Self Assessment Towards Optimization of Building Energy

Deliverable 1.1

Role of Actors

and Design of Stakeholder Framework

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Table of Contents

List of Figures

List of Tables

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DISCLAIMER

EXECUTIVE SUMMARY / ABSTRACT / SCOPE

The work developed in this subtask produced a clear picture of the actors that will use the SATO platform. In addition, this work defined the desired level of user interaction as well as confirming the proposed division of the interfaces of the SATO platform into two levels (Web and BIM based models).

The web-based survey of 105 potential SATO users identified a large untapped potential for the deployment of automated control of energy systems. The market penetration of digital control systems is low (50-80%), in part due to cost concerns. In this context there is a high potential for the adoption of the proposed SATO platform as long as it is cost effective. The users show a high degree of curiosity and receptivity towards the capabilities of AI for energy system control. This interest should allow for an easy deployment of these approaches, although several of the experts mentioned that the robustness of the proposed systems must be tested in advance.

1. Objectives of the task

The potential improvement of building intelligence is highly dependent on the requirements of the building users and their level of engagement with the functionalities of the interface of the building energy systems. This task aims to define the specific user needs on the market for upgrading the intelligence of existing buildings towards providing self-assessment and optimization of energy performance. More specifically, identify:

1. Actors and their roles
2. The desired level of user interaction with SATO platform
3. The adequate interfaces related to A&O services

The first question focuses on the characterization of the human actors, an essential step to the design and development of the interfaces. In particular, the first question that needs to be answered is: who are the users of the SATO platform. For this purpose, we propose to adopt the following three categories of actors: (residential and service building) *users*, (building/facility) *managers*, and *grid operators*.

The second question focuses on the state of the art of existing energy system interfaces (already deployed in the market). This market review aims at supporting the design and development of the SATO interfaces. This development will be divided into two classes of interface:

1. For residential apartments and small service buildings, the SATO platform will rely on a simple WEB-based or smartphone app-based interfaces.
2. For large buildings, SATO will use a BIM (Building Information Modelling) based interface that will display data in a 3D building model. This interface will be a plugin on an existing BIM tool (CYPE, partner of SATO).

2. General approach and methodology

The work developed in this task was performed in the following steps:

1. A literature and market **review** of the current interfaces and their characteristics.

   As a first step, the review focused on listing the available and marketable energy management devices in both residential and non-residential buildings, from more straightforward to more complex interfaces. Interfaces were classified according to the available features and services offered. The literature review intends to understand the state of the art of smart building energy management and control and evaluate the potential for further progress.

2. A **web-survey** directed to the three actor classes that were identified.

   The survey objective is to know the current level of interaction with the systems for users and managers, analyze the user needs and preferences, and identify the possible barriers to the widespread distribution of control and management interfaces.

3. Expert **interviews**.

   For each identified actor class, the expert interviews complement the survey results by collecting their perspectives about the best services and features and possible barriers to implementation.

The distinct sources of information will contribute to attaining what the different actors do and need from the interfaces, which will help define the interface features related to A&O services.

3. R&D and market review

This section will use several acronyms: Smart Homes (SH), Demand Response (DR), Home Energy Management Systems (HEMS) and Smart HEMS (SHEMS), Smart Building EMS (SBEMS), demand side management[1] (DSM), peak shaving (PS) and load shifting (LS) [1]. The SATO platform will operate in the SHEMS and SBEMS market. This section presents a market review that aims to clarify the technological developments and services offered by this market.

3.1. Research & developments

A smart building that can interact with the power grid needs to ensure occupant comfort without compromising the building energy consumption. This goal requires a continuous two-way communication with the smart grid and grid services that can be used to deploy demand flexibility [2,3]. There are a variety of papers which have reviewed the SHEMS literature. The reviews were published from 2014 to 2020 (Table 1).

Vega et al [4] investigated the infrastructure, protocols, system variables and the role of the consumer. In the same article, a new HEMS methodology was formulated with the objective of introducing the end user to an active role in the energy market, filling one of the gaps identified in the SHEMS. Beaudin et al. [5] presented a comparative analysis on the identified SHEMS methodologies and their impacts, highlighting the common limitation in the building energy consumption forecasting. Nanda et al. [6] presented a literature review including the development of smart homes, smart home energy controls, smart home real time energy managements and smart home communication systems. Liu et al. [7] analysed the concept of HEMS, through the study and identification of its components, comparison between methods, and finally a discussion over the ways to overcome the difficulties on SHEMS implementation. It should be noted that [4], also addresses SHEMS on the topic of DR. Hosseine et al. [8] investigate the enhanced utilization of Appliance Load Monitoring (ALM), and consequently, the potential benefits and applicability of the Non-Intrusive Load Monitoring (NILM) in SHEMS. Additionally [5], also propose an advanced NILM concept and describe its properties to provide an improvement in DR. Molla et al. [9] delivers the comprehensive review on HEMS optimization techniques. Note that this article, identifies the following mathematical and heuristic optimization techniques: Mixed Integer Linear Programming (MILP), Linear Programming (LP), Particle Swarm Optimization (PSO), Gray Wolf Optimization (GWO), Genetic Algorithm (GA), Evolutionary Algorithm (EA), Bee Colony (BEC), Bacterial Colony (BAC) and Ant Colony (AC) [6]. Hartono et al. [10] analyses the development of HEMS from the point of view of its contribution to DSM and Electric Vehicles (EV) programs in the smart grid schemes with the aim to improve power quality in the electric network.

[1] Modifications in the demand side energy consumption pattern to foster better efficiency and operations in electrical energy systems.

More recently, Shareef et al. [3] conducted a review over the implications on SHEMS of DR programs, smart technologies, and load scheduling controllers. The same article [8], addresses the applicability of AI in the control of electrical consumption, using optimization techniques such as Artificial Neural Network (ANN), Fuzzy Logic (FL), and Adaptive Neural Fuzzy Inference System (ANFIS). Mahapatra et al. [11] focused on concept evaluation, technical background, architecture and infrastructure and goals including various issues and challenges faced by the HEMS systems. Mahapatra et al. [9], also proposes a novel methodology to incorporate the concept of green building[2] into SHEMS, and that through a pilot study showed a reduction of 35% in the electricity cost. Shaw-Williams [12], focused on concept evaluation, technical background, architecture, and targets. Also including various issues and challenges faced by the HEMS systems.

Through the presented reviews analysis, it was possible to understand the different paths and their interconnection necessary for SHEMS evolution. Emphasizing a high research on energy optimization algorithms with the introduction of AI, and on the advance of central gateway that not only enables data acquisition from non-smart appliances, but also improve the interfaces to present information for users in a way that is appealing and easy to use for them.

Table 1: List of reviews on SHEMS.

Publication title	Publication year	Reference
Modeling for home electric energy management: A review	2014	[4]
Home energy management systems: A review of modelling and complexity	2014	[5]
Review on smart home energy management	2015	[6]
Review of smart home energy management systems	2016	[7]
Non-intrusive load monitoring through home energy management systems: A comprehensive review	2017	[8]
A comprehensive analysis of smart home energy management system optimization techniques	2018	[9]
Review: Home energy management system in a smart grid scheme to improve reliability of power systems	2018	[10]
Review on home energy management system considering demand responses, smart technologies, and intelligent controllers	2018	[3]
Home energy management system (HEMS): concept, architecture, infrastructure, challenges, and energy management schemes	2019	[12]
The expanding role of home energy management ecosystem: an Australian case study	2020	[13]

[2] Building that, to the greatest extent, saves resources (energy, land, water, materials), protects the environment and reduces pollution throughout the whole lifecycle, to provide people with healthy, suitable, and efficient use space, which is also in harmony with nature.

3.2. SHEMS development

The SHEMS model was conceptualized by [13], that developed a Solar Energy Management System (SEMS) consisting of a control system made up of different thermostats and logic relays. Similarly, one of the first algorithms was proposed by [14], for Electrical Energy Management (EEM) and compiled optimization functions in the following areas: metering, cost monitoring, direct and indirect load control, and real-time control for small power producers.

It has been observed a high interest and development in SHEMS algorithms, with the goal to optimize energy consumption in buildings. One of the first developments was the introduction of a Modified Genetic Algorithm (MGA) for optimizing the scheduling of direct load control strategies [15]. In architecture terms, its composed with a master MGA and a sequence slaves MGAs, as the master MGA assesses the status combination, iteratively requests a slave MGA at each time step for computations. Resulting in an algorithm that tends to level-off the accumulated shedding time of each load, without minimizing consumer comfort.

Managing high power consuming household appliances can be realized by an intelligent algorithm with simulation for DR programs [16]. This algorithm manages to keep consumption below the established limit while maintaining comfort level settings. Also, a low demand limit level could cause an adverse effect by generating a new peak during an off-peak period after DR event ends. The most important achievement of this study was the ability to keep consumption below the established limit while maintaining comfort level settings. Also, a low demand limit level could cause in an adverse effect by generating a new peak during an off-peak period after DR event ends [16].

With the focus for improving energy consumption and production, a Moving Window Algorithm (MWA) demonstrate a 2.4% increase in energy costs due to consumption forecast errors [17]. This study also produces three important conclusions: *1)* devices with larger energy cycles (ex. EVs, space heaters, etc.) tend to not recover in a timely manner for its operation fulfilling consumers needs; *2)* devices with considerable energy losses (ex: water heater) may ultimately reach an unwanted low energy state; *3)* devices with scheduled run times, occasionally cannot properly allocate total run time due to network interferences [17]. The same authors in subsequent research [18], propose a two-horizon algorithm (THA) with the goal of minimizing MWA errors, and with the objective to improve high resolution schedules, while reducing computation time. The simulation results show a 19.5% reduction on energy costs when compared to an MWA. This suggests that the THA is more robust for handling forecasting errors.

Optimal scheduling of energy services in buildings is a crucial point for energy consumption optimization. A Binary Backtracking Search Algorithm (BBSA) to optimize the energy consumption through an optimal schedule for appliances, showed induced savings in energy consumption of 21.1% on weekdays and 26.1% on weekends [19]. This algorithm was compared with the PSO algorithm and presented better results [19]. Another algorithm focused on scheduling home appliances according to electricity price, forecasted outdoor temperature and renewable power output, well as user preferences and was able to reduce energy costs by 47.8% [20].

As shown, various algorithms were applied to optimize the schedule of energy services in buildings. In this sense, an optimal scheduling solution was developed, being based on an adaptive neuro-fuzzy inference system to forecast values of uncertain parameters for a day ahead management and real-time regulation. This methodology was able to regulate the gaps between the forecasted and real values and showed a 95% success rate to handle the deviations on demand profile [21]. Furthermore, this algorithm can optimize the operating schemes close to the ideal deterministic solutions [21].

AI was able to introduce very important improvements on SHEMS. Two AI based optimization techniques, binary multi objective Bird Swarm Optimization (BSO) and a hybrid of bird swarm and Cuckoo Search Algorithms (CSO) were compared with existing techniques such as multi objective binary Particle Swarm Optimization (PSO) and multi objective Cuckoo Search Algorithms (CSA), and concluded that, assuming a variable electricity time rating, the highest reductions in energy cost is CSO with 22% and in energy consumption is PSO with 77% [22].

The application of game theoretic to capture and encourage the attention of SHEMS users was demonstrated in [23-24]. The approach using Nash H-learning in attempt to capture the correlation and interactions of different occupants' movements and so improving their thermal comfort and energy consumption, demonstrated that the daily average energy consumption can be kept about 4 kWh, in contrast with 20 kWh without predictions [23]. On the other hand, game theory-based consumption scheduling game, where players are the consumers, and their strategies are the daily schedules of their household appliances and loads showed a 18% decrease in energy consumption, and assuming a 90% time shiftable load, enables a 41% of peak load reduction [24].

The comparison between algorithms is also a field of study with high importance for SHEMS. The comparison of different linear and nonlinear algorithms: LP, PSO, Extended Particle Swarm Optimization (EPSO) and Adaptive Dynamic Programming (ADP) for home energy resource scheduling, demonstrated that LP produces the highest average reduction of the energy costs, with a 7% reduction [25].

SHEMS architectures can influence the assessment and optimization of energy consumption in buildings. A self-learning architecture with only a single critic neural network instead of the action-critic dual network architecture of a typical ADP, demonstrated a 30% saving in energy cost, and so a simple and effective method for optimizing energy consumption in real-life conditions [26].

ANNs are a considerable instrument for SHEMS improvement. The study and evaluation of an energy consumption forecasting method consisted with techniques of data selection, wavelet transform (WT), ANN-based forecasting, and error-correcting functions concluded that the mean absolute percentage error is 0.7%, and so, smaller than the method with only ANN (3.0%) or with ANN and WT (1.9%) [27].

The development of an architecture that enables the efficient and easy expansion of the system to remote control and schedule appliances was developed for an android-based app [28]. This architecture improvement consists in a three-tier architecture, where the master and client nodes are based on Arduino platform and the app-based platform performs the connection layer through Wi-Fi communication [28].

Due to the high complexity assignment of energy consumption optimization in buildings, a heuristic based control model using LP and a multi-time scale for scheduling household appliances of different characteristics showed a 30% reduction on energy costs when compared with a ruled based control [29]. Also considering a heuristic based model, the inclusion of real time pricing data and an Inclining Block Rate (IBR) model was able to reduce the maximum peak load on 35%, and a 10% reduction on monthly energy costs [30].

Besides optimizing the schedules of energy loads in buildings, incorporating thermal dynamics, temperature measurements, and real-time pricing was introduced in [31]. This predictive control algorithm, through stochastic optimization showed a 20% savings in energy cost for the consumer, while aiming to minimize customer discomfort level, and being subject to real cost and peak power constraints. A comparable study, although considering data assessment from Renewable Energy Sources (RES), battery banks, power grid availability and multi-rate tariff, was able to decrease consumers energy cost in 28%, and 25% when supplied from grid only [32].

Evaluating SHEMS improvements can also occur through methodology based on Simulator for Buildings and Devices (SIMBAD) [33]. This simulator operates in Simulink environment and uses TRANSYS and HVACSIM+ programs, and the case study demonstrated that in best case scenario can produce a 20% reduction on electricity costs [33].

Data assessment and optimization in buildings can also occur using an intelligent cloud. This method [34] assigns dynamically priority to household appliances according to the respective type, operation status, and considering renewable energy capability, showed the capacity to reduce the average total power consumption in 7.3%.

Exploring the improvement in DSM via SHEMS potentialities, an integer linear programming was developed in [35]. Revealing the ability to balance the loads in the way that peak power is just 19% higher than the daily average. Comparably, a DR program with half-hourly rolling optimization and a real-time control strategy, that includes the introduction of a fuzzy logic controller to regulate battery banks, showed the ability to produce a 17.2% average reduction on energy costs [36].

Communication frameworks between SHEMS components have a fundamental role in his proper and efficient operation. In this regard, a simplistic strategy for appliance control using a home automation communications network, microcontrollers, and user interface software was developed for enabling appliance operation during energy shortages and minimize electricity costs for the consumers [37].

Monitor and control energy devices in buildings is an important field of SHEMS development. Studying this field, was developed a low-cost and highly reliable controller with Plug and Play [38]. This gateway was integrated on a small embedded hardware running with Java, providing a graphical user interface (GUI) that can suggest energy saving advices [38].

Comparably, a GUI gateway that supports the use of different communication technologies offering an efficient interoperability between the different devices was able to introduce the possibility to define energy management strategies through Semantic Web based Rules (SWRL) [39].

Appliances with network communication and monitoring capabilities are indispensable for SHEMS. In this regard, a methodology was developed that gives appliances intercommunication with the network capabilities without increasing cost [40]. This is achieved giving an interface software and a network adapter to be embed in non-smart appliances [40].

ZigBee based communication frameworks enabling remote control in buildings were studied in [41-42]. The principal accomplishment of these studies was a web based SHEMS that could be accessed through an easy to use web platform [37], and a high accuracy monitoring methodology, showing an average power standard deviation of 0.047 kWh.

Table 2: Nomenclature

Nomenclature	References
SEMS – Solar Energy Management Systems	[14]
EEM – Electrical Energy Management	[15]
HEMS – Home Energy Management Systems	[19], [20], [22], [24], [27], [28], [30], [34], [36], [38], [39], [40], [41]
HEM – Home Energy Management	[16], [21], [29], [31], [32]
BEMS – Building Energy Management System	[33]
LSS – Load Schedule Scheme	[35]
EMS – Energy Management Scheme	[23]
SHEMS – Smart Home Energy Management Systems	[36]
ULM – Utility Load Management	[37]
REMS – Residential Energy Management System	[26]
HERS – Home Energy Resource Scheduling	[25]
RES – Residential Energy System	[17], [18]
Home Energy Monitoring and Control System (HEMCS)	[42]

3.3. Market review

The market review presented in Table 8 was carried out having as main premise the search for the largest number of services that have monitor or control capabilities over energy systems in buildings.

After surveying, the available services were analysed to understand and identify their capabilities. These capabilities were framed according to the components of the SHEMS presented in Figure 1. Technically, HEMS consist of six interconnected components:

- Home Energy Management (HEM) – describes an intelligent class of technologies that enables the assessment and optimization of energy consumption in buildings, through the communication with through intercommunication with all the other components.
- Metering devices – devices that measure consumptions, for example electricity, gas, or water.
- Sensing devices – sensors that sense different parameters, convert, and send signals to a centralized system.
- Information and Communications Technology (ICT) devices – devices that provide the interconnection between both metering and sensing devices, and a central gateway.
- Smart appliances – appliances with embedded intelligence and communication systems that enables their monitoring and/or remote control.
- Smart actuators – technology devices that carry out the actions based on remote control (e.g., valves, motors, pumps, fans, window actuators, frequency controllers, etc.). The embedded intelligence and communications of these devices have increased, and so granting their monitoring and remote control.

The market offers a large variety and very different HEM devices, but all with the objectives to monitor or control the energy consumption buildings. In some cases, as seen in Annex 1, these devices are also capable to remotely control appliances, and perform energy optimization measures both manually and automatically.

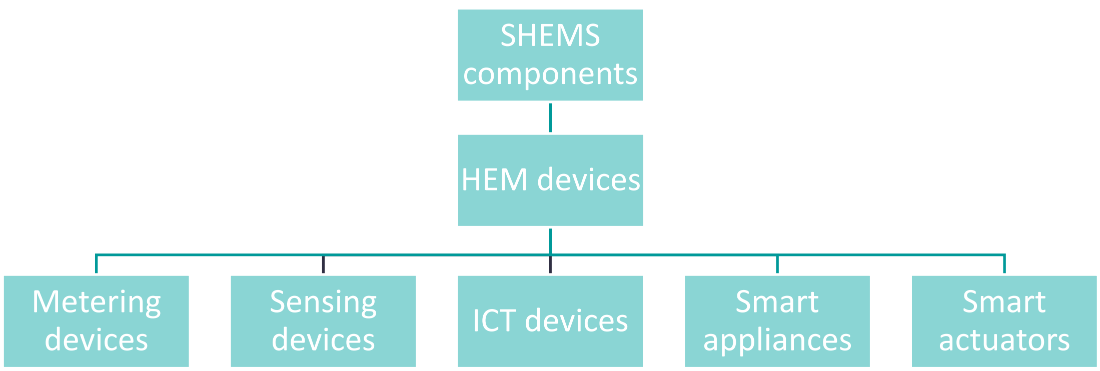

Figure 1: Schematic of SHEMS components.

4. Identification of actors and roles

The identification of the actors was performed according to the definition presented in the IEC 62559-2 standard, which defines an actor as any entity that communicates and interacts with the SATO platform. These actors can include humans, software applications, systems, databases, and even the power system itself. With that in mind, the actors were divided into two groups: human actors and software/systems actors.

4.1. Human actors

Table 3 presents the human actors identified in the SATO project, as well as a brief description of each actor and its role in SATO.

Table 3: Description and role of the identified human actors.

Human Actors	Description and Role
Occupant	An occupant is an energy consumer (or a prosumer) who has a direct control over his energy systems in a residential or service building. SATO will allow the users who want to decrease their energy bill, by providing them with incentives and decision support to maximize energy savings, improve comfort and implement energy sustainable behaviors. In addition, the SATO platform will also suggest users to subscribe to energy flexibility services that are expected to be financially rewarded.
Facility/Building manager	The facility manager's main objective is to supervise the building's operation mode. From the occupant's point of view the role of facility managers is to reduce CO_2 emissions, maintain the indoor environmental comfort of the occupants and at the same time optimize energy consumption. On the other hand, from the point of view of the grid operator the facility manager ensures that the systems provide the required Demand Response DR capabilities required for DSM. With a SATO platform, building managers can also detect any equipment or installation that requires maintenance or repairs to increase their performance.
Grid operators	Aggregators will be able to provide energy balancing and flexibility services to DSOs. The integration of several SATO services will allow aggregators to reduce the electricity price, which is a consequence of the various flexibility events provided by the platform. Energy provider is an entity who offers energy management and energy commercialization services. SATO will allow energy providers to provide flexibility services (e.g., through the introduction of dynamic tariffs to consumers). DSOs are responsible for the operation and the maintenance of the electric distribution grid. The SATO platform will allow DSO to obtain flexibility through the local market and guarantee the security and quality of supply. The DSO can also detect problems at the low voltage level where there are greater control difficulties. The TSO is responsible for transporting energy from energy producers to the distribution system, usually carried out at high voltage and very high voltage. TSO's capability to manage energy flows will enable them to use

	new optimization and techniques of energy flow. In this way, the TSO will be allowed to request more detailed information on the available energy flexibility which will result in a more stabilized grid.

4.2. Software/Services

The software and service actors were defined as any modular, self-contained, software functional unit that continuously performs a task that provides value to diverse receivers and actors. Table 4 presents the software and service actors identified in the SATO project, along with a brief description of each actor and its role in SATO.

Table 4: Description and role of identified software and service actors.

Software/Service	Description	Baseline technologies
SATO platform	Cloud based software/hardware that support data exchange with IoT enabled devices, SA&O and SRI framework, along with, the creation of an open competitive market for third party development of energy management services for residential and service buildings. Introduce a standardized web-service REST interfaces and APIs that will use a common communication framework.	EDP re:dy; Siemens TWIN; Internet-of-Things (IoT); EEBus SHIP SPINE stack; MQTT;
SATO APP	App-based interface that combines building equipment control and information services into user interaction services. Resort to gamification techniques within the user-interaction with the building energy performance schema to engage users and promote product uptake.	Android; iOS; Python
SATO self-assessment framework (SAF)	Automated real-time performance assessment displaying information on building and energy consuming equipment performance, considering the impact categories related to energy efficiency, energy flexibility, comfort, and health and wellbeing. Compatible with SRI, whilst adding the ability to move from a theoretical to a real and dynamic building performance assessment.	R; PyTorch; Communication protocols

SATO self-optimization service (SOS)	Using the SAF results, optimizes the operation of energy consuming devices while safeguarding the needs of the occupant/user needs.	R; PyTorch; Scikit learn; TensorFlow;
SATO APL	Provide data for SAF framework, for systems with short life cycles.	EDP re:dy; Google nest; Apple Homekit
SATO BMS	Provide data for SAF framework, for systems with long life cycles.	Siemens TWIN; Google nest; Apple Homekit
Flexibility Management Service (FMS)	Provides demand side flexibility, and so, improves load balancing for DSOs and TSOs. User centred design, ensuring an active part of the control loop by providing incentives and rewards for system flexibility enhancing behaviour.	SATO platform; SATO APP; SAF; SOS;
Web based interface	Residential visual interface to consumers input their requirements, control energy consumption, and assess the impact of their decisions.	Web app; SATO APP; SATO APL;
BIM model	Aggregated and disaggregated analysis and visualization of the assessments in non-residential buildings of the various applicable scales, setting locations and specifications of energy consuming equipment, sensors, and actuators.	CYPE BIM; SATO APP; SATO BMS;

5. Identify the desired level of user interaction with the system in different building types

A web-based survey questionnaire was designed to evaluate the current and the desired level of user interaction with the energy systems in buildings and identify the user needs. The questionnaire was divided into three parts (one for each human actor, see Table 3). Each part was conceived with specific questions to characterize the given human actor. In total, the questionnaire consisted of 52 questions (see Table 5).

Originally, this questionnaire was developed in English so that it could be reviewed by all partners. Then, the reviewed version of the questionnaire was translated into the native language of each partner: Portuguese, Spanish, German, Italian and Danish. The six versions of the questionnaire were implemented in Google Forms.

The online survey was deployed on February 18th and was available during a three-week interval that ended on March 10th. To meet data-privacy requirements, the survey remained anonymous, and no personal identification was collected. Overall, the questionnaire had a total of 105 responses.

The project includes eight pilots in three climate regions. The Mediterranean region is considered as a warm climate region (Portugal and Spain), central Europe as intermediate climate region (Austria and Italy) and finally northern Europe as a cold climate region (Denmark). However, the results of the questionnaires did not show any significant trends regarding the different climates assessed.

Table 5: Summary of the 52 survey questions with the identification of the human actor.

#	Survey question	Quest ID	Actor
1	Age	1.1	All human actors
2	Which option best describes you?	1.2	All human actors
3	Do you operate any energy systems in a service building?	2.1	Service building occupant
4	What type of control do you have over the energy systems?	2.2	Service building occupant
5	How often do you use your energy systems?	2.3	Service building occupant
6	Which management tools do you use with your energy systems?	2.4	Service building occupant
7	How satisfied are you with your degree of the energy systems' control?	2.5	Service building occupant
8	What makes you environmentally uncomfortable in buildings?	3.1	Service building occupant
9	Would you like to have an interface with multiple energy systems integrated?	3.2	Service building occupant
10	Which energy systems would you like to aggregate in that interface?	3.3	Service building occupant
11	What are the barriers that prevent the widespread use of interfaces in the building energy devices and systems sector?	4.1	Service building occupant
12	Choose the most important features in an interface for your energy systems.	5.1	Service building occupant
13	What is the most appropriate time step for data acquisition?	5.2	Service building occupant
14	In which platform would you prefer to use an interface?	5.3	Service building occupant
15	Do you operate any energy systems in a residential building?	6.1	Residential building occupant
16	What is the building configuration that you manage?	6.2	Residential building occupant

17	What type of control do you have over the energy systems?	6.3	Residential building occupant
18	How often do you use your energy systems?	6.4	Residential building occupant
19	Which management tools do you use with your energy systems?	6.5	Residential building occupant
20	How satisfied are you with your degree of the energy systems' control?	6.6	Residential building occupant
21	What makes you environmentally uncomfortable in buildings?	7.1	Residential building occupant
22	Would you like to have an interface with multiple energy systems integrated?	7.2	Residential building occupant
23	Which energy systems would you like to aggregate in that interface?	7.3	Residential building occupant
24	What are the barriers that prevent the widespread use of interfaces in the building energy devices and systems sector?	8.1	Residential building occupant
25	Choose the most important features in an interface for your energy systems.	9.1	Residential building occupant
26	What is the most appropriate time step for data acquisition?	9.2	Residential building occupant
27	In which platform would you prefer to use an interface?	9.3	Residential building occupant
28	Is there any comment, suggestion or advice that you would like to make regarding this questionnaire or the SATO platform interface?	10.1	Service/Residential building occupant
29	What is the type of building that you manage?	11.1	Building manager
30	What is the floor area (in square meters) of the building that you manage?	11.2	Building manager
31	What type of control do you have over the energy systems?	12.1	Building manager
32	How often do you interact with your energy systems?	12.2	Building manager
33	Which management tools do you interact with your energy systems?	12.3	Building manager
34	How satisfied are you with your degree of the energy systems' control?	12.4	Building manager
35	What drives your control actions?	13.1	Building manager
36	Would you like to have an interface with multiple energy systems integrated?	13.2	Building manager
37	Which energy systems would you like to aggregate in that interface?	13.3	Building manager

38	What are the barriers that prevent the widespread use of interfaces in the building energy devices and systems sector?	14.1	Building manager
39	Choose the most important features in an interface for your energy systems.	15.1	Building manager
40	Which type of flexibility managements tools would you like to have access in the interface?	15.2	Building manager
41	What is the most appropriate time step for data acquisition?	15.3	Building manager
42	Grade the importance of having an interface feature to display the amount of power available for flexibility management.	15.4	Building manager
43	In which platform would you prefer to use an interface?	15.5	Building manager
44	Is there any comment, suggestion, or advice that you would like to make regarding this questionnaire or the SATO platform interface?	16.1	Building manager
45	Which type of grid operator are you?	17.1	Grid operator
46	Grade the importance for the electric grid to have buildings with flexible energy consumption.	17.2	Grid operator
47	Choose the most important features in an interface to respond to electrical grid requests.	18.1	Grid operator
48	How often do you think to be appropriate the communication between the interface and the electric grid?	18.2	Grid operator
49	How often would you like to have data for each energy system?	18.3	Grid operator
50	Which appliances would you like to have an aggregate information of their power consumption?	18.4	Grid operator
51	In which platform would you prefer to use an interface?	18.5	Grid operator
52	Is there any comment, suggestion, or advice that you would like to make regarding this questionnaire or the SATO platform interface?	19.1	Grid operator

In our sample there was an underrepresentation of people younger than 20 years old and older than 60 years old. The most prevalent age group of respondents was 21-40 years old (60%), followed by the age group between 41-60 years old (33.3%) and lastly 6.7% of respondents answered that they were over 60 years old. None of the respondents were under 20 years old.

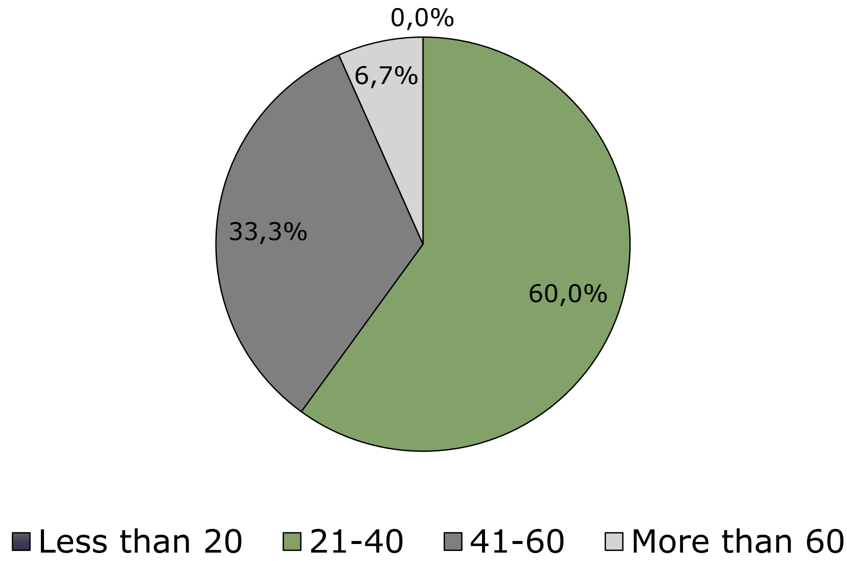

Figure 2: Age (Question 1.1)

The targets of the project are service/residential building occupants, building owner/managers or facility managers, and grid operators.

Therefore, each interviewee identified which option best describes them. This question triggered a specific questionnaire for each user profile. We collected 70 responses from residential/service building occupants (66.7%), 26 responses from building managers (24.8%) and 9 responses from grid operators (8.6%).

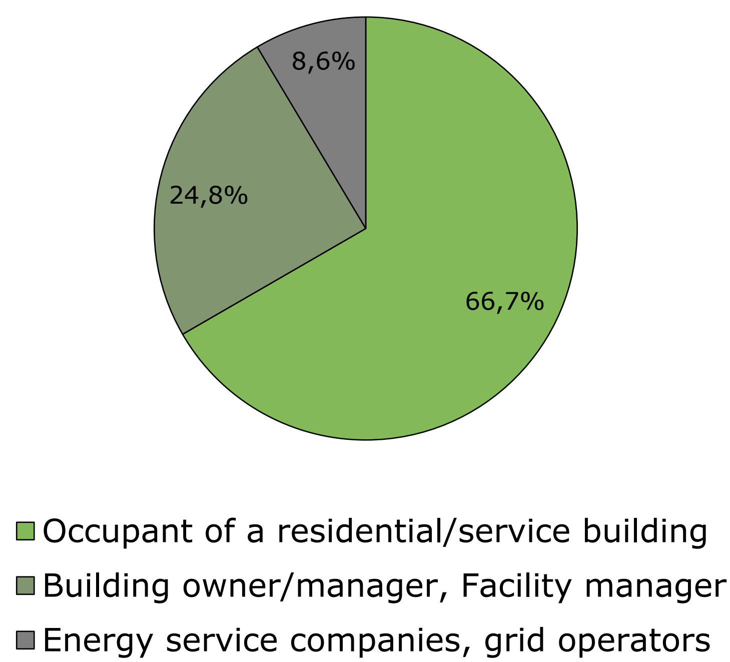

Figure 3: 1.2 - Which option best describes you? (Question 1.2)

5.1. Occupant of a residential/service building

5.1.1. Service building occupants

Of the surveyed occupants, only about 36% operate energy systems in service buildings (Figure 4). If the respondent answered that they do not operate the energy systems, one would proceed to the residential occupants' questionnaire.

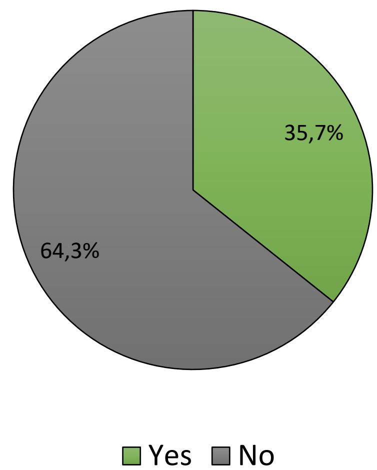

Figure 4: Do you operate any energy systems in a service building? (Question 2.1)

The questionnaire started by asking what type of control each user had over each energy systems in a service building to understand the level of digital control users currently have. Disaggregated results per energy system are shown in Figure 5. One can observe that both EV charging stations and the PV systems are still not available to most of the respondents. In general, the remaining energy systems are manually controlled. The energy systems with the highest level of digital control are heating, cooling, and lighting.

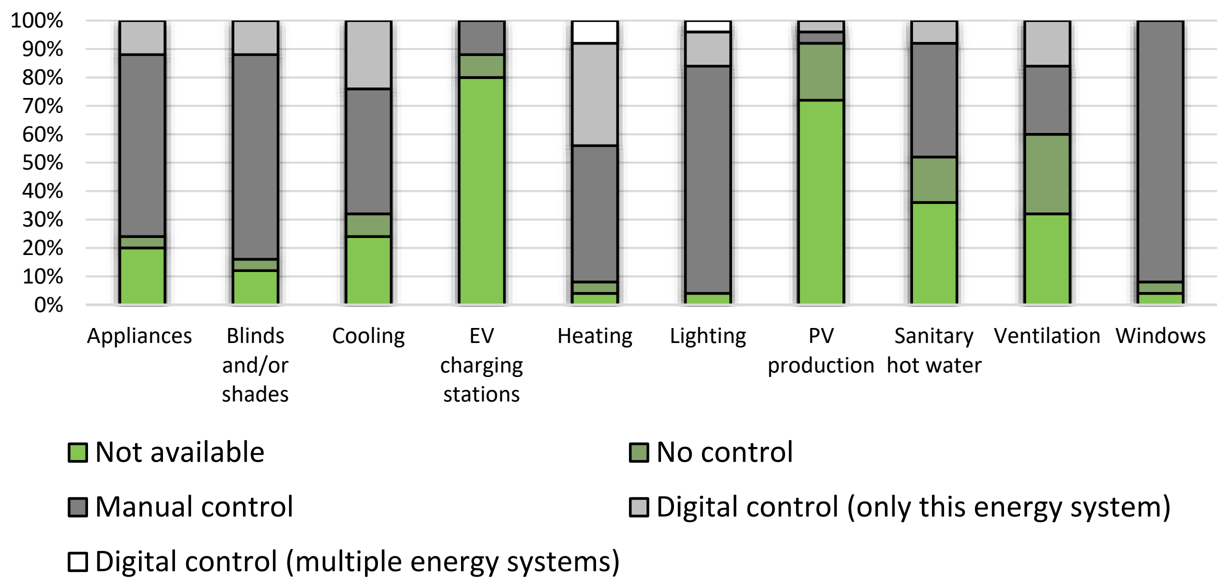

Figure 5: What type of control do you have over the energy systems? (Question 2.2)

Figure 6 shows the same results presented in Figure 5, but aggregating all energy systems and dividing them by the type of control. It is worth noting the residual adoption of solutions with digital control over multiple energy systems (white bar).

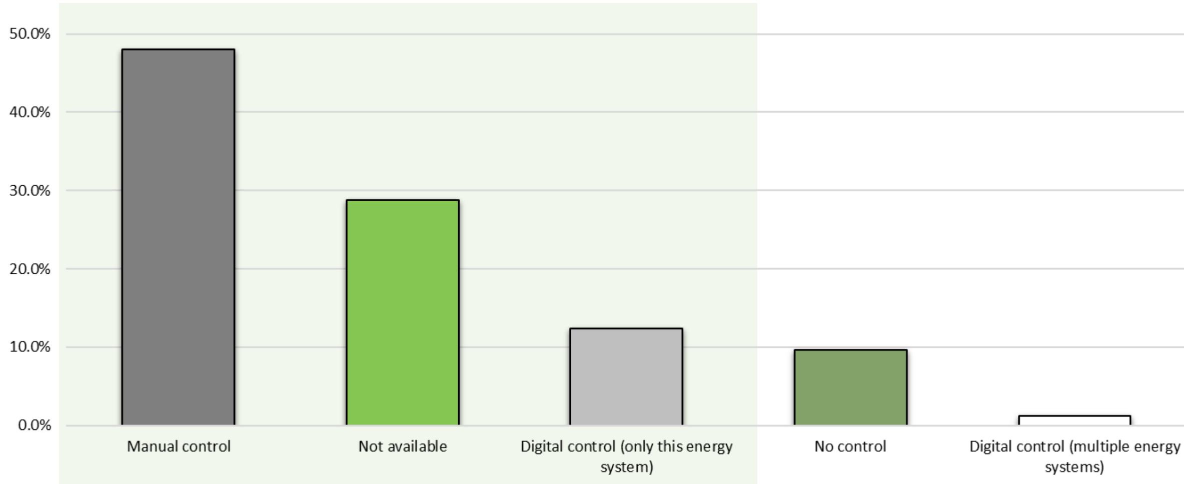

Figure 6: Average of all energy systems (from Figure 5) for each type of control option.

To assess the current level of interaction of respondents with the energy systems, occupants were asked about how often they use these systems (Figure 7). As concluded in the previous question (see Figure 5), few of the respondents have EV charging stations or PV systems, and as a consequence the option 'Not applicable' has a strong preponderance in these energy systems. Apart from that, lighting, blinds and/or shades and windows handling are the most used energy systems on a daily basis. Appliances and air conditioning systems (heating and cooling) have the highest percentage of weekly usages.

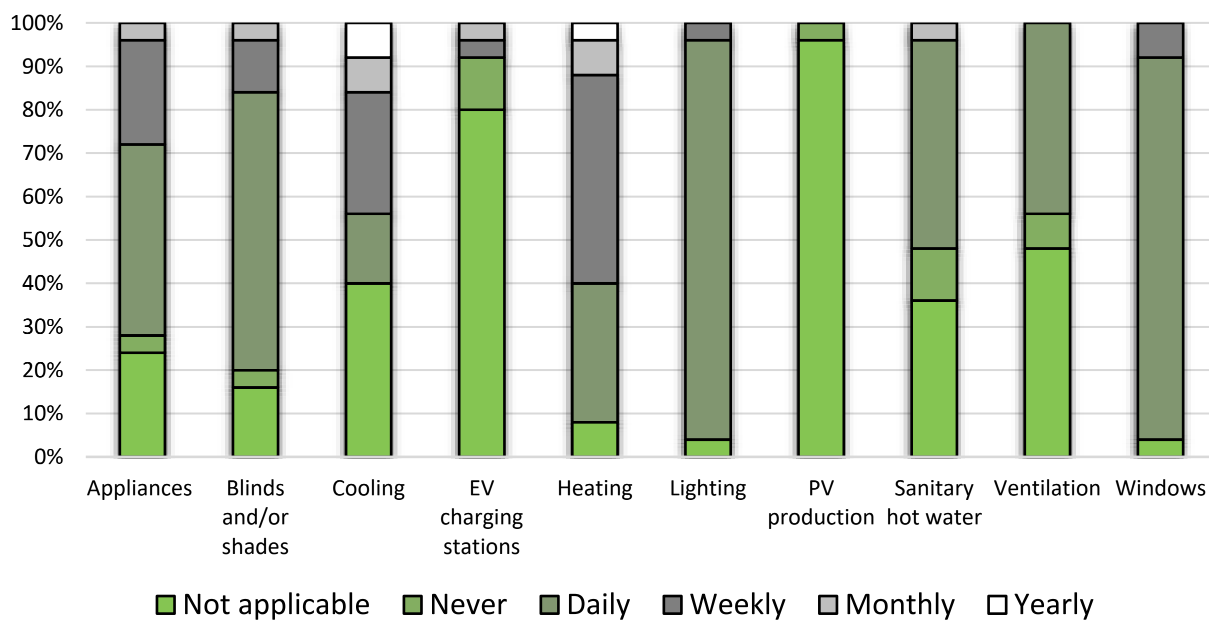

Figure 7: How often do you use your energy systems? (Question 2.3)

To assess how often an occupant will interact with an interface to manage multiple energy systems, we have aggregated the information from Figure 7 in Figure 8 by averaging all energy systems for each frequency of use. It can be concluded that 43% of the respondents would daily control their energy systems and, consequently, use the SATO interface on a daily basis.

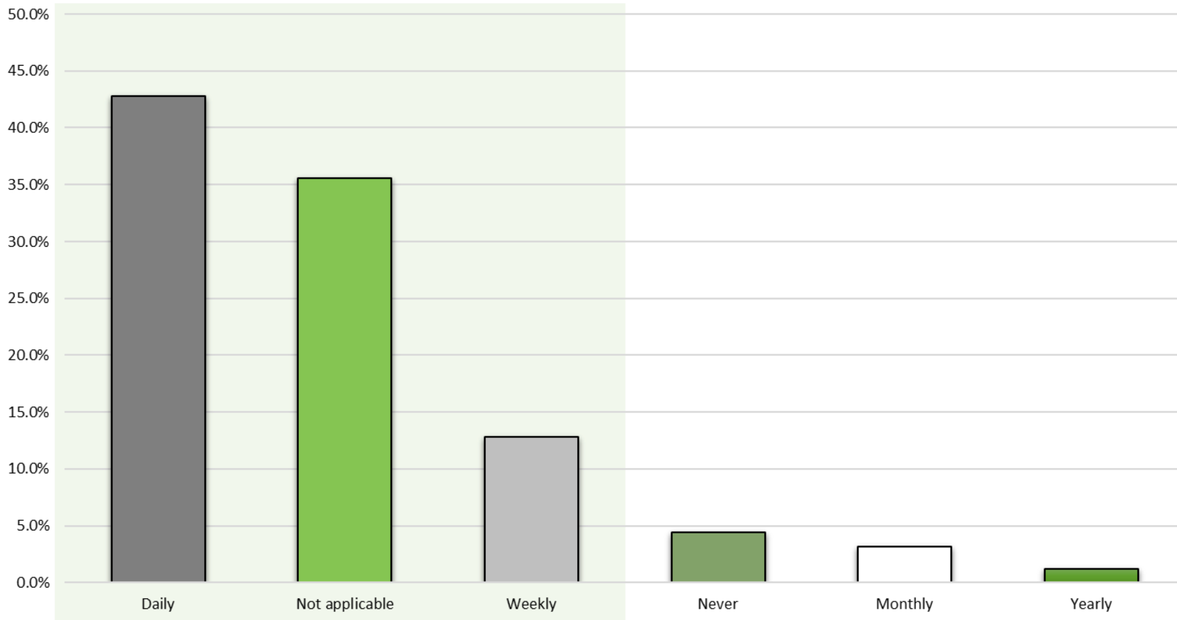

Figure 8: Average of all energy systems (from Figure 7) for each type of frequency option.

Figure 9 shows the different management tools that occupants use to interact with the available energy systems. Most of the users do not use any tool (30%) or only use on-device controls (25%) to manage the energy systems. This was already expected given the high percentage of users that manually control the energy systems (see Figure 6).

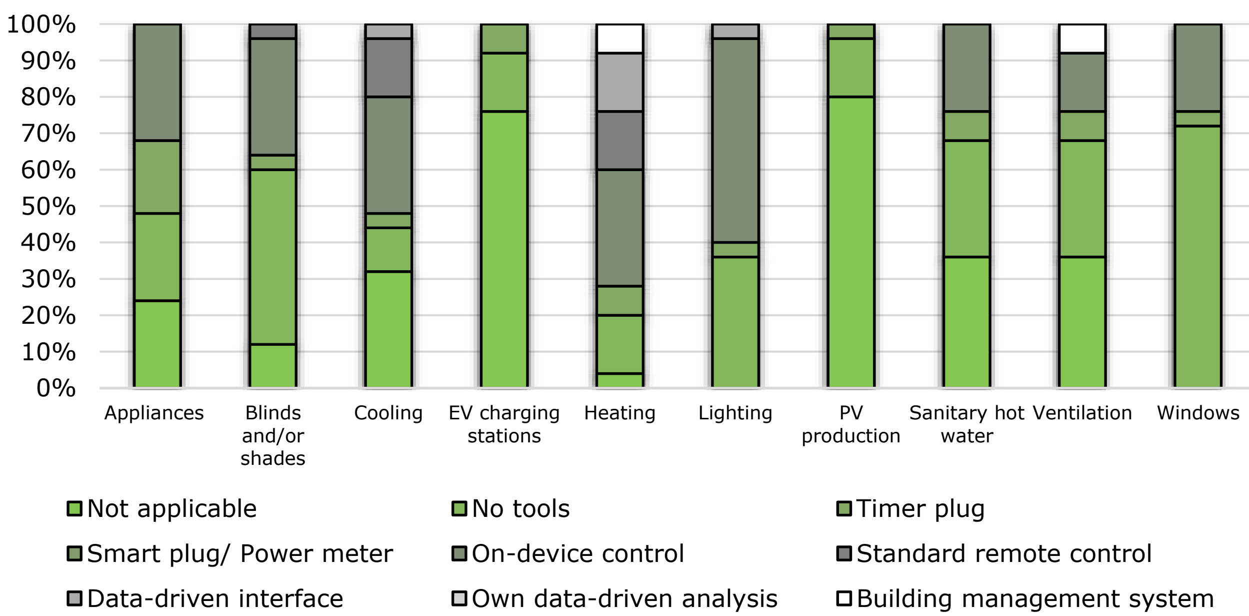

Figure 9: Which management tools do you use with your energy systems? (Question 2.4)

From Figure 10, one may conclude that regular occupants of service buildings do not use complex interfaces (such as, BMSs, DDIs and ODDAs). This was already expected because these buildings often have facility managers responsible for the operation and management of the energy systems, usually using a centralized monitoring system.

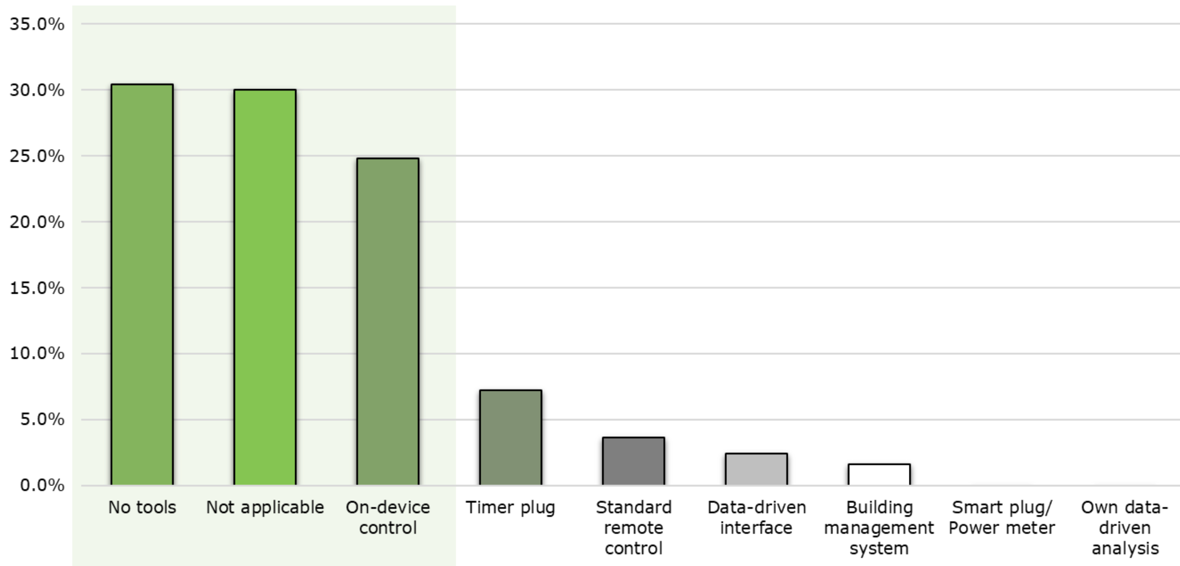

Figure 10: Average of all energy systems (from Figure 9) for each type of management tool.

Figure 11 and Figure 12 show how satisfied respondents are with the degree of control of the energy systems. Results showed that the majority of the occupants are satisfied with their current level of control of the energy systems. Less than 10% of the occupants felt that their level of control is poor or very poor. Respondents seemed to be less satisfied with the control of the heating system.

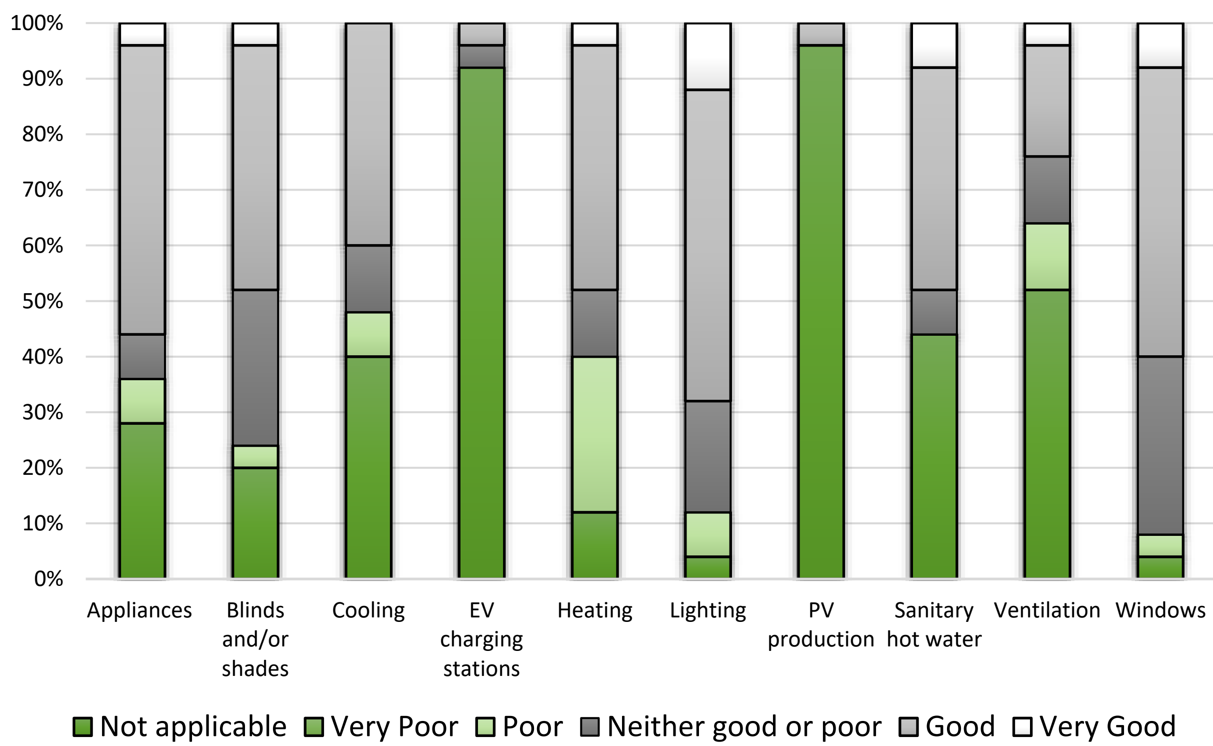

Figure 11: How satisfied are you with your degree of the energy systems' control? (Question 2.5)

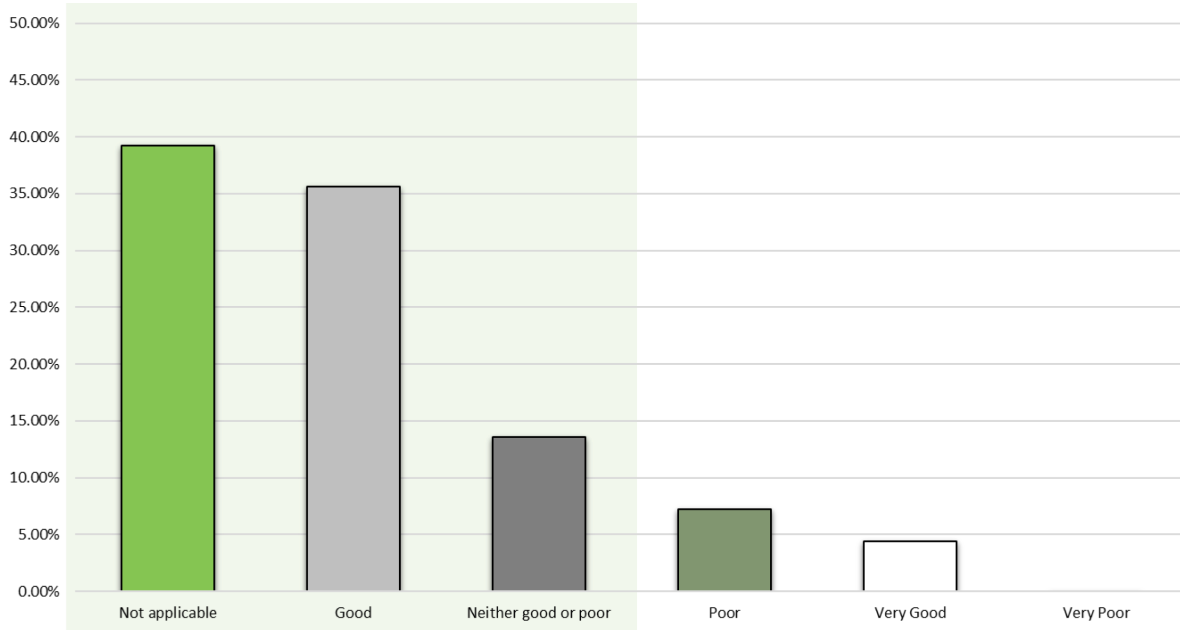

Figure 12: Average of all energy systems (from Figure 11) for each type of satisfaction degree.

Figure 13 illustrates the most important sources of discomfort for service building occupants. As we expected, thermal and visual comfort are the main drivers for user's action, therefore, extreme temperatures during the summer and winter seasons and the improper level of lighting were mentioned as being the biggest sources of discomfort.

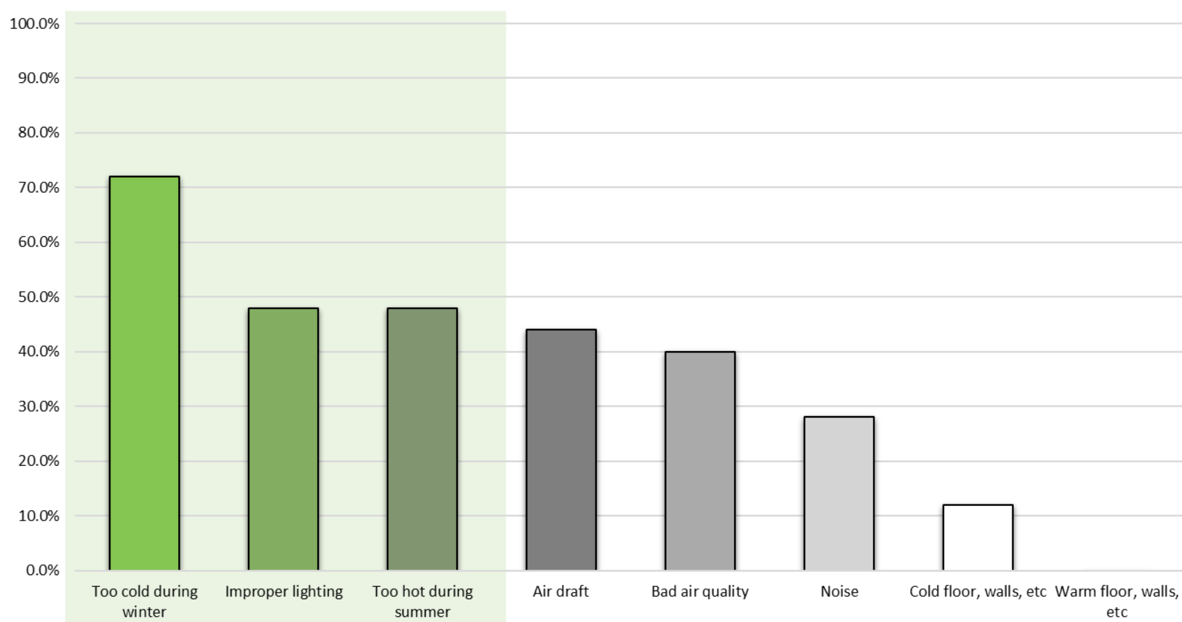

Figure 13: What makes you environmentally uncomfortable in buildings? (Question 3.1)

With the knowledge that currently few service building occupants have digital controls we sought to understand whether occupants would like to have such functionality in an interface. As Figure 14 illustrates, 80% of respondents answered that they would like to have an interface with this functionality.

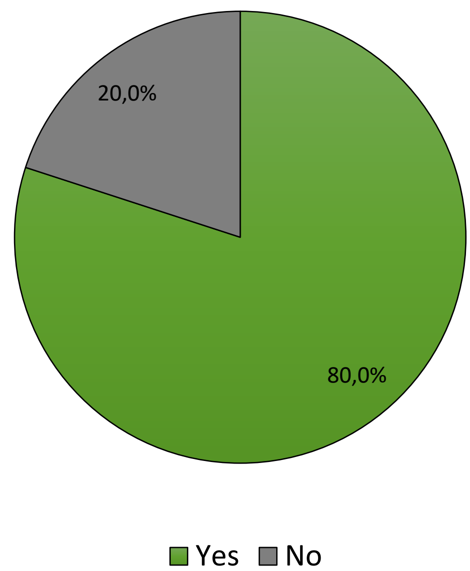

Figure 14: Would you like to have an interface with multiple energy systems integrated? (Question 3.2)

The project will develop and demonstrate solutions that integrate power devices in the SATO management platform for self-assessment and optimization. In this way, it is intended to understand which energy systems the users would prefer to add on a single platform. As shown in Figure 15 the HVAC and lighting systems were the most selected energy systems followed by mechanical ventilation and automated blinds and/or shades. If we compare this information with Figure 7 we can see that the most frequently used energy systems are the same systems that occupants intend to aggregate in an interface.

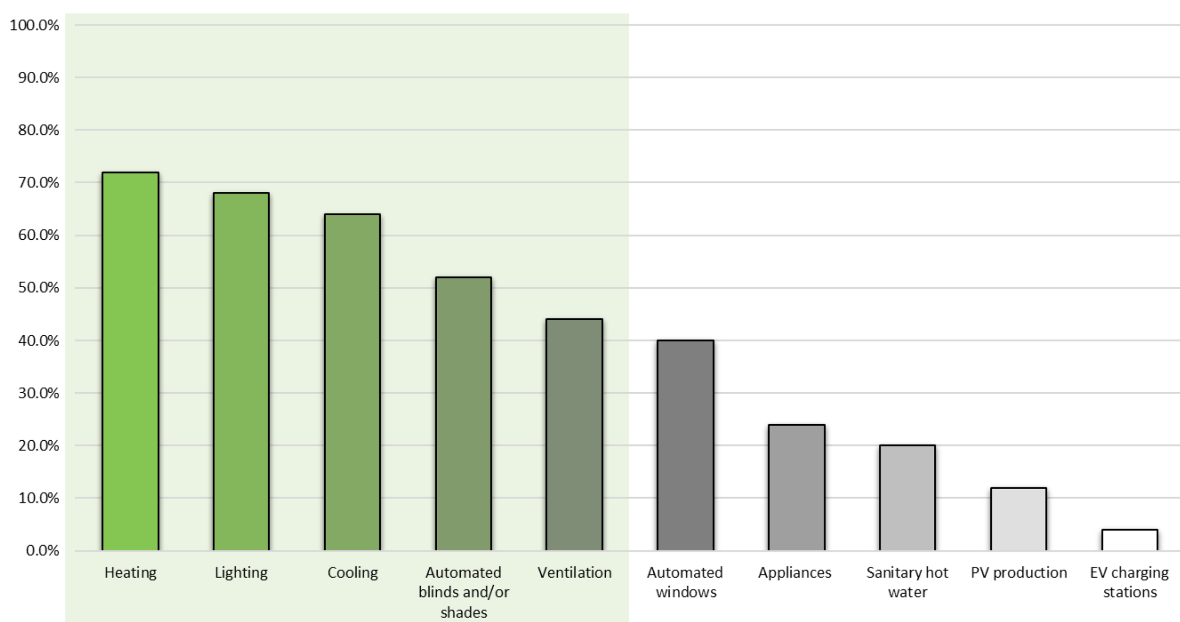

Figure 15: Which energy systems would you like to aggregate in that interface? (Question 3.3)

Figure 16 shows that the main barrier identified by service building occupants for market uptake of a platform like SATO were expensive solutions, lack of planning and/or implementation and lack of technical expertise. Expensive solutions are the option most chosen by the occupants (80%), so we can infer that an economically viable solution will have a greater acceptance.

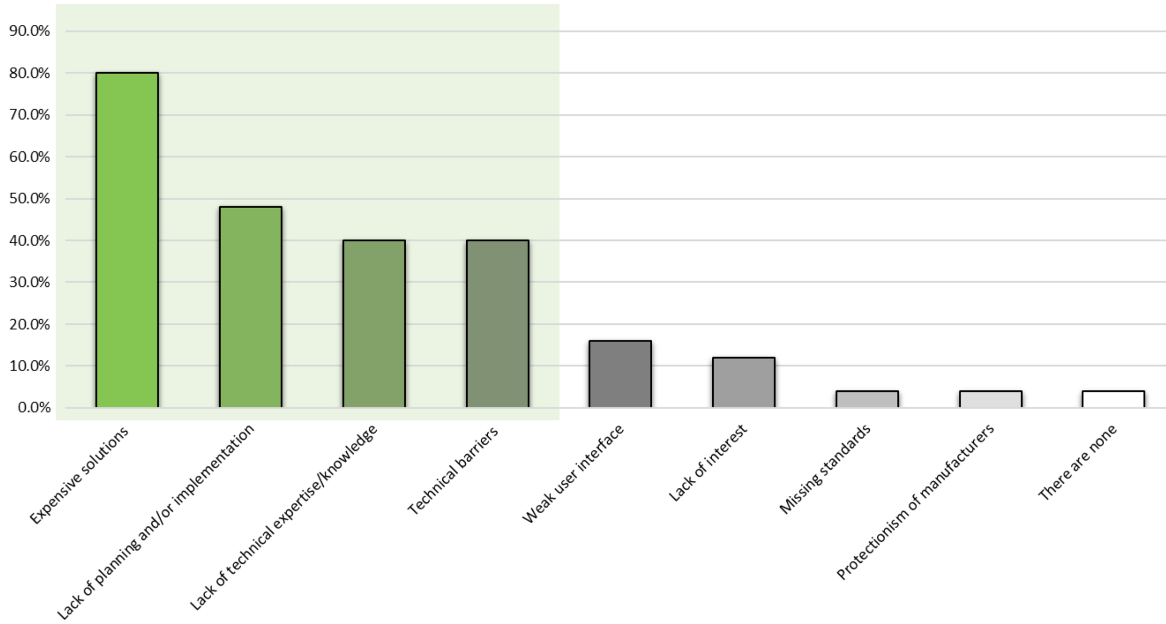

Figure 16: What are the barriers that prevent the widespread use of interfaces in the building energy devices and systems sector? (Question 4.1)

Among the feature options available for an interface, the respondents seem to give more importance to the ease of use of the interface and to the information of the energy consumed in real-time. Thermal comfort monitoring, automated control over the energy systems and a historical database of energy consumption are also options that respondents have high interest to have these features in an interface (Figure 17). It is interesting to see that Respondents reported a lack of interest about the outdoor environment information.

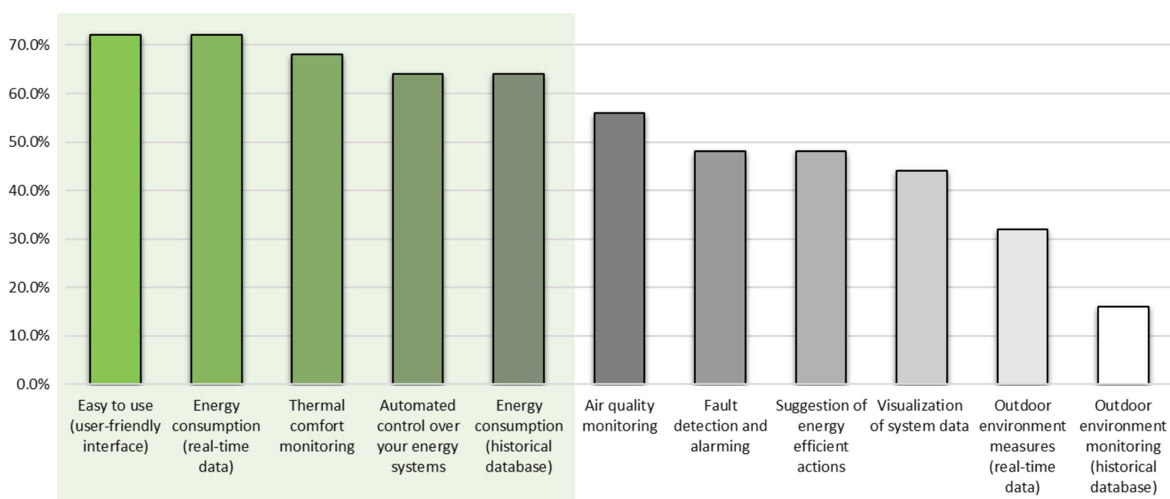

Figure 17: Choose the most important features in an interface for your energy systems. (Question 5.1)

In order to understand the desired detail of information, the most appropriate time interval for data acquisition was asked. The results show that most of the respondents prefer to receive the information in time steps under 15 minutes. There is no marked discrepancy between the options chosen for each energy system (see Figure 18).

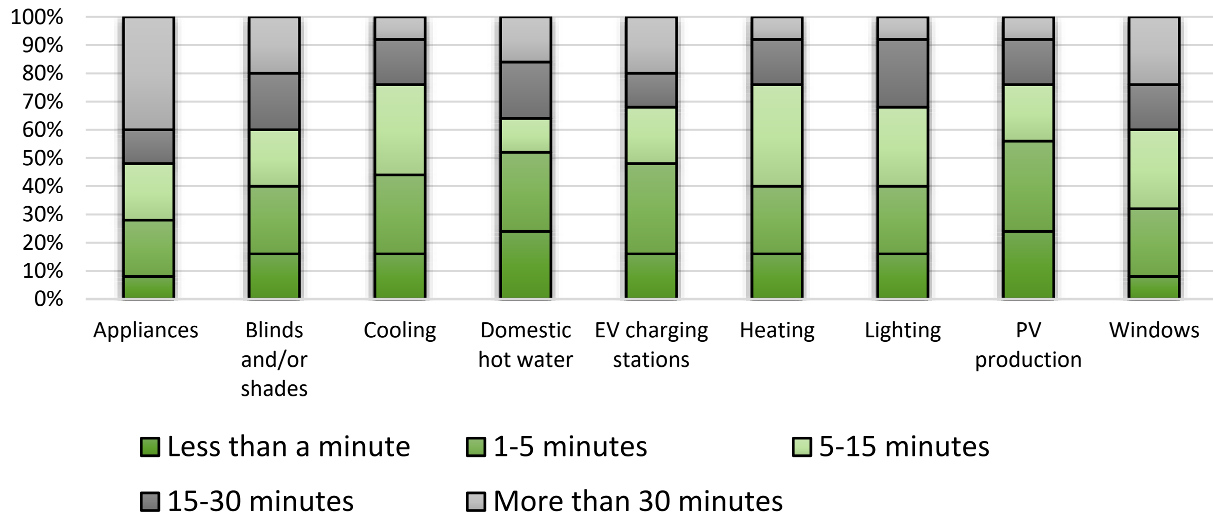

Figure 18: What is the most appropriate time step for data acquisition? (Question 5.2)

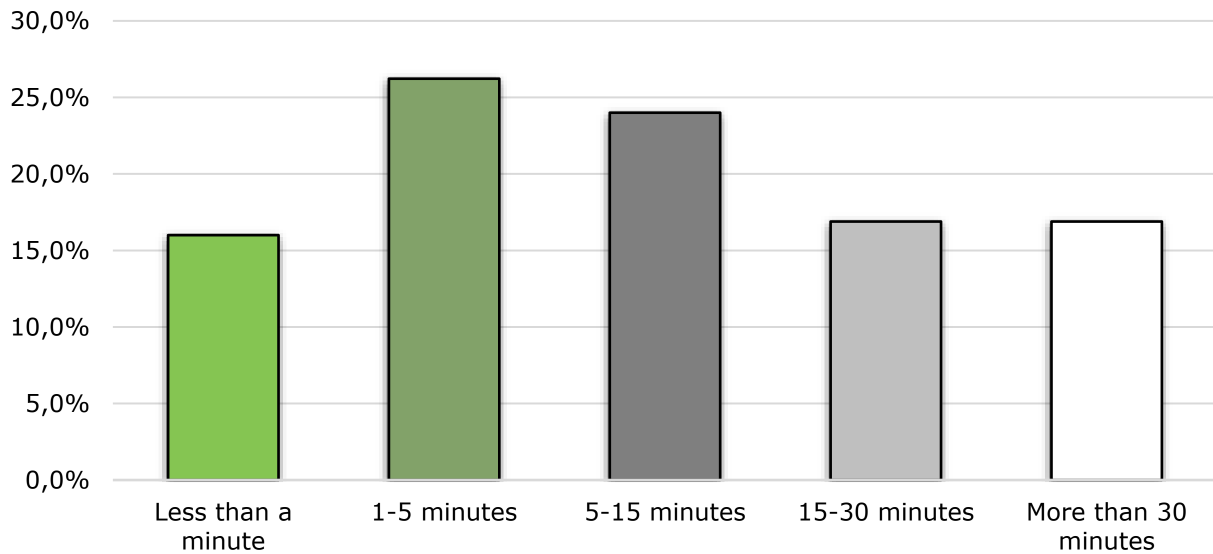

Figure 19: Average of all energy systems (from Figure 18) for each time step option.

The SATO project will provide a web-based platform and will also create a mobile application that combines building equipment control and information services. Thus, it was sought to know what are the users' preferences in relation to the interface. It was concluded that two thirds of the interviewees prefer to have both types of interface as it is shown in Figure 20. In addition, 32% of respondents prefer to have only one application-based platform. The sample of respondents, only 4% would like to have just a web-based platorm.

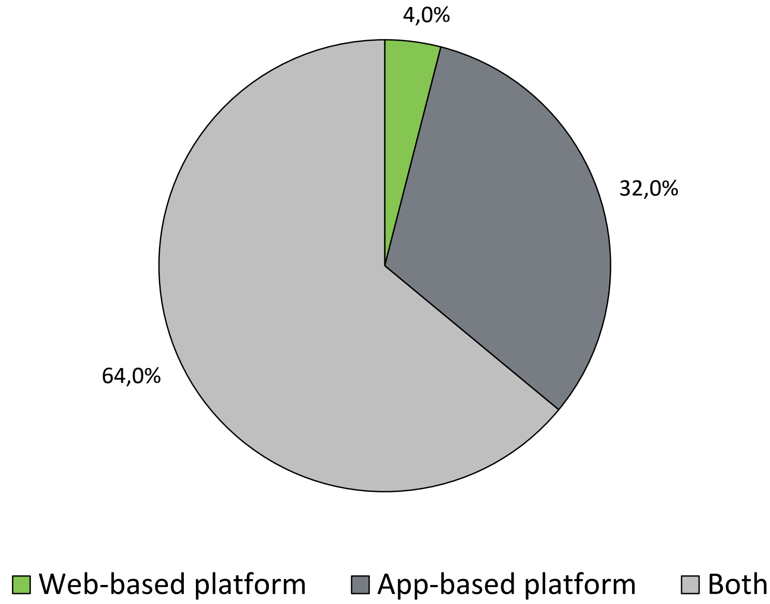

Figure 20: In which platform would you prefer to use an interface? (Question 5.3)

5.1.2. Residential building occupants

Through the analyzes of the survey for residential building occupants it is possible to conclude, as shown in Figure 21, that approximately two thirds (63%) of the occupants operate energy system in buildings. Among building configurations (see Figure 22), the most common building types are apartments (53%), and detached houses (36%), while the less common are semi-detached houses (7%) and small rooms (5%).

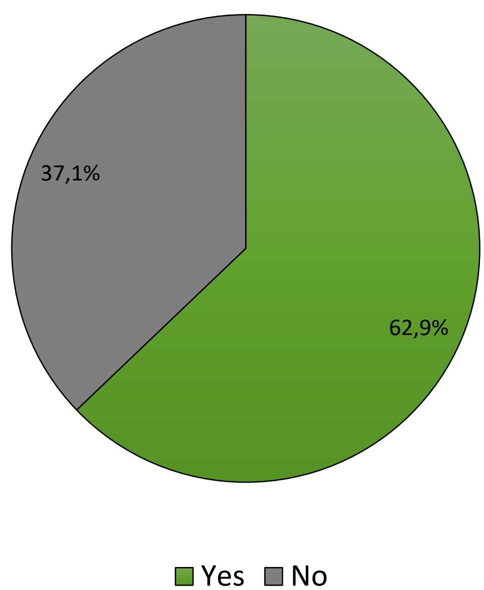

Figure 21: Do you operate any energy systems in a residential building? (Question 6.1)

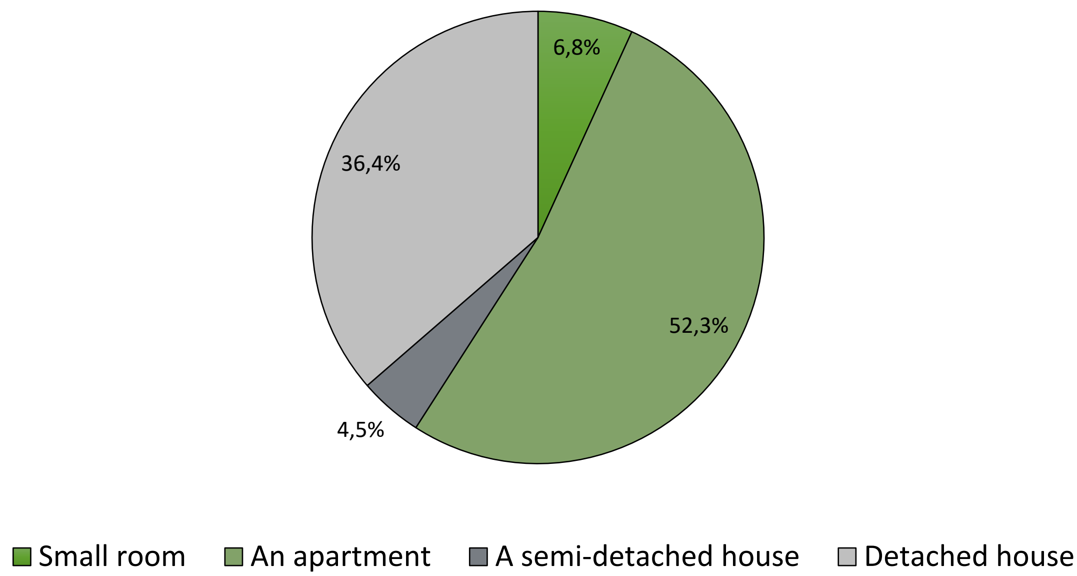

Figure 22: What is the building configuration that you manage? (Question 6.2)

From Figure 23 it is possible to conclude that, for the analyzed sample, EV charging stations and PV production are technologies with low level of implementation, also the implementation levels of ventilation and cooling systems are surprisingly low, 40% and 50%, respectively. The controls of these energy services tend to have any or manual controls.

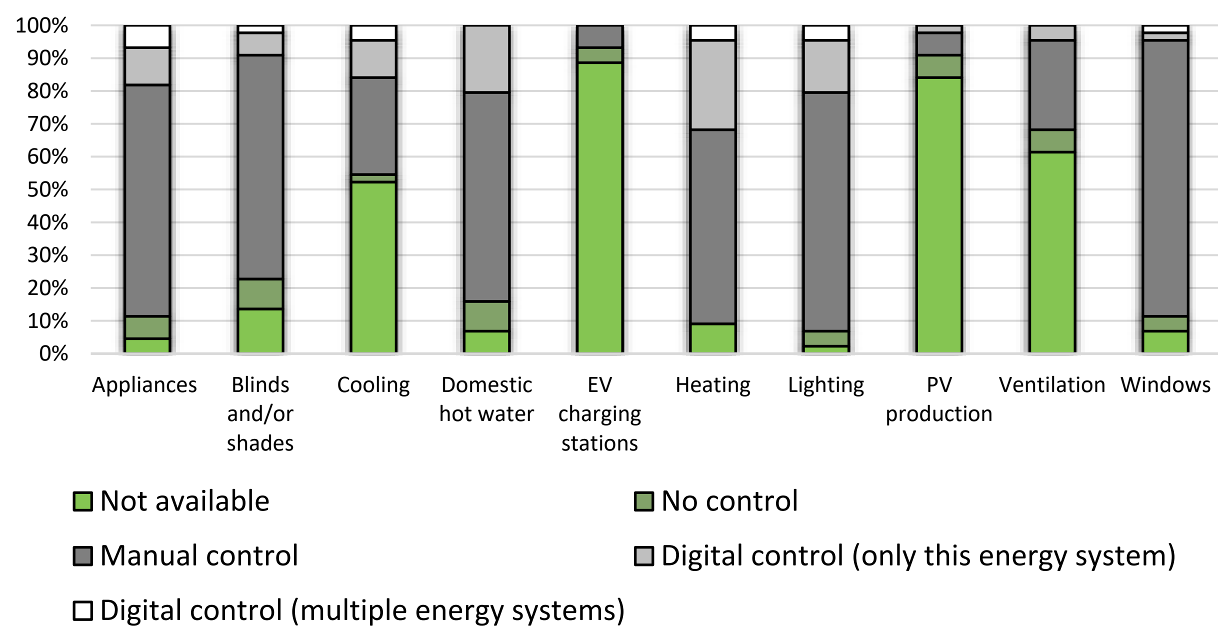

Figure 23: What type of control do you have over the energy systems? (Question 6.3)

In terms of control, it is possible to infer that for all energy systems the major type of control is manual control (see Figure 24). It is interesting to realize that digital control (considering only one energy system) tends to supplant the "no control" option, except for the blinds and/or shades, ventilation, and windows. Similar to service building occupants, the implementation level of digital control (considering multiple energy systems) within the residential building occupants is residual (<5%).

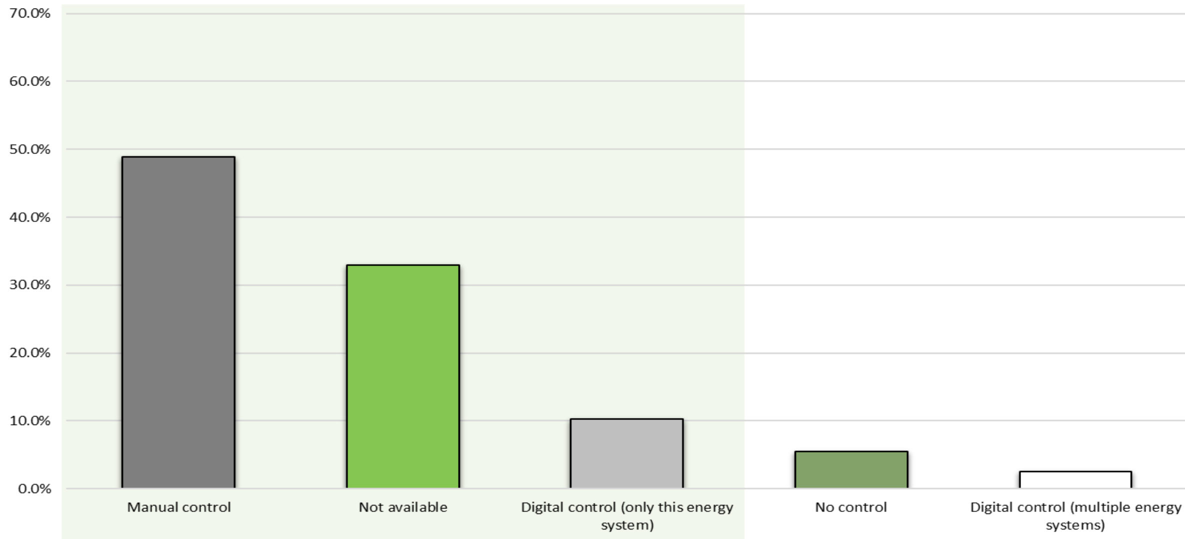

Figure 24: Average of all energy systems (from Figure 23) for each type of control option

As shown in Figure 25 and Figure 26, appliances, blind and/or shades, domestic hot water, lighting, and windows mostly tends to be operated on a daily basis. This conclusion was expected due to the daily interaction of the inhabitants in residential buildings with these energy systems (e.g., take a shower, etc.).

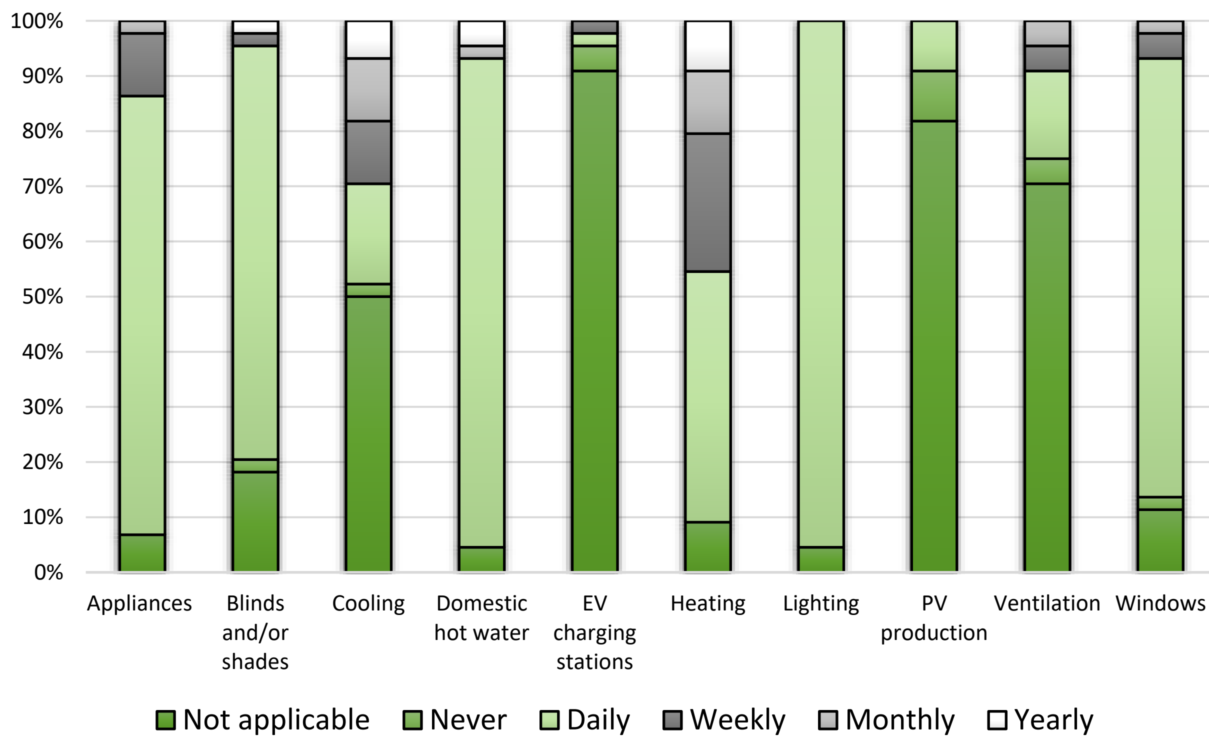

Figure 25: How often do you use your energy systems? (Question 6.4)

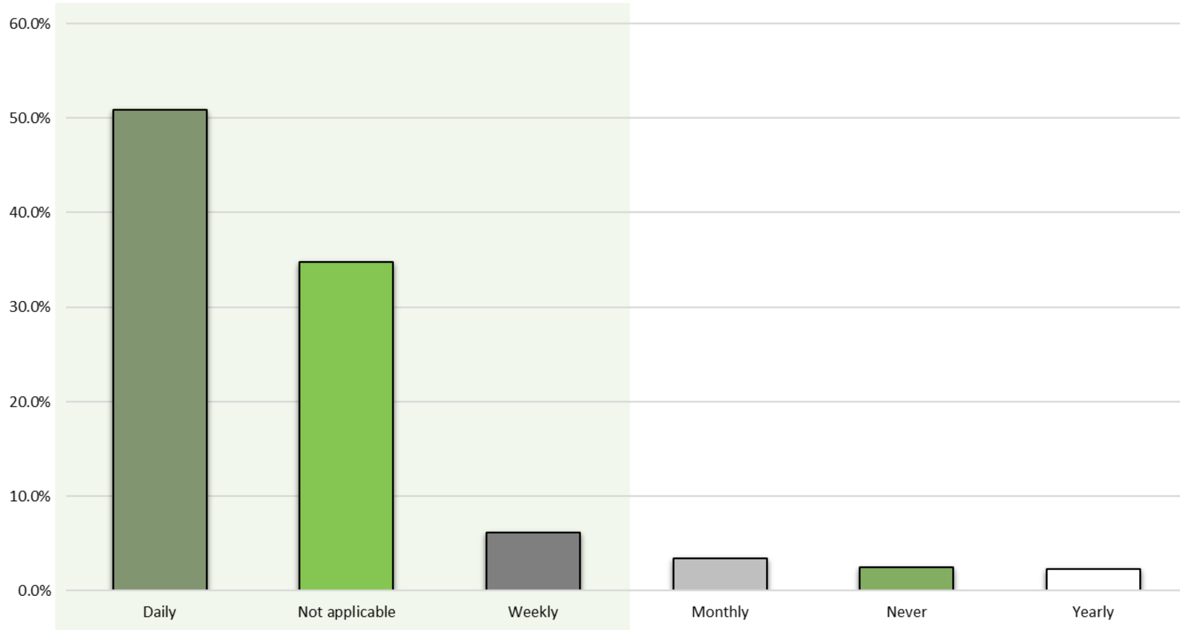

Figure 26: Average of all energy systems (from Figure 25) for each type of frequency option.

Figure 27 and Figure 28 show the management tools used to control the energy systems. Results show that 37% of the residential users have no tools to control their energy systems and 15% of users have only on-device control. The most advanced interfaces (BMSs, DDIs and ODDAs) are clearly the least present management tools, with less than 5%.

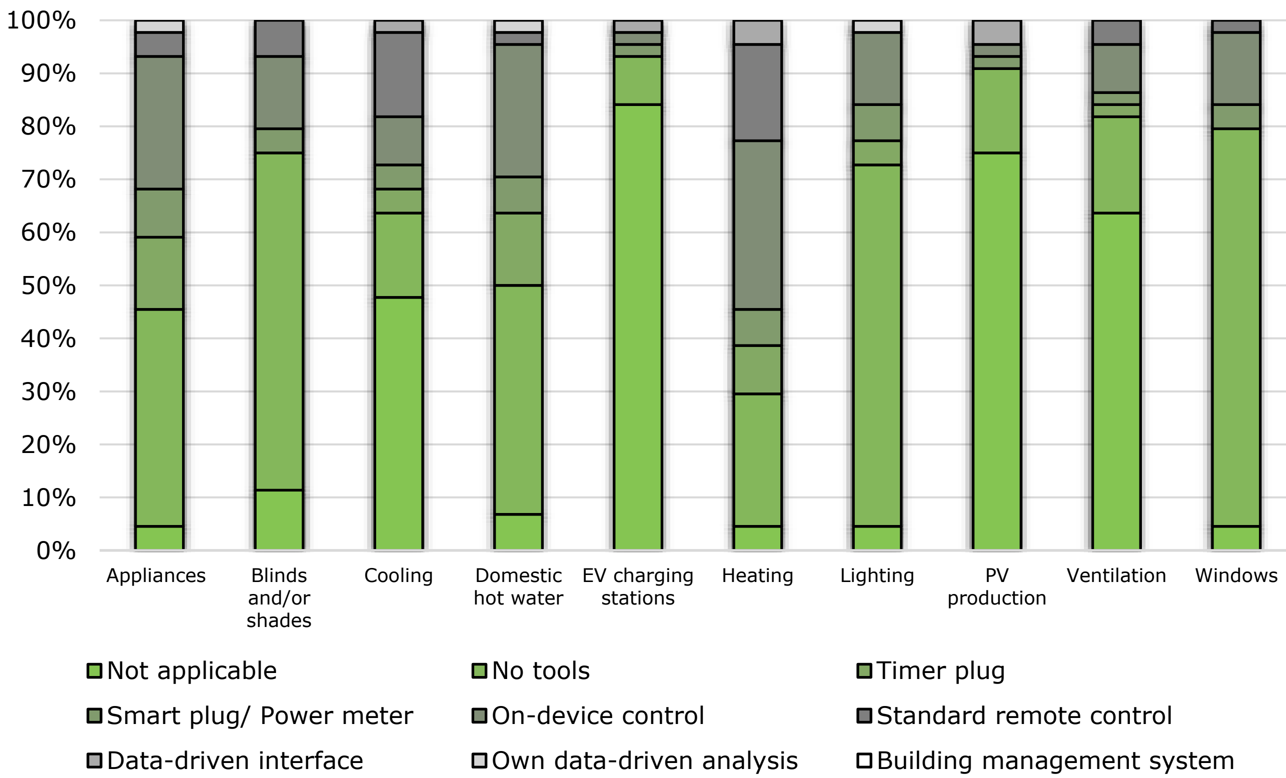

Figure 27: Which management tools do you use with your energy systems? (Question 6.5)

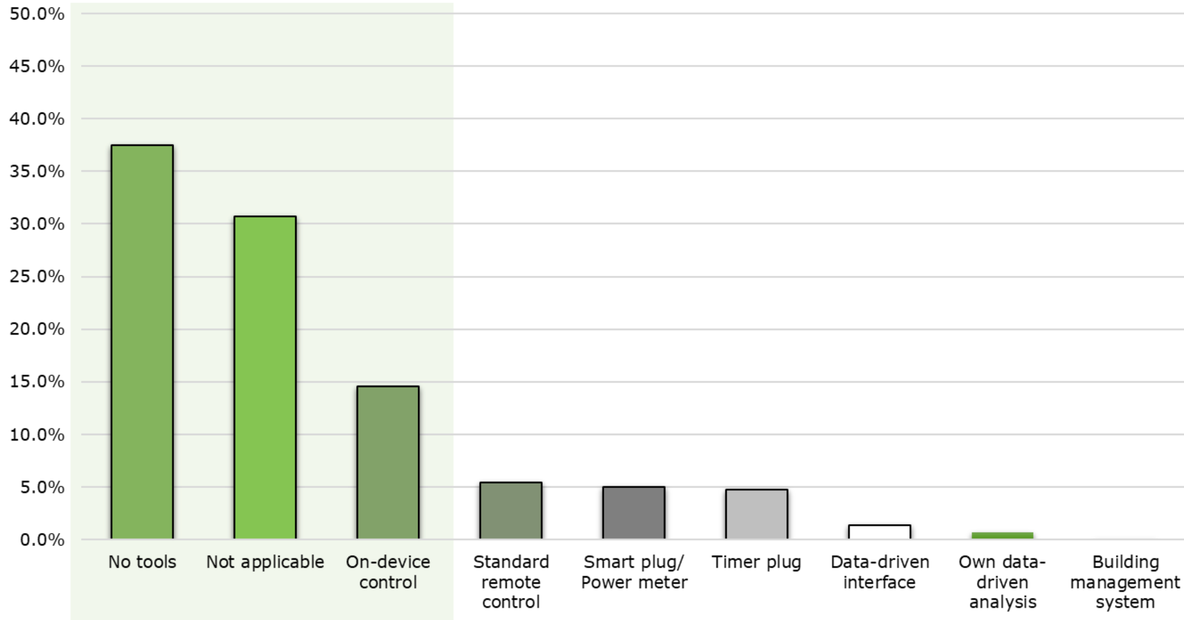

Figure 28: Average of all energy systems (from Figure 27) for each type of management tool.

In terms of satisfaction (Figure 29 and Figure 30), only 35% of the respondents are satisfied with the degree of control of their energy systems. However, it is worth noting that the more than 50% of the users consider that have a good or very good degree of control over appliances, blind and/or shades, and windows.

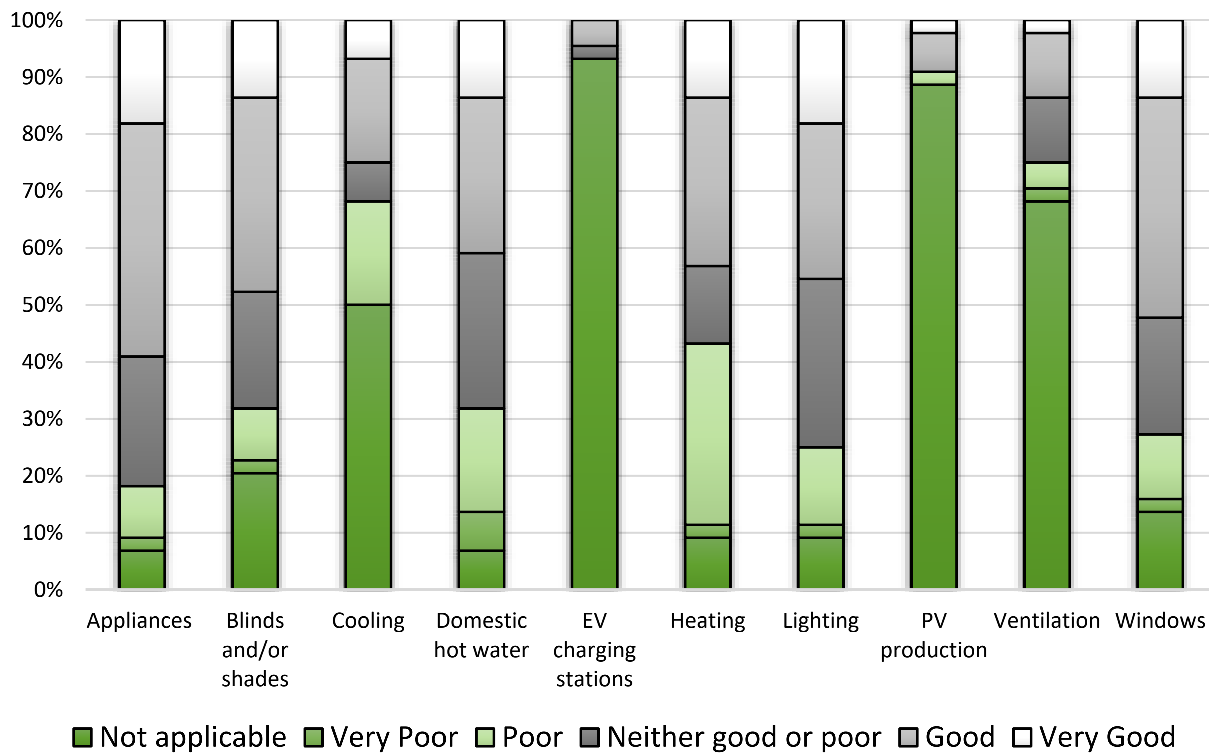

Figure 29: How satisfied are you with your degree of the energy systems' control? (Question 6.6)

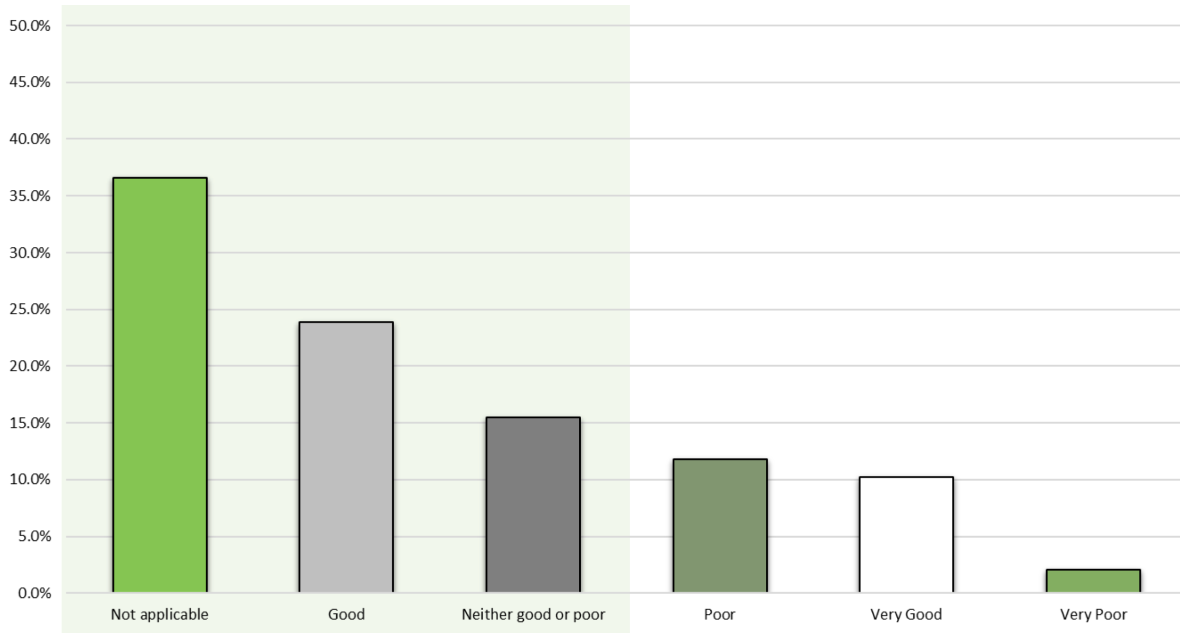

Figure 30: Average of all energy systems (from Figure 29) for each type of satisfaction degree.

Assessing thermal comfort in buildings, it is possible to infer in Figure 31 that the three main discomfort factors are cold during winter, heat during summer, and noise. Also, bad air quality, improper lighting and air draft highly contribute to thermal discomfort.

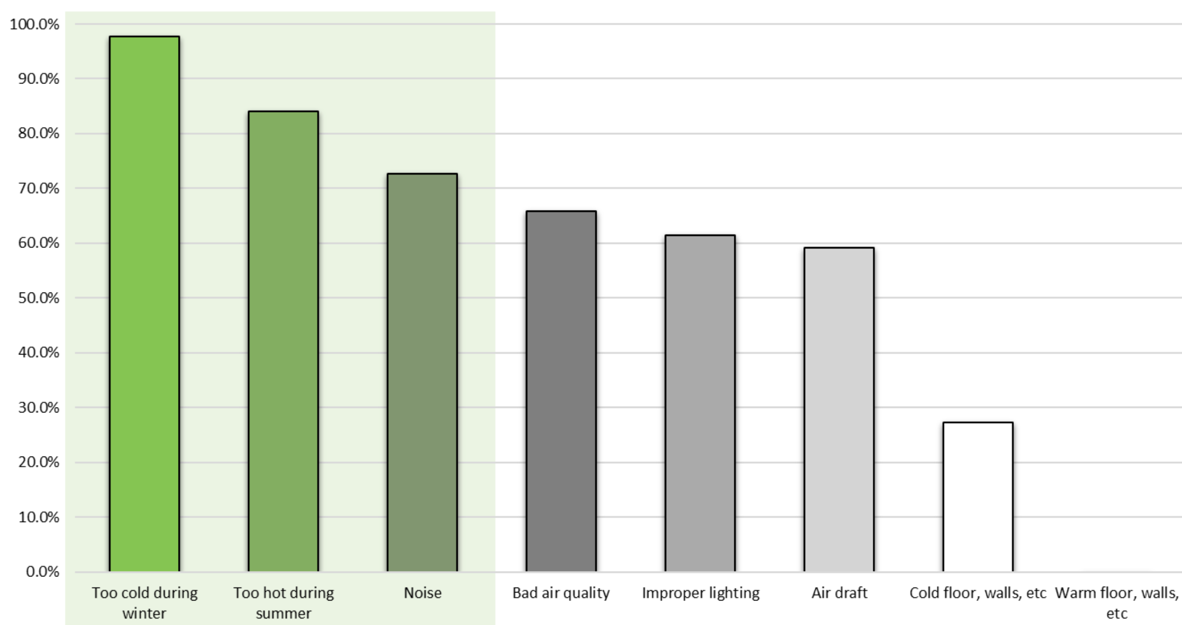

Figure 31: What makes you environmentally uncomfortable in buildings? (Question 7.1)

The majority of the respondents (87%) wants an interface with multiple energy systems integrated, as shown in Figure 32. When analysing what types of energy systems, the respondents would definitely like to aggregate three main energy systems in one interface: heating, cooling, and lighting (see Figure 33).

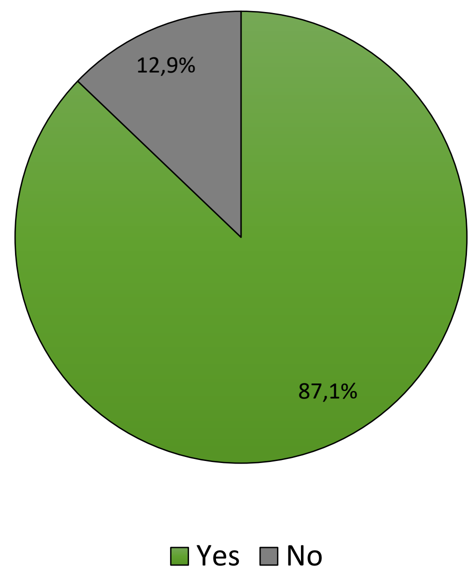

Figure 32: Would you like to have an interface with multiple energy systems integrated? (Question 7.2)

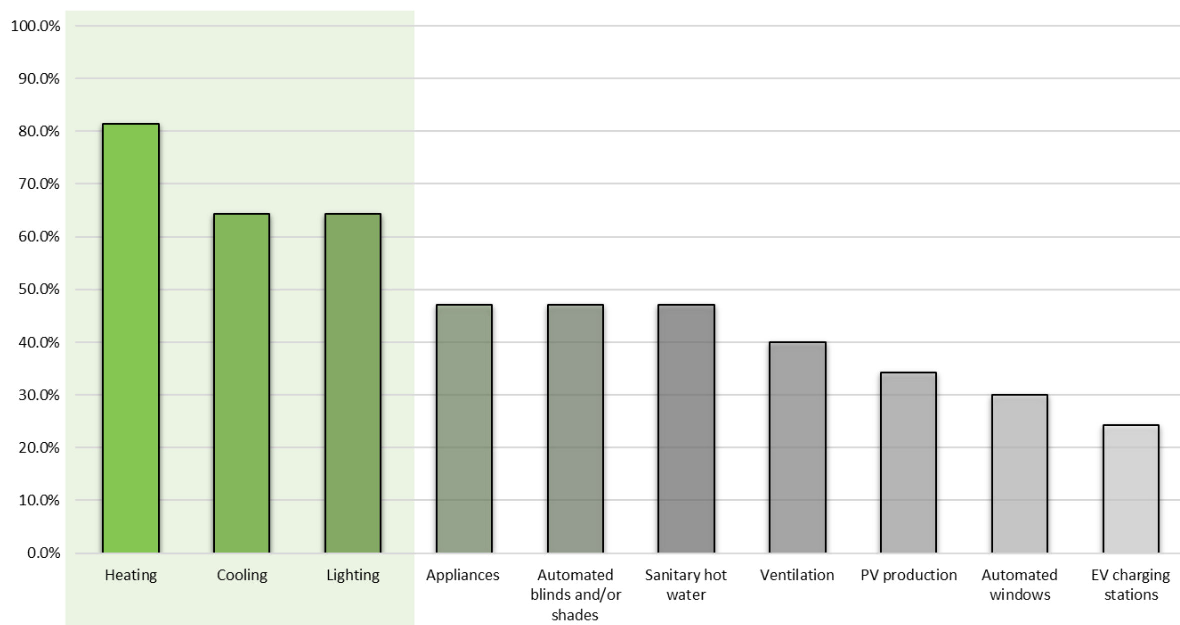

Figure 33: Which energy systems would you like to aggregate in that interface? (Question 7.3)

Figure 34 assessed which are the main barriers that prevent the widespread use of interfaces in residential buildings. Results show that the main barriers consist of expensive solutions, the lack of planning and/or implementation, lack of technical expertise and technical barriers (such as, communication protocols). In this sense, it is possible to conclude, without neglecting the other barriers, that the development of an interface at a reasonable price will be a key factor in order to have a high level of adherence.

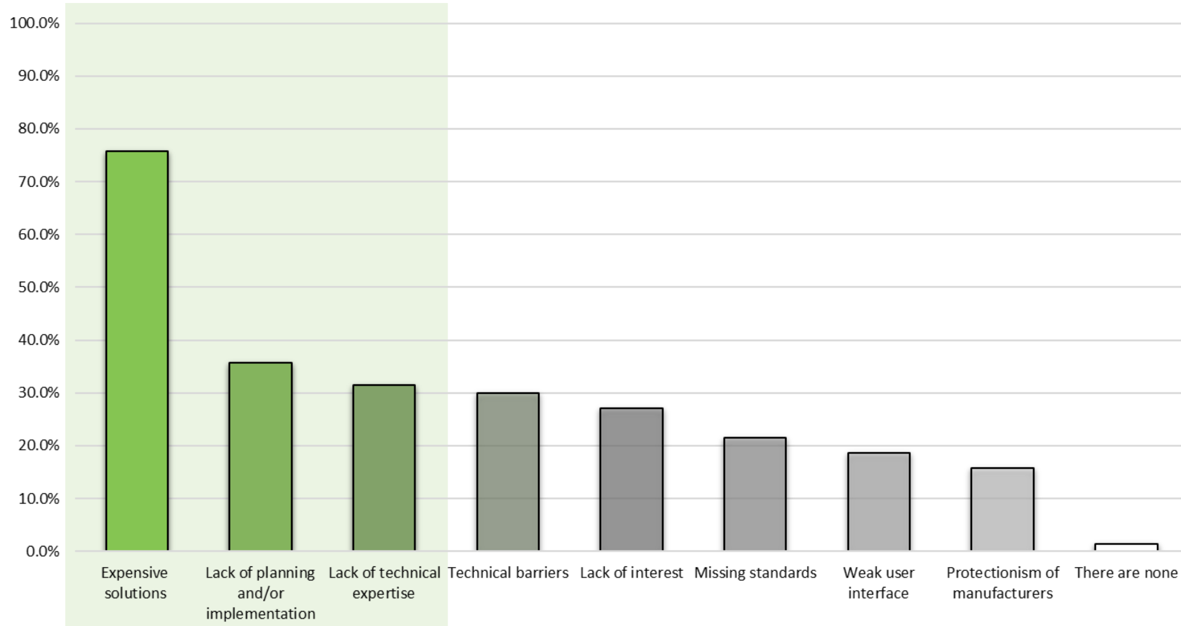

Figure 34: What are the barriers that prevent the widespread use of interfaces in the building energy devices and systems sector? (Question 8.1)

The choice of the most important features in an interface for your energy systems, as you can see in Figure 35, has five main features: energy consumption, easy to use, automated control over energy systems, energy consumption, and thermal comfort monitoring. It is interesting to note that the outdoor environment monitoring has a lower percentage of when compared with another features.

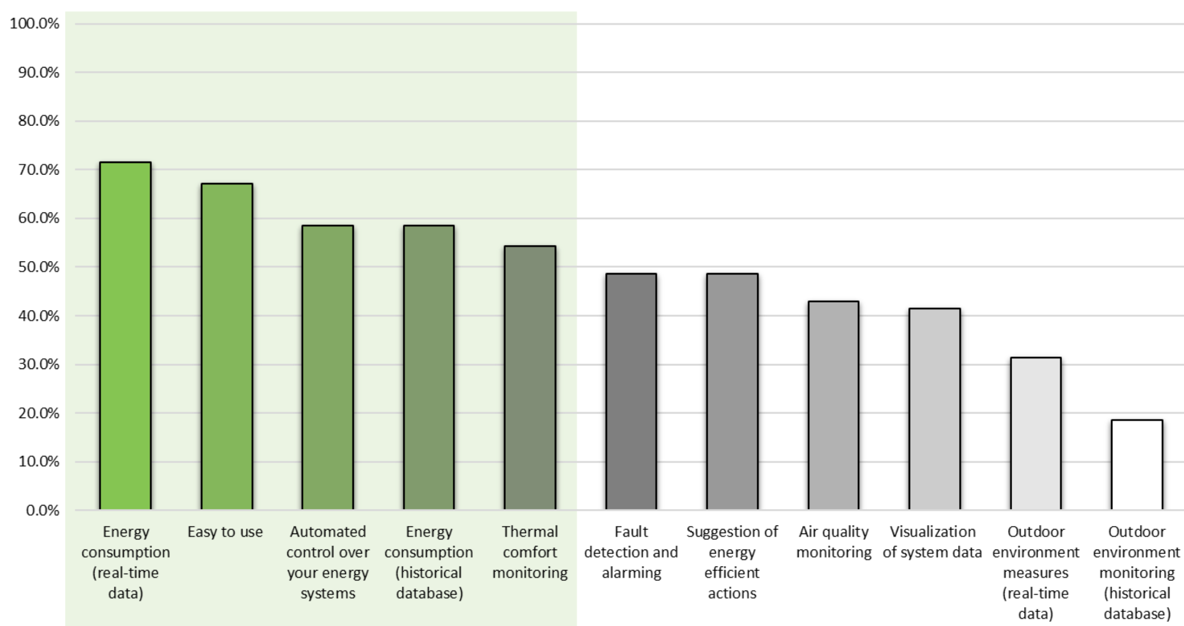

Figure 35: Choose the most important features in an interface for your energy systems. (Question 9.1)

Figure 36 and Figure 37 assess the most appropriated time step for data acquisition. A time step above 30 minutes was the least chosen option with 17% and a time step between 1 to 5 minutes was the most chosen with 24%. Therefore, all the time step options were almost equally chosen and no significant trends can be inferred.

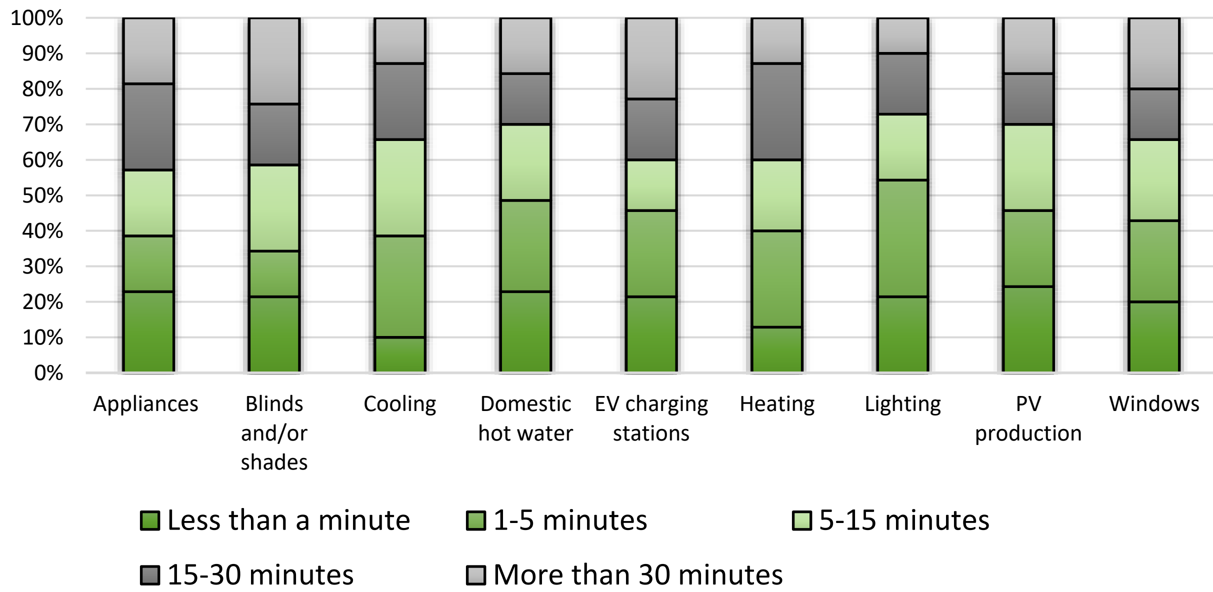

Figure 36: What is the most appropriate time step for data acquisition? (Question 9.2)

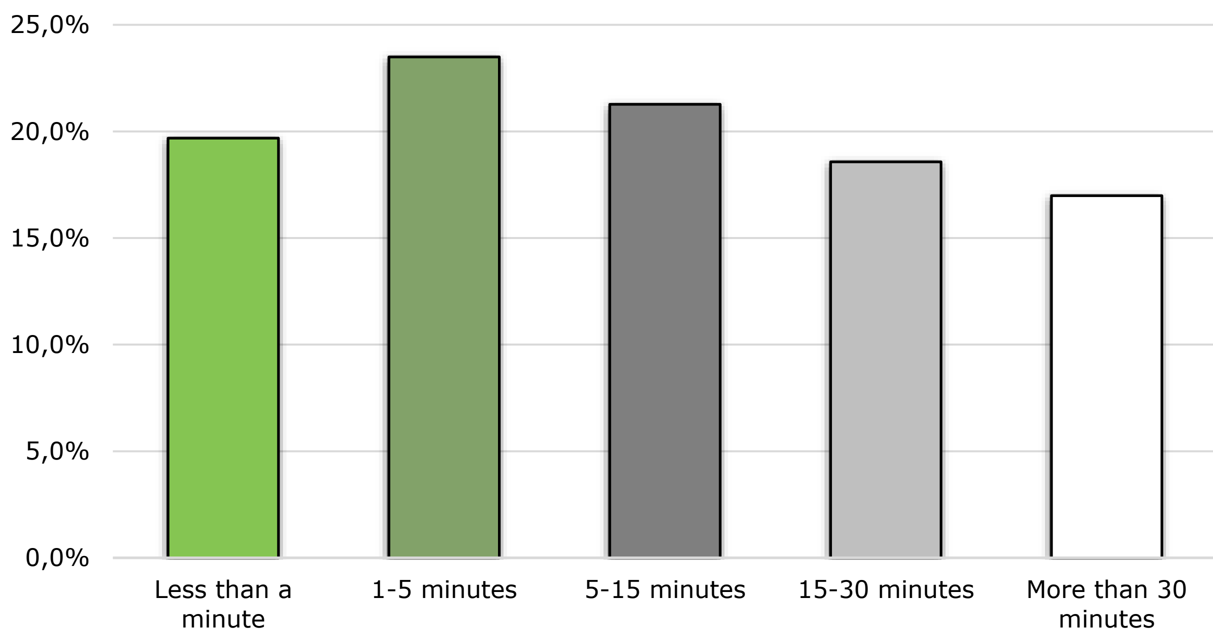

Figure 37: Average of all energy systems (from Figure 36) for each time step option.

Concerning the platform that the respondents prefer to use, through Figure 38, it is possible to note that there is a preference for an app-based platform (93%), but a web-based version of the interface is also appreciated by 64% of the respondents.

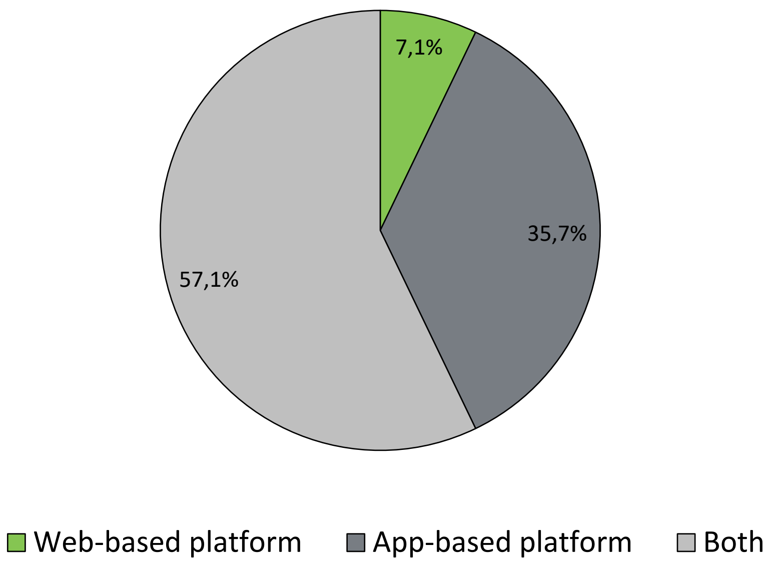

Figure 38: In which platform would you prefer to use an interface? (Question 9.3)

5.2. Building owner/manager, Facility manager

The SATO platform aims to serve residential and service buildings. From the building managers perspective, the complexity of a residential or a service building is similar in terms of the energy system challenges that can be found in both building types. From the sample collected, the number of service building managers interviewed is the same as the number of residential building managers interviewed.

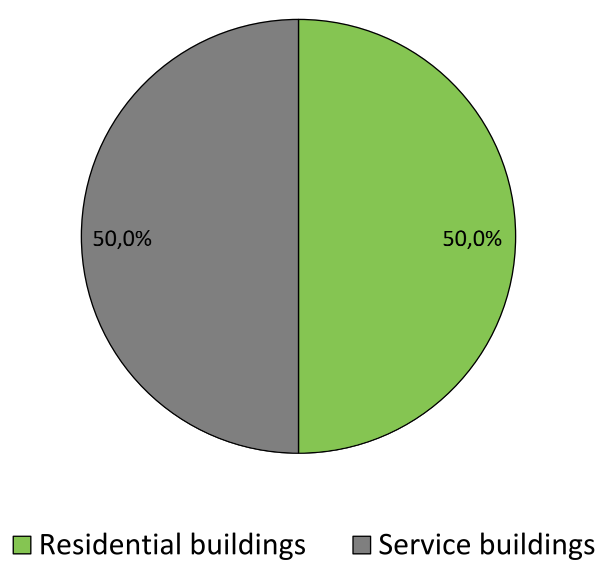

Figure 39: What is the type of building that you manage? (Question 11.1)

Among the control options available (Figure 40), it is interesting to note that the percentage of building managers who have control over PV production and EV charging stations is much higher compared to regular occupants. In addition, building managers already have more digital control systems that add several energy systems.

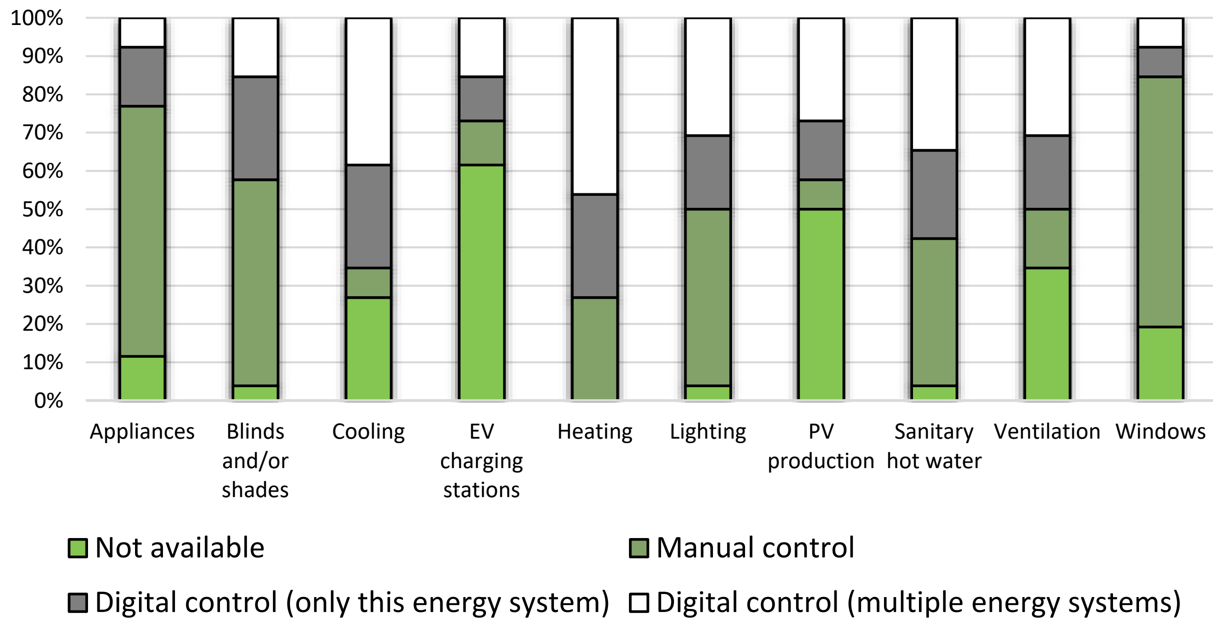

Figure 40: What type of control do you have over the energy systems? (Question 12.1)

Similar to regular occupants, most of building managers (34%) still have only manual control over the energy systems (see Figure 41). However, as opposed to the results obtained in section 5.1 (regular occupants), about 26% of building managers already have the type of control that the SATO platform intends to implement, more specifically, digital controls for multiple energy systems.

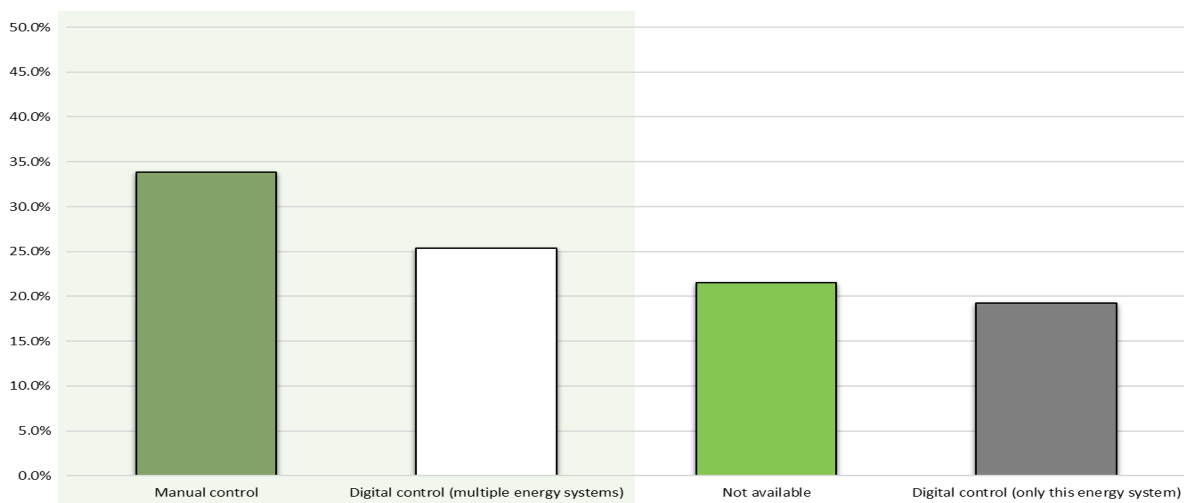

Figure 41: Average of all energy systems (from Figure 40) for each type of control option.

In order to understand what level of interaction there will be with the SATO platform, respondents were asked how often a building manager interacts with energy systems (Figure 42 and Figure 43). Excluding EV charging stations and PV production, the remaining energy systems are mostly managed on a daily basis (47%).

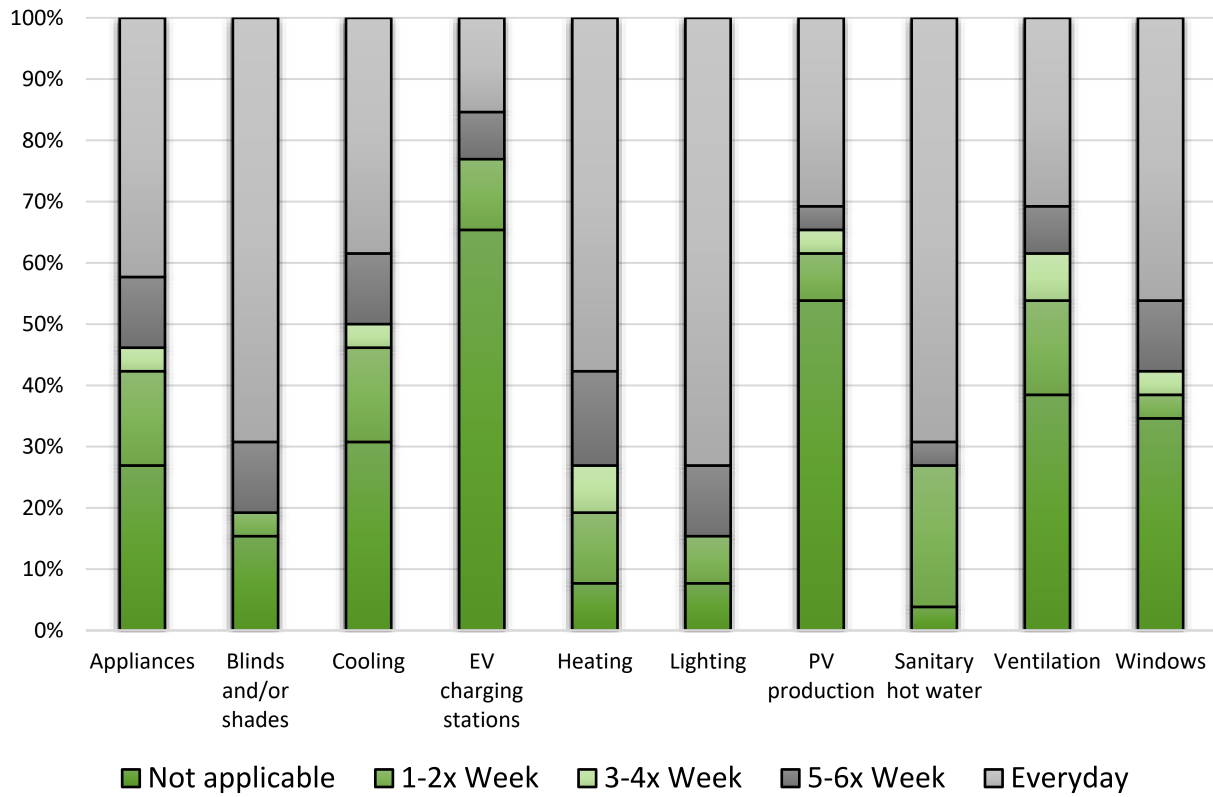

Figure 42: How often do you interact with your energy systems? (Question 12.2)

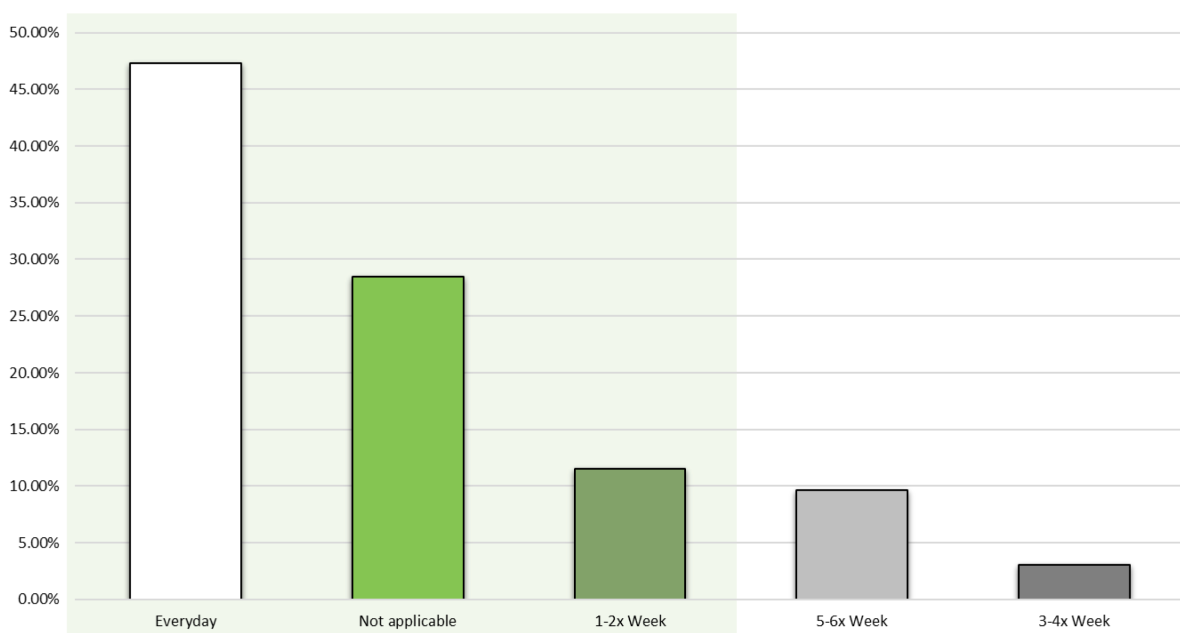

Figure 43: Average of all energy systems (from Figure 42) for each type of frequency option.

Figure 44 shows that there are great differences in the type of management tools used in the different energy systems. Considering HVAC (includes heating, cooling, and ventilation) and lighting systems, it can be seen that the use of advanced interfaces (BMSs, DDIs, and ODDAs) is much more relevant when compared with regular users (cf. Figure 9 and Figure 27). Despite having more control by building managers over EV charging stations and PV production, these energy systems still are the least controlled ones.

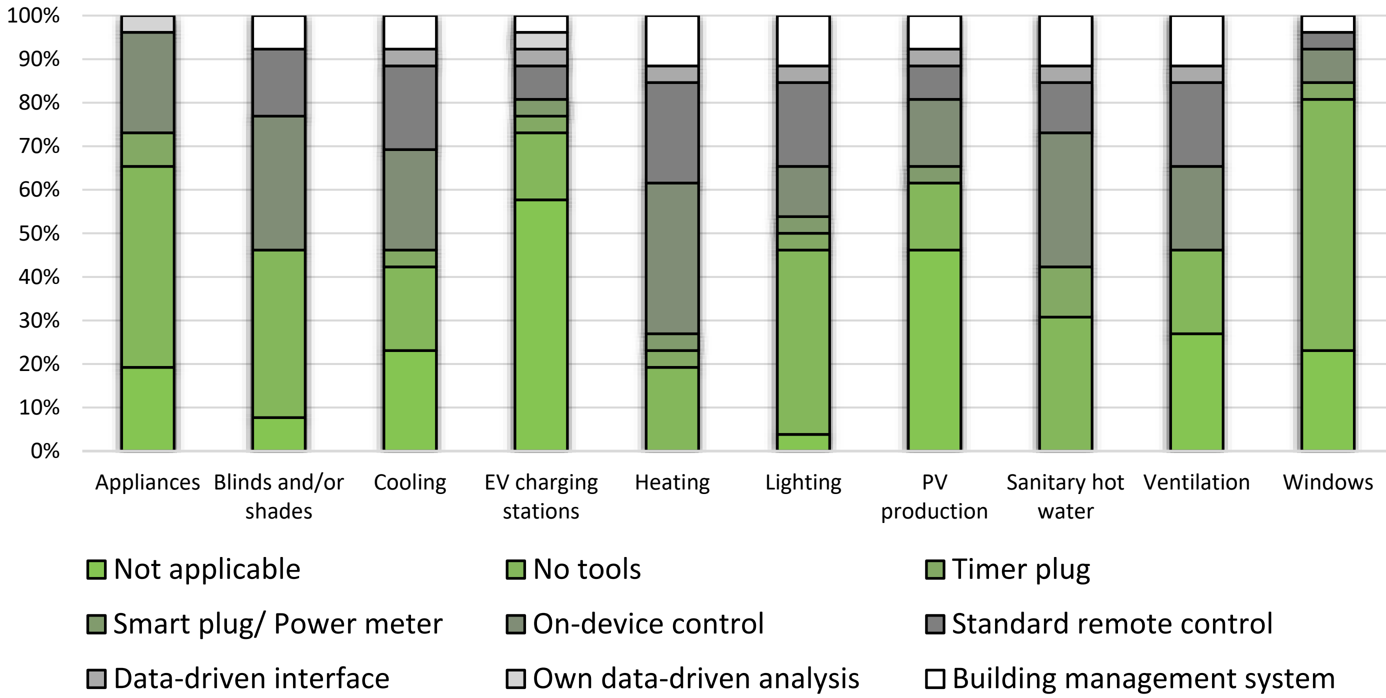

Figure 44: Which management tools do you interact with your energy systems? (Question 12.3)

Despite the technical knowledge by building managers, the type of management tools most used are on-device control (~20%) and standard remote control (~13%). So, it may be concluded that the SATO platform will change the mode of operation of these actors because the type of control currently used is quite rudimentary when compared to what SATO platform proposes.

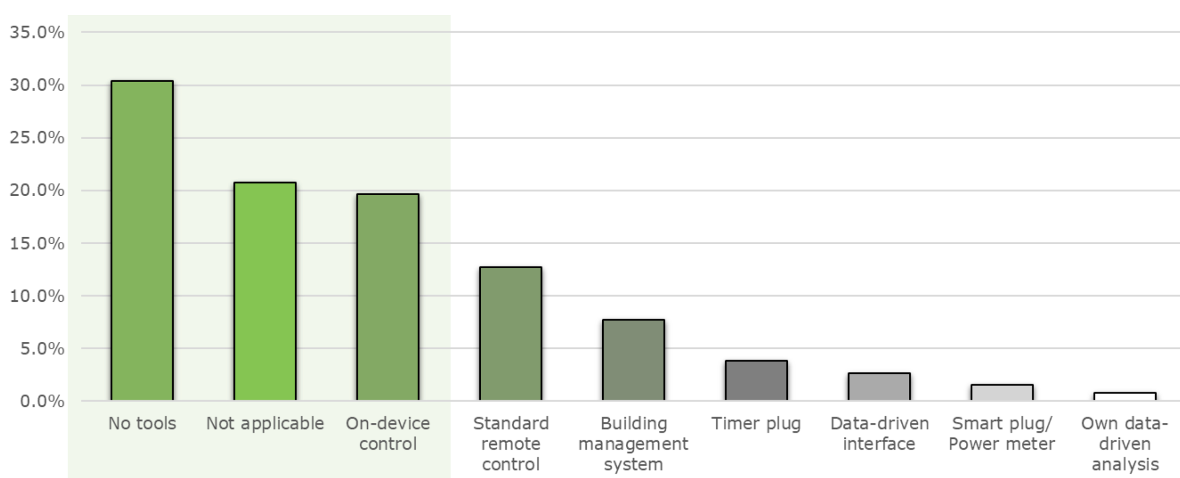

Figure 45: Average of all energy systems (from Figure 44) for each type of management tool.

To measure satisfaction, respondents were asked to what extent they are satisfied with the degree of the energy systems' control (see Figure 46). Satisfaction rates were coded on a scale, where 'very poor' indicates a negative correlation of each variable towards satisfaction and 'very good' indicates positive correlation. Interestingly, the energy systems that building managers are less satisfied with their level of control are those that are most used, such as cooling, heating, and sanitary hot water.

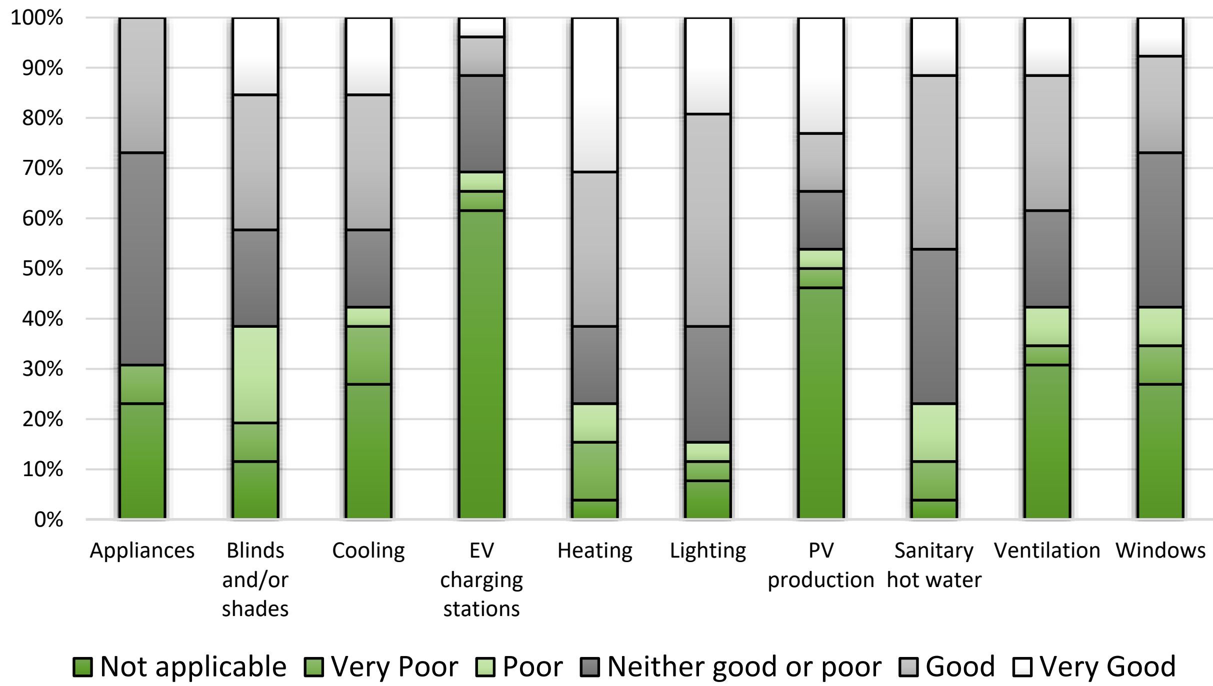

Figure 46: How satisfied are you with your degree of the energy systems' control? (Question 12.4)

Although the majority of respondents (~40%) are satisfied with their level of control of the energy systems, there is a significant number of responses that indicates indifference ('neither good or poor') with 23% and, lastly, around 15% of the respondents are dissatisfied with the level of control (Figure 47).

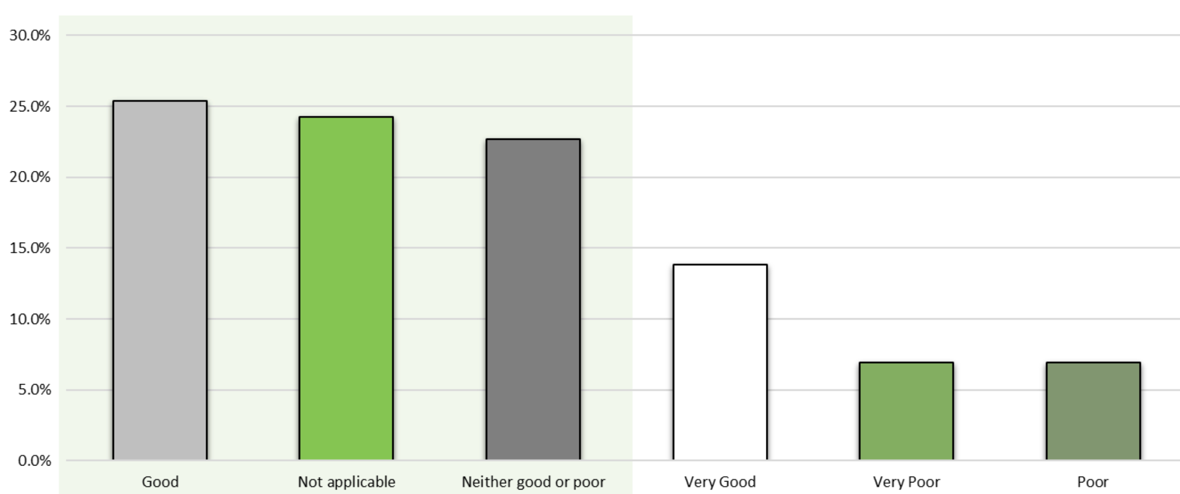

Figure 47: Average of all energy systems (from Figure 46) for each type of satisfaction degree.

Figure 48 assesses the main factors that motivate control actions in buildings, and it is possible to infer that the main drivers for building managers' actions are comfort-adaptive and energy-saving behaviors.

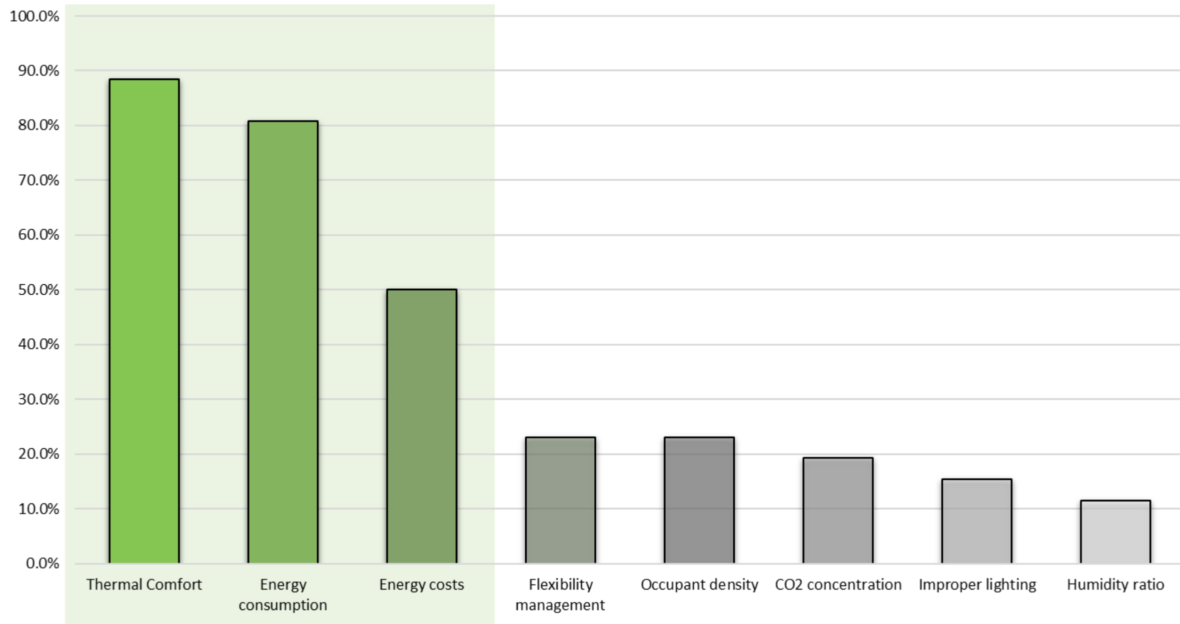

Figure 48: What drives your control actions? (Question 13.1)

It would be expected that all building managers surveyed would prefer to have an interface with multiple energy systems integrated. However, about 15% of respondents prefer to have an interface for each energy system (Figure 49).

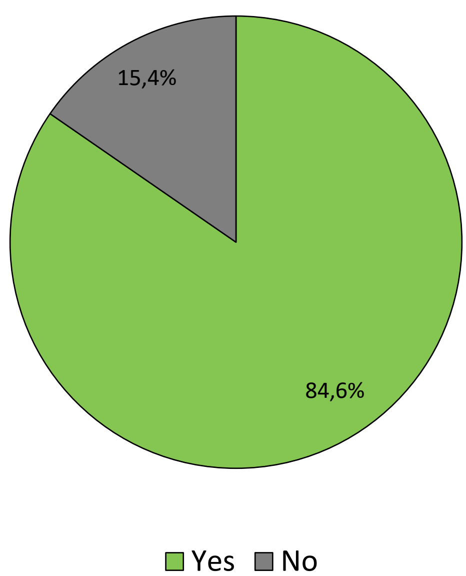

Figure 49: Would you like to have an interface with multiple energy systems integrated? (Question 13.2)

Figure 50 shows that the highest acceptability over the energy systems aggregated were observed for the HVAC systems, sanitary hot water, and mechanical ventilation.

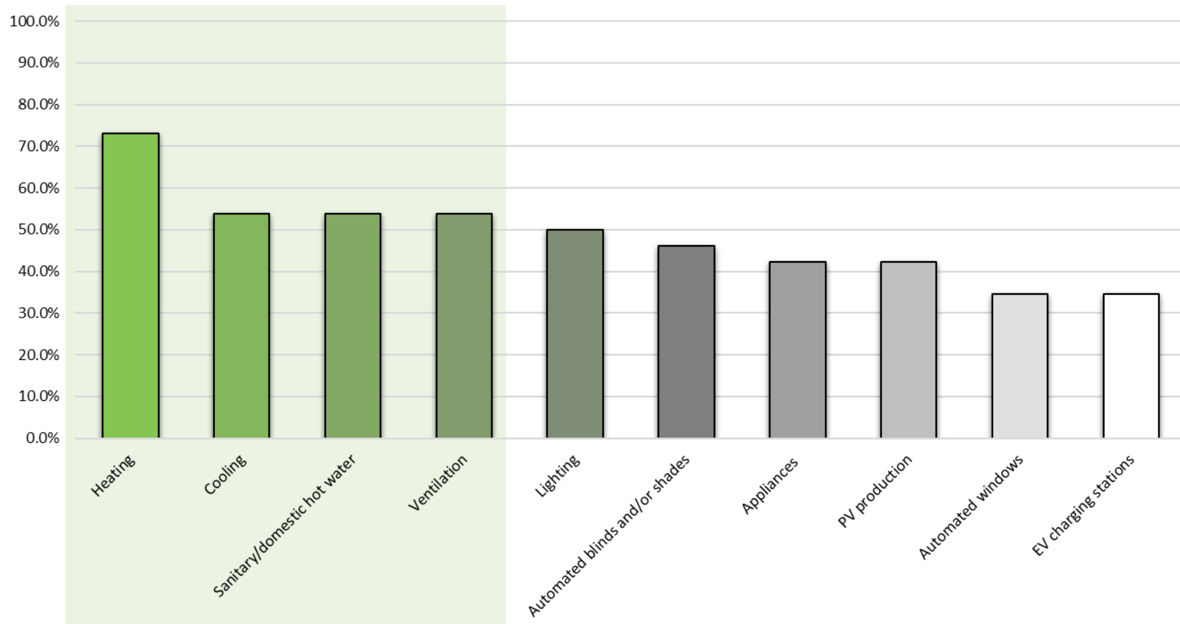

Figure 50: Which energy systems would you like to aggregate in that interface? (Question 13.3)

The main barriers identified by the building managers for market uptake (Figure 51) are similar to those of the occupants (expensive solutions and lack of planning and / or implementation). However, building managers stress manufacturers' protectionism as the third biggest barrier.

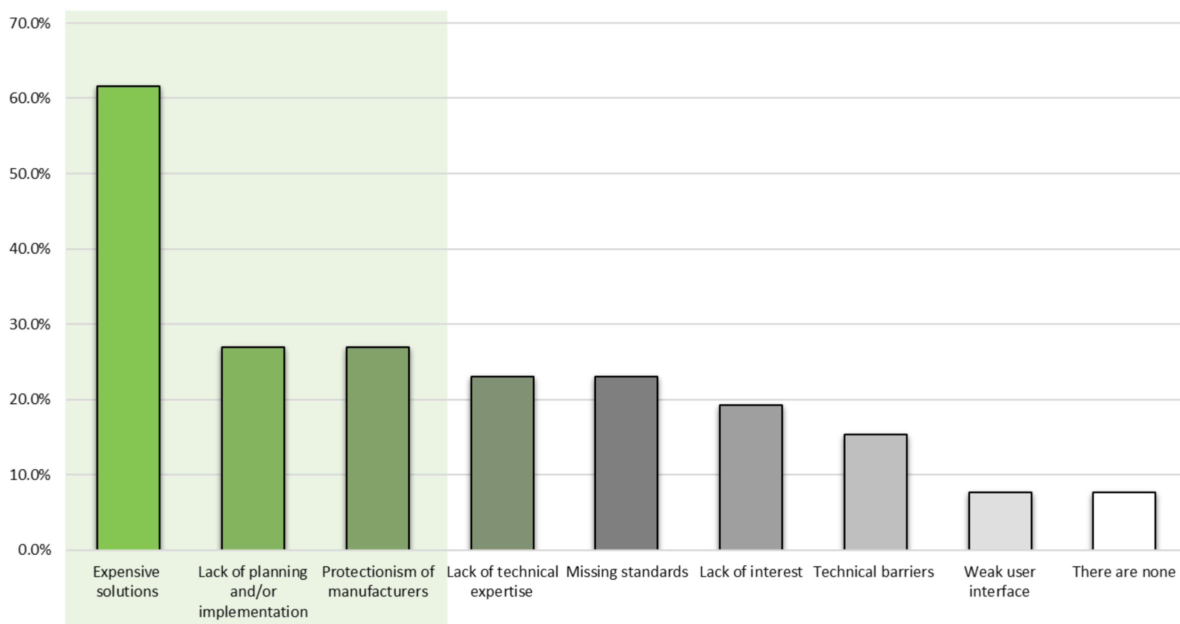

Figure 51: What are the barriers that prevent the widespread use of interfaces in the building energy devices and systems sector? (Question 14.1)

Figure 52 shows the most important feature of an interface for the building managers. The automated control over the energy systems, an ease to use interface and real-time data of energy consumption were identified as the three most important features to have in an interface.

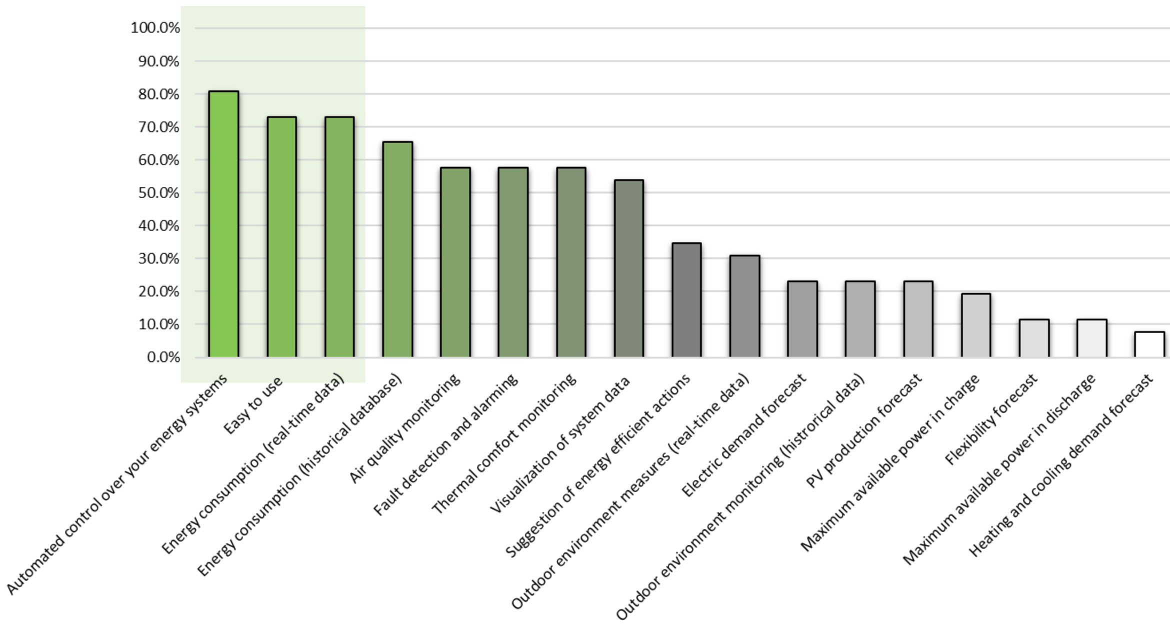

Figure 52: Choose the most important features in an interface for your energy systems. (Question 15.1)

To ensure that the SATO platform provides the DR capabilities required for DSM, we sought to understand what flexibility tools the building manager would like to have. Thermal storage, thermostatically controlled appliances and time shiftable appliances were the most selected tools (Figure 53).

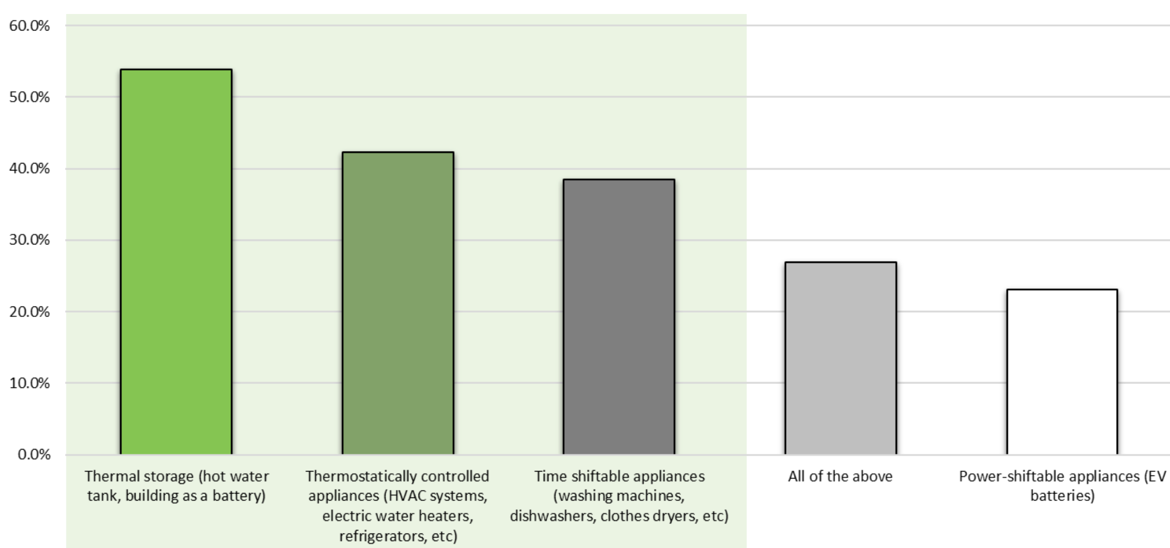

Figure 53: Which type of flexibility managements tools would you like to have access in the interface? (Question 15.2)

In order to understand the desired detail of the information, the most appropriate time interval for data acquisition was requested (see Figure 54). The results show that the majority of the respondents prefer to receive the information in intervals of less than 15 minutes. Contrary to what was observed in the section for occupants, there is a different preponderance over the 5-15 minutes option regarding the lighting system.

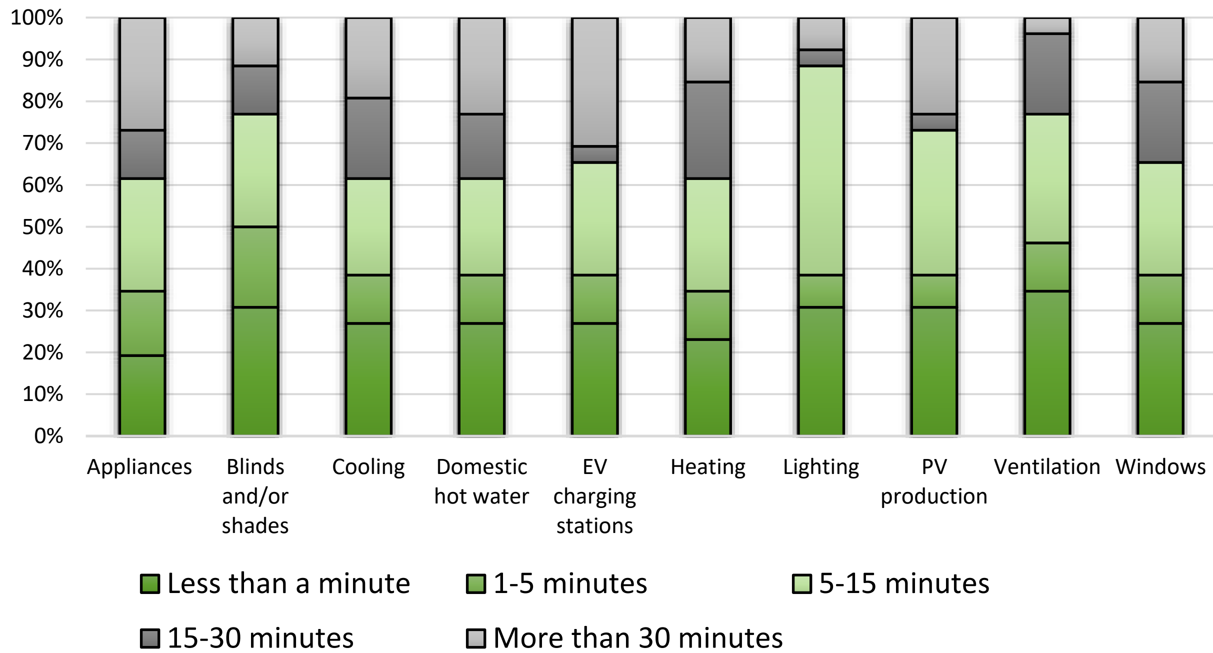

Figure 54: What is the most appropriate time step for data acquisition? (Question 15.3)

When comparing the results of the regular occupants with the building managers, it is observed that the most selected time interval was 5-15 minutes. On the other hand, the second most selected option by the building managers was the time step under a minute which reflects the desire of the building managers to have real-time information about the energy systems (Figure 55).

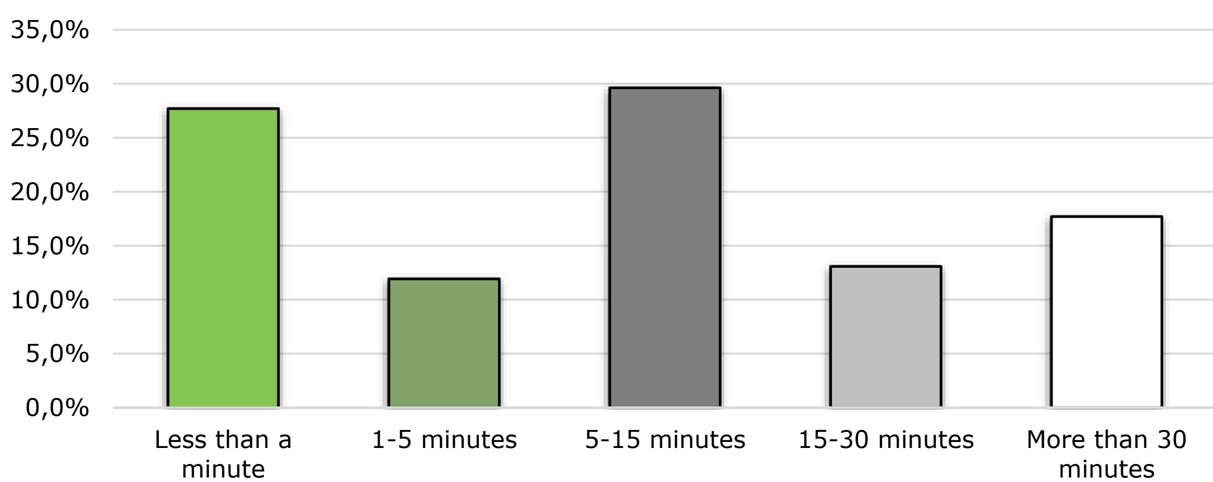

Figure 55: Average of all energy systems (from Figure 54) for each time step option

Flexibility management services can help grid operators in achieving a balanced electric grid and the flexibility providers will benefit from these services via financial incentives. Knowing that, the building managers were asked about the importance of having the amount of power available for flexibility management displayed in the interface as a feature. Most respondents indicated that this feature would be very important, with grade 4 and 5 being chosen by 60% of the building managers (Figure 56).

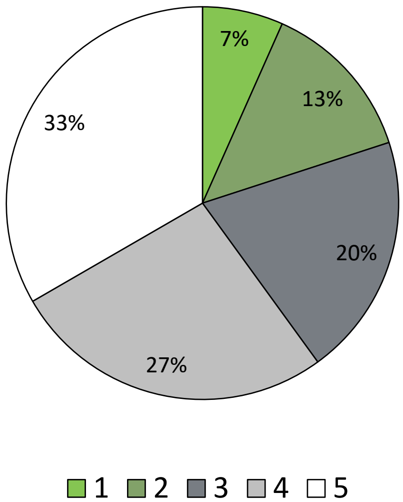

Figure 56: Grade the importance of having an interface feature to display the amount of power available for flexibility management. (Question 15.4)

The objective of SATO is to provide an optimal interface for each type of actor. So, Figure 57 aims to understand which interface building managers would prefer. The results are similar to those previously obtained in the section for occupants, with 88% preferring an app-based interface and 77% a web-based interface.

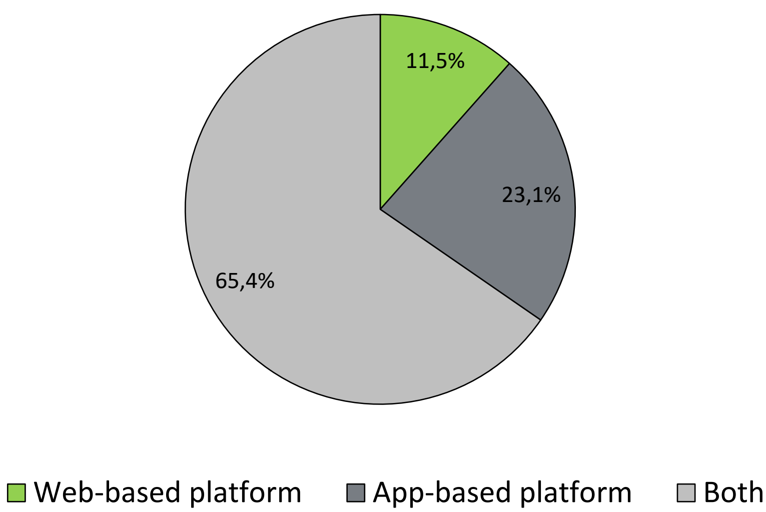

Figure 57: In which platform would you prefer to use an interface? (Question 15.5)

5.3. Grid operators

Through the analyzes of the survey for grid operators, it is possible to conclude (Figure 58) that the respondents were from energy services providers and DSOs. It is important to mention that this questionnaire had no responses from TSOs.

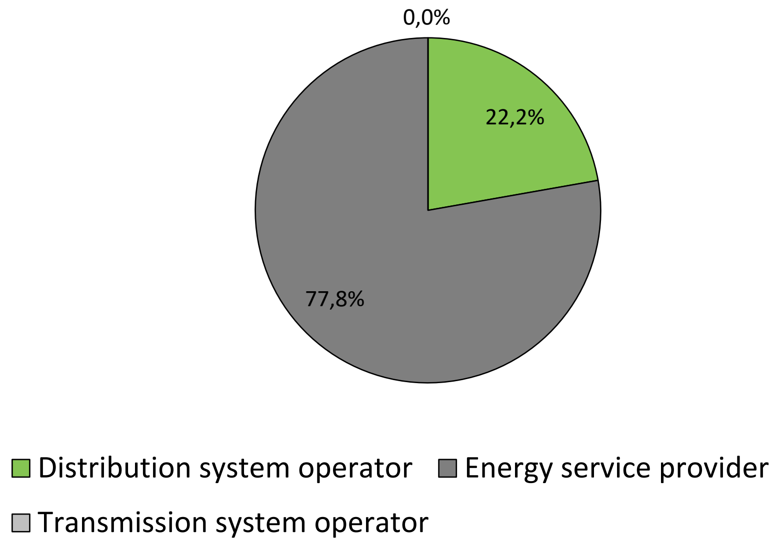

Figure 58: Which type of grid operator are you? (Question 17.1)

From Figure 59 it is possible to understand that the respondents recognized the importance for the electric grid to have buildings with flexible energy consumption (60%).

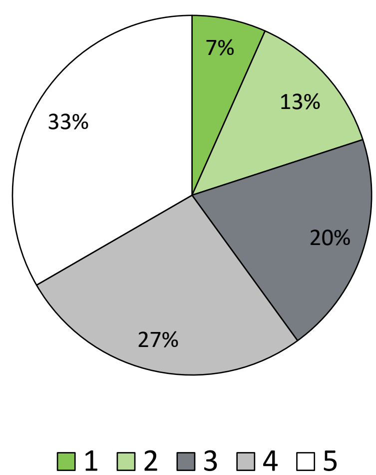

Figure 59: Grade the importance for the electric grid to have buildings with flexible energy consumption. (Question 17.2)

As shown in Figure 60, concerning the most important features in an interface to respond to electrical grid requests, one may infer that the load shifting is the most important feature. Additionally, the flexibility forecast, and dispatch can also be of high interest to the grid operators.

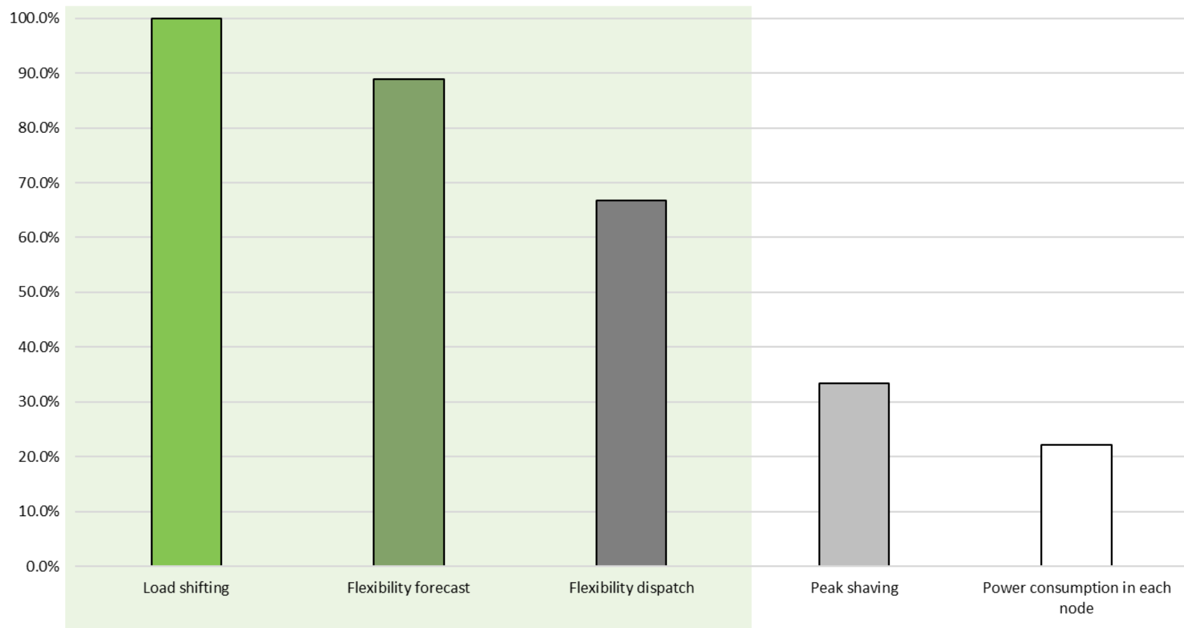

Figure 60: Choose the most important features in an interface to respond to electrical grid requests. (Question 18.1)

Regarding the communication time interval between the interface and the electrical grid, as it is possible to observe in Figure 61, the most chosen option is 1-5 minutes (56%), followed by the option less than a minute (22%). Overall, it is possible to infer that grid operators prefer a fast response by the interface.

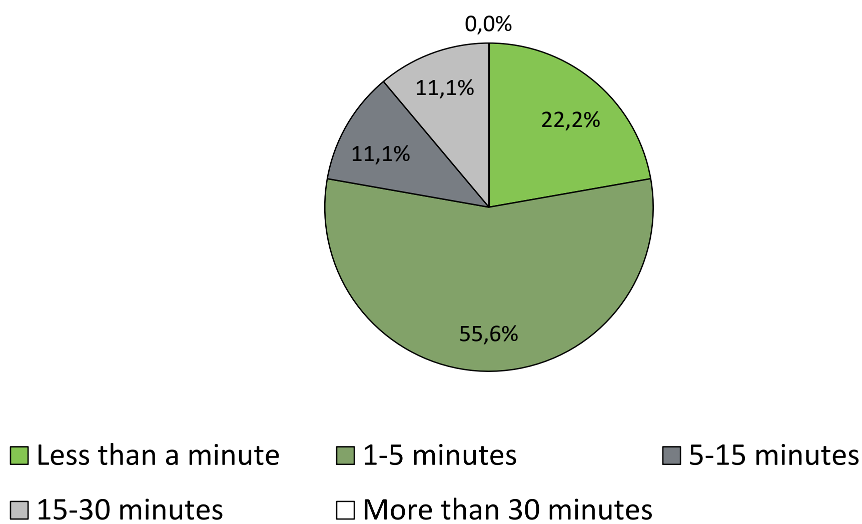

Figure 61: How often do you think to be appropriate the communication between the interface and the electric grid? (Question 18.2)

Concerning the time interval that the sample intends to receive consumption information for different energy systems, Figure 62 indicates that air handling units, dishwashers, electric boilers, EV charging stations, HVAC, PV, refrigerators, and washing machines are the options where a fast response (high percentage of less than 5 minutes) would be valuable. It is important to note that, HVAC has approximately a percentage of 50% for the time interval of 1-5 minutes, which also points to the need for a quick response by this energy system.

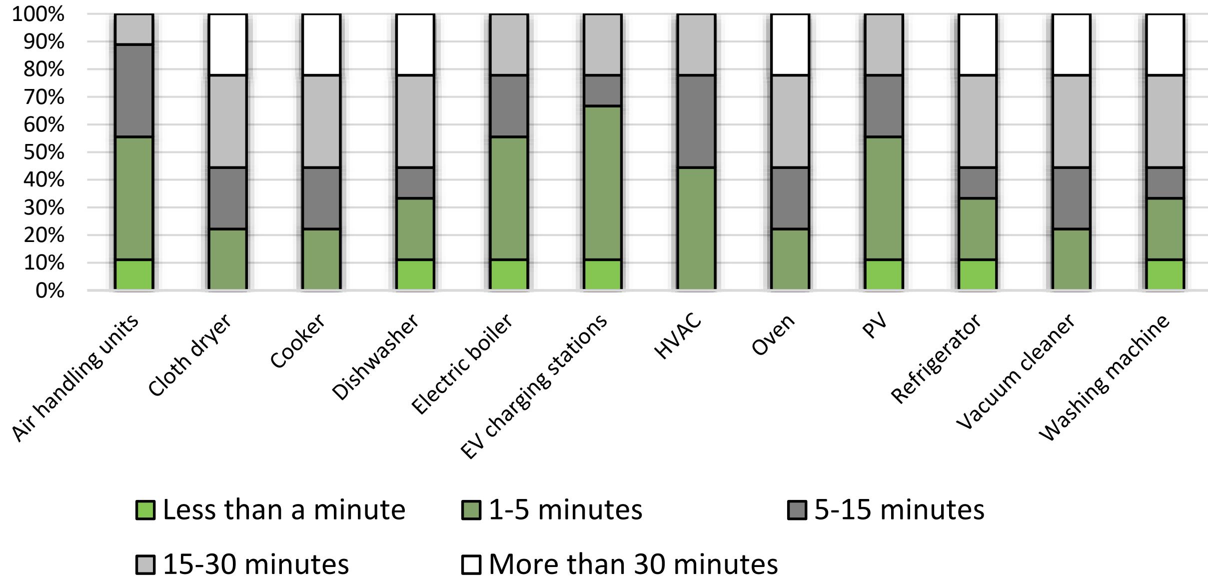

Figure 62: How often would you like to have data for each energy system? (Question 18.3)

Figure 63 suggests that the most wanted energy systems for flexibility are the HVAC, EV charging station, air handling units, PV, and electric boilers. These energy services tend to be the largest sources of energy consumption in buildings and could also be the energy systems with a main role for the flexibility services identified in Figure 60.

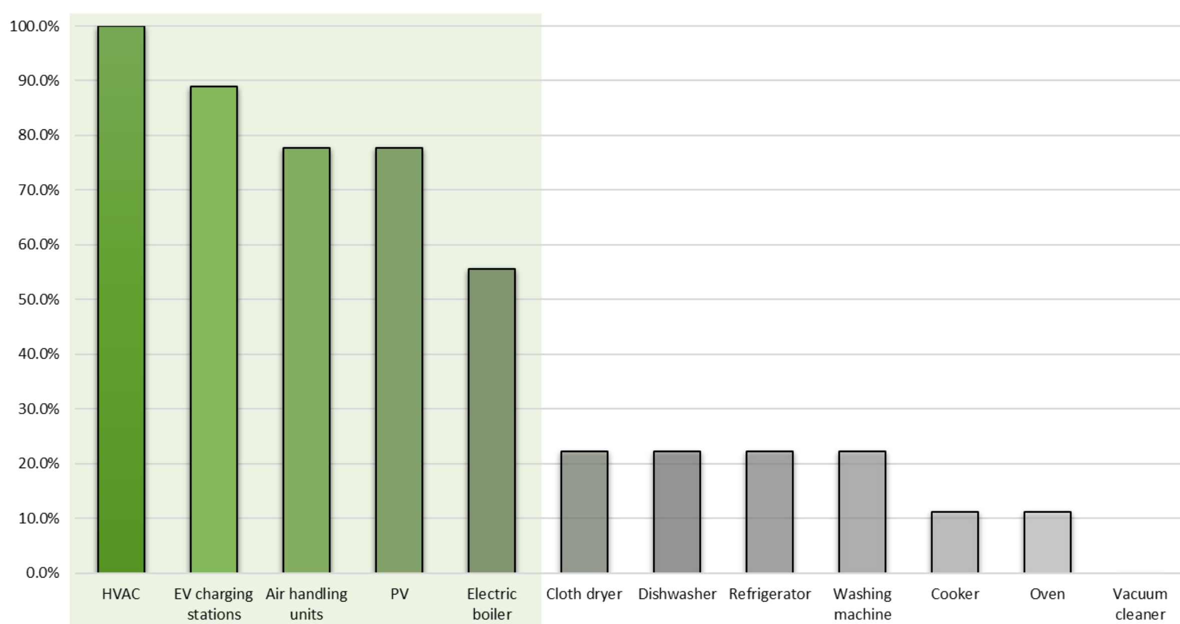

Figure 63: Which appliances would you like to have an aggregate information of their power consumption? (Question 18.4)

Similar to the tendency observed in the other respondents, through Figure 64 grid operators tend to prefer an app-based platform (89%), but also with a high preference for a web-based platform (78%).

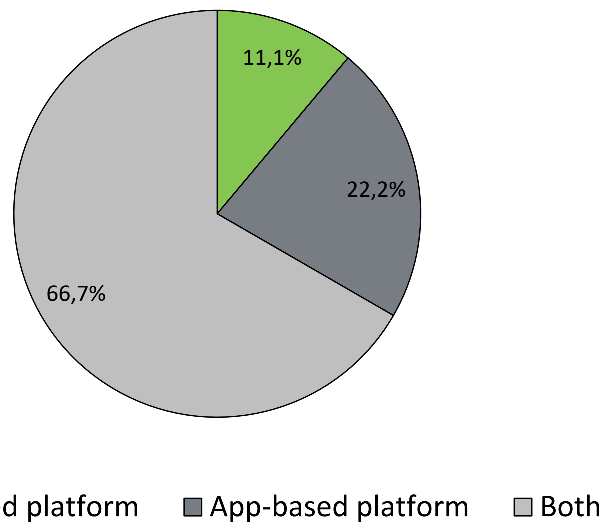

Figure 64: In which platform would you prefer to use an interface? (Question 18.5)

6. Define the most adequate interfaces related to A&O services

Proceeding for a relative analysis between the various aspects of the work carried out, it was possible to recognize the desired needs and level of interaction for different human actors identified. Basically, these are some of the responses that the different software's and services of the SATO project should provide to human actors to enhance his development and acceptance with consumers.

Based on the previous correlation, it was possible to identify among the various services that the market offers, those that most closely match the identified requirements. And so, through this analysis it will be possible to understand its features and gaps, contributing to a sustained development of SATO platform.

Table 6: Needs and level of interaction by actors and most adequate interfaces.

	Needs and level of interaction	Available interfaces that most answer to the requirements
Occupants	• Integration of multiple energy systems with automated control • Heating, cooling, and lighting • Low price solutions • Easy to use • Easy connectivity • Real-time and historical data	Service Buildings • ACIS BMS (Airedale) • Smart Home (Ecobee) • Digital Twin (Siemens) Residential Buildings • Smart Home (Honda) • Smart Home (Ecobee)

	• Energy consumption (with disaggregation), thermal comfort and air quality monitoring • Data acquisition lower than 15 minutes • Daily/weekly information (or personalised) • Inefficiency alerts and notifications • App-based (complemented with web-based) • Building plan view	• Philips Hue (Philips) • Re:dy (EDP Comercial)
Facility/Building managers	• Integration of multiple energy systems with automated control • Heating, cooling, DHW and ventilation • Low price solutions • Easy to use • Real-time and historical data • Flexibility management tools for thermal storage, thermostatic controlled appliances and time shiftable appliances • Data acquisition lower than 15 minutes • App-based (complemented with web-based)	• C-Bus Home Automation (Schneider Electric) • ACIS BMS (Airedale) • Energy IQ (Genesis) • Dream Watts (Makas Energy)
Grid operators	• Load shifting • Flexibility forecast • Flexibility dispatch • Data acquisition lower than 5 minutes • Energy systems available for flexibility • App-based (complemented with web-based)	• C-Bus Home Automation (Schneider Electric) • Energy IQ (Genesis)

7. Relation to other tasks

The output of this deliverable will serve as the base for the technical developments and extensions leading to the SATO platform, in particular it directly contributes to different tasks of WP 2, 3 and 5 (Table 7).

Table 7: Task contribution to other tasks of the project.

	Contribution level	Main contribution
The development of the SRI enabled SATO platform concept (2.1)	Low	Understand the types of equipment that is currently controlled by residential users
Development of equipment/appliances energy performance assessments (3.5)	Low	Understand the level of digital sophistication in existing appliance of typical residential users
Development of Energy Efficiency optimization Services (4.1)	Medium	Understand the current level of digital control deployment in residential and service buildings
Definition of actors interaction with SATO A&O services through BIM-based interfaces (5.1)	High	Identification of building manager needs, and level of interaction required
Definition of actors operational interaction with SATO platform and services through friendly user-centered design (5.2)	High	Identification of user needs, and level of interaction required
Evaluation of the SA&O Services Interfaces with the Actors (5.5)	High	Identified needs and requirements are used during the evaluation.

8. Conclusions

The work developed in this subtask produced a clear picture of the actors that will use the SATO platform. In addition, this work defined the desired level of user interaction as well as confirming the proposed division of the interfaces of the SATO platform into two levels (App and BIM based).

The survey of residential users showed that this market has a large untapped potential, with 80% of residential users using manual or no relevant control system for their energy systems. Among the several energy system classes, appliances, heating, cooling, DHW and lighting have the highest penetration of digital control (20%). As expected in light of the prevalence of manual control, the survey found residual penetration of data driven/digital interfaces. The results also confirmed that the simplified App-based interface that will be developed for this user class is a good step to deploy the capabilities of SATO to users that have low contact with digital control. The users show a high degree of curiosity and receptivity towards the capabilities of AI for energy system control. This interest should allow for an easy deployment of these approaches. Overall, the results are encouraging, clearly SATO is needed for residential users if it can be offered in a cost-effective way.

The survey of building energy managers showed that this market has a significant untapped potential, with 50% of buildings using manual or no centralized control for their energy systems. Among the several energy system classes, HVAC has the highest penetration of digital control (40%). Currently, data-driven and digital interfaces have residual penetration. The results also confirmed that the 3D BIM based interface that will be developed for this user class is a good step to deploy the capabilities of SATO to users that manage large buildings with a significant dispersion of different energy consuming equipment. These users show a high degree of curiosity and receptivity towards the capabilities of AI for energy system control. This interest should allow for an easy deployment of these approaches, although several of the experts mentioned that the robustness of the proposed systems must be tested in advance. Overall, the results are encouraging, clearly SATO is needed for large building energy managers if the system can be cost effective and easy to use.

The survey of grid operators showed that this class of potential users has the high interest in the capabilities of SATO for the deployment of automated load shifting and flexibility in groups of clients. The need for communication between the system and the grid lies in the 1-5min range. Finally, at this point, this user class showed limited interest in control of appliances.

Annex 1 – Market Review

Table 8: Interfaces market review.

	SHEMS component																
	Building type		Metering devices			Sensing devices				ICT devices			Smart Appliances	HEM devices			
	Residential	Non residential	Electricity	Water	Gas	Fault	Indoor Temperature	Occupancy	Safety/Fire	Remote building control and communication	Web based platform	App based platform	Domestic appliances	Energy consumptio n forecast	Energy consumption comparison	Autonomous ability to minimize energy consumption	CAD / BIM building representation
Smart Home OS 3 (Control 4)	✓									✓		✓					
HomeTroller (HomeSeer)	✓									✓		✓					
Wiser Smart Home (Schneider Eletric)	✓									✓		✓					
C-Bus Home Automation (Schneider Eletric)	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓				✓	
Home Automation (KNX)	✓	✓	✓							✓		✓					
PLC Tecomat Foxtrot (Teco Advanced Automation)	✓	✓								✓		✓					
PLC Tecomat TC700 (Teco Advanced Automation)	✓	✓	✓							✓		✓					

Autopilot (Aeotec)	✓									✓		✓					
One e EZ Connect (Daintree)	✓						✓	✓		✓[3]		✓					
Networked (Daintree)		✓					✓	✓		✓		✓					
Harmony (Logitech)	✓									✓		✓					
Smart Homes (Shifra)	✓									✓		✓					
Home Assistant	✓		✓			✓	✓	✓		✓	✓						
Metasys (Johnson Controls)	✓	✓				✓	✓	✓	✓	✓	✓	✓					
Open remote	✓		✓							✓		✓					
Total Connect 2.0 (Honeywell)	✓		✓				✓	✓		✓		✓					
Valena Life with Netatmo (Legrand)	✓		✓			✓				✓		✓					
Re:dy (EDP comercial)	✓		✓			✓				✓		✓					
Digital Twin (Siemens)		✓	✓			✓	✓	✓		✓	✓						✓
IoT Energy Meter (Verdigris)	✓	✓	✓			✓					✓						
Energy IQ (Genesis)	✓	✓	✓		✓	✓						✓		✓	✓		

[3] Only remotely controls lighting.

ACIS BMS (Airedale)		✓	✓	✓	✓	✓			✓	✓	✓	✓					✓
Murphy & Miller	✓	✓	✓			✓		✓	✓		✓						
Digital Energy (Catalyst)		✓	✓	✓	✓						✓						
Building (Socomec)		✓	✓							✓	✓	✓					
Energy Management System (Energywise)		✓	✓							✓	✓						
Intelligent Energy Management (CarbonTrack)	✓	✓	✓			✓			✓	✓	✓	✓					
BuildingOS		✓	✓			✓					✓			✓			
Building Energy Management (BEMOSS)		✓	✓			✓				✓	✓						
Home Energy Monitor (Neurio)	✓		✓[4]								✓	✓			✓		
Energy Monitor (Sense)	✓		✓								✓	✓			✓		
Home Energy Monitor (Eyedro)	✓		✓								✓	✓					
Home Energy Meter Gen5 (Aeotec)	✓		✓				✓			✓	✓	✓					
Smart Home Energy	✓		✓				✓			✓	✓	✓					

[4] Only the last software update, still in beta, performs the breakdown of energy consumption.

Management System (Emporia)																	
Engage & Elite Kit (Efergy)	✓		✓				✓					✓					
Open Energy Monitor (Emon)	✓		✓			✓	✓[5]	✓				✓					
Open Energy Management (OGEMA)	✓		✓				✓	✓		✓		✓					
Dream Watts (Makas Energy)	✓		✓			✓	✓	✓		✓		✓				✓[6]	
HomeKit (Insteon)	✓		✓			✓	✓	✓		✓		✓					
Iris Home Smart Kit (Lowes)	✓		✓				✓	✓		✓		✓					
Pro Home Energy Monitor (TED)	✓		✓								✓						
EMU-2 (Rainforest Automation)	✓		✓								✓[7]						
Home Energy Management (E.ON)	✓		✓			✓	✓	✓		✓		✓					
Wattvision		✓	✓			✓					✓						
PlotWatt		✓	✓			✓					✓	✓					
WattDepot		✓	✓			✓					✓						

[5] Includes humidity monitoring inside the building.

[6] Providing proactive measures and alerts to be taken by users.

[7] Intelligent devices provided by Rainforest Automation, and specific for building control.

Smart Home[8] (Honda)	✓		✓	✓		✓	✓	✓		✓		✓[9]		✓		✓	
Wink Hub 2 (Wink)	✓		✓			✓				✓	✓	✓					
Google Nest (Google)	✓	✓					✓	✓		✓		✓					
HomeKit (Apple)	✓	✓					✓	✓		✓		✓					
Echo & Alexa[3] (Amazon)	✓	✓					✓	✓		✓		✓					
Philips Hue (Philips)	✓	✓								✓[10]		✓					
Smart Home (Ecobee)	✓	✓					✓	✓		✓[11]		✓				✓	
SmartThings Hub (Samsung)	✓	✓					✓	✓		✓		✓					
ThinQ (LG)	✓									✓		✓					
Smart Home (Lenovo)	✓									✓		✓					

[8] Interface developed to operate in intelligent buildings developed from construction phase.

[9] Intelligent devices provided by Honda, and specific for building control.

[10] Only remotely controls lighting.

[11] Only remotely control cooling & heating.

Annex 2 - Questionnaires

This survey is part of the SATO project, funded by European Union. More info about the project here: https://cordis.europa.eu/project/id/957128

This survey assesses the current level of user interaction with the energy systems in residential and service buildings, and identifies the user's needs.

One should consider an energy system as any device that has relevant energy consumption in buildings.

Please refer your answers to the previous era of COVID-19.

Your participation in this study will be confidential.

It should take no more than 5-10 minutes to complete this questionnaire.

Thank you for your time and collaboration.

*Required

1 - User characterization

1.1 - Age *

- ◯ a) Less than 20
- ◯ b) 21-40
- ◯ c) 41-60
- ◯ d) More than 60

1.2 - Which option best describes you? *

- ◯ a) Occupant of a residential/service building
- ◯ b) Building owner/manager, Facility manager
- ◯ c) Energy service companies, grid operators

2 - Service building occupant

2.1 - Do you operate any energy systems in a service building? *

Offices, Educational buildings, Health clubs, Restaurants, Shopping Centers, sports facilities, Hotels, etc.

- ◯ a) Yes
- ◯ b) No

2.2 - What type of control do you have over the energy systems? *

Choose one option for each energy system.

	1) Not available	2) No control	3) Manual control	4) Digital control (only this energy system)	5) Digital control (multiple energy systems)
a) Appliances (washing machine, microwave, dishwasher, etc)	◯	◯	◯	◯	◯
b) Blinds and/or shades	◯	◯	◯	◯	◯
c) Cooling	◯	◯	◯	◯	◯
d) EV charging stations	◯	◯	◯	◯	◯
e) Heating	◯	◯	◯	◯	◯
f) Lighting	◯	◯	◯	◯	◯
g) PV production	◯	◯	◯	◯	◯
h) Sanitary hot water	◯	◯	◯	◯	◯
i) Ventilation	◯	◯	◯	◯	◯
j) Windows	◯	◯	◯	◯	◯

2.3 - How often do you use your energy systems? *

Choose one option for each energy system. If in Question 2.2 one has chosen "Not Available" or "No control" for a certain energy system, in this question one should choose "Not Applicable" for that same energy system.

	1) Not applicable	2) Never	3) Daily	4) Weekly	5) Monthly	6) Yearly
a) Appliances (washing machine, microwave, dishwasher, etc)	◯	◯	◯	◯	◯	◯
b) Blinds and/or shades	◯	◯	◯	◯	◯	◯
c) Cooling	◯	◯	◯	◯	◯	◯
d) EV charging stations	◯	◯	◯	◯	◯	◯
e) Heating	◯	◯	◯	◯	◯	◯
f) Lighting	◯	◯	◯	◯	◯	◯
g) PV production	◯	◯	◯	◯	◯	◯
h) Sanitary hot water	◯	◯	◯	◯	◯	◯
i) Ventilation	◯	◯	◯	◯	◯	◯
j) Windows	◯	◯	◯	◯	◯	◯

2.4 - Which management tools do you use with your energy systems? *

Choose one option for each energy system. If in Question 2.2 one has chosen "Not Available" or "No control" for a certain energy system, in this question one should choose "Not Applicable" for that same energy system.

	1) Not applicable	2) No tools	3) Timer plug	4) Smart plug/ Power meter	5) On-device control	6) Standard remote control	7) Data-driven interface	8) Own data-driven analysis	9) Building management system
a) Appliances (washing machine, microwave, dishwasher, etc)	○	○	○	○	○	○	○	○	○
b) Blinds and/or shades	○	○	○	○	○	○	○	○	○
c) Cooling	○	○	○	○	○	○	○	○	○
d) EV charging stations	○	○	○	○	○	○	○	○	○
e) Heating	○	○	○	○	○	○	○	○	○
f) Lighting	○	○	○	○	○	○	○	○	○
g) PV production	○	○	○	○	○	○	○	○	○
h) Sanitary hot water	○	○	○	○	○	○	○	○	○
i) Ventilation	○	○	○	○	○	○	○	○	○
j) Windows	○	○	○	○	○	○	○	○	○

2.5 - How satisfied are you with your degree of the energy systems' control? *

Choose one option for each energy system. If in Question 2.2 one has chosen "Not Available" or "No control" for a certain energy system, in this question one should choose "Not Applicable" for that same energy system.

	1) Not applicable	2) Very Poor	3) Poor	4) Neither good or poor	5) Good	6) Very Good
a) Appliances (washing machine, microwave, dishwasher, etc)	○	○	○	○	○	○
b) Blinds and/or shades	○	○	○	○	○	○
c) Cooling	○	○	○	○	○	○
d) EV charging stations	○	○	○	○	○	○
e) Heating	○	○	○	○	○	○
f) Lighting	○	○	○	○	○	○
g) PV production	○	○	○	○	○	○
h) Sanitary hot water	○	○	○	○	○	○
i) Ventilation	○	○	○	○	○	○
j) Windows	○	○	○	○	○	○

3 - User preferences

3.1 - What makes you environmentally uncomfortable in buildings? *

Select the three most important sources of discomfort.

- ◯ a) Air draft
- ◯ b) Bad air quality
- ◯ c) Cold floor, walls, etc
- ◯ d) Improper lighting
- ◯ e) Noise
- ◯ f) Too cold during winter
- ◯ g) Too hot during summer
- ◯ h) Warm floor, walls, etc
- ◯ Other

3.2 - Would you like to have an interface with multiple energy systems integrated? *

- ◯ a) Yes
- ◯ b) No

3.3 - Which energy systems would you like to aggregate in that interface? *

- ◯ a) Appliances (refrigerator, microwave, dishwasher, etc)
- ◯ b) Automated blinds and/or shades
- ◯ c) Automated windows
- ◯ d) Cooling
- ◯ e) EV charging stations
- ◯ f) Heating
- ◯ g) Lighting
- ◯ h) PV production
- ◯ i) Sanitary hot water
- ◯ j) Ventilation

4 - Barriers

4.1 - What are the barriers that prevent the widespread use of interfaces in the building energy devices and systems sector? *

- ◯ a) Expensive solutions (e.g. high investment costs for retrofit, sensors, interface, etc)
- ◯ b) Lack of interest
- ◯ c) Lack of planning and/or implementation
- ◯ d) Lack of technical expertise/knowledge
- ◯ e) Missing standards
- ◯ f) Protectionism of manufacturers
- ◯ g) Technical barriers (e.g. missing communication protocols)
- ◯ h) Weak user interface
- ◯ i) There are none
- ◯ Other

5 - Interface preferences

5.1 - Choose the most important features in an interface for your energy systems. *

- ◯ a) Air quality monitoring
- ◯ b) Automated control over your energy systems
- ◯ c) Easy to use (user-friendly interface)
- ◯ d) Energy consumption (historical database)
- ◯ e) Energy consumption (real-time data)
- ◯ f) Fault detection and alarming
- ◯ g) Outdoor environment measures (real-time data)
- ◯ h) Outdoor environment monitoring (historical database)
- ◯ i) Suggestion of energy efficient actions
- ◯ j) Thermal comfort monitoring
- ◯ k) Visualization of system data (eg: temperature, power, pressure, state of charge)
- ◯ Other

5.2 - What is the most appropriate time step for data acquisition? *

	1) Less than a minute	2) 1-5 minutes	3) 5-15 minutes	4) 15-30 minutes	5) More than 30 minutes
a) Appliances (refrigerator, microwave, Dishwasher, etc)	◯	◯	◯	◯	◯
b) Blinds and/or shades	◯	◯	◯	◯	◯
c) Cooling	◯	◯	◯	◯	◯
d) Domestic hot water	◯	◯	◯	◯	◯
e) EV charging stations	◯	◯	◯	◯	◯
f) Heating	◯	◯	◯	◯	◯
g) Lighting	◯	◯	◯	◯	◯
h) PV production	◯	◯	◯	◯	◯
j) Windows	◯	◯	◯	◯	◯

5.3 - In which platform would you prefer to use an interface? *

◯ a) Web-based platform

◯ b) App-based platform

◯ c) Both

6 - Residential building occupant

6.1 - Do you operate any energy systems in a residential building? *

◯ a) Yes

◯ b) No

6.2 - What is the building configuration that you manage? *

Choose one option

◯ a) Small room

◯ b) An apartment

◯ c) A semi-detached house

◯ d) Detached house

6.3 - What type of control do you have over the energy systems? *

Choose one option for each energy system.

	1) Not available	2) No control	3) Manual control	4) Digital control (only this energy system)	5) Digital control (multiple energy systems)
a) Appliances (refrigerator, microwave, Dishwasher, etc)	○	○	○	○	○
b) Blinds and/or shades	○	○	○	○	○
c) Cooling	○	○	○	○	○
d) Domestic hot water	○	○	○	○	○
e) EV charging stations	○	○	○	○	○
f) Heating	○	○	○	○	○
g) Lighting	○	○	○	○	○
h) PV production	○	○	○	○	○
i) Ventilation	○	○	○	○	○
j) Windows	○	○	○	○	○

6.4 - How often do you use your energy systems? *

Choose one option for each energy system. If in Question 6.3 one has chosen "Not Available" or "No control" for a certain energy system, in this question one should choose "Not Applicable" for that same energy system.

	1) Not applicable	2) Never	3) Daily	4) Weekly	5) Monthly	6) Yearly
a) Appliances (refrigerator, microwave, Dishwasher, etc)	○	○	○	○	○	○
b) Blinds and/or shades	○	○	○	○	○	○
c) Cooling	○	○	○	○	○	○
d) Domestic hot water	○	○	○	○	○	○
e) EV charging stations	○	○	○	○	○	○
f) Heating	○	○	○	○	○	○
g) Lighting	○	○	○	○	○	○
h) PV production	○	○	○	○	○	○
i) Ventilation	○	○	○	○	○	○
j) Windows	○	○	○	○	○	○

6.5 - Which management tools do you use with your energy systems? *

Choose one option for each energy system. If in Question 6.3 one has chosen "Not Available" or "No control" for a certain energy system, in this question one should choose "Not Applicable" for that same energy system.

	1) Not applicable	2) No tools	3) Timer plug	4) Smart plug/ Power meter	5) On-device control	6) Standard remote control	7) Data-driven interface	8) Own data-driven analysis	9) Building management system
a) Appliances (refrigerator, microwave, Dishwasher, etc)	◯	◯	◯	◯	◯	◯	◯	◯	◯
b) Blinds and/or shades	◯	◯	◯	◯	◯	◯	◯	◯	◯
c) Cooling	◯	◯	◯	◯	◯	◯	◯	◯	◯
d) Domestic hot water	◯	◯	◯	◯	◯	◯	◯	◯	◯
e) EV charging stations	◯	◯	◯	◯	◯	◯	◯	◯	◯
f) Heating	◯	◯	◯	◯	◯	◯	◯	◯	◯
g) Lighting	◯	◯	◯	◯	◯	◯	◯	◯	◯
h) PV production	◯	◯	◯	◯	◯	◯	◯	◯	◯
i) Ventilation	◯	◯	◯	◯	◯	◯	◯	◯	◯
j) Windows	◯	◯	◯	◯	◯	◯	◯	◯	◯

6.6 - How satisfied are you with your degree of the energy systems' control? *

Choose one option for each energy system. If in Question 3.3 one has chosen "Not Available" or "No control" for a certain energy system, in this question one should choose "Not Applicable" for that same energy system.

	1) Not applicable	2) Very Poor	3) Poor	4) Neither good or poor	5) Good	6) Very Good
a) Appliances (refrigerator, microwave, Dishwasher, etc)	◯	◯	◯	◯	◯	◯
b) Blinds and/or shades	◯	◯	◯	◯	◯	◯
c) Cooling	◯	◯	◯	◯	◯	◯
d) Domestic hot water	◯	◯	◯	◯	◯	◯
e) EV charging stations	◯	◯	◯	◯	◯	◯
f) Heating	◯	◯	◯	◯	◯	◯
g) Lighting	◯	◯	◯	◯	◯	◯
h) PV production	◯	◯	◯	◯	◯	◯
i) Ventilation	◯	◯	◯	◯	◯	◯
j) Windows	◯	◯	◯	◯	◯	◯

7 - User preferences

7.1 - What makes you environmentally uncomfortable in buildings? *

Select the three most important sources of discomfort.

- ◯ a) Air draft
- ◯ b) Bad air quality
- ◯ c) Cold floor, walls, etc
- ◯ d) Improper lighting
- ◯ e) Noise
- ◯ f) Too cold during winter
- ◯ g) Too hot during summer
- ◯ h) Warm floor, walls, etc
- ◯ Other

7.2 - Would you like to have an interface with multiple energy systems integrated? *

- ◯ a) Yes
- ◯ b) No

7.3 - Which energy systems would you like to aggregate in that interface? *

- ◯ a) Appliances (refrigerator, microwave, dishwasher, etc)
- ◯ b) Automated blinds and/or shades
- ◯ c) Automated windows
- ◯ d) Cooling
- ◯ e) EV charging stations
- ◯ f) Heating
- ◯ g) Lighting
- ◯ h) PV production
- ◯ i) Sanitary hot water
- ◯ j) Ventilation

8 - Barriers

8.1 - What are the barriers that prevent the widespread use of interfaces in the building energy devices and systems sector? *

- ○ a) Expensive solutions (e.g. high investment costs for retrofit, sensors, interface, etc)
- ○ b) Lack of interest
- ○ c) Lack of planning and/or implementation
- ○ d) Lack of technical expertise/knowledge
- ○ e) Missing standards
- ○ f) Protectionism of manufacturers
- ○ g) Technical barriers (e.g. missing communication protocols)
- ○ h) Weak user interface
- ○ i) There are none
- ○ Other

9 - Interface preferences

9.1 - Choose the most important features in an interface for your energy systems. *

- ○ a) Air quality monitoring
- ○ b) Automated control over your energy systems
- ○ c) Easy to use (user-friendly interface)
- ○ d) Energy consumption (historical database)
- ○ e) Energy consumption (real-time data)
- ○ f) Fault detection and alarming
- ○ g) Outdoor environment measures (real-time data)
- ○ h) Outdoor environment monitoring (historical database)
- ○ i) Suggestion of energy efficient actions
- ○ j) Thermal comfort monitoring
- ○ k) Visualization of system data (eg: temperature, power, pressure, state of charge)
- ○ Other

9.2 - What is the most appropriate time step for data acquisition? *

	1) Less than a minute	2) 1-5 minutes	3) 5-15 minutes	4) 15-30 minutes	5) More than 30 minutes
a) Appliances (refrigerator, microwave, Dishwasher, etc)	◯	◯	◯	◯	◯
b) Blinds and/or shades	◯	◯	◯	◯	◯
c) Cooling	◯	◯	◯	◯	◯
d) Domestic hot water	◯	◯	◯	◯	◯
e) EV charging stations	◯	◯	◯	◯	◯
f) Heating	◯	◯	◯	◯	◯
g) Lighting	◯	◯	◯	◯	◯
h) PV production	◯	◯	◯	◯	◯
j) Windows	◯	◯	◯	◯	◯

9.3 - In which platform would you prefer to use an interface? *

◯ a) Web-based platform

◯ b) App-based platform

◯ c) Both

10 - Suggestions

10.1 - Is there any comment, suggestion or advice that you would like to make regarding this questionnaire or the SATO platform interface? *

11 - Building type

11.1 - What is the type of building that you manage? *

In case of managing both building type, choose the one with the largest floor area.

◯ a) Residential buildings

◯ b) Service buildings

11.2 - What is the floor area (in square meters) of the building that you manage? *

12 - Building manager

12.1 - What type of control do you have over the energy systems? *

Choose one option for each energy system.

	1) Not available	2) Manual control	3) Digital control (only this energy system)	4) Digital control (multiple energy systems)
a) Appliances (washing machine, microwave, dishwasher, etc)	○	○	○	○
b) Blinds and/or shades	○	○	○	○
c) Cooling	○	○	○	○
d) EV charging stations	○	○	○	○
e) Heating	○	○	○	○
f) Lighting	○	○	○	○
g) PV production	○	○	○	○
h) Sanitary hot water	○	○	○	○
i) Ventilation	○	○	○	○
j) Windows	○	○	○	○

12.2 - How often do you interact with your energy systems? *

Choose one option for each energy system. If in Question 12.1 one has chosen "Not Available" for a certain energy system, in this question one should choose "Not Applicable" for that same energy system.

	1) Not applicable	2) 1-2x Week	3) 3-4x Week	4) 5-6x Week	5) Everyday
a) Appliances (washing machine, microwave, dishwasher, etc)	○	○	○	○	○
b) Blinds and/or shades	○	○	○	○	○
c) Cooling	○	○	○	○	○
d) EV charging stations	○	○	○	○	○
e) Heating	○	○	○	○	○
f) Lighting	○	○	○	○	○
g) PV production	○	○	○	○	○
h) Sanitary hot water	○	○	○	○	○
i) Ventilation	○	○	○	○	○
j) Windows	○	○	○	○	○

12.3 - Which management tools do you interact with your energy systems? *

Choose one option for each energy system. If in Question 12.1 one has chosen "Not Available" for a certain energy system, in this question one should choose "Not Applicable" for that same energy system.

	1) Not applicable	2) No tools	3) Timer plug	4) Smart plug/ Power meter	5) On-device control	6) Standard remote control	7) Data-driven interface	8) Own data-driven analysis	9) Building management system
a) Appliances (washing machine, microwave, dishwasher, etc)	○	○	○	○	○	○	○	○	○
b) Blinds and/or shades	○	○	○	○	○	○	○	○	○
c) Cooling	○	○	○	○	○	○	○	○	○
d) EV charging stations	○	○	○	○	○	○	○	○	○
e) Heating	○	○	○	○	○	○	○	○	○
f) Lighting	○	○	○	○	○	○	○	○	○
g) PV production	○	○	○	○	○	○	○	○	○
h) Sanitary hot water	○	○	○	○	○	○	○	○	○
i) Ventilation	○	○	○	○	○	○	○	○	○
j) Windows	○	○	○	○	○	○	○	○	○

12.4 - How satisfied are you with your degree of the energy systems' control? *

Choose one option for each energy system. If in Question 12.1 one has chosen "Not Available" for a certain energy system, in this question one should choose "Not Applicable" for that same energy system.

	1) Not applicable	2) Very Poor	3) Poor	4) Neither good or poor	5) Good	6) Very Good
a) Appliances (washing machine, microwave, dishwasher, etc)	○	○	○	○	○	○
b) Blinds and/or shades	○	○	○	○	○	○
c) Cooling	○	○	○	○	○	○
d) EV charging stations	○	○	○	○	○	○
e) Heating	○	○	○	○	○	○
f) Lighting	○	○	○	○	○	○
g) PV production	○	○	○	○	○	○
h) Sanitary hot water	○	○	○	○	○	○
i) Ventilation	○	○	○	○	○	○
j) Windows	○	○	○	○	○	○

13 - User preferences

13.1 - What drives your control actions? *

- ○ a) CO2 concentration
- ○ b) Energy consumption
- ○ c) Energy costs
- ○ d) Flexibility management
- ○ e) Humidity ratio
- ○ f) Improper lighting
- ○ g) Occupant density
- ○ h) Thermal Comfort

13.2 - Would you like to have an interface with multiple energy systems integrated? *

- ○ a) Yes
- ○ b) No

13.3 - Which energy systems would you like to aggregate in that interface? *

- ○ a) Appliances (refrigerator, microwave, dishwasher, etc)
- ○ b) Automated blinds and/or shades
- ○ c) Automated windows
- ○ d) Cooling
- ○ e) EV charging stations
- ○ f) Heating
- ○ g) Lighting
- ○ h) PV production
- ○ i) Sanitary/domestic hot water
- ○ j) Ventilation

14 - Barriers

14.1 - What are the barriers that prevent the widespread use of interfaces in the building energy devices and systems sector? *

- ○ a) Expensive solutions (e.g. high investment costs for retrofit, sensors, interface, etc)
- ○ b) Lack of interest
- ○ c) Lack of planning and/or implementation
- ○ d) Lack of technical expertise/knowledge
- ○ e) Missing standards
- ○ f) Protectionism of manufacturers
- ○ g) Technical barriers (e.g. missing communication protocols)
- ○ h) Weak user interface
- ○ i) There are none
- ○ Other

15 - Interface preferences

15.1 - Choose the most important features in an interface for your energy systems. *

- ○ a) Air quality monitoring
- ○ b) Automated control over your energy systems
- ○ c) Easy to use (user-friendly interface)
- ○ d) Electric demand forecast
- ○ e) Energy consumption (historical database)
- ○ f) Energy consumption (real-time data)
- ○ g) Fault detection and alarming
- ○ h) Flexibility forecast
- ○ i) Heating and cooling demand forecast
- ○ j) Maximum available power in charge
- ○ k) Maximum available power in discharge
- ○ l) Outdoor environment measures (real-time data)
- ○ m) Outdoor environment monitoring (histrorical data)
- ○ n) PV production forecast
- ○ o) Suggestion of energy efficient actions
- ○ p) Thermal comfort monitoring
- ○ q) Visualization of system data (eg: temperature, power, pressure, state of charge)
- ○ Other

15.2 - Which type of flexibility managements tools would you like to have access in the interface? *

- ◯ a) Power-shiftable appliances (EV batteries)
- ◯ b) Thermal storage (hot water tank, building as a battery)
- ◯ c) Thermostatically controlled appliances (HVAC systems, electric water heaters, refrigerators, etc)
- ◯ d) Time shiftable appliances (washing machines, dishwashers, clothes dryers, etc)
- ◯ e) All of the above
- ◯ Other

15.3 - What is the most appropriate time step for data acquisition? *

	1) Less than a minute	2) 1-5 minutes	3) 5-15 minutes	4) 15-30 minutes	5) More than 30 minutes
a) Appliances (refrigerator, microwave, Dishwasher, etc)	◯	◯	◯	◯	◯
b) Blinds and/or shades	◯	◯	◯	◯	◯
c) Cooling	◯	◯	◯	◯	◯
d) Domestic hot water	◯	◯	◯	◯	◯
e) EV charging stations	◯	◯	◯	◯	◯
f) Heating	◯	◯	◯	◯	◯
g) Lighting	◯	◯	◯	◯	◯
h) PV production	◯	◯	◯	◯	◯
i) Ventilation	◯	◯	◯	◯	◯
j) Windows	◯	◯	◯	◯	◯

15.4 - Grade the importance of having an interface feature to display the amount of power available for flexibility management. *

- ◯ 1 - Not Important
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 - Very Important

15.5 - In which platform would you prefer to use an interface? *

- ◯ a) Web-based platform
- ◯ b) App-based platform
- ◯ c) Both

16 - Suggestions

16.1 - Is there any comment, suggestion or advice that you would like to make regarding this questionnaire or the SATO platform interface? *

17 - Grid operators

17.1 - Which type of grid operator are you? *

- ○ a) Distribution system operator
- ○ b) Energy service provider
- ○ c) Transmission system operator

17.2 - Grade the importance for the electric grid to have buildings with flexible energy consumption. *

- ○ 1 - Not Important
- ○ 2
- ○ 3
- ○ 4
- ○ 5 - Very Important

18 - Interface preferences

18.1 - Choose the most important features in an interface to respond to electrical grid requests. *

- ○ a) Flexibility dispatch
- ○ b) Flexibility forecast
- ○ c) Load shifting
- ○ d) Peak shaving
- ○ e) Power consumption in each node
- ○ Other

18.2 - How often do you think to be appropriate the communication between the interface and the electric grid? *

- ○ a) Less than a minute
- ○ b) 1-5 minutes
- ○ c) 5-15 minutes
- ○ d) 15-30 minutes
- ○ e) More than 30 minutes

18.3 - How often would you like to have data for each energy system? *

	1) Less than a minute	2) 1-5 minutes	3) 5-15 minutes	4) 15-30 minutes	5) More than 30 minutes
a) Air handling units	○	○	○	○	○
b) Cloth dryer	○	○	○	○	○
c) Cooker	○	○	○	○	○
d) Dishwasher	○	○	○	○	○
e) Electric boiler	○	○	○	○	○
f) EV charging stations	○	○	○	○	○
g) HVAC	○	○	○	○	○
h) Oven	○	○	○	○	○
i) PV	○	○	○	○	○
j) Refrigerator	○	○	○	○	○
k) Vacuum cleaner	○	○	○	○	○
l) Washing machine	○	○	○	○	○

18.4 - Which appliances would you like to have an aggregate information of their power consumption? *

○ a) Air handling units

○ b) Cloth dryer

○ c) Cooker

○ d) Dishwasher

○ e) Electric boiler

○ f) EV charging stations

○ g) HVAC

○ h) Oven

○ i) PV

○ j) Refrigerator

○ k) Vacuum cleaner

○ l) Washing machine

○ Other

18.5 - In which platform would you prefer to use an interface? *

○ a) Web-based platform

○ b) App-based platform

○ c) Both

19 - Suggestions

19.1 - Is there any comment, suggestion or advice that you would like to make regarding this questionnaire or the SATO platform interface? *

Annex 3 – Expert interviews

Expert interviews – Residential users

Interview guideline:

0. Introduce the SATO project (do a quick guided tour of the website, not more than 5min).
1. How are you currently managing your building energy systems and devices using digital tools?
    a. Do you use any interface to manage building energy systems and appliances? If yes, how many? (if not, go to question #2)
    b. Do you receive information about the energy performance of the building and its energy-consuming devices?
    c. How often do you perform management actions on the energy systems?
    d. What are currently the main barriers that you feel using digital systems?
2. If you are currently not using any digital tools to manage energy systems, could tell us why?
3. Do you have any renewable energy systems (e.g., PV)?
    a. The integration and optimization features of the SATO platform would encourage you to introduce renewable energy systems (e.g., PV).
4. When purchasing appliances, do you consider their energy class and connectivity capabilities?
5. In a perfect scenario, how would you like to manage your energy system?
    a. Would you like to have a 3D model or a simplified plan view of your house?
    b. What information you would like to see in this interface? (e.g., room temps, CO_2, Energy consumption).
    c. How often would you like to receive energy consumption data?
    d. What level of energy consumption detail would you like on a spatial scale? (each node, division, etc)
    e. Would you be available for the introduction of dynamic tariffs, with the assumption that this will guarantee savings in your energy consumption?
    f. Would you be available to enable control of your energy systems by the electric network operators?
    g. Would you like to receive comparative information (is it using more or less energy than comparable buildings/appliances) about the energy consumption of your building and even individual appliances?
    h. Would you like to have your household energy certification and smart readiness carried out in dynamic way? Why?
6. Would you like to have AI-based energy assessments about your house and its energy-consuming equipment?
7. Would you accept AI-based control? Aceitaria o controlo baseado em inteligência artificial?
    a. Would you like to have suggested actions to reduce energy consumption?
    b. Would you accept a system with full autonomous control?
8. Do you have any suggestions for the SATO platform, features, services, etc?

Expert interviews – Building energy managers

Interview guideline:

0. Introduce the SATO project (do a quick guided tour of the website, not more than 5min).
1. How are you currently managing building energy systems and devices?
    a. Do you use any interface to manage building energy systems and appliances? If yes, how many?
    b. Do you receive information about the energy performance of the building and its energy-consuming devices?
    c. Do you manage any renewable energy systems (e.g., PV)?
    d. How often do you perform management actions on the energy systems?
2. In a perfect scenario, how would you like to manage your energy system?
    a. Would a 3D BIM model of the building and energy systems be essential to understand energy consumption?
    b. What information you would like to see in a BIM interface? (e.g., Temps, CO_2, Energy consumption)
    c. How often would you like to receive energy consumption data?
    d. How important would it be to have detailed information on a room-scale?
    e. Would you like to receive comparative information (is it using more or less energy than comparable buildings/appliances) about the energy consumption of your building and even individual appliances?
3. Would you accept AI-based energy assessments?
4. Do you have any automated control features in your systems?
    a. If yes, what are the actions that are triggered automatically?
5. Would you accept AI-based automated control?
    a. Would you like to have suggested actions to reduce energy consumption?
    b. Would you accept a system with full autonomous control?
6. Do you have any suggestions for the SATO platform, features, services, etc?

Expert interviews – Grid operators

Interview guideline:

0. Introduce the SATO project (do a quick guided tour of the website, not more than 5min).
1. Would you be interested in having access to real-time demand/supply data and its forecast? Why would/wouldn’t it be important?
    a. How often would you like to have real-time demand/supply data? And its forecast?
2. Do you currently have any flexibility management service to assist the grid operation?
    a. Is the service from the supply or demand side?
    b. Do you provide any load shifting or peak shaving services?

   c. Do you provide any ancillary services? If so, which ones?
   d. What is the minimum power capacity to provide ancillary services? For how long?
3. What is the maximum granularity in measuring demand? And in forecasting supply or demand?
   a. Is it at a region-scale, district-scale, building-scale?
4. Would you be interested in using an interface that can implement advanced control strategies for energy systems in buildings and provide flexibility services to the grid?
   a. Note: Once scaled to a certain level, the SATO platform can be used to send signals (by standardized APIs) to flexible electrical and thermal storage capacities and devices authorized for remote control in the connected buildings.
5. If you are an energy service provider wanting to establish a business model for green, local energy for their clients: The SATO platform can be used for the implementation of an adaptive control for the energy systems on-site with the objective to maximize the use of locally available renewable energies. Is this a type of service that would interest you?
6. Do you have any suggestions for services that the SATO platform could provide?

Annex 4 – Summary of responses

- **Summary of the interviews to the residential users**

Table 9: Summary of responses from residential occupants.

	Respondent #1	Respondent #2	Respondent #3	Respondent #4	Respondent #5	Respondent #6	Respondent #7	Respondent #8	Respondent #9	Respondent #10	Respondent #11	Respondent #12
1.a	-Inverter for PV production enabling production monitoring. -Power meter for kitchen energy services.	-Cloogy	-Monitor energy entering the building and the main appliances (dishwasher, oven, washing machine, heat pump) via Konnex system	-Heating system, with weekly schedule with the option for the occupant to change the setpoints whenever needed. Solar thermal system, with DHW pre-heating managed with a thermostatic valve on the generator.	-Yes;	- A system connected to the heat generator and gives me an accounting of consumption monthly, requires the user to go to the site and connect to provide data such as the thermal kWh consumed and the m^3 of hot and cold water. Beta system for app-based interconnection, connected to electricity meter and based on the analysis of the load profiles and on an initial questionnaire, it tries to identify the different appliances connected.	-Heat pump: "TCA Remote Control" web app for monitoring and adjustment of control parameters Use on desktop or mobile phone. -Heat pump boiler: device display and buttons for adjustment of control parameters. Display of live values, no historical data available. -PV inverter: SolarEdge app for monitoring PV-production, total building consumption, grid supply and return, degree of self-consumption and self-sufficiency. Heat Energy Meter: MyNeovac Web App on mobile phone for monitoring the heating energy produced and the electricity consumption. Automatically calculates the seasonal performance factor of the heat pump.	-No, systems are old and do not have any interfaces to connect. -Phillips hue for control illumination.	-iBricks for room automation and control, it was planned to integrate heating and ventilation systems into iBricks, but it was too expensive. -PV-System Monitoring of energy production with the inverters manufacturer platform (SolarEdge).	-Automated and remote-controlled heating and cooling;	-Control heating and cooling by changing the thermostats on each room. -Ventilation is automatic. -No control of the lighting besides on/off function.	Yes, for HVAC that has an application for the mobile phone that allows to interact with the appliances. -EDP application that allows to monitor the consumption and to access the consumption estimates.
1.b	-Aggregate consumption.	-Disaggregate consumption.	-Yes.	-No;	No;	-Yes.	-Total electricity and heating energy consumption on building level.	-No, only the energy bills on paper.	-No digital Information on energy	-Receives heating and cooling energy	-No, I can follow my disaggregated	- Yes, through EDP electronic invoice.

							No information for individual devices, except heat pump and PV-System.		consumption expect for the PV-System production. -Energy meters are not connected, an automatic meter readout with monitoring would be useful.	consumption trough an intelligent panel. Also receives information about moisture in the air;	energy consumption on a small information panel. (Cooling, heating, lighting, DHW).	
1.c	-Never	-In winter for consumption monitoring purposes. -As the interface has been in operation for 5 years, there is no longer any need for regular monitoring, as it has already developed the necessary awareness about the optimized management of the various energy systems.	-Do not need to perform management actions, because after years living in this house I have already set and fine-tuned the automations. -Never exceed the hired power threshold, so do not need to perform management actions to reduce the instantaneous loads.	-Since the pandemic has started, we have been spending more time at home and I started correcting the system setpoint daily, much based on the sensation. -Seasonally adjust a reversible heat pump to manage heating/cooling with heat pump or radiators.	-Every 3-6 months. -In the first phases even frequently.	- Once a year I intervene on the climatic curve of the heat generator, to improve the performance of my heating/cooling system.	-Heat pump and PV-System in use since Oct. 2020. Since then, 2 – 3 times. Done adjustments of parameters to optimize the systems (lowering temperature) or to better adapt to the user behavior (change of schedule).	-No actions, because have no access to the systems as tenant.	-Today not very often (1-2 times a year); -In the first two years after construction every month. Manly for the heating system.	-Never;	-Once or twice a year for heating. -During summer open windows daily.	- It is not done very regularly just in relation to the use of natural gas.

1.d	-Cost. -Lack of uniformity in communicatio n protocols.	-Lack of long-term interest. -Difficulties of communicatio n. -Lack of warnings in case of communicatio n failure.	-Not answered.	-Lack of long-term interest. -Small energy saving potential.	-Not answered.	-Lack of privacy. -Not user friendly.	-Not answered.	-Not answered.	-High cost (e.g., KNX)	-Not answered.	-Not answered.	-Necessary technical knowledge. -Ease of use for the average user;
2.	-NA	-NA	-NA	-NA	-It is not yet so diffused in residential sector;	-NA.	-NA.	-No, because as tenant no influence on systems owned by the owner of the building. -If I be the owner, I would use digital tools for monitoring and controlling.	-NA.	-Not possible;	-NA;	-NA;
3.	-PV and solar thermal. -Replace the solar thermal system with a heat pump, because through a platform like	-No. -Yes, because one of the identified problems is the fact that consumers do not monitor their	-No.	-Solar thermal;	No;	-Not, but it is my intention to integrate PV, solar thermal and geothermal heat pump.	-PV system.	-No.	-PV-System.	-No;	-No;	-No. - From the point of view of an occupant of residential buildings the introduction of renewable systems depends

	SATO it would allow to program the heat pump so that it works only in the period of greatest production of the photovoltaic system.	production systems and only realize it when they receive the electricity bill. It is very important to develop low-cost tools for monitoring Production Units for Self-consumption (UPAC) for systems to become more attractive.										also on the remaining tenants and these decisions. -For occupants, whose decision depends on themselves, the optimization services that SATO proposes together with the introduction of dynamic tariffs would encourage the introduction of renewable systems.
4	-Considers the energy class, due to the energy efficiency and quality. -Does not consider its connectivity. -There is not still a perfect match between the quality of the equipment and the interconnectivity of the same	-Considers the energy class. -Does not consider its connectivity. -He considers that a brand is something that is still highly regarded by consumers.	-Yes, to both.	-Considers the energy class. -Does not consider its connectivity. -Prefer manual management in real time.	-Considers the energy class. -Does not consider its connectivity.	Consider both;	-Considers the energy class. -Does not consider its connectivity. -Do not consider connectivity capabilities, but could be interesting for washing machine, dryer, dishwasher;	-Considers the energy class for TV, IT equipment, etc. but not for household appliances because these are replaced by the owner. -Equal for connectivity;	-Considers the energy class. -Considers connectivity, to ensure the appliances can be implemented in the existing system.	-No, but I am aware of the energy label on the products. -I care about the total consumption in the apartment;	-Yes, I consider both, since I know it has an impact on my consumption and I often follow my consumption on the information panel.	-Considers the energy class. -Does not consider its connectivity.

	with the internet.											
5.a	-Digital floor plan for apartments. -3D model for service buildings and residences with more than one floor.	-Does not consider essential.	-Already have a simplified plan view, in which the different instantaneous power. consumptions are highlighted with different colors. -Do not think that would need a 3D view.	-A schematic model indicating the number of rooms would be enough. -A residential apartment does not need complex visualization.	-Simplified plan;	-It seems to me an excellent idea to have a 3D map of all the systems present, to be able to manage them efficiently.	-Yes, would be interesting if detailed data from single rooms or appliances is available.	-Of course, because it is fancy but not very useful from a tenant perspective. -Useful if you can add actions you performed on a room or appliance (kind of a logbook for the history of actions).	-3D is interesting but it should not become too complicated/ complex to use. -2D view of the building layout is often enough;	Personally, I would not use either, it is too much detail.	-It would be interesting to see a graphic or floor plan to control it. -Maybe have an option to time control it on this view plan, so I do not have a high consumption while not at home.	-Yes, it would be very interesting mainly for more detailed monitoring.
5.b	-Energy consumption. -Indoor temperature. -Humidity. -CO2 concentration.	-Energy consumption. -Indoor temperature. -Comparison with similar buildings.	-Instantaneous electric power. -Energy used in a certain period (e.g., last 24 hours), with the option to reset this value. -It is important the storage of the data.	-Information for each system, for each energy carrier broken down by end use (heating, cooling, cooking, DHW, lighting, appliances). For electrical uses, divided by electrical device, to understand obsolescence and highlight	-Room temperatures. -Energy consumption. -Schedule (remaining time for appliances with cycles). -Average consumption per appliance (monthly/yearly).	-Energy consumption. -Instantaneous power. -Indoor temperature. -Environmental temperature. -Operating parameters of the energy systems (e.g., the temperatures of the heat transfer fluids, or to know if the heat pump is also producing domestic hot water).	-Room temperature. -Schedules. -Energy consumption. -Energy production.	-Visualization of the user's presence. -Forecast of behavior; -Energy consumption. -Energy production. -Booking system for EVs. -Indoor temperature.	-Status of light. -Shading (actual position (open/close) -Indoor temperature (setpoint and actual value). -CO2 levels. -Energy consumption;	-Indoor temperature. -Ventilation. -Moisture in the air.	-Energy consumption which is user friendly. -Calculate it to something that is easy to understand. Maybe compare consumption with something else.	-Ambient temperature. -Energy consumption. -Water consumption. -Gas consumption. -Proposes the possibility of personalizing information;

				the need for replacement. -It would be useful to provide indicators that can be easily understood even by users who are not familiar with some physical quantities.				- Environmental temperature. -Video feed from cameras -Status of devices (on/off). -Energy consumption per device;				
5.c	-5-10 minutes, not only for the energy consumed in real time but also for the historical database.	-Once a month. -In events of flexibility or tariff reduction, the platform must send an alert, and there should be no constant communicatio n.	-Every day.	-Real time. -Daily based history, for electrical and thermal uses. -Average daily profiles.	-Every week;	-Real time information. -Data history (last day, week, month). -For electricity consumption a sampling every 15 minutes. -For thermal and environmental data, sampling could be hourly. -Receive notifications on events, such as exceeding predefined thresholds.	-Live-data should be available all time;	-Real time information. -Historic data on a 15-minute scale;	-For monitoring purposes: monthly and annually to compare different periods. -For optimization: a shorter resolution would be useful to find optimization potential.	-Daily. -Weekly. -Monthly. -Yearly.	-Weekly;	-Hourly basis. -Every half hour. -Ideally, the frequency would be adaptive to the occupant's personalization;
5.d	-At apartment level it would be important to disassociate the kitchen from the	-It does not make sense to break down consumption by division.	-Not important. -Already know that the most energy-using appliances are concentrated	-Not about electrical uses because I know where the devices are.	-Non important in residential sector;	-Distinguish the kitchen from the bedrooms, especially in terms of air quality. -If it is too complex and expensive to divide room by room, you could at least	-Would be interesting but not very important.	-Important for billing the effective consumption per room/ apartment to the tenants.	-Only for light, shading and room temperature. -Other values are not very	-Yes, it would be fine to see these things on a room level.	-Yes, the rooms have different functions, so the consumption will be different for	-I would like to have information about each outlet. -For the common occupant it is a lot of information

	remaining divisions. -For detect faults and problems it makes sense to have for each outlet.		in the kitchen, plus some single appliances in other rooms (washing machine, heat pump).	-Regarding heating/coolin g it may be interesting to have information on a room-scale, to be able to make some considerations about zoning.		divide between living and sleeping areas.		-Monitor the operational behavior of a room (temperature, air quality, etc.)	relevant for the daily use.		each room and period of the day.	that they will not take advantage. -Since SATO presupposes the visualization of the BIM plant / model, the introduction of a color code (traffic light style) at the location of each outlet could be considered.
5.e	-Encouraged to divert non-urgent cargo. -Not deprive of essential energy systems. -Dynamic tariffs cannot be harmful to the consumer.	-Only if there is certainty of a reduction in energy consumption.	-Not answered.	-Not answered.	-Not answered.	-Not answered.	-Not answered.	-Not answered.	-Not answered.	-Not answered.	-Not answered.	-Yes, however, the way of presenting this information should be explanatory and should be supported by examples.
5.f	-Only domestic hot water systems due to the reservation system they have as it would not influence consumers routines.	-If it is my renewable energy cooperative, yes. -If you are the national network operator, do not. -It only gave access to the	-Not answered.	-Not answered.	-Not answered.	-Not answered.	-Not answered.	-Not answered.	-Not answered.	-Not answered.	-Not answered.	- I would like them to have only access to information to suggest flexibility actions.

		consumptions of the air conditioning systems, but total control did not.										
5.g	-Yes, for enable a perspective on the energy consumed in relation to 'normal'.	-Yes, comparing energy consumption of home appliances makes sense.	-I would rather receive comparison information about my energy consumptions over time. -Regarding the comparison with the consumptions of comparable appliances, it may be interesting. The comparison with similar buildings (showing aggregated average data) may be interesting.	-It would be useful the AI to be able to provide an ideal optimization plan for deferrable energy services, based on the input needs.	-At appliance level: divided by appliance type or family. -At room level temperatures and consumption. -Average temperature in the room. -Energy consumption (kWh) for heating/cooling.	-I would like to receive this information and receive advice on how to improve my behaviours, if they are not in line with best practices. -I would also be interested in comparative evaluations on my own building, relating to previous periods.	-Yes, would be important. -Without comparing to other buildings, you do not know if your building is running good or not.	-Yes, compare inside the building and similar buildings (building, type, age, size) in the neighbourhood. -Comparison, will motivate to be better than the average, which could motivate to a more energy saving behaviour.	-This would be a nice to have, only for control. -This could also be more interesting for a real estate/ property management company. -It would be more relevant on a building level then on an appliance level.	-No.	-Compare to my previous consumption or average. I would not agree to my consumption being public to my neighbour. -It would have to be anonymized.	-Yes, the comparison helps to normalize the consumption of similar buildings.
5.h	-Yes, for both.	-Yes, if it does not incur in extra costs.	-Not answered.	-Not answered.	-Not answered.	-Not answered.	-Not answered.	-Not answered.	-Not answered.	-Yes, but I will not pay extra for a better energy label. I cannot control	-Yes.	Yes, dynamic energy certification would be interesting, as it helps to

										them through internet or app.		understand the behaviour of the occupants. -It would increase the volume of information on the internet considerably which would result in an increase in energy consumption. -It would be interesting to do a study prior to the implementation of this functionality.
6	-Yes	-Yes.	-Yes.	-Yes, in a qualitative way of quality, without presenting numbers, but some kinds of quality indicators, easily understood by anyone;	-For the main end-uses (heating, cooling) or less controlled systems such as shading systems.	-Yes, obviously it should also consider the composition of the family unit and the technical characteristics of the building-plant system.	-Yes. -Interesting to compare own house with a benchmark to know much good/ efficient one is.	Yes, this type of assessment would be more comparable to other buildings because KI is less subjective and can take more parameters (e.g.: individual figures of the building and individual user behaviour) into account	-Yes, this is a good idea but should be kept within reasonable bounds. It should focus on the main parameters and not automate every detail.	-Not answered.	-Not answered.	- Yes, I would;

								to get very well comparable figures.					
7.a	-Yes	-Yes.	-Yes.	I would like to be able to bypass the artificial intelligence. Then it would be necessary to establish after how much time to return to automatic control. A.I. could only work subsystems, e.g., choose which type of generator is most efficient to use at a certain time. -Wouldn't want AI to interfere with my setpoints.	-Yes.	-I would first like to be made aware of the choices that the system intends to make and evaluate whether to implement them as they are, modify them or reject them.	-Yes. -Different Ideas, suggestions, and best practices how to improve efficiency. -Mainly for optimization of self-consumption.	-AI should make proposals to the user and he should confirm or refuse them. -User must be able to manually override if necessary.	-This would be a nice to have. -Probably only interesting in the beginning.	- Yes, but personally I think I would not benefit from it, due to the building quality.	- Yes, it would be interesting to get suggestions. -However, I would like it to be tangible, but with a possibility to get it elaborated if the consumer wants more details for maximize energy savings.	-Yes.
7.b	-Yes, also if in agreement with some optimization action then the platform could assume	-No.	Not from the beginning. After one year managed by me, I may try an autonomous	-No.	-Not for all end-uses;	-Before accepting a completely automated control, I would first like some intermediate steps where I can understand the logic of the system.	-Rather no, possibilities for manual intervention must be given.	-No;	-Yes, but not complete autonomous. -But manual intervention must be	- Yes, we have already accepted that in this building, but I would still like to be able to	- Yes, it sounds smart and effective. However, I would still like to have a weekly	-Yes, but the information on the actions taken must be kept in case the occupant

	that whenever it was necessary to apply this measure it would not be necessary to suggest it again.		control system in the following year, to test how it performs in terms of energy consumptions and comfort, compared to my management.						possible if AI does not do what is expected or required.	control the temperature in each room myself.	message about my consumption and tips. -Maybe also tell me in a weekly message how effective the automatic system has been, and so how much energy was saved.	wants to view this information.

- **Summary of the interviews to the building managers**

Table 10: Summary of responses from Facility/Building managers (Part 1 of 2).

	Respondent #1	Respondent #2
1.a	-Yes, two. BMS system for management and energy monitoring system for billing. Comparison of both interfaces allow fault detection.	-Yes, two. Simplified systems that manage HVAC only and have control boxes (buttons and a small LCD screen) with no remote access.
1.b	-Yes, the energy consumption is monitored at the building, system, and component level.	-Yes, a remote monitoring system for total energy consumption.
1.c	-No.	No.
1.d	-Only when the users complain or an alarm sound.	Twice a month.
2.a	-Yes, especially with a PC interface. Would like to see real location of systems and sensors. The interface should be able to be updated if changes in sensors/systems occur.	In single stores, such as the Worten strip mall stores, this system may be too much, but for larger operations such as supermarkets with adjoining stores under the same roof, the system could be very valuable.
2.b	-Temp, CO_2, energy consumption, sensor type, model.	Temp, CO_2, energy consumption, Relative humidity.
2.c	-Hourly data.	Hourly.
2.d	-Very important.	The room scale makes sense in the context of a large building. For small buildings, room scale may be too much detail.
2.e	-Yes, if the compared buildings are representative.	It can be immensely valuable for the operators.
3.	-Yes.	Yes, it sounds like a promising feature.
4.	-No, there is only triggered alarms, no changes are made automatically. In general, the system is rule based, with no automatic control options.	The systems used in larger shopping malls that the group runs have some automated control features, such as free cooling.
5.a	-Yes but should give a few precise suggestions.	-Yes, in principle this feature could be very valuable.
5.b	-Yes, it would be useful in some non-critical buildings, if the system could send detailed information about what	-Yes.

	has been done. Would not accept it in critical buildings.	
6.	-Precise feedback from the system. -Simple interface: Do not want a system with lots of data and graphs. Instead, it should only display the main KPI's and suggestions for improvements. -AI system should not enact control over the system and sould only give optimization suggestions to the building managers.	-Not at the moment.

Table 11: Summary of responses from Facility/Building managers (Part 2 of 2).

	Respondent #3	Respondent #4
1.a	-Yes, one. BMS with a web-based interface that controls lighting, switches, heat pumps, AHUs, PV, solar thermal for DHW.	-Yes, one. A basic remote monitoring system that gathers data from dozens to hundreds of energy systems sensors each 15 minutes and communicates with a cloud platform via GSM. This cloud platform runs a company's proprietary software that performs basic data treatment.
1.b	-Yes, multiple energy meters to measure each energy system and the user consumption in each room.	- Yes, there are information about the electrical energy consumption, gas and water consumption, enthalpy, etc.
1.c	-Yes, PV-System and Solar Thermal System. -Heat pump system with 100% renewable electricity (100% hydropower).	-Yes, PV and solar thermal.
1.d	Monthly reads of the data from the meters for energy accounting. Monthly adjustments of the shading control to achieve optimal mix of daylighting with glare protection. Automation of this feature would be very important. Daily monitoring of energy systems and rooms (BMS). Adjustments to BMS are scarce because the system is running for some years and is already very optimized.	-Weekly.

2.a	No, if the building that is being operated as a building manager on site. Otherwise, it will be useful to have the BIM model to see the zone where the devices and sensors are.	-The interface should be able to be updated if changes in sensors/systems occur. Interesting, however the 3D functionality is nothing new, neither an outstanding visualization tool for complex system. Sometimes, having a BMS system with a simplified 2D blueprints in combination with a good color scheme may be easier to visualization purposes.
2.b	Any relevant information usually seen in BMSs.	-Indoor air temperatures, energy consumption and performance of the energy systems (e.g., chiller plants).
2.c	15-minute data for optimization purposes. 1-month data for energy accounting.	-15 minutes.
2.d	Very important. It would be great to have a feedback from the energy systems (and possible failures) at a room scale. Live and historical data of temperature to prevent eventual discomfort complains.	-Not answered.
2.e	Yes, on a building level with comparable building in terms of size, usage type, same region).	-The benchmarking is an essential feature, specially to identify possible energy systems malfunctions at a reduced cost.
3.	Yes.	-Yes, it would be wonderful to have a feature like that.
4.	Yes. -Control of pumps by differential pressure -Control of supply air, heating and cooling by heating curve - Night cooling with natural ventilation by room and outside temperature (and rain, wind) - Central functions per room (all light on/off, all shadings up/down, etc.) - Schedule programs: lighting, ventilation, door locking system.	-Yes. There are basic automated control features such as, hourly activation systems and variable control (e.g., indoor air temperature); and advanced control features such as, the optimization of the chilled water production temperature.
5.a	-Yes, one can miss a specific topic, so it would be useful to have a comprehensive list with possible actions.	- Yes, it would be useful.

5.b	-Yes. Each energy system should be controlled based on specific KPIs. The same is valid for the whole building, however in this case KPIs should be trained over 1 year.	-Yes, if the interface would allow the user to always have the final decision while the interface should also show how well the energy systems are being managed.
6.	-Integration is key. SATO should support the commonly used integration protocols (e.g., OPC-UA and BACnet). -Simple user interface. Fault detection should lead to notifications. Operator/user should be able to prioritize the fault relevance (i.e., avoid notifications of less relevant faults). -Simple optimization adjustments should be done automatically (e.g., the shading control). -Interface should present live and historical data.	- Not at the moment.

- **Summary of the interviews to the grid operators**

Table 12: Summary of responses from grid operators.

	Respondent #1
1.a	-We already have 15-minute and hourly data from the demand and supply sides at low voltage, however it is limited to 110 000 users. We would like to reduce this data acquisition timestep, but the grid is still being upgraded to handle the increased amount of data.
2	-There is no regulated market for flexibility in Portugal.
2.a	-Not answered.
2.b	-Not answered.
2.c	-Not answered.
2.d	-Not answered.
3.a	-The current maximum granularity occurs on low voltage, at a scale of a district, where the voltage is converted from mid to low voltage in distribution transformer stations.
4	-Definitely, yes. Specially if the given grid constraint justifies the control over the supply side. It is expected that our need for flexible control over the energy systems on a building scale will grow with the massification of photovoltaics and electric vehicles.
5	-Not answered.
6	-Not answered.

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