmental Ergonomics 2009, August.

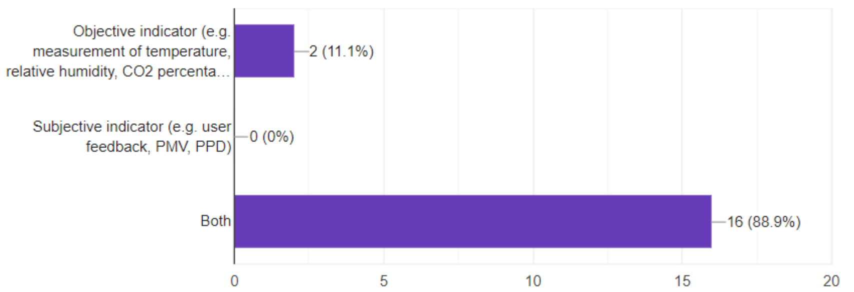
ASHRAE, 2021; Handbook – Fundamentals: Chapter 10; Indoor Environmental Health; American Society of Heating, Refrigerating and Air-conditioning Engineers;

Annex 1 – Survey results

Section 1: Identify benchmarks that can be used to measure the performance in each impact area according to the SRI

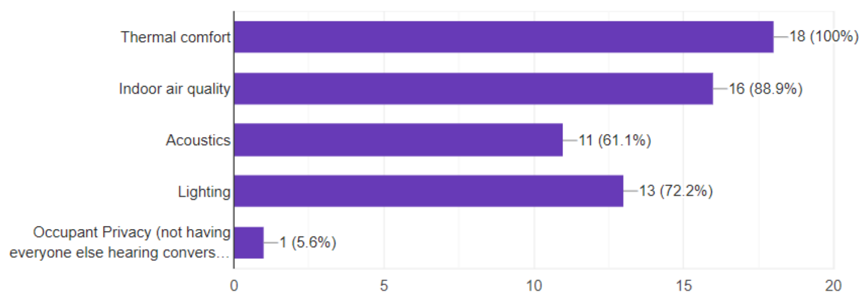
1. What type of indicator would you recommend to use to quantify smartness performance on the following impact domain – thermal comfort?

18 responses



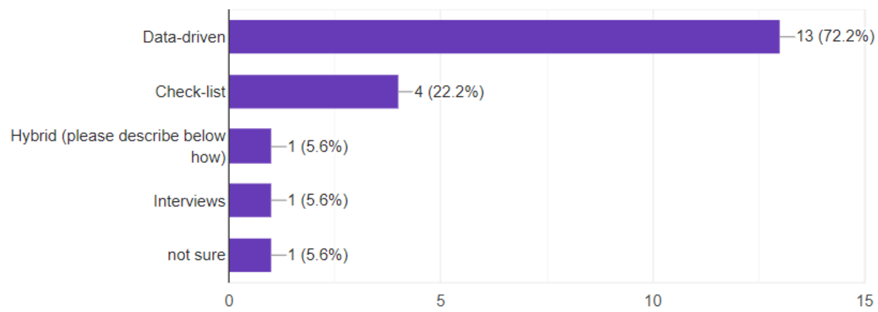
2. For main impact domain on comfort, which aspects would you recommend to be included in the SPA&A [Multiple answering options possible];

18 responses



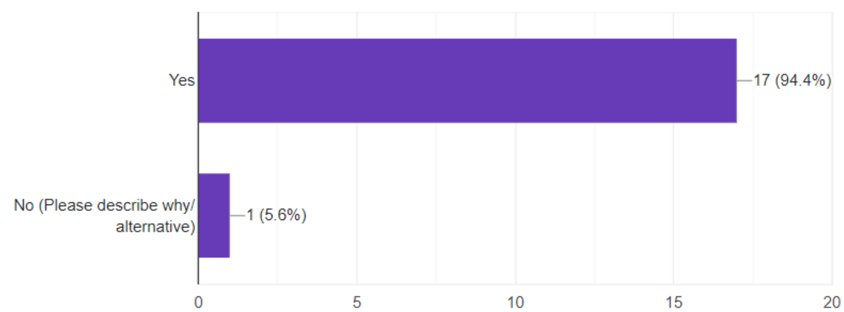
3. In general, do you think data-driven indicators or check-list (asset rating) approaches to be best suitable for use in the SPA&A?

18 responses



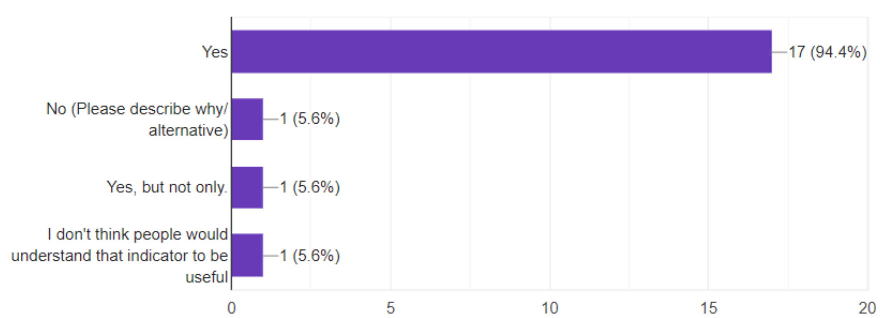
4. Do you think economic aspects (e.g. investment costs, incentives about data collection/automated energy efficiency with zero human intervention/user teleoperation, convenience/low installation disruption) of smartness improvement measures should be included in the SPA&A?

18 responses



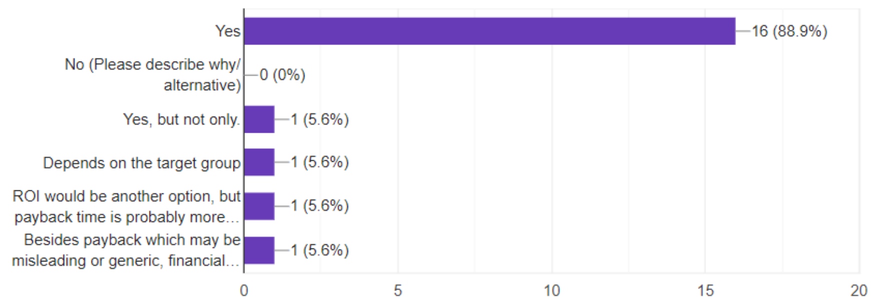
5. Would you agree to use CO2 saving to communicate environmental impact in the SPA&A?

18 responses



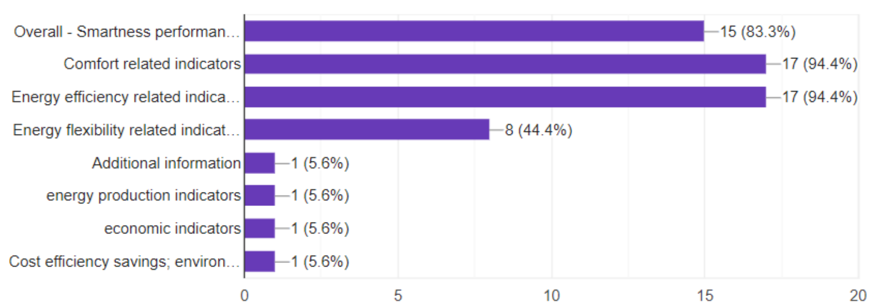
6. Would you agree to use payback time to communicate economic/financial impact in the SPA&A?

18 responses



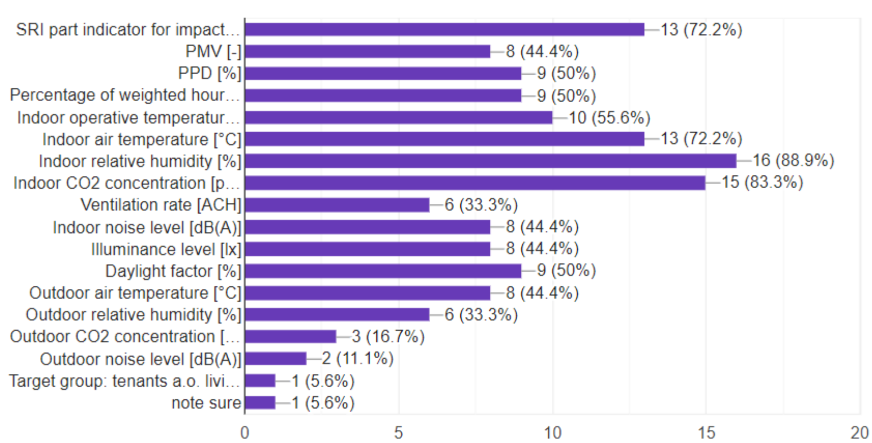
7. Which category of indicators should/could/to be included in SPA&A?

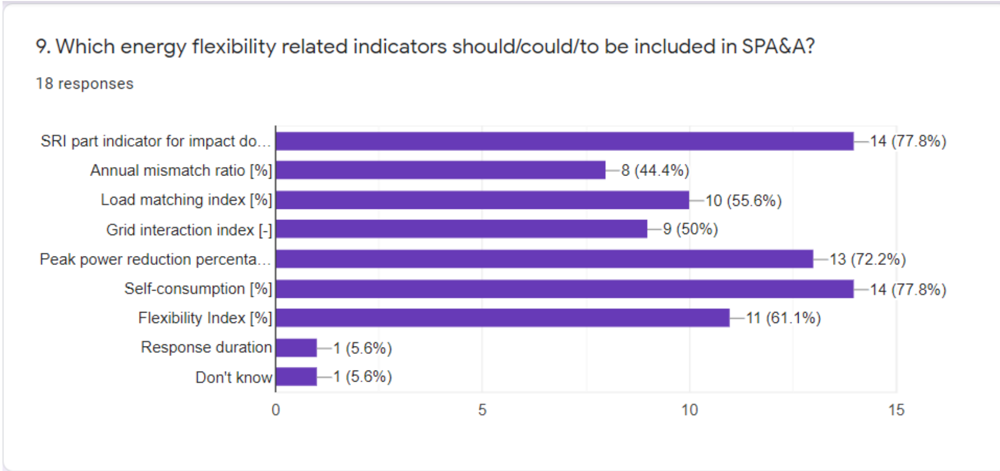
18 responses

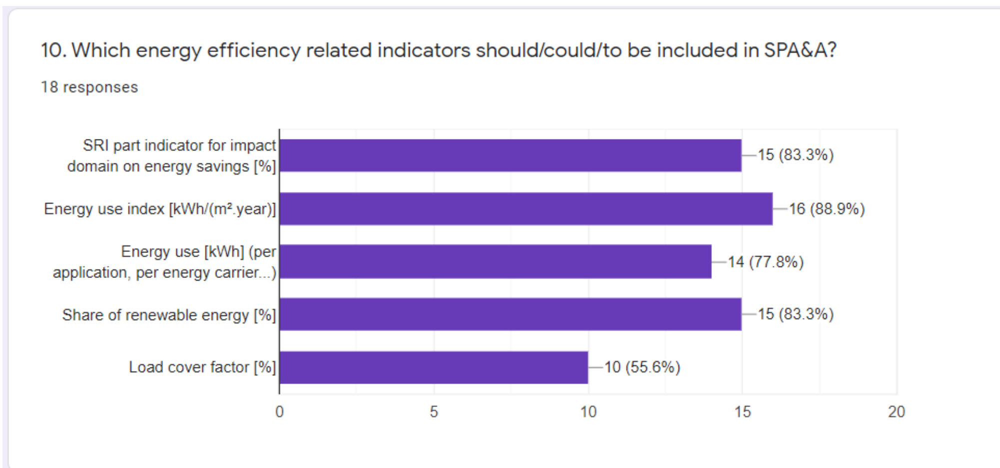


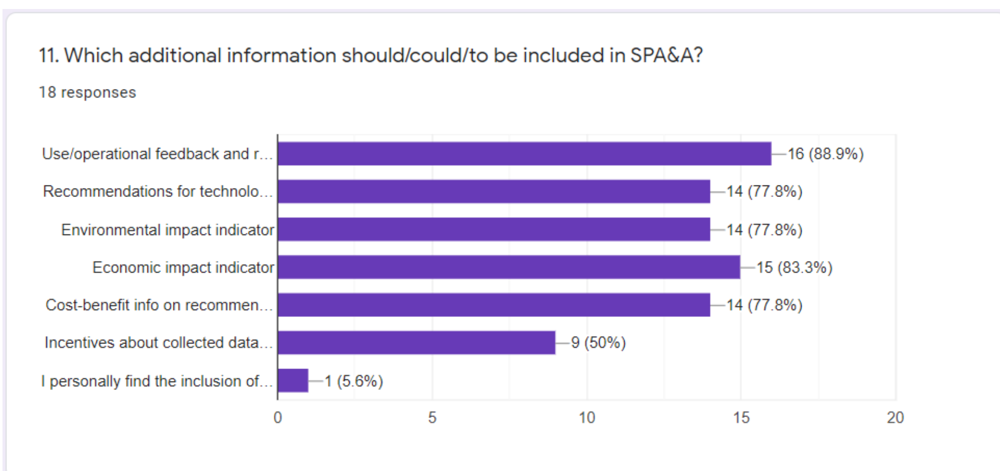
8. Which comfort related indicators should/could/to be included in SPA&A?

18 responses




9. Which energy flexibility related indicators should/could/to be included in SPA&A?
18 responses
SRI part indicator for impact do...
14 (77.8%)
Annual mismatch ratio [%]
8 (44.4%)
Load matching index [%]
10 (55.6%)
Grid interaction index [-]
9 (50%)
Peak power reduction percenta...
13 (72.2%)
Self-consumption [%]
14 (77.8%)
Flexibility Index [%]
11 (61.1%)
Response duration
1 (5.6%)
Don't know
1 (5.6%)
0
5
10
15

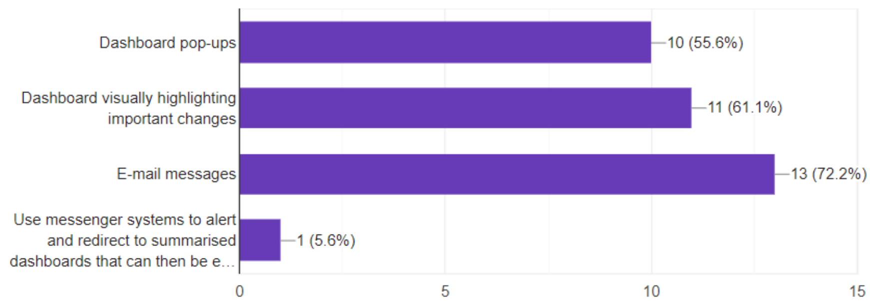

10. Which energy efficiency related indicators should/could/to be included in SPA&A?
18 responses
SRI part indicator for impact domain on energy savings [%]
15 (83.3%)
Energy use index [kWh/(m².year)]
16 (88.9%)
Energy use [kWh] (per application, per energy carrier...)
14 (77.8%)
Share of renewable energy [%]
15 (83.3%)
Load cover factor [%]
10 (55.6%)
0
5
10
15
20


11. Which additional information should/could/to be included in SPA&A?
18 responses
Use/operational feedback and r...
16 (88.9%)
Recommendations for technolo...
14 (77.8%)
Environmental impact indicator
14 (77.8%)
Economic impact indicator
15 (83.3%)
Cost-benefit info on recommen...
14 (77.8%)
Incentives about collected data...
9 (50%)
I personally find the inclusion of...
1 (5.6%)
0
5
10
15
20

Section 2: Identify methodologies that can be used to communicate the impact to the end-users

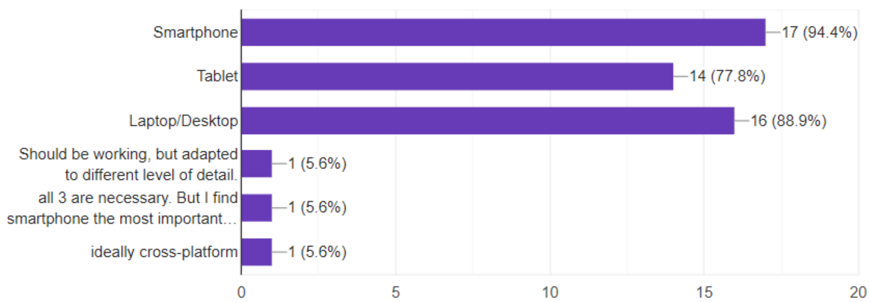
1. What type of communication approach(es) do you think are useful to include in the SPA&A to regularly notify users on changes (by taking into account the implementation difficulty)?

18 responses



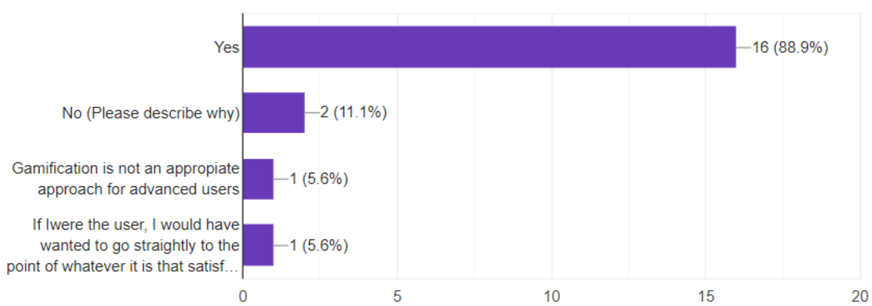
2. SPA&A dashboard should be working on below device(s):

18 responses



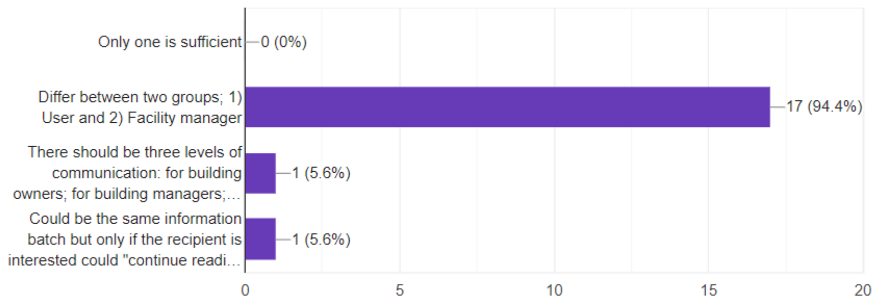
3. Do you agree to include a gamification approach with competition elements in the SPA&A, in order to trigger user interaction and feedback?

18 responses



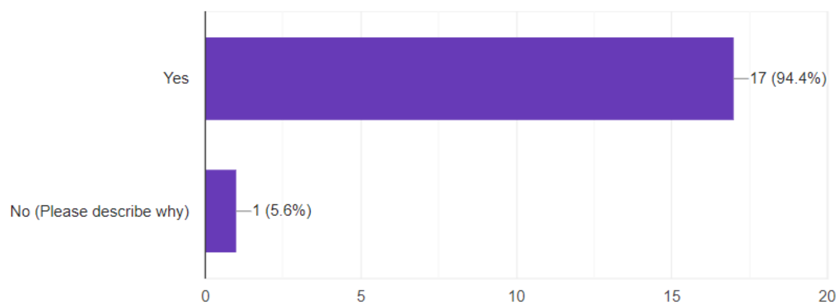
4. To what level do you think the communication (e.g. approach, content and format) needs to be diversified for various user groups?

18 responses



5. Would you agree to send customized information to the end user?

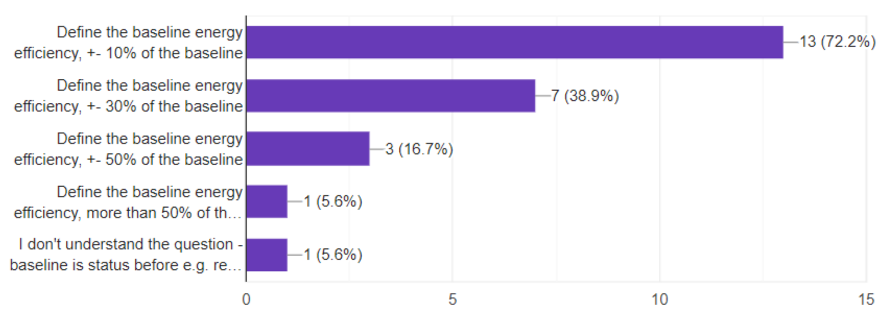
18 responses

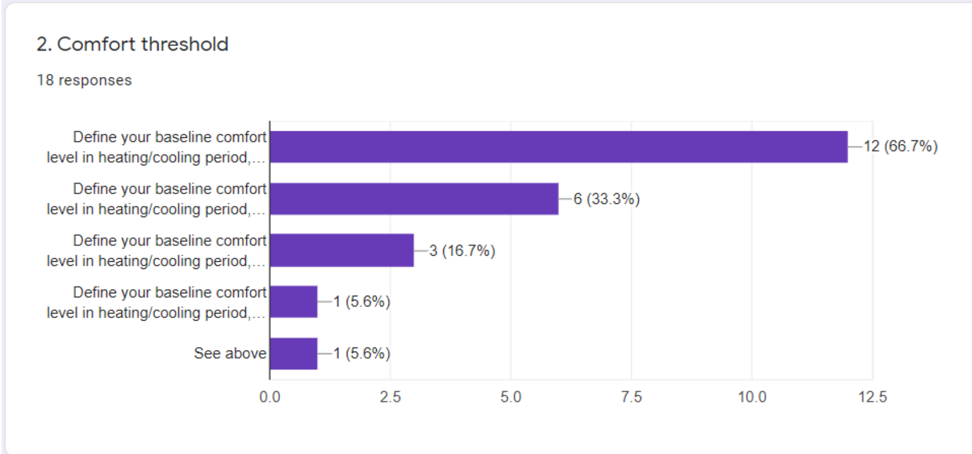


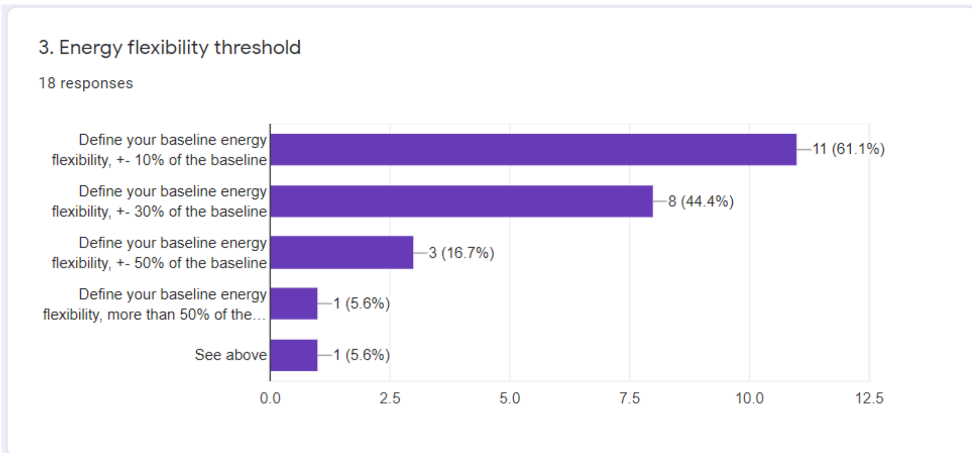
Section 3: Define the system performance thresholds that trigger occupant feedback

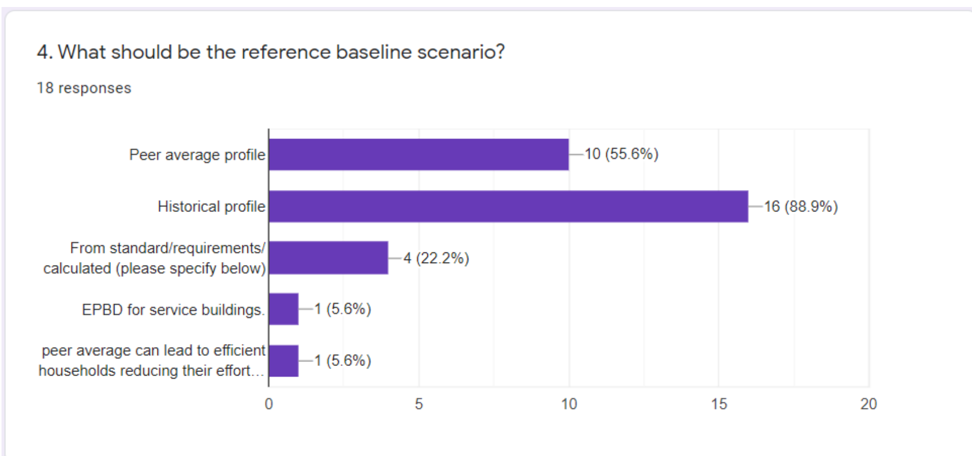
1. Energy efficiency threshold

18 responses



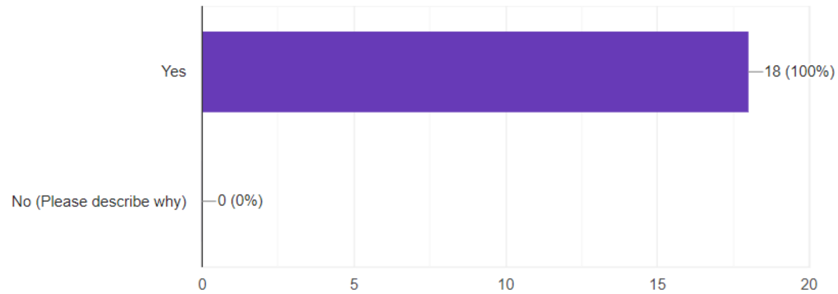

2. Comfort threshold
18 responses
Define your baseline comfort level in heating/cooling period,…
Define your baseline comfort level in heating/cooling period,…
Define your baseline comfort level in heating/cooling period,…
Define your baseline comfort level in heating/cooling period,…
See above
12 (66.7%)
6 (33.3%)
3 (16.7%)
1 (5.6%)
1 (5.6%)
0.0
2.5
5.0
7.5
10.0
12.5


3. Energy flexibility threshold
18 responses
Define your baseline energy flexibility, +- 10% of the baseline
Define your baseline energy flexibility, +- 30% of the baseline
Define your baseline energy flexibility, +- 50% of the baseline
Define your baseline energy flexibility, more than 50% of the…
See above
11 (61.1%)
8 (44.4%)
3 (16.7%)
1 (5.6%)
1 (5.6%)
0.0
2.5
5.0
7.5
10.0
12.5


4. What should be the reference baseline scenario?
18 responses
Peer average profile
Historical profile
From standard/requirements/ calculated (please specify below)
EPBD for service buildings.
peer average can lead to efficient households reducing their effort…
10 (55.6%)
16 (88.9%)
4 (22.2%)
1 (5.6%)
1 (5.6%)
0
5
10
15
20

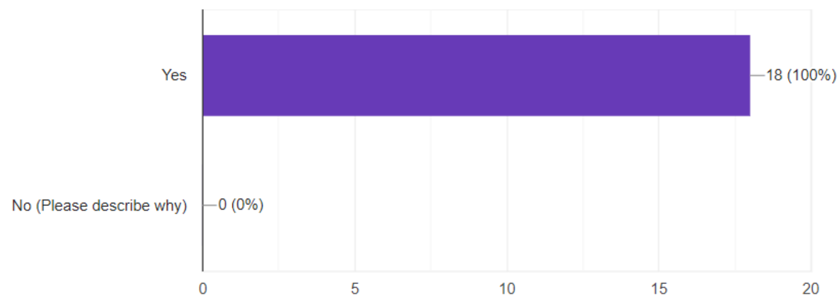
5. Would you agree to ask users to rank on importance of aspects/topics to obtain feedback on?

18 responses



6. Would you agree to take user inputs into account while defining the system performance threshold?

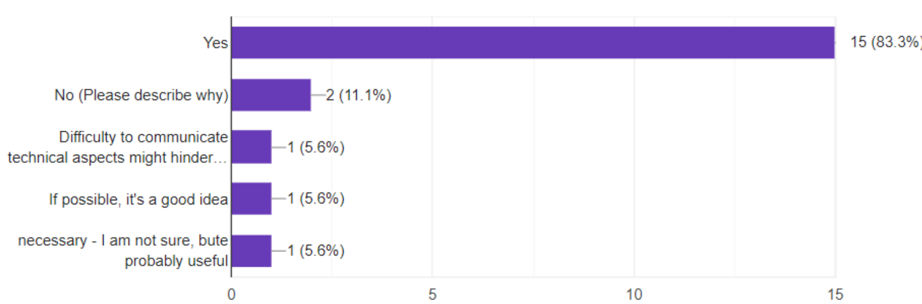
18 responses



Section 4: Define the type of feedback that will be provided

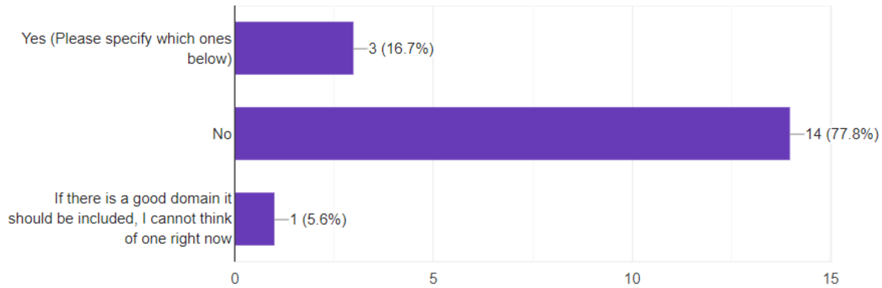
1. Would you think that co-design process is necessary in terms of collecting inputs from end users?

18 responses



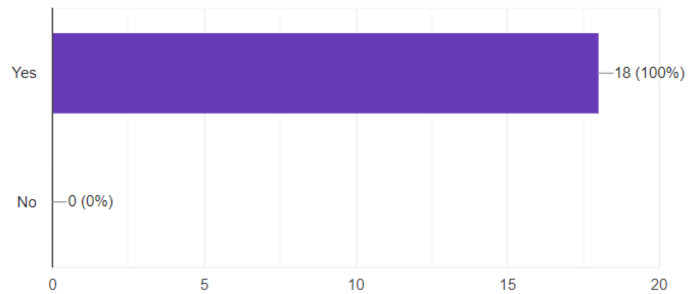
2. Do you think additional impact domain(s) to account for co-benefits should be included in the SPA&A?

18 responses



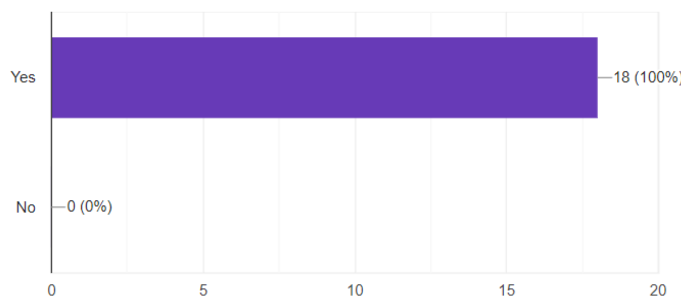
3. Would you agree to have benchmarking functionalities (historical or peer) in the SPA&A?

18 responses



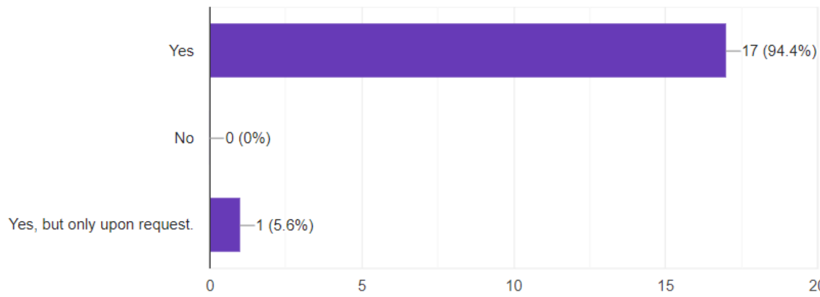
4. Would you like to see color codes that indicate the quality of the performance level?

18 responses



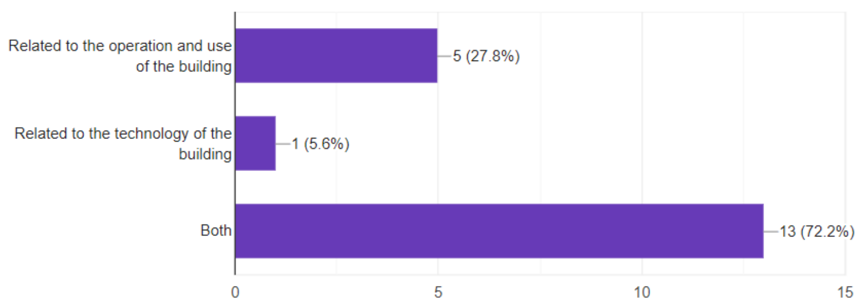
5. Would you agree to have descriptive feedback on smartness related aspects of the building in SPA&A?

18 responses



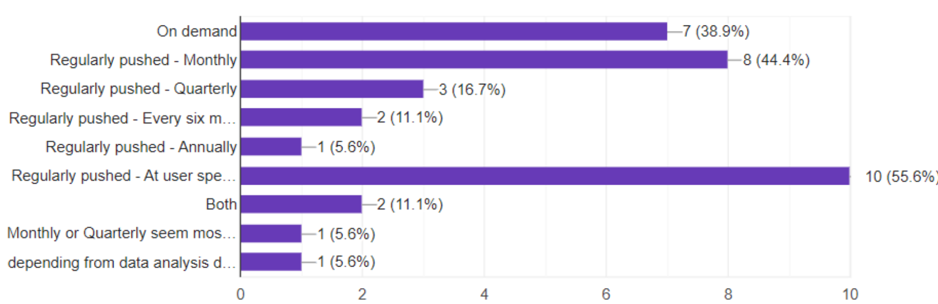
6. Which type of recommendation would you like to have with regard to the estimated smartness impact?

18 responses



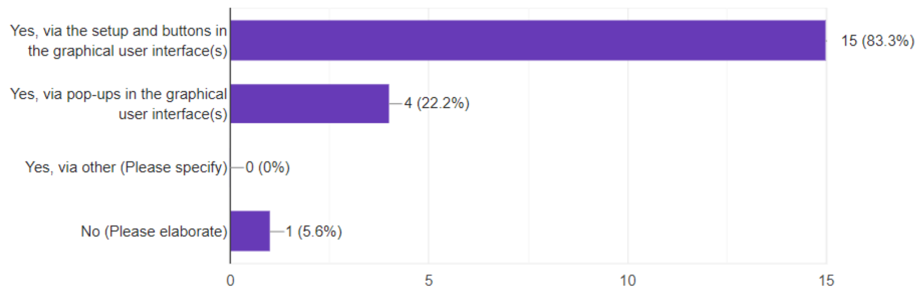
7. How often would you prefer to have an overview report?

18 responses



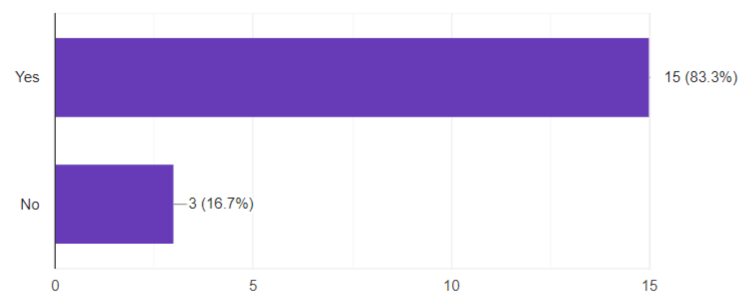
8. Would you recommend to ask the user on his/her preference to include specific recommendations or feedback options?

18 responses



9. Do you think that the content, occurrence and frequency of the feedback should be as much as possible automatically generated from the data?

18 responses



Is there anything you would like to add that was not yet (sufficiently) covered by the questions above? Or do you have specific suggestions on the functionalities of the SPA&A?

5 responses

No

Nothing to add

No, it is pretty complete. Thank you!

no