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Self Assessment Towards Optimization of Building Energy

Deliverable 1.5

Description of the Use Cases and Test Experiments

Deliverable Lead: EDP NEW

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EXECUTIVE SUMMARY / ABSTRACT / SCOPE

The work developed in this report represents a basis for further definition of SATO Services and a guide for their application in pilot sites by providing a plan of actions that defines the different solutions envisioned for SATO and details their implementation.

Using IEC 62559 standard as a model for the Use Case Methodology, 15 High-Level Use Cases (HLUC) were identified in five complementary areas of SATO: Monitoring, Self-Assessment and benchmarking, Visualization, Self-Optimization, and Control. Most HLUCs address the innovative solutions proposed in SATO, while some provide support for the deployment of specific solutions or functionalities that already exist in the market but will be incorporated in the SATO platform and services.

The identification of the 15 High-Level Use Cases was detailed through the identification of objectives and KPIs needed for the evaluation, the specification of a narrative of interaction of the actors identified, and the definition of requirements, pre-requisites and the scenarios for the correct implementation (further work to be continued in Task 1.5).

According to these factors a set of 37 Primary Use Cases were defined, allowing to tailor some of the High-Level Use Cases to specific needs of some solutions or pilots. Finally, the Use Cases described will ensure an easier and consistent implementation of the solutions across the different pilots and will allow the replicability and scalability of the solutions.

1. Objectives of the task

The deployment of the SATO Platform and the different SATO Services is highly dependent of the identification and description of the most suitable use cases. The use cases must increase building intelligence level and increase the level of user engagement with the interface, resulting in enhanced comfort and satisfaction while reducing the building energy costs.

This task has two main objectives:

1. Identify the use cases of SATO
2. Provide a complete description of each use case in order to be implemented and replicated

The first objective focuses on the identification of the areas of intervention of the SATO (e.g., Monitoring, Control, or Self-Assessment) and on the identification of the use cases needed to deploy the SATO functionalities and services.

The second objective focuses on providing a complete description of all use cases. This description will allow a smooth deployment and testing of the use cases by the different pilot owners. Further, it will help the developers of the SATO Platform and Services to understand the specific requirements of each use case. Finally, a first list of key performance indicators (KPIs) will be identified (considering the KPI tool developed in Task 1.2) to evaluate the performance of the use cases.

Finally, this document is intended to provide the consortium and stakeholders an overall view of all actions to be developed throughout the project, supporting the development of SATO Services in WP3 and WP4 and guiding the implementation phase in WP6.

2. Use case methodology

This section will describe the methodology used to identify and describe the different Use Cases (UC). Use Cases are structured documents that allow the identification, clarification, and organization of system requirements. UC describe, in a technology-neutral way, a set of possible sequences of interactions or a set of actions performed by a system or between different actors to achieve defined goals valuable for one or more actors or stakeholders of the system [1]. One of the objectives of the UC is to ensure an easier replicability, thus UC should be generic about the technological implementation. UC can be divided in different levels of granularity according to their specification and the level of detail. The UCs identified in this study are technical Use Cases. These describe the functionality level of a system and therefore specify functions or services that the system provides to the user or to other system.

2.1. IEC 62559-2

IEC 62559 is an international standard on Use Case Methodology, prepared by the International Electrotechnical Commission (IEC). The IEC is an organization promoting international cooperation concerning standardization in electrical and electronic fields. Due to the nature of SATO project in the electrical field and the objective of improving energy efficiency in buildings, the IEC standard on Use Case Methodology (IEC 62559) was used as a basis to develop SATO Use Cases.

IEC 62559 defines the concepts and terms related with Use Case development, the basis for a common repository for uses cases, the structure for a Use Case template and a serialization method for the definition of Use Cases. SATO will leverage on the template provided by this standard to define the set of actions that will be developed and implemented during the project, helping to define requirements and actors in this early stage of development and contributing to a faster definition of a consortium reviewed plan of actions.

IEC 62559-2 is the second document of the IEC 62559 series and focus on the definition of the template structure for Use Cases definition. The current deliverable, SATO D1.5, is based on the template provided in this standard, with some modifications that were agreed that would fit better the project and the partners involved in the writing of the Use Cases. All Use Case related terms are defined in SATO according to the definition presented in the standard, as showed in the next subsection (Definitions).

The structure of Use Cases used is divided in seven different sections: Description of Use Case, Diagram of Use Case, Technical Details, Step-by-step Analysis of Use Case, Information Exchanged, Requirements and Common Terms and Definitions [1].

Section one – **1. Description of the use case** – is the main section of the template, describing Use Case according to its objectives, key performance indicators, actors, and other relevant information.

Section two – **Diagrams of use case** – contains a diagram that shows the relations between the current Use Case with the others and also with the human and non-human actors engaging with it.

Section three – **3. Technical details** – addresses the actors involved (human and non-human) and their roles as well as the references used to define the Use Case.

Sections four, five and six – **4. Step by step analysis of use case**, **5. Information exchanged** and **6. Requirements** – is where the application scenario of the Use Case is defined. With the definition of the application scenario and respective steps, the Information Exchanged within those steps is then defined and the Requirements for the exchange of information are subsequently defined.

Finally, section seven – **7. Common Terms and Definitions** – aims at providing the definition of the technical terms and acronyms used in the Use Case description.

For further detail on the Use Case template used (adapted from IEC 62559-2 Use Case Template [1]) refer to Annex I – Template, where the whole template is provided with additional explanation on the expected information in each section of the template.

2.2. Definitions

To complete the IEC Use Case template, it is important to understand a set of definitions. Among these definitions the most important are: Actor, Area, Scenarios, High-level Use Case (HLUC) and Primary Use Case (PUC).

- An **Actor** is defined as any entity that communicates and interacts with the different SATO platforms and services. These actors, identified in SATO Deliverable 1.1 [2], can include humans, software applications, systems, databases, and even the power system itself (e.g., aggregator, distributor system operators, DSOs, or transmission system operators, TSOs).
- An **Area** is an area of knowledge or activity which uses a set of concepts and terminology commonly understood by the practitioners in that area. Further, an area can be used for grouping, filtering, and administration of UC in a determined UC database. In the case of SATO, the area can be defined according to the different phases needed to deploy the different self-assessment and optimization services, from monitoring to control.
- A **Scenario** is a possible sequence of interactions, which are described in different steps and with all the interactions and information exchanged described.
- A **High-Level Use Case** is a Use Case that describes a general requirement, idea, or concept independently from a specific technical realization like and architectural solution. HLUCs are usually generic and serve as the basis for the development of Primary Use Cases.
- A **Primary Use Case** describes important features, functionalities or solutions that may only be relevant to some countries or pilots. Most often, PUCs are related to a goal or a system requirement of a HLUC and may not be applied in all pilots targeted by the respective HLUC. PUCs are derived from HLUC and therefore provide more detailed and case-specific information than the HLUC. HLUCs are implemented without the need to define PUCs but the opposite is not possible.

2.3. Use case identification and definition

The methodology used to produce this document, considered a set of sequential steps:

1. Identification of the Area – Considering the SATO architecture, objectives, and pilots involved, a list of Area was identified.

2. Identification of Actors – The list of Actors identified in Deliverable 1.1 was expanded considering the area previously identified.

3. Identification of the HLUCs – HLUCs were identified for each Area, considering the objectives and pilots of SATO.
4. Workshop on the definition of SATO Areas, Actors, and HLUCs – A workshop was held with the partners involved in WP1 to further develop and define the Area, Actors, and HLUCs. The definition of PUCs was also discussed in the workshop.
5. Definition of HLUCs and PUCs – The results of the workshop were compiled and the HLUCs and PUCs were defined.
6. Workshop on the pilots involved in each UC and identification of Key Performance Indicators (KPIs) – A second workshop was held with the partners of WP1 to identify which pilots will deploy each UC and define the first version of the KPIs (using the KPI Tool developed in Task 1.2 [3]) that will be used to evaluate the UC. Further, the complete description of the HLUCs was assigned to the partners with the most expertise in the respective HLUC.
7. HLUC complete description – The HLUCs were described using the IEC 62559-2 standard template (Annex I – Template) [1]. For each HLUC a Leader (L), a Contributor (C) and a Reviewer (R) were identified and were responsible for providing a complete version of the HLUCs. A Leader is the overall use case responsible, in charge of detailing the description of the use case according to schedule and gathering (requesting) all relevant inputs from the contributing partners. A Contributor is the responsible partner(s) for one or multiple elements of the scope of the use case description. A Reviewer is the reviewer of the use case description and with potential minor participation to detail one or multiple elements of the scope of the use case description.
8. HLUC uniformization – To ensure consistence between all HLUCs, a review was performed to uniformized all the documents.

3. Overview of high-level use cases

The definition of the final set of Use Cases was obtained after a series of workshops and interactions between the different partners. The list of HLUCs, PUCs, Areas and Actors was constantly updated during the work carried out in this deliverable, and the finalized versions are presented in the following subsections.

3.1. Areas

The SATO project identified five Areas (Figure 1): Monitoring, Self-Assessment and Benchmarking, Visualization, Self-Optimization, and Control. Monitoring relates with the monitoring equipment deployed in the different buildings (residential and commercial), and with the third-party data (e.g., weather data) that will be collected and processed by SATO. The Self-Assessment and Benchmarking is the area where the UCs that will use the Self-Assessment Framework are incorporated, as well as the benchmarking tools that will be developed within the SATO project. This area receives data to process and perform the self-assessments from all the other areas. The Visualization area will encompass the UCs that will provide information (coming from Self-Assessment and the Self-Optimization areas) to the different SATO users using visual interfaces (e.g., APP or BIM). The Self-Optimization area relates with the SATO Self-

Optimization Services and will be fed by the Self-Assessment area. Finally, the Control area is related with control of the actuators in the buildings and the deployment of the optimization strategies.

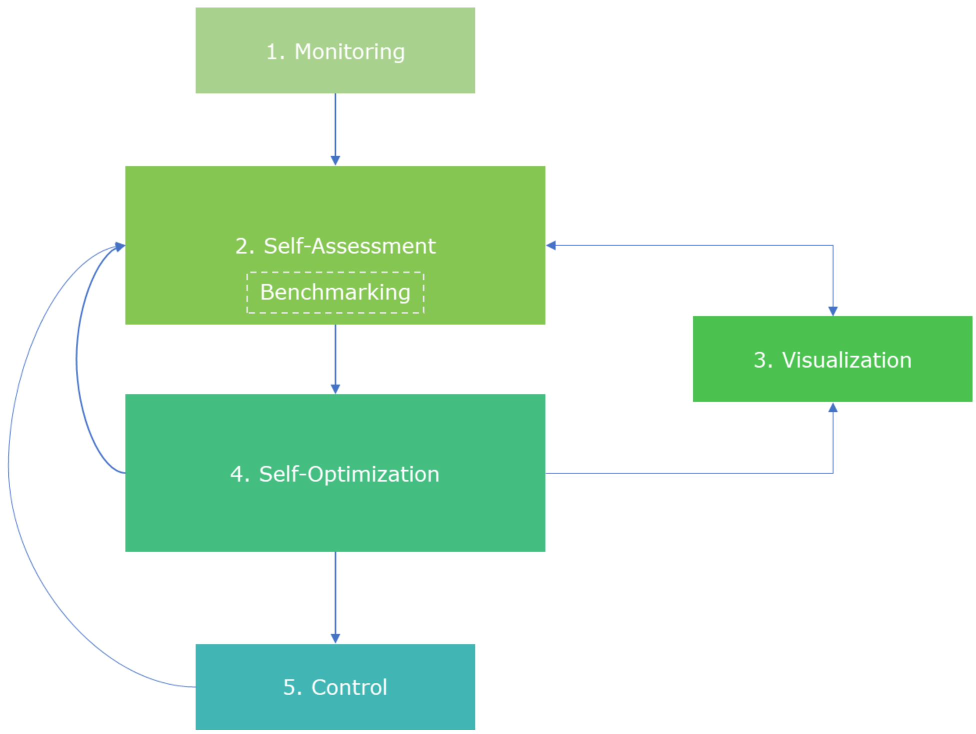


Figure 1 - Areas identified and respective connections.

3.2. Actors

The actors presented in this deliverable are an extended version of the actors identified in SATO Deliverable 1.1 [2]. As in the mentioned deliverable, the actors were divided into two groups: human actors and software/systems actors. The complete list of Actors that were identified and used in the UC are presented in Table 1 as well as with the respective description.

Table 1: Description and role of the identified actors.

Actor	Human actor, Software/System actor	Description.
Facility/ building manager	Human actor	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 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.
Building owner	Human actor	Owner of buildings that may or may not have control over the building energy system nevertheless they may impose constraints on the building energy system operation.
Building occupant	Human actor	An occupant is an energy consumer (or a prosumer) who has a direct or indirect 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 behaviours. In addition, the SATO Platform will also suggest users to subscribe to energy flexibility services that are expected to be financially rewarded.
Aggregator	Human actor	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.
SATO Platform	Software/ systems/ applications/ devices	Cloud based software/hardware that supports data exchange with IoT enabled devices, Self-Assessment and Optimization (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.
SATO APP	Software/ systems/ applications/ devices	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.
SATO APL	Software/ systems/ applications/ devices	Provide data for SAF framework, for systems with short life cycles.

SATO BMS	Software/ systems/ applications/ devices	Provide data for SAF framework, for systems with long life cycles.
SATO Self-Assessment Framework (SAF)	Software/ systems/ applications/ devices	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.
SATO Self-Optimization Services	Software/ systems/ applications/ devices	Using the SAF results, optimizes the operation of energy consuming devices while safeguarding the needs of the occupant/user needs.
SATO Flexibility Management Service (FMS)	Software/ systems/ applications/ devices	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 BIM tool	Software/ systems/ applications/ devices	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.

3.3. Use cases

In SATO, 15 HLUCs, which are subdivided in 37 PUCs, were identified and summarized in Table 2. All HLUCs (except HLUC10, HLUC11 and HLUC12) are divided into multiple PUCs. The PUCs identified represent specific functionalities of a system and may not apply to all pilot sites. Regarding the division in area, the Monitoring has only HLUC01 which aims to collect building data and third-party data. Self-Assessment and Benchmarking have four HLUCs (HLUC02 to HLUC05) that encompasses the Self-Assessment (SA) of historical, real-time, and forecast of building energy data as well as benchmarking of building and appliance performances. The Visualization area has two HLUCs, one related with the SATO BIM Tool (HLUC06) and other related with the SATO APP (HLUC07). The Self-Optimization area has the highest number of HLUCs (seven) due to the different optimization strategies that will be evaluated simultaneously (HLUC08 to HLUC13) and to the HLUC that will merge and define the optimal strategy for each time step (HLUC14). Finally, the Control area has the HLUC15 which relates to the control of actuators and deployment of the self-optimization strategies.

Table 2: High-Level Use Cases and respective Primary Use Cases identified.

High-level Use Cases	Primary Use Cases
HLUC01 - Securely collecting, processing, and storing building and third-party data	PUC1.1 - Collect building information using sensing devices
	PUC1.2 - Collect third-party data from external data sources
	PUC1.3 - Collect control actions from SA&O services
	PUC1.4 - Storing data in the corresponding database with a standard model
HLUC02 - Data-driven self-assessment diagnosis of building performance	PUC2.1 - Energy performance self-assessment
	PUC2.2 - Indoor conditions self-assessment
	PUC2.3 - Occupants' behaviour self-assessment
	PUC2.4 - EBC smartness levels self-assessment
	PUC2.5 - KPI's first phase calculation
HLUC03 - Forecasting of energy loads, indoor air conditions, occupancy, and weather	PUC3.1 - Whole building scale forecasts
	PUC3.2 - Small scale forecasts
	PUC3.3 - Weather forecasts
HLUC04 - Benchmarking building performance	PUC4.1 - Benchmarking whole building performance
	PUC4.2 - Benchmarking building control system
	PUC4.3 - Benchmarking user practices
HLUC05 - Benchmarking appliance performance	PUC5.1 - Use the assessed deviations to provide/suggest warranty and repairing services and new appliances
	PUC5.2 - Provide recommendation when incorrect usage of appliances is detected
HLUC06 - Integration of sensors layer into BIM projects for visualization and location optimization	PUC6.1 - Visualization of 3D models
	PUC6.2 - Building data management
	PUC6.3 - Sensor data management
HLUC07 - Visualization of the main KPIs and energy flows using a web/mobile interface	PUC7.1 - Real-time and historical visualization of the main KPIs and energy flows
	PUC7.2 - User interaction with web/mobile interface
HLUC08 - Optimization of building energy efficiency	PUC8.1 - Self-Optimization of energy efficiency
	PUC8.2 - Self-Optimization of energy costs

	PUC8.3 - Self-Optimization of self-consumption
HLUC09 - Improving building indoor environmental quality	PUC9.1 - Improve thermal comfort
	PUC9.2 - Improve indoor air quality
	PUC9.3 - Improve visual comfort
	PUC9.4 - Improve acoustic comfort
HLUC10 - Providing grid flexibility services to an energy aggregator	–
HLUC11 - Load-shifting as an energy cost reduction strategy	–
HLUC12 - Using thermal mass for BaB energy storage	–
HLUC13 - Exploitation of natural ventilation as a cost-effective indoor comfort strategy	PUC13.1 - Daytime natural ventilation
	PUC13.2 - Night cooling
HLUC14 - Holistic optimal control of energy resources	PUC14.1 - Holistic optimal control of energy resources in office buildings
	PUC14.2 - Holistic optimal control of energy resources in residential buildings
	PUC14.3 - Holistic optimal control of energy resources in commercial buildings
HLUC15 - Cloud managing of legacy and smart appliances as well as technical building equipment	PUC15.1 - Cloud managing of legacy appliances and equipment
	PUC15.2 - Cloud managing of smart appliances and equipment
	PUC15.3 - Cloud managing of EV chargers and batteries

Figure 2 shows the relation between the different HLUCs, the areas, and some of the actors involved in the exchange of information. All the relations are further explained in the complete description of each individual HLUC (Annex II – High-Level use cases). However, from the diagram it is possible to understand that SATO Platform will be the most relevant actor involved in the UCs. All the data generated externally (sensors and third-party data) and internally (SA and SO) will be stored and distributed through SATO Platform.

The HLUCs that, theoretically, will be deployed in the different pilot sites are described in the description of the different HLUCs, present in the following subsections. The development of the strategies to implement the UCs in the different pilots will be refined in subsequent deliverables (namely Deliverable 1.6 of Task 1.5).

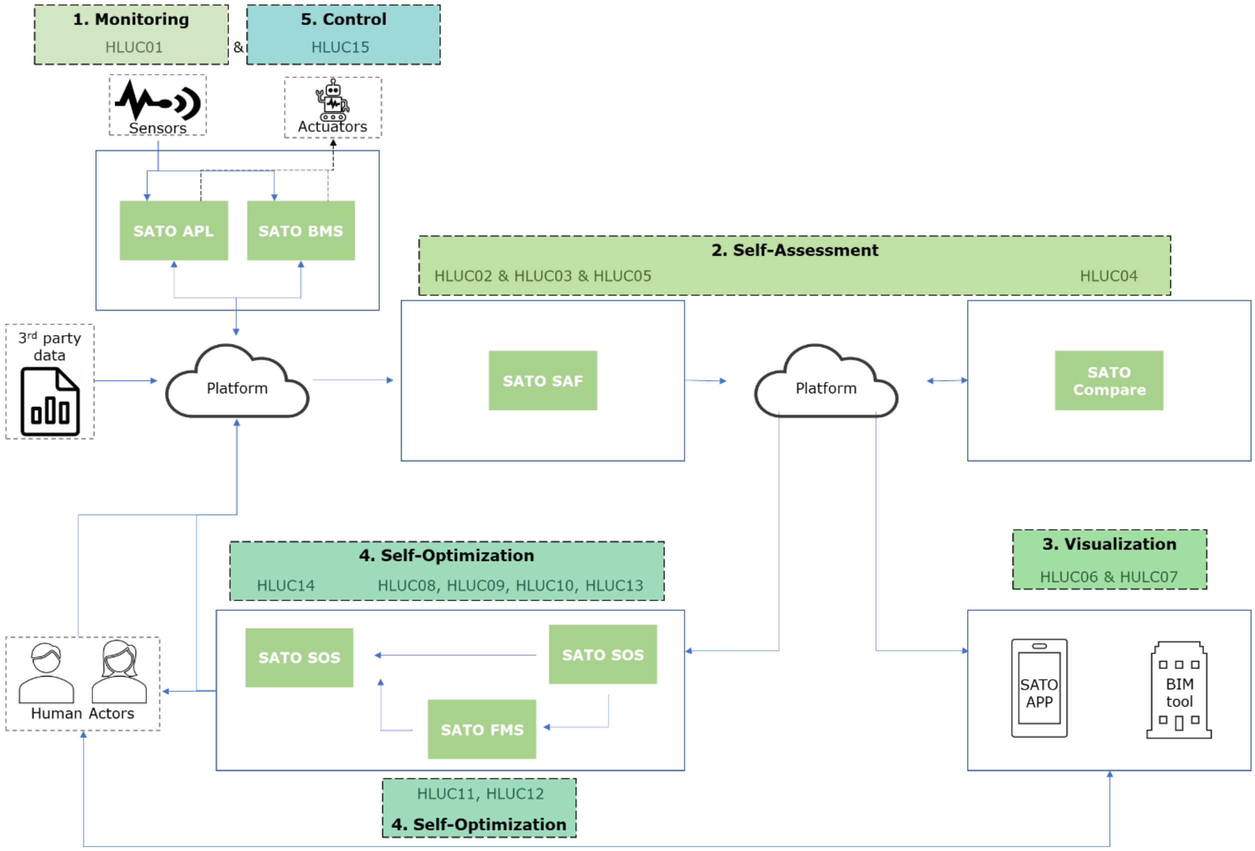


Figure 2 Description of the interactions between the different Areas, Actors and HLUCs

3.4. HLUC01 - Securely collecting, processing, and storing building and third-party data

3.4.1. Objectives

HLUC01 is a High-Level Use Case (HLUC) focused on securely collecting, processing, and storing building and third-party data. It presents how data will flow from buildings into the SATO Platform and how it will be standardized and stored for the subsequent processing steps from the assessments.

This use case assumes the availability of sensing devices in buildings and of external services that will provide data to the SATO Platform. Alternatively, the SATO Platform can include data quality components that will infer missing data points if it does not receive them within a deadline.

The objectives of this HLUC are related with the collection, processing, and storage of data. The following objectives were defined:

1. Collect building information using sensing devices
2. Create a database with building information in a standard data model
3. Collect weather data from external meteorology services (live and forecast)
4. Collect grid data (price and CO_2-eq) from energy provider/ grid operator (live and predictive)

3.4.2. Description

The SATO Platform will be able to receive building data collected from all energy-consuming devices in the buildings of the SATO pilots. Additionally, third-party data (e.g., weather data and electricity price) will also be collected. Data collected will be ingested and secured as fast as possible (Transient storage) and subsequently will be pre-processed to be in a standardized data model with trustworthy data quality (Refined storage). This data will then be used in the SA&O Services, which will also produce data to be stored (Results storage). All this data should be stored and processed in useful time securely and anonymously, to comply with the EU privacy legislation (e.g., GDPR).

3.4.3. Primary use cases

Four Primary Use Cases (PUCs) may be derived from HLUC01: PUC1.1 (Collect building information using sensing devices), PUC1.2 (Collect third-party data from external data sources), PUC 1.3 (Collect Control Actions from Self-Assessment and Optimization (SA&O) Services), and PUC1.4 (Storing data from PUC 1.1-3 to the corresponding database with a standard model). The first addresses the data points coming from sensing devices, the second deals with third-party data coming from external data sources, the third handles control actions, and the fourth provides a standard data model for the events and stores the building information in a database.

3.4.4. Use case diagram

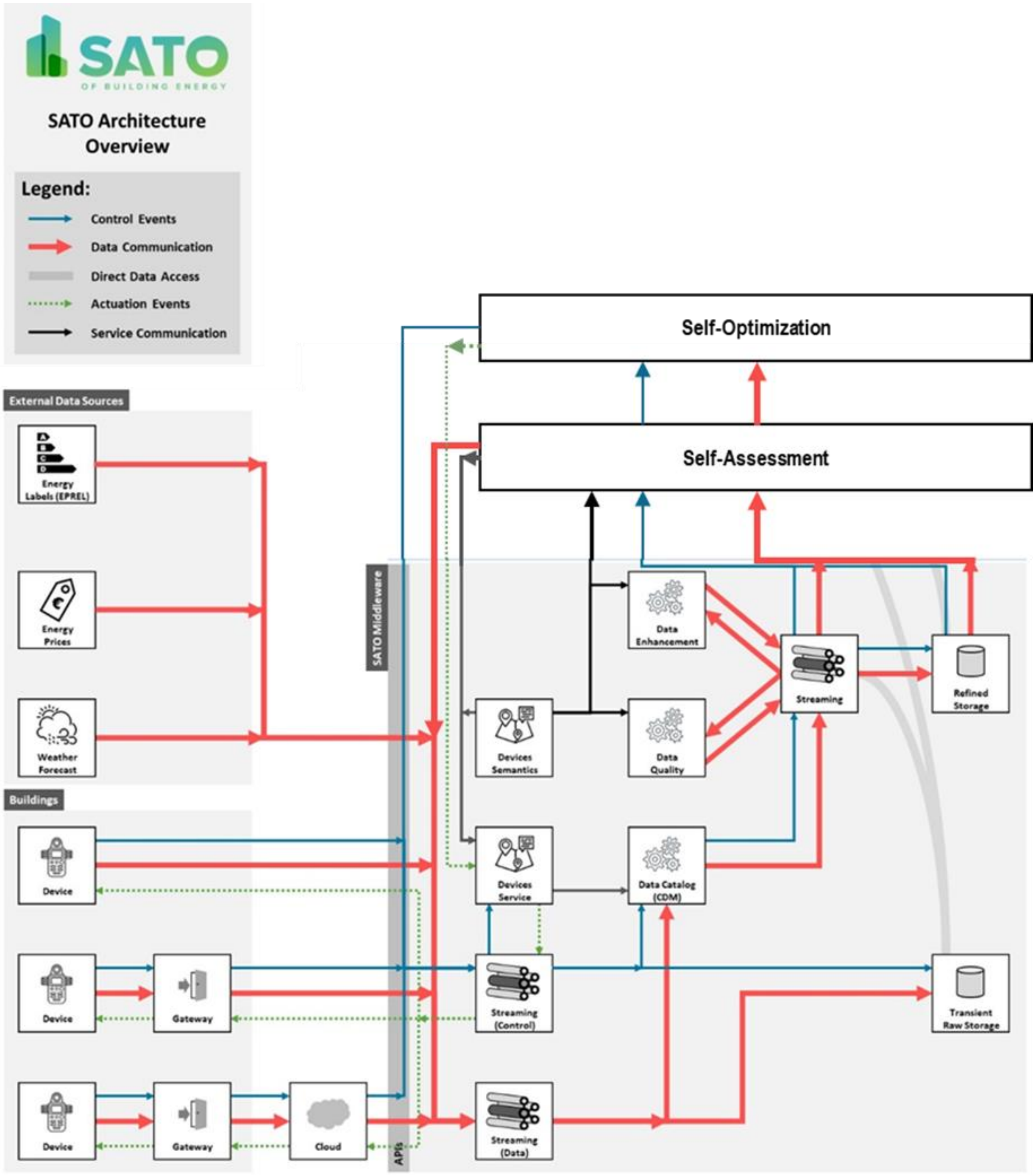


Figure 3 - HLUC01 diagram (all interactions present in this diagram will be detailed further in the Deliverable D1.4 of the SATO Project.)

3.4.5. Pilots

The pilot site(s) associated with this use case are referred to in the following table:

High-level Use Cases	Pilots
HLUC01 - Securely collecting, processing, and storing building and third-party data	All Pilots

3.5. LUC02 - Data-driven self-assessment diagnosis of building performance

3.5.1. Objectives

HLUC02 is a High-Level Use Case (HLUC) planned for designing a framework that connects SATO Platform, through SATO BMS and SATO APL, with building equipment & building components (EBC) to receive real-time data of building performance and indoor conditions enabling SATO Self-Assessment Framework (SAF). From the collected data analysis, this HLUC will also perform the calculation of the building Key Performance Indicators (KPI), and so, assist the SATO Self-Optimization Services.

This HLUC will provide the SATO Platform, SATO APP and users (building occupants, facility/building managers, aggregators, etc.) with data-driven assessments on the EBC performance and smartness. These insights are intended to not only raise awareness and nudge users towards energy efficient behaviour, but also perform the SATO SAF and enable SATO self-optimization actions for increased energy efficiency.

This HLUC does not require direct intervention from human actors, but it is related to several SATO software/hardware functionalities such as the SATO Self-Assessment Framework, the SATO Self-Optimization Services, SATO BMS, SATO APL, and SATO APP.

The objectives of this HLUC are related to the data-driven self-assessment framework and calculation of the building key performance indicators (KPI). The following objectives were defined:

1. Analysis and real-time acquisition of data collected through SATO APL and BMS supporting SATO Self-Assessment Framework.
2. Real-time building performance and indoor conditions self-assessment.
3. Calculation of building KPI's.
4. Defining input parameters for energy efficiency optimization

3.5.2. Description

The SATO Self-Assessment Framework connects with the SATO Platform through SATO APL and SATO BMS to buildings EBC and receives real-time building performance and indoor conditions data. This data is then analysed and enables the calculation of KPIs that are used by SATO Self-Optimization Services for optimal management.

3.5.3. Primary use cases

Five PUCs will be derived from this HLUC: PUC2.1 named "Energy performance self-assessment"; PUC2.2 named "Indoor conditions self-assessment"; PUC2.3 named "Occupant's behaviour self-assessment"; PUC2.4 named "EBC smartness levels self-assessment"; and PUC2.5 named "KPI's first phase calculation".

PUC2.1 enables the real-time acquisition of building energy data from building EBC through SATO APL and SATO BMS that assess legacy appliances with short and long-life cycles, respectively, and other building components.

PUC2.2 relates to data acquisition of indoor environmental conditions (e.g., air temperature, carbon dioxide concentration, illuminance) employing non-intrusive IoT monitoring and actuation devices, and enabling improvements on building performance and occupants' comfort.

PUC2.3 relates to data acquisition of the building occupants' behaviour, such as indoor occupation levels and presence through monitoring systems connected to the SATO Platform as well as user preferences through user feedback from the SATO APL. Like

PUC2.4 performs real-time data acquisition on the smartness levels of the building EBC, supporting the calculation of SRI domains and whole building SRI.

PUC2.5 integrates and analyses the data acquired in PUC2.1 to PUC2.4 to calculate the building KPIs.

3.5.4. Use case diagram

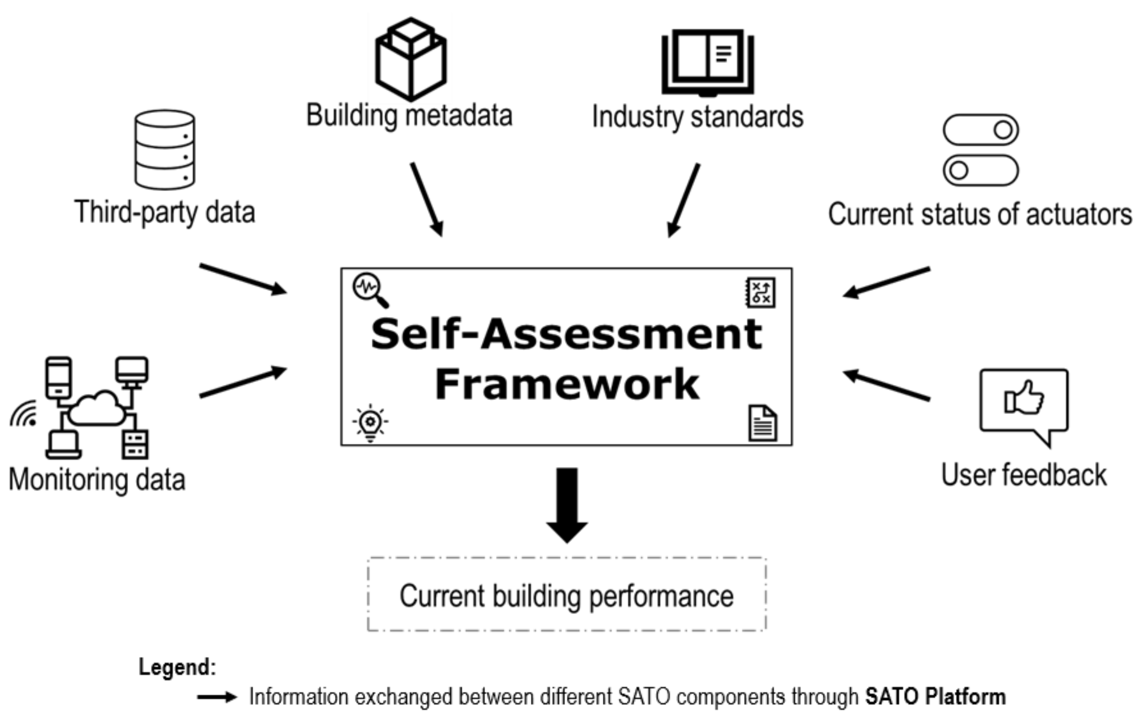


Figure 4 - HLUC02 diagram

3.5.5. Pilots

The pilot site(s) associated with this use case are referred to in the following table:

High-level Use Cases	Pilots
HLUC02 - Data-driven self-assessment diagnosis of building performance	All Pilots

3.6. HLUC03 - Forecasting of energy loads, indoor air conditions, occupancy, and weather

3.6.1. Objectives

The HLUC03 is a High-Level Use Case (HLUC) that will focus on the short-term forecasting of energy loads, indoor air conditions, and occupation density at different building levels, as well as the local weather.

The SATO Platform will receive raw (untreated) monitored data from the building IoT enabled devices (e.g., energy meters), sensors (e.g., occupancy sensors) and external sources (e.g., real-time weather databases), and will process it to be sent to the SATO Self-Assessment Framework (SAF). This HLUC3 consists of one of the assessments performed by the SATO Self-Assessment Framework. The SAF will be responsible for structuring the data (received from SATO Platform) and perform short-term forecasting of the energy loads, indoor air conditions, occupancy and local weather using statistical and machine learning technologies/tools.

The forecasts made by the HLUC03 will be sent to:

1. SATO BIM tool and SATO APP, allowing users to visualize forecasts (e.g., energy consumption);
2. and to SATO Self-Optimization Services, which will use the outputs to perform the different self-optimization strategies.

3.6.2. Description

The SATO Self-Assessment Framework will receive real-time data from SATO Platform and, together with the historical data and metadata, will perform a short-term forecast of the energy demand, indoor air conditions, occupancy patterns of the building and local weather data. This HLUC will use statistical and machine learning technologies to perform the different forecasts and will provide relevant inputs to the SATO Self-Optimization Services, SATO BIM tool and SATO APP.

3.6.3. Primary use cases

Three PUCs will be derived from this HLUC:

- PUC3.1 is named “Whole building scale forecasts”

- PUC3.2 is named "Small scale forecasts"
- PUC3.3 is named "Weather forecasts"

3.6.4. Use case diagram

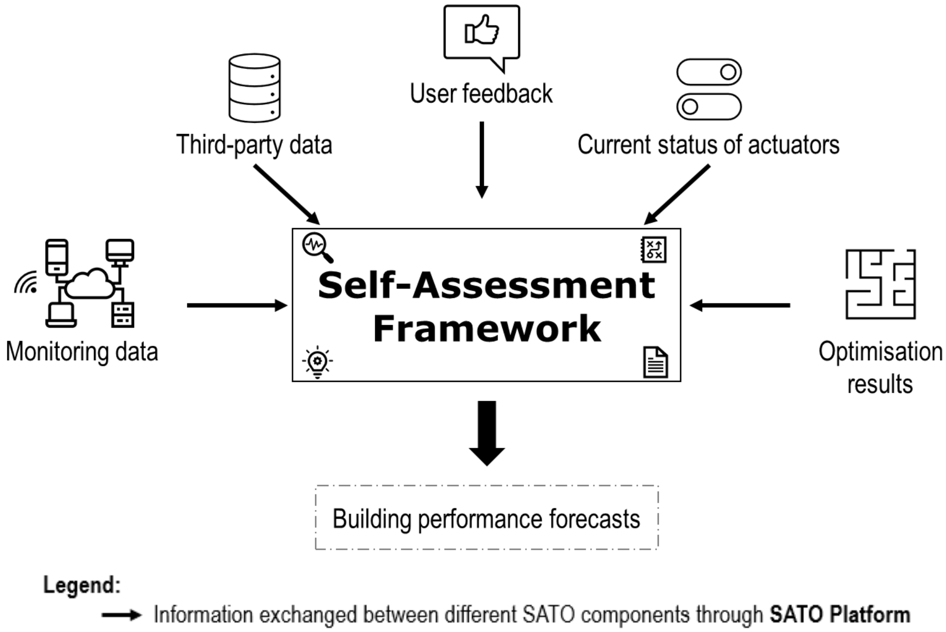


Figure 5 - HLUC03 diagram

3.6.5. Pilots

The pilot site(s) associated with this use case are referred to in the following table:

High-level Use Cases	Pilots
HLUC03 - Forecasting of energy loads, indoor air conditions, occupancy, and weather	All Pilots

3.7. HLUC04 - Benchmarking building performance

3.7.1. Objectives

HLUC04 is a High-Level Use Case (HLUC) focused on benchmarking monitored building performance in relation to different types of reference performance to enable cross comparisons and to evaluate optimization need and opportunities.

Benchmarking of building performance is also very important to raise awareness among facility managers, occupants and building owners and as basis for decision-making related to maintenance, optimization, and upgrade of existing systems.

3.7.2. Description

Benchmarking building performance will be performed using SATO Compare. The monitoring devices deployed in the building and the self-assessment performed, will give the inputs for building performance comparison of different variables and performance indicators related to e.g., energy use, energy costs, associated CO_2 emissions and indoor environmental quality. It will also allow for building performance evaluation according to different reference performance types.

The benchmarking can be performed at different levels from individual building to a European level. The final objective is to provide a basis for building management decision-making and to make building managers and occupants aware of and trigger behavioural changes that will improve building overall performance (e.g., using SATO APP).

3.7.3. Primary use cases

Three PUCs will be derived from this HLUC:

PUC4.1 is named "Benchmarking whole building performance"

PUC4.2 is named "Benchmarking building control system"

PUC4.3 is named "Benchmarking user practices"

3.7.4. Use case diagram

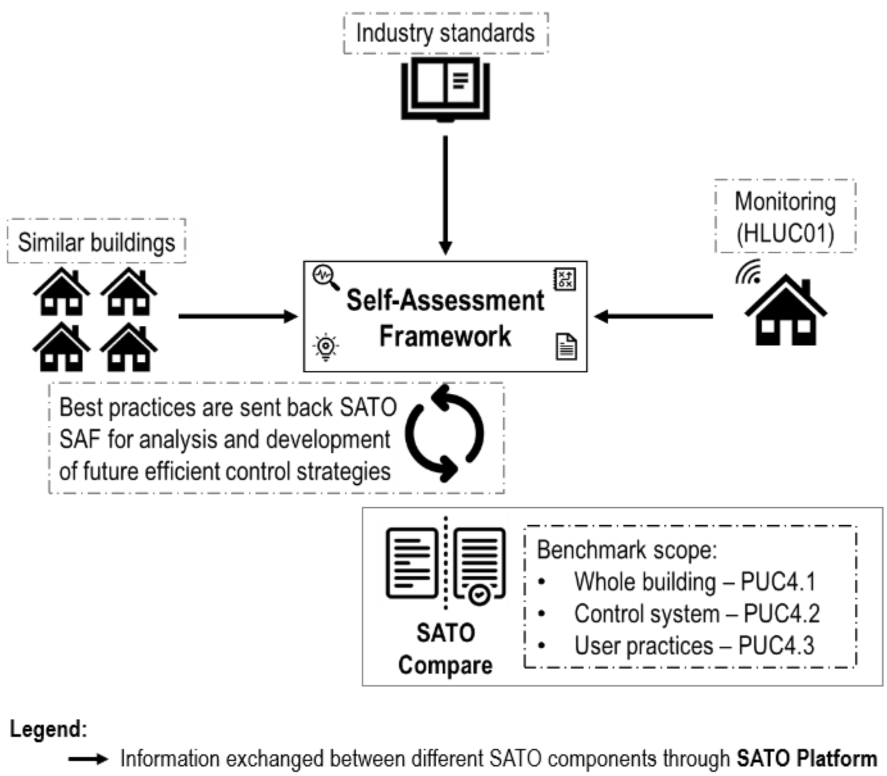


Figure 6 - HLUC04 diagram

3.7.5. Pilots

The pilot site(s) associated with this use case are referred to in the following table:

High-level Use Cases	Pilots
HLUC04 - Benchmarking building performance	All Pilots

3.8. HLUC05 - Benchmarking appliance performance

3.8.1. Objectives

HLUC05 is a High-Level Use Case (HLUC) regarding the self-assessment and benchmarking performed by the SATO Platform with the domestic appliances data.

The normal flow in this HLUC would be the constant monitoring of the performance of the appliances (performed in HLUC01), benchmark this data with industry standards and with real monitored data from similar appliance, and generate recommendations when there are energy performance deviations and it is financially interesting to replace/repair the appliance. The assessment made with this data should enable to:

- Provide warranty services/information;
- Suggest repairing services;
- Detect incorrect usage of appliances and generate recommendations accordingly;
- Detect energy usage outliers and recommend corrections/external intervention;
- Detect abnormal appliance behaviour and suggest external intervention;
- Suggest replacement to more sustainable appliances when economically feasible.

In this Use Case Building manager, owners and occupants, and Appliance Services Provider will intervene as human actors, and through SATO software/ hardware functionalities such as the SATO Self-Assessment Framework, the SATO Platform, and SATO APP.

3.8.2. Description

Benchmarking appliance performance will take advantage of the individual SATO monitoring devices deployed at appliance level to constantly monitor the performance of such appliances, comparing this performance to industry standards and with real monitored data from similar appliances in the different pilots or available databases. The HLUC will also be generating recommendations when energy performance is low, and it is financial interesting to replace the appliance for a new one. The results of the benchmarking can be used to provide warranty services or suggest repairing services. This service could also detect incorrect usage of appliances and generate recommendations accordingly.

3.8.3. Primary use cases

Two PUCs will be derived from this HLUC:

- PUC5.1 is named "Use the assessed deviations to provide/suggest warranty and repairing services, and new appliances";
- PUC5.2 is named "Recommendations when incorrect usage of appliances is detected".

3.8.4. Use case diagram

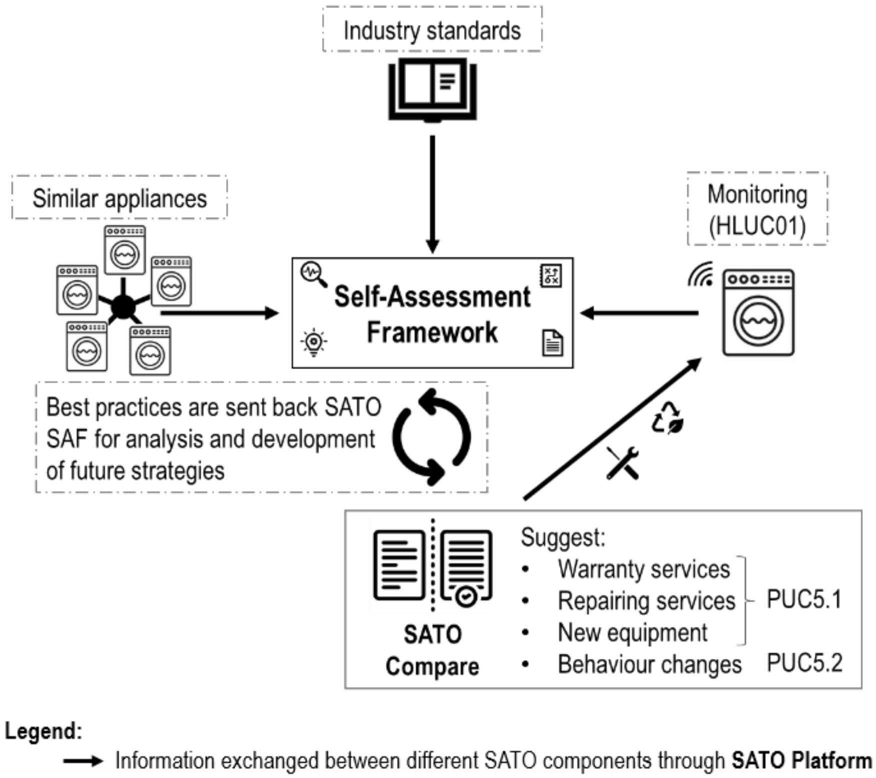


Figure 7 - HLUC05 diagram

3.8.5. Pilots

The pilot site(s) associated with this use case are referred to in the following table:

High-level Use Cases	Pilots
HLUC05 - Benchmarking appliance performance	Aalborg Residential, Seixal Residential, Milan Single Apartment

3.9. HLUC06 - Integration of sensors layer into BIM projects for visualization and location optimization

3.9.1. Objectives

HLUC06 is a High-Level Use Case focused on the interaction and visualization of Building Information Model (BIM) models.

The SATO BIM tool will be able to integrate BIM information in SATO workflow, having some other features to manage this data with different purposes.

The creation of a BIM interface will allow the possibility of working in a 3D environment. The owners/facility managers/occupants will be able to know exactly in each part of a building and room, sensors have been located, how many occupants are, the properties of the different construction elements and what are the design calculated values of energy, acoustics, or lighting. Alerts will be displayed within the 3D visualization tool, warning signals will be displayed when indoor conditions or energy consumption are outside the expected performances or when sensors are missing in places with significant impact on energy or occupants' comfort. These will allow actors to perform knowledge-based decisions with a high degree of confidence.

3.9.2. Description

Integration of BIM models in the SATO workflow to provide users 3D models where the sensors infrastructure has been integrated based in smart algorithms. This feature allows designers and project managers to place the different sensors according to the specific conditions of the project and reuse these two layers (BIM project + BIM sensors layer) to provide this data to the users of the system.

3.9.3. Primary use cases

Three PUCs will be derived from this HLUC:

- PUC6.1 is named "Visualization of 3D models"
- PUC6.2 is named "Building data management"
- PUC6.3 is named "Sensors data management".

3.9.4. Use case diagram

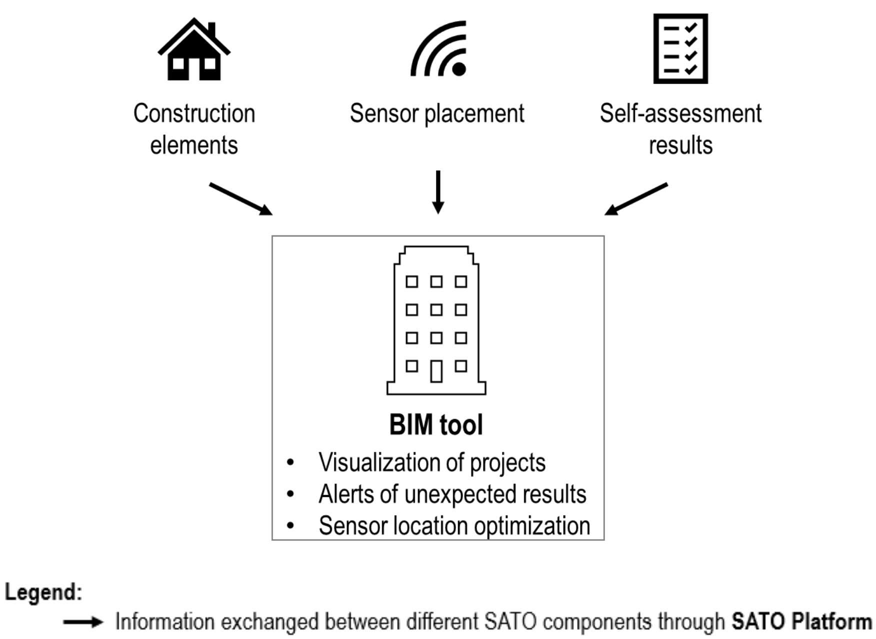


Figure 8 - HLUC06 diagram

3.9.5. Pilots

The pilot site(s) associated with this use case are referred to in the following table:

High-level Use Cases	Pilots
HLUC06 - Integration of sensors layer into BIM projects for visualization and location optimization	All non-residential pilots

3.10. HLUC07 - Visualization of the main KPIs and energy flows using a web/mobile interface

3.10.1. Objectives

HLUC07 is a High-Level Use Case (HLUC) focused on the visualisation of energy consumption, production and flows within the whole building, systems, and components.

The SATO APP will display building information to several building users (building owners, facility managers, occupants) with the purpose of increase energy efficiency by improving awareness towards local energy production and energy consumption of the building, and of the different systems and components. The notifications displayed in the graphical user interface will be provided by the SATO Self-Assessment Framework and SATO Self-Optimization Services), giving recommendations to building users on what are the best strategies to improve efficiency without compromising or further improving user comfort or indoor air quality and energy costs.

3.10.2. Description

The creation of a web and mobile interface (SATO APP) will allow real-time and historical visualization of the main KPIs and energy flows inside a building. The building owners/facility managers/occupants will be able to know exactly the status and consumption of different systems and appliances related to energy performance, as well as energy costs and CO_2 emissions associated with their consumptions. Notifications will be displayed when energy efficiency, CO_2, costs, or room comfort are outside the expected performance levels. These will allow the mentioned actors to perform knowledge-based decisions with a high degree of confidence. Further, users will have access to historical data, to help them adjust and plan its energy habits for future situations.

3.10.3. Primary use cases

Two PUCs can be derived from the HLUC07. PUC7.1 is named "Real-time and historical visualization of the main KPIs (key performance indicators) and energy flows" and PUC7.2 is named "User interaction with web/mobile interface".

PUC7.1 is divided in passive feedback and active feedback. Passive feedback is divided in four visualisation options:

1. Visualisation of energy consumption and production – Through the SATO APP the net production and consumption of the building will be shown. Additionally, the energy consumption of individual legacy and smart appliances and building equipment, as well as the energy production of PV panels, and electrical vehicle chargers' interaction with the building (V2G) will be displayed.
2. Visualisation of CO_2 emissions and energy costs.
3. Visualisation of room comfort conditions.
4. Visualisation of building performance benchmarking (HLUC4 and HLUC05).

The active feedback is related with the display of notifications (recommendations, alerts, warning signals, etc.).

PUC7.2 is related with the user interaction and feedback loop between the web/mobile application (SATO APP) and the building owners, facility managers and building occupants.

3.10.4. Use case diagram

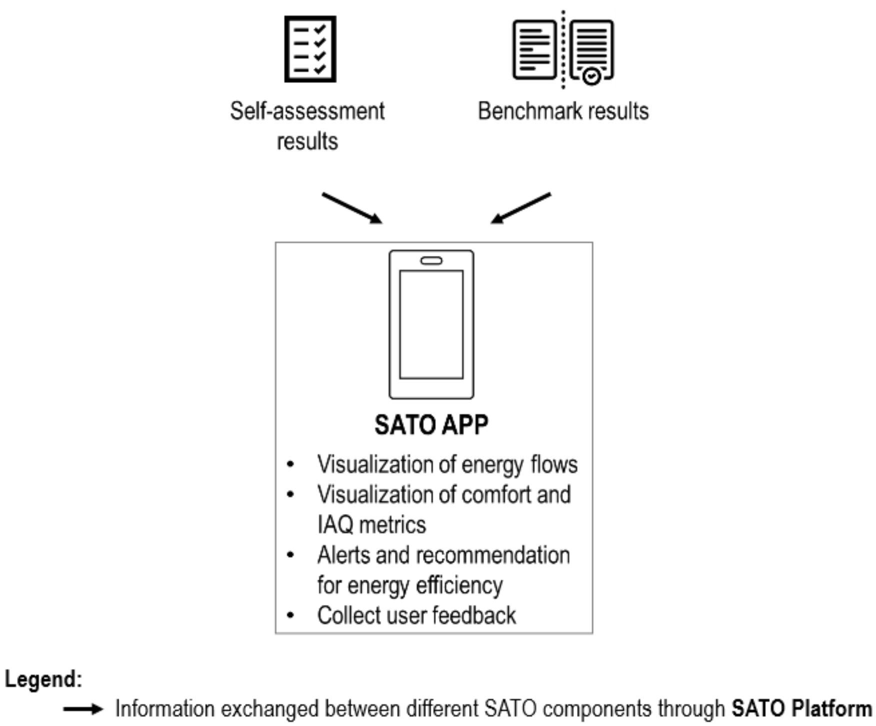


Figure 9 - HLUC07 diagram

3.10.5. Pilots

The pilot site(s) associated with this use case are referred to in the following table:

High-level Use Cases	Pilots
HLUC07 - Visualization of the main KPIs and energy flows using a web/mobile interface	All Pilots

3.11. HLUC08 - Optimization of building energy efficiency

3.11.1. Objectives

HLUC08 is a High-Level Use Case (HLUC) focused on the energy efficiency (EE) optimization actions applied to the static and dynamic elements of building fabric, technical building equipment, appliances, and V2G charger and batteries. The EE actions have multi-objectives, i.e., together with optimizing the energy performance they should meet the energy cost and occupants' requirements for indoor environment quality (IEQ) and if applicable the self-consumption goals.

SATO Self-Optimization Services will be deployed with the inputs received from the SATO Self-Assessment Framework (SAF). The optimization fitness function will take into consideration energy costs while accommodating or even enhancing the IEQ needs identified in the SATO Self-Assessment Framework. The control strategies and setpoints identified in this use case will be applied through SATO BMS and SATO APL.

The human actors involved in this HLUC are the building owners, managers and building occupants. Depending on the identified energy efficient strategy provided by SATO Self-Optimization Services the direct intervention will involve either single human actor (i.e., building occupant) or multi human actors (i.e., building manager and occupants). They should be able to overwrite the SATO Self-Optimization Services commands, to ensure High-Level of comfort. In such cases, through SATO APP (HLUC07) the building manager or occupants may input their needs in SATO BMS and SATO APL, and SATO Self-Optimization Services adjusts the dynamic elements of building fabric, technical building equipment as well as legacy and smart appliances accordingly.

3.11.2. Description

Optimization of building energy efficiency will be performed using SATO Self-Optimization Services. Real-time building and weather data are analysed and converted to key performance indicators in SATO Self-Assessment Framework. Together with inputs on energy cost will provide the necessary information to develop optimal strategies for building energy efficiency optimization.

The optimal strategies will be developed with five objectives: 1-2) reduction of energy needs for heating, cooling, ventilation, domestic hot water, lighting and of total primary energy use, 3-5) optimization of energy efficiency of equipment, and of energy and capacity costs, and of self-consumption. Using SATO

APP users will be able to define which of these strategies should be prioritized and applied first in their building.

3.11.3. Primary use cases

Three PUCs will be derived from this HLUC. PUC8.1 "Self-Optimization of energy efficiency". PUC8.2 "Self-Optimization of energy costs". PUC8.3 "Self-Optimization of self-consumption".

PUC8.1 and PUC 8.2 are related to the improvements of energy efficiency of:

1. dynamic and static elements of building fabric
2. building equipment: single components, such like heat pumps and fans
3. building equipment: system/installation, such like heating or ventilation installation
4. legacy and smart appliances, such like washing machines
5. V2G charges and batteries.

PUC8.3 is related to the optimization of consumption of energy produced on-site from renewable energy sources.

3.11.4. Use case diagram

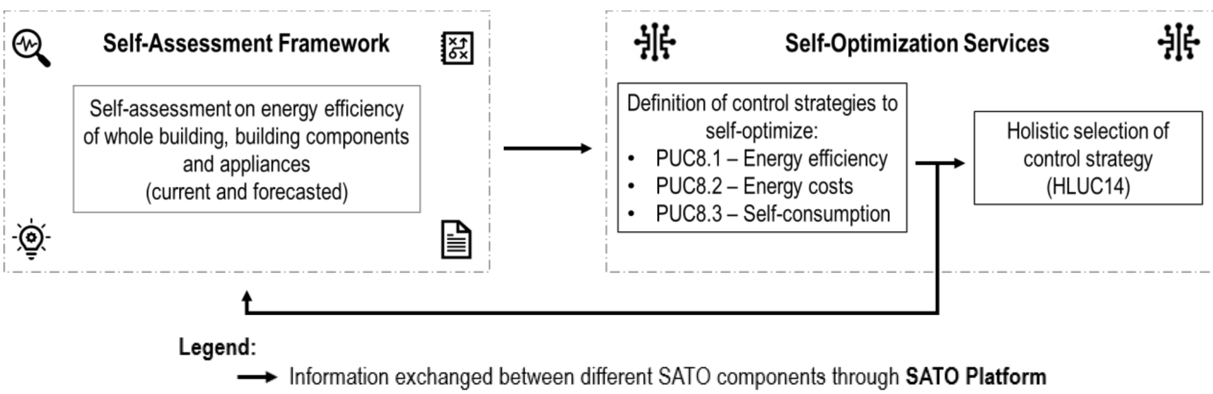


Figure 10 - HLUC08 diagram

3.11.5. Pilots

The pilot site(s) associated with this use case are referred to in the following table:

High-level Use Cases	Pilots
HLUC08 - Optimization of building energy efficiency	All Pilots

3.12. HLUC09 - Improving building indoor environmental quality

3.12.1. Objectives

HLUC09 is a High-Level Use Case (HLUC) that will leverage on the SATO Self-Optimization Services to improve the building's Indoor Environmental Quality (IEQ), which refers to the quality of a building's environment in relation to the health and wellbeing of those who occupy a space within it.

The SATO Self-Optimization Service will consider thermal, visual, and acoustic comfort, as well as indoor air quality (IAQ), with a data-driven approach based on the available sensors in the building and on post occupancy evaluation (POE) carried out via the SATO APP.

The comfort assessment will be based

1. on the selected comfort thresholds as codified in international standards and guidelines;

2. on the feedback of building occupants/manager on indoor conditions, in order to aim at parallel achievement of energy efficiency and occupants' comfort.

The SATO Self-Assessment Framework will consider both these aspects (comfort models and users' feedback), comparing them to identify discrepancies and their sources (issues related to building fabric, building systems (active and passive) or related to monitoring systems (too poor quality/quantity of data to perform a reliable comfort assessment) improper users' behaviour and expectations, gaps in technical standards) and take related actions via SATO Self-Optimization Services to define better setpoints for building energy efficiency while improving comfort and indoor air quality and/or to provide recommendations to users, depending on the kind of building (residential of office/retail).

3.12.2. Description

The SATO Self-optimization use case Improving building indoor environmental quality will consider thermal, visual, and acoustic comfort, as well as indoor air quality (IAQ), according to the available sensors in the building. The thermal comfort assessment will be based on the selected comfort categories of the thermal comfort models as codified in international standards and on the feedback of building occupants/manager on indoor conditions. This use case contributes to the parallel achievement of energy efficiency and occupants' comfort.

3.12.3. Primary use cases

Four PUCs will be derived from this HLUC.

- PUC9.1 is named "Improve thermal comfort"
- PUC9.2 is named "Improve indoor air quality"
- PUC9.3 is named "Improve visual comfort"
- PUC9.4 is named "Improve acoustic comfort".

3.12.4. Use case diagram

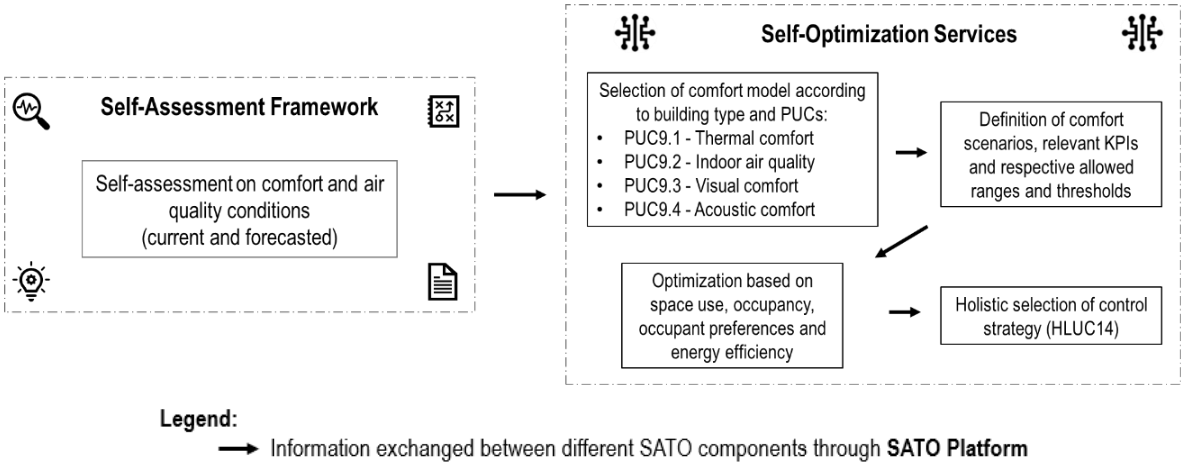


Figure 11 - HLUC09 diagram

3.12.5. Pilots

The pilot site(s) associated with this use case are referred to in the following table:

High-level Use Cases	Pilots
HLUC09 - Improving building indoor environmental quality	All Pilots

3.13. HLUC10 - Providing grid flexibility services to an energy aggregator

3.13.1. Objectives

HLUC10 is a High-Level Use Case (HLUC) focused on the self-optimization performed by SATO Self-Optimization Services to determine the flexibility potential of a building, provide that information to be exploited by an energy aggregator, and ultimately increase the revenue streams for building owners and facility managers.

This HLUC is linked with several SATO software functionalities such as the SATO Self-Assessment Framework and SATO Self-Optimization Services, requiring direct communication with an energy aggregator, which will be the one exploring the flexibility potential.

3.13.2. Description

SATO will assess the electric energy flexibility potential available and make this information available for potential energy aggregators, which will be able to use this information to trigger defined building flexibility assets. This HLUC will allow aggregators to have a bigger pool of flexibility assets to manage grid related issues, such as grid congestion. Buildings providing the flexibility services may be paid in the near future for providing these services to the grid. SATO will ensure the flexibility provided by buildings goes in synergy with occupant comfort.

3.13.3. Primary use cases

No PUCs (intended as sub-analyses carried out in parallel on different aspects) foreseen since all the steps of this HLUC are in a sequence.

3.13.4. Use case diagram

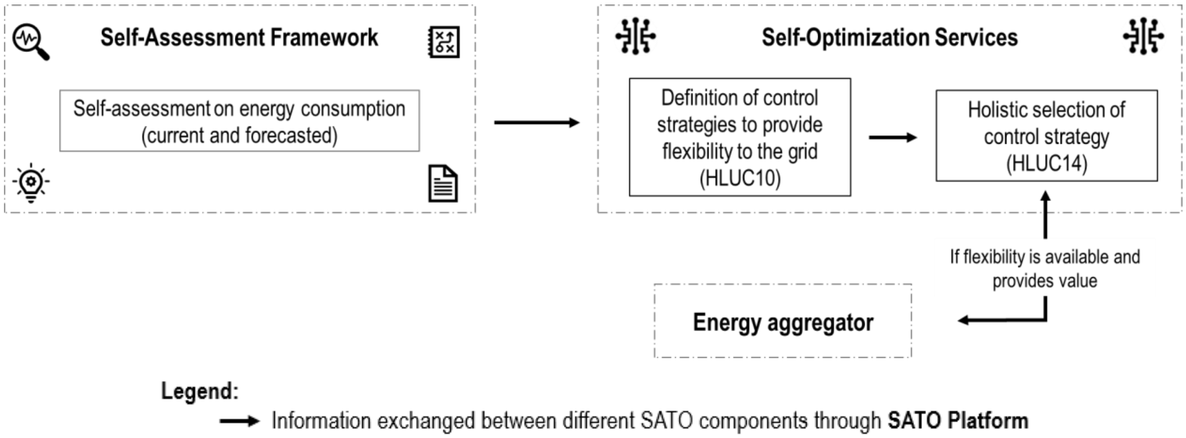


Figure 12 - HLUC10 diagram

3.13.5. Pilots

The pilot site(s) associated with this use case are referred to in the following table:

High-level Use Cases	Pilots
HLUC10 - Providing grid flexibility services to an energy aggregator	Lisbon Service Building, Worten Retail Store

3.14. HLUC11 - Load-shifting as an energy cost reduction strategy

3.14.1. Objectives

Load shifting, the ability to change the timing of electricity use to minimize demand during peak periods or to take advantage of the cheapest electricity prices, will be evaluated in this use case as a reliable and easy way to implement methods for energy cost reduction, using SATO Platform. The procedure will allow for real-time optimized control of legacy and smart appliances, as well as building equipment and vehicle-to-grid (V2G) chargers and batteries.

3.14.2. Description

This HLUC aims to evaluate the flexibility potential of the different energy assets present in the building.

SATO BMS and SATO APL will be used to gather data (energy use and energy from renewable sources) from the building and, if possible, from the electric grid. SATO Self-Assessment Framework will use this information to determine the available flexibility in building appliances and equipment. This information is then used by the SATO Self-Optimization Services to come up with the optimal control and time schedule of equipment and appliance operation.

3.14.3. Primary use cases

No PUCs (intended as sub-analyses carried out in parallel on different aspects) foreseen since all the steps of this HLUC are in a sequence.

3.14.4. Use case diagram

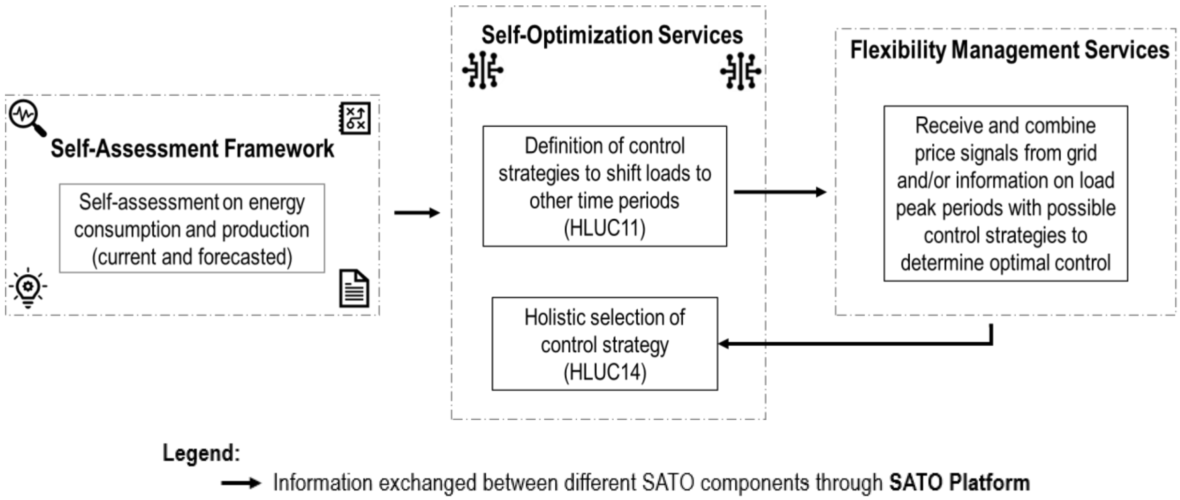


Figure 13 - HLUC11 diagram

3.14.5. Pilots

The pilot site(s) associated with this use case are referred to in the following table:

High-level Use Cases	Pilots
HLUC11 - Load-shifting as an energy cost reduction strategy	Aalborg Residential, Lisbon Service Building, Worten Retail Stores, Aalborg University

3.15. HLUC12 - Using thermal mass for BaB energy storage

3.15.1. Objectives

In this use case, buildings will be evaluated according to their thermal mass and energy use profiles for heating and cooling. This information will be provided to SATO Self-Assessment Framework for the evaluation of available flexibility. SATO Self-Optimization Services will use this additional flexibility together with other flexibility sources to determine the optimal operation mode. SATO APL and SATO BMS will receive data on the optimal set-points for heating, ventilation, and air conditioning (HVAC) systems and apply it to develop optimal HVAC control.

3.15.2. Description

Using thermal mass for BaB (building as thermal battery) energy storage Use Case aims to determine optimal setpoints for HVAC systems, taking profit of the thermal mass of the building fabric to shift the energy demand for the mechanical systems. Depending on the availability of data from the local energy grid, this can be done in two ways. If no communication with the grid is set, the optimization will be performed at building scale. If Building-to-Grid (B2G) integration framework can be deployed, the optimization will include grid data. This means, in the periods of surplus energy in the local energy grid (low demand periods), the building is in preheating mode, i.e., energy consumption from energy system is higher than the energy demand required to meet the residents' thermal comfort requirements and the surplus heat is stored in the structural thermal mass of the building. In the opposite situation (i.e., high demand periods in the energy grid), when the building is in discharging mode, none or very little energy is consumed from local energy grid and the heat demand needed to maintain the thermal comfort is met by utilizing the heat stored in the buildings' thermal mass.

3.15.3. Primary use cases

No PUCs (intended as sub-analyses carried out in parallel on different aspects) foreseen since all the steps of this HLUC are in a sequence.

3.15.4. Use case diagram

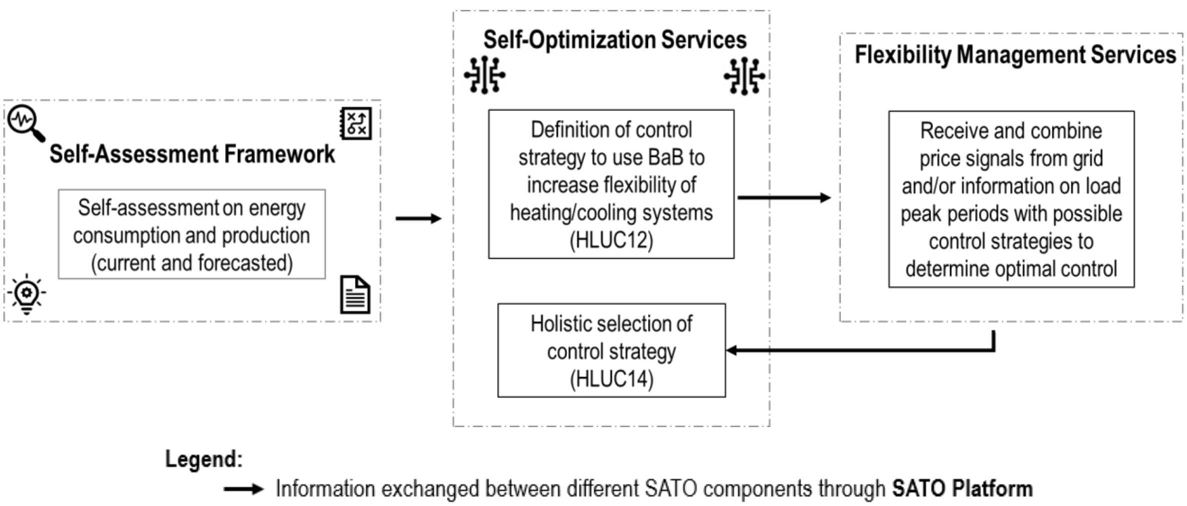


Figure 14 - HLUC12 diagram

3.15.5. Pilots

The pilot site(s) associated with this use case are referred to in the following table:

High-level Use Cases	Pilots
HLUC12 - Using thermal mass for BaB energy storage	Aalborg Residential, Seixal Residential, Lisbon Service Building, Seixal Municipality Office

	Building, Milan Residential, Milan Single Apartment

3.16. HLUC13 - Exploitation of natural ventilation as a cost-effective indoor comfort strategy

3.16.1. Objectives

HLUC13 is a High-Level Use Case (HLUC) with focus on the use of natural ventilation in buildings in order to reduce the energy costs (reducing the energy need for cooling and energy use for ventilation) associated with ensuring at the same time proper levels of comfort to the building's occupants.

The SATO Platform will be equipped with automated self-assessment capabilities that are partially supported by statistical/machine learning methods. These technologies are used to obtain insights into user, equipment and building behaviour that can be exploited to provide innovative high-performance self-optimized energy management services. Natural ventilation is one of these Self-Assessment and Optimization (SA&O) services that SATO will provide to users.

In the SATO Platform, the Self-Assessment Framework will investigate the potential of the use of natural ventilation based on:

1. The cooling/heating capacity of the indoor space
2. The reduction of energy use (turning off heating ventilation and air conditions, HVAC, & air handling unit, AHU)
3. Providing indoor air quality
4. Maintaining low noise levels

On the other hand, the Self-Optimization Services will combine this natural ventilation potential with the remaining optimization services and, ultimately, choose the best combination of services that minimizes the energy use and still providing thermal and acoustic comfort to the occupants.

1. Assess impact of different natural ventilation control strategies on energy use, energy savings and user (thermal, acoustic, visual, …) comfort.
2. Develop automated controls and strategies for air intake that enables natural ventilation.
3. Dynamic calculation of the SRI domain "controlled ventilation".

3.16.2. Description

Natural ventilation will be evaluated using SATO Self-Assessment Framework, allowing to perform a data-driven decision about the potential of natural ventilation to improve the user comfort and the indoor air quality, while reducing the energy needs for cooling. SATO Platform will have control over some windows to automatically deploy the best natural ventilation control strategy given by the SATO Self-Optimization Services.

3.16.3. Primary Use Cases

In the HLUC, two PUCs will be studied. PUC13.1 focus on daytime natural ventilation assessment while PUC13.2 focus on night cooling. While both strategies can be complementary, night cooling is used to cool the thermal mass of the building while daytime natural ventilation is usually used for the instant ability to provide comfort without the use of electrical systems.

3.16.4. Use case diagram

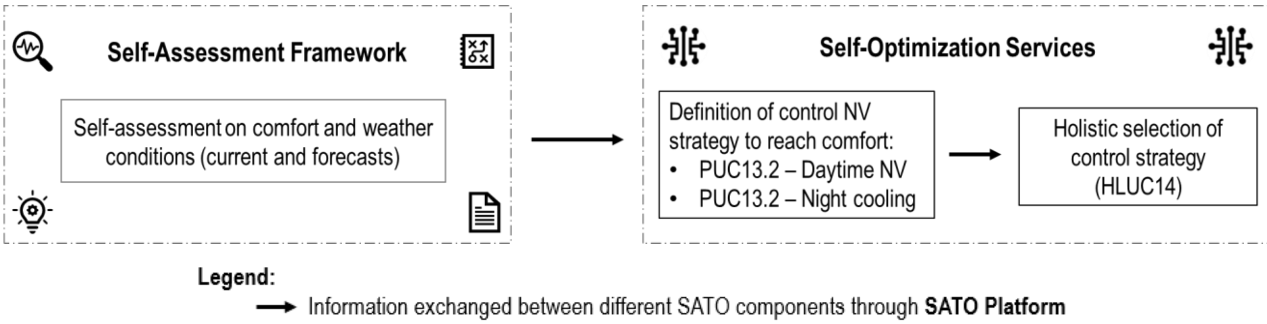


Figure 15 - HLUC13 diagram

3.16.5. Pilots

The pilot site(s) associated with this use case are referred to in the following table:

High-level Use Cases	Pilots
HLUC13 - Exploitation of natural ventilation as a cost-effective indoor comfort strategy	Lisbon Service Building, Seixal Municipality Office Building, Milan Single Apartment

3.17. HLUC14 - Holistic optimal control of energy resources

3.17.1. Objectives

The High-Level Use Case (HLUC14) considers the holistic optimal control of energy resources in the building. It will aggregate the control of energy efficiency services, flexibility services, and other optimization services that have an impact on energy utilization within the building.

Different services may be used to control indicators related to the utilization of energy in buildings. For instance, thermal, acoustic, and visual comfort, air quality, energy consumption, or available flexibility indicators. When executed individually, these services are likely to generate conflicting control requirements and actions to be implemented in the building.

HLUC14 focuses on the coordinated control of the different services, considering different user preferences and requirements, and building resources context.

The HLUC14 assumes the existence of a service or tool that can optimize the control of individual services considering user preferences and requirements as well as different building control possibilities.

3.17.2. Description

Holistic optimal control of energy resources aims to establish an overarching service that oversees and coordinates the control actions of individual energy management services and other services related to the utilization of energy in buildings, to optimize various performance indicators according to the preferences and requirements of users.

3.17.3. Primary use cases

Three PCUs may be derived from HLUC14: PUC14.1 (Holistic optimal control of energy resources in office buildings), PUC14.2 (Holistic optimal control of energy resources in residential buildings) and PCU14.3 (Holistic optimal control of energy resources in commercial and public buildings). The first deals with the scenarios of office buildings, the second with the scenarios of residential buildings and the third with the scenarios of commercial buildings.

3.17.4. Use case diagram

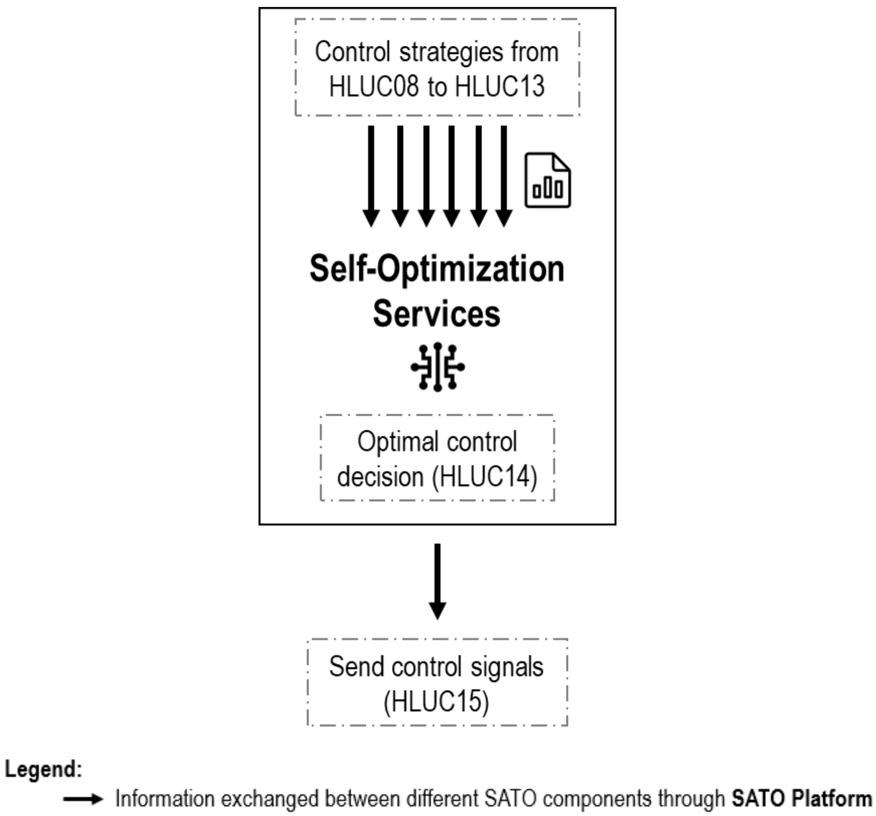


Figure 16 - HLUC14 diagram

3.17.5. Pilots

The pilot site(s) associated with this use case are referred to in the following table:

High-level Use Cases	Pilots
HLUC14 - Holistic optimal control of energy resources	All Pilots

3.18. HLUC15 - Cloud managing of legacy and smart appliances as well as technical building equipment

3.18.1. Objectives

HLUC15 is a High-Level Use Case (HLUC) focused on the cloud-based control actions applied to the smart and legacy appliances and technical building equipment installed in a building.

Given that the Self-Optimization Services will generate smart management strategies for building equipment and appliances, these strategies may be deployed over the devices using two approaches: a direct approach, or an indirect approach that implies the intervention of a building manager/owner to deploy the strategies. This HLUC will enable the direct approach that consist of creating a channel of communication between the SATO Self-Optimization Services and the building equipment/appliances.

As such, this HLUC requires no direct intervention from human actors but is linked with several SATO software/ hardware functionalities such as the SATO Self-Assessment Framework, the SATO Self-Optimization Services, SATO BMS, SATO APP and SATO APL.

Although direct intervention from human actors is not required, building occupants or the building manager may be able to overwrite the SATO Self-Optimization Services commands, to ensure High-Level of comfort. In such cases, the building manager or occupants may use the SATO BMS and SATO APP to adjust the technical building equipment as well as legacy and smart appliances accordingly.

3.18.2. Description

Cloud managing of legacy and smart appliances and technical building equipment aims to establish a communication channel for control, between SATO Platform and the actuators deployed in the buildings, to send/receive commands that will enable the application of the self-optimization strategies generated by the SATO Self-Optimization Services.

3.18.3. Primary use cases

Three PUCs will be derived from this HLUC. PUC15.1 is named "Cloud managing of legacy appliances and equipment", PUC15.2 is named "Cloud managing of smart appliances and equipment" and PUC15.3 is named "Cloud managing of EV chargers and batteries".

PUC15.1 will enable the control and management over legacy devices (appliances and technical building equipment), such as, i.) legacy appliances with longer life-cycles such as stoves and refrigerators, that are responsible for large peaks in residential energy consumption but typically lack remote control features, ii.) legacy appliances with shorter life-cycles, such as washing machines and dishwashers, as well as iii.) technical building equipment, such as HVAC systems and boilers.

PUC15.2 concerns the cloud-based control of smart building equipment, e.g., HVAC or DHW systems, to enable the deployment of energy efficiency strategies computed on the cloud and directly applicable in the building.

PUC15.3 concerns the cloud-based management of vehicle-to-grid (V2G) chargers and batteries as a strategy to reduce peak consumption and increase self-consumption.

3.18.4. Use case diagram

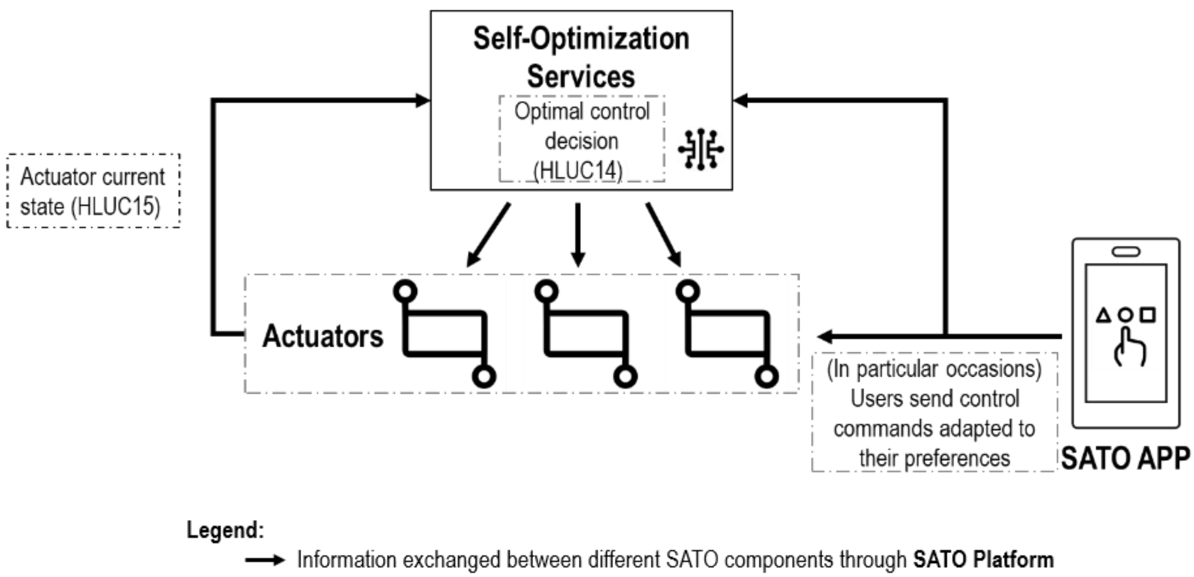


Figure 17 - HLUC15 diagram

3.18.5. Pilots

The pilot site(s) associated with this use case are referred to in the following table:

High-level Use Cases	Pilots
HLUC15 - Cloud managing of legacy and smart appliances as well as technical building equipment	All Pilots

4. Relation to other tasks

The output of this deliverable will serve as the base for the implementation of the UC in the different pilots, and the relations and scenarios described in the UC will also help in the development of the SATO software features. Particularly, this deliverable will contribute directly to different task of WP 1, 2, 3, 4, 5 and 6 (Table 3).

Table 3: Task contribution to other tasks of the project.

Tasks	Contribution level	Main contribution
Definition of the Pilots Demonstration Framework and KPIs to evaluate SATO SA&O services and Business Models (1.5)	Medium	Understand the use cases that will be deployed in SATO
Sensors and upgrade of existing devices to non-intrusively monitor and manage building environment and energy (2.2)	Low	Understand the sensors and monitoring devices necessary in each UC
Development of building energy performance assessments (3.6)	Low	Understand the types of assessments that are needed to feed the different UC
Development of user and occupancy behaviour assessments (3.7)	Low	Understand the types of assessments that are needed to feed the different UC
Development of Aggregated Optimal Control for Energy Resources (4.3)	Low	Understand the types of optimization services that will be deployed
Definition of actors interaction with SATO A&O services through BIM-based interfaces (5.1)	Medium	Understand the interactions between the BIM tool and the other actors
Definition of actors operational interaction with SATO platform and services through friendly user-centred design (5.2)	Medium	Understand the requirements to develop the applications for end-users
Residential multi-apartment pilots (Aalborg, Milan, Seixal): SA&O operational experiments and monitoring (6.2)	High	Understand the UC that will be deployed in the residential pilots

Office building pilots (Aalborg, Aspern, Seixal, Lisboa): SA&O operational experiments and monitoring (6.3)	High	Understand the UC that will be deployed in the office pilots
Appliance retail store pilots (Lisboa, Madrid): SA&O operational experiments and monitoring (6.4)	High	Understand the UC that will be deployed in the retail store pilots
Compliance and certifications plan (7.1)	Medium	Provides detailed and relevant information for all WP7

5. Conclusions

This deliverable identifies the Use Cases of SATO project to be developed and deployed in the pilot sites. The work developed in this subtask is fundamental for the planning of the SATO pilot site activities, mainly the deployment of SATO services across the different typologies of buildings. Further, this work enables to oversee all the solutions planned in SATO together with the relations between them, leading to a solution-centred architecture that allows consortium members and stakeholders to define the requirements for their solutions in respect with SATO characteristics and features.

Using the Use Case Methodology described in this document, in accordance with IEC 62559 standard, it was possible to divide all SATO planned features into 15 High-Level Use Cases, that provide details on relevant requirements for the development of each SATO Service. Most of the High-Level Use Cases split into PUCs, further detailing the Use Cases to specific scenarios with the rational that High-Level Use Cases might only be partially implemented in a pilot due to its typology, data available, occupants, and other factors. There are 12 High-Level Use Cases that can be separated in a total of 37 different PUCs and another 3 High-Level Use Cases that need to be fully implemented. This architecture allows for an increased flexibility in the selection of pilot sites and contributes to the development of highly replicable solutions.

The 15 High-Level Use Cases are divided over 5 different areas (Monitoring, Self-assessment and benchmarking, Visualization, Self-Optimization and Controlling) where SATO Platform will perform a role.

Most of the solutions identified have innovative elements and therefore will be tested for the first time, making it crucial to list all the requirements needed to assure that the implementation of the solutions in their pilot sites is successful and that most of the risks are mitigated. This document will be the main support of Task 1.5, where all the requirements will be identified according to the Use Cases and the associated pilot sites.

Overall, the result of this document is a pathway to future development of the SATO Services in Work Packages 3 and 4 and a guide for the implementation phase in Work Package 6 and 7. Additional detail on the associated business cases will be studied in Task 1.6.

References

[1] IEC International Standard, 2015. 62559-2:2015 Use case methodology - Part 2: Definition of the templates for use cases, actor list and requirements list

[2] H2020 SATO project. Deliverable 1.1: Role of Actors and Design of Stakeholder Framework

[3] H2020 SATO project. Deliverable 1.2: Requirements of the Self-Assessment Framework – KPI Tool

Annex I – Template

1. Description of the use case

Use case describes functions of a system in a technology-neutral way. It identifies participating actors which can for instance be other systems or human actors which are playing a role within a use case. Use cases can be specified on different levels of granularity and are according to their level of technological abstraction and granularity either described as High-Level Use Case (HL-UC) or Primary Use Case (PUC).

HL-UCs will describe a general requirement, idea or concept independently from a specific technical realization like an architectural solution that should be generic enough to include all the relevant information.

PUCs will describe important features, architectures and specific technological realization that are only relevant to some countries, pilots or other limitations.

1.1 Name of the use case

ID	Area	Name of Use Case
The identification number of a use case is unique within a repository or project and serves for organization/administration of use cases. Please use the following syntax: HLUSX	*Select from: (1) Monitoring; (2) Self-assessment and benchmarking; (3) Visualization of building energy performance; (4) Self-optimization; (5) Controlling*	*Please include use case name from the excel file: Use Case Short Description V6.xlsx*

1.2 Version management

Version No.	Date	Name of Author (s)	Changes
0.0	*DD.MM.JJ*	*Name*	First template provided
1.0	*DD.MM.JJ*	*Name*	
…			

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	The scope defines the limits as well as the primary actors of the use case
Objective(s)	List of objectives of the use case which should be evaluated based on the set of KPIs defined in section 1.5.
Related business case(s)	Provides a description or reference with some rationale for the suggested use case. Usually one business case is related to several use cases. Therefore, an external reference or link to a business case/ business requirements might be more efficient and can be added here.

1.4 Narrative of use case

1.4.1 Narrative of High-Level use case

Narrative of Use Case
Short description
Short text intended to summarize the main idea as service for the reader who is searching for a use case or looking for an overview. Recommendation: This short description should have not more than 150 words.
Complete description

<u>Complete Description</u>: Provides a complete narrative of the use case from a user's point of view (user story), describing what occurs when, why, with what expectation, and under what conditions. This narrative should be written in plain text so that non-domain experts can understand it. The complete description of the Use Case can range from a few sentences to a few pages. This section often helps the area expert to think through the user requirements for the function before getting into the details required by the next sections of the Use Case.

1.4.2 Narrative of primary use cases

ID	*Name*	*Description*
Please use the following syntax: PUSX.Y	*Please include primary use case name*	Text intended to summarize the idea as service and the differentiation factors for the reader who is searching for a primary use case or looking for an overview.

1.5 Key performance indicators (KPI)

<u>This information will be used in the remaining WP of SATO, so it is crucial.</u>

High-level use cases should define KPI linked to specific objectives (and ad-hoc indicators) from the DoA, as well as business processes. For these UC, a KPI tool was elaborated by AAU and the writes should try to use the KPI from this tool.

ID	*Name*	*Description*	*Reference to mentioned use case objectives*
The identification number of a key performance indicator is unique within a repository or project and serves for organization/ administration of key performance indicators. Please use the following syntax: KPIX	*Please define a unique name for each KPI included.*	The description specifies the KPI and may include specific targets in relation to one of the objectives of the use case and the calculation of these targets.	Here is the link to one of the use case objectives (in section 1.3) which are specified in the targets and the KPI before.

1.6 Use case conditions

Use case conditions
Assumptions
May be used to define further, general assumption for this use case. In some use cases, it is critical to understand which preconditions or other assumptions are being made. • *Any assumptions shall be identified, such as: which systems already exist, which contractual relations exist, and which configurations of systems are probably in place.* • *Any initial states of information exchanged in the steps in the next section shall be identified.*
Prerequisites

Please describe what condition(s) should have been met prior to the initiation of the use case, such as prior state of the actors and activities.

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
Known relations to other use cases can be provided here if e.g. the use case is a more detailed one related to a High-Level use case, or it is an alternative to an existing use case. *Could be used to include the IDs of SATO use cases related to this one, or even to refer to external Use Cases from which the particular SATO Use Case derives.* *In case the High-Level use case relates to other primary use cases, the relationship and potential level of interaction should be specified here.*
Level of depth
Defines the level of depth of the use case: ***High-level use case** (HL-UC) use case which describes a general requirement, idea or concept independently from a specific technical realization like an architectural solution* ***Primary use case** (PUC) use case which describes in detail the functionality of (a part of) a business process (e.g. applicability to specific sectors such as residential/service buildings).* ***Specialized use case** (SUC) use case which is using specific technological solutions/implementations.*
Prioritisation
Considering a larger number of use cases it might be interesting to cluster them according to priority. This prioritisation might be different from country to country. *Nonetheless, in SATO, this field should indicate whether the solutions will be implemented in more than one demo and if replicability is a key objective.*
Generic, regional or national relation
Generic, regional or national relation: On international level, the use case description might be generic enough to describe a use case in a more general way independently from the national or regional market design. But use cases might be used to describe regional or national specific circumstances like laws or even project-specific details. If the use case reflects those circumstances, it should be characterized accordingly. ***Note**: **Use Cases demonstrated in more than one country should be classified and written as Generic.***
Nature of the use case
This field can help to classify the main focus of the use case. EXAMPLE: Technical/system use case, business use cases (e.g. market processes), political, test use cases.
Further keywords for classification
Keywords can be defined in order to support extended search functionalities within a use case repository. Multiple keywords should be provided as a comma-separated list. *EXAMPLE: Self-assessment, self-optimization, electricity metering, storage.*

2. Diagrams of use case

For clarification, in general it is recommended to provide drawing(s) by hand, by a graphic or as UML graphics. The drawing should show interactions which identify the steps where possible.

Diagram(s) of use cases
Please paste below the Use Case Diagram: shows how actors interact within the Use Case by participating in the technical functions *Please paste below the HLUC-PUC Relations Diagram: shows which primary use cases (PUC) are used by the High-level Use Case (HLUC). This is diagram is only included in HLUC (if applicable).*

Please paste below the Sequence Diagram: shows the dynamic sequence of the activities (information exchanges/internal operations) required in the sub-functionality

3. Technical details

In this section 3.1, actors which are involved in the use case are listed and described. These can for instance include people, systems, applications, databases, devices, etc. (as referenced in the Excel file: Use Case Short Description V6.xlsx).

With the aim of improving consistency among Use Case descriptions, a list of actors based on standard definitions (IEC 62559-2), should be used. Thus, the information included in the fields of the following table should be obtained from the Actors List defined in SATO.

3.1 Actors

Actors		
Actor Name	***Actor Type***	***Actor Description***
Please select among the following actors: *1) Facility/ building managers,* *2) Building owners,* *3) Building occupants,* *4) Aggregators,* *5) Grid operators,* *6) Other,* *7) SATO Platform,* *8) SATO APP,* *9) SATO APL,* *10) SATO BMS,* *11) SATO SAF,* *12) SATO Services.*	*Please select among 1) Human actor, and 2) Software/ systems/ applications/ devices*	*Please specify the actors' main responsibility and role in the building energy system/ energy system as a whole (this applies in particular if option 'Other' was selected in column 1 of this table).*

3.2 References

References (which are standards, reports, mandates and regulatory constraints) associated with the Use Case. The Use Case Leader (**L**) and Contributors (**C**) must identify the standards that should be used to realize the Use Case and improve the replicability of the solution (e.g. GDPR).

Identify any legal issues that might affect the design and requirements of the function, including contracts, regulations, policies, financial considerations, engineering constraints, pollution constraints, and other environmental quality issues.

References						
No.	***References type***	***Reference***	***Status***	***Impact on use case***	***Originator/ organization***	***Link***
Please include a consecutive numbering.	*Please indicate the type of reference: function, including contracts, regulations, policies, financial considerations, engineering constraints,*	*Please include the document reference/ name here.*	*Please indicate the status of the referenced document.*	*Please specify the impact of the reference on the use case, e.g. copyright, IPR, data privacy.*	*Please indicate the legal entity issuing/ imposing the reference.*	*Please include the link to the referenced document here.*

	pollution constraints, and other environmental quality issues					

4. Step by step analysis of use case

Template section 4 focuses on describing scenarios of the use case with a step-step analysis (sequence description). There should be a clear correlation between the narrative and these scenarios and steps.

4.1 Overview of scenarios

The table provides an overview of the different scenarios of the use case like normal and alternative scenarios which are described in section 4.2 of the template.

In general, the writer of the use case starts with the normal sequence (success). In case precondition or post-condition does not provide the expected output (e.g. no success = failure), alternative scenarios have to be defined.

Scenarios conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
Please include a consecutive numbering.	*Please indicate a unique name for the scenario.*	*Please provide a short description of the scenario and indicate the rationale why this scenario was selected and what it shall circumvent in case a failure of the original use case takes place.*	*Refers to the actor that triggers the scenario. For instance, a function called "Protection" would probably be triggered by an "Intelligent Electronic Device (IED)". It is worth pointing out that the names of the Actors should be consistent with Actors List in all sections of the Use Case description.*	*Please indicated the event that will trigger the scenario. It can be a real event (such as, "a fault occurs in the grid"), or it is also possible to define scenarios that occur "periodically".*	*Please describe the state of the system before the scenario starts.*	*Please describe the expected state of the system after the scenario is realized.*

4.2 Steps – Scenarios

For this scenario, all the steps performed shall be described going from start to end using simple verbs like – get, put, cancel, subscribe etc. Steps shall be numbered sequentially – 1, 2, 3 and so on. Further steps can be added to the table, if needed (number of steps are not limited).

Should the scenario require detailed descriptions of steps that are also used by other use cases, it should be considered creating a new "sub" use case, then referring to that "subroutine" in this scenario.

Scenario								
Scenario name:		***Reference scenario***						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirements, R-IDs***
Please include a consecutive numbering.	*Event that triggers the activity. This triggering event can be an event, such as "a fault that occurs in the grid", or it may refer to an activity that occurs "periodically".*	*Label that would appear in a process diagram. Action verbs should be used when naming activity. EXAMPLE: "Fault occurs in the grid".*	*This describes what action takes place in this step. The focus should be less on the algorithms of the applications and more on the interactions and information flows between actors.*	*Identifies the nature of flow of information and the originator of the information (*).*	*Name of the actor that produces the information. When the activity is an internal process, the information producer is the actor that carries out the internal process. For instance, when the activity is an internal algorithm within an Intelligent Electronic Device (IED), then the information producer is the actor "Intelligent Electronic Device (IED)".*	*Name of the actor that receives the information. When the activity is an internal process, the information receiver is the same actor as the information producer.*	*Here the information can use a short ID referring to template section 5 for further details. Several information exchanged IDs can be listed, comma separated.*	*Refer to the identifiers (R-ID) of the detailed requirements that apply for each activity.*

(*) Available options are:

- *CREATE means that an information object is to be created at the Producer.*
- *GET (this is the default value if none is populated) means that the Receiver requests information from the Producer (default).*
- *CHANGE means that information is to be updated. Producer updates the Receiver's information.*
- *DELETE means that information is to be deleted. Producer deletes information from the Receiver.*
- *CANCEL, CLOSE imply actions related to processes, such as the closure of a work order or the cancellation of a control request.*
- *EXECUTE is used when a complex transaction is being conveyed using a service, which potentially contains more than one verb.*
- *REPORT is used to represent transferral of unsolicited information or asynchronous information flows. Producer provides information to the Receiver.*
- *TIMER is used to represent a waiting period. When using the TIMER service, the Information Producer and Information Receiver fields shall refer to the same actor.*
- *REPEAT is used to indicate that a series of steps is repeated until a condition or trigger event. The condition is specified as the text in the "Event" column for this row or step. Following the word REPEAT, shall appear, in parenthesis, the first and last step numbers of the series to be repeated in the following form REPEAT(X-Y) where X is the first step and Y is the last step.*

5. Information exchanged

These information objects are corresponding to the "Name of Information" of the "Information Exchanged" column referenced in the scenario steps in template section 4 "Step by Step Analysis". If appropriate, further requirements to the information objects can be added.

Information exchanged			
Information exchanged (ID)	*Name of information*	*Description of information exchanged*	*Requirement, R-IDs*
Refers to an identifier used in the field "Information Exchanged" of Table 4.2.	*Is a unique ID which identifies the selected information in the context of the use case.*	*Brief description, in case a reference to existing data models/information classes should be added. Using existing canonical data models is recommended.*	*Can be used to define requirements referring to the information and not to the step as in the step by step analysis (see template section 6 below): EXAMPLE: Data protection class corresponding to this information object.*

6. Requirements

This table summarizes the requirements of all steps in the use case and it is linked to template section 4 "Step by Step Analysis". The ID for requirements (R-ID) is a unique ID which identifies the requirement in all use cases (e.g. in a repository).

A list of non-functional requirements and KPIs was defined in SATO D1.2 to provide guidelines on possible values that could be given to each type of requirement/ KPI. However, other values not included in the list could be used if necessary.

Requirements		
Categories ID	*Category name for requirements*	*Category description*
Unique identifier for the category.	*Name for the category of requirements.*	*Description of the requirement category.*
Requirement R-ID	*Requirement name*	*Requirement description*
Unique identifier which identifies the requirement within its category, and which can link the requirement to an external requirement document.	*A name of the requirement.*	*Description of the requirement (this might be populated automatically from the repository, if the requirement has already been described in the external document before).*

7. Common Terms and Definitions

Should be defined in a common glossary for all use cases. Here relevant terms belonging to this use case are listed. Using a database repository for the glossary, the definitions might be filled automatically based on existing information.

Common Terms and Definitions	
Term	*Definition*

Annex II – High-Level use cases

HLUC01 – Securely collecting, processing and storing building and third-party data

1. Description of the use case

1.1 Name of the use case

ID	*Area*	*Name of Use Case*
HLUC01	*(1) Monitoring*	*Securely collecting, processing and storing building and third-party data*

1.2 Version management

Version No.	*Date*	*Name of Author (s)*	*Changes*
1	*19.05.21*	*Vinicius Cogo*	*First version of HLUC01*
1.1	*04.06.21*	*Filipe Silva*	*Review*
1.2	*11.06.21*	*Thomas Fehr, Michael Liniger, Christoph Ospelt*	*Review*
2.0	*18.06.21*	*Vinicius Cogo*	*Second version of HLUC01*
3.0	*24.06.21*	*João Dias, Filipe Silva*	*Third version of HLUC01 Metadata and Industry standards*

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	HLUC01 is a High-Level Use Case (HLUC) focused on securely collecting, processing, and storing building and third-party data. It presents how data will flow from buildings into the **SATO Platform** and how it will be standardized and stored for the subsequent processing steps from the assessments. This use case assumes the availability of sensing devices in buildings and of external services that will provide data to the **SATO Platform**. Alternatively, the **SATO Platform** can include data quality components that will infer missing data points if it does not receive them within a deadline. Four Primary Use Cases (PUCs) may be derived from HLUC01: PUC1.1 (Collect building information using sensing devices), PUC1.2 (Collect third-party data from external data sources), PUC 1.3 (Collect Control Actions from Self-Assessment and Optimization (SA&O) Services), and PUC1.4 (Storing data from PUC 1.1-3 to the corresponding database with a standard model). The first addresses the data points coming from sensing devices, the second deals with third-party data coming from external data sources, the third handles control actions, and the fourth provides a standard data model for the events and stores the building information in a database.
Objective(s)	The objectives of this HLUC are related with the collection, processing, and storage of data. The following objectives were defined: 1. Collect building information using sensing devices 2. Create a database with building information in a standard data model 3. Collect weather data from external meteorology services (live and forecast) 4. Collect grid data (price and CO_2-eq) from energy provider/ grid operator (live and predictive)

1.4 Narrative of use case

1.4.1 Narrative of High-Level use case

Narrative of Use Case
Short description
The **SATO Platform** will be able to receive building data collected from all energy-consuming devices in the buildings of the SATO pilots. Additionally, third-party data (e.g., weather data and electricity price) will also be collected. Data collected will be ingested and secured as fast as possible (Transient storage) and subsequently will be pre-processed to be in a standardized data model with trustworthy data quality (Refined storage). This data will then be used in the SA&O Services, which will also produce data to be stored (Results storage). All this data should be stored and processed in useful time securely and anonymously, to comply with the EU privacy legislation (e.g., GDPR).
Complete description
The **SATO Platform** will receive data collected from all energy-consuming devices in the buildings of the SATO pilots. This data includes data points from multiple types of systems and components with diverse functions and sensors. Moreover, the platform will also receive control events (e.g., adding or removing a system or component from a building) that must be treated separately. Finally, third-party data (e.g., weather data and electricity price) from external services, industry standards, and metadata (building metadata refers to building information that is not continuously monitored, but acquired once during the construction or commissioning phase, or periodically during the building operation, to characterize the building as a physical object and its operation) will also be collected in the platform. The **SATO Platform** will receive data from systems and components in a building through three different options: (1) SATO-enabled devices will directly announce themselves for the **SATO Platform** and directly send their measurements for the platform; legacy devices will interact with gateways located in the building. These gateways can (2) directly send data to the **SATO Platform** or can (3) provide the data through an external cloud platform from where the **SATO Platform** collects the data measurements. Additionally, the platform will collect data from third-party data sources using their publicly available APIs. A service will be responsible for receiving control events (e.g., adding a new device to the platform) to keep an up-to-date snapshot of the systems and components present in the building and their functions. This service will also interact with other semantic services and will provide a standardized representation of the data traversing the **SATO Platform** through the specification of a Common Data Model (CDM). All this data will be ingested by the platform and will be stored in a transient storage component as soon as possible. After data availability is preserved, data will flow within the platform through several internal steps that will standardize it, verify its quality, protect the privacy of people associated with it, enhance it with metadata and semantics, and securely store it for the subsequent processing steps. These initial steps compose the SATO middleware, which will store all the data into a refined storage component that will serve as input for all subsequent processing steps (e.g., **SA&O Services**). The stored enhanced data will be used for **SA&O Services**, which also produce data to be kept in a result storage component. The **Self-Assessment Framework (SAF)** enables the continuous estimation of the energy consumption of the monitored buildings in useful time for optimizing it in the **Self-Optimization Services**. The results from this framework will empower end-users and stakeholders to identify opportunities for optimizing the energy resources of the buildings connected to the platform. All data storage and communication in **SATO Platform** will be stored and processed in useful time securely and anonymously, to comply with the EU privacy legislation (e.g., GDPR).

1.4.2 Narrative of primary use cases

ID	***Name***	***Description***
PUC1.1	Collect building information using sensing devices	The **SATO Platform** will receive or collect data points (e.g., measurements) from the sensing devices and appliances available in the buildings. This data is stored in a transient storage, harmonized in a common data model (CDM) and stored in a refined storage. This refined storage is the input where the assessments will fetch data they need for processing. The resulting assessments will be stored in the result storage component for visualization and to be used by the optimization processes.
PUC1.2	Collect third-party data from external data sources	Weather forecast and historical data, energy labelling data (e.g., EPREL), and energy prices are collected by the **SATO Platform** and will be provided in a normalized way in the refined storage. Assessments can fetch this data from the refined storage for processing purposes.
PUC1.3	Collect Control Actions from SA&O Services	The **SATO Platform** will receive and collect the control actions (e.g., actuations) determined by the **SA&O Services**. This collection will enable additional meta-analyses of the decisions taken

		by the platform to optimize even further the energy consumption of buildings and the comfort of their occupants. The actuations will also be forwarded to the equipment and appliances in buildings following the specification of the High-Level Use Case HLUC14, through **SATO Platform**.
PUC1.4	Storing data in the corresponding database with a standard model	Data coming from the buildings is heterogeneous since buildings have heterogeneous devices and energy-management systems. This data and third-party data are received by the platform and stored unmodified in transient storage. Then, a data cataloguing component will standardize the data applying a common data model (CDM) that will make more homogeneous the data flowing within the platform. All data stored in the refined storage will be stored using the CDM, which will be accessed by processing resources for the self-assessment.

1.5 Key performance indicators (KPI)

Name	*Description*	*Reference to mentioned use case objectives*
Data availability	The continuous streaming of data must be monitored in the **SATO Platform** to guarantee that data arrive to the **SAF** in the expected timeframes.	1, 3, 4
Data quality	The data being delivered to the **SATO Platform** must have its quality monitored to guarantee that the **SAF** is using the appropriate measurements to enable the **SA&O Services** taking decisions based on them.	1, 2, 3, 4
Availability of the streaming components	The streaming components receive the data points and forward them to the storage components that will be used by the **SAF**. Given its importance in the data flow, the streaming component must be available as much as possible and should be monitored.	3, 4
Availability of the storage components	The storage components will receive the data points and will provide data for the **SAF**. Given its importance in the data flow, the storage components must be available as much as possible and should be monitored.	1, 2
Data throughput for the SAF	The **SATO Platform** must support the data throughput required for the **SAF**.	2

1.6 Use case conditions

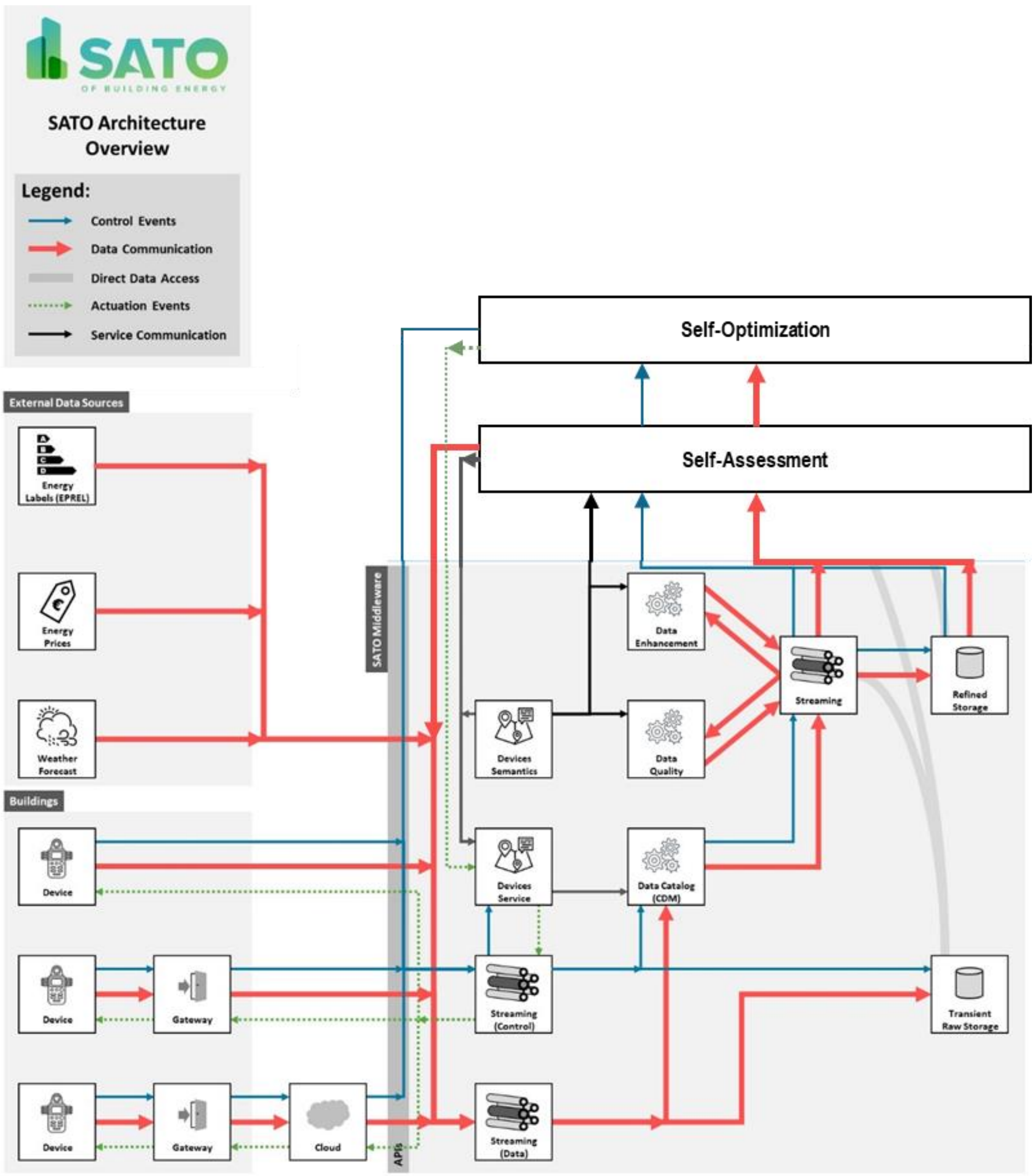
Use case conditions
Assumptions
The data from energy consuming devices from buildings are being collected and sent to the **SATO Platform**. Third-party data is being collected and sent to the **SATO Platform**. The **Facility/building managers**, **Building owners** or **Building occupants**, have given their consent for SATO to collect data from their properties, systems, appliances and equipment (GDPR compliant).
Prerequisites
Buildings are connected to the **SATO Platform**. Third-Party data API is available.

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
All HLUC depend on this use case, the collection, processing and storing is the basis of SATO.
Level of depth
Defines the level of depth of the use case: ***HLUC** - Securely collecting, processing, and storing building and third-party data*

Collect building information using sensing devices Collect third-party data from external data sources Collect Control Actions from SA&O Services Create a database with building information in a standard model
Prioritisation
This HLUC is considered of top priority to SATO as other HLUC depend on this to receive/send data to systems and components. All PUC from this HLUC should be applied in all project pilots.
Generic, regional or national relation
Generic Use Case
Nature of the use case
Technical Use Case
Further keywords for classification
Data, sensor, cloud, storage, processing, streaming, privacy-protection, security.

2 Diagrams of use case

Diagram(s) of use cases
 All interactions present in this diagram will be detailed further in the Deliverable D1.4 of the SATO Project.

3. Technical details

3.1 Actors

Actors		
Actor Name	***Actor Type***	***Actor Description***
Facility/building managers	*Human actor*	*This actor has an indirect role in this HLUC. His role is to install and configure the devices within the building and connect them to the **SATO Platform** to start collecting data.*
SATO Platform	Software/ systems/ applications/ devices	**SATO Platform** will receive sensors' data and prepare it to the **SATO SAF**.
SATO APL	*Software/ systems/ applications/ devices*	***SATO APL** will allow connection and acquisition real-time data from legacy appliances with shorter life cycles for the **SATO Platform**.*
SATO BMS	*Software/ systems/ applications/ devices*	***SATO BMS** will allow connection and acquisition of real-time data from legacy appliances with long life cycles for the **SATO Platform**.*
SATO Self-Assessment Framework (SAF)	*Software/ systems/ applications/ devices*	***SATO SAF** will receive the data from the sensing devices and will perform the assessments for the building.*

3.2 References

References						
No.	***References type***	***Reference***	***Status***	***Impact on use case***	***Originator/ organization***	***Link***
1	*Internal Document*	*SATO KPI tool reference list*	*n/a*	*Provision of KPI to be included*	*AAU*	*SATO KPI tool*
2	*Internal Document*	*SATO actors reference list*	*n/a*	*Provision of actors to be included*	*EDP NEW*	*Use Case Short Description V6.xlsx*
3	*Internal Document*	*SATO Deliverable 1.4*	*n/a*	*Complete description of the diagram*		*link*

4. Step by step analysis of use case

4.1 Overview of scenarios

Scenarios conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
1	***SATO Platform** receives data from sensing devices or third-party data from external data sources*	*The **SATO Platform** receives data from sensing devices or third-party data from external data sources and appropriately normalizes and stores it*	***SATO Platform***	*Receive a data point (e.g., a measurement) from sensing devices or from the external data sources*	*The sensing device or the external data source is correctly connected to the **SATO Platform***	*The data event is normalized and stored in the refined storage for processing purposes by the **SAF**.*
2	***SATO Platform** does not receive a data point in the*	*The **SATO Platform** does not receive a data point in the expected*	***SATO Platform***	*A deadline has passed, and the **SATO Platform***	*The sensing devices is unavailable*	*The **SATO Platform** will use data quality*

	expected time frame	*time frame and needs to estimate a replacement value for that data point*		*has not received a new data point from a sensing device*	*or cannot connect to the **SATO Platform** to send the new data point*	*mechanisms to detect the missing point and will provide an estimate based in the recent history data points and the remaining data available to the platform.*

4.2 Steps – Scenarios

Scenario								
Scenario name:		***SATO Platform receives data from sensing devices***						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirements, R-IDs***
1.1a	*Sensing device produces a data point*	*Collected sensing data point*	*The **SATO Platform** receives the data point indicating that the sensing devices produced a new measurement*	*REPORT*	***Sensing device***	***SATO Platform***	*IE1*	*R-CONFIG-1, R-CONFIG-2, R-DATA-2, R-DATA-3*
1.1b	*Data coming from 3rd party services*	*Collected 3rd party data*	*The **SATO Platform** fetches third-party data from external data sources*	*GET*	***Third-party services***	***SATO Platform***	*IE1*	*R-CONFIG-1, R-CONFIG-2, R-DATA-2, R-DATA-3*
1.2	*Original data point is stored*	*Store original event in transient storage*	*The **SATO Platform** stores the original received event into the transient storage as soon as possible*	*EXECUTE*	***SATO Platform***	***SATO Platform***	*IE1*	*R-CONFIG-1, R-CONFIG-2, R-DATA-2, R-DATA-3*
1.3	*Original data point is converted into CDM*	*Standardizing the events*	*The **SATO Platform** converts the original event into a standardized data model that is used across the whole platform*	*EXECUTE*	***SATO Platform***	***SATO Platform***	*IE1, IE2*	*R-CONFIG-1, R-CONFIG-2, R-DATA-2, R-DATA-3*
1.4	*Standardized event is stored*	*Store the standardized event into the refined storage*	*The **SATO Platform** stores the standardized event into the refined storage and make it available for the subsequent processing steps.*	*EXECUTE*	***SATO Platform***	***SATO Platform***	*IE2*	*R-CONFIG-1, R-CONFIG-2, R-DATA-2, R-DATA-3*

Scenario								
Scenario name:		***SATO Platform does not receive a data point in the expected time frame***						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirements, R-IDs***
2.1	*Detection of a missing data point*	*Missing data point*	*The **SATO Platform** detect if it has not received an event before a deadline was met and warns a data quality component to provide an estimated value*	*REPORT*	***SATO Platform***	***SATO Platform***	*IE3*	*R-CONFIG-2, R-DATA-1*
2.2	*Estimation of a data point*	*Data point estimation*	*The Data quality component (internal to the **SATO Platform**) estimates a data point based on historical data and current context.*	*EXECUTE*	***SATO Platform***	***SATO Platform***	*IE4*	*R-CONFIG-1, R-CONFIG-2*

2.3	*Store the estimated data point*	*Store data point*	*The **SATO Platform** receives the estimated data point and stores it (standardized) into the refined storage*	*EXECUTE*	*SATO Platform*	***SATO Platform***	*IE4*	*R-CONFIG-1, R-CONFIG-2*

(*) Available options are:

- *CREATE means that an information object is to be created at the Producer.*
- *GET (this is the default value if none is populated) means that the Receiver requests information from the Producer (default).*
- *CHANGE means that information is to be updated. Producer updates the Receiver's information.*
- *DELETE means that information is to be deleted. Producer deletes information from the Receiver.*
- *CANCEL, CLOSE imply actions related to processes, such as the closure of a work order or the cancellation of a control request.*
- *EXECUTE is used when a complex transaction is being conveyed using a service, which potentially contains more than one verb.*
- *REPORT is used to represent transferal of unsolicited information or asynchronous information flows. Producer provides information to the Receiver.*
- *TIMER is used to represent a waiting period. When using the TIMER service, the Information Producer and Information Receiver fields shall refer to the same actor.*
- *REPEAT is used to indicate that a series of steps is repeated until a condition or trigger event. The condition is specified as the text in the "Event" column for this row or step. Following the word REPEAT, shall appear, in parenthesis, the first and last step numbers of the series to be repeated in the following form REPEAT(X-Y) where X is the first step and Y is the last step.*

5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE1	*Original data point*	*The original data point coming from the sensing devices or third-party data source*	*R-CONFIG-1, R-CONFIG-2, R-DATA-2, R-DATA-3*
IE2	*Standardized event*	*The standardized event converted using the CDM*	*R-CONFIG-1, R-CONFIG-2, R-DATA-2, R-DATA-3*
IE3	*The detection of a missing data point*	*An event created for informing the data quality component that there is a missing value and that it needs to estimate one data point*	*R-CONFIG-2, R-DATA-1*
IE4	*The estimated data point*	*The data point estimated by the data quality component*	*R-CONFIG-1, R-CONFIG-2*

6 Requirements

Requirements		
Categories ID	***Category name for requirements***	***Category description***
R-DATA	Data Management	Covers both the management of the data exchanges in each Use Case step and the management of data at either end if that management is impacted by data exchanges. An example of the first type of data management is the initial setting up and on- going maintenance of what data needs to be exchanged, say between a Geographic Information System and the many different applications that use its data. An example of the second type of data management is the need to backup data or ensure consistency of data whenever it is exchanged, such as if new protection settings are issued to multiple field devices, these settings need to be reflected in Contingency Analysis functions. It should not address database design but should concentrate on the user requirements for the interfaces to databases and other data handling applications.
R-QoS	Quality of Service (QoS)	Address availability of the system, such as acceptable downtime, recovery, backup, rollback, etc. QoS issues also address accuracy and precision of data, the frequency of data exchanges, and the necessary flexibility for future changes.
R-SEC	Security	Assess how different security measures applied to different items can potentially interact and either leave security holes or make user interfaces very laborious and possibly unworkable. Security must not only protect against the very harmful but quite rare deliberate attacks, but also against the far more likely inadvertent mistakes, failures, and errors. At the same time, it is necessary to try to identify the requirements and the concerns for implementing security measures.
R-CONFIG	Configuration	Reflect the typical, probable, or envisioned communication configurations that are relevant to the use case step. These configuration issues include numbers of devices and/or systems, expected growth of the system over time, locations, distances, communication types, network bandwidth, existing protocols, etc., but only from the user's point of view. In some cases, only one of the possible choices is reasonable, while for other situations, more than one choice is reasonable.
Requirement R-ID	***Requirement name***	***Requirement description***
R-CONFIG-1	Commonly used data model	Heterogeneous data coming from sensors in the buildings will be standardized to a common data model
R-CONFIG-2	Communication access services requirements	Periodic data transfer/update according to the QoS requirements or request response
R-DATA-1	Alarms and notifications	Rank and store several types of alarms and notifications pertaining the status of different actions related with the HEMS operation.
R-DATA-2	Data access	Provide access to data.
R-DATA-3	Data format requirements	Any formats are acceptable

7 Common Terms and Definitions

Common Terms and Definitions	
Term	*Definition*
CDM	Common Data Model
EPREL	European Product Database for Energy Labelling

HLUC02 – Data-driven self-assessment diagnosis of building performance

1. Description of the use case

1.1 Name of the use case

ID	*Area*	*Name of Use Case*
HLUC02	(2) Self-assessment	Data-driven self-assessment diagnosis of building performance

1.2 Version management

Version No.	*Date*	*Name of Author (s)*	*Changes*
1.0	*09.05.21*	*Frederico Melo, Marta Panão*	*First version*
1.1	*25.05.21*	*Alexandra Mostovoy*	*Revision of HLUC02.v1*
2.0	*22.06.21*	*Frederico Melo*	*Second version of HLUC02*
3.0	*24.06.21*	*João Dias, Filipe Silva*	*Third version of HLUC02*

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	HLUC02 is a High-Level Use Case (HLUC) planned for designing a framework that connects **SATO Platform,** through **SATO BMS** and **SATO APL,** with building equipment & building components (EBC) to receive real-time data of building performance and indoor conditions enabling **SATO Self-Assessment Framework (SAF)**. From the collected data analysis, this HLUC will also perform the calculation of the building Key Performance Indicators (KPI), and so, assist the **SATO Self-Optimization Services**. This HLUC will provide the **SATO Platform, SATO APP** and users (**building occupants, facility/building managers, aggregators**, etc.) with data-driven assessments on the EBC performance and smartness. These insights are intended to not only raise awareness and nudge users towards energy efficient behaviour but also perform the **SATO SAF** and enable SATO self-optimization actions for increased energy efficiency. This HLUC does not require direct intervention from human actors, but it is related to several SATO software/hardware functionalities such as the **SATO Self-Assessment Framework**, the **SATO Self-Optimization Services**, **SATO BMS, SATO APL** and **SATO APP**. Five Primary Use Cases (PUCs) will be derived from this HLUC: PUC2.1 named “Energy performance self-assessment”; PUC2.2 named “Indoor conditions self-assessment”; PUC2.3 named “Occupant’s behaviour self-assessment”; PUC2.4 named “EBC smartness levels self-assessment”; and PUC2.5 named “KPI’s first phase calculation”. PUC2.1 enables the real-time acquisition of building energy data from building EBC through **SATO APL** and **SATO BMS** that assess legacy appliances with short and long-life cycles, respectively, and other building components. PUC2.2 relates to data acquisition of indoor environmental conditions (e.g., air temperature, carbon dioxide concentration, illuminance) employing non-intrusive IoT monitoring and

	actuation devices, and enabling improvements on building performance and occupants' comfort. PUC2.3 relates to data acquisition of the building occupants' behaviour, such as indoor occupation levels and presence through monitoring systems connected to the **SATO Platform** as well as user preferences through user feedback from the **SATO APL**. Like PUC2.4 performs real-time data acquisition on the smartness levels of the building EBC, supporting the calculation of SRI domains and whole building SRI. PUC2.5 integrates and analyses the data acquired in PUC2.1 to PUC2.4 to calculate the building KPIs.
Objective(s)	The objectives of this HLUC are related to the data-driven self-assessment framework and calculation of the building key performance indicators (KPI). The following objectives were defined: 1. Analysis and real-time acquisition of data collected through **SATO APL** and **BMS** supporting **SATO Self-Assessment Framework**. 2. Real-time building performance and indoor conditions self-assessment. 3. Calculation of building KPI's. 3. Defining input parameters for energy efficiency optimization.

1.4 Narrative of use case

1.4.1 Narrative of High-Level use case

Narrative of Use Case
Short description
The **SATO Self-Assessment Framework** connects with the **SATO Platform** through **SATO APL** and **SATO BMS** to buildings EBC and receives real-time building performance and indoor conditions data. This data is then analysed and enables the calculation of KPIs that are used by **SATO Self-Optimization Services** for optimal management.
Complete description
The HLUC02 - Data-driven self-assessment diagnosis of building performance - concerns not only the acquisition of energy and environmental data, but also the levels of comfort and SRI functionality, through **SATO APL** and **BMS** to **SATO Self-Assessment Framework.** This HLUC will provide automated real-time performance and smartness assessments, displaying information on EBC performance, considering the impact categories related to energy efficiency, energy flexibility, comfort, health, and wellbeing. Compatible with SRI, whilst adding the ability to move from a theoretical to a real and dynamic building performance assessment. In this sense, **SATO Platform, SATO APP** and so users (**building occupants**, **facility/building managers**, **aggregators**, etc.) will be provided with data-driven assessments on the EBC performance and smartness. These insights are intended to not only raise awareness and nudge users towards energy efficient behaviour, but also perform the **SATO SAF** and enable SATO self-optimization actions for increased energy efficiency. HLUC02 is a High-Level Use Case (HLUC) planned to design a framework that connects the data collected in HLUC01 (historical and real-time data of building performance and indoor conditions) by the **SATO Platform** and will perform an analysis of this data. From the collected data analysis, this HLUC will also perform the calculation of the key performance indicators (KPI), therefore enabling the **SATO Self-Optimization Services** actions. This HLUC indirectly involves the human actors (**Facility/building manager and Building occupants**) through the identification of their preferences through the **SATO APP** (using the results of HLUC07)**,** and directly involve several SATO software/hardware functionalities such as the **SATO Self-Assessment Framework**, the **SATO Self-Optimization Services**, **SATO BMS**, **SATO APL** and **SATO APP**. The following three steps map the necessary actions to implement this HLUC: 1. Receive real-time EBC and indoor conditions data. Through non-intrusive IoT monitoring and actuation devices, this HLUC will assess EBC performance, indoor conditions and occupants' behaviour. In this step they will fetch data from the **SATO Platform**, **SATO APL** and **SATO BMS** (HULC01 is responsible for connecting these monitoring and actuator devices with the **SATO Platform**). Further, data from external sources that was fetched in HLUC01, such as weather data, will also be collected to be analysed by **SATO SAF**. 2. Analyse data collected.

The **SATO Self-Assessment Framework (SAF**) embedded into **SATO Platform** will be responsible for analysis of all real-time data collected in cloud storage. 3. Perform calculation of KPIs. Finally, the KPIs calculation will be performed for supporting the **SATO APP**, **SATO Compare** and **SATO Self-Optimization Services**.

1.4.2 Narrative of primary use cases

ID	*Name*	*Description*
PUC2.1	Energy performance self-assessment	Enables real-time data analysis of building energy data from building EPCs through **SATO Platform**, which will communicate all data gather in HLUC01.
PUC2.2	Indoor conditions self-assessment	Relates to data analysis of indoor environmental conditions (e.g. air temperature, carbon dioxide concentration, illuminance), employing non-intrusive IoT monitoring and actuation devices (data gather in HLUC01 by **SATO Platform**). This solves one of the main problems of enhancing buildings' indoor conditions and energy efficiency: the physical and financial limits faced when installing monitoring, automation, and control systems. The proposed plug & play devices will interact with existing devices and feed data into the platform.
PUC2.3	Occupants' behaviour self-assessment	Performs the building occupants' behaviour self-assessment, like PUC2.2, through non-intrusive IoT monitoring and actuation devices. This PUC produces a user-behaviour analysis focusing on user actions and their relation to the building indoor environment and energy flows, to automatically extract user preferences and operational parameters that will provide automated and transparent operation of energy services, thus enabling minimal input and interaction from users. Additionally, this PUC performs the direct self-assessment of feedback from users (e.g. through **SATO APP** in HLUC07) on their perception and reasons for interference with building and systems.
PUC2.4	EBC smartness levels self-assessment	Performs real-time data analysis on the smartness levels of the building EBC, supporting the calculation of SRI domains and the whole building. Moreover, this PUC will provide more information to the **users**/**occupants**/**facility managers** to improve the performance of their building and its energy flexibility.
PUC2.5	KPI's first phase calculation	Integrate and analyse data acquired in PUC2.1 to PUC2.4 to calculate the building KPI's, and so introducing this data into **SATO Platform** and **SATO SAF**, for supporting artificial intelligence (AI) optimization for improved building energy performance and flexibility management.

1.5 Key performance indicators (KPI)

This section includes the list of KPI's present in the SATO KPI tool to prevent their inclusion and facilitate the implementation of this HLUC. Also, during the implementation of HLUC02, some KPI's related to user presence (building use time), user load and user actions (overriding of set point, activation of solar shading, windows, etc.) may be included.

Name	*Description*	*Reference to mentioned use case objectives*
Total annual specific energy use	Measures the amount of specific energy (e.g. electricity, natural gas, district heating, district cooling, domestic hot water) during a year. Depending on the installed HVAC systems, it can also be divided for different end uses, such as space heating and cooling. Can also be referred to specific electric domestic appliances, to the lighting system and to domestic hot water production.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI and so contributing to **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy performance.
Specific energy use over a period	Measures the amount of specific energy (e.g. electricity, natural gas, district heating, district cooling, domestic hot water) in a certain period (i.e. daily, monthly, yearly).	Like the previous KPI, this KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI and so contributing to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy performance.
Deepest winter energy use (electricity)	Measures the deepest winter electricity use.	Like the previous KPI, this KPI directly links to the third objective of this HLUC. Enabling the

		calculation of this KPI and so contributing to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy performance.
Deepest winter energy use (thermal)	Measures the deepest winter energy use for thermal use.	Like the previous KPI, this KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI and so contributing to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy performance.
Peak power for specific period	Peak electricity use in a certain period (e.g. daily, monthly, yearly).	Like the previous KPI, this KPI directly link to the third objective of this HLUC. Enabling the calculation of this KPI and so contributing to **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed **SATO Self-Optimization Service** and improve energy performance.
Energy signature curve	Represents an instrument for analysis and prediction of energy use in the buildings. Energy signature curve estimates energy use as a function of outdoor temperature and may include other parameters.	Like the previous KPI, this KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI and so contributing to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy performance.
Heating signature curve	The heating signature curve estimates energy use as a function of outdoor temperature and may include other parameters.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on heating EBC, feed the **SATO Self-Optimization Service** and improve energy performance in the heating domain.
Cooling signature curve	The cooling signature curve estimates energy use as a function of outdoor temperature and may include other parameters.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on cooling EBC, feed the **SATO Self-Optimization Service** and improve energy performance in the cooling domain.
Heating coefficient	The amount of district heating. In the case of space heating, it can be also normalized to heating degree hours (HDH) in order to consider the variation of climate conditions.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on heating EBC, feed the **SATO Self-Optimization Service** and improve energy performance in the heating domain.
Cooling coefficient	The amount of district cooling. Can be also normalized to cooling degree hours (CDH) in order to consider the variation of climate conditions.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on cooling EBC, feed the **SATO Self-Optimization Service** and improve energy performance in the cooling domain.
Primary delivered energy	Represents the overall annual building energy consumption. It is necessary to use the primary energy conversion factors to transform the energy related to the different carriers into primary energy.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy performance.
Renewable Energy Ratio	Share of primary renewable energy from the total primary energy.	This KPI directly links to all objectives of this HLUC.

Annual produced energy system	Describes the annual energy production of the building renewable systems installed in the building.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy performance.
Produced energy system	Measures the amount of specific energy produced in a certain period (i.e. daily, monthly, season).	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy performance.
Specific energy produced by system	Describe the annual energy production of each renewable systems installed in the building.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy performance.
Specific Fan Power	The combined amount of electric power consumed by all the fans in the air distribution system divided by the total airflow rate through the building under design load conditions described in EN 13779.	This KPI directly link to the third objective of this HLUC. Enabling the calculation of this KPI and so contributing to **SATO SAF**. By the end of the project the target is to produce a proper analysis on ventilation EBC, feed **SATO Self-Optimization Service** and improve energy performance on ventilation domain.
Specific Pump Power	Measures the specific pump power (e.g. electricity, natural gas, district heating, district cooling, domestic hot water) in a certain period (i.e. daily, monthly, yearly).	This KPI directly link to the third objective of this HLUC. Enabling the calculation of this KPI and so contributing to **SATO SAF**. By the end of the project the target is to produce a proper analysis on cooling EBC, feed **SATO Self-Optimization Service** and improve energy performance on cooling domain.
Coefficient of performance (COP)	COP is defined as the relationship between the power (kW) that is drawn out of the heat pump as cooling or heat, and the power (kW) that is supplied to the compressor.	This KPI directly link to the third objective of this HLUC. Enabling the calculation of this KPI and so contributing to **SATO SAF**. By the end of the project the target is to produce a proper analysis on heating/cooling EBC, feed **SATO Self-Optimization Service** and improve energy performance.
Seasonal Coefficient of Performance (SCOP)	SCOP is defined as the ratio between the reference annual heating demand and annual electricity consumption. For heat pumps it is called HSPF or heating seasonal performance factor.	This KPI directly link to the third objective of this HLUC. Enabling the calculation of this KPI and so contributing to **SATO SAF**. By the end of the project the target is to produce a proper analysis on heating/cooling EBC, feed **SATO Self-Optimization Service** and improve energy performance.
Seasonal Energy Efficiency Ratio	SEER is defined as the ratio between the reference annual cooling demand and annual electricity consumption considering the varied outdoor air temperature. Similarly, may be calculated the SCOP index - Seasonal coefficient of performance (heating).	This KPI directly link to the third objective of this HLUC. Enabling the calculation of this KPI and so contributing to **SATO SAF**. By the end of the project the target is to produce a proper analysis on heating/cooling EBC, feed **SATO Self-Optimization Service** and improve energy performance.
Cooling/heating recovery rate	n/d	This KPI directly link to the third objective of this HLUC. Enabling the calculation of this KPI and so contributing to **SATO SAF**. By the end of the project the target is to produce a proper analysis on heating/cooling EBC, feed **SATO Self-Optimization Service** and improve energy performance.

Ventilation Effectiveness	Ventilation effectiveness is the common notion for the indices used to characterize the ability of a ventilation system to exchange the air in the room and the ability of a ventilation system to remove airborne contaminants.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on ventilation EBC, feed the **SATO Self-Optimization Service** and improve energy performance in the ventilation domain.
Utilization factor (Self-consumption)	Represents the percentage of the on-site generation that is used by the building.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy performance.
Load cover factor (Self-sufficiency)	Represents the percentage of the electrical demand covered by on-site electricity generation.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy performance.
Flexibility Index	Represents the change of heating use during medium and high price periods when the energy is accumulated during low price periods compared to a reference scenario without any thermal storage strategy.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy flexibility.
Flexibility factor	Illustrates the ability to shift the energy use from high to low price periods.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy flexibility.
Energy flexibility factor	Evaluates the performance of energy flexibility for different buildings with different control strategies.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy flexibility.
Available capacity for active demand response	Represents the maximum amount of heat that can be stored in the structural storage capacity of the building, given the boundary conditions for thermal comfort, climate, occupant behaviour.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy flexibility.
Flexibility	Represents the ability to deviate from the reference electric load profile during the flexibility interval. The total power shift is integrated over the flexibility interval and expressed in units of energy.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy flexibility.
Delayed operation flexibility	Represents the time of heating/cooling operation, e.g. CHP or heat pump, can be postponed while the energy demand is met by the storage.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy flexibility.
Forced operation flexibility	Defined the heating/cooling unit operation time, e.g. CHP or heat pump, can be forced while the excess heat produced is stored for later use.	This KPI directly links to the third objective of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and improve energy flexibility.

Total emission of CO_2, equivalent	The amount of CO_2 equivalent caused by the energy consumption. A measure of how much carbon dioxide and how much the users might contribute to climate change is created. It is necessary to use national CO_2 conversion factors in order to translate the different types of energy related to carriers into emissions.	This KPI directly links to the third and fourth objectives of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and reduce CO_2 emissions.
CO_2 emissions for energy carrier	n/d	Like the previous KPI, this KPI directly links to the third and fourth objectives of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and reduce CO_2 emissions.
Specific Emission of CO_2, equivalent	The amount of CO_2 equivalent caused by the energy consumption. Can be related to the conditioned net building area	Like the previous KPI, this KPI directly links to the third and fourth objectives of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and reduce CO_2 emissions.
Specific Emission of CO_2, equivalent	The amount of CO_2equivalent caused by the energy consumption. Can be related to the conditioned net building volume	Like the previous KPI, this KPI directly links to the third and fourth objectives of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF**. By the end of the project the target is to produce a proper analysis on EBC, feed the **SATO Self-Optimization Service** and reduce CO_2 emissions.
Heating Smart Readiness Score	Corresponds to the heating domain smart readiness score.	This KPI is related to the third objective, being an indirect measure/value in the whole building's SRI calculation.
Cooling Smart Readiness Score	Corresponds to the cooling domain smart readiness score.	Like the previous KPI, this KPI is related to the third objective, being an indirect measure/value in the whole building's SRI calculation.
Domestic Hot Water Smart Readiness Score	Corresponds to the domestic hot water domain smart readiness score.	Like the previous KPI, this KPI is related to the third objective, being an indirect measure/value in the whole building's SRI calculation.
Controlled Ventilation Smart Readiness Score	Corresponds to the controlled ventilation domain smart readiness score.	Like the previous KPI, this KPI is related to the third objective, being an indirect measure/value in the whole building's SRI calculation.
Lighting Smart Readiness Score	Corresponds to the lighting domain smart readiness score.	Like the previous KPI, this KPI is related to the third objective, being an indirect measure/value in the whole building's SRI calculation.
Dynamic Building Envelope Smart Readiness Score	Corresponds to the dynamic building envelope domain smart readiness score.	Like the previous KPI, this KPI is related to the third objective, being an indirect measure/value in the whole building's SRI calculation.
Electricity Smart Readiness Score	Corresponds to the dynamic building envelope domain smart readiness score.	Like the previous KPI, this KPI is related to the third objective, being an indirect measure/value in the whole building's SRI calculation.
Electric Vehicle Charging Smart Readiness Score	Corresponds to the electric vehicle charging domain smart readiness score.	Like the previous KPI, this KPI is related to the third objective, being an indirect measure/value in the whole building's SRI calculation.
Monitoring and Control Smart Readiness Score	Corresponds to the monitoring and control domain smart readiness score.	Like the previous KPI, this KPI is related to the third objective, being an indirect measure/value in the whole building's SRI calculation.
Criteria Smart Readiness Score	Corresponds to the 7 different criteria: energy savings (ES), maintenance and fault prediction (MFP), comfort (COM), convenience (CON), health and wellbeing (HW), information to occupants (IO), energy flexibility and storage (EFS)] smart readiness score.	Like the previous KPI, this KPI is related to the third objective, being an indirect measure/value in the whole building's SRI calculation.

Smart Readiness Indicator	Corresponds to the building's smart readiness score.	This KPI is related to the third objective, being a final value in the whole building's SRI calculation.
Costs for electricity consumption	Represents the amount of money the users must pay for their bills related to electric energy consumptions (can be divided for different end uses or different domestic appliances). The users can easily understand and relate to costs.	This KPI directly links to the third and fourth objectives of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF,** and therefore contributes to reducing the energy cost.
Costs for natural gas consumption	Represents the amount of money the users must pay for their bills related to natural gas consumptions (can be divided for different end uses). The users can easily understand and relate to costs.	This KPI directly links to the third and fourth objectives of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF,** and therefore contributes to reducing the energy cost.
Costs for district heating consumption	Represents the amount of money the users must pay for their bills related to district heating consumptions (can be divided for different end uses, for example space heating, domestic hot water production, etc.) The users can easily understand and relate to costs.	This KPI directly links to the third and fourth objectives of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF,** and therefore contributes to reducing the energy cost.
Costs for district cooling consumption	Represents the amount of money the users must pay for their bills related to district cooling consumptions. The users can easily understand and relate to costs.	This KPI directly links to the third and fourth objectives of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF,** and therefore contributes to reducing the energy cost.
Costs for domestic water use	Represents the amount of money the users must pay for their bills related to domestic water use. The users can easily understand and relate to costs.	This KPI directly links to the third and fourth objectives of this HLUC. Enabling the calculation of this KPI contributes to the **SATO SAF,** and therefore contributes to reducing the energy cost.
Thermal comfort (Air temperature / operative temperature)	Represents the temperature measured in the room. It can be given as the present value or as an average value for a given time period (daily, weekly).	This KPI is related to the second objective, enabling the evaluation of occupant comfort, which supports the third and fourth objectives.
Thermal comfort categories (POR)	Based on the percentage of thermally dissatisfied persons (PPD index) thermal comfort sensations are divided into different categories (Cat. I PPD<6%; Cat. II PPD<10%; Cat III PPD<15%; Cat. IV PPD > 15%). It can value or as an average value for a given time period (daily, weekly) be given as the present.	This KPI is related to the second objective, enabling the evaluation of occupant comfort, which supports the third and fourth objectives.
Atmospheric comfort	Represents the CO_2 indoor concentration levels.	This KPI is related to the second objective, enabling the evaluation of occupant comfort, which supports the third and fourth objectives.
Atmospheric comfort	Represents the relativity humidity indoor concentration levels.	This KPI is related to the second objective, enabling the evaluation of occupant comfort, which supports the third and fourth objectives.
Atmospheric comfort (VOC)	n/d	This KPI is related to the second objective, enabling the evaluation of occupant comfort, which supports the third and fourth objectives.
Acoustic comfort (Reverberation time)	Represent the indoor acoustic comfort based on reverberation time.	This KPI is related to the second objective, enabling the evaluation of occupant comfort, which supports the third and fourth objectives.
Acoustic comfort (Noise)	Represent the indoor acoustic comfort based on noise measures.	This KPI is related to the second objective, enabling the evaluation of occupant comfort, which supports the third and fourth objectives.
Visual comfort (Illuminance)	Represent the indoor visual comfort based on Illuminance.	This KPI is related to the second objective, enabling the evaluation of occupant comfort, which supports the third and fourth objectives.
Visual comfort (Daylight autonomy)	Represent the indoor visual comfort based on daylight autonomy.	This KPI is related to the second objective, enabling the evaluation of occupant comfort, which supports the third and fourth objectives.
Thermal comfort (Draught rate)	The draught rate expresses the percentage of persons predicted to be bothered by draught.	This KPI is related to the second objective, enabling the evaluation of occupant comfort, which supports the third and fourth objectives.

1.6 Use case conditions

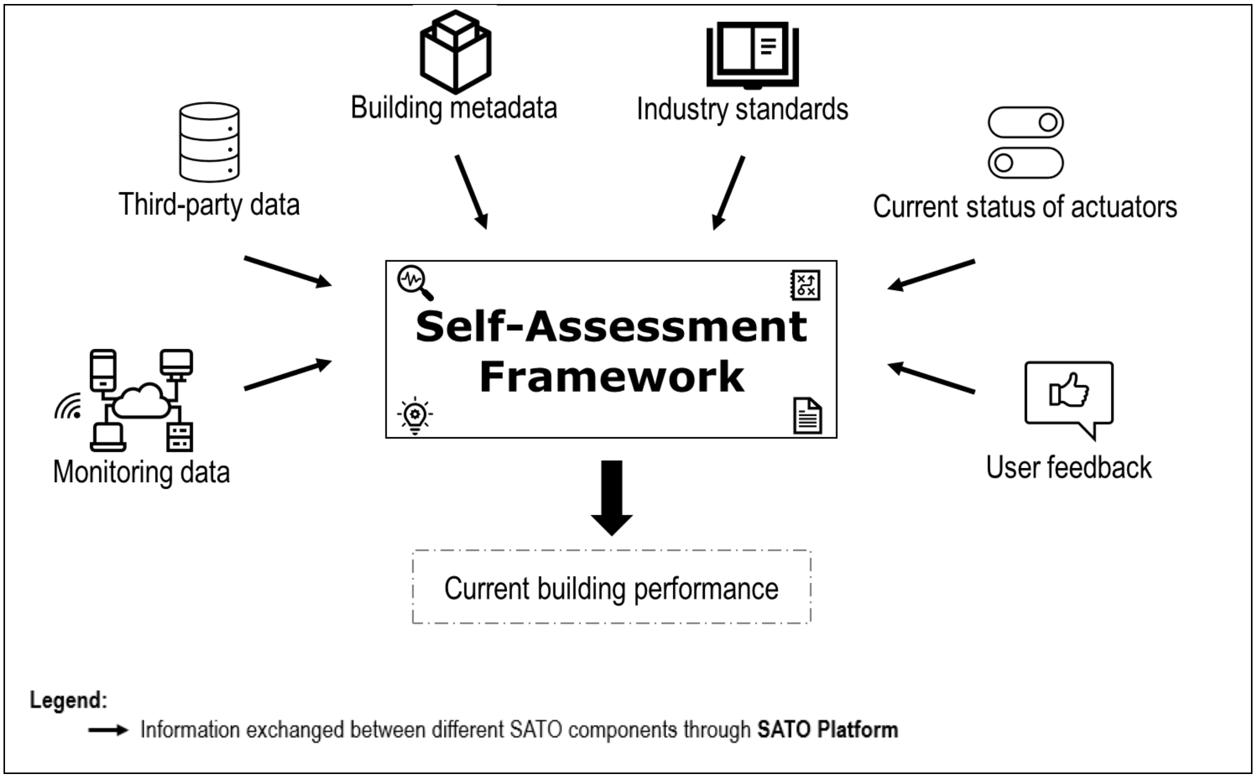
Use case conditions
Assumptions
The **SATO Platform must be in operation (**the different IoT and Wi-Fi-based interfaces) and the data must made available for **SATO SAF**. The SATO users (**Facility/building managers**, **Building owners** or **Building occupants)** must give their consent for SATO to access EBC's assess data and perform analysis.
Prerequisites
The appliance/equipment is correctly installed and connected to the **SATO Platform.** Link to HLUC01

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
HLUC01 – Securely collecting, processing and storing building data is a prerequisite for **SATO SAF, APL** and **BMS.** HLUC03 - Forecasts will need the results of the self-assessments. HLUC04 – **SATO Compare** will need the results of the self-assessments (e.g. KPIs) HLUC05 – The results of the self-assessments will be used to perform the benchmarking of appliances and equipment. HLUC06 – Visualisation of historical, real-time and forecasted energy flows and occupancy using a BIM interface. HLUC07 – Visualisation of energy flows using web or mobile interface. HLUC08 to HLUC13 – All self-optimization HLUC will use the results of the self-assessments.
Level of depth
Defines the level of depth of the use case: **HLUC02** - Data-driven self-assessment diagnosis of building performance PUC2.1 - Energy performance self-assessment PUC2.2 - Indoor conditions self-assessment PUC2.3 - Occupants' behaviour self-assessment PUC2.4 - EBC smartness levels self-assessment PUC2.5 - KPI's first phase calculation
Prioritisation
This HLUC is considered of top priority for SATO as other HLUCs depend on the self-assessments performed in this HLUCS. In this sense this HLUC should be applied in all pilots, to enable the **SATO Self-Optimization Services.**
Generic, regional or national relation
Generic Use Case
Nature of the use case
Technical/system use case.
Further keywords for classification
Self-assessment, Self-Assessment Framework, SAF, KPI, Data-driven, Performance, Analysis

2 Diagrams of use case

Diagram(s) of use cases



3. Technical details

3.1 Actors

Actors		
Actor Name	***Actor Type***	***Actor Description***
Facility/building managers	*Human actor*	*This actor has an indirect role for this HLUC. In this sense, his role is to adapt building conditions to occupants' preferences when the SATO system is not able to meet these preferences. This indirect participation enables the SATO SAF to identify and analyse data-driven future scenarios.*
Building owners	*Human actor*	*This actor has an indirect role for this HLUC. In this sense, his role is to adapt building conditions to occupants' preferences when the SATO system is not able to meet these preferences. This indirect participation enables the SATO SAF to identify and analyse data-driven future scenarios.*
Building occupants	*Human actor*	*This actor has an indirect role for this HLUC. In this sense, his role is to adapt building conditions to their preferences when the SATO system is not able to meet these preferences. This indirect participation enables the SATO SAF to identify and analyse data-driven future scenarios.*
SATO APP	*Software/ systems/ applications/ devices*	*SATO APP allows human actors (Facility/building managers, building owners, Building occupants) to input new preferences for the EBC.*
SATO APL	*Software/ systems/ applications/ devices*	*SATO APL will allow connection and acquisition real-time data from legacy appliances with shorter life cycles for the SATO platform.*
SATO BMS	*Software/ systems/ applications/ devices*	*SATO BMS will allow connection and acquisition of real-time data from legacy appliances with long life cycles for the SATO platform.*
SATO SAF	*Software/ systems/ applications/ devices*	*SATO SAF will receive and analyse data regarding EBC energy, indoor conditions, occupant behaviour and smartness performance.*

3.2 References

References						
No.	**References type**	**Reference**	**Status**	**Impact on use case**	**Originator/ organization**	**Link**
1	*Internal Document*	*SATO KPI tool reference list*	*n/a*	*Provision of KPI to be included*	*AAU*	*SATO KPI tool*
2	*Internal Document*	*SATO actors reference list*	*n/a*	*Provision of actors to be included*	*EDP NEW*	*Use Case Short Description V6.xlsx*
3	*Internal Document*	*WP3 cross task workshops April 2021 Day 1, 2 and 3*	*n/a*	*Building components definitions*	*FCID*	*n/d*

4. Step by step analysis of use case

4.1 Overview of scenarios

Scenarios conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
1.	*Implement data-driven self-assessment diagnosis of building performance.*	*The employment of non-intrusive IoT monitoring and actuation devices will monitor and send real-time data from EBC performance and indoor conditions to the **SATO Platform** to be analysed by the **SATO SAF.***	***SATO SAF.***	*The monitoring and actuators devices will assess real-time, energy performance data, indoor conditions and occupants' behaviour for the EBC performance conditions.*	***SATO SAF** must be connected with **SATO Platform**. IoT and Wi-Fi-based monitor and actuation device interfaces must be in operation.*	*The data collected is analysed, KPI are calculated, and is sent to the **SATO Platform**.*

4.2 Steps – Scenarios

Scenario								
Scenario name:		**Reference scenario**						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirements, R-IDs**
1.1	*Request data*	*Request building data*	*The SATO SAF sends a request to the **SATO Platform** to obtain the building data necessary for the self-assessments and KPI calculation.*	*GET*	*SATO Platform*	*SATO SAF*	*IE1*	*R-DATA-1; R-DATA-2; R-DATA-3; R-DATA-4; R-DATA-5; R-DATA-6; R-DATA-7; R-DATA-8; R-DATA-10; R-DATA-11; R-DATA-12; R-DATA-13; R-DATA-14; R-DATA-15; R;* R-SEC-1; R-SEC-2; R-SEC-3
1.2	*Data processing*	*Check data consistency*	*The SATO SAF evaluates the data collected and identifies possible errors/inconsistencies.*	*CHANGE*	*SATO SAF*	*SATO SAF*	*IE2*	*R-CONFIG-1; R-COMP-1; R-DATA-6*
1.3	*KPI calculation*	*Data analysis and KPI calculation*	*Processed data is analysed and KPI's are calculated.*	*REPORT*	*SATO SAF*	*SATO Platform*	*IE3*	*R-COMP-1;* R-SEC-1; R-SEC-2; R-SEC-3

(*) Available options are:

- *CREATE means that an information object is to be created at the Producer.*
- *GET (this is the default value if none is populated) means that the Receiver requests information from the Producer (default).*
- *CHANGE means that information is to be updated. Producer updates the Receiver's information.*
- *DELETE means that information is to be deleted. Producer deletes information from the Receiver.*
- *CANCEL, CLOSE imply actions related to processes, such as the closure of a work order or the cancellation of a control request.*
- *EXECUTE is used when a complex transaction is being conveyed using a service, which potentially contains more than one verb.*
- *REPORT is used to represent transferal of unsolicited information or asynchronous information flows. Producer provides information to the Receiver.*
- *TIMER is used to represent a waiting period. When using the TIMER service, the Information Producer and Information Receiver fields shall refer to the same actor.*
- *REPEAT is used to indicate that a series of steps is repeated until a condition or trigger event. The condition is specified as the text in the "Event" column for this row or step. Following the word REPEAT, shall appear, in parenthesis, the first and last step numbers of the series to be repeated in the following form REPEAT(X-Y) where X is the first step and Y is the last step.*

5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE1	*Request building data*	*Building data stored in* ***SATO Platform*** *is requested by* ***SATO SAF***	*R-DATA-1; R-DATA-2; R-DATA-3; R-DATA-4; R-DATA-5; R-DATA-6; R-DATA-7; R-DATA-8; R-DATA-10; R-DATA-11; R-DATA-12; R-DATA-13; R-DATA-14; R-DATA-15; R;* R-SEC-1; R-SEC-2; R-SEC-3
IE2	*Data processing*	*Receive data from IE1, and delivers consolidate data to IE3.*	*R-CONFIG-1; R-COMP-1; R-DATA-6*
IE3	*KPI calculation*	*The data received will be converted into building KPIs.*	*R-COMP-1;* R-SEC-1; R-SEC-2; R-SEC-3

6 Requirements

Requirements		
Categories ID	***Category name for requirements***	***Category description***
R-DATA	Data Management	Covers both the management of the data exchanges in each Use Case step and the management of data at either end if that management is impacted by data exchanges. An example of the first type of data management is the initial setting up and on- going maintenance of what data needs to be exchanged, say between a Geographic Information System and the many different applications that use its data. An example of the second type of data management is the need to backup data or ensure consistency of data whenever it is exchanged, such as if new protection settings are issued to multiple field devices, these settings need to be reflected in Contingency Analysis functions. It should not address database design but should concentrate on the user requirements for the interfaces to databases and other data handling applications.
R-SEC	Security	Assess how different security measures applied to different items can potentially interact and either leave security holes or make user interfaces very laborious and possibly unworkable. Security must not only protect against the very harmful but quite rare deliberate attacks, but also against the far more likely inadvertent mistakes, failures, and errors. At the same time, it is necessary to try to identify the requirements and the concerns for implementing security measures.
R-COMP	Compatibility	Compatibility with other functions.
R-CONFIG	Configuration	Reflect the typical, probable, or envisioned communication configurations that are relevant to the use case step. These configuration issues include numbers of devices and/or systems, expected growth of the system over time, locations, distances, communication types, network bandwidth, existing protocols, etc., but only from the user's point of view. In some cases, only one of the possible choices is reasonable, while for other situations, more than one choice is reasonable.
Requirement R-ID	***Requirement name***	***Requirement description***
R-DATA-1	*Alarms and notifications*	*Rank and store several types of alarms and notifications pertaining the status of different actions related with the SHEMS operation.*
R-DATA-2	*Consent Contract*	*Processing and storing digital consent contract where tenants allow access of energy metering data to third parties*
R-DATA-3	*Consistency of historic data*	*The measurements historic used as source data for forecasting, must not contain information gaps that surpass the specified threshold (e.g. measurements historic must not be missing a week of information and should provide a time resolution of 10 minutes).*
R-DATA-4	*Control set-points sent to SHEMS/BMS data format*	(HH:mm – HH:mm; MWh) and (HH:mm – HH:mm; MW)
R-DATA-5	*Data access*	*Provide access to data.*
R-DATA-6	*Device energy consumption data*	*Get metering data from the existing devices energy and power consumption with a sample period of 15 minutes maximum.*

R-DATA-7	*Distribution network status*	*Access to the distribution network operational status must be provided (e.g. on-off status on switching devices)*
R-DATA-8	*Existence of end-user flexibility activation technologies*	*End users providing flexibility services must have the technological capability to do so (SHEMS, smart meter, smart inverter, etc.).*
R-DATA-9	*Global consumption data*	*Get metering data from the house energy and power consumption with a sample period of 10 minutes maximum.*
R-DATA-10	*Management of large volumes of data that are being exchanged*	*Some part of step involves handling large volumes of data*
R-DATA-11	*Naming of data items*	*Matching of names is handled by a "converter" at Information Receiver*
R-DATA-12	*Real-time status*	*Store locally the current status of operation of the different devices and systems under control by the SHEMS automation system.*
R-DATA-13	*Room data*	*Get metering data from room thermometer, occupancy sensor and air quality sensor with a sample period of 10 minutes maximum*
R-DATA-14	*Smart plug consumption data*	*Get metering data from the existing smart plugs (where legacy devices are connected) energy and power consumption with a sample period of 15 minutes maximum.*
R-DATA-15	*Usage statistics*	*Store usage statistics of the SHEMS configuration and operation. This includes the number of configurations made by the users of SHEMS as well as the number of accepted or rejected optimal schedules.*
R-COMP-1	Compatibility	Compatibility with other functions.
R-SEC-1	Data privacy	Ensuring confidentiality, avoiding illegitimate use of data, and preventing unauthorized reading of data, is quite important
R-SEC-2	Authentication	Ensuring that data comes from the stated source or goes to authenticated receiver is important.
R-SEC-3	Data security	Ensuring that data cannot be stolen or deleted by an unauthorized entity is important.

7 Common Terms and Definitions

Common Terms and Definitions	
Term	***Definition***
EBC	Equipment & building components
SHEMS	Smart home energy management system
Actuator	Device with the capacity to receive and apply a control command EBC.
Monitor devices	Device with the capacity to receive and monitor a control command EBC.

HLUC03 – Forecasting of energy loads, indoor air conditions, occupancy and weather

1. Description of the use case

1.1 Name of the use case

ID	*Area*	*Name of Use Case*
HLUC03	*(2) Self-assessment*	*Forecasting of energy loads, indoor air conditions, occupancy and weather*

1.2 Version management

Version No.	*Date*	*Name of Author (s)*	*Changes*
1.0	11.05.21	Daniel P. Albuquerque	First version of HLUC03
2.0	21.05.21	Daniel P. Albuquerque	Second version of HLUC03

2.1	26.05.21	João Bravo Dias	Revision of HLUC03.v2
2.2	31.05.21	Thomas Fehr	Review
2.3	21.06.21	Andrea Sangalli	Review
3.0	29.06.21	Daniel P. Albuquerque	Third version of HLUC03
4.0	29.06.21	João Dias, Filipe Silva	Fourth version of HLUC03

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	The HLUC03 is a High-Level Use Case (HLUC) that will focus on the short-term forecasting of energy loads, indoor air conditions, and occupation density at different building levels, as well as the local weather. The **SATO Platform** will receive raw (untreated) monitored data from the building IoT enabled devices (e.g., energy meters), sensors (e.g., occupancy sensors) and external sources (e.g., real-time weather databases), and will process it to be sent to the **SATO Self-Assessment Framework (SAF)**. This HLUC3 consists of one of the assessments performed by the **SATO Self-Assessment Framework**. The SAF will be responsible for structuring the data (received from **SATO Platform**) and perform short-term forecasting of the energy loads, indoor air conditions, occupancy and local weather using statistical and machine learning technologies/tools. The forecasts made by the HLUC03 will be sent to: • **SATO BIM tool** and **SATO APP**, allowing users to visualize forecasts (e.g. energy consumption); • and to **SATO Self-Optimization Services**, which will use the outputs to perform the different self-optimization strategies.
Objective(s)	1. Forecast the energy loads, indoor air conditions, occupancy patterns and local weather 2. Useful inputs to the optimization process (**SATO Self-Optimization Services**) 3. Maximize energy efficiency and self-consumption

1.4 Narrative of use case

1.4.1 Narrative of High-Level use case

Narrative of Use Case
Short description
The **SATO Self-Assessment Framework** will receive real-time data from **SATO Platform** and, together with the historical data and metadata, will perform a short-term forecast of the energy demand, indoor air conditions, occupancy patterns of the building and local weather data. This HLUC will use statistical and machine learning technologies to perform the different forecasts and will provide relevant inputs to the **SATO Self-Optimization Services**, **SATO BIM tool** and **SATO APP**.
Complete description
Enabled by the **SATO Platform**, an extensive amount of raw data will be collected regarding energy flows, indoor air conditions, occupancy patterns, and ambient/weather conditions. In **SATO Platform**, this raw data will have a first layer of treatment, being catalogued, assessed and appended to the existing database (including metadata) through the state-of-the-art processes of data catalogue, data quality and data enhancement, respectively. Ultimately, **SATO Platform** is responsible to send this data to the **SATO Self-Assessment Framework**, which is the SATO module that will perform the forecast of the HLUC03. Before the forecasts, the **SATO Self-Assessment Framework** will perform a second layer of data treatment that consists of organize the data into a coherent structure in order to be useful for the different assessments (data structuring) – performed in HLUC02. The short-term forecasting of the energy loads, indoor air conditions (such as indoor air temperature, relative humidity, CO_2 concentration levels, etc.), occupancy and local weather (such as outdoor air temperature, relative humidity, wind speed, etc.) will be performed using the corresponding timeseries (i.e., a combination of real-time and historical data) that will feed statistical and machine learning technologies/tools (such as R, PyTorch, Scikit learn, or TensorFlow). The main objective is to predict energy loads, indoor air conditions and occupancy levels at several space scales (from a single equipment/room to a whole building) and the local weather. These predictions will

be sent to **SATO Self-Optimization Services** to effectively control smart and IoT enabled appliances and equipment, and will be also sent to **SATO BIM Model** and **SATO APP** which will present the forecast data to the users or building managers/owners using visualization tools.

Aiming to provide quality and meaningful operational forecasts to the **SATO Self-Optimization Services**, statistical and machine learning techniques (e.g., distribution estimation, clustering, neural networks) will also be implemented to continuously feed the **SATO Self-Optimization Services** data stream and to improve on such forecasts with the comparative data from the previous predictions of the energy loads, occupancy and local weather, and the actual measurements.

This HLUC03 will give to SATO the very important feature of predicting future loads, indoor air conditions and occupancy levels of buildings in conjunction with the local weather predictions. This feature may potentially strengthen all the HLUCs related with the **SATO Self-Optimization Services**, since it can improve:

- the potential energy efficient measures;
- the indoor user comfort;
- the prediction of the grid flexibility services;
- the assessment of the thermal storage capacity;
- natural ventilation potential and its control.

In resume the following steps are necessary to implement this HLUC:

1. Get real-time and historical data from **SATO Platform** to **SATO Self-Assessment Framework**.
2. Perform a second layer of data treatment that consists of organize the data into a coherent structure in order to be useful for the different assessments (data structuring) – performed by HLUC02.
3. Perform short-term forecasting of the energy loads, indoor air conditions, occupancy and local weather.
4. Store the forecasts in the **SATO Self-Assessment Framework** and in **SATO Platform** to be used by other SATO modules (e.g., **SATO Self-Optimization Services**, **SATO BIM Model** and **SATO APP**).

1.4.2 Narrative of primary use cases

ID	*Name*	*Description*
PUC3.1	Whole building scale forecasts	Forecasts of the energy loads, indoor air conditions, and occupancy for the entire building.
PUC3.2	Small scale forecasts	Forecasts down to a single-room or single-equipment scale for the indoor air conditions/occupancy or energy loads, respectively.
PUC3.3	Weather forecasts	Forecasts of local (close to building) weather.

1.5 Key performance indicators (KPI)

Name	*Description*	*Reference to mentioned use case objectives*
Total annual specific energy consumption	Amount of specific energy (e.g. electricity, natural gas, district heating, district cooling, domestic hot water) during a year. Depending on the installed HVAC systems, it can also be divided for different end uses, such as space heating and cooling. It can also be referred to specific electric domestic appliances, to the lighting system and to domestic hot water production.	1, 3
Monthly avg specific energy consumption	Monthly amount of specific energy consumption (e.g., electricity, natural gas, district heating, district cooling, domestic hot water).	1, 3
Daily avg specific energy consumption	Daily amount of specific energy (e.g., electricity, natural gas, district heating, district cooling, domestic hot water).	1, 2, 3
Utilization factor (Self-consumption of renewables)	Ratio of renewable energy consumption in the total energy consumed by the building.	1, 2, 3
Load production to grid	On-site energy generated that was sold to the grid.	1, 2, 3

Load cover factor (Self-sufficiency)	Represents the percentage of the electrical demand covered by on-site electricity generation.	2, 3
Costs for electricity consumption	Represents the amount of money the users have to pay for their bills related to electric energy consumptions (can be divided for different end uses or different domestic appliances). The users can easily understand and relate to costs.	2, 3
Cost for district heating use	Represents the amount of money the users have to pay for their bills related to district heating consumptions (can be divided for different end uses, for example space heating, domestic hot water production, ...). The users can easily understand and relate to costs.	2, 3
Cost for district cooling use	Represents the amount of money the users have to pay for their bills related to district cooling consumptions. The users can easily understand and relate to costs.	2, 3
Cost for DHW use	Represents the amount of money the users have to pay for their bills related to domestic water use. The users can easily understand and relate to costs.	2, 3
Cost for DCW use	Represents the amount of money the users have to pay for their bills related to domestic water use. The users can easily understand and relate to costs.	2, 3
Cost for gas use	Represents the amount of money the users have to pay for their bills related to natural gas consumptions (can be divided for different end uses). The users can easily understand and relate to costs.	2, 3
Cost for other energy use	Represents the amount of money the users have to pay for their bills related to other energy consumptions.	2, 3
CO_2 emissions	The amount of CO_2e caused by the energy consumption. A measure of how much carbon dioxide and how much the users might contribute to climate change is created. It is necessary to use national CO_2 conversion factors in order to translate the different types of energy related to carriers into emissions.	3
Load shift ability	Energy consuming device that can be used to offer flexibility services to the grid or to shift its load from peak hours to a period of the day with lower electricity prices (off-peak hours).	1, 2, 3

1.6 Use case conditions

Use case conditions
Assumptions
The **SATO Platform** should have access to weather station data from a location close to user/pilot or use its own weather data from the **Building Management System** if available. The **SATO Platform** should also have a real-time communication with the building to get relevant data (energy usage, indoor conditions, and occupancy). The **SATO Platform** should be able to send this data to the **SATO Self-Assessment Framework**, and the **SAF** should also send the forecasts back to the **SATO Platform**, to be used by other SATO services (e.g. **SATO Self-Optimization Services**, **SATO BIM tool** and **SATO APP**).
Prerequisites
The sensors have to be properly located and must have an active communication with the **SATO Platform**. It is linked to: HLUC01 (Collection of relevant data) HLUC02 (Data structuring)

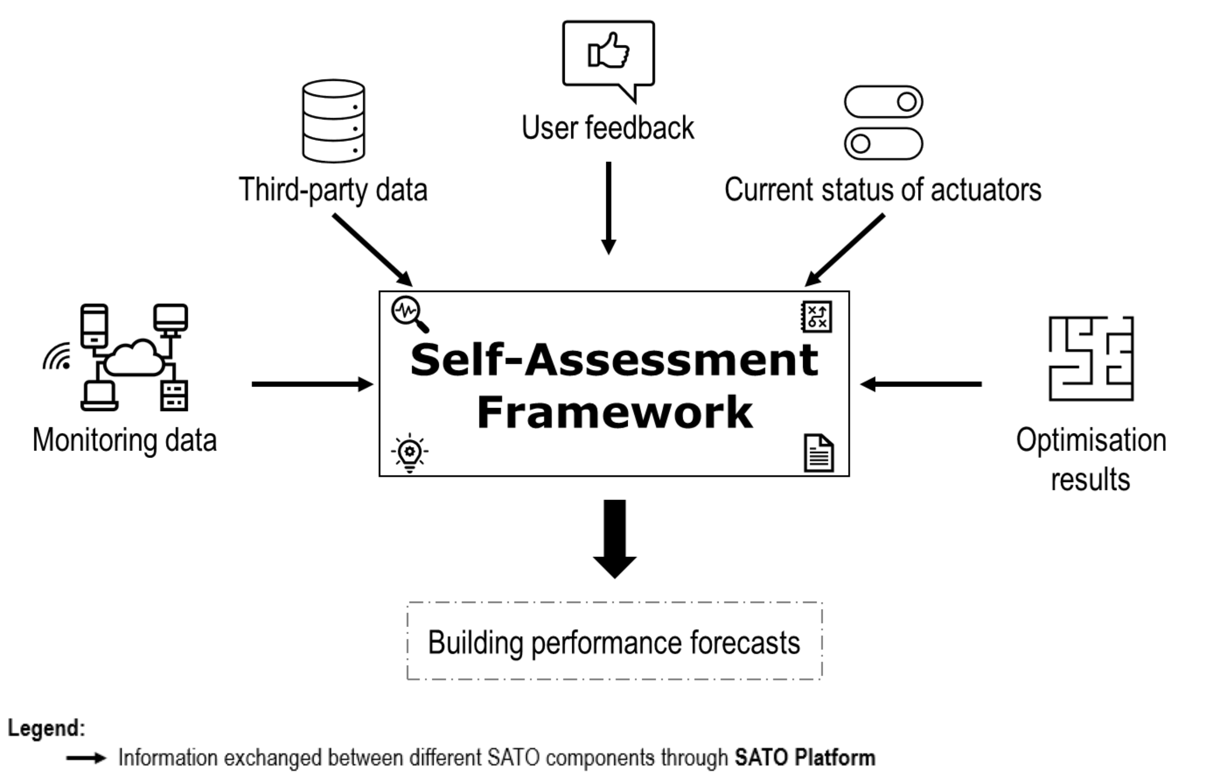
1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
HLUC01 – Monitoring of the relevant data for this HLUC03 (energy loads, indoor air conditions, occupancy levels and weather data) is essential for the precision of the forecasts. HLUC02 - Forecasts will need the results of the self-assessments. HLUC06 – Visualisation of historical, real-time and forecasted energy flows and occupancy using a BIM interface. HLUC07 – Visualisation of energy flows using web or mobile interface. HLUC08 to HLUC13 – All self-optimization HLUC will use the results of the self-assessments.
Level of depth
HLUC3 – Forecasting of energy loads, indoor air conditions, occupancy and weather

PUC3.1 – Whole building scale forecasts PUC3.2 – Small scale forecasts PUC3.3 – Weather forecasts
Prioritisation
This HLUC is considered of top priority to SATO, because the forecasting will enhance the energy efficiency and will provide good control predictions to the IoT devices in case communication with the **SATO Platform** could not be possible. Several other HLUCs will depend upon this data to achieve their objectives, namely the HLUCs from the **SATO Self-Optimization Services**, the **SATO BIM** and the **SATO APP**.
Generic, regional or national relation
Generic Use Case
Nature of the use case
Technical use case
Further keywords for classification
Self-assessment, forecasts, monitoring, energy loads, indoor air conditions, occupancy, weather

2 Diagrams of use case

Diagram(s) of use cases



3. Technical details

3.1 Actors

Actors		
Actor Name	***Actor Type***	***Actor Description***
SATO Platform	Software/ systems/ applications/ devices	**SATO Platform** will receive relevant data from building sensors and the weather data from external sources and will send it to the **SATO SAF**.
SATO APP	Software/ systems/ applications/ devices	**SATO APP** gets forecast data from the **SATO SAF** and displays it in form of KPIs or other relevant metrics. **SATO APP** will also justify some control actions given by the **SATO Self-Optimization Services** with the forecasts results.
SATO BIM	Software/ systems/ applications/ devices	**SATO BIM** gets forecast data from the **SATO SAF** and displays it in form of KPIs or other relevant metrics. **SATO BIM** will also justify some control actions given by the **SATO Self-Optimization Services** with the forecasts results.
SATO Self-Assessment Framework (SAF)	Software/ systems/ applications/ devices	**SATO SAF** will receive data regarding current sensors and controls, as well as weather data from the **SATO Platform**, which will be treated and used to produce the forecasts.
SATO Self-Optimization Services	Software/ systems/ applications/ devices	**SATO Self-Optimization Services** will receive the forecast data from the **SATO SAF** and will run cloud-based machine learning algorithms to choose the optimal control strategy based on the predictions of future energy loads, occupancy levels and local weather.

3.2 References

References						
No.	***References type***	***Reference***	***Status***	***Impact on use case***	***Originator/ organization***	***Link***
1	Internal Document	SATO D1.2	Delivered	Provision of KPI to be included	AAU	*SATO Key Performance Indicator Tool.xlsm*
2	Internal Document	SATO D1.1	Delivered	Provision of actors to be included	FC.ID	N.A.

4. Step by step analysis of use case

4.1 Overview of scenarios

Scenarios conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
1	**SATO Self-Assessment Framework** performs forecasts	**SATO Self-Assessment Framework** performs forecasts of energy loads, indoor conditions and occupancy levels at different space scales as well as of local weather	**SATO Self-Assessment Framework**	**SATO Self-Assessment Framework** will receive relevant data from the **SATO Platform** to perform the forecasts.	Relevant data available on **SATO Platform**. Machine learning algorithms to perform the forecast.	Forecast data will be sent to **SATO Self-Optimization Services**.

4.2 Steps – Scenarios

Scenario								
Scenario name:		***Reference scenario***						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirements, R-IDs***
1.1	Submission of relevant data by the **SATO Platform**	Send data to **SATO Self-Assessment Framework**.	Data collected by the **SATO Platform** of the energy loads, indoor conditions, occupancy levels and local weather is sent to **SATO self-assessment framework**.	GET	**SATO Platform**	**SATO Self-Assessment Framework**	IE1	*R-DATA-1; R-DATA-2;* R-SEC-1; R-SEC-2; R-SEC-3
1.2	Application of machine learning algorithms	Apply machine learning algorithms by the **SATO Self-Assessment Framework**	Machine learning algorithms to produce the forecasts.	EXECUTE	**SATO Self-Assessment Framework**	**SATO Self-Assessment Framework**	IE2	*R-COMP-1; R-DATA-2*
1.3	Submission of forecast data	Send forecast data	The **SATO Self-Assessment Framework** sends the forecast data to the **SATO Self-Optimization Services**.	REPORT	**SATO Self-Assessment Framework**	**SATO Self-Optimization Services**	IE3	*R-COMP-1;* R-SEC-1; R-SEC-2; R-SEC-3

(*) Available options are:

- *CREATE means that an information object is to be created at the Producer.*
- *GET (this is the default value if none is populated) means that the Receiver requests information from the Producer (default).*
- *CHANGE means that information is to be updated. Producer updates the Receiver's information.*
- *DELETE means that information is to be deleted. Producer deletes information from the Receiver.*
- *CANCEL, CLOSE imply actions related to processes, such as the closure of a work order or the cancellation of a control request.*
- *EXECUTE is used when a complex transaction is being conveyed using a service, which potentially contains more than one verb.*
- *REPORT is used to represent transferral of unsolicited information or asynchronous information flows. Producer provides information to the Receiver.*
- *TIMER is used to represent a waiting period. When using the TIMER service, the Information Producer and Information Receiver fields shall refer to the same actor.*
- *REPEAT is used to indicate that a series of steps is repeated until a condition or trigger event. The condition is specified as the text in the "Event" column for this row or step. Following the word REPEAT, shall appear, in parenthesis, the first and last step numbers of the series to be repeated in the following form REPEAT(X-Y) where X is the first step and Y is the last step*

5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE1	*Request building data*	*Building data stored in **SATO Platform** is requested by **SATO SAF***	*R-DATA-1; R-DATA-2;* R-SEC-1; R-SEC-2; R-SEC-3
IE2	*Data processing*	*Receive data is processed and forecast data is generated*	*R-COMP-1; R-DATA-2*
IE3	*Forecast data*	*Forecast data is sent to SATO SA&O*	*R-COMP-1;* R-SEC-1; R-SEC-2; R-SEC-3

6 Requirements

Requirements		
Categories ID	***Category name for requirements***	***Category description***
R-DATA	Data Management	Covers both the management of the data exchanges in each Use Case step and the management of data at either end if that management is impacted by data exchanges. An example of the first type of data management is the initial setting up and on- going maintenance of what data needs to be exchanged, say between a Geographic Information System and the many different applications that use its data. An example of the second type of data management is the need to backup data or ensure consistency of data whenever it is exchanged, such as if new protection settings are issued to multiple field devices, these settings need to be reflected in Contingency Analysis functions. It should not address database design but should concentrate on the user requirements for the interfaces to databases and other data handling applications.
R-SEC	Security	Assess how different security measures applied to different items can potentially interact and either leave security holes or make user interfaces very laborious and possibly unworkable. Security must not only protect against the very harmful but quite rare deliberate attacks, but also against the far more likely inadvertent mistakes, failures, and errors. At the same time, it is necessary to try to identify the requirements and the concerns for implementing security measures.
R-COMP	Compatibility	Compatibility with other functions.
R-CONFIG	Configuration	Reflect the typical, probable, or envisioned communication configurations that are relevant to the use case step. These configuration issues include numbers of devices and/or systems, expected growth of the system over time, locations, distances, communication types, network bandwidth, existing protocols, etc., but only from the user's point of view. In some cases, only one of the possible choices is reasonable, while for other situations, more than one choice is reasonable.
Requirement R-ID	***Requirement name***	***Requirement description***
R-DATA-1	*Consistency of historic data*	*The measurements historic used as source data for forecasting, must not contain information gaps that surpass the specified threshold (e.g. measurements historic must not be missing a week of information and should provide a time resolution of 10 minutes).*
R-DATA-2	*Data access*	*Provide access to data.*
R-COMP-1	Compatibility	Compatibility with other functions.
R-SEC-1	Data privacy	Ensuring confidentiality, avoiding illegitimate use of data, and preventing unauthorized reading of data, is quite important
R-SEC-2	Authentication	Ensuring that data comes from the stated source or goes to authenticated receiver is important.
R-SEC-3	Data security	Ensuring that data cannot be stolen or deleted by an unauthorized entity is important.

7 Common Terms and Definitions

Common Terms and Definitions	
Term	***Definition***
IoT	Internet of Things

HLUC04 – Benchmarking building performance

1. Description of the use case

1.1 Name of the use case

ID	*Area*	*Name of Use Case*
HLUC04	(2) Self-assessment	Benchmarking building performance

1.2 Version management

Version No.	*Date*	*Name of Author (s)*	*Changes*
1.0	21.05.21	Per Heiselberg	First draft
1.1	24.05.21	Filipe Neves Silva	Review of v1.0 of HLUC04
1.2	27.05.21	Daniel P. Albuquerque	Review of v1.1
2.0	24.06.21	Per Heiselberg	Second version of HLUC04
3.0	06.07.21	Filipe Silva, João Dias	Third version of HLUC04

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	HLUC04 is a High-Level Use Case (HLUC) focused on benchmarking monitored building performance in relation to different types of reference performance to enable cross comparisons and to evaluate optimization need and opportunities. Benchmarking of building performance is also very important to raise awareness among facility managers, occupants and building owners and as basis for decision-making related to maintenance, optimization and upgrade of existing systems.
Objective(s)	1. Ensure valid comparison and evaluation of building performance 2. Cross comparison of building performance 3. Create a basis for decision-making related to maintenance, optimization and upgrades 4. Increase managers/owners/users' awareness on building performance in relation to energy use, energy costs and CO_2 emissions as well as the level of indoor environmental quality 5. Increase users' awareness on the influence of their habits and actions on building performance related to both energy and indoor environmental quality

1.4 Narrative of use case

1.4.1 Narrative of High-Level use case

Narrative of Use Case
Short description
Benchmarking building performance will be performed using **SATO Compare**. The monitoring devices deployed in the building and the self-assessment performed, will give the inputs for building performance comparison of different variables and performance indicators related to e.g. energy use, energy costs, associated CO_2 emissions and indoor environmental quality. It will also allow for building performance evaluation according to different reference performance types. The benchmarking can be performed at different levels from individual building to a European level. The final objective is to provide a basis for building management decision-making and to make **building managers** and **occupants** aware of and trigger behavioural changes that will improve building overall performance (e.g. using **SATO APP**).
Complete description
HLUC04 – *Benchmarking building performance* – concerns the comparison of building performance with references, using **SATO SAF** to characterize the actual performance and **SATO Compare**, evaluating the "performance gap" between what is the expected performance

and the real performance. The assessment of the performance gap enables building owners/managers and building users through the use of **SATP APP** to deploy concrete actions that will improve the performance and reduce the performance gap.

HLUC04 will be implemented using **SATO Compare**. This feature is exclusively used in SATO to implement HLUC04, on benchmarking of performance. The importance of such feature is derived from the fact that buildings, in most situations, perform differently compared with the simulations and analysis done pre use-phase. This is what causes the "performance gap" and one of the goals of SATO is to use **SATO Compare** to identify these gaps and find the building best practices and optimal management.

Benchmarking will be performed for the integrated performance of equipment and building components, for the whole building and for the building control system. In HLUC04 the focus is on the whole building (PUC4.1), the building control (PUC4.2) and user practices (PUC4.3).

Benchmarking will be performed in relation to different reference assessment types, see table below. For type "Reference" monitored performance (using **SATO SAF**) is compared to **performance as expected during standard operating conditions** (conditions as defined in standards and regulations and typically used in simulations and analysis in the design phase). For type "Actual" monitored performance is compared to **performance as expected under actual dynamic operating conditions** and for type "Contextual" monitored performance is compared to **performance as expected in meeting services objectives,** e.g. provided indoor environmental quality level.

Performance Assessment Types Equipment and Building Components	SATO SAF	Reference	Actual	Contextual
Appliances	Yes	Yes	Yes	Yes
Equipment	Yes	Yes/No	Yes	No
Building Systems	Yes	Yes/No	Yes	Yes
Building Fabric/Envelopes	Yes	Yes/No	Yes	Yes
Building Control System	Yes	Yes/No	Yes	Yes
Whole building	Yes	YES/No	Yes	Yes
Occupant interaction	Yes	No	Yes	Yes

1.4.2 Narrative of primary use cases

ID	*Name*	*Description*
PUC4.1	Benchmarking whole building performance	This primary use case focus on benchmarking of the integrated performance of equipment and building components as well as benchmarking performance in relation to meeting the services objectives, including the smart readiness indicator (SRI) The purpose it to evaluate if the integrated performance of installed equipment and building components perform as expected under dynamic operating conditions and how well the building/system perform in meeting services objectives, e.g. provided indoor environmental quality level, self-consumption of renewables or energy use. The dynamic integrated performance (weekly, seasonal, yearly) is based on actual operating conditions including dynamic weather conditions, dynamic loads and the dynamic interaction of different equipment and building components in meeting services objectives.
PUC4.2	Benchmarking building	This primary use case focus on benchmarking of the performance of the building control system as well as benchmarking performance in relation to meeting the services objectives.

	control system	The purpose is to evaluate the ability of the building control system to respond to the dynamic operating conditions including dynamic weather conditions and dynamic loads and to control the dynamic interaction of different equipment and building components in meeting services objectives.
PUC4.3	Benchmarking user practices	This primary use case focus on benchmarking the interaction of users with the control system and how user practices and behaviour influence building performance and the building's ability to meet services objectives. The purpose is to evaluate to what extent users interact with equipment and building components and with building control systems and how this interaction influences building performance. The purpose is also to evaluate the impact of user practices on building performance and the ability of equipment and building components to respond to these practices while meeting services objectives and user expectations.

1.5 Key performance indicators (KPI)

Name	*Description*	*Reference to mentioned use case objectives*
User engagement	Number of clicks, time of usage, interactions with the SATO APP, etc.	3 - 5
Utilization factor	Monitored building use compared to design expectations	1 - 5
Relative occupant load	Monitored occupant load profile compared to design expectations	1 - 5
Activation of solar shading and window opening	For automatic systems the monitored activation by control system and user override. For manual systems monitored user activation	1 - 5
Adjustment of setpoint for heating/cooling/ventilation	For automatic systems the monitored adjustment of setpoint by control system and user override. For manual systems monitored user adjustment	1 - 5
Adjustment of lighting level	For automatic systems the monitored adjustment by control system and user override. For manual systems monitored user adjustment	1 - 5
Total annual specific energy use for heating, hot water, electricity	Includes individual energy use for separate systems as well as for the whole building compared to potential optimum	1 – 3
Monthly avg specific energy use for heating, hot water, electricity	Includes individual energy use for separate systems as well as for the whole building compared to potential optimum	1 - 3
Running weekly avg specific energy use for heating, hot water, electricity	Includes individual energy use for separate systems as well as for the whole building compared to potential optimum	1 - 3
User Indoor Environmental quality evolution - Thermal environment - Indoor air quality - Lighting level	Monitored IEQ level in individual rooms and on building level compared expected service level	1 - 5
User energy performance evolution:	Includes individual energy use for separate systems as well as for the whole building in relation to changed in user load, practices and behaviour	1 - 5
Self-consumption of renewables	Ability to use produced renewable energy in the building	1 - 3
Annual produced renewable energy -	Renewable energy production compared to expectations under the actual climate conditions	1 - 3
Monthly produced renewable energy	Renewable energy production compared to expectations under the actual climate conditions	1 - 3

1.6 Use case conditions

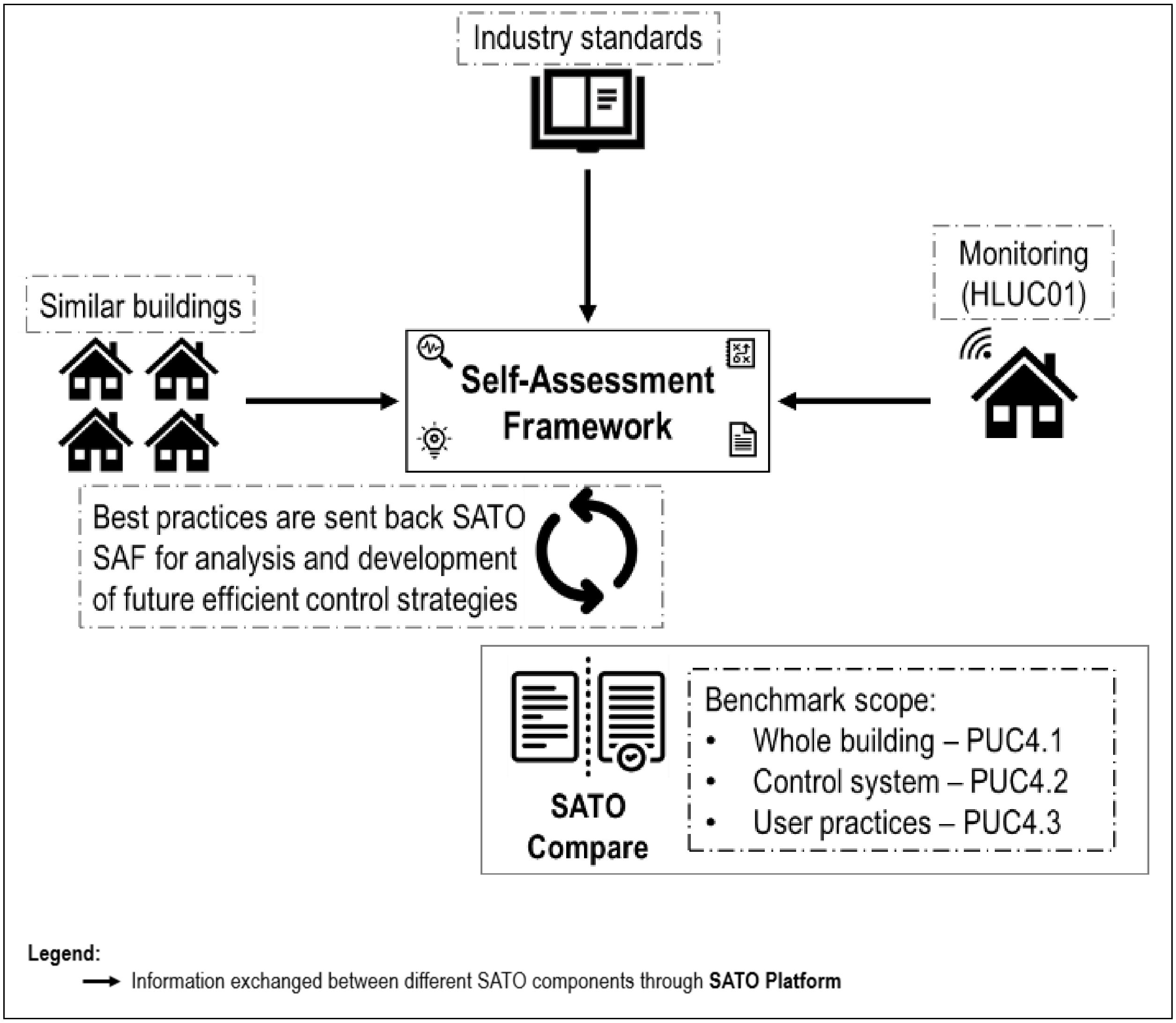
Use case conditions
Assumptions
The **SATO Platform**, **SATO Self-Assessment Framework** and different IoT and Wi-Fi-based interfaces must be in operation. The **Facility/building managers**, **Building owners** and/or **Building occupants** have given their consent for SATO to perform cloud managing of legacy and smart appliances and equipment (GDPR compliant).
Prerequisites
The building and all systems have completed a commissioning process and have been released for normal operation. Link is established to HLUC01 (Data collection) and HLUC02 (SATO Self-Assessment Framework).

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
HLUC01 – Data collection is a prerequisite for the benchmarking and performance evaluation. HLUC02 – Self-assessment is a prerequisite for benchmarking and performance evaluation. HLUC06 and HLUC07 – Dissemination of the outcome of benchmarking and performance evaluation through visualization and feedback is required to improve awareness and facilitate behavioural changes.
Level of depth
HLUC04 – Benchmarking building performance PUC4.1 - Benchmarking whole building performance PUC4.2 - Benchmarking building control system PUC4.3 - Benchmarking user practices
Prioritisation
This HLUC is a key part of the SATO objectives and will be implemented in all demo cases – High priority
Generic, regional or national relation
Generic Use Case
Nature of the use case
Technical/system Use Case
Further keywords for classification
Benchmarking, reference performance types, energy performance, indoor environmental quality, CO_2 emission, decision-making, feedback and awareness

2 Diagrams of use case

Diagram(s) of use cases



3. Technical details

3.1 Actors

Actors		
Actor Name	***Actor Type***	***Actor Description***
Facility/building managers	Human actor	This actor has a direct role in this HLUC. His role is to make management decisions based on the benchmarking outcome.
Building occupants	Human actor	This actor has a direct role in this HLUC. Their role is to consider behavioural changes and adapt the building conditions to their preferences. This indirect participation enables the system to react better to future scenarios.
Building owners	Human actor	This actor has a direct role in this HLUC. His role is to make management decisions based on the benchmarking outcome.

SATO APP	Software/ systems/ applications/ devices	SATO APP will allow to send feedback and recommendations to facility manager occupants and owners.
SATO Self-Assessment Framework (SAF)	Software/ systems/ applications/ devices	SATO SAF will receive data regarding current performance, which can be analysed and used to benchmark and evaluate performance
SATO Self-Optimization Services	Software/ systems/ applications/ devices	SATO Self-Optimization Services will receive information about benchmarking and performance evaluation which will enable targeting of services.

3.2 References

References						
No.	***References type***	***Reference***	***Status***	***Impact on use case***	***Originator/ organization***	***Link***
1	Internal Document	SATO KPI tool reference list	n/a	Provision of KPIs	AAU	KPI tool
2	Internal Document	SATO Use Case list	n/a	Provision of actors	EDP NEW	*Use Case Short Description V6.xlsx*
3	Internal Document	SATO Reference Assessment Types	n/a	Provision of definition of reference performance definition and approach	AAU (WP3)	
4	National regulations and international standards	Reference to relevant national regulations and international standards	n/a			

4. Step by step analysis of use case

4.1 Overview of scenarios

Scenarios conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
1	Benchmarking	Benchmark self-assessment performance to different reference performance assessment types	SATO Compare	Carried out continuously	Building in normal operation	Building in improved operation

4.2 Steps – Scenarios

Scenario								
Scenario name:		***Reference scenario***						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirements, R-IDs***
1	Information to perform benchmark	Information request	Collect information about monitored performance and the self-assessment analysis	GET	SATO Platform	SATO Compare	IE1	R-SEC-1; R-SEC-2; R-SEC-3; R-QoS-1; R-QoS-2
2	Perform the benchmark	Benchmark	Benchmark self-assessment performance to different reference performance assessment types	CREATE	SATO Compare	SATO Compare	-	
3	Comparison based evaluation	Evaluation	Evaluate performance based on benchmarking outcome	CREATE	SATO Compare	SATO Compare	-	
4	Provide feedback on benchmark	Feedback and Awareness	Provide feedback and recommendations for behavioural changes and/or management decisions to **SATO Platform** to be sent to the users of **SATO APP**	REPORT	SATO Compare	SATO Platform	IE2	R-SEC-1; R-SEC-2; R-SEC-3; R-QoS-1; R-QoS-2

(*) Available options are:

- *CREATE means that an information object is to be created at the Producer.*
- *GET (this is the default value if none is populated) means that the Receiver requests information from the Producer (default).*
- *CHANGE means that information is to be updated. Producer updates the Receiver's information.*
- *DELETE means that information is to be deleted. Producer deletes information from the Receiver.*
- *CANCEL, CLOSE imply actions related to processes, such as the closure of a work order or the cancellation of a control request.*
- *EXECUTE is used when a complex transaction is being conveyed using a service, which potentially contains more than one verb.*
- *REPORT is used to represent transferral of unsolicited information or asynchronous information flows. Producer provides information to the Receiver.*
- *TIMER is used to represent a waiting period. When using the TIMER service, the Information Producer and Information Receiver fields shall refer to the same actor.*
- *REPEAT is used to indicate that a series of steps is repeated until a condition or trigger event. The condition is specified as the text in the "Event" column for this row or step. Following the word REPEAT, shall appear, in parenthesis, the first and last step numbers of the series to be repeated in the following form REPEAT(X-Y) where X is the first step and Y is the last step.*

5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE1	*Refined building data*	*SATO Compare will receive data from the SATO Platform that was previously refined for analysis*	R-SEC-1; R-SEC-2; R-SEC-3; R-QoS-1; R-QoS-2
IE2	*Feedback information*	*SATO Compare will provide feedback on best practices to improve efficiency that are identified through benchmarking*	R-SEC-1; R-SEC-2; R-SEC-3; R-QoS-1; R-QoS-2

6 Requirements

Requirements		
Categories ID	***Category name for requirements***	***Category description***
R-DATA	Data Management	Covers both the management of the data exchanges in each Use Case step and the management of data at either end if that management is impacted by data exchanges. An example of the first type of data management is the initial setting up and on- going maintenance of what data needs to be exchanged, say between a Geographic Information System and the many different applications that use its data. An example of the second type of data management is the need to backup data or ensure consistency of data whenever it is exchanged, such as if new protection settings are issued to multiple field devices, these settings need to be reflected in Contingency Analysis functions. It should not address database design but should concentrate on the user requirements for the interfaces to databases and other data handling applications.
R-SEC	Security	Assess how different security measures applied to different items can potentially interact and either leave security holes or make user interfaces very laborious and possibly unworkable. Security must not only protect against the very harmful but quite rare deliberate attacks, but also against the far more likely inadvertent mistakes, failures, and errors. At the same time, it is necessary to try to identify the requirements and the concerns for implementing security measures.
R-COMP	Compatibility	Compatibility with other functions.
R-CONFIG	Configuration	Reflect the typical, probable, or envisioned communication configurations that are relevant to the use case step. These configuration issues include numbers of devices and/or systems, expected growth of the system over time, locations, distances, communication types, network bandwidth, existing protocols, etc., but only from the user's point of view. In some cases, only one of the possible choices is reasonable, while for other situations, more than one choice is reasonable.
Requirement R-ID	***Requirement name***	***Requirement description***
R-SEC-1	Data privacy	Ensuring confidentiality, avoiding illegitimate use of data, and preventing unauthorized reading of data, is quite important
R-SEC-2	Authentication	Ensuring that data comes from the stated source or goes to authenticated receiver is important.
R-SEC-3	Data security	Ensuring that data cannot be stolen or deleted by an unauthorized entity is important.

R-QoS-1	Availability of information flows	Continuous availability not required but must be available at specific times or under specific conditions.
R-QoS-2	Accuracy of data requirements	Age of data needs to be known; Quality of data characterization is important.

HLUC05 – Benchmarking appliance performance

1. Description of the use case

1.1 Name of the use case

ID	*Area*	*Name of Use Case*
HLUC05	*(2) Self-assessment and benchmarking*	*Benchmarking appliance performance*

1.2 Version management

Version No.	*Date*	*Name of Author (s)*	*Changes*
1.0	*05.05.21*	*Ricardo Barros*	*First version of HLUC05*
1.1	*31.05.21*	*João Bravo Dias*	*Reviser version of HLUC05.v1*
1.1	*07.06.21*	*Anna Marszal-Pomianowska*	*Review of HLUC05.v1*
2.0	*29.06.21*	*Filipe Silva, João Dias*	*Second version of HLUC05*

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	HLUC05 is a High-Level Use Case (HLUC) regarding the self-assessment and benchmarking performed by the **SATO Platform** with the domestic appliances data. The normal flow in this HLUC would be the constant monitoring of the performance of the appliances (performed in HLUC01), benchmark this data with industry standards and with real monitored data from similar appliance, and generate recommendations when there is energy performance deviations and it is financially interesting to replace/repair the appliance. The assessment made with this data should enable to: • provide warranty services/information; • suggest repairing services; • detect incorrect usage of appliances and generate recommendations accordingly; • detect energy usage outliers and recommend corrections/external intervention; • detect abnormal appliance behaviour and suggest external intervention; • suggest replacement to more sustainable appliances when economically feasible. In this Use Case **Building manager**, **owners** and **occupants**, and **Appliance Services Provider** will intervene as human actors, and through SATO software/ hardware functionalities such as the **SATO Self-Assessment Framework**, the **SATO Platform**, and **SATO APP.** Two Primary Use Cases (PUCs) will be derived from this HLUC: • PUC5.1 is named “Use the assessed deviations to provide/suggest warranty and repairing services, and new appliances” and; • PUC5.2 is named “Recommendations when incorrect usage of appliances is detected”.
Objective(s)	The objectives of this HLUC are related with Benchmarking appliance performance. The objectives defined are: 1. Compare performance with industry standards 2. Use the assessed deviations to provide/suggest warranty and repairing services, and new appliances 3. Provide recommendation when incorrect usage is detected

1.4 Narrative of use case

1.4.1 Narrative of High-Level use case

Narrative of Use Case
Short description
Benchmarking appliance performance will take advantage of the individual SATO monitoring devices deployed at appliance level to constantly monitor the performance of such appliances, comparing this performance to industry standards and with real monitored data from similar appliances in the different pilots or available databases. The HLUC will also be generating recommendations when energy performance is low and it is financial interesting to replace the appliance for a new one. The results of the benchmarking can be used to provide warranty services or suggest repairing services. This service could also detect incorrect usage of appliances and generate recommendations accordingly.
Complete description
The HLUC – self-assessment and benchmarking appliance performed by the **SATO Platform** aims to collect the data from the domestic appliances, do the comparison with the industry standards and with monitored data from similar appliances, and deliver recommendations and provide services to enhance energy performance. The following steps map the necessary actions to implement this HLUC: 1. Access the appliance performance data from **SATO Platform** and **SATO Self-Assessment Framework**. HLUC02 is responsible for the real-time self-assessment of the appliance energy performance, and will provide the necessary data to perform the benchmarking. 2. Benchmark the appliance energy performance with the industry standards and monitored data from similar appliances. The **SATO Self-Assessment Framework** will compare the energy performance of appliances with the industry standards and with monitored data from similar appliances (e.g. installed in other houses or with historical performance data of that same house). 3. Communicate the results of the benchmarking to **building managers, owners and occupants** through **SATO APP** and to **Appliance Services Provider** through **SATO Platform**. The benchmarking results will be shared with the interested parties. If the energy performance can be improved by simple changing behaviour it will be communicated via **SATO APP**. If the appliance is no longer working as expected, the **Appliance Services Provider** will be able to suggest the repairing services before higher or permanent damages happen to the appliance, or if no solution is available could suggest new and more efficient appliances (e.g. showing the cost benefit, payback time or energy saved by changing the appliances). Due to the many different types of appliances available in the market, SATO will focus on the ones responsible for the highest energy consumptions.

1.4.2 Narrative of primary use cases

ID	*Name*	*Description*
PUC5.1	Use the assessed deviations to provide/suggest warranty and repairing services and new appliances	Use the information received from the comparison to detect abnormal appliance behaviour, automatically define the possible causes and suggest a type of service accordingly in order to address the cause. Further, suggestion of new and more efficient appliances could be provided, including the advantages of changing the appliance (e.g. the cost benefit, payback time or energy saved by changing the appliances)
PUC5.2	Provide recommendation when incorrect usage of appliances is detected	Use the info received from the comparison to detect incorrect appliance behaviour/usage, and usage and recommend better or correct usage of the appliance.

1.5 Key performance indicators (KPI)

Name	*Description*	*Reference to mentioned use case objectives*
Total annual specific energy consumption	Measures the amount of specific energy (e.g. electricity, natural gas, district heating, district cooling, domestic hot water) consumed during a year. It can also be divided for different end-uses, such as space heating and cooling,	This KPI links to objectives 1 and 3 and allows a direct comparison of the appliance performance.

	appliances, lighting system, domestic hot water production and others.	
Monthly average specific energy consumption	Measures the monthly amount of specific energy consumption (e.g. electricity, natural gas, district heating, district cooling, domestic hot water).	This KPI links to objectives 1 and 3 and can be used as a direct measure of performance for this HLUC.
Daily average specific energy consumption	Measures the daily amount of specific energy consumption (e.g. electricity, natural gas, district heating, district cooling, domestic hot water).	This KPI links to objectives 1 and 3 and can be used as a direct measure of performance for this HLUC.
Utilization factor	Represents the percentage of the on-site energy generation that is used by the building.	This KPI links to objectives 1 and 3 and can be used as a direct measure of performance for this HLUC.
Cost for electricity consumption	Measures the cost of all electricity used during a certain period (e.g. yearly).	This KPI links to objectives 1 and 3 and can be used as a direct measure of performance for this HLUC.
Response to call to action/Effective action after recommendation	Records the number of effective actions after recommendations.	This KPI links to objectives 2. Tracking user effective actions after recommendations could be used as an indicator of success of the implementation of the benchmarking and the SATO APP.

1.6 Use case conditions

Use case conditions
Assumptions
The **SATO Platforms** and different IoT and Wi-Fi-based interfaces must be in operation (HLUC01). The **Building managers, Building owners and Building occupants**, have given their consent for SATO to perform the assessments and recommendations, and share data with the **Appliance Services Provider**. Enough relevant data is gathered from the appliances industry.
Prerequisites
Link is established to HLUC01 (Data collection) and HLUC02 (SATO Self-Assessment Framework).

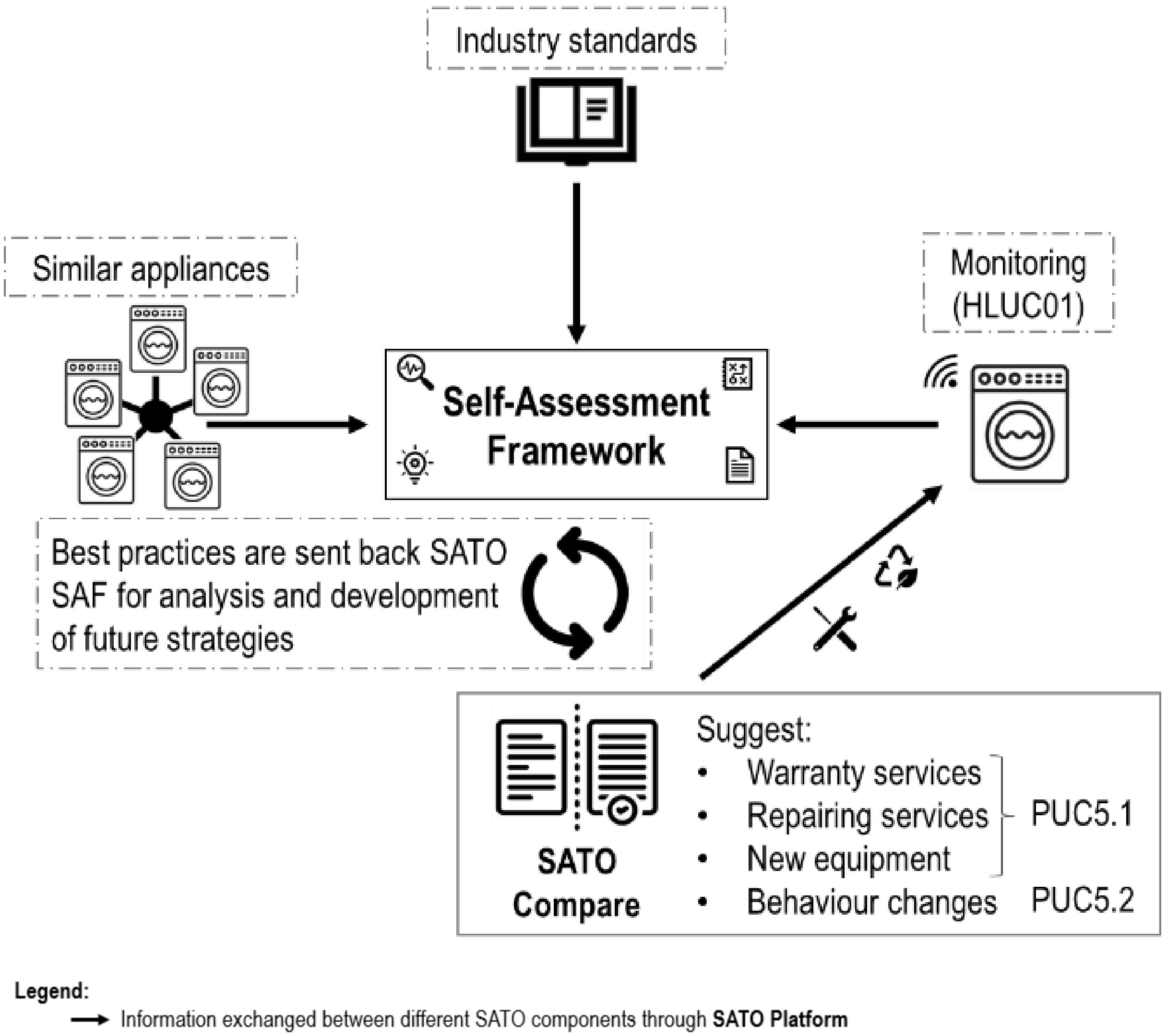
1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
HLUC01 – Data collection is a prerequisite for the benchmarking and performance evaluation. HLUC02 – Self-assessment is a prerequisite for benchmarking and performance evaluation. HLUC07 – Dissemination of the outcome of benchmarking and performance evaluation through visualization and feedback is required to improve awareness and facilitate behavioural changes.
Level of depth
HLUC05 - Benchmarking appliance performance. PUC5.1: Use the assessed deviations to provide/suggest warranty and repairing services, and new appliances PUC5.2: Provide recommendation when incorrect usage of appliances is detected
Prioritisation
This HLUC is considered of normal priority to SATO. PUC5.1; PUC5.2; - should be applied in the Seixal, with the goal to achieve a low-cost replicable solution that can be retrofitted to any domestic ecosystem.
Generic, regional or national relation
Generic Use Case
Nature of the use case
Technical Use Case

Further keywords for classification
Appliances, cloud, sensor, actuator, smart management, smart control, energy efficiency, benchmark, appliances data, Appliance Services Provider, Warranty services, Repairing

2 Diagrams of use case

Diagram(s) of use cases



3. Technical details

3.1 Actors

Actors		
Actor Name	*Actor Type*	*Actor Description*
Building managers	*Human actor*	*This actor as an indirect role in this HLUC. His role is to receive the information of the benchmarking and decide if they want to enhance the energy performance of its appliances by accepting the*

		suggestions to better use the appliance, receive the warranty/repairing services, or suggestion of new and more efficient appliances.
Building occupants	*Human actor*	*This actor as an indirect role in this HLUC. His role is to receive the information of the benchmarking and decide if they want to enhance the energy performance of its appliances by accepting the suggestions to better use the appliance, receive the warranty/repairing services, or suggestion of new and more efficient appliances.*
Appliance Services Provider	*Human actor*	*The role of this actor is to receive the information provided by the benchmarking and suggest warranty/repairing services to the building managers and occupants.*
SATO APP	*Software/ systems/ applications/ devices*	*SATO APP will allow to send new commands to the building equipment and appliances.*
SATO Self-Assessment Framework (SAF)	*Software/ systems/ applications/ devices*	*SATO SAF will receive data regarding current controls, which can be analysed and used to produce the assessments that generate the energy efficiency strategies.*

3.2 References

References						
No.	***References type***	***Reference***	***Status***	***Impact on use case***	***Originator/ organization***	***Link***
1	*Internal Document*	*SATO KPI tool reference list*	*n/a*	*Provision of KPI to be included*	*AAU*	[KPI tool]
2	*Internal Document*	*SATO actors reference list*	*n/a*	*Provision of actors to be included*	*EDP NEW*	*Use Case Short Description V6.xlsx*
3	*Appliance datasheets*	*Appliance standard performance*		*Provision of the standard performance condition of the appliance*	*Appliance manufacturer*	

4. Step by step analysis of use case

4.1 Overview of scenarios

Scenarios conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
1	*Benchmark energy performance of appliances to provide recommendations to its users (building owner/manager/occupant and Appliance Services Provider)*	*The* ***SATO Self-Assessment Framework*** *will benchmark the energy performance of appliances with manufacturer standard performance conditions and with monitored data from similar appliances, and will provide recommendation to*	*SATO Self-Assessment Framework*	*The data collected through the appliance monitoring is analysed by the* ***SATO Self-Assessment Framework****.*	*Availability of data from the appliance monitoring devices and data from standard operation from manufacturer and/or from similar appliances in*	*Recommendation to enhance user's appliance performance,*

		enhance the energy performance (e.g. suggest behaviour changes, suggest warranty/repairing services, or suggest new and more efficient appliances)			*operation conditions.*	

4.2 Steps – Scenarios

Scenario								
Scenario name:		***Implement real-time cloud-based control actions***						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirements, R-IDs***
1.1	*Data request*	*Access the appliance performance data*	*The **SATO Platform** and **SATO Self-Assessment Framework,*** responsible for the real-time self-assessment of the appliance *energy performance, will provide the necessary data to perform the benchmarking.*	*GET*	*SATO Self-Assessment Framework*	*SATO Self-Assessment Framework*	*IE1*	R-SEC-1; R-SEC-2; R-SEC-3; R-QoS-1; R-QoS-2
1.2	*Performance comparison*	Benchmark the appliance energy performance	The **SATO Self-Assessment Framework** will compare the energy performance of appliances with the industry standards and with monitored data from similar appliances (e.g. installed in other houses or with historical performance data of that same house)	*CREATE*	*SATO Self-Assessment Framework*	*SATO Self-Assessment Framework*	-	
1.3	*Data push*	*Communication of results*	*Communicate the results of the benchmarking to building managers, owners and occupants through **SATO APP** and to Appliance Services Provider through **SATO Platform***	*REPORT*	*SATO Self-Assessment Framework*	*SATO APP*	*IE2*	R-SEC-1; R-SEC-2; R-SEC-3; R-QoS-1; R-QoS-2

(*) Available options are:

- *CREATE means that an information object is to be created at the Producer.*
- *GET (this is the default value if none is populated) means that the Receiver requests information from the Producer (default).*
- *CHANGE means that information is to be updated. Producer updates the Receiver's information.*
- *DELETE means that information is to be deleted. Producer deletes information from the Receiver.*
- *CANCEL, CLOSE imply actions related to processes, such as the closure of a work order or the cancellation of a control request.*
- *EXECUTE is used when a complex transaction is being conveyed using a service, which potentially contains more than one verb.*
- *REPORT is used to represent transferal of unsolicited information or asynchronous information flows. Producer provides information to the Receiver.*
- *TIMER is used to represent a waiting period. When using the TIMER service, the Information Producer and Information Receiver fields shall refer to the same actor.*
- *REPEAT is used to indicate that a series of steps is repeated until a condition or trigger event. The condition is specified as the text in the "Event" column for this row or step. Following the word REPEAT, shall appear, in parenthesis, the first and last step numbers of the series to be repeated in the following form REPEAT(X-Y) where X is the first step and Y is the last step.*

5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE1	*Refined building data*	***SATO Self-assessment Framework*** *will receive data from the SATO Platform to benchmark appliances*	R-SEC-1; R-SEC-2; R-SEC-3; R-QoS-1; R-QoS-2
IE2	*Feedback information*	***SATO Self-assessment Framework*** *will provide recommendations for maintenance or replacement of the appliances based on the benchmarking*	R-SEC-1; R-SEC-2; R-SEC-3; R-QoS-1; R-QoS-2

6 Requirements

Requirements		
Categories ID	***Category name for requirements***	***Category description***
R-CONFIG	Configuration	Reflect the typical, probable, or envisioned communication configurations that are relevant to the use case step. These configuration issues include numbers of devices and/or systems, expected growth of the system over time, locations, distances, communication types, network bandwidth, existing protocols, etc., but only from the user's point of view. In some cases, only one of the possible choices is reasonable, while for other situations, more than one choice is reasonable.
R-SEC	Security	Assess how different security measures applied to different items can potentially interact and either leave security holes or make user interfaces very laborious and possibly unworkable. Security must not only protect against the very harmful but quite rare deliberate attacks, but also against the far more likely inadvertent mistakes, failures, and errors. At the same time, it is necessary to try to identify the requirements and the concerns for implementing security measures.
R-COMP	Compatibility	Compatibility with other functions.
R-QoS	Quality of Service (QoS)	Address availability of the system, such as acceptable downtime, recovery, backup, rollback, etc. QoS issues also address accuracy and precision of data, the frequency of data exchanges, and the necessary flexibility for future changes.
R-DATA	Data Management	Covers both the management of the data exchanges in each Use Case step and the management of data at either end if that management is impacted by data exchanges. An example of the first type of data management is the initial setting up and on- going maintenance of what data needs to be exchanged, say between a Geographic Information System and the many different applications that use its data. An example of the second type of data management is the need to backup data or ensure consistency of data whenever it is exchanged, such as if new protection settings are issued to multiple field devices, these settings need to be reflected in Contingency Analysis functions. It should not address database design but should concentrate on the user requirements for the interfaces to databases and other data handling applications.
Requirement R-ID	***Requirement name***	***Requirement description***
R-SEC-1	Data privacy	Ensuring confidentiality, avoiding illegitimate use of data, and preventing unauthorized reading of data, is quite important
R-SEC-2	Authentication	Ensuring that data comes from the stated source or goes to authenticated receiver is important.
R-SEC-3	Data security	Ensuring that data cannot be stolen or deleted by an unauthorized entity is important.
R-QoS-1	Availability of information flows	Continuous availability not required but must be available at specific times or under specific conditions.
R-QoS-2	Accuracy of data requirements	Age of data needs to be known; Quality of data characterization is important.
R-COMP-1	Compatibility with the data sent by **SATO Platform**	The optimal control strategies for every timestep coming from the holistic optimal control must be compatible with the actuator they target. Ensure compatibility with HLUC14.

HLUC06 – Integration of sensors layer into BIM projects for visualization and location optimization

1. Description of the use case

1.1 Name of the use case

ID	*Area*	*Name of Use Case*
HLUC06	*(3) Visualization of building energy performance*	Integration of sensors layer into BIM projects for visualization and location optimization

1.2 Version management

Version No.	*Date*	*Name of Author (s)*	*Changes*
1.0	*07.06.21*	*Pablo Gilabert*	*First version*
2.0	*02.07.21*	*João Dias, Filipe Silva*	*Review and second version of HLUC06*

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	HLUC06 is a High-Level Use Case focused on the interaction and visualization of Building Information Model (BIM) models. The **SATO BIM tool** will be able to integrate BIM information in SATO workflow, having some other features to manage this data with different purposes. The creation of a BIM interface will allow the possibility of working in a 3D environment. The **owners/facility managers/occupants** will be able to know exactly in each part of a building and room, sensors have been located, how many occupants are, the properties of the different construction elements and what are the design calculated values of energy, acoustics or lighting. Alerts will be displayed within the 3D visualization tool, warning signals will be displayed when indoor conditions or energy consumption are outside the expected performances or when sensors are missing in places with significant impact on energy or occupants' comfort. These will allow actors to perform knowledge-based decisions with a high degree of confidence.
Objective(s)	List of objectives of the use case 1. Creation of a BIM sensors management tool 2. Access to the building information (spaces, construction elements, etc.) 3. Integrate libraries of sensors to be included in projects 4. Develop algorithms to analyse BIM geometry to identify the best location for the sensors' infrastructure. 5. Integration in a BIM cloud viewer 6. Communication with **SATO Platform** to connect with dynamic data managed by the different sensors

1.4 Narrative of use case

1.4.1 Narrative of High-Level use case

Narrative of Use Case
Short description
Integration of BIM models in the SATO workflow to provide users 3D models where the sensors infrastructure has been integrated based in smart algorithms. This feature allows designers and project managers to place the different sensors according to the specific conditions of the project and reuse these two layers (BIM project + BIM sensors layer) to provide this data to the users of the system.

Complete description
The HLUC06 – Integration of sensors layer into BIM projects for visualization and location optimization – has a basic goal which is taking profit of existing data and the data obtained by the sensors to improve the decision-making process. The following steps are necessary to implement this HLUC: 1. Having a Building Information Model (BIM) of the building. That means having a 3D model connected to a database with some information about the different elements of the building (spaces, windows, doors, etc.). 2. BIM models are imported to the software and are adapted to display and analyse the data being generate by **SATO Self-Assessment Framework** in order to apply some rules to identify energy and occupant needs. 3. According to the results we can digitally identify the best location to place the different sensors (new or replacing the existing ones). The technical user should specify the type of sensor installed. Each sensor will have different properties and requirements. 4. This data is exported in a new layer with the information of the digital sensors (BIM sensors layer) 5. After the physical installation of the sensors it is needed to build a link between the real sensors and the digital ones. This will be created based in GUIDs (Globally Unique Identifier) 6. The digital sensors will read the dynamic data generated by the sensors and apply the different rules to work in a flexible system adapted to the real conditions of the building and control the system performance evolution. 7. Some alarms/alerts will be defined to have a better control of the data managed.

1.4.2 Narrative of primary use cases

ID	***Name***	***Description***
PUC6.1	*Visualization of 3D models*	Working with 3D models opens a new possibility of displaying graphical data in different components of SATO project. Usually the generic systems organize the information by naming the spaces of the building and connecting the different devices to each space. In **SATO BIM tool** we have the possibility to visualize the exact position of all the sensors based on a 3D model. It gives us more information about the real condition of every location. Since Open BIM data will be used, there is the opportunity of displaying information from a lot of different applications in different domains such as Augmented Reality, Virtual Reality, Energy Simulation, etc. The **SATO BIM tool** will be the component in charge of integrating and distributing this 3D into the SATO environment.
PUC6.2	*Building data management*	Building data could be considered as static data but we need to take into account that buildings are alive and many changes are occurring during the operation phase. For that reason, the **SATO BIM tool** will integrate a component with a dynamic link to include the possibility of updating the construction definition of the project. All the information available in the BIM models will be displayed for visualization but the internal algorithms implemented for identifying the best locations according to the real performance of the building will filter the data required to speed the process. Alarms and warnings will be implemented if some needed data is missed. The system will be adapted to read BEM models (BIM Energy Models) or any other BIM model created as a result of a simulation. By this way we can visualize the lighting results, the fire extinguishing elements or the heating, ventilation and air conditioning (HVAC) system of the digital project (not the existing building). The **SATO BIM tool** will include a layer for integrating the libraries of sensors with specific geometric conditions and requirements. This information will be exported to the **SATO Platform** in order to display all the BIM information (BIM project + BIM sensors layer) in the different components. All the information will be generated in open formats as IFC (building data), glTF (3D data) or Json (requirements).
PUC6.3	*Sensors data management*	A link with **SATO Platform** will provide the information to the **SATO BIM tool** the dynamic data registered by the different sensors. With this data we increase the accuracy of analysis of the different algorithms implemented to identify the best location of sensors. This data will provide new possibilities of displaying dynamic data based on a BIM model.

1.5 Key performance indicators (KPI)

Name	*Description*	*Reference to mentioned use case objectives*
Accuracy of information, alarms and alerts	Counts the amount of datapoints sent that generated alerts that do not correspond to real situations or needs.	This KPI enables to track if the information displayed in this UC is accurate and as such it allows to determine the level of success of its application.
User engagement	Records the number of visits, clicks and time-on-app in the web/mobile application of SATO.	Tracking user engagement allows for the monitoring of how many users are using the BIM tool and for how long which could be used as an indicator of success of the implementation of an application with a user interface.
Total annual specific energy use	Measures the amount of specific energy (e.g. electricity, natural gas, district heating, district cooling, domestic hot water) during a year. Depending on the installed HVAC systems, it can also be divided for different end uses, such as space heating and cooling. It can also be referred to specific domestic appliances, to the lighting system and to domestic hot water production, etc.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Specific energy use over a period	Measures the amount of specific energy (e.g. electricity, natural gas, district heating, district cooling, domestic hot water) in a certain period (i.e. hourly, daily, monthly, yearly).	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Thermal comfort (Air temperature / operative temperature)	Represents the temperature measured in the room. It can be given as the present value or as an average value for a given time period (daily, weekly).	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Thermal comfort categories (POR)	Based on the percentage of thermally dissatisfied persons (PPD index) thermal comfort sensations are divided into different categories (Cat. I PPD<6%; Cat. II PPD<10%; Cat III PPD<15%; Cat. IV PPD > 15%). It can be a value or an average value for a given time period (daily, weekly)	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Atmospheric comfort (CO_2 concentration)	CO_2 concentration is one of the parameters used to assess indoor air quality. The CO_2 concentration is usually measured in parts per million [ppm].	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Atmospheric comfort (Relative humidity)	Percentage of the moisture against the highest possible level of moisture in the air at a specific temperature.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Atmospheric comfort (VOC)	The concentration of Volatile Organic Compounds (VOCs) is often reported using the following units: parts per million [ppm] or micrograms of VOCs per cubic meter of air [$\mu g/m^3$].	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Acoustic comfort (Reverberation time)	It evaluates the time (s) that would be required for the sound pressure level to decrease by 60 dB after the sound source stopped.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.

Acoustic comfort (Noise)	Measures the noise, in dB, coming from outside sound sources.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Visual comfort (Illuminance)	Measures the illuminance in lux at a certain point(s) in the building	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Visual comfort (Daylight autonomy)	Measures the amount of artificial light required to maintain visual comfort	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Thermal comfort (Draught rate)	Percentage of people dissatisfied due to draught, usually assessed through user feedback.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Atmospheric comfort (Perceived air quality)	People perception of indoor air quality, usually assessed through user feedback.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Annual produced energy system	Measures the total amount of energy by type (EL / HEAT / COLD) produced in a certain period by the building (i.e. daily, monthly, season).	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Produced energy system over a period	Measures the amount of specific energy by type (EL / HEAT / COLD) produced in a certain period by a system (i.e. daily, monthly, season).	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Specific energy produced by system	Measures the amount of specific energy by type (EL / HEAT / COLD) produced in a certain period (i.e. daily, monthly, season) related to one specific system.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Specific Fan Power	The combined amount of electric power consumed by all the fans in the air distribution system divided by the total airflow rate through the building under design load conditions	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Specific Pump Power	The combined amount of electric power consumed by all the pump as a function of a dependent variable.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.

Coefficient of performance (COP)	COP is defined as the relationship between the power (kW) that is drawn out of the heat pump as cooling or heat, and the power (kW) that is supplied to the compressor	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Seasonal Coefficient of Performance (SCOP)	SCOP is defined as the ratio between the reference annual heating demand and annual electricity consumption. For heat pumps it is called HSPF or heating seasonal performance factor.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Seasonal Energy Efficiency Ratio	SEER is defined as the ratio between the reference annual cooling demand and annual electricity consumption considering the varied outdoor air temperature.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Comparison of specific building energy performance with references	Compares the actual performance of the building or building systems with reference values.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.

1.6 Use case conditions

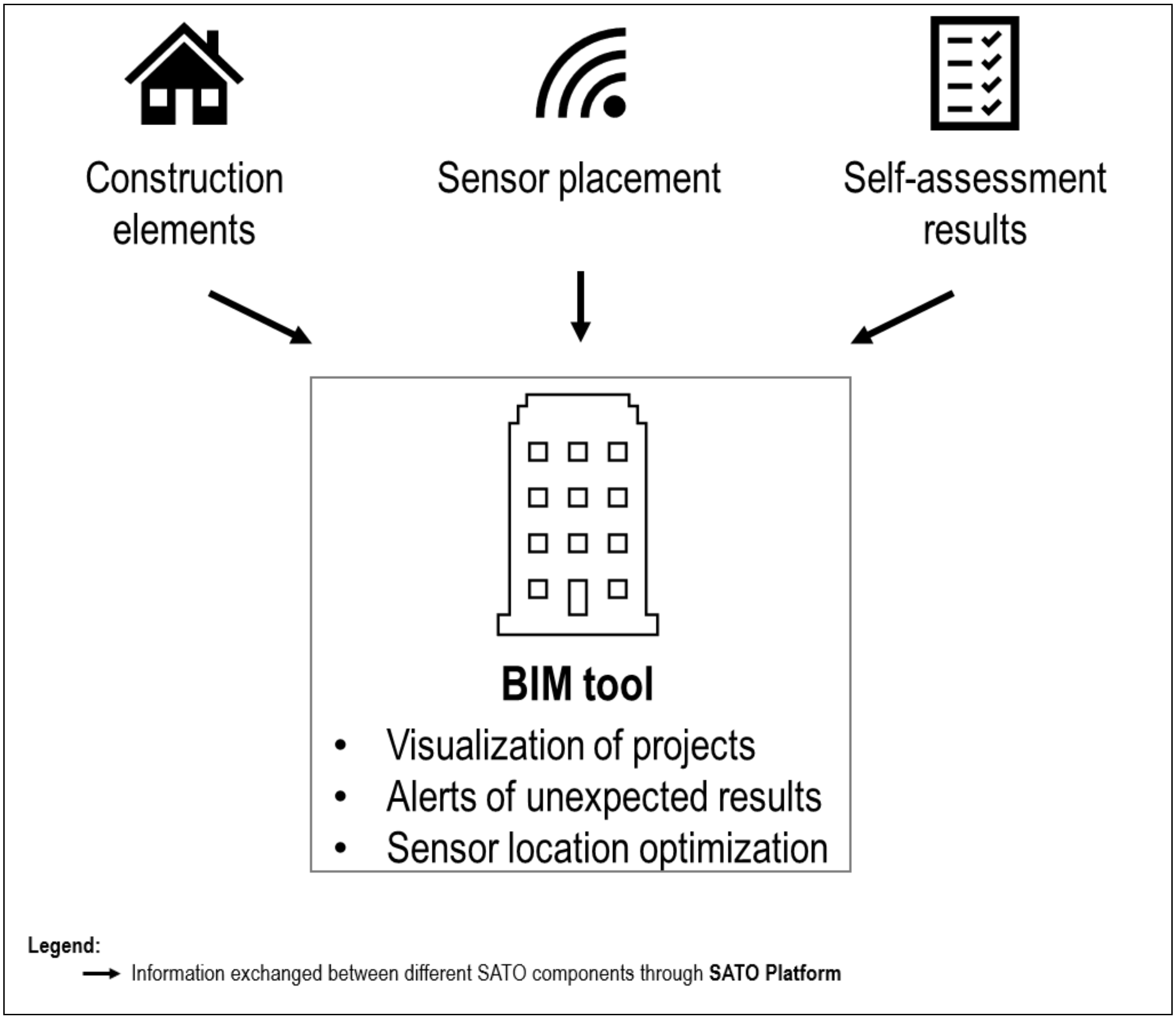
Use case conditions
Assumptions
SATO BIM tool will have an API for sharing data with the external components. Sensors generate readable data in json format, and are available through **SATO Platform**
Prerequisites
A BIM model with the information of the project is required. This is quite common in new projects. In existing buildings there are many different possibilities to develop a BIM model using technologies of data capture (point cloud, photogrammetry, etc.) *Relation with HLUC01, HLUC02*

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
HLUC01 – Securely collecting, processing and storing building data is a prerequisite HLUC02 – Data-driven self-assessment will send data to be incorporated in the BIM
Keywords for classification
BIM, 3D, Visualization, Self-Assessment, Self-Optimization, sensors

2 Diagrams of use case

Diagram(s) of use cases



3. Technical details

3.1 Actors

Actors		
Actor Name	**Actor Type**	**Actor Description**
Facility/ building managers	*Human Actor*	*The facility/building managers are the actors most closely linked to HLUC06. They will be in charge of managing the interface and sharing data with the other components of the project.*
Building occupants	*Human Actor*	*The building occupants will access to the visualization data generated in this use case.*
Building owners	*Human Actor*	*Building owners will have a new valuable asset to exploit (BIM model linked to sensors data) in many different ways.*
SATO Platform	Software/ systems/ applications/ devices	SATO Platform will feed data into the SATO BIM tool based in an API to control securely the information transfer between the different components.
SATO Self-Assessment Framework (SAF)	*Software/ systems/ applications/ devices*	*SATO SAF will provide data, which can be analysed and used in the SATO BIM tool*
SATO BIM tool	Software/ systems/ applications/ devices	SATO BIM tool will be the primary actor in this HLUC. It will allow the visualization of the building in 3D model and all other features described in section 1.

3.2 References

References						
No.	***Reference type***	***Reference***	***Status***	***Impact on use case***	***Originator/ organization***	***Link***
1	Internal document	SATO Deliverable 1.2 KPI tool reference list	n/a	Provision of KPI to be included	AAU	KPI tool
2	Internal document	SATO actors reference list	n/a	Provision of actors to be included	EDP NEW	Use Case Short Description V6.xlsx

4. Step by step analysis of use case

4.1 Overview of scenarios

Scenarios conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
1	*Provide building real-time and historical data and information using 3D models*	*The **SATO BIM tool** will provide a way for **building owners**, **managers** and **occupants** to visualize in a 3D model relevant building information and the exact sensor position within a room.*	*SATO BIM tool*	*The data collected through the building monitoring is analysed by the **SATO SAF** and sent to **SATO BIM tool** for visual display though the **SATO Platform***	*Availability of BIM model for the building and data from the building monitoring devices*	*Visual display of building data in a 3D model.*

4.2 Steps – Scenarios

Scenario								
Scenario name:		**Reference scenario**						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirements, R-IDs**
1.1	*Create BIM model*	*A BIM model is built and imported into the **SATO BIM tool***	*The **SATO BIM tool** will import the building BIM model that was previously built.*	*CREATE*	*SATO BIM tool*	*SATO BIM tool*	-	-
1.2	*Data request*	*Processed data is sent to the **SATO BIM tool***	*The **SATO BIM tool** requests sensor information and real-time data from **SATO** **Self-Assessment Framework** to enable its display.*	*GET*	*SATO* Self-Assessment Framework and SATO Platform	*SATO BIM tool*	*IE1*	*R-SEC-1; R-SEC-2; R-QoS-1; R-QoS-2; R-DATA-1; R-DATA-2; R-DATA-3*
1.3	*Graphical display*	***SATO BIM tool** displays the data received*	*The data received by **SATO** **Self-Assessment Framework** is displayed on a 3D interface.*	*CREATE*	*SATO BIM tool*	*SATO BIM tool*	-	-

(*) Available options are:

- *CREATE means that an information object is to be created at the Producer.*
- *GET (this is the default value if none is populated) means that the Receiver requests information from the Producer (default).*
- *CHANGE means that information is to be updated. Producer updates the Receiver's information.*
- *DELETE means that information is to be deleted. Producer deletes information from the Receiver.*
- *CANCEL, CLOSE imply actions related to processes, such as the closure of a work order or the cancellation of a control request.*
- *EXECUTE is used when a complex transaction is being conveyed using a service, which potentially contains more than one verb.*
- *REPORT is used to represent transferral of unsolicited information or asynchronous information flows. Producer provides information to the Receiver.*
- *TIMER is used to represent a waiting period. When using the TIMER service, the Information Producer and Information Receiver fields shall refer to the same actor.*
- *REPEAT is used to indicate that a series of steps is repeated until a condition or trigger event. The condition is specified as the text in the "Event" column for this row or step. Following the word REPEAT, shall appear, in parenthesis, the first and last step numbers of the series to be repeated in the following form REPEAT(X-Y) where X is the first step and Y is the last step.*

5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE1	*Building information data*	*All information collected via sensors implemented in the building*	*R-SEC-1; R-SEC-2; R-QoS-1; R-QoS-2; R-DATA-1; R-DATA-2; R-DATA-3*

6 Requirements

Requirements		
Categories ID	***Category name for requirements***	***Category description***
R-CONFIG	Configuration	Reflect the typical, probable, or envisioned communication configurations that are relevant to the use case step. These configuration issues include numbers of systems and/or components, expected growth of the system over time, locations, distances, communication types, network bandwidth, existing protocols, etc., but only from the user's point of view. In some cases, only one of the possible choices is reasonable, while for other situations, more than one choice is reasonable.
R-SEC	Security	Assess how different security measures applied to different items can potentially interact and either leave security holes or make user interfaces very laborious and possibly unworkable. Security must not only protect against the very harmful but quite rare deliberate attacks, but also against the far more likely inadvertent mistakes, failures, and errors. At the same time, it is necessary to try to identify the requirements and the concerns for implementing security measures.
R-COMP	Compatibility	Compatibility with other functions In the SATO Platform and external systems and components (e.g. 3rd party Clouds)
R-QoS	Quality of Service (QoS)	Address availability of the system, such as acceptable downtime, recovery, backup, rollback, etc. QoS issues also address accuracy and precision of data, the frequency of data exchanges, and the necessary flexibility for future changes.
R-DATA	Data Management	Covers both the management of the data exchanges in each Use Case step and the management of data at either end if that management is impacted by data exchanges. An example of the first type of data management is the initial setting up and ongoing maintenance of what data needs to be exchanged, say between a Geographic Information System and the many different applications that use its data. An example of the second type of data management is the need to backup data or ensure consistency of data whenever it is exchanged, such as if new protection settings are issued to multiple field devices, these settings need to be reflected in Contingency Analysis functions. It should not address database design but should concentrate on the user requirements for the interfaces to databases and other data handling applications.
Requirement R-ID	***Requirement name***	***Requirement description***
R-SEC-1	Data privacy	Ensuring confidentiality, avoiding illegitimate use of data, and preventing unauthorized reading of data, is quite important
R-SEC-2	Authentication	Ensuring that data comes from the stated source or goes to authenticated receiver is important.
R-QoS-1	Availability of information flows	Continuous availability not required but must be available at specific times or under specific conditions.
R-QoS-2	Accuracy of data requirements	Age of data needs to be known; Quality of data characterization is important.
R-DATA-1	Correctness of source data	Ensures that the data is correctly interpreted and used for the purpose it was designed to.
R-DATA-2	Management of accessing different types of data to be exchanged	Sets the type of data being exchanged and the expected periodic update (asynchronous or every x time).

R-DATA-3	Validation of data exchange	Guarantees that data exchanged between parties is valid. It can provide confirmation to the originally sending party.

7 Common Terms and Definitions

Common Terms and Definitions	
Term	***Definition***
BEM	BIM Energy Models
BIM	Building information modelling
GUIDs	Globally Unique Identifier
HVAC	Heating, ventilation and air conditioning

HLUC07 – Visualization of the main KPIs and energy flows using a web/mobile interface

1. Description of the use case

1.1 Name of the use case

ID	*Area*	*Name of Use Case*
HLUC07	Visualization of building energy performance	Visualization of the main KPIs and energy flows using a web/mobile interface.

1.2 Version management

Version No.	*Date*	*Name of Author (s)*	*Changes*
1.0	12.05.21	Alexandra Mostovoy, Filipe Neves Silva, João Bravo Dias	First version of HLUC07
1.1	*27.05.21*	*Daniel P. Albuquerque*	*Review of HLUC07*
1.2	*31.05.21*	*Thomas Fehr, Michael Liniger, Christoph Ospelt*	*Review of HLUC07*
2.0	*29.06.21*	*Filipe Silva, João Dias*	*Second version of HLUC07*

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	HLUC07 is a High-Level Use Case (HLUC) focused on the visualisation of energy consumption, production and flows within the whole building, systems and components. The **SATO APP** will display building information to several building users (**building owners**, **facility managers**, **occupants**) with the purpose of increase energy efficiency by improving awareness towards local energy production and energy consumption of the building, and of the different systems and components. The notifications displayed in the graphical user interface will be provided by the **SATO Self-Assessment Framework** and **SATO Self-Optimization Services)**, giving recommendations to building users on what are the best strategies to improve efficiency without compromising user comfort or indoor air quality and energy costs. Two Primary Use Cases (PUC) can be derived from the HLUC07. PUC7.1 is named “Real-time and historical visualization of the main KPIs (key performance indicators) and energy flows” and PUC7.2 is named “User interaction with web/mobile interface”.

	PUC7.1 is divided in passive feedback and active feedback. Passive feedback is divided in four visualisation options: 1- Visualisation of energy consumption and production – Through the **SATO APP** the net production and consumption of the building will be shown. Additionally, the energy consumption of individual legacy and smart appliances and building equipment, as well as the energy production of PV panels, and electrical vehicle chargers' interaction with the building (V2G) will be displayed. 2- Visualisation of CO_2 emissions and energy costs. 3- Visualisation of room comfort conditions. 4- Visualisation of building performance benchmarking (HLUC4 and HLUC05). The active feedback is related with the display of notifications (recommendations, alerts, warning signals, etc.). PUC7.2 is related with the user interaction and feedback loop between the web/mobile application (**SATO APP**) and the **building owners**, **facility managers** and **building occupants**.
Objective(s)	1. Create a web or mobile interface showing historical and real-time energy flows (production and consumption in buildings) 2. Display of accurate information regarding the status and energy consumption of different systems and components 3. Visualization of CO_2 emissions and related costs 4. Visualization of indoor air conditions and comfort parameters

1.4 Narrative of use case

1.4.1 Narrative of High-Level use case

Narrative of Use Case
Short description
The creation of a web and mobile interface (**SATO APP**) will allow real-time and historical visualization of the main KPIs and energy flows inside a building. The **building owners/facility managers/occupants** will be able to know exactly the status and consumption of different systems and appliances related to energy performance, as well as energy costs and CO_2 emissions associated with their consumptions. Notifications will be displayed when energy efficiency, CO_2, costs or room comfort are outside the expected performance levels. These will allow the mentioned actors to perform knowledge-based decisions with a high degree of confidence. Further, users will have access to historical data, to help them adjust and plan its energy habits for future situations.
Complete description
The HLUC07 – Visualisation of the main KPIs and energy flows using web or mobile interface – concerns the visualisation of information collected by the **SATO Self-Assessment Framework** in HLUC02. The HLUC07 aims to provide real-time and historical information on energy consumption and production of the whole building and from individual appliances and building equipment. This HLUC requires a web or mobile interface, **SATO APP**, to visualise the data for the convenience of the **building owners, facility managers** and **occupants.** Through the **SATO APP** notifications will be sent to its users to enhance energy, CO_2 and cost-efficient behaviours and promote room comfort good conditions. The alerts and warnings information are produced by both the **SATO Self-Assessment Framework** and the **SATO Self-Optimization Services** in HLUC02 and HLUC14, respectively. The following steps map the necessary actions to implement the HLUC: 1. Receive the analysed data from the **Self-Assessment Framework** (HLUC02, HLUC04, HLUC05). 2. Receive the analysed data from the **Self-Optimization Services** (HLUC14). HLUC02 is responsible for analysing the real-time data collected through the **SATO Platform**, while HLUC04 and HLUC05 are responsible for benchmarking the building and appliance energy performances. HLUC08 will optimize the energy efficiency at different scales (from a single equipment to the entire building) and the HLUC09 will perform an optimization over the user comfort (thermal/visual/acoustic comfort and indoor air quality). HLUC14 will receive the different optimization scenarios performed in **SATO Self-Optimization Services** (including

HLUC08 and HLUC09) and, using machine learning algorithms, HLUC14 will provide an optimal control strategy and suggest control actions (through alerts and warning) to the **SATO APP**.

1.4.2 Narrative of primary use cases

ID	*Name*	*Description*
PUC7.1	Real-time and historical visualization of the main KPIs and energy flows	PUC7.1 is entirely related with providing, through **SATO APP,** the visualisation of building energy performance. This PUC will feed from the data provided by the **Self-Assessment Framework**. This PUC is divided in passive feedback and active feedback. Passive feedback means that the results of **SATO Self-Assessment Framework** are openly available to end-users who wish to have a better understanding of the energy, CO_2 and cost performance and room comfort conditions of their buildings, systems and components in the form of figures, graphs, diagrams, KPIs, etc. The different types of passive feedback are: 1. Display the data on the interface (**SATO APP**) in a user-friendly and simple format, for example, using a building plan with energy flow arrows or plots with periodic energy performance data (using KPIs calculated in HLUC02, HLUC04, HLUC05, HLUC08, HLUC09, HLUC14). The data is not limited but must include, when data is available, historical and real-time: whole building energy consumption and production; energy used for self-consumption; individual energy consumption of systems and components and building equivalent; CO_2 emissions and energy costs; room comfort parameters. 2. Display the real-time status of systems and components (actual load [%] or setpoints [ºC]). 3. Display the benchmarks of building and appliance energy performance. Active feedback means that the **SATO Self-Assessment Framework** directly communicates with end-users by sending notifications to inform and increase end-user's awareness about the energy performance and room comfort conditions of their buildings, systems and components and to provide user guidance to trigger behaviour changes. The different types of active feedback are: 4. Display recommendations on how to improve energy performance or self-consumption. 5. Display notifications when measured values are outside expected performance metrics.
PUC7.2	User interaction with web/mobile interface	PUC7.2 is related with the bi-directional communicating between **SATO Self-Assessment Framework** and end-users (**building owners**, **facility managers**, **occupants**). Using the user feedback loop, users will be encouraged to provide feedback, using **SATO APP**, in case of malfunctions, but also regarding the recommendations received and user preferences. The following steps are necessary for the implementation of the PUC: 1. A dashboard on the **SATO APP** allows users to provide feedback on malfunctions, such as missing data points, bugs, or incorrect information shown on the **SATO APP**. The feedback will be communicated to the **SATO Platform** which will then analyse the information provided and trigger warnings to the **SATO Platform** and **Building managers**. 2. **SATO APP** will access the degree of satisfaction with the self-assessment and self-optimization strategies implemented in the building as well as the usefulness of functionalities offered, using for example ad-hoc surveys (e.g., How often do you use functionality XYZ? Rate from 1 to 5; Did you find this information helpful? Rate from 1 to 5; with 1 – fully agree and 5 – totally disagree). The information provided will then be incorporated in the **SATO Self-Assessment Framework** and **SATO Self-Optimization Services** allowing a constant improvement of the SATO system. 3. A dashboard on the **SATO APP** allows users to manage their preferences (for example, define unoccupied periods and set preferred room comfort parameters), which will be considered by **SATO Self-Assessment Framework** and **SATO Self-Optimization Services** for future self-assessments and self-optimizations.

1.5 Key performance indicators (KPI)

Name	*Description*	*Reference to mentioned use case objectives*
Accuracy of information, alarms and alerts	Counts the amount of datapoints sent that generated alerts that do not correspond to real situations or needs.	This KPI enables to track if the information displayed in this UC is accurate and as such it allows to determine the level of success of its application.
User engagement	Records the number of visits, clicks and time-on-app in the web/mobile application of SATO.	Tracking user engagement allows for the monitoring of how many users are using the application and for how long which could be used as an indicator of success of the implementation of an application with a user interface.
Total annual specific energy use	Measures the amount of specific energy (e.g. electricity, natural gas, district heating, district cooling, domestic hot water) during a year. Depending on the installed HVAC systems, it can also be divided for different end uses, such as space heating and cooling. It can also be referred to specific domestic appliances, to the lighting system and to domestic hot water production, etc.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Specific energy use over a period	Measures the amount of specific energy (e.g. electricity, natural gas, district heating, district cooling, domestic hot water) in a certain period (i.e. hourly, daily, monthly, yearly).	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Thermal comfort (Air temperature / operative temperature)	Represents the temperature measured in the room. It can be given as the present value or as an average value for a given time period (daily, weekly).	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Thermal comfort categories (POR)	Based on the percentage of thermally dissatisfied persons (PPD index) thermal comfort sensations are divided into different categories (Cat. I PPD<6%; Cat. II PPD<10%; Cat III PPD<15%; Cat. IV PPD > 15%). It can be a value or an average value for a given time period (daily, weekly)	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Atmospheric comfort (CO_2 concentration)	CO_2 concentration is one of the parameters used to assess indoor air quality. The CO_2 concentration is usually measured in parts per million [ppm].	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Atmospheric comfort (Relative humidity)	Percentage of the moisture against the highest possible level of moisture in the air at a specific temperature.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Atmospheric comfort (VOC)	The concentration of Volatile Organic Compounds (VOCs) is often reported using the following units: parts per million [ppm] or micrograms of VOCs per cubic meter of air [$\mu g/m^3$].	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Acoustic comfort (Reverberation time)	It evaluates the time (s) that would be required for the sound pressure level to decrease by 60 dB after the sound source stopped.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.

Acoustic comfort (Noise)	Measures the noise, in dB, coming from outside sound sources.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Visual comfort (Illuminance)	Measures the illuminance in lux at a certain point(s) in the building	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Visual comfort (Daylight autonomy)	Measures the amount of artificial light required to maintain visual comfort	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Thermal comfort (Draught rate)	Percentage of people dissatisfied due to draught, usually assessed through user feedback.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Atmospheric comfort (Perceived air quality)	People perception of indoor air quality, usually assessed through user feedback.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Annual produced energy system	Measures the total amount of energy by type (EL / HEAT / COLD) produced in a certain period by the building (i.e. daily, monthly, season).	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Produced energy system over a period	Measures the amount of specific energy by type (EL / HEAT / COLD) produced in a certain period by a system (i.e. daily, monthly, season).	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Specific energy produced by system	Measures the amount of specific energy by type (EL / HEAT / COLD) produced in a certain period (i.e. daily, monthly, season) related to one specific system.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Specific Fan Power	The combined amount of electric power consumed by all the fans in the air distribution system divided by the total airflow rate through the building under design load conditions	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Specific Pump Power	The combined amount of electric power consumed by all the pump as a function of a dependent variable.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.

Coefficient of performance (COP)	COP is defined as the relationship between the power (kW) that is drawn out of the heat pump as cooling or heat, and the power (kW) that is supplied to the compressor	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Seasonal Coefficient of Performance (SCOP)	SCOP is defined as the ratio between the reference annual heating demand and annual electricity consumption. For heat pumps it is called HSPF or heating seasonal performance factor.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Seasonal Energy Efficiency Ratio	SEER is defined as the ratio between the reference annual cooling demand and annual electricity consumption considering the varied outdoor air temperature.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.
Comparison of specific building energy performance with references	Compares the actual performance of the building or building systems with reference values.	Although this KPI does not allow for direct evaluation of impact for the HLUC, one of the factors contributing to its improvement overtime can be due to the application of the visualization tool and as such this HLUC can be used as an indirect performance indicator.

1.6 Use case conditions

Use case conditions
Assumptions
The communication between ***SATO Platform***, ***SATO Self-Assessment Framework*** and **SATO Self-Optimization Services** is available, as well as the communication between the **SATO Platform** with the **SATO APP**.
Prerequisites
HLUC01 (Securely collecting, processing and storing building and third-party data). HLUC02 (Data-driven self-assessment diagnosis of building performance) HLUC03 (Forecast of energy loads, indoor air conditions, occupancy and weather HLUC04 (Benchmarking building performance) HLUC05 (Benchmarking appliance performance) HLUC14 (Holistic optimal control of energy resources)

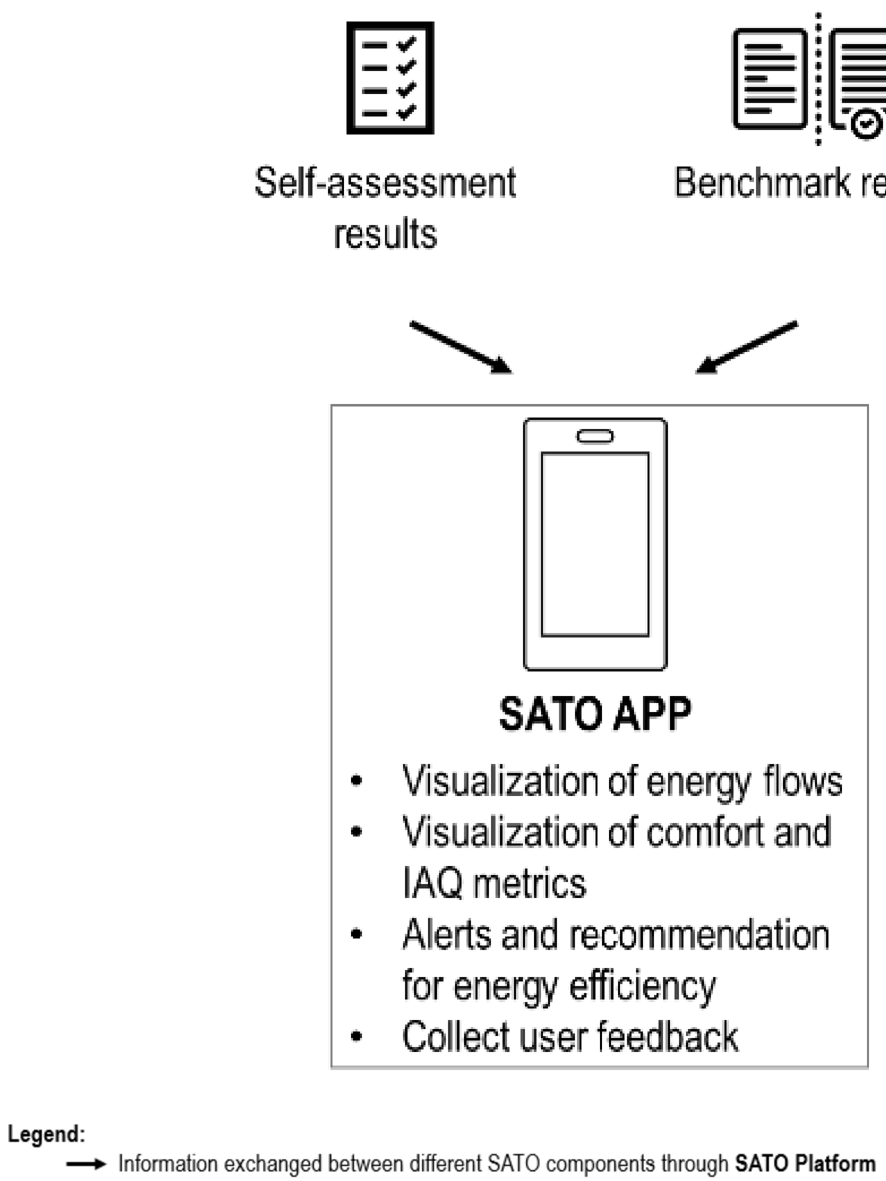
1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
HLUC02 – Self-Assessment is a prerequisite since it will provide the data to be displayed and will receive the user feedback. HLUC03 – Self-Assessment is a prerequisite since it will provide the forecasted data to be displayed and will receive the user feedback. HLUC04 – Self-Assessment benchmarking is a prerequisite since it will provide the building data to be displayed. HLUC05 – Self-Assessment benchmarking is a prerequisite since it will provide the appliance data to be displayed. HLUC14 – It will provide the alerts and warnings to be displayed in the **SATO APP**. The **SATO APP** will provide the feedback from users that will be incorporated in future **SATO Self-Optimization Services**.
Level of depth
HLUC: Visualization of the main KPIs and energy flows using web or mobile interface.
Prioritisation
Low priority
Generic, regional or national relation

Generic Use Case
Nature of the use case
Technical/system use case.
Further keywords for classification
SATO APP, Self-Assessment, Self-Optimization, , energy visualisation, KPIs, electricity metering, energy consumption, energy production, CO_2 emissions, energy costs, indoor air quality, room comfort, user feedback, notifications, alerts

2 Diagrams of use case

Diagram(s) of use cases



3. Technical details

3.1 Actors

Actors		
Actor Name	***Actor Type***	***Actor Description***
Facility/ building managers	Human actor	While facility/building managers may have access to the results of HLUC07, in some pilots where BIM is not available, the web/mobile applications will be used as the facility managers interface with building data.
Building owners	Human actor	Building owners may use the web/mobile application to consult the energy consumption of the building and see possible actions to improve it.
Building occupants	Human actor	This actor will be the main user of the web/mobile application and will use it to visualize their energy consumptions and get possible actions that would improve the overall building energy efficiency.
SATO Platform	Software/ systems/ applications/ devices	SATO Platform will feed data into the SATO APP, allowing to have a graphical user interface with real-time building data.
SATO APP	Software/ systems/ applications/ devices	SATO APP is the main output of this HLUC, providing a visualization tool for SATO platform.
SATO Self-Assessment Framework	Software/ systems/ applications/ devices	The SATO Self-Assessment Framework will generate the alerts that are sent through the SATO APP, indicating went the system is not working in an optimal way.
SATO Self-Optimization Services	Software/ systems/ applications/ devices	The SATO Self-Optimization Services will generate the alerts that are sent through the SATO APP, indicating went the system is not working in an optimal way.

3.2 References

References						
No.	***Reference type***	***Reference***	***Status***	***Impact on use case***	***Originator/ organization***	***Link***
1	Internal document	SATO Deliverable 1.2 KPI tool reference list	n/a	Provision of KPI to be included	AAU	KPI tool
2	Internal document	SATO actors reference list (Task 1.4)	n/a	Provision of actors to be included	EDP NEW	Use Case Short Description V6.xlsx
3	Internal document	SATO Deliverable 1.2: Requirements of the Self-Assessment Framework	n/a	Provision of types of user communication	AAU	D1.2

4. Step by step analysis of use case

4.1 Overview of scenarios

Scenarios conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
1	*Provide building real-time and historical data and information through a graphical user interface*	*The **SATO APP** will provide a way for building occupants to monitor building data using a user-friendly application where they can also check relevant building information that provides the optimal building operation*	*SATO APP*	*The data collected through the building monitoring is analysed by the **SATO Platform** and **SATO SAF** and sent to*	*Availability of data from the building monitoring devices*	*Visual display of building data available to users.*

		parameters towards energy efficiency and comfort. Users will also receive notifications and will be able to provide feedback on malfunctions and control strategies adopted.		***SATO APP*** *for visual display.*		

4.2 Steps – Scenarios

Scenario								
Scenario name:		**Reference scenario**						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirements, R-IDs**
1.1	*Data request*	*Processed data is sent to the **SATO APP***	*The **SATO APP** requests real-time data to **SATO Self-Assessment Framework** to enable its display.*	*GET*	SATO Self-Assessment Framework	*SATO APP*	*IE1, IE2*	*R-SEC-1; R-SEC-2; R-QoS-1; R-QoS-2; R-DATA-1; R-DATA-2; R-DATA-3*
1.2	*Graphical display*	***SATO APP** displays the data received*	*The data received by **SATO APP** is displayed on a graphical user interface.*	*CREATE*	*SATO APP*	*SATO APP*	*-*	
1.3	*User manual control*	***Users** of **SATO APP** setting manual control strategies*	*The users of **SATO APP** are able to send feedback on the automatic control strategies applied in the building, being able to overwrite this in case its necessary and also to providing data on individual preferences.*	*REPORT*	*End-Users*	*SATO APP*	*IE3*	*R-SEC-1; R-SEC-2; R-QoS-2; R-DATA-1; R-DATA-3*
1.4	*Application of commands*	*Confirmation of application of commands is sent back to **SATO Self-Assessment Framework***	*After the application of a control command, a signal is sent back to **SATO Self-Assessment Framework** confirming the new state of operation of the device. This signal is then sent to **SATO APP** which also presents it in the graphical user interface.*	*GET*	SATO Self-Assessment Framework	*SATO APP*	*IE4*	*R-SEC-1; R-SEC-2; R-QoS-2; R-DATA-1; R-DATA-3*
1.5	*Notifications*	***SATO APP** sends alerts and warning to users*	*The **SATO APP** sends alerts and warnings to end-users when conditions/energy consumption are outside expected or defined values.*	*REPORT*	*SATO APP*	*End-Users*	*IE3*	*R-SEC-1; R-SEC-2; R-QoS-2; R-DATA-1; R-DATA-3*
1.6	*User feedback*	***SATO APP** asks feedback from users on strategies adopted*	*The **SATO APP** asks users to provide feedback on the strategies adopted to enhance future self-assessments and self-optimizations.*	*GET*	*End-Users*	*SATO APP*	*IE3*	*R-SEC-1; R-SEC-2; R-QoS-2; R-DATA-1; R-DATA-3*
1.7	*User feedback*	***Users** of **SATO APP** send feedback*	*The users of **SATO APP** are able to send feedback on malfunctions, such as missing data points, bugs,*	*REPORT*	*End-Users*	*SATO APP*	*IE3*	*R-SEC-1; R-SEC-2; R-QoS-2; R-DATA-1; R-DATA-3*

		on malfunctions	*or incorrect information shown on the* ***SATO APP****.*					

(*) Available options are:

- *CREATE means that an information object is to be created at the Producer.*
- *GET (this is the default value if none is populated) means that the Receiver requests information from the Producer (default).*
- *CHANGE means that information is to be updated. Producer updates the Receiver's information.*
- *DELETE means that information is to be deleted. Producer deletes information from the Receiver.*
- *CANCEL, CLOSE imply actions related to processes, such as the closure of a work order or the cancellation of a control request.*
- *EXECUTE is used when a complex transaction is being conveyed using a service, which potentially contains more than one verb.*
- *REPORT is used to represent transferral of unsolicited information or asynchronous information flows. Producer provides information to the Receiver.*
- *TIMER is used to represent a waiting period. When using the TIMER service, the Information Producer and Information Receiver fields shall refer to the same actor.*
- *REPEAT is used to indicate that a series of steps is repeated until a condition or trigger event. The condition is specified as the text in the "Event" column for this row or step. Following the word REPEAT, shall appear, in parenthesis, the first and last step numbers of the series to be repeated in the following form REPEAT(X-Y) where X is the first step and Y is the last step.*

5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE1	*Building information data*	*All information collected via sensors implemented in the building*	*R-SEC-1; R-SEC-2; R-QoS-1; R-QoS-2; R-DATA-1; R-DATA-2; R-DATA-3*
IE2	*Third-party data*	*All information collected by a third-party and accessed through SATO*	*R-SEC-1; R-SEC-2; R-QoS-1; R-QoS-2; R-DATA-1; R-DATA-2; R-DATA-3*
IE3	*Control actions*	*The data regarding the setpoints that will be implemented in the actuators*	*R-SEC-1; R-SEC-2; R-QoS-2; R-DATA-1; R-DATA-3*
IE4	*State of actuators*	*Current setpoints being implemented in the actuators*	*R-SEC-1; R-SEC-2; R-QoS-2; R-DATA-1; R-DATA-3*

6 Requirements

Requirements		
Categories ID	***Category name for requirements***	***Category description***
R-CONFIG	Configuration	Reflect the typical, probable, or envisioned communication configurations that are relevant to the use case step. These configuration issues include numbers of systems and/or components, expected growth of the system over time, locations, distances, communication types, network bandwidth, existing protocols, etc., but only from the user's point of view. In some cases, only one of the possible choices is reasonable, while for other situations, more than one choice is reasonable.
R-SEC	Security	Assess how different security measures applied to different items can potentially interact and either leave security holes or make user interfaces very laborious and possibly unworkable. Security must not only protect against the very harmful but quite rare deliberate attacks, but also against the far more likely inadvertent mistakes, failures, and errors. At the same time, it is necessary to try to identify the requirements and the concerns for implementing security measures.
R-COMP	Compatibility	Compatibility with other functions In the SATO Platform and external systems and components (e.g. 3rd party Clouds)
R-QoS	Quality of Service (QoS)	Address availability of the system, such as acceptable downtime, recovery, backup, rollback, etc. QoS issues also address accuracy and precision of data, the frequency of data exchanges, and the necessary flexibility for future changes.
R-DATA	Data Management	Covers both the management of the data exchanges in each Use Case step and the management of data at either end if that management is impacted by data exchanges. An example of the first type of data management is the initial setting up and ongoing maintenance of what data needs to be exchanged, say between a Geographic Information System and the many different applications that use its data. An example of the second type of data management is the need to backup data or ensure consistency of data whenever it is exchanged, such as if new protection settings are issued to multiple field devices, these settings need to be reflected in Contingency Analysis functions. It should not address database design but should concentrate on the user requirements for the interfaces to databases and other data handling applications.
Requirement R-ID	***Requirement name***	***Requirement description***
R-SEC-1	Data privacy	Ensuring confidentiality, avoiding illegitimate use of data, and preventing unauthorized reading of data, is quite important
R-SEC-2	Authentication	Ensuring that data comes from the stated source or goes to authenticated receiver is important.
R-QoS-1	Availability of information flows	Continuous availability not required but must be available at specific times or under specific conditions.

R-QoS-2	Accuracy of data requirements	Age of data needs to be known; Quality of data characterization is important.
R-DATA-1	Correctness of source data	Ensures that the data is correctly interpreted and used for the purpose it was designed to.
R-DATA-2	Management of accessing different types of data to be exchanged	Sets the type of data being exchanged and the expected periodic update (asynchronous or every x time).
R-DATA-3	Validation of data exchange	Guarantees that data exchanged between parties is valid. It can provide confirmation to the originally sending party.

7 Common Terms and Definitions

Common Terms and Definitions	
Term	***Definition***
CO_2	Carbon dioxide
KPI	Key performance indicator
V2G	Vehicle-to-grid

HLUC08 – Optimization of building energy efficiency

1. Description of the use case

1.1 Name of the use case

ID	*Area*	*Name of Use Case*
HLUC08	*(4) Self-optimization*	*Optimization of building energy efficiency*

1.2 Version management

Version No.	*Date*	*Name of Author (s)*	*Changes*
1.0	*05.05.21*	*Anna Marszal-Pomianowska*	*First version of HLUC8*
1.1	*24.05.21*	*João Bravo Dias*	*Review of v1.0of HLUC08*
1.2	*05/06/2021*	*Frederico Cardoso Melo*	*Review of v1.1 of HLUC08*
2.0	*14.06.2021*	*Anna Marszal-Pomianowska*	*Second version of HLUC0708*
3.0	*30.06.2021*	*João Dias, Filipe Silva*	*Third version of HLUC08*

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	HLUC08 is a High-Level Use Case (HLUC) focused on the energy efficiency (EE) optimization actions applied to the static and dynamic elements of building fabric, technical building equipment, appliances, and V2G charger and batteries. The EE actions have multi-objectives, i.e. together with optimizing the energy performance they should meet the energy cost and occupants' requirements for indoor environment quality (IEQ) and if applicable the self-consumption goals. **SATO Self-Optimization Services** will be deployed with the inputs received from the **SATO Self-Assessment Framework (SAF)**. The optimization fitness function will take into consideration energy costs while accommodating or even enhancing the IEQ needs identified in the **SATO Self-Assessment Framework**. The control strategies and setpoints identified in this use case will be applied through **SATO BMS** and **SATO APL.** The human actors involved in this HLUC are the **building owners, managers** and **building occupants**. Depending on the identified energy efficient strategy provided by **SATO Self-Optimization Services** the direct intervention will involve ether single human actor (i.e. **building occupant**) or multi human actors (i.e. **building manager** and **occupants**). They should be able to overwrite the **SATO Self-Optimization Services** commands, to ensure

	High-Level of comfort. In such cases, through **SATO APP** (HLUC07) the **building manager** or **occupants** may input their needs in **SATO BMS** and **SATO APL**, and **SATO Self-Optimization Services** adjusts the dynamic elements of building fabric, technical building equipment as well as legacy and smart appliances accordingly. Three Primary Use Cases (PUCs) will be derived from this HLUC. PUC8.1 "Self-Optimization of energy efficiency". PUC8.2 "Self-Optimization of energy costs". PUC8.3 "Self-Optimization of self-consumption". PUC8.1 and PUC 8.2 are related to the improvements of energy efficiency of: i) dynamic and static elements of building fabric ii) building equipment: single components, such like heat pumps and fans, iii) building equipment: system/installation, such like heating or ventilation installation iv) legacy and smart appliances, such like washing machines v) V2G charges and batteries. PUC8.3 is related to the optimization of consumption of energy produced on-site from renewable energy sources.
Objective(s)	The objectives of this HLUC are related to optimization of energy performance and costs of energy while maintaining or even enhancing IEQ and with maximizing the self-consumption of on-site generated energy. The following objectives were defined: 1. reduce *energy needs for heating, cooling, ventilation, domestic hot water, lighting* (e.g. by optimal operation of heat recovery on ventilation, of solar protections, of ceiling fans or by insulation of window shutters,) 2. optimize energy efficiency of equipment (e.g. reduce *delivered energy* per unit of *energy demand* covered) 3. optimize energy (kWh) and capacity (kW) costs 4. reduce *total primary energy use*, by increasing the efficiency of conversion of generation equipment 5. optimize self-consumption (e.g. reduce non-*renewable primary energy use)*

1.4 Narrative of use case

1.4.1 Narrative of High-Level use case

Narrative of Use Case
Short description
Optimization of building energy efficiency will be performed using **SATO Self-Optimization Services**. Real-time building and weather data are analysed and converted to key performance indicators in **SATO Self-Assessment Framework.** Together with inputs on energy cost will provide the necessary information to develop optimal strategies for building energy efficiency optimization. The optimal strategies will be developed with five objectives: 1-2) reduction of *energy needs for heating, cooling, ventilation, domestic hot water, lighting* and of *total primary energy use*, 3-5) optimization of energy efficiency of equipment, and of energy and capacity costs, and of self-consumption. Using SATO APP users will be able to define which of these strategies should be prioritized and applied first in their building.
Complete description
The HLUC - Optimization of building energy efficiency concerns the evaluation and definition of the best strategies to enhance the energy efficiency and optimize the energy costs of the SATO pilot buildings. These will be performed using the **SATO Self-Optimization Services** using the data obtained and generated by the **SATO Self-Assessment Framework**. The following steps are required for the implementation of this HLUC: 1. Receive the building performance (energy production, complete description of the building consumption, EV charging, indoor comfort conditions) self-assessment data from HLUC02. HLUC02 is responsible for the real-time self-assessment of the building energy performance and occupancy.

2. Receive the building performance (energy production, complete description of the building consumption, EV charging, indoor comfort conditions) forecasted data from HLUC03. HLUC03 is responsible for the forecast of the building performance and occupancy. 3. Evaluate the energy efficiency possibilities using the **SATO Self-Optimization Services**. The **SATO Self-Optimization Services** will consider the real-time self-assessment and the forecasted energy performance of the building to calculate the energy efficient actions in the building for the shorter (following hours) and longer term (measures to enhance use behaviour changes). 4. Communicate the available short-term energy efficiency measures to the Holistic optimal control of energy resources (HLUC14). HLUC14 will receive the available and forecasted energy efficiency measures and will evaluate it with the other self-optimization services. 5. Communicate the long-term energy efficiency measures to **SATO Platform** to be used by the **SATO Self-Assessment Framework** and **SATO APP**. The **SATO Platform** will receive the energy efficiency measures and **SATO APP** (HLUC07) will communicate to the users which behaviour and energy efficiency measures could be performed to enhance their energy performance.

1.4.2 Narrative of primary use cases

ID	*Name*	*Description*
PUC8.1	Self-Optimization of energy efficiency	PUC8.1 is related to the improvements of energy efficiency of i) dynamic and static elements of building fabric ii) building equipment: single components, such like heat pumps and fans, iii) building equipment: system/installation, such like heating or ventilation installation, iv) legacy and smart appliances, such like washing machines, v) V2G charges and batteries.
PUC8.2	Self-Optimization of energy costs	PUC 8.2 is related to the optimization of energy and capacity cost of i) dynamic and static elements of building fabric ii) building equipment: single components, such like heat pumps and fans, iii) building equipment: system/installation, such like heating or ventilation installation, iv) legacy and smart appliances, such like washing machines, v) V2G charges and batteries.
PUC8.3	Self-Optimization of self-consumption	PUC8.3 is related to the optimization of consumption of energy produced on-site from renewable energy sources (e.g. by reducing non renewable primary energy use)

1.5 Key performance indicators (KPI)

Optimization of building energy efficiency with objectives related to cost, IEQ and self-consumption performed for individual building equipment, building systems and appliances is related to almost all KPIs included in KPI tool developed in WP1.

Name	*Description*	*Reference to mentioned use case objectives*
Energy use for heating and cooling (hourly, daily, monthly, yearly)	Energy input to heating, cooling system to satisfy energy need for heating, cooling (ref. 3.4.18 in EN-ISO 52000-1:2017)	1-4
Energy use for domestic hot water (hourly, daily, monthly, yearly)	Energy input to DHW system to satisfy energy need for DHW (ref. 3.4.18 in EN-ISO 52000-1:2017)	1-4
Energy use for ventilation (hourly, daily, monthly, yearly)	Electric energy input to a ventilation system for air transport and heat recovery (ref. 3.4.19 in EN-ISO 52000-1:2017)	1-4
Energy use for lighting (hourly, daily, monthly, yearly)	Electric energy input to a lighting system (ref. 3.4.16 in EN-ISO 52000-1:2017)	1-4
Total primary energy use (hourly, daily, monthly, yearly)	Energy that has not been subjected to any conversion or transformation process, taking into account both non-renewable energy and renewable energy (ref. 3.4.29 in EN-ISO 52000-1:2017)	1-4

Renewable primary energy use/total primary energy use (which is equivalent to indicating the non-renewable primary energy use defined in EN ISO 52000)	Renewable energy consumed in the building	1-5
Numerical indicator of non-renewable energy use with compensation	Indicator of existing compensation for non-renewable energy consumption	1-5
Renewable Primary energy generated on-site	Renewable energy generated on-site	2-5
Renewable Primary energy generated on-site and Self consumed	Renewable energy generated on-site and self-consumed	2-5
Renewable Primary energy exported to the grid	Renewable energy generated on-site that was not self-consumed (injected into the public grid)	2.5
Non-Renewable Primary energy use without compensation	Non-renewable without compensation energy consumed	2-5
Non-Renewable Primary energy use with 100% compensation for exported energy (consumption minus on-site generation	n/d	2-5
Ratio of renewable primary energy over the total primary energy use (with and without compensation) (%)	n/d	2-5
Self-consumption of renewables	Ratio of renewable energy used over the total energy used by the building.	2-5
Load production to grid	On-site energy generated that was sold to the grid.	2-5
Load factor	Represents the percentage of the electrical demand covered by on-site electricity generation.	2-5
Costs for energy use	Represents the amount of money the users have to pay for their bills related to energy consumptions, divided by energy carrier (it can be also divided for different end uses or different domestic appliances). The users can easily understand and relate to costs.	4
CO_2 emissions	The amount of CO_2 equivalent caused by the energy use. A measure of how much carbon dioxide and how much the users might contribute to climate change is created. It is necessary to use national CO_2 conversion factors to translate the kWh of energy use from each energy carrier into the respective CO_2 emissions.	4
Load shift ability	Energy using device that can be used to offer flexibility services to the grid or to shift its load from peak hours to a period of the day with lower electricity prices (off-peak hours).	1-5
IEQ KPIs	n/d	1-5

1.6 Use case conditions

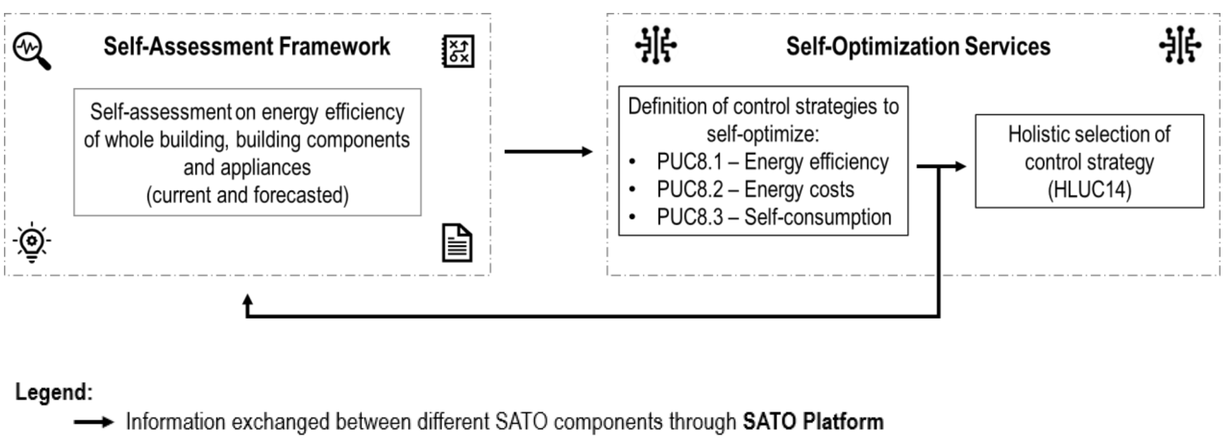
Use case conditions
Assumptions
The **SATO Platforms** and different IoT and Wi-Fi-based interfaces must be in operation. The **Facility/building managers**, **Building owners** or **Building occupants**, have given their consent for SATO to perform cloud managing of legacy and smart appliances and equipment (GDPR compliant)
Prerequisites
The building and weather data are collected and analysed in Self-Assessment and benchmarking *Link to* HLUC01, HLUC02, HLUC03

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
HLUC01 – Input from building and third-party data. HLUC02 – Self-Assessment is a prerequisite to perform the self-optimization. HLUC03 – Forecasting input on energy loads, occupancy and weather HLUC14 – Input to holistic optimal control of energy resources
Level of depth
HLUC08: Optimization of building energy efficiency PUC8.1: Self-Optimization of energy efficiency PUC8.2: Self-Optimization of energy costs PUC8.3: Self-Optimization of self-consumption
Prioritisation
This HLUC is a key part of the SATO objectives and will be implemented in all demo cases – High Priority
Generic, regional or national relation
Generic Use Case.
Nature of the use case
Technical Use Case
Further keywords for classification
self-optimization, energy efficiency, energy cost, multi-objectives, comfort, cost, data-driven,

2 Diagrams of use case

Diagram(s) of use cases



3. Technical details

3.1 Actors

Actors		
Actor Name	***Actor Type***	***Actor Description***
Facility/ building managers	*Human actor*	This actor has a direct role in this HLUC. His role is to make management decisions based on the optimization strategies proposal.

Building occupants	*Human actor*	This actor has a direct role in this HLUC. Their role is to consider behavioural changes and adapt the building conditions to their preferences. This indirect participation enables the system to react better to future scenarios.
SATO Self-Assessment Framework (SAF)	*Software/ systems/ applications/ devices*	SATO SAF will provide data regarding current performance, which can be analysed and used to develop optimization strategies.
SATO Self-Optimization Services	*Software/ systems/ applications/ devices*	SATO *Self-Optimization* Services will perform the optimization of energy efficiency and performance evaluation which will enable targeting of services.

3.2 References

References						
No.	***References type***	***Reference***	***Status***	***Impact on use case***	***Originator/ organization***	***Link***
1	Internal Document	SATO KPI tool reference list	n/a	Provision of KPI to be included	AAU	KPI tool
2	*Internal Document*	*SATO actors reference list*	*n/a*	*Provision of actors to be included*	*EDP NEW*	*Use Case Short Description V6.xlsx*
3	National energy carriers price level	Reference to relevant national statistics	n/a	Provision of electricity prices		

4. Step by step analysis of use case

4.1 Overview of scenarios

Scenarios conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
1.	Run optimization	Apply energy cost function and specific optimization objectives	SATO Self-optimization Framework	Periodically, however also continuously	Building in operation	Building in optimized operation

4.2 Steps – Scenarios

Scenario								
Scenario name:		***Reference scenario***						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirements, R-IDs***
1.1	*Receiving information of the building performance*	*Receiving SATO self-assessments*	***SATO Self-Optimization Services*** *collects information on the building performance from* ***SATO Platform.***	*GET*	*SATO Platform*	*SATO Self-Optimization Services*	*IE1*	R-QoS-1; R-SEC-4; R-SEC-5; R-DATA-3;
1.2	*Identifying energy efficiency actions through* ***SATO Self-optimization Services***	*Identification of energy efficiency actions*	***SATO Self-Optimization Services*** *identifies energy efficiency actions to be applied in the shorter (following hours) and longer (e.g. behaviour changes) terms.*	*CREATE*	*SATO Self-Optimization Services*	*SATO Self-Optimization Services*	-	-
1.3	*Communicating energy efficiency actions*	*Sending energy efficiency action*	*Sends energy efficiency actions to the* ***SATO Platform*** *to be sent to HLUC14 and HLUC07.*	*REPORT*	*SATO Self-Optimization Services*	*SATO Platform*	*IE2*	R-QoS-1; R-SEC-4; R-SEC-5; R-DATA-3;

(*) Available options are:

- *CREATE means that an information object is to be created at the Producer.*
- *GET (this is the default value if none is populated) means that the Receiver requests information from the Producer (default).*
- *CHANGE means that information is to be updated. Producer updates the Receiver's information.*
- *DELETE means that information is to be deleted. Producer deletes information from the Receiver.*
- *CANCEL, CLOSE imply actions related to processes, such as the closure of a work order or the cancellation of a control request.*
- *EXECUTE is used when a complex transaction is being conveyed using a service, which potentially contains more than one verb.*
- *REPORT is used to represent transferral of unsolicited information or asynchronous information flows. Producer provides information to the Receiver.*
- *TIMER is used to represent a waiting period. When using the TIMER service, the Information Producer and Information Receiver fields shall refer to the same actor.*
- *REPEAT is used to indicate that a series of steps is repeated until a condition or trigger event. The condition is specified as the text in the "Event" column for this row or step. Following the word REPEAT, shall appear, in parenthesis, the first and last step numbers of the series to be repeated in the following form REPEAT(X-Y) where X is the first step and Y is the last step.*

5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE1	*Building performance information*	*Information regarding building performance sent by the* ***SATO Platform*** *to the* ***SATO Self-Optimization Services***	R-SEC-1; R-SEC-2; R-SEC; R-SEC-3; R-SEC-4; R-SEC-5; R-DATA-1; R-DATA-2; R-DATA-3;
IE2	*Energy Efficiency actions*	***SATO Self-assessment Framework*** *will send energy efficiency actions to the SATO Platform that will be further assessed in HLUC14.*	R-SEC-1; R-SEC-2; R-SEC; R-SEC-3; R-SEC-4; R-SEC-5; R-DATA-1; R-DATA-2; R-DATA-3;

6 Requirements

Requirements		
Categories ID	***Category name for requirements***	***Category description***
R-CONFIG	Configuration	Reflect the typical, probable, or envisioned communication configurations that are relevant to the use case step. These configuration issues include numbers of devices and/or systems, expected growth of the system over time, locations, distances, communication types, network bandwidth, existing protocols, etc., but only from the user's point of view. In some cases, only one of the possible choices is reasonable, while for other situations, more than one choice is reasonable.
R-SEC	Security	Assess how different security measures applied to different items can potentially interact and either leave security holes or make user interfaces very laborious and possibly unworkable. Security must not only protect against the very harmful but quite rare deliberate attacks, but also against the far more likely inadvertent mistakes, failures, and errors. At the same time, it is necessary to try to identify the requirements and the concerns for implementing security measures.
R-COMP	Compatibility	Compatibility with other functions.
R-QoS	Quality of Service (QoS)	Address availability of the system, such as acceptable downtime, recovery, backup, rollback, etc. QoS issues also address accuracy and precision of data, the frequency of data exchanges, and the necessary flexibility for future changes.
R-DATA	Data Management	Covers both the management of the data exchanges in each Use Case step and the management of data at either end if that management is impacted by data exchanges. An example of the first type of data management is the initial setting up and on- going maintenance of what data needs to be exchanged, say between a Geographic Information System and the many different applications that use its data. An example of the second type of data management is the need to backup data or ensure consistency of data whenever it is exchanged, such as if new protection settings are issued to multiple field devices, these settings need to be reflected in Contingency Analysis functions. It should not address database design but should concentrate on the user requirements for the interfaces to databases and other data handling applications.
Requirement R-ID	***Requirement name***	***Requirement description***
R-SEC-1	Eavesdropping	Ensuring confidentiality, avoiding illegitimate use of data, and preventing unauthorized reading of data
R-SEC-2	Information integrity violation	Ensuring that historical data is not changed or destroyed
R-SEC-3	Authentication: Masquerade and/or spoofing	Ensuring that data comes from the stated source or goes to authenticated receiver
R-SEC-4	Replay	Ensuring that data cannot be resent by an unauthorized source
R-SEC-5	Information theft	Ensuring that data cannot be stolen or deleted by an unauthorized entity
R-DATA-1	Type of source data	Source data was calculated or output by **SATO SAF**
R-DATA-2	Correctness of source data	Source data is always correct (e.g. by definition)

R-DATA-3	Validation of data exchanges	Data can be assumed as valid (or validity checking is handled elsewhere);

7 Common Terms and Definitions

Should be defined in a common glossary for all use cases. Here relevant terms belonging to this use case are listed. Using a database repository for the glossary, the definitions might be filled automatically based on existing information.

Common Terms and Definitions	
Term	*Definition*
EE	Energy efficiency
IEQ	indoor environment quality
V2G	Vehicle to grid

HLUC09 – Improving building indoor environmental quality

1. Description of the use case

1.1 Name of the use case

ID	*Area*	*Name of Use Case*
HLUC9	*(4) Self-optimization*	*Improving building indoor environmental quality*

1.2 Version management

Version No.	*Date*	*Name of Author (s)*	*Changes*
1.0	*24.05.21*	*Andrea Sangalli*	*First draft*
1.1	*27.05.21*	*Filipe Neves Silva*	*Review of version 1.0*
1.2	*07.06.21*	*Andrea Sangalli*	*Revised version of HLUC09*
1.3	*10.06.21*	*Per Heiselberg*	*Review of version 1.2*
1.4	*28.06.21*	*Andrea Sangalli, Lorenzo Pagliano*	*Revised version of HLUC09*
1.5	*28.06.21*	*Anna Marszal-Pomianowska*	*Review of version 1.4*
2.0	*30.06.21*	*Andrea Sangalli, Lorenzo Pagliano*	*Second version of HLUC09*
3.0	*01.07.21*	*João Dias, Filipe Silva*	*Third version of HLUC09*

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	HLUC09 is a High-Level Use Case (HLUC) that will leverage on the **SATO Self-Optimization Services** to improve the building's Indoor Environmental Quality (IEQ), which refers to the quality of a building's environment in relation to the health and wellbeing of those who occupy a space within it. The **SATO Self-Optimization Service** will consider thermal, visual and acoustic comfort, as well as indoor air quality (IAQ), with a data-driven approach based on the available sensors in the building and on post occupancy evaluation (POE) carried out via the **SATO APP**. The comfort assessment will be based (i) on the selected comfort thresholds as codified in international standards and guidelines; (ii) on the feedback of building occupants/manager on indoor conditions, in order to aim at parallel achievement of energy efficiency and occupants' comfort. The **SATO Self-Assessment Framework** will consider both these aspects (comfort models and users' feedback), comparing them to identify discrepancies and their sources (issues related to building fabric, building systems (active and passive) or related to monitoring systems (too poor quality/quantity of data to perform a reliable comfort assessment) improper users' behaviour and expectations, gaps in technical standards) and take related

	actions via **SATO Self-Optimization Services** to define better setpoints for building energy efficiency while improving comfort and indoor air quality and/or to provide recommendations to users, depending on the kind of building (residential of office/retail). Four Primary Use Cases (PUCs) will be derived from this HLUC. PUC9.1 is named "Improve thermal comfort" PUC9.2 is named "Improve indoor air quality" PUC9.3 is named "Improve visual comfort" PUC9.4 is named "Improve acoustic comfort"
Objective(s)	The objectives of this HLUC are related to improve building occupant comfort, concerning 1. Improve thermal comfort 2. Improve indoor air quality 3. Improve visual comfort 4. Improve acoustic comfort

1.4 Narrative of use case

1.4.1 Narrative of High-Level use case

Narrative of Use Case
Short description
The SATO Self-optimization use case *Improving building indoor environmental quality* will consider thermal, visual and acoustic comfort, as well as indoor air quality (IAQ), according to the available sensors in the building. The thermal comfort assessment will be based on the selected comfort categories of the thermal comfort models as codified in international standards and on the feedback of building occupants/manager on indoor conditions. This use case contributes to the parallel achievement of energy efficiency and occupants' comfort.
Complete description
The revised Energy performance of buildings directive (2018/844/EU) emphasizes the need to improve the indoor comfort and wellbeing of occupants in parallel to the energy performance. IEQ, which includes thermal comfort, acoustic comfort, visual comfort and indoor air quality, has in fact a major impact on building occupant health, comfort and work performance. One of the main goals of the **SATO Platform** is to guarantee the selected levels of IEQ in the occupied zones of the building, while minimizing the use of energy. Therefore, the **SATO Self-Optimization Services** must first check all the passive/low energy strategies and in case they don't suffice to achieve the selected comfort scenario (according to the assessment provided by HLUC09), switch to active systems (optimized to be efficient in HLUC08) for the shortest period necessary. The defined PUCs represent the four aspects taken into account in this HLUC (thermal, visual and acoustic comfort, and IAQ). The interactions between the PUCs will be taken into account, e.g. if PUC9.1 (thermal comfort) requires to activate natural ventilation, this can be done (when occupants are present, e.g. during the day in an office) only if outdoor pollutant level (PUC9.2) and outdoor noise (PUC9.4) are below the respective thresholds so that the output command will comply with the requirements of all PUCs. This HLUC requires the use of hardware: actuators, sensors, and gateways, that will provide the required control and communication capacities. This hardware is able to change the state/setpoint of equipment to implement passive strategies such as operation of solar protections/shading devices and automated windows, if available. Control commands developed by **SATO Self-Optimization Services,** including those related to comfort developed in HLUC09, will be evaluated in HLUC14 and filtered for a correct application, ensuring user and system preferences are considered. The following steps map the necessary actions to implement this HLUC: 1. Receive historical, real-time and forecasted building performance, comfort conditions and weather data from the Self-Assessment Framework (HLUC02, HLUC03) 2. Elaborate the output commands according to the defined priorities regarding the different health and comfort parameters; 3. Communicate the output command to HLUC14 (Holistic optimal control of energy resources) for its evaluation and potential implementation in HLUC15 (Cloud managing of legacy and smart appliances and equipment).

1.4.2 Narrative of primary use cases

ID	*Name*	*Description*

PUC9.1	Improve thermal comfort	The scope of this PUC is to guarantee adequate indoor thermal comfort to the building occupants, based on thermal comfort models, KPIs and thresholds and taking into account occupants' feedback.
		A possible procedure for this PUC is described below.
		The general functioning of the Building Management System (BMS) is set on passive/low energy strategies and on ADAPTIVE model indicators and thresholds. Therefore,
		
		1) in summer the following strategies examples might be deployed:
		- Management of solar protections to guarantee the minimum requirement of illuminance and minimize solar gains (ref. PUC9.3)
		- Natural ventilation (during day and night) (checking outdoor temperature compared to indoor temperature, outdoor air velocity, relative humidity (RH), rain, also outdoor pollution and noise if deemed necessary – e.g. an unoccupied building at night might be ventilated irrespective of the outside noise levels - and the information is available) (refer to HLUC13)
		- Exploitation of thermal mass for reducing the indoor daily temperature oscillations (ref. HLUC12)
		- IF despite passive/low energy strategies, discomfort occurs according to comfort thresholds AND occupants' feedback (according to ***significant*** occupants' feedback and its assessment and advice to users as by comfort experts within SATO and later available locally at the building manager level OR, in absence of that, on adaptive comfort thresholds):
		    o Activate ceiling fans for *comfort ventilation* (increase air velocity - see Reference 7 (Givoni)) during day, mechanical ventilation at high air changes per hour (ACH) at night for free cooling and thermal mass storage)
		    o Activate Earth-to-air heat exchanger, or other passive and low energy cooling strategies if present – *in that case they would deserve a dedicated HLUC*
		
		2) In winter the following strategies examples might be deployed:
		- Management of solar protections to maximize solar gains without glare in occupied spaces (ref. PUC9.3)
		- Exploitation of thermal mass for maximizing the use of solar and internal heat gains (ref. HLUC12)
		- Activate Earth-to-air heat exchanger, or other passive and low energy heating strategies if present – *they would deserve a dedicated HLUC*
		
		3) IF, despite all of the above, discomfort occurs according to comfort thresholds AND occupants' feedback (according to **significant** occupants' feedback and its assessment and advice to users as by comfort experts within SATO and later available locally at the building manager level OR, in absence of that, on adaptive comfort thresholds), THEN activate heating/cooling system and switch to FANGER model. However, use of Adaptive comfort scenarios for controls also when heating, ventilation and air conditioning (HVAC) is operating is possible and has been successfully tested (see Reference 8 (Tartarini))
		
		Coordination with flexibility objectives:
		(to be performed by HLUC14, which will consider all SATO Self-Optimization strategies and define which one should be applied)
		In summer: when activating active cooling systems,-,**SATO Self-Optimization Services** should consider the use of thermal mass to shift load to hours where on site renewables are available e.g. from photovoltaic (PV), or away from system peak load, in a way which allows indoor conditions to remain within the range of the selected comfort scenario of HLUC09.
		
		In winter: when activating active heating systems, **SATO Self-Optimization Services** should consider the use of thermal mass to shift load to hours where on site renewables are available, e.g. from PV, or away from system peak load, in a way which allows indoor conditions to remain within the range of the selected comfort scenario of HLUC09.

PUC9.2	Improve indoor air quality	The scope of this PUC is to guarantee adequate indoor air quality levels to the building occupants and avoid the sick building syndrome (SBS), based on IAQ KPIs and thresholds and taking into account occupants' feedback. A possible procedure for this PUC is described below. -IF IAQ does not fulfil one of the KPIs thresholds OR based on occupants' feedback, - and IF possible, according to thermal comfort (ref. PUC9.1) (checking outdoor temperature compared to desired indoor temperature, outdoor air velocity, RH, rain, also outdoor pollution and noise if deemed necessary and the information is available) -THEN activate natural ventilation. IF natural ventilation is not possible, THEN activate mechanical ventilation (with filtration if outdoor air pollution is present).
PUC9.3	Improve visual comfort	The scope of this PUC is to guarantee adequate indoor visual comfort to the building occupants, based on visual comfort KPIs and thresholds and taking into account occupants' feedback. A possible procedure for this PUC is described below. - IF presence of occupants is detected or based on a fixed schedule (periodically verified and adapted by the building manager) -IF visual comfort does not fulfil one the KPIs thresholds OR based on occupants' feedback, -and if possible, according to thermal comfort (ref. PUC9.1) (checking outdoor solar irradiance) -THEN operate solar protections accordingly or give advice to occupants/building manager IF the above is not possible or sufficient, THEN turn on/off artificial lighting based on occupants' presence/absence.
PUC9.4	Improve acoustic comfort	The scope of this PUC is to guarantee adequate indoor acoustic comfort to the building occupants, based on acoustic comfort KPIs and thresholds and taking into account occupants' feedback. An example procedure for this PUC is described below, in case of noise from outside: - IF presence of occupants is detected or based on a fixed schedule (periodically verified and adapted by the building manager) - IF natural ventilation is on AND, due to outdoor noise, acoustic comfort does not fulfil one the KPIs thresholds OR based on occupants' feedback, -THEN close the windows / dedicated ventilation openings or give advice to occupants/building manager.

1.5 Key performance indicators (KPI)

Name	***Description***	***Reference to mentioned use case objectives***
Percentage of time outside an operative temperature range (Adaptive)	Calculate the number or percentage of hours, during the hours the building is occupied, the operative temperature is outside a specified range calculated according to the adaptive thermal comfort model	1
Percentage of time outside an operative temperature range (Fanger)	Calculate the number or percentage of hours, during the hours the building is occupied, the operative temperature is outside a specified range defined according to the Fanger comfort model	1
Degree-hours (Adaptive)	The time during which the actual operative temperature exceeds the specified range (calculated according to the adaptive thermal comfort model) during the occupied hours is weighted with a factor which is a function of how many degrees the range has been exceeded	1
Degree-hours (Fanger)	The time during which the actual operative temperature exceeds the specified range (defined according to the Fanger comfort model) during the occupied hours is weighted with a factor which is a function of how many degrees the range has been exceeded	1
Number of hours within a certain temperature range	Calculate the number of hours during which the operative temperature is within a certain temperature range	1

Daylight Autonomy (DA)	It is a metric defined as the fraction of occupied time of a day, week, month, or a year, that the daylight levels exceed a specified target illuminance, 300 lux	3
Useful Daylight Illuminance (UDI)	It is the illumination of indoor spaces by natural light, calculated by means of UDI, which is defined as the fraction of the time in a year when indoor horizontal daylight illuminance at a given point falls in a given range. 100 lux is often used as the lower threshold of useful illuminance, and 2000 lux as the upper bound	3
HVAC noise level	Measured sound pressure level in the receiving room from all sources except the loudspeaker in the source room. Reference: (HVAC) systems per 2011 ASHRAE Handbook, HVAC Applications, Chapter 48, Table 1; AHRI Standard 885-2008, BS 8233:2014; or a local equivalent	4

Users' feedback on indoor environmental quality

The feedback of building occupants/manager on indoor conditions will be acquired by the **SATO APP** and sent to the **SATO Platform** as an input data for the optimization of the control strategies, to aim at parallel achievement of energy efficiency and occupants' comfort. Two main categories of feedback can be identified:

- ***Direct/active/intrusive users' feedback**:* Feedback actively provided by users answering to a web or app-based questionnaire related to indoor environmental quality. This input can be qualitative or quantitative (e.g. expressed through the ASHRAE seven-points thermal sensation scale). The feedback can be requested to the users (e.g. a notification asking periodically to provide a feedback) or be voluntary (e.g. to highlight a discomfort issue). It is important to identify and record the time and place where the user provides a feedback, to allow **SATO Platform** to properly interpret the data.
- ***Indirect/passive/nonintrusive users' feedback**:* Users' actions of adjustment of building components (e.g. windows, solar protections) and equipment (e.g. changing the setpoint of heating/cooling) are recorded to identify behavioural patterns to support comfort assessment and optimization. This indirect feedback may be followed by the request from **SATO APP** to be sent to **SATO Platform** to provide a direct feedback to allow it to properly interpret the data (e.g. the user closes a window and after it receives a notification from the APP to understand the reason for that action: outdoor noise, too cool temperature, too high air velocity, rain, etc.). It is important to identify and record the time and place where the user provides a feedback, to allow **SATO Platform** to properly interpret the data.

Variables continuously monitored

These are physical quantities that are continuously monitored and acquired by the **SATO Platform** (i) to calculate the KPIs and (ii) as input data in the control logics (e.g. in summer. The logic: "if indoor air temperature is outside comfort range for 30 minutes, then activate ceiling fans" requires that we monitor HERE and NOW the temperature). Some examples of variables related to this HLUC are reported below and will be furtherly detailed in SATO WP3.

- ***Indoor variables:*** *indoor air temperature, indoor air velocity in the occupied zone, indoor luminance, indoor relative humidity, indoor CO_2 concentration.*
- ***Outdoor variables:*** *outdoor air temperature, solar irradiance, wind speed, rain, outdoor CO_2 concentration (since indoor thresholds are defined taking outdoor CO_2 levels as a reference).*

Metadata

This information is not continuously monitored, but acquired during the construction phase or in the commissioning phase right after the construction of the building, or periodically during the building operation and is provided to the **SATO Platform** as meta-KPIs to characterize the building as a physical object (like done for other physical information like U-values, g-values, window-to-wall ratio, etc.) and its operation. Metadata should be preferably measured (even only once) values, when possible, or values declared by the manufacturer (based on what has been actually installed), or calculated/simulated after construction (based on what has been actually installed), e.g. the energy needs calculated for the Energy Performance Certificate of the building. If the options above are not available, design parameters can be considered, but with their clear identification as design values, since they may have not been transferred in the as-built construction.

Name	***Description***	***Reference to mentioned use case objectives***
Relaxed Clothing code (YES/NO)	A number of Organisation (from UN to large financial institutions, e.g. under the "CoolFashion" campaign of Japanese Government) support light dressing in summer and warm dressing in winter in their buildings, in order to set thermostat to a less energy-demanding level, with the same level of comfort (see also Reference 9 (IEA Outlook 2020), where this is one of the measures of the Net Zero Emissions Path)	1

Presence of Operable windows or other openings for natural ventilation (YES/NO). accessible to occupants (YES/NO) for comfort ventilation	Based on new data availability (ASHRAE Global Comfort database) in the recent revision of ASHRAE 55 (2020) air velocity has been included as a key parameter for comfort both in the adaptive and Fanger + SET methods	1, 2, 4
Presence of ceiling fans (YES/NO operable under control of occupants (YES/NO)	Based on new data availability (ASHRAE Global Comfort database) in the recent revision of ASHRAE 55 (2020) air velocity has been included as a key parameter for comfort both in the adaptive and Fanger + SET methods	
Organic compound	Formaldehyde (systematic name methanal) is a naturally occurring organic compound polychlorinated biphenyl (PCB) is an organic chlorine compound with the formula	2
Inorganic gases (other than CO_2)	Carbon monoxide (CO), Nitrogen dioxide (NO_2), Sulfur Dioxide SO_2, Ozone O_3	2
VOCs	Volatile organic compounds (VOC) are organic chemicals that have a high vapour pressure at room temperature. High vapor pressure correlates with a low boiling point, which relates to the number of the sample's molecules in the surrounding air, a trait known as volatility	2
Particulates (filtration)	defined as atmospheric aerosol particles, atmospheric particulate matter, particulate matter (PM), or suspended particulate matter (SPM)	2
Reverberation time	Time required for the sound pressure level in a room to decrease by 60 dB after the sound source has stopped. Reference: EN ISO 354:2003	4
Equivalent continuous sound Level	It is the constant noise level that would result in the same total sound energy being produced over a given period	4
Glare control	Glare control indexes that are used to assess daylight spaces for large-area sources of daylight glare such as glazed façades. In particular: -Daylight Glare Probability (DGP) is used to quantify the percentage probability of glare perception, developed for an office room under daylight conditions. -Daylight glare index (DGI) aims at predicting glare from large sources, such as a window, described by its luminance	3
Airborne sound insulation	Sound reduction index: Dw represents the sound insulation between rooms on-site; Rw represents the lab tested sound insulation of an element making up a partition wall/floor type. Reference: EN ISO 16283:2014, EN ISO 354:2003	4
Noise from hydraulic systems	There is a Standard about this	4

1.6 Use case conditions

Use case conditions
Assumptions
The **SATO Platforms** and different IoT and Wi-Fi-based interfaces must be in operation. The **Facility/building managers**, **Building owners** or **Building occupants**, have given their consent for SATO to perform monitoring of comfort and IAQ parameters and cloud managing of building components and equipment (GDPR compliant)
Prerequisites
*The monitoring system with a minimum set of sensors is correctly installed and connected to the **SATO Platform**.* *To enable the automation of passive strategies, actuators must be available and connected to the **SATO Platform**, e.g. concerning solar protections and windows.* HLUC01, HLUC02, HLUC03

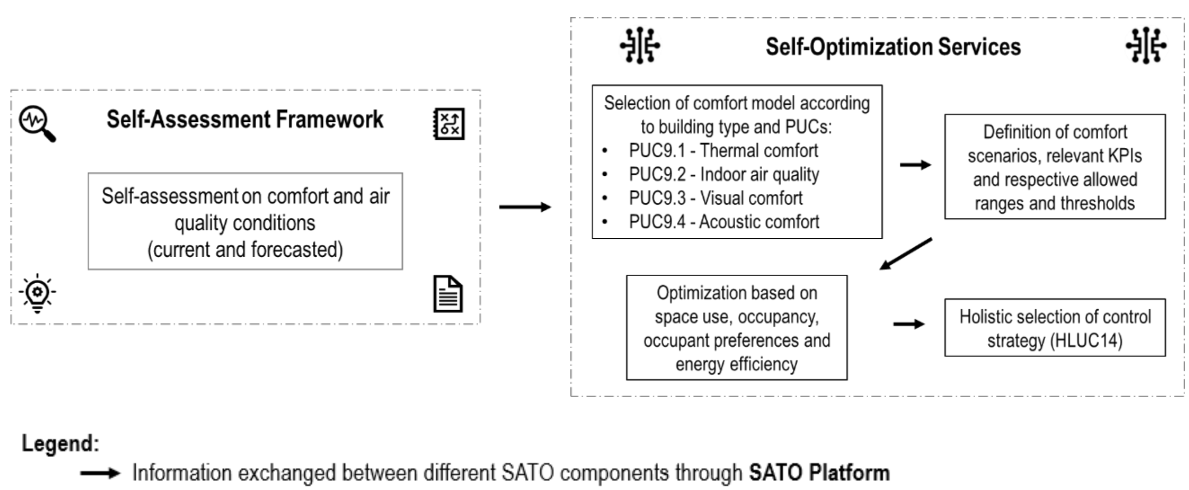
1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
HLUC01 – Monitoring is a prerequisite for the definition of smart-optimization strategies and hence, the application of those strategies *HLUC02 – Data driven self-assessment diagnosis of building performance*

HLUC03 – Forecasts performed by the self-assessments will be used *HLUC14 - Holistic optimal control of energy resources*
Level of depth
HLUC09: Improving building indoor environmental quality *PUC9.1:* Improve thermal comfort *PUC9.2:* Improve indoor air quality *PUC9.2:* Improve visual comfort *PUC9.2:* Improve acoustic comfort
Prioritisation
This HLUC is considered of high priority to SATO as it is meant to guarantee comfort conditions to building occupants.
Generic, regional or national relation
Generic Use Case
Nature of the use case
Technical Use Case
Further keywords for classification
Sensor, monitoring, comfort, thermal comfort, acoustic comfort, visual comfort, indoor air quality, IAQ, self-assessment, self-optimization

2 Diagrams of use case

Diagram(s) of use cases



3. Technical details

3.1 Actors

Actors		
Actor Name	***Actor Type***	***Actor Description***
SATO Self-Assessment Framework (SAF)	*Software/ systems/ applications/ devices*	*SATO SAF acquires indoor and outdoor sensors' data, calculate in real-time the predefined relevant comfort KPIs and compare them with the predefined thresholds, to determine the current comfort level*
SATO Self-Optimization Services	*Software/ systems/ applications/ devices*	*SATO Self-optimization Services will acquire the result of the comfort assessment coming from SATO SAF and, taking into account other constraints (such as comfort model, energy use,*

		energy cost, CO_2 emissions, available passive strategies, information about HVAC systems (power, inertia, …), information about the building fabric, available energy flexibility (coming from HLUC11 & 12)) will determine the optimal comfort strategy
Facility/ building managers	*Human actor*	*Human actor can provide feedback, using **SATO APP**, to the automation implemented by **SATO BMS** and **SATO APL** coming from the SATO Services.* The **SATO Self-Assessment Framework** will consider those inputs, comparing them with the expected comfort levels according to comfort models, to identify discrepancies and their sources (issues related to building systems (active and passive) or in monitoring systems (too poor quality/quantity of data to perform a reliable comfort assessment) improper users' behaviour and expectations, gaps in technical standards) and take related actions via **SATO Self-Optimization Services** to define better setpoints for building energy efficiency while improving comfort and indoor air quality.
Building occupants	*Human actor*	

3.2 References

References						
No.	***References type***	***Reference***	***Status***	***Impact on use case***	***Originator/ organization***	***Link***
1	*Internal Document*	*SATO KPI tool reference list*	*n/a*	*Provision of KPI to be included*	*AAU*	KPI tool
2	*Internal Document*	*SATO actors reference list*	*n/a*	*Provision of actors to be included*	*EDP NEW*	*Use Case Short Description V6.xlsx*
3	*Standard*	*EN 16798-1:2019 Energy performance of buildings - Ventilation for buildings. Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics - Module M1-6*	*current*	*Reference for comfort and IAQ assessment*	*CEN*	
4	*Standard*	*CEN/TR 16798-2:2019 - Energy performance of buildings - Ventilation for buildings. Part 2: Interpretation of the requirements in EN 16798-1 - Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics (Module M1-6)*	*current*	*Reference for comfort and IAQ assessment*	*CEN*	
5	*Standard*	*ASHRAE 55:2020 Thermal Environmental Conditions for Human Occupancy*	*current*	*Reference for comfort and IAQ assessment*	*ANSI/ASHRAE*	
6	*Public report*	*Erba S, Barbieri A, Pagliano L, ABC21 – D3.2 Report on comfort indicators and scenarios, 2021*	*n/a*	*Literature review on IEQ assessment*	*ABC21 European Project*	
7	*Paper*	*Givoni B. Performance and applicability of passive and low-energy cooling systems. Energy and Buildings. 1991 Jan 1;17(3):177–99.*	*n/a*	*Reference for comfort ventilation concept mentioned in PUC9.1 description and other passive or low-energy strategies*		

8	*Paper*	*Tartarini F, Schiavon S. pythermalcomfort: A Python package for thermal comfort research. SoftwareX. 2020 Jul;12:100578.*	*n/a*	*Reference showing that it I possible and has been successfully tested to use Adaptive comfort scenarios for controls also when HVAC is operating*		
9	*Report*	*https://www.iea.org/reports/world-energy-outlook-2020/achieving-net-zero-emissions-by-2050#abstract*	*n/a*	*Reference for behavioural change required for climate protection, including in buildings*		

4. Step by step analysis of use case

4.1 Overview of scenarios

Scenarios conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
1	*Assess and optimize occupants' comfort*	*Using the comfort levels assessed by the **SATO Self-Assessment Framework,** the* **SATO Self-Optimization Services** will elaborate multi-objective comfort-based optimization strategies	**SATO Self-Optimization Services**	*Comfort is continuously assessed in occupied building spaces, at a predefined timestep*	*Existence of monitored data from sensors and users' feedback from **SATO APP***	*Passive/low energy/active building components will be controlled*

4.2 Steps – Scenarios

Scenario								
Scenario name:		***Reference scenario***						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirements, R-IDs***
1.1	*Receiving information of the assessment*	*Receiving SATO Self-Assessments*	**SATO Self-Optimization Services** collects information on the building performance from **SATO Platform**.	GET	*SATO Platform*	*SATO Self-Optimization Services*	*IE1*	*R-DATA-1; R-QoS-1;*
1.2	*Elaborating output commands*	*Elaborating output commands*	**SATO Self-Optimization Services** elaborate the output commands according to the rules written in the PUCs of this HLUC09 and according to the defined priorities among the PUCs	CREATE	*SATO Self-Optimization Services*	*SATO Self-Optimization Services*	*IE2*	*R-CONFIG-1; R-DATA-1; R-COMP-1; R-SEC-1; R-SEC-2; R-SEC-3;*
1.3	*Sending output commands*	*Sending output commands*	**SATO Self-Optimization Services** communicate the output commands to **SATO Platform**, namely HLUC14 (Holistic optimal control of energy resources) for its evaluation and potential implementation in HLUC15 (Cloud managing of legacy and smart appliances and equipment).	REPORT	*SATO Self-Optimization Services*	*SATO Platform (HLUC14)*	*IE2*	*R-CONFIG-1; R-DATA-1; R-COMP-1; R-SEC-1; R-SEC-2; R-SEC-3;*

(*) Available options are:

- *CREATE means that an information object is to be created at the Producer.*
- *GET (this is the default value if none is populated) means that the Receiver requests information from the Producer (default).*
- *CHANGE means that information is to be updated. Producer updates the Receiver's information.*
- *DELETE means that information is to be deleted. Producer deletes information from the Receiver.*
- *CANCEL, CLOSE imply actions related to processes, such as the closure of a work order or the cancellation of a control request.*
- *EXECUTE is used when a complex transaction is being conveyed using a service, which potentially contains more than one verb.*
- *REPORT is used to represent transferral of unsolicited information or asynchronous information flows. Producer provides information to the Receiver.*
- *TIMER is used to represent a waiting period. When using the TIMER service, the Information Producer and Information Receiver fields shall refer to the same actor.*
- *REPEAT is used to indicate that a series of steps is repeated until a condition or trigger event. The condition is specified as the text in the "Event" column for this row or step. Following the word REPEAT, shall appear, in parenthesis, the first and last step numbers of the series to be repeated in the following form REPEAT(X-Y) where X is the first step and Y is the last step.*

5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE1	*Comfort levels*	*Comfort levels assessed by SATO Self-Assessment framework*	*R-DATA-1; R-QoS-1*
IE2	*Output commands*	*Output commands generated by SATO Self Optimizations Services*	*R-CONFIG-1; R-DATA-1; R-COMP-1; R-SEC-1; R-SEC-2; R-SEC-3*

6 Requirements

Requirements		
Categories ID	***Category name for requirements***	***Category description***
R-CONFIG	Configuration	Reflect the typical, probable, or envisioned communication configurations that are relevant to the use case step. These configuration issues include numbers of devices and/or systems, expected growth of the system over time, locations, distances, communication types, network bandwidth, existing protocols, etc., but only from the user's point of view. In some cases, only one of the possible choices is reasonable, while for other situations, more than one choice is reasonable.
R-SEC	Security	Assess how different security measures applied to different items can potentially interact and either leave security holes or make user interfaces very laborious and possibly unworkable. Security must not only protect against the very harmful but quite rare deliberate attacks, but also against the far more likely inadvertent mistakes, failures, and errors. At the same time, it is necessary to try to identify the requirements and the concerns for implementing security measures.
R-COMP	Compatibility	Compatibility with other functions.
R-QoS	Quality of Service (QoS)	Address availability of the system, such as acceptable downtime, recovery, backup, rollback, etc. QoS issues also address accuracy and precision of data, the frequency of data exchanges, and the necessary flexibility for future changes.
R-DATA	Data Management	Covers both the management of the data exchanges in each Use Case step and the management of data at either end if that management is impacted by data exchanges. An example of the first type of data management is the initial setting up and on- going maintenance of what data needs to be exchanged, say between a Geographic Information System and the many different applications that use its data. An example of the second type of data management is the need to backup data or ensure consistency of data whenever it is exchanged, such as if new protection settings are issued to multiple field devices, these settings need to be reflected in Contingency Analysis functions. It should not address database design but should concentrate on the user requirements for the interfaces to databases and other data handling applications.
Requirement R-ID	***Requirement name***	***Requirement description***
R-CONFIG-1	Data exchange methods	Data exchange from sensors to SATO Platform and from SATO Platform to actuators
R-DATA-1	Management of large volumes of data being exchanged	Some part of step involves handling large volumes of data
R-COMP-1	Compatibility	Compatibility with other functions to exchange data with related HLUCs.
R-QoS-1	Availability of information flows	Continuous availability is crucial
R-SEC-1	Data privacy	Ensuring confidentiality, avoiding illegitimate use of data, and preventing unauthorized reading of data, is quite important
R-SEC-2	Eavesdropping	confidentiality, avoiding illegitimate use of data, and preventing unauthorized reading of data
R-SEC-3	User roles	Set distinct roles for the user (general, administrator, etc) to allow the protection of sensitive information like e.g. indoor temperatures, CO_2 levels, occupation in the apartments.

7 Common Terms and Definitions

Common Terms and Definitions	
Term	**Definition**
ACH	Air changes per hour
Cx	Building commissioning
HVAC	heating, ventilation and air conditioning
IAQ	Indoor air quality
IEQ	Indoor environmental quality
PAQ	Perceived air quality
POE	Post occupancy evaluation
RH	Relative Humidity
SBS	Sick Building Syndrome

HLUC10 – Providing grid flexibility services to an energy aggregator

1. Description of the use case

1.1 Name of the use case

ID	Area	Name of Use Case
HLUC10	*(4) Self-optimization*	*Providing grid flexibility services to an energy aggregator*

1.2 Version management

Version No.	Date	Name of Author (s)	Changes
1.0	*DD.MM.JJ*	*João Bravo Dias, Filipe Neves Silva*	*First version of HLUC10*
1.1	*04.06.2021*	*João Simões*	*Revised version of HLUC10*
1.2	*31.05.21*	*Andrea Sangalli, Lorenzo Pagliano*	*PoliMi review of HLUC10*
2.0	*01.07.21*	*Filipe Silva, João Dias*	*Second version of HLUC10*

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	HLUC10 is a High-Level Use Case (HLUC) focused on the self-optimization performed by **SATO Self-Optimization Services** to determine the flexibility potential of a building, provide that information to be exploited by an energy aggregator, and ultimately increase the revenue streams for **building owners** and **facility managers.** This HLUC is linked with several SATO software functionalities such as the **SATO Self-Assessment Framework** and **SATO Self-Optimization Services**, requiring direct communication with an energy **aggregator**, which will be the one exploring the flexibility potential.
Objective(s)	The objectives of this HLUC are related with the provision of grid flexibility services to an **aggregator**. The following objectives were defined: 1. Determine the flexibility potential 2. Provide flexibility services

1.4 Narrative of use case

1.4.1 Narrative of High-Level use case

Narrative of Use Case
Short description
SATO will assess the electric energy flexibility potential available and make this information available for potential energy **aggregators**, which will be able to use this information to trigger defined building flexibility assets. This HLUC will allow **aggregators** to have a bigger pool of flexibility assets to manage grid related issues, such as grid congestion. Buildings providing the flexibility services may be paid in the near future for providing these services to the grid. SATO will ensure the flexibility provided by buildings goes in synergy with occupant comfort.
Complete description
The HLUC - Providing grid flexibility services to an energy **aggregator** concerns the evaluation of the electric energy flexibility potential in the building, the communication of the potential to an energy **aggregator**, that will explore this flexibility potential according to the necessities of the grid. This will be performed while ensuring that flexibility goes in synergy with occupant comfort. This HLUC aims to evaluate the flexibility potential of the different electric energy assets present in the building. The following steps are required for the implementation of this HLUC: 1. Receive the building performance (energy production, complete description of the building consumption, EV charging, indoor comfort conditions) <u>self-assessment</u> data from HLUC02. HLUC02 is responsible for the real-time self-assessment of the building energy performance and occupancy, and will provide the current state of operation of the electric energy flexibility assets operating in the building (e.g. HVAC system, DHW, batteries, or EV connected to a vehicle-to-grid (V2G) charger), which derive their flexibility potential also from the static and dynamic components of the building fabric. 2. Receive the building performance (energy production, complete description of the building consumption, EV charging, indoor comfort conditions) <u>forecasted</u> data from HLUC03. HLUC03 is responsible for the forecast of the building performance and occupancy, and will provide forecast about the future state of operation of the electric energy flexibility assets operating in the building (e.g. HVAC system, DHW, batteries, or EV connected to a V2G charger), which derive their flexibility potential also from the static and dynamic components of the building fabric. 3. Evaluate the flexibility potential using the **SATO Self-Optimization Services** and **SATO Flexibility Management Services** for the following hours. The **SATO Self-Optimization Services** and **SATO Flexibility Management Services** will consider the real-time self-assessment and the forecasted energy performance of the building to calculate the flexibility potential available in the building for the following hours. 4. Communicate the available flexibility potential to the Holistic optimal control of energy resources (HLUC14). HLUC14 will receive the available and forecasted electric energy flexibility potential and will evaluate it with the other self-optimization services. 5. Receive from HLUC14 the final forecasted electric energy flexibility potential and communicate the forecasted available potential to the energy **aggregator** The final forecasted flexibility potential considering the other self-optimization services done by HLUC14 will be received and communicated to the **SATO Platform**, which will then directly communicate with the energy **aggregator**. 6. Receive control signals from the energy **aggregator**. The **SATO Self-Optimization Services** will receive control signals from the energy **aggregator**, through **SATO Platform**, whenever there is a grid necessity matching the building flexibility availability. 7. Send the control signal to the Holistic optimal control of energy resources (HLUC14). The **SATO Self-optimization Services** will send the signals received from the energy aggregator to HLUC14, which is responsible for evaluating all self-optimization services and for communicating the control signals to HLUC15.

1.4.2 Narrative of primary use case

ID	*Name*	*Description*
		No PUCs (intended as sub-analyses carried out in parallel on different aspects) foreseen since all the steps of this HLUC are in a sequence

1.5 Key performance indicators (KPI)

Name	*Description*	*Reference to mentioned use case objectives*
Available capacity for active demand response	Represents the maximum amount of energy that can be stored in thermal form in the structural storage capacity of the building in XXX, given the boundary conditions for thermal comfort, climate, occupant behaviour	This KPI directly links to all objectives of this HLUC, being necessary for the evaluation of the flexibility potential.
Flexibility	*Represents the ability to deviate from the reference electric load profile during the flexibility interval. The total power shift is integrated over the flexibility interval and expressed in units of energy (in this paper kWh)*	This KPI directly links to all objectives of this HLUC, being necessary for the evaluation of the flexibility potential.
Delayed operation flexibility	*Represents the time the operation of the heating/cooling unit, e.g. CHP or heat pump, can be postponed while the energy demand is met by the storage.*	This KPI directly links to the all objectives of this HLUC, being necessary for the evaluation of the flexibility potential.
Forced operation flexibility	*Represents the amount of time the operation of the heating/cooling unit, e.g. CHP or heat pump, can be forced while the excess heat produced is stored for later use.*	This KPI directly links to the all objectives of this HLUC, being necessary for the evaluation of the flexibility potential.
Load shift ability	It assesses the potential related to energy consuming device that can be used to offer flexibility services to the grid or to shift its load from peak hours to a period of the day with lower electricity prices (off-peak hours). A number of KPIs of this category are available in KPI tool and in literature. The most suitable ones will be chosen according to the characteristics and data available in each pilot building	Define flexibility strategies Determine the available flexibility from current appliances/equipment
Daily avg specific energy consumption	Daily amount of specific energy (e.g., electricity, natural gas, district heating, district cooling, domestic hot water).	This KPI directly links to the all objectives of this HLUC, being necessary for the evaluation of the flexibility potential.
Monthly avg specific energy consumption	Monthly amount of specific energy use (e.g., electricity, natural gas, district heating, district cooling, domestic hot water). Daily amount of specific energy (e.g., electricity, natural gas, district heating, district cooling, domestic hot water).	This KPI directly links to the all objectives of this HLUC, being necessary for the evaluation of the flexibility potential.
Daily produced energy	*Daily energy generated on-site*	Links to objective 1
Monthly produced energy	*Monthly energy generated on-site*	Links to objective 1
Self-consumption of renewables	Ratio of renewable energy use over the total energy used by the building.	Links to objective 1
Costs for electricity consumption	Represents the amount of money the users have to pay for their bills related to electric energy use (can be divided for different end uses or different domestic appliances). The users can easily understand and relate to costs.	Links to objective 1 and 2

1.6 Use case conditions

Use case conditions
Assumptions
The **SATO Platforms** and different IoT and Wi-Fi-based interfaces must be in operation. The **Facility/building managers**, **Building owners** or **Building occupants**, have given their consent to SATO perform assessments of the flexibility potential (GDPR compliant)
Prerequisites
The building has controllable assets with electric energy flexibility capabilities being monitored.

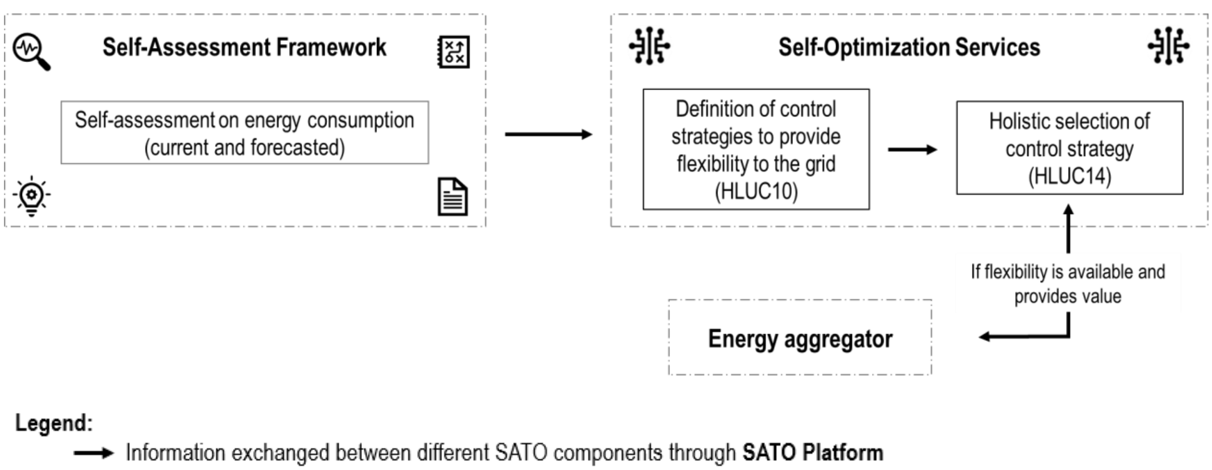
Link to HLUC01 Link to HLUC02 Link to HLUC03

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
HLUC01 – Monitoring is a prerequisite for the definition of smart-optimization strategies and hence, the application of those strategies. *HLUC02 – Self-assessment is a prerequisite for the definition of smart-optimization strategies and hence, the application of those strategies.* *HLUC03 – Self-assessment of future building performance is fundamental for the definition of smart-optimization strategies.* *HLUC14 – Holistic self-optimization will solve conflicts between competing strategies developed by **SATO Self-Optimization Services** and send the optimal control*
Level of depth
Defines the level of depth of the use case: ***HLUC –** Providing grid flexibility services to an energy aggregator*
Prioritisation
*This HLUC is considered of normal priority, however the self-optimization performed will send and receive information through the **SATO Self-Optimization Services** in HLUC14.*
Generic, regional or national relation
This is a national Use Case, since it will only be performed in the Portuguese pilot sites. Since national legislation is still not prepared for buildings to provide flexibility services directly to the grid or using an aggregator, this HLUC may only be performed at simulation level. This information could be updated if new legislation becomes available during SATO project.
Nature of the use case
Technical Use Case
Further keywords for classification
Self-optimization, flexibility, aggregator, DSO, electric grid

2 Diagrams of use case

Diagram(s) of use cases



3. Technical details

3.1 Actors

Actors		
Actor Name	**Actor Type**	**Actor Description**
Aggregators	*Human actor*	*Aggregators will be the main actor of the HLUC, using the information on controllable loads to monetize the available flexibility of the buildings.*
SATO Platform	*Software/ systems/ applications/ devices*	*SATO Platform collected the information on building and appliances status that is used to determine whether a load is controllable or not.*
SATO Self-Optimization Services	*Software/ systems/ applications/ devices*	*SATO Self-Optimization Services will decide which electric energy load could be used to provide flexibility services to the grid.*
Flexibility Management Service (FMS)	*Software/ systems/ applications/ devices*	*SATO FMS is responsible for flexibility, exchanging data with the energy grid and improving load balancing for distributor system operators (DSOs) and transmission system operators (TSOs).*

3.2 References

References						
No.	**References type**	**Reference**	**Status**	**Impact on use case**	**Originator/ organization**	**Link**
1	*Internal Document*	*SATO KPI tool reference list*	*n/a*	*Provision of KPI to be included*	*AAU*	KPI tool
2	*Internal Document*	*SATO actors reference list*	*n/a*	*Provision of actors to be included*	*EDP NEW*	*Use Case Short Description V6.xlsx*

4. Step by step analysis of use case

4.1 Overview of scenarios

Scenarios conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
1	*Manage controllable loads to exploit energy flexibility*	***SATO Self-Optimization Services** and **SATO Flexibility Management Service** will evaluate controllable loads that can provide flexibility to the grid without impacting occupants, creating potential for **aggregators** to sell this flexibility in the market.*	***Aggregators***	***Aggregators** will use SATO to identify controllable loads that can be used to provide flexibility services to the grid.*	*Existence of controllable loads that can be used for flexibility services with a minimal impact for building occupants. Communication between SATO and **Aggregators***	*Loads will be activated or deactivated according to the grid requirements*

4.2 Steps – Scenarios

Scenario								
Scenario name:		***Reference scenario***						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirements, R-IDs***
1.1	*Receiving information of the building performance*	*Receiving SATO self-assessment s*	***SATO Self-Optimization Services*** *collects information on the building performance from* ***SATO Platform.***	*GET*	*SATO Platform*	*SATO Self-Optimization Services and SATO Flexibility Management Service*	*IE1*	R-QoS-1; R-SEC-4; R-SEC-5; R-DATA-3;
1.2	*Identifying available flexibility through* ***SATO Self-Optimization Services***	*Identification of flexibility potential*	***SATO Self-Optimization Services*** *and* ***SATO Flexibility Management Service*** *identifies electric energy flexible assets available to provide flexibility services to the grid.*	*CREATE*	*SATO Flexibility Management Service*	*SATO Self-Optimization Services*	*IE2*	R-CONFIG-1; R-CONFIG-2; R-QoS-1; R-SEC-1; R-SEC-3; R-DATA-1; R-DATA-2;
1.3	*Communicating available flexibility potential*	*Sending available flexibility potential*	*Sends available flexibility potential to the* ***SATO Platform*** *to be sent to HLUC14.*	*REPORT*	*SATO Self-Optimization Services*	*SATO Platform*	*IE2*	R-QoS-1; R-SEC-4; R-SEC-5; R-DATA-3;
1.4	*Receiving* final forecasted electric energy flexibility potential from HLUC14	*Changing the available flexible potential*	*Receives the* final forecasted electric energy flexibility potential and exchanges this information on the **SATO Flexibility Management Services.**	*CHANGE*	*SATO Platform*	*SATO Flexibility Management Services*	*IE3*	R-QoS-1; R-SEC-4; R-SEC-5; R-DATA-3;
1.5	*Communicating available flexibility potential to the* ***aggregator***	*Sending available flexibility potential*	*Sends available flexibility potential to* ***aggregator.***	*REPORT*	*SATO Flexibility Management Services*	*Aggregator*	*IE4*	R-CONFIG-1; R-CONFIG-2; R-QoS-1; R-SEC-1; R-SEC-2; R-SEC-3; R-DATA-1; R-DATA-2; R-DATA-3;
1.6	*Receiving control signals from the energy* ***aggregator***	*Receiving control signals*	*Receives control signals to activate the flexibility potential from the* ***aggregator.***	*REPORT*	*Aggregator*	*SATO Flexibility Management Services*	*IE4*	R-CONFIG-1; R-CONFIG-2; R-QoS-1; R-SEC-1; R-SEC-2; R-SEC-3; R-DATA-1; R-DATA-2; R-DATA-3;
1.7	*Communicating control signals to HLUC14*	*Sending control signals to HLUC14*	*Send the controls signals to activate flexible loads to the* ***SATO Platform*** *to be sent to HLUC14, to be implemented by HLUC15*	*REPORT*	*SATO Flexibility Management Services*	*SATO Platform*	*IE3*	R-QoS-1; R-SEC-4; R-SEC-5; R-DATA-3;

(*) Available options are:

- *CREATE means that an information object is to be created at the Producer.*
- *GET (this is the default value if none is populated) means that the Receiver requests information from the Producer (default).*
- *CHANGE means that information is to be updated. Producer updates the Receiver's information.*
- *DELETE means that information is to be deleted. Producer deletes information from the Receiver.*
- *CANCEL, CLOSE imply actions related to processes, such as the closure of a work order or the cancellation of a control request.*
- *EXECUTE is used when a complex transaction is being conveyed using a service, which potentially contains more than one verb.*
- *REPORT is used to represent transferral of unsolicited information or asynchronous information flows. Producer provides information to the Receiver.*
- *TIMER is used to represent a waiting period. When using the TIMER service, the Information Producer and Information Receiver fields shall refer to the same actor.*
- *REPEAT is used to indicate that a series of steps is repeated until a condition or trigger event. The condition is specified as the text in the "Event" column for this row or step. Following the word REPEAT, shall appear, in parenthesis, the first and last step numbers of the series to be repeated in the following form REPEAT(X-Y) where X is the first step and Y is the last step.*

5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE1	*Building performance information*	*Information regarding building performance sent by the **SATO Platform** to the **SATO Self-Optimization Services and SATO Flexibility Management Services***	R-QoS-1; R-SEC-4; R-SEC-5; R-DATA-3;
IE2	*Flexibility potential*	*Communication of the flexibility potential internally through the **SATO Self-Optimization Services and SATO Flexibility Management Services***	R-QoS-1; R-SEC-4; R-SEC-5; R-DATA-3;
IE3	*Communication of available controllable loads*	*Communication between the **SATO Platform** and **SATO Flexibility Management Services**.*	R-CONFIG-1; R-CONFIG-2; R-QoS-1; R-SEC-1; R-SEC-3; R-DATA-1; R-DATA-2;
IE4	*Information exchanged with the aggregator*	*Communications between the **SATO Self-Optimization Services, SATO Flexibility Management Services** and the **Aggregator***	R-CONFIG-1; R-CONFIG-2; R-QoS-1; R-SEC-1; R-SEC-2; R-SEC-3; R-DATA-1; R-DATA-2; R-DATA-3;

6 Requirements

Requirements		
Categories ID	***Category name for requirements***	***Category description***
R-CONFIG	Configuration	Reflect the typical, probable, or envisioned communication configurations that are relevant to the use case step. These configuration issues include numbers of devices and/or systems, expected growth of the system over time, locations, distances, communication types, network bandwidth, existing protocols, etc., but only from the user's point of view. In some cases, only one of the possible choices is reasonable, while for other situations, more than one choice is reasonable.
R-SEC	Security	Assess how different security measures applied to different items can potentially interact and either leave security holes or make user interfaces very laborious and possibly unworkable. Security must not only protect against the very harmful but quite rare deliberate attacks, but also against the far more likely inadvertent mistakes, failures, and errors. At the same time, it is necessary to try to identify the requirements and the concerns for implementing security measures.
R-COMP	Compatibility	Compatibility with other functions.
R-QoS	Quality of Service (QoS)	Address availability of the system, such as acceptable downtime, recovery, backup, rollback, etc. QoS issues also address accuracy and precision of data, the frequency of data exchanges, and the necessary flexibility for future changes.
R-DATA	Data Management	Covers both the management of the data exchanges in each Use Case step and the management of data at either end if that management is impacted by data exchanges. An example of the first type of data management is the initial setting up and on- going maintenance of what data needs to be exchanged, say between a Geographic Information System and the many different applications that use its data. An example of the second type of data management is the need to backup data or ensure consistency of data whenever it is exchanged, such as if new protection settings are issued to multiple field devices, these settings need to be reflected in Contingency Analysis functions. It should not address database design but should concentrate on the user requirements for the interfaces to databases and other data handling applications.
Requirement R-ID	***Requirement name***	***Requirement description***
R-CONFIG-1	Data exchange methods	An event will be triggered by SATO, sending data to the aggregator via the **SATO SAF**

R-CONFIG-2	Operation mode of Information Producer	Automatic
R-QoS-1	Frequency of data exchanges	Upon event
R-SEC-1	Eavesdropping	Ensuring confidentiality, avoiding illegitimate use of data, and preventing unauthorized reading of data
R-SEC -2	Information integrity violation	Ensuring that historical data is not changed or destroyed
R-SEC-3	Authentication: Masquerade and/or spoofing	Ensuring that data comes from the stated source or goes to authenticated receiver
R-SEC-4	Replay	Ensuring that data cannot be resent by an unauthorized source
R-SEC-5	Information theft	Ensuring that data cannot be stolen or deleted by an unauthorized entity
R-DATA-1	Type of source data	Source data was calculated or output by **SATO SAF**
R-DATA-2	Correctness of source data	Source data is always correct (e.g. by definition)
R-DATA-3	Validation of data exchanges	Data can be assumed as valid (or validity checking is handled elsewhere);

7 Common Terms and Definitions

Common Terms and Definitions	
Term	***Definition***
V2G	vehicle-to-grid

HLUC11 – Load-shifting as an energy cost reduction strategy

1. Description of the use case

1.1 Name of the use case

ID	*Area*	*Name of Use Case*
HLUC11	*(4) Self-optimization*	*Load-shifting as an energy cost reduction strategy*

1.2 Version management

Version No.	*Date*	*Name of Author (s)*	*Changes*
1.0	*27.05.21*	*Andrea Sangalli*	*First version of HLUC11*
1.1	*28.05.21*	*Filipe Neves Silva*	*Review of v1.0 of HLUC11*
1.2	*04.06.21*	*Anna Marszal-Pomianowska*	*Review of v1.1 of HLUC11*
2.0	*17.06.21*	*Andrea Sangalli*	*Second version of HLUC11*
3.0	*01.07.21*	*João Dias, Filipe Silva*	*Third version of HLUC11*

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	Load shifting, the ability to change the timing of electricity use to minimize demand during peak periods or to take advantage of the cheapest electricity prices, will be evaluated in this use case as a reliable and easy way to implement methods for energy cost reduction, using **SATO Platform**. The procedure will allow for real-time optimized control of legacy and smart appliances, as well as building equipment and vehicle-to-grid (V2G) chargers and batteries.

	No Primary Use Cases are foreseen for this HLUC, since all its steps are in a sequence, without alternative scenarios.
Objective(s)	1. Define flexibility strategies 2. Determine the available flexibility from current appliances/equipment 3. Implement load shifting in pilot sites 4. Evaluate the impact of load shifting

1.4 Narrative of use case

1.4.1 Narrative of High-Level use case

Narrative of Use Case
Short description
This HLUC aims to evaluate the flexibility potential of the different energy assets present in the building. **SATO BMS** and **SATO APL** will be used to gather data (energy use and energy from renewable sources) from the building and, if possible, from the electric grid. **SATO Self-Assessment Framework** will use this information to determine the available flexibility in building appliances and equipment. This information is then used by the **SATO Self-Optimization Services** to come up with the optimal control and time schedule of equipment and appliance operation.
Complete description
The HLUC11 - *Load-shifting as an energy cost reduction strategy* – concerns the evaluation of the energy flexibility potential in the building, while ensuring that flexibility does not cause occupant discomfort. This is done by assessing the actual energy performance of the building (onsite RES generation and energy demand) and forecasting operational scenarios in the near future (typically some hours), where a shift in electricity loads can lead to optimized use of RES and reduced energy costs. If a real-time exchange of information with the grid is possible, the optimization will consider also peak periods in the electricity networks and price signals. The following steps are required for the implementation of this HLUC: 1. Receive the building performance (RES generation, complete description of the building energy use, EV charging, indoor comfort conditions) <u>self-assessment</u> data from **Self-Assessment Framework** (HLUC02). HLUC02 is responsible for the real-time self-assessment of the building energy performance and occupancy and will provide the current state of operation of the energy flexibility assets operating in the building. 2. Receive the building performance (RES generation, complete description of the building energy use, EV charging, indoor comfort conditions) <u>forecast</u> data from **Self-Assessment Framework** (HLUC03). HLUC03 is responsible for the forecast of the building performance and occupancy and will provide forecast about the future state of operation of the energy flexibility assets operating in the building. 3. If a Building(s)-to-grid (B2G) scenario is present, receive actual and forecast data from the local energy grid (i.e. peak periods in the electricity and price signals), via **SATO Platform** and **Flexibility Management Service** (**FMS**). The first 3 steps will serve to develop flexibility strategies based on load shifting. 4. Evaluate the flexibility potential using the **SATO Self-Optimization Services** for the following hours. The **SATO Self-Optimization Services** will consider the real-time self-assessment and the forecasted energy performance of the building to calculate the flexibility potential available in the building for the following hours (up to e.g. 24 hours, similar to the electricity balancing market). The duration of the flexibility window will take into account the specific time constant of each system (e.g. appliances have short time constant, whereas a heating system has in general a longer time constant). 5. Communicate the available flexibility potential to the *Holistic optimal control of energy resources* (HLUC14), which will prioritize the control strategies and send control signals to *Cloud managing of legacy and smart appliances and equipment* (HLUC15). 6. If the suggested control strategy is deployed, HLUC11 will keep monitoring the performance of the building, receiving information from HLUC02, to have a feedback on the implemented flexibility strategies and evaluate the impact of load shifting on building energy performances, energy costs, occupants' comfort and use of renewables.

1.4.2 Narrative of primary use cases

ID	*Name*	*Description*
		No PUCs (intended as sub-analyses carried out in parallel on different aspects) foreseen since all the steps of this HLUC are in a sequence

1.5 Key performance indicators (KPI)

Name	*Description*	*Reference to mentioned use case objectives*
Load shift ability	It assesses the potential related to energy consuming device that can be used to offer flexibility services to the grid or to shift its load from peak hours to a period of the day with lower electricity prices (off-peak hours). A number of KPIs of this category are available in KPI tool and in literature. The most suitable ones will be chosen according to the characteristics and data available in each pilot building	Define flexibility strategies Determine the available flexibility from current appliances/equipment
Load factor	Represents the percentage of the electrical demand covered by on-site electricity generation.	Define flexibility strategies Determine the available flexibility from current appliances/equipment Evaluate the impact of load shifting
Self-consumption of renewables	Ratio of renewable energy use over the total energy used by the building.	Evaluate the impact of load shifting
Load production to grid	On-site energy generated that is sold to the grid.	Evaluate the impact of load shifting
Costs for electricity consumption	Represents the amount of money the users have to pay for their bills related to electric energy use (can be divided for different end uses or different domestic appliances). The users can easily understand and relate to costs.	Define flexibility strategies Evaluate the impact of load shifting
CO_2 emissions	The amount of CO_2 equivalent caused by the energy use. A measure of how much carbon dioxide and how much the users might contribute to climate change is created. It is necessary to use national CO_2 conversion factors to translate the different types of energy related to carriers into emissions.	Evaluate the impact of load shifting
Flexibility	Represents the ability to deviate from the reference electric load profile during the flexibility interval. The total power shift is integrated over the flexibility interval and expressed in units of energy (e.g. kWh)	Define flexibility strategies Determine the available flexibility from current appliances/equipment

1.6 Use case conditions

Use case conditions
Assumptions
The **SATO Platforms** and different IoT and Wi-Fi-based interfaces must be in operation. The **Facility/building managers**, **Building owners** or **Building occupants**, have given their consent to SATO perform assessments of the flexibility potential (GDPR compliant)
Prerequisites
The building has controllable assets with electric energy flexibility capabilities being monitored. HLUC01, HLUC02, HLUC03

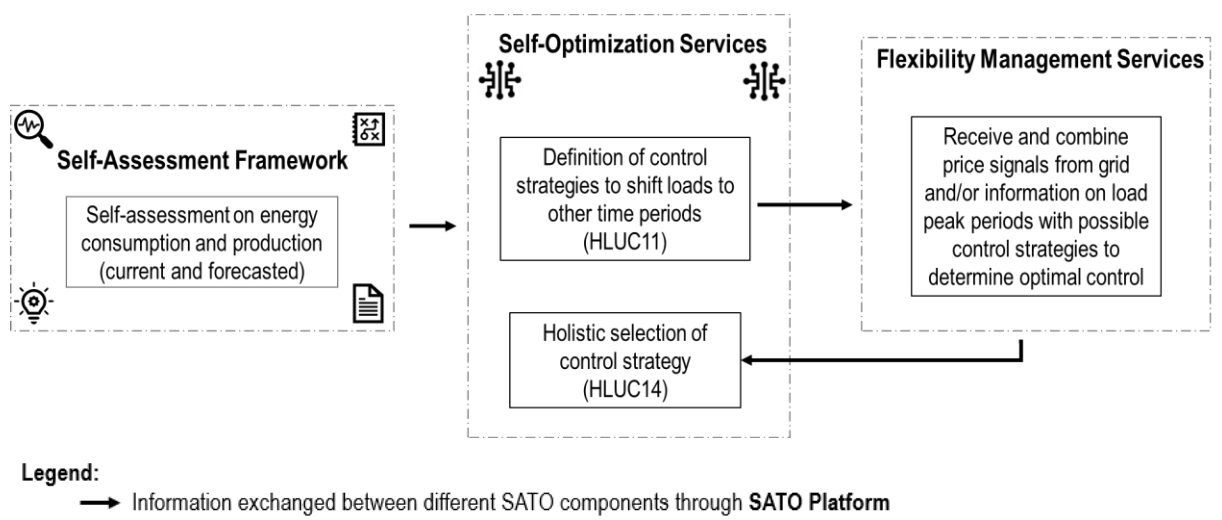
1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
HLUC01 – Monitoring is a prerequisite for the definition of smart-optimization strategies and hence, the application of those strategies. *HLUC02 – Self-assessment is a prerequisite for the definition of smart-optimization strategies and hence, the application of those strategies.* *HLUC03 – Self-assessment of future building performance is fundamental for the definition of smart-optimization strategies.*

HLUC14 - Holistic self-optimization will solve conflicts between competing strategies developed by ***SATO Self-optimization Services*** *and send the optimal control*
Level of depth
Defines the level of depth of the use case: ***High-level use case*** *(HLUC)*
Prioritisation
This HLUC is considered of top priority, since it deals with energy flexibility, which is one of the most important services that will be provided by the SATO platform. The self-optimization performed will send and receive information through the ***SATO Self-Optimization Services*** *in HLUC14.*
Generic, regional or national relation
Generic
Nature of the use case
Technical Use Case
Further keywords for classification
Self-optimization, flexibility, load-shifting, DSO

2 Diagrams of use case

Diagram(s) of use cases



3. Technical details

3.1 Actors

Actors		
Actor Name	***Actor Type***	***Actor Description***
Facility/ building managers	*Human actor*	*This actor as an indirect role in this HLUC. His role is to adapt the building conditions to occupants' preferences when the SATO system is not able to meet these preferences. This indirect participation enables the system to react better to future scenarios.*
Building occupants	*Human actor*	*This actor as an indirect role in this HLUC. His role is to adapt the building conditions to their preferences when the SATO system is not able to meet these preferences. This indirect participation enables the system to react better to future scenarios.*

SATO Platform	Software/ systems/ applications/ devices	**SATO Platform** collects the information on building, appliances status and third-party data that is used to determine whether a load is controllable and the market value of the load shift.
SATO APL	Software/ systems/ applications/ devices	**SATO BMS** and **SATO APL** will be used to gather data (energy consumption and production) from the building
SATO BMS	Software/ systems/ applications/ devices	
SATO Self-Assessment Framework (SAF)	Software/ systems/ applications/ devices	**SATO Self-assessment framework** will use this information to determine the available flexibility in building appliances and equipment
SATO Self-Optimization Services	Software/ systems/ applications/ devices	This information is then used by the Optimization framework to come up with the optimal time schedule of equipment and appliance operation.
SATO Flexibility Management Service (FMS)	Software/ systems/ applications/ devices	SATO FMS is responsible for demand side flexibility, exchanging data with the energy grid and improving load balancing for distributor system operators (DSOs) and transmission system operators (TSOs).

3.2 References

References						
No.	**References type**	**Reference**	**Status**	**Impact on use case**	**Originator/ organization**	**Link**
1	Internal Document	SATO KPI tool reference list	n/a	Provision of KPI to be included	AAU	KPI tool
2	Internal Document	SATO actors reference list	n/a	Provision of actors to be included	EDP NEW	Use Case Short Description V6.xlsx
3	Report	Satchwell A, Piette M, Khandekar A, Granderson J, Frick N, Hledik R, et al. A National Roadmap for Grid-Interactive Efficient Buildings. 2021 May	Published	State of the art on load shifting and Grid-interactive efficient buildings (GEBs)	US Department of Energy	https://www.osti.gov/servlets/purl/1784302/

4. Step by step analysis of use case

4.1 Overview of scenarios

Scenarios conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
1	Manage controllable loads to exploit energy flexibility	**SATO Self-Optimization Services** will evaluate controllable loads that can provide flexibility without impacting occupants	SATO Self-Optimization Services	The need to optimize energy consumption, production and energy costs	Existence of controllable loads that can be used for flexibility services with a minimal impact for building occupants	Loads will be activated or deactivated according to the energy requirements

4.2 Steps – Scenarios

Scenario								
Scenario name:		***Reference scenario***						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirements, R-IDs***
1.1	*Receiving information of the building performance*	*Receiving SATO self-assessments*	***SATO Self-Optimization Services*** *collects information on the building performance from* ***SATO Platform.***	*GET*	*SATO Platform*	*SATO Self-Optimization Services*	*IE1*	R-QoS-1; R-SEC-1; R-SEC-2; R-DATA-1;
1.2	*Receiving information form the energy grid(s), if available*	*B2G*	***SATO Self-Optimization Services*** *collects information on load peak periods and price signals from the grid from* ***SATO Flexibility Management Service and SATO Platform***	*GET*	*SATO Flexibility Management Service and SATO Platform*	*SATO Self-Optimization Services*	*IE2*	R-QoS-1; R-SEC-1; R-SEC-2; R-DATA-1;
1.3	*Identifying available flexibility through* ***SATO Self-Optimization Services***	*Identification of flexibility potential*	***SATO Self-Optimization Services*** *identifies energy flexible assets available flexibility potential to perform load-shifting.*	*CREATE*	*SATO Self-Optimization Services*	*SATO Self-Optimization Services*	*IE3*	R-QoS-1; R-SEC-1; R-SEC-2; R-DATA-1;
1.4	*Communicating available flexibility potential*	*Sending available flexibility potential*	*Sends available flexibility potential to the* ***SATO Platform*** *to be sent to HLUC14.*	*REPORT*	*SATO Self-Optimization Services*	*SATO Platform*	*IE3*	R-QoS-1; R-SEC-1; R-SEC-2; R-DATA-1;
1.5	*Use continuous monitoring to improve flexibility strategies*	*Continuous monitoring of operation*	After a control strategy is deployed, continuous monitoring of the performance of the building, will generate a feedback on the implemented strategies.	*GET*	*SATO Platform*	*SATO Self-Optimization Services*	*IE1*	R-QoS-1; R-SEC-1; R-SEC-2; R-DATA-1;

(*) Available options are:

- *CREATE means that an information object is to be created at the Producer.*
- *GET (this is the default value if none is populated) means that the Receiver requests information from the Producer (default).*
- *CHANGE means that information is to be updated. Producer updates the Receiver's information.*
- *DELETE means that information is to be deleted. Producer deletes information from the Receiver.*
- *CANCEL, CLOSE imply actions related to processes, such as the closure of a work order or the cancellation of a control request.*
- *EXECUTE is used when a complex transaction is being conveyed using a service, which potentially contains more than one verb.*
- *REPORT is used to represent transferral of unsolicited information or asynchronous information flows. Producer provides information to the Receiver.*
- *TIMER is used to represent a waiting period. When using the TIMER service, the Information Producer and Information Receiver fields shall refer to the same actor.*
- *REPEAT is used to indicate that a series of steps is repeated until a condition or trigger event. The condition is specified as the text in the "Event" column for this row or step. Following the word REPEAT, shall appear, in parenthesis, the first and last step numbers of the series to be repeated in the following form REPEAT(X-Y) where X is the first step and Y is the last step.*

5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE1	*Building performance information*	*Information regarding building performance sent by the **SATO Platform** to the **SATO Self-Optimization Services***	R-QoS-1; R-SEC-1; R-SEC-2; R-DATA-1;
IE2	*Grid information*	*Information regarding load peak periods and price signals sent by the grid from **SATO Flexibility Management Service and SATO Platform***	R-QoS-1; R-SEC-1; R-SEC-2; R-DATA-1;
IE3	*Flexibility potential*	*Identification and communication of the flexibility potential internally through the **SATO Self-Optimization Services***	R-QoS-1; R-SEC-1; R-SEC-2; R-DATA-1;

6 Requirements

Requirements		
Categories ID	***Category name for requirements***	***Category description***
R-SEC	Security	Assess how different security measures applied to different items can potentially interact and either leave security holes or make user interfaces very laborious and possibly unworkable. Security must not only protect against the very harmful but quite rare deliberate attacks, but also against the far more likely inadvertent mistakes, failures, and errors. At the same time, it is necessary to try to identify the requirements and the concerns for implementing security measures.
R-QoS	Quality of Service (QoS)	Address availability of the system, such as acceptable downtime, recovery, backup, rollback, etc. QoS issues also address accuracy and precision of data, the frequency of data exchanges, and the necessary flexibility for future changes.
R-DATA	Data Management	Covers both the management of the data exchanges in each Use Case step and the management of data at either end if that management is impacted by data exchanges. An example of the first type of data management is the initial setting up and on- going maintenance of what data needs to be exchanged, say between a Geographic Information System and the many different applications that use its data. An example of the second type of data management is the need to backup data or ensure consistency of data whenever it is exchanged, such as if new protection settings are issued to multiple field devices, these settings need to be reflected in Contingency Analysis functions. It should not address database design but should concentrate on the user requirements for the interfaces to databases and other data handling applications.
Requirement R-ID	***Requirement name***	***Requirement description***
R-QoS-1	Frequency of data exchanges	Upon event
R-SEC-1	Replay	Ensuring that data cannot be resent by an unauthorized source
R-SEC-2	Information theft	Ensuring that data cannot be stolen or deleted by an unauthorized entity
R-DATA-1	Validation of data exchanges	Data can be assumed as valid (or validity checking is handled elsewhere);

7 Common Terms and Definitions

Common Terms and Definitions	
Term	***Definition***
B2G – Building(s)-to-grid	Building-to-Grid describes the instrumentation and communication infrastructure to allow a dynamic near real-time two-way communication between building(s) and the utility in order to optimize energy use

RES	Renewable energy sources
V2G	vehicle-to-grid

HLUC12 – Using thermal mass for BaB energy storage

1. Description of the use case

1.1 Name of the use case

ID	*Area*	*Name of Use Case*
HLUC12	*(4) Self-optimization*	*Using thermal mass for BaB energy storage*

1.2 Version management

Version No.	*Date*	*Name of Author (s)*	*Changes*
1.0	*27.05.21*	*Andrea Sangalli*	*First version of HLUC12*
1.1	*28.05.21*	*João Bravo Dias*	*Review of HLUC12 v.1.0*
1.1	*07.06.21*	*Anna Marszal-Pomianowska*	*Review of HLUC12 v.1.1*
1.1	*07.06.21*	*João Simões*	*Review of HLUC12 v.1.1*
2.0	*15.06.21*	*Andrea Sangalli*	*Second version of HLUC12*
3.0	*01.07.21*	*João Dias, Filipe Silva*	*Third version of HLUC12*

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	In this use case, buildings will be evaluated according to their thermal mass and energy use profiles for heating and cooling. This information will be provided to **SATO Self-Assessment Framework** for the evaluation of available flexibility. **SATO Self-Optimization Services** will use this additional flexibility together with other flexibility sources to determine the optimal operation mode. **SATO APL** and **SATO BMS** will receive data on the optimal set-points for heating, ventilation and air conditioning (HVAC) systems and apply it to develop optimal HVAC control.
Objective(s)	1. Determine the thermal storage capacity in each pilot 2. Implement peak shaving and load shifting strategies based on the thermal storage 3. Evaluate the impact of those strategies on energy use and energy costs, user comfort and use of RES

1.4 Narrative of use case

1.4.1 Narrative of High-Level use case

Narrative of Use Case
Short description
Using thermal mass for BaB (building as thermal battery) energy storage Use Case aims to determine optimal setpoints for HVAC systems, taking profit of the thermal mass of the building fabric to shift the energy demand for the mechanical systems. Depending on the availability of data from the local energy grid, this can be done in two ways. If no communication with the grid is set, the optimization will be performed at building scale. If Building-to-Grid (B2G) integration framework can be deployed, the optimization will include grid data. This means, in the periods of surplus energy in the local energy grid (low demand periods), the building is in preheating mode, i.e. energy consumption from energy system is higher than the energy demand required to meet the residents' thermal comfort requirements and the surplus heat is stored in the structural thermal mass of the building. In the opposite situation (i.e. high demand periods in the energy grid), when the building is in discharging mode, none or very little energy is consumed from local energy grid and the heat demand needed to maintain the thermal comfort is met by utilizing the heat stored in the buildings' thermal mass.
Complete description
The HLUC12 - *Using thermal mass for BaB energy storage* – concerns the evaluation of the energy flexibility potential embedded in the building thermal capacity, while ensuring that flexibility events do not cause occupant discomfort.

This HLUC aims to evaluate the flexibility potential related to energy need for heating and cooling. The following steps are required for the implementation of this HLUC: 1. Receive the data related to the physical properties of the building fabric and to the building performance (energy from onsite RES, description of the building energy use, indoor comfort conditions), coming from **Self-Assessment Framework** (HLUC02). HLUC02 is responsible for the real-time self-assessment of the building energy performance and occupancy and will provide the current state of the BaB potential, taking into account the thermal capacity of the building and the current status and level of charge/discharge of the thermal mass (estimated based on the recent charge/discharge history and indoor temperatures). 2. Receive the building performance (energy from onsite RES, description of the building energy use, outdoor and indoor comfort conditions) forecast data from **Self-Assessment Framework** (HLUC03). HLUC03 is responsible for the forecast of the building performance, occupancy and indoor climate, based on future outdoor conditions forecasts (acquired from external weather forecast services, e.g. concerning availability of solar radiation for PV production, or a coming heat wave in summer) and own algorithms. 3. If a B2G scenario is present, receive actual and forecast data from the local energy grid (i.e. peak periods in the electricity and/or district heating and cooling networks, price signals), via **SATO Platform** and **Flexibility Management Service** (FMS)). The first 3 steps will serve as a basis to develop short and long-term flexibility strategies to determine if and when it is worth charging/discharging the thermal mass of the building (i.e. providing heating or cooling, depending on the season, keeping the indoor temperature not at a fixed setpoint, but with fluctuations within the selected comfort category). 4. Evaluate the flexibility potential for the following hours using the **SATO Self-Optimization Services**. The **SATO Self-Optimization Services** will consider the real-time self-assessment and the forecasted energy performance of the building to calculate the flexibility potential available in the building thermal mass for the following hours or days if possible. 5. Communicate the available flexibility potential to the *Holistic optimal control of energy resources* (HLUC14), which will prioritize the control strategies and send control signals to *Cloud managing of legacy and smart appliances and equipment* (HLUC15). 6. If the suggested control strategy is deployed, HLUC12 will keep monitoring the performance of the building, by receiving information from HLUC02, to have a feedback on the implemented flexibility strategies and evaluate the impact of load shifting and peak shaving on building energy performances, energy costs, occupants' comfort and use of renewables.

1.4.2 Narrative of primary use cases

ID	*Name*	*Description*
		No PUCs (intended as sub-analyses carried out in parallel on different aspects) foreseen since all the steps of this HLUC are in a sequence

1.5 Key performance indicators (KPI)

Name	*Description*	*Reference to mentioned use case objectives*
Load shift ability	It assesses the potential related to energy consuming device that can be used to offer flexibility services to the grid or to shift its load from peak hours to a period of the day with lower electricity prices (off-peak hours). A number of KPIs of this category are available in KPI tool and in literature. The most suitable ones will be chosen according to the characteristics and data available in each pilot building	Implement peak shaving and load shifting strategies based on the thermal storage
Total annual specific energy use	Amount of specific energy (e.g. electricity, natural gas, district heating, district cooling, domestic hot water) during a year. Depending on the installed HVAC systems, it can also be divided for different end uses, such as space heating and cooling. Can also be referred to specific electric domestic appliances, to the lighting system and to domestic hot water production.	This KPI directly links to the all objectives of this HLUC, being necessary for the evaluation of the flexibility potential.

Monthly avg specific energy use	Monthly amount of specific energy use (e.g., electricity, natural gas, district heating, district cooling, domestic hot water). Daily amount of specific energy (e.g., electricity, natural gas, district heating, district cooling, domestic hot water).	This KPI directly links to the all objectives of this HLUC, being necessary for the evaluation of the flexibility potential.
Daily avg specific energy use	Daily amount of specific energy (e.g., electricity, natural gas, district heating, district cooling, domestic hot water).	This KPI directly links to the all objectives of this HLUC, being necessary for the evaluation of the flexibility potential.
Self-consumption of renewables	Ratio of renewable energy use over the total energy used by the building.	Evaluate the impact of those strategies in energy costs, user comfort and use of renewable sources
Load production to grid	On-site energy generated that is sold to the grid.	Implement peak shaving and load shifting strategies based on the thermal storage
Load factor	Represents the percentage of the electrical demand covered by on-site electricity generation.	Implement peak shaving and load shifting strategies based on the thermal storage
Costs for electricity consumption	Represents the amount of money the users have to pay for their bills related to electric energy use (can be divided for different end uses or different domestic appliances). The users can easily understand and relate to costs.	Evaluate the impact of those strategies in energy costs, user comfort and use of renewable sources
CO_2 emissions	The amount of CO_2 equivalent caused by the energy use. A measure of how much carbon dioxide and how much the users might contribute to climate change is created. It is necessary to use national CO_2 conversion factors to translate the different types of energy related to carriers into emissions.	Evaluate the impact of those strategies in energy costs, user comfort and use of renewable sources
Available capacity for active demand response	Represents the maximum amount of heat that can be stored in the structural storage capacity of the building in I_{ADR}, given the boundary conditions for thermal comfort, climate, occupant behaviour	This KPI directly links to all objectives of this HLUC, being necessary for the evaluation of the flexibility potential.
Delayed operation flexibility	*Represents the time the operation of the heating/cooling unit, e.g. CHP or heat pump, can be postponed while the energy demand is met by the storage.*	This KPI directly links to the all objectives of this HLUC, being necessary for the evaluation of the flexibility potential.
Forced operation flexibility	*Represents the amount of time the operation of the heating/cooling unit, e.g. CHP or heat pump, can be forced while the excess heat produced is stored for later use.*	This KPI directly links to the all objectives of this HLUC, being necessary for the evaluation of the flexibility potential.

1.6 Use case conditions

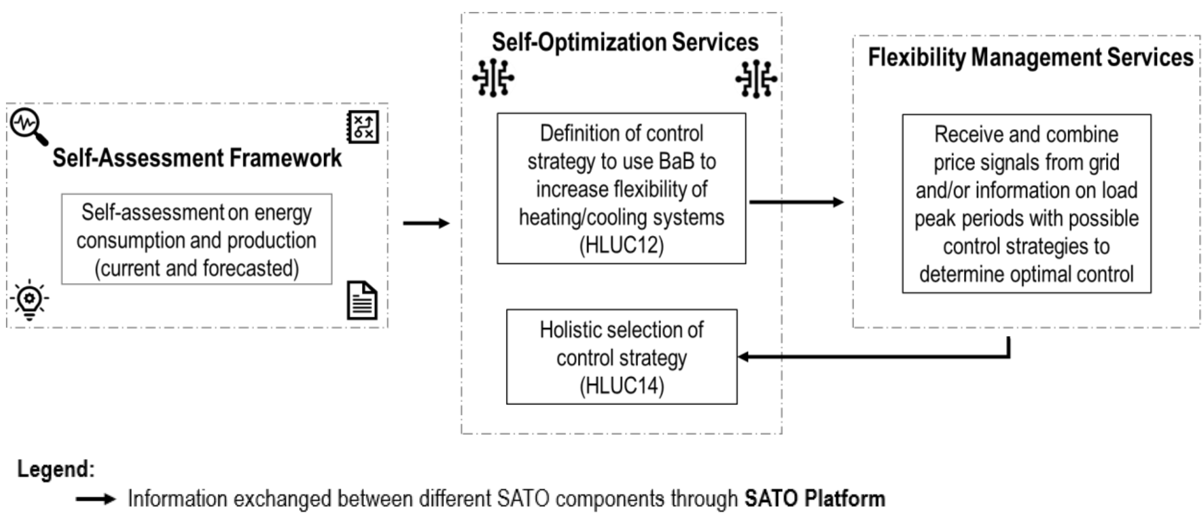
Use case conditions
Assumptions
The **SATO Platforms** and different IoT and Wi-Fi-based interfaces must be in operation. The **Facility/building managers**, **Building owners** or **Building occupants**, have given their consent to SATO perform assessments of the flexibility potential (GDPR compliant)
Prerequisites
Regarding hardware, to elaborate the flexibility strategies there must be a minimum monitoring setting in the indoor spaces of the buildings, to know at least the values of air temperature at adequate time and spatial resolutions. To implement the strategies automatically, at least the HVAC system/electric heaters/etc. must be connected to the **SATO Platform** to apply the control signals (operating schedules and setpoints). *HLUC01, HLUC02, HLUC03*

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
HLUC01 – Monitoring is a prerequisite for the definition of smart-optimization strategies and hence, the application of those strategies. HLUC02 – Data-driven self-assessment diagnosis of building performance HLUC03 – Building-level forecasting of energy loads, indoor air conditions, occupation and weather HLUC14 - Holistic optimal control of energy resources
Level of depth
Defines the level of depth of the use case: ***High-level use case*** *(HL-UC)*
Prioritisation
This HLUC is considered of top priority, since it deals with energy flexibility, which is one of the most important services that will be provided by the SATO platform. The self-optimization performed will send and receive information through the ***SATO Self-Optimization Services*** *in HLUC14.*
Generic, regional or national relation
Generic
Nature of the use case
Technical Use Case
Further keywords for classification
Self-optimization, flexibility, load-shifting, DSO, peak shaving, thermal storage, building as thermal battery, BaB

2 Diagrams of use case

Diagram(s) of use cases



3. Technical details

3.1 Actors

Actors		
Actor Name	***Actor Type***	***Actor Description***
Facility/ building managers	*Human actor*	*This actor as an indirect role in this HLUC. His role is to adapt the building conditions to occupants' preferences when the SATO system is not able to meet these preferences. This indirect participation enables the system to react better to future scenarios.*

Building occupants	*Human actor*	*This actor as an indirect role in this HLUC. His role is to adapt the building conditions to their preferences when the SATO system is not able to meet these preferences. This indirect participation enables the system to react better to future scenarios.* *Indeed the occupants' acceptance of not having a fixed setpoint of indoor temperature, but a fluctuation within the range of the selected comfort category, should be monitored*
SATO Self-Assessment Framework	*Software/ systems/ applications/ devices*	*The information about building thermal mass and energy needs for heating / cooling will be provided to SATO Self-Assessment Framework for the evaluation of available flexibility*
SATO Self-Optimization Services	*Software/ systems/ applications/ devices*	*SATO Self-Optimization Services will use this additional flexibility provided by SATO SAF together with other flexibility sources to determine the optimal operation mode*
SATO APL	*Software/ systems/ applications/ devices*	*SATO APL will receive and apply the optimal setpoints for HVAC systems*
SATO BMS	*Software/ systems/ applications/ devices*	
SATO Flexibility Management Service (FMS)	*Software/ systems/ applications/ devices*	*SATO FMS is responsible for demand side flexibility, exchanging data with the energy grid and improving load balancing for distributor system operators (DSOs) and transmission system operators (TSOs).*

3.2 References

References						
No.	***References type***	***Reference***	***Status***	***Impact on use case***	***Originator/ organization***	***Link***
1	*Internal Document*	*SATO KPI tool reference list*	*n/a*	*Provision of KPI to be included*	*AAU*	[*KPI tool*]
2	*Internal Document*	*SATO actors reference list*	*n/a*	*Provision of actors to be included*	*EDP NEW*	*Use Case Short Description V6.xlsx*
3	*Paper*	*Reynders G, Diriken J, Saelens D. Generic characterization method for energy flexibility: Applied to structural thermal storage in residential buildings. Applied Energy. 2017 Jul 15;198:192–202.*	*n/a*	*Reference for possible evaluation of flexibility and KPIs*		
4	*Paper*	*Oliveira Panão MJN, Mateus NM, Carrilho da Graça G. Measured and modeled performance of internal mass as a thermal energy battery for energy flexible residential buildings. Applied Energy. 2019 Apr 1;239:252–67.*	*n/a*	*Reference for possible evaluation of flexibility and KPIs*		
5	*Paper*	*Le Dreau J, Heiselberg P. Energy flexibility of residential buildings using short term heat storage in the thermal mass. Energy. 2016;*	*n/a*	*Reference for possible evaluation of flexibility and KPIs*		

4. Step by step analysis of use case

4.1 Overview of scenarios

Scenarios conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***

1	*Manage controllable loads to exploit energy flexibility linked to building thermal mass*	***SATO Self-Optimization Services*** *will evaluate building thermal mass storage capacity to provide flexibility services (e.g. peak shaving or load shifting) without impacting occupants*	***SATO Self-Optimization Services***	*The need to optimize energy consumption, production and energy costs*	*Existence of controllable HVAC system (or other heating/cooling systems) that can be used for flexibility services. Existence of adequate thermal capacity of the building fabric*	*Continuous monitoring of indoor temperatures to determine the end of the charge/discharge phase (i.e. heating/cooling)*

4.2 Steps – Scenarios

Scenario								
Scenario name:		***Reference scenario***						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirements, R-IDs***
1.1	*Receiving information of the building performance*	*Receiving SATO self-assessments*	***SATO Self-Optimization Services*** *collects information on the building performance from* ***SATO Platform***	*GET*	*SATO Platform*	*SATO Self-Optimization Services*	*IE1*	R-QoS-1; R-SEC-1; R-SEC-2; R-DATA-1;
1.2	*Receiving information form the energy grid(s), if available*	*B2G*	***SATO Self-Optimization Services*** *collects information on load peak periods and price signals from the grid from* ***SATO Flexibility Management Service and SATO Platform***	*GET*	*SATO Flexibility Management Service and SATO Platform*	*SATO Self-Optimization Services*	*IE2*	R-QoS-1; R-SEC-1; R-SEC-2; R-DATA-1;
1.3	*Identifying available flexibility through* ***SATO Self-Optimization Services***	*Identification of flexibility potential related to thermal mass*	***SATO Self-Optimization Services*** *identifies thermal energy flexibility potential available on the building thermal mass*	*CREATE*	*SATO Self-Optimization Services*	*SATO Self-Optimization Services*	*IE3*	R-QoS-1; R-SEC-1; R-SEC-2; R-DATA-1;
1.4	*Communicating available flexibility potential*	*Sending available flexibility potential*	*Sends available flexibility potential to the* ***SATO Platform*** *to be sent to HLUC14*	*REPORT*	*SATO Self-Optimization Services*	*SATO Platform*	*IE3*	R-QoS-1; R-SEC-1; R-SEC-2; R-DATA-1;
1.5	*Use continuous monitoring to improve flexibility strategies*	*Continuous monitoring of operation*	After a control strategy is deployed, continuous monitoring of the performance of the building, will generate a feedback on the implemented strategies.	*GET*	*SATO Platform*	*SATO Self-Optimization Services*	*IE1*	R-QoS-1; R-SEC-1; R-SEC-2; R-DATA-1;

(*) Available options are:

- *CREATE means that an information object is to be created at the Producer.*
- *GET (this is the default value if none is populated) means that the Receiver requests information from the Producer (default).*
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- *TIMER is used to represent a waiting period. When using the TIMER service, the Information Producer and Information Receiver fields shall refer to the same actor.*
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5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE1	*Building performance information*	*Information regarding building performance sent by the **SATO Platform** to the **SATO Self-Optimization Services***	R-QoS-1; R-SEC-1; R-SEC-2; R-DATA-1;
IE2	*Grid information*	*Information regarding load peak periods and price signals sent by the grid from **SATO Flexibility Management Service and SATO Platform***	R-QoS-1; R-SEC-1; R-SEC-2; R-DATA-1;
IE3	*Flexibility potential*	*Identification and communication of the flexibility potential internally through the **SATO Self-Optimization Services***	R-QoS-1; R-SEC-1; R-SEC-2; R-DATA-1;

6 Requirements

Requirements		
Categories ID	***Category name for requirements***	***Category description***
R-SEC	Security	Assess how different security measures applied to different items can potentially interact and either leave security holes or make user interfaces very laborious and possibly unworkable. Security must not only protect against the very harmful but quite rare deliberate attacks, but also against the far more likely inadvertent mistakes, failures, and errors. At the same time, it is necessary to try to identify the requirements and the concerns for implementing security measures.
R-QoS	Quality of Service (QoS)	Address availability of the system, such as acceptable downtime, recovery, backup, rollback, etc. QoS issues also address accuracy and precision of data, the frequency of data exchanges, and the necessary flexibility for future changes.
R-DATA	Data Management	Covers both the management of the data exchanges in each Use Case step and the management of data at either end if that management is impacted by data exchanges. An example of the first type of data management is the initial setting up and on- going maintenance of what data needs to be exchanged, say between a Geographic Information System and the many different applications that use its data. An example of the second type of data management is the need to backup data or ensure consistency of data whenever it is exchanged, such as if new protection settings are issued to multiple field devices, these settings need to be reflected in Contingency Analysis functions. It should not address database design but should concentrate on the user requirements for the interfaces to databases and other data handling applications.
Requirement R-ID	***Requirement name***	***Requirement description***
R-QoS-1	Frequency of data exchanges	Upon event
R-SEC-1	Replay	Ensuring that data cannot be resent by an unauthorized source
R-SEC-2	Information theft	Ensuring that data cannot be stolen or deleted by an unauthorized entity
R-DATA-1	Validation of data exchanges	Data can be assumed as valid (or validity checking is handled elsewhere);

7 Common Terms and Definitions

Common Terms and Definitions	
Term	*Definition*
B2G – Building(s)-to-grid	Building-to-Grid describes the instrumentation and communication infrastructure to allow a dynamic near real-time two-way communication between building(s) and the utility in order to optimize energy use
BaB – Building as thermal battery	Use of the structural thermal capacity as a heat storage medium, typically in winter
HVAC	heating, ventilation and air conditioning
RES	Renewable energy sources

HLUC13 – Exploitation of natural ventilation as a cost-effective indoor comfort strategy

1. Description of the use case

1.1 Name of the use case

ID	*Area*	*Name of Use Case*
HLUC13	(4) Self-optimization	Exploitation of natural ventilation as a cost-effective indoor comfort strategy

1.2 Version management

Version No.	*Date*	*Name of Author (s)*	*Changes*
1.0	11.05.21	Daniel P. Albuquerque	First version of HLUC13
2.0	21.05.21	Daniel P. Albuquerque	Second version of HLUC13
2.1	31.05.21	Filipe Silva	Revision of 2.0
2.2a	07.06.21	Per Heiselberg	Revision of 2.1
2.2b	08.06.21	Andrea Sangalli	Revision of 2.1
3.0	21.06.21	Daniel P. Albuquerque	Third version of HLUC13
4.0	02.07.21	Filipe Silva, João Dias	Fourth version of HLUC13

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	HLUC13 is a High-Level Use Case (HLUC) with focus on the use of natural ventilation in buildings in order to reduce the energy costs (reducing the energy need for cooling and energy use for ventilation,) associated with ensuring at the same time proper levels of comfort to the building's occupants. The **SATO Platform** will be equipped with automated self-assessment capabilities that are partially supported by statistical/machine learning methods. These technologies are used to obtain insights into user, equipment and building behaviour that can be exploited to provide innovative high-performance self-optimized energy management services. Natural ventilation is one of these **Self-Assessment and Optimization (SA&O) services** that SATO will provide to users. In the **SATO Platform**, the **Self-Assessment Framework** will investigate the potential of the use of natural ventilation based on: 1. The cooling/heating capacity of the indoor space 2. The reduction of energy use (turning off heating ventilation and air conditions, HVAC, & air handling unit, AHU) 3. Providing indoor air quality 4. Maintaining low noise levels

	On the other hand, the **Self-Optimization Services** will combine this natural ventilation potential with the remaining optimization services and, ultimately, choose the best combination of services that minimizes the energy use and still providing thermal and acoustic comfort to the occupants. In the HLUC, two Primary Use Cases (PUCs) will be studied. PUC13.1 focus on daytime natural ventilation assessment while PUC13.2 focus on night cooling. While both strategies can be complementary, night cooling is used to cool the thermal mass of the building while daytime natural ventilation is usually used for the instant ability to provide comfort without the use of electrical systems.
Objective(s)	1. Assess impact of different natural ventilation control strategies on energy use, energy savings and user (thermal, acoustic, visual, …) comfort. 2. Develop automated controls and strategies for air intake that enables natural ventilation. 3. Dynamic calculation of the SRI domain “controlled ventilation”.

1.4 Narrative of use case

1.4.1 Narrative of High-Level use case

Narrative of Use Case
Short description
Natural ventilation will be evaluated using **SATO Self-Assessment Framework**, allowing to perform a data-driven decision about the potential of natural ventilation to improve the user comfort and the indoor air quality, while reducing the energy needs for cooling. **SATO Platform** will have control over some windows to automatically deploy the best natural ventilation control strategy given by the **SATO Self-Optimization Services**.
Complete description
Natural ventilation consists of the air exchange between the interior and exterior of a room through a certain aperture. In buildings, this air exchange often occurs through one, or more, openable windows and is promoted by the wind, the thermal buoyancy, or a combination of the two. Natural ventilation takes advantage of favourable exterior weather conditions (availability of fresh air and cool temperatures) as a strategy to preserve user thermal comfort and improve the indoor air quality. This way, natural ventilation helps to reduce the energy use and consequently the costs (to the stakeholders) that are linked to indoor air conditioning (HVAC) and/or air filtration (AHU). In the context of SATO, natural ventilation will be one of the **SATO Self-Optimization Services** provided. The potential use of natural ventilation will be firstly evaluated using the data collected from a multitude of building sensors (indoor air temperature and CO_2 concentration, occupancy, etc.) and close-to-building weather station (outdoor air temperature, relative humidity, wind velocity, rain, etc.), through the **SATO Self-Assessment Framework**. Then, the natural ventilation potential will be considered together with the remaining optimization services by the HLUC14, and an optimal holistic control will dictate the control actions that will minimize user discomfort and increase the energy efficiency and the available flexibility. In HLUC14, SATO will promote a passive/low energy strategy, which means that when natural ventilation is available it will be prioritized over mechanical ventilation/active cooling and the resulting thermal comfort conditions will be evaluated in according to the adaptive comfort model. In case that HLUC14 opted to use a natural ventilation strategy, the action controls will be remotely passed to window actuators (from the **SATO APL** or **SATO BMS**) that can open or close the selected windows and even control its opening area (controlling how much the window opens/tilts, depending on the window configuration). HLUC13 must also guarantee that the **SATO Self-Optimization Services** receive the status data from each window actuator. For that purpose, the window actuators should be able to send this data, in real-time, back to the **SATO Platform**. The latter will eventually send this data (already treated and structured) to the **SATO Self-Optimization Services**. If **SATO Self-Optimization** is unable to predict possible uncomfortable situations, building managers, and building owners may use the **SATO BMS** or **SATO APL** to overwrite the controls from **SATO Self-Optimization Services** and send new commands adapting the natural ventilation strategy to user preferences. These commands will then be analysed by **SATO Self-Optimization Services** and incorporated for future assessments/optimizations. If there is no available communication between the window actuators and the **SATO Platform**, SATO proposes to embed localized intelligence, providing devices the capability of, when needed, operate in isolation, with no cloud communication. To do so, simplified control

algorithms will be implemented on the window actuators, which will make them able not only to receive and actuate over real-time cloud-dictated signals, but also to predict the next ones (e.g., in the coming hours), until a different cloud-elaborated signal arrives. One of the advantages of the SATO project, is its capacity to dynamically assess the building performance using the smart **Self-Assessment Framework**. Whereas the SRI is a static assessment of the presence of smart services in a building, SATO will be able to move this theoretical, static SRI value to a real and dynamic SRI depending on real-time building performance. SRI evaluates a total of 9 domains, with the “controlled ventilation” of a building being one of them. As the HLUC13 will provide an automated control over the natural ventilation, the “controlled ventilation” SRI domain can consider natural ventilation potential and its contribution to the overall SRI can be dynamically calculated.

1.4.2 Narrative of primary use cases

ID	*Name*	*Description*
PUC13.1	Daytime natural ventilation	Natural ventilation to cool/heat the space and/or improve indoor air quality during the time the building is being occupied.
PUC13.2	Night cooling	Natural ventilation to leverage from the cooler air temperatures during the night to pre-cool the building for the next day.

1.5 Key performance indicators (KPI)

Name	*Description*	*Reference to mentioned use case objectives*
Air change rate (ACH)	Represents the measure of the air volume added to or removed from a space in one hour, divided by the volume of the space. Higher values of ACH correspond to higher ventilation rates.	1, 3
Natural ventilation potential	Possibility, or probability, to ensure both indoor air quality and thermal comfort by natural ventilation only.	1, 2, 3
Thermal comfort (Air temperature / operative temperature)	Represents the temperature measured in the room. It can be given as the present value or as an average value for a given time period (daily, weekly).	1, 2, 3
Thermal comfort categories	Based on the percentage of thermally dissatisfied persons (PPD index) thermal comfort sensations are divided into different categories (Cat. I PPD<6%; Cat. II PPD<10%; Cat III PPD<15%; Cat. IV PPD > 15%). It can be given as the present value or as an average value for a given time period (daily, weekly)	1, 2, 3
Atmospheric comfort (CO_2 concentration)	CO_2 concentration is one of the parameters used to assess indoor air quality. The CO_2 concentration is usually measured in parts per million [ppm]. High values of CO_2 in buildings may cause headaches, fatigue, eye symptoms, nasal symptoms and respiratory tract symptoms. These symptoms are part of the sick building syndrome (SBS).	1, 2, 3
Atmospheric comfort (Relative humidity)	Percentage of the moisture against the highest possible level of moisture in the air at a specific temperature.	1, 2, 3
Atmospheric comfort (VOC)	The concentration of Volatile Organic Compounds (VOCs) is often reported using the following units: parts per million [ppm] or micrograms of VOCs per cubic meter of air [$\mu g/m^3$].	1, 3
Thermal comfort (Draught rate)	Percentage of people dissatisfied due to draught	1, 2, 3
Atmospheric comfort (Perceived air quality)	People perception of indoor air quality, usually assessed through questionnaires.	1, 2, 3
Total annual specific energy consumption	Measures the amount of specific energy (e.g., electricity, natural gas, district heating, district cooling, domestic hot water) consumed during a year. It can also	1, 3

	be divided for different end-uses, such as space heating and cooling, appliances, lighting system, domestic hot water production and others.	
Monthly avg specific energy consumption	Measures the monthly amount of specific energy consumption (e.g., electricity, natural gas, district heating, district cooling, domestic hot water).	1, 3
Daily avg specific energy consumption	Measures the daily amount of specific energy consumption (e.g., electricity, natural gas, district heating, district cooling, domestic hot water).	1, 3
Costs for electricity consumption	Measures the cost of all electricity used during a certain period (e.g., yearly).	1, 3
Cost for district cooling consumption	Represents the amount of money the users have to pay for their bills related to district cooling consumptions.	1, 3
CO_2 emissions	The amount of CO_2 equivalent caused by the energy consumption. A measure of how much carbon dioxide and how much the users might contribute to climate change is created. It is necessary to use national CO_2 conversion factors in order to translate the different types of energy related to carriers into emissions.	3

1.6 Use case conditions

Use case conditions
Assumptions
The **SATO Platform** should have access to weather station data from a location close to user/pilot. The **SATO Platform** should also have a real-time communication with the building to get relevant data (e.g., energy usage, indoor air temperature and relative humidity, occupancy, noise levels, …). The **SATO Platform** should be able to receive the best natural ventilation control strategy from the **SATO Self-Optimization Services** and remotely control the actuators to open or close windows to achieve the desired levels of natural ventilation.
Prerequisites
The different sensors should be properly located and should have an active communication with the **SATO Platform**. It is linked to: HLUC01 HLUC02 HLUC03

1.7 Further Information to the use case for classification / mapping

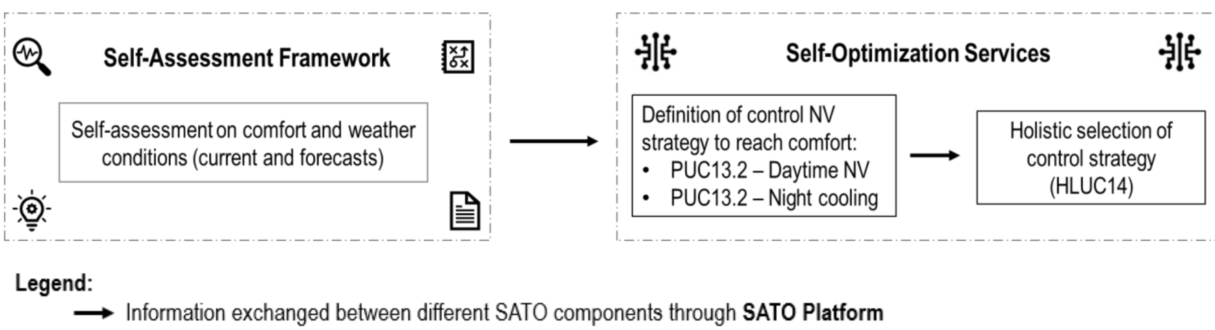
Classification Information
Relation to other use cases
HLUC01 – Monitoring is essential for the evaluation of the natural ventilation potential (e.g., indoor/outdoor air temperatures, wind velocity) HLUC02 - Self-Assessment provides the data to be analysed by the **Self-Optimisation Services**. HLUC03 – The forecasting of energy loads, indoor air conditions, occupation and weather from the **Self-Assessment Framework** will feed data into **SATO Self-Optimization Services** and the latter will create future scenarios of optimal operation. HLUC14 – This HLUC will make an optimal control decision between competing strategies developed in **SATO Self-Optimization Services**.
Level of depth
HLUC13 – Exploitation of natural ventilation as an energy saving and cost-effective indoor comfort strategy PUC13.1 – Daytime natural ventilation PUC13.2 – Night cooling
Prioritisation
This HLUC is amongst the HLUCs that can have the most impact on the energy savings of buildings.

The HLUC13 will be used in more than one pilot and, eventually, it can be expanded to pilots from other regions as well. PUC13.1 and PUC13.2 will be applied, at least, in Seixal Municipality Office and in Lisbon Services Building.
Generic, regional or national relation
Generic Use Case
Nature of the use case
System use case
Further keywords for classification
Self-optimization, user comfort, energy savings, natural ventilation, actuators, sensors, weather station

2 Diagrams of use case

For clarification, in general it is recommended to provide drawing(s) by hand, by a graphic or as UML graphics. The drawing should show interactions which identify the steps where possible.

Diagram(s) of use cases



3. Technical details

3.1 Actors

Actors		
Actor Name	***Actor Type***	***Actor Description***
Facility/ building managers	Human actor	This actor as an indirect role in this HLUC. His role is to adapt the building conditions to occupants' preferences when the SATO system is not able to meet these preferences. This indirect participation enables the system to react better to future scenarios.
Building occupants	Human actor	This actor as an indirect role in this HLUC. His role is to adapt the building conditions to their preferences when the SATO system is not able to meet these preferences. This indirect participation enables the system to react better to future scenarios.
SATO Platform	Software/ systems/ applications/ devices	**SATO Platform** will receive sensors and actuators data and send it to the **SATO SAF**. The **SATO Platform** will then receive from **SATO SOS** the orders need to achieve an optimal natural

		ventilation control strategy and will send them to the window actuators.
SATO Self-Assessment Framework	Software/ systems/ applications/ devices	**SATO SAF** will receive data regarding current sensors and controls from the **SATO Platform**, which will be analysed and used to produce the assessment over the natural ventilation potential.
SATO Self-Optimization Services	Software/ systems/ applications/ devices	**SATO SOS** will receive the natural ventilation potential assessment from the **SATO SAF** and will run cloud-based machine learning algorithms to choose the optimal control strategy. The natural ventilation control strategies generated by the **SATO SOS** will be sent to the **SATO Platform**.

3.2 References

References						
No.	***References type***	***Reference***	***Status***	***Impact on use case***	***Originator/ organization***	***Link***
1	*Internal Document*	*SATO KPI tool reference list*	*n/a*	*Provision of KPI to be included*	*AAU*	[KPI tool]()
2	*Internal Document*	*SATO actors reference list*	*n/a*	*Provision of actors to be included*	*EDP NEW*	*Use Case Short Description V6.xlsx*

4. Step by step analysis of use case

4.1 Overview of scenarios

Scenarios conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
1	**SATO Platform** actively controls window **actuators** to exploit natural ventilation potential.	The window actuators in the building will perform control-actions received from the **SATO Platform**.	**Self-optimization services**	The actuators will receive control actions from the **SATO Platform**.	Capacity to actively control windows. Available communication between **SATO Platform** and the actuators.	Control actions will be deployed, changing the natural ventilation strategy as needed.
2	Window **actuators** controls the natural ventilation using previous predictions/forecast from **SATO SOS**.	Due to a lack of connection with the **SATO Platform**, the window actuators will be able to perform control actions based on simplified control algorithms that will be implemented into the actuators.	**Actuators**	Lack of connection with the **SATO Platform**.	Capacity to actively control windows. Previously receive future optimal scenarios from **SATO SOS**.	Control actions will be deployed, changing the natural ventilation strategy as previously predicted by **SATO SOS**.

4.2 Steps – Scenarios

Scenario								
Scenario name:		*SATO platform actively controls window actuators to exploit natural ventilation potential*						
Step No.	*Event*	*Name of process/ activity*	*Description of process/ activity*	*Service*	*Information producer (actor)*	*Information receiver (actor)*	*Information Exchanged (IDs)*	*Requirements, R-IDs*
1.1	Reception of data previously treated by the **SATO Self-Assessment Framework**	Receive data from **SATO Self-Assessment Framework**	Self-assessment data is sent by **SATO Platform** to the **SATO Self-Optimization Services**.	GET	SATO Platform	SATO Self-Optimization Services	IE1	*R-SEC-1; R-SEC-2; R-QoS-1; R-QoS-2; R-DATA-1; R-DATA-2; R-DATA-3*
1.2	*Identifying natural ventilation potential through* ***SATO Self-Optimization Services***	*Identification of natural ventilation potential*	***SATO Self-Optimization Services*** *identifies natural ventilation potential to cool/heat the building.*	*CREATE*	*SATO Self-Optimization Services*	*SATO Self-Optimization Services*	*IE2*	R-QoS-1; R-SEC-4; R-SEC-5; R- DATA -3;
1.3	*Communicating natural ventilation strategies*	*Sending natural ventilation strategies*	*Sends natural ventilation strategies to the* ***SATO Platform*** *to be sent to HLUC14.*	*REPORT*	*SATO Self-Optimization Services*	*SATO Platform*	*IE3*	R-QoS-1; R-SEC-4; R-SEC-5; R- DATA -3;
1.4	*Use continuous monitoring to improve flexibility strategies*	*Continuous monitoring of operation*	After a control strategy is deployed, continuous monitoring of the performance of the building, will generate a feedback on the implemented strategies.	*GET*	*SATO Platform*	*SATO Self-Optimization Services*	*IE1*	R-QoS-1; R-SEC-4; R-SEC-5; R-DATA-3;

Scenario								
Scenario name:		***Window actuators controls the natural ventilation using previous predictions/forecasts from SATO SOS.***						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirements, R-IDs***
2.1	Lack of connection with **SATO Platform**	Lack of connection	The window actuators fail to connect with **SATO Platform** and the actuators "know" that must use the onboard predictions.	REPORT	Window actuators	Window actuators	-	
2.2	Implementation of control actions by the window actuators	Apply controls predicted by simplified algorithms	The control actions used were predicted by the smart simplified control algorithms embedded in the actuators.	EXECUTE	Window actuators	Window actuators	-	
2.3	Creation of a log of actions during the lack of connection	Creation of an actions log	The window actuators create a log of control actions taken while offline.	CREATE	Window actuators	Window actuators	-	
2.4	Submission of control actions taken and actuator status	Send actions log and window actuators state	When the connection re-establishes, window actuators will send the control actions log (taken while offline) and the current state of the actuators to the **SATO Platform**.	GET	Window actuators	SATO Platform	IE4	*R-SEC-1; R-SEC-2; R-QoS-2; R-DATA-1; R-DATA-3*

(*) Available options are:

- *CREATE means that an information object is to be created at the Producer.*
- *GET (this is the default value if none is populated) means that the Receiver requests information from the Producer (default).*
- *CHANGE means that information is to be updated. Producer updates the Receiver's information.*
- *DELETE means that information is to be deleted. Producer deletes information from the Receiver.*
- *CANCEL, CLOSE imply actions related to processes, such as the closure of a work order or the cancellation of a control request.*
- *EXECUTE is used when a complex transaction is being conveyed using a service, which potentially contains more than one verb.*
- *REPORT is used to represent transferral of unsolicited information or asynchronous information flows. Producer provides information to the Receiver.*
- *TIMER is used to represent a waiting period. When using the TIMER service, the Information Producer and Information Receiver fields shall refer to the same actor.*

- *REPEAT is used to indicate that a series of steps is repeated until a condition or trigger event. The condition is specified as the text in the "Event" column for this row or step. Following the word REPEAT, shall appear, in parenthesis, the first and last step numbers of the series to be repeated in the following form REPEAT(X-Y) where X is the first step and Y is the last step.*

5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE1	Assessment data	Data generated by the Self-assessment framework based on the collect data and building characteristics	*R-SEC-1; R-SEC-2; R-QoS-1; R-QoS-2; R-DATA-1; R-DATA-2; R-DATA-3*
IE2	Control actions	Setpoint that are sent to **SATO Platform** to be implemented.	*R-SEC-1; R-SEC-2; R-QoS-2; R-DATA-1; R-DATA-3*
IE3	State of actuators	Current setpoints being implemented in the actuators.	*R-SEC-1; R-SEC-2; R-QoS-2; R-DATA-1; R-DATA-3*
IE4	Historical data upload	Upload of historical state of actuators when real-time connection is broken	*R-SEC-1; R-SEC-2; R-QoS-2; R-DATA-1; R-DATA-3*

6 Requirements

Requirements		
Categories ID	***Category name for requirements***	***Category description***
R-CONFIG	Configuration	Reflect the typical, probable, or envisioned communication configurations that are relevant to the use case step. These configuration issues include numbers of systems and/or components, expected growth of the system over time, locations, distances, communication types, network bandwidth, existing protocols, etc., but only from the user's point of view. In some cases, only one of the possible choices is reasonable, while for other situations, more than one choice is reasonable.
R-SEC	Security	Assess how different security measures applied to different items can potentially interact and either leave security holes or make user interfaces very laborious and possibly unworkable. Security must not only protect against the very harmful but quite rare deliberate attacks, but also against the far more likely inadvertent mistakes, failures, and errors. At the same time, it is necessary to try to identify the requirements and the concerns for implementing security measures.
R-COMP	Compatibility	Compatibility with other functions In the SATO Platform and external systems and components (e.g. 3rd party Clouds)
R-QoS	Quality of Service (QoS)	Address availability of the system, such as acceptable downtime, recovery, backup, rollback, etc. QoS issues also address accuracy and precision of data, the frequency of data exchanges, and the necessary flexibility for future changes.
R-DATA	Data Management	Covers both the management of the data exchanges in each Use Case step and the management of data at either end if that management is impacted by data exchanges. An example of the first type of data management is the initial setting up and ongoing maintenance of what data needs to be exchanged, say between a Geographic Information System and the many different applications that use its data. An example of the second type of data management is the need to backup data or ensure consistency of data whenever it is exchanged, such as if new protection settings are issued to multiple field devices, these settings need to be reflected in Contingency Analysis functions.

		It should not address database design but should concentrate on the user requirements for the interfaces to databases and other data handling applications.
Requirement R-ID	***Requirement name***	***Requirement description***
R-SEC-1	Data privacy	Ensuring confidentiality, avoiding illegitimate use of data, and preventing unauthorized reading of data, is quite important
R-SEC-2	Authentication	Ensuring that data comes from the stated source or goes to authenticated receiver is important.
R-QoS-1	Availability of information flows	Continuous availability not required but must be available at specific times or under specific conditions.
R-QoS-2	Accuracy of data requirements	Age of data needs to be known; Quality of data characterization is important.
R-DATA-1	Correctness of source data	Ensures that the data is correctly interpreted and used for the purpose it was designed to.
R-DATA-2	Management of accessing different types of data to be exchanged	Sets the type of data being exchanged and the expected periodic update (asynchronous or every x time).
R-DATA-3	Validation of data exchange	Guarantees that data exchanged between parties is valid. It can provide confirmation to the originally sending party.

7 Common Terms and Definitions

Common Terms and Definitions	
Term	***Definition***
AHU	Air handling unit
HVAC	Heating, ventilation and air conditioning
IoT	Internet of Things
NV	Natural ventilation
SRI	Smart readiness indicator

HLUC14 – Holistic optimal control of energy resources

1. Description of the use case

1.1 Name of the use case

ID	***Area***	***Name of Use Case***
HLUC14	Self-optimization	Holistic optimal control of energy resources

1.2 Version management

Version No.	Date	Name of Author (s)	Changes
1.0	24/05/2021	Pedro M. Ferreira	Initial version
1.1	26/05/2021	Frederico Cardoso Melo	Revised version
1.2	28/05/2021	Daniel P. Albuquerque	Revision of version 1.1
1.3	03/06/2021	Filipe N. Silva e João B. Dias	Review
2.0	25/06/2021	Pedro M. Ferreira	Integration of reviews

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	The High-Level Use Case (HLUC14) considers the holistic optimal control of energy resources in the building. It will aggregate the control of energy efficiency services, flexibility services, and other optimization services that have an impact on energy utilization within the building. Different services may be used to control indicators related to the utilization of energy in buildings. For instance, thermal, acoustic, and visual comfort, air quality, energy consumption, or available flexibility indicators. When executed individually, these services are likely to generate conflicting control requirements and actions to be implemented in the building. HLUC14 focuses on the coordinated control of the different services, considering different user preferences and requirements, and building resources context. The HLUC14 assumes the existence of a service or tool that can optimize the control of individual services considering user preferences and requirements as well as different building control possibilities. Three Primary Use Cases (PCUs) may be derived from HLUC14: PUC14.1 (Holistic optimal control of energy resources in office buildings), PUC14.2 (Holistic optimal control of energy resources in residential buildings) and PCU14.3 (Holistic optimal control of energy resources in commercial and public buildings). The first deals with the scenarios of office buildings, the second with the scenarios of residential buildings and the third with the scenarios of commercial buildings.
Objective(s)	HLUC14 main objective is to provide a user centred coordinated control of energy resources. To achieve it, HLUC14 is subdivided in three base objectives: 1. Compile all self-optimization strategies and KPIs. 2. Prioritize which self-optimization strategies will be triggered in the buildings. 3. Send control signals to the different appliances, equipment and actuators.

1.4 Narrative of use case

1.4.1 Narrative of High-Level use case

Narrative of Use Case
Short description
Holistic optimal control of energy resources aims to establish an overarching service that oversees and coordinates the control actions of individual energy management services and other services related to the utilization of energy in buildings, to optimize various performance indicators according to the preferences and requirements of users.
Complete description
HLUC14 – Holistic optimal control of energy resources concerns the optimal selection of control actions to be implemented by the management system. The goal is to evaluate and prioritize conflicting types of controls in accordance with the priorities defined by users and improving energy efficiency without impacting building occupant activities. HLUC14 will not have a direct interaction with occupants since prioritization preferences should be selected before implementation.

To achieve the goal of holistic energy management in buildings, the HLUC14 defines the following steps: 1. Fetch data from SATO Platform to know which strategies are available for each timestep. Additionally, the preferences of the users (defined in HLUC07) should be incorporated to define which strategies should be prioritized. 2. Receive the results of the different Self-Optimisation Services (HLUC08 to HLUC13). 3. The holistic control service will use the information to coordinate the individual services, providing continuously a unique and coherent set of actuator signals to the **SATO Platform**, which will optimize the set of performance indicators related to the individual services under coordination. 4. Send the control signal to the **SATO Platform** that will be sent to the HLUC15 that will deploy them using **SATO APL** and **SATO BMS.**

1.4.2 Narrative of primary use cases

ID	*Name*	*Description*
PUC14.1	Holistic optimal control of energy resources in office buildings	PUC14.1 aims to implement a coordinated control for office buildings, considering different user preferences and requirements, and building resources context. It will aggregate the control of energy efficiency services, flexibility services, and other optimization services that have an impact on energy utilization within the building.
PUC14.2	Holistic optimal control of energy resources in residential buildings	PUC14.2 aims to implement a coordinated control for office residential buildings, considering different user preferences and requirements, and building resources context. It will aggregate the control of energy efficiency services, and other optimization services that have an impact on energy utilization within the building.
PCU14.3	Holistic optimal control of energy resources in commercial buildings	PUC14.1 aims to implement a coordinated control for commercial buildings, considering different user preferences and requirements, and building resources context. It will aggregate the control of energy efficiency services, flexibility services, and other optimization services that have an impact on energy utilization within the building.

1.5 Key performance indicators (KPI)

This HLUC considers all the KPIs from linked HLUC8 to HLUC13 and HLUC15, plus user satisfaction KPIs.

Name	*Description*	*Reference to mentioned use case objectives*
Total annual specific energy use	Measures the amount of specific energy (e.g. electricity, natural gas, district heating, district cooling, domestic hot water) during a year. Depending on the installed HVAC systems, it can also be divided for different end uses, such as space heating and cooling. Can also be referred to specific electric domestic appliances, to the lighting system and to domestic hot water production.	This KPI directly contribute for objectives 1, 2 of this HLUC. Especially in allowing to prioritize self-optimization strategies based on actual building performance.
Monthly average specific energy use	Measures the average amount of specific energy (e.g. electricity, natural gas, district heating, district cooling, domestic hot water) during a month. Depending on the installed HVAC systems, it can also be divided for different end uses, such as space heating and cooling. Can also be referred to specific electric domestic appliances, to the lighting system and to domestic hot water production.	This KPI directly contribute for objectives 1, 2 of this HLUC.
Daily average specific energy use	Measures the average amount of specific energy (e.g. electricity, natural gas, district heating, district cooling, domestic hot water) during a day. Depending on the installed HVAC systems, it can also be divided for different end uses, such as space heating and cooling. Can also be referred to specific electric domestic appliances, to the lighting system and to domestic hot water production.	This KPI directly contribute for objectives 1, 2 of this HLUC.

Self-consumption of renewables	Represents the renewable energy amount produced on-site and self-consumed in the building system.	This KPI directly contribute for objectives 1, 2 of this HLUC.
Yearly local produced energy	Represents the yearly energy produced on-site.	This KPI directly contribute for objectives 1, 2 of this HLUC.
Monthly local produced energy	Represents the monthly energy produced on-site.	This KPI directly contribute for objectives 1, 2 of this HLUC.
Daily local produced energy	Represents the daily energy produced on-site.	This KPI directly contribute for objectives 1, 2 of this HLUC.
Load production to grid	Represents the percentage of the electrical demand introduced in the grid by the on-site electricity generation.	This KPI directly contribute for objectives 1, 2 of this HLUC.
Load factor	Represents the percentage of the electrical demand covered by on-site electricity generation.	This KPI directly contribute for objectives 1, 2 of this HLUC.
Costs for electricity consumption	Represents the amount of money the users have to pay for their bills related to electric energy consumptions (can be divided for different end uses or different domestic appliances). The users can easily understand and relate to costs	This KPI directly contribute for objectives 1, 2 of this HLUC.
Costs for natural gas consumption	Represents the amount of money the users have to pay for their bills related to natural gas consumptions (can be divided for different end uses). The users can easily understand and relate to costs.	This KPI directly contribute for objectives 1, 2 of this HLUC.
Costs for district heating consumption	Represents the amount of money the users have to pay for their bills related to district heating consumptions (can be divided for different end uses, for example space heating, domestic hot water production, ...). The users can easily understand and relate to costs.	This KPI directly contribute for objectives 1, 2 of this HLUC.
Costs for district cooling consumption	Represents the amount of money the users have to pay for their bills related to district cooling consumptions. The users can easily understand and relate to costs.	This KPI directly contribute for objectives 1, 2 of this HLUC.
Costs for domestic water use	Represents the amount of money the users have to pay for their bills related to domestic water use. The users can easily understand and relate to costs.	This KPI directly contribute for objectives 1, 2 of this HLUC.
Total emission of CO_2, equivalent	The amount of CO_2 equivalent caused by the energy consumption. A measure of how much carbon dioxide and how much the users might contribute to climate change is created. It is necessary to use national CO_2 conversion factors in order to translate the different types of energy related to carriers into emissions.	This KPI directly contribute for objectives 1, 2 of this HLUC.
CO_2 emissions for energy carrier	Evaluates CO_2 emissions for each energy vector consumed in the building system (on-site).	This KPI directly contribute for objectives 1, 2 of this HLUC.
Specific Emission of CO_2, equivalent	The amount of CO_2 equivalent caused by the energy consumption. Can be related to the conditioned net building area.	This KPI directly contribute for objectives 1, 2 of this HLUC.
Specific Emission of CO_2, equivalent	The amount of CO_2 equivalent caused by the energy consumption. Can be related to the conditioned net building volume.	This KPI directly contribute for objectives 1, 2 of this HLUC.
Air change rate (ACH)	Evaluates the ventilation of a building zone by measuring the concentration of a tracer-gas.	Although this KPI is not directly linked to the objectives of this HLUC, it is indirectly linked to objective 3, allowing to infer the indoor environmental conditions and occupants comfort.
Natural ventilation potential	Evaluates the flow-rate potential from natural ventilation.	Although this KPI is not directly linked to the objectives of this HLUC, it is indirectly linked to objective 3.
Thermal comfort (Air temperature / operative temperature)	Represents the temperature measured in the room. It can be given as the present value or as an average value for a given time period (daily, weekly).	Although this KPI is not directly linked to the objectives of this HLUC, it is indirectly linked to objective 3.
Thermal comfort categories	Based on the percentage of thermally dissatisfied persons (PPD index) thermal comfort sensations are divided into different categories (Cat. I PPD<6%; Cat. II PPD<10%; Cat III PPD<15%; Cat. IV PPD > 15%). It can value or as an	Although this KPI is not directly linked to the objectives of this HLUC, it is indirectly linked to objective 3.

	average value for a given time period (daily, weekly) be given as the present.	
Thermal comfort (Draught rate)	The draft rate expresses the percentage of occupants expected to be disturbed by the draft. In this sense, this KPI expresses the occupants uncomfortable with the temperature.	Although this KPI is not directly linked to the objectives of this HLUC, it is indirectly linked to objective 3.
Atmospheric comfort (CO_2 concentration)	Represents the CO_2 indoor concentration levels.	Although this KPI is not directly linked to the objectives of this HLUC, it is indirectly linked to objective 3.
Atmospheric comfort (Relative humidity)	Represents the relativity humidity indoor concentration levels.	Although this KPI is not directly linked to the objectives of this HLUC, it is indirectly linked to objective 3.
Atmospheric comfort (VOC)	Evaluates the indoor concentration of volatile organic compounds.	Although this KPI is not directly linked to the objectives of this HLUC, it is indirectly linked to objective 3.
Atmospheric comfort (Perceived air quality)	Evaluates the indoor air quality perceived by the occupants.	Although this KPI is not directly linked to the objectives of this HLUC, it is indirectly linked to objective 3.
Acoustic comfort (Reverberation time)	Represent the indoor acoustic comfort based on reverberation time.	Although this KPI is not directly linked to the objectives of this HLUC, it is indirectly linked to objective 3.
Acoustic comfort (Noise)	Represent the indoor acoustic comfort based on noise measures.	Although this KPI is not directly linked to the objectives of this HLUC, it is indirectly linked to objective 3.
Visual comfort (Illuminance)	Represent the indoor visual comfort based on Illuminance.	Although this KPI is not directly linked to the objectives of this HLUC, it is indirectly linked to objective 3.
Visual comfort (Daylight atonomy)	Represent the indoor visual comfort based on daylight autonomy.	Although this KPI is not directly linked to the objectives of this HLUC, it is indirectly linked to objective 3.
Flexibility Index	Represents the change of heating use during medium and high price periods when the energy is accumulated during low price periods compared to a reference scenario without any thermal storage strategy.	This KPI is linked to objective 2 because it contributes to prioritizing the self-optimization techniques considering flexibility events.
Flexibility factor	Illustrates the ability to shift the energy use from high to low price periods.	This KPI is linked to objective 2.
Energy flexibility factor	Evaluates the performance of energy flexibility for different buildings with different control strategies.	This KPI is linked to objective 2.
Available capacity for active demand response	Represents the maximum amount of heat that can be stored in the structural storage capacity of the building, given the boundary conditions for thermal comfort, climate, occupant behaviour.	This KPI is linked to objective 2.
Flexibility	Represents the ability to deviate from the reference electric load profile during the flexibility interval. The total power shift is integrated over the flexibility interval and expressed in units of energy.	This KPI is linked to objective 2.
Delayed operation flexibility	Represents the time of heating/cooling operation, e.g. CHP or heat pump, can be postponed while the energy demand is met by the storage.	This KPI is linked to objective 2.
Forced operation flexibility	Defined the heating/cooling unit operation time, e.g. CHP or heat pump, can be forced while the excess heat produced is stored for later use.	This KPI is linked to objective 2.

1.6 Use case conditions

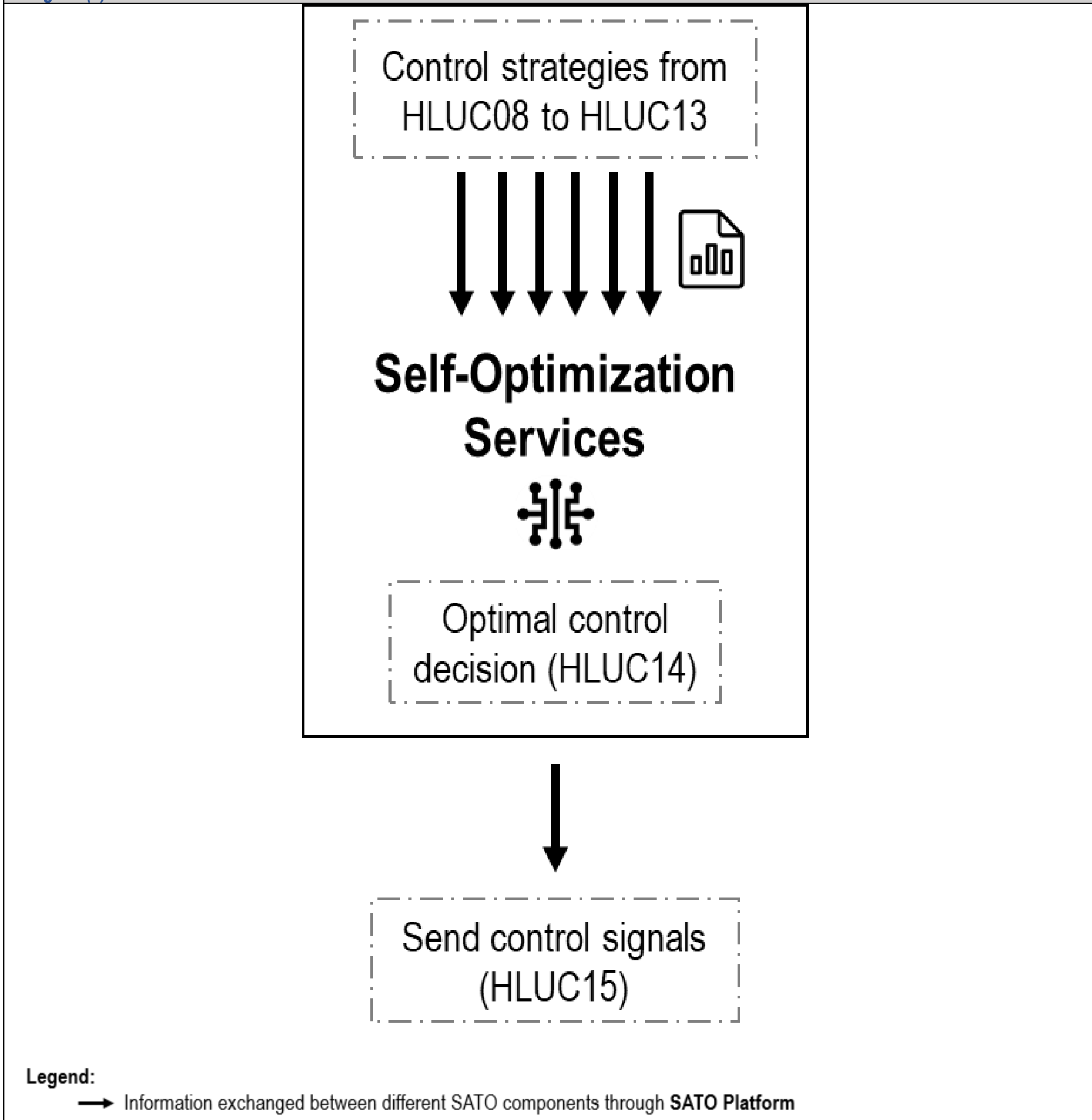
Use case conditions
Assumptions
Proper data flow transmission between metering devices and sensors, the **SATO Platform**, **SATO Self-Assessment Framework** and the remaining **SATO Self-Optimization Services**.

The **SATO Platform** must be deployed and tested in the pilots where this HLUC will be tested. The relevant actors have been identified or recruited and are aware of the experiments that will be carried out to test the use case.
Prerequisites
Links to: Data monitoring (HLUC01) Self-assessment of building performance (HLUC02) Data forecasts (HLUC03) Remaining SATO Self-Optimization Services (HLUC8 to HLUC13)

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
Since the implicit energy management service of HLUC14 coordinates other individual **SATO Self-Optimization Services**, this HLUC relates to HLUC8 to HLUC13 and HLUC15 (which will implement the control actions). HLUC01 to HLUC03 will provide data to evaluate and weigh the different optimisation strategies.
Level of depth
High-level use case *(HL-UC) use case which describes a general requirement, idea or concept independently from a specific technical realization like an architectural solution.*
Prioritisation
The HLUC14 is of top importance in SATO since it will: • demonstrate how the self-assessments can be employed to build energy management services. • aggregate the control of energy resources, balancing individual energy management services. • optimize multiple performance indicators simultaneously.
Generic, regional or national relation
This is a generic use case that will be demonstrated in various countries in residential, office and commercial building pilots, possibly with variations linked to the available individual energy management services considered in each pilot.
Nature of the use case
Technical and test use case.
Further keywords for classification
Self-assessment, self-optimization, holistic building energy management.

2 Diagrams of use case

Diagram(s) of use cases


3. Technical details

3.1 Actors

Actors		
Actor Name	*Actor Type*	*Actor Description*
Facility/building managers	Human actor	This actor has an indirect role for this HCUL. In this sense, his role is to adapt building conditions to occupants' preferences and comfort when the SATO system is not able to meet them. This

		indirect participation enables the **SATO Self-Optimization Services** to accommodate these preferences in future scenarios.
Building occupants	Human actor	This actor has an indirect role for this HCUL. In this sense, his role is to adapt building conditions to his preferences and comfort when the SATO system is not able to meet them. This indirect participation enables the **SATO Self-Optimization Services** to accommodate these preferences in future scenarios.
SATO Self-Optimization Services	Software/ systems/ applications/ devices	**SATO Self-Optimization Services** have a direct role in this HLUC because they provide self-optimizing strategies for being prioritized and implemented by this HLUC.
SATO Platform	Software/ systems/ applications/ devices	**SATO Platform** will provide the building occupants' input regarding their preferences and comfort levels.

3.2 References

References						
No.	***References type***	***Reference***	***Status***	***Impact on use case***	***Originator/ organization***	***Link***
1	Internal Document	SATO KPI tool reference list	n/a	Provision of KPI to be included	AAU	KPI tool
2	Internal Document	SATO actors reference list	n/a	Provision of actors to be included	EDP NEW	Use Case Short Description V6.xlsx
3	Internal Document	WP3 cross task workshops April 2021 Day 1, 2 and 3	n/a	Building components definitions	FCID	n/d

4. Step by step analysis of use case.

4.1 Overview of scenarios

Scenarios conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
1.	Holistic optimal control of energy resources	This HLUC aims to develop a user centred coordinated control of energy resources for **SATO Self-Optimization Services**, and indirectly optimizing indoor environmental conditions, occupants' comfort, energy efficiency and energy costs	**SATO Self-Optimization Services**	Receive data from the different optimization services.	Capacity to receive the result of the assessments (including the forecast), as well as the result of the optimization services.	Self-optimization strategies are sent to the **SATO Platform**, which in turn will send control actions to the different EBC and actuators.

4.2 Steps – Scenarios

Scenario								
Scenario name:		**Reference scenario**						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirements, R-IDs**
1.1	*Request data*	*Receive self-optimization strategies*	*The self-optimization from previous HLUCs formulates different optimization strategies that are sent to HLUC14.*	*GET*	***SATO Platform***	***SATO Self-Optimization Services***	*IE1*	*R-DATA-2*
1.2	*Analise data*	*Prioritization of self-optimization strategies*	*Analysis of self-optimization strategies and definition of priorities based on different inputs (such as: indoor environmental conditions, flexibility events, performance strategies).*	*CHANGE*	***SATO Self-optimization Services***	***SATO Self-optimization Services***	*IE2*	*R-DATA-1; R-DATA-2; R-DATA-3; R-DATA-4; R-DATA-5; R-QoS-1; R-QoS-2; R-QoS-3*
1.3	*Perform actions*	*User centred optimal control*	*Send control signals to **SATO Platform** based on the selected optimal control strategy.*	*EXECUTE*	***SATO Self-optimization Services***	***SATO Platform***	*IE3*	*R-COMP-1*

(*) Available options are:

- *CREATE means that an information object is to be created at the Producer.*
- *GET (this is the default value if none is populated) means that the Receiver requests information from the Producer (default).*
- *CHANGE means that information is to be updated. Producer updates the Receiver's information.*
- *DELETE means that information is to be deleted. Producer deletes information from the Receiver.*
- *CANCEL, CLOSE imply actions related to processes, such as the closure of a work order or the cancellation of a control request.*
- *EXECUTE is used when a complex transaction is being conveyed using a service, which potentially contains more than one verb.*
- *REPORT is used to represent transferral of unsolicited information or asynchronous information flows. Producer provides information to the Receiver.*
- *TIMER is used to represent a waiting period. When using the TIMER service, the Information Producer and Information Receiver fields shall refer to the same actor.*
- *REPEAT is used to indicate that a series of steps is repeated until a condition or trigger event. The condition is specified as the text in the "Event" column for this row or step. Following the word REPEAT, shall appear, in parenthesis, the first and last step numbers of the series to be repeated in the following form REPEAT(X-Y) where X is the first step and Y is the last step.*

5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE1	*Strategies optimization*	*Receive self-optimization strategies.*	*R-DATA-2*
IE2	*Strategies prioritization*	*Prioritize self-optimization strategies.*	*R-DATA-1; R-DATA-2; R-DATA-3; R-DATA-4; R-DATA-5;* R-QoS-1; R-QoS-2; R-QoS-3
IE3	*Send strategies signals*	*Send control signals for EBC's and actuators.*	R-COMP-1

6 Requirements

Requirements		
Categories ID	***Category name for requirements***	***Category description***
R-DATA	Data Management	Covers both the management of the data exchanges in each Use Case step and the management of data at either end if that management is impacted by data exchanges. An example of the first type of data management is the initial setting up and on- going maintenance of what data needs to be exchanged, say between a Geographic Information System and the many different applications that use its data. An example of the second type of data management is the need to backup data or ensure consistency of data whenever it is exchanged, such as if new protection settings are issued to multiple field devices, these settings need to be reflected in Contingency Analysis functions. It should not address database design but should concentrate on the user requirements for the interfaces to databases and other data handling applications.
R-QoS	Quality of Service (QoS)	Address availability of the system, such as acceptable downtime, recovery, backup, rollback, etc. QoS issues also address accuracy and precision of data, the frequency of data exchanges, and the necessary flexibility for future changes.
R-COMP	Compatibility	Compatibility with other functions.
Requirement R-ID	***Requirement name***	***Requirement description***
R-DATA-1	Usage statistics	Store usage statistics of the HEMS configuration and operation. This includes the number of configurations made by the users of HEMS as well as the number of accepted or rejected optimal schedules.
R-DATA-2	Management of large volumes of data that are being exchanged	Some part of step involves handling large volumes of data
R-DATA-3	Room temperature data	Get metering data from room thermometer with a sample period of 15 minutes maximum
R-DATA-4	Optimal schedule	Store in the local database and publish in the HEMS UI the optimal schedule of appliances and systems for the following day.
R-DATA-5	Price forecast signal	A price forecast signal that we updated at least on a weekly basis
R-QoS-1	Availability of information flows	Continuous availability not required but must be available at specific times or under specific conditions.
R-QoS-2	Optimization runtime	Ensure that the energy optimization procedure is carried out within a specified time limit.
R-QoS-3	Accuracy of data requirements	Age of data needs to be known. Quality of data characterization is important.
R-COMP-1	Compatibility with the data sent by **SATO Platform**	The optimal control strategies for every timestep coming from the holistic optimal control must be compatible with the actuator they target. Ensure compatibility with HLUC15.

7 Common Terms and Definitions

Common Terms and Definitions	
Term	**Definition**
EBC	Equipment & building components
Self-optimization	Development of self-optimization strategies.
Holistic building energy management.	Management of building EBC and actuators as a global system

HLUC15 – Cloud managing of legacy and smart appliances as well as technical building equipment

1. Description of the use case

1.1 Name of the use case

ID	Area	Name of Use Case
HLUC15	(5) Control	Cloud managing of legacy and smart appliances as well as technical building equipment

1.2 Version management

Version No.	Date	Name of Author (s)	Changes
1.0	26.04.21	Filipe Neves Silva	First version of HLUC15
2.0	27.05.21	Daniel P. Albuquerque	Second version of HLUC15
3.0	01.07.21	Filipe Silva, João Dias	Third version of HLUC15

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	HLUC15 is a High-Level Use Case (HLUC) focused on the cloud-based control actions applied to the smart and legacy appliances and technical building equipment installed in a building. Given that the **Self-Optimization Services** will generate smart management strategies for building equipment and appliances, these strategies may be deployed over the devices using two approaches: a direct approach, or an indirect approach that implies the intervention of a **building manager/owner** to deploy the strategies. This HLUC will enable the direct approach that consist of creating a channel of communication between the **SATO Self-Optimization Services** and the building equipment/appliances. As such, this HLUC requires no direct intervention from human actors but is linked with several SATO software/ hardware functionalities such as the **SATO Self-Assessment Framework**, the **SATO Self-Optimization Services**, **SATO BMS, SATO APP** and **SATO APL**. Although direct intervention from human actors is not required, **building occupants** or the **building manager** may be able to overwrite the **SATO Self-Optimization Services** commands, to ensure High-Level of comfort. In such cases, the **building manager** or **occupants** may use the **SATO BMS** and **SATO APP** to adjust the technical building equipment as well as legacy and smart appliances accordingly. Three Primary Use Cases (PUCs) will be derived from this HLUC. PUC15.1 is named “Cloud managing of legacy appliances and equipment”, PUC15.2 is named “Cloud managing of smart appliances and equipment” and PUC15.3 is named “Cloud managing of EV chargers and batteries”. PUC15.1 will enable the control and management over legacy devices (appliances and technical building equipment), such as, i.) legacy appliances with longer life-cycles, such as stoves and refrigerators, that are responsible for large peaks in residential energy consumption but typically lack remote control features, ii.) legacy appliances with shorter life-cycles, such as washing machines and dishwashers, as well as iii.) technical building equipment, such as HVAC systems and boilers.

	PUC15.2 concerns the cloud-based control of smart building equipment, e.g., HVAC or DHW systems, to enable the deployment of energy efficiency strategies computed on the cloud and directly applicable in the building. PUC15.3 concerns the cloud-based management of vehicle-to-grid (V2G) chargers and batteries as a strategy to reduce peak consumption and increase self-consumption.
Objective(s)	The objectives of this HLUC are related with the cloud-based control of legacy and smart appliances and technical equipment. The following objectives were defined: 1. Real-time cloud-based control of legacy appliances and technical building equipment; 2. Real-time cloud-based control of smart appliances and technical building equipment; 3. Real-time cloud management of V2G chargers and batteries.

1.4 Narrative of use case

1.4.1 Narrative of High-Level use case

Narrative of Use Case
Short description
Cloud managing of legacy and smart appliances and technical building equipment aims to establish a communication channel for control, between **SATO Platform** and the actuators deployed in the buildings, to send/receive commands that will enable the application of the self-optimization strategies generated by the **SATO Self-Optimization Services**.
Complete description
The HLUC – Cloud management of legacy and smart appliances and building equipment concerns the cloud-based control of building equipment and appliances, through the **SATO Self-Optimization Services**. The HLUC aims to establish the means for the control of appliances and technical building equipment that traditionally are not able to connect to the cloud, having no communication capacities or limited capacities, as well as smart appliances and technical equipment which are already capable of interacting with cloud-based control systems. This HLUC requires the use of hardware, actuators (which can change the state/setpoint and, if necessary, gateways) that will provide the required control and communication capacities. To provide the necessary communication capacities, smart home energy management (HEMS) and central technical management (CTM) systems will be provided to enable the connection of legacy devices but also for the existing smart devices to connect to the **SATO Platform**. The systems used will be the EDP Re:dy and SIEMENS TWIN, which are commercial solutions already available in the market but further development will be made during SATO to upgrade these systems and make them compatible with the **SATO Platform** and **SATO Self-Optimization Services**. Control commands developed by **SATO Self-Optimization Services** will be evaluated in HLUC14 and filtered for an optimal application, ensuring user and system preferences are considered. HLUC15 will present flexibility for the application of different type of control actions, as follows: • On/off control – The simplest form of control, it implies to turn a device on/off according to the rules provided. • Change setpoint - Control type that involves sending a value to control a device, according to the device type. Most of the times, this value either corresponds to a temperature (for HVAC and AC equipment) or a percentage (for lighting, windows opening or equipment that has power control). The following steps map the necessary actions to implement this HLUC: 1. Receive the control action from HLUC14 – Holistic optimal control of energy resources HLUC14 is responsible for selecting the controls that will be performed for each building, according to a set of predetermined rules. Upon the system decision, HLUC15 will receive and apply the control. 2. Apply the received control actions to the actuators in real-time The communication channel established will enable **SATO Self-Optimization Services** to send controls via the **SATO Platform** that will be implemented through **SATO BMS** or **SATO APL** in the actuators, executing strategies that will increase the overall building performance. 3. Allow users of the web-application to send commands Sometimes, in particular conditions, **SATO Self-Optimization Services** may not be able to predict the most comfortable conditions for the current use of the building. In those cases, **Facility/Building managers**, **Building owners** or **Building occupants** may use the **SATO APP**

to overwrite the controls from **SATO Self-Optimization Services** and send new commands adapted to their preferences. These commands will be analysed by **SATO Self-Optimization Services** and incorporated for future optimisations. 4. Sends control signal back to the **SATO Platform** HLUC15 must also guarantee that **SATO Self-Optimization Services** recognize the current control being applied for each device and building. For that purpose, the Cloud-based management system should be able to send this data, in real-time, back to **SATO Platform**.

1.4.2 Narrative of primary use cases

ID	*Name*	*Description*
PUC15.1	Cloud managing of legacy appliances and equipment	Smart management of appliances based on the introduction of third-party actuators, enabling to define different control strategies aiming to improve the flexibility of such devices. This PUC aims mainly at appliances that are responsible for large peaks in residential energy consumption but typically lack remote control features, such as dishwashers, DHW boilers and others.
PUC15.2	Cloud managing of smart appliances and equipment	Cloud-based control of building equipment and appliances by directly connecting these to the **SATO Platform,** centralizing the control process of devices that typically work via native apps. This PUC is mainly aimed at large building equipment that is connected to CTM systems but also residential IoT-ready appliances.
PUC15.3	Cloud managing of EV chargers and batteries	Management of vehicle-to-grid chargers and batteries will be performed by directly sending the optimal commands to this equipment. To achieve this, PUC15.3 must ensure that the **SATO Platform** is able to communicate with these devices, that are usually not incorporate in building management systems.

1.5 Key performance indicators (KPI)

Name	*Description*	*Reference to mentioned use case objectives*
SRI monitoring and controlling	Corresponds to the monitoring and control domain smart readiness score. It evaluates the functionality level of the controllability of performance, flexibility and information provided to occupants.	This KPI directly links to all objectives of this HLUC, which is to increase the level of functionality regarding monitoring and controlling. By the end of the project the target is to achieve the highest level of functionality of the SRI scale.
Ratio between control action received and control actions performed	Ratio between the control actions sent by the **SATO Cloud** and the number of control actions performed by the appliances and equipment.	This KPI directly link to all objectives of this HLUC. The goal is to have a ratio of 1, which means that all control actions sent by SATO were performed by the different actuators.
Total annual specific energy consumption	Measures the amount of specific energy (e.g. electricity, natural gas, district heating, district cooling, domestic hot water) consumed during a year. It can also be divided for different end-uses, such as space heating and cooling, appliances, lighting system, domestic hot water production and others.	Although this KPI is not directly linked with the communication capacities enabled by this HLUC, it can be used as a measure of performance as without the communication it is not possible to apply the smart management strategies and as such there will be no reduction in the total energy consumption.
Monthly average specific energy consumption	Measures the monthly amount of specific energy consumption (e.g. electricity, natural gas, district heating, district cooling, domestic hot water).	Similar to the “Total energy consumption” this KPI can be used as an indirect measure of performance for this HLUC.
Daily average specific energy consumption	Measures the daily amount of specific energy consumption (e.g. electricity, natural gas, district heating, district cooling, domestic hot water).	Similar to the “Total energy consumption” this KPI can be used as an indirect measure of performance for this HLUC.
Utilization factor	Represents the percentage of the on-site energy generation that is used by the building.	Similar to the “Total energy consumption” this KPI can be used as an indirect measure of performance for this HLUC due to being a condition for the application of smart energy management.

Cost for electricity consumption	Measures the cost of all electricity used during a certain period (e.g. yearly).	Similar to the “Total energy consumption” this KPI can be used as an indirect measure of performance for this HLUC.

1.6 Use case conditions

Use case conditions
Assumptions
The **SATO Platform** and different IoT and Wi-Fi-based interfaces must be in operation. The **Facility/building managers**, **Building owners** or **Building occupants**, have given their consent for SATO to perform cloud managing of legacy and smart appliances and equipment (GDPR compliant).
Prerequisites
The appliance/equipment is correctly installed and connected to the **SATO Platform**. Link to HLUC01 Link to HLUC14

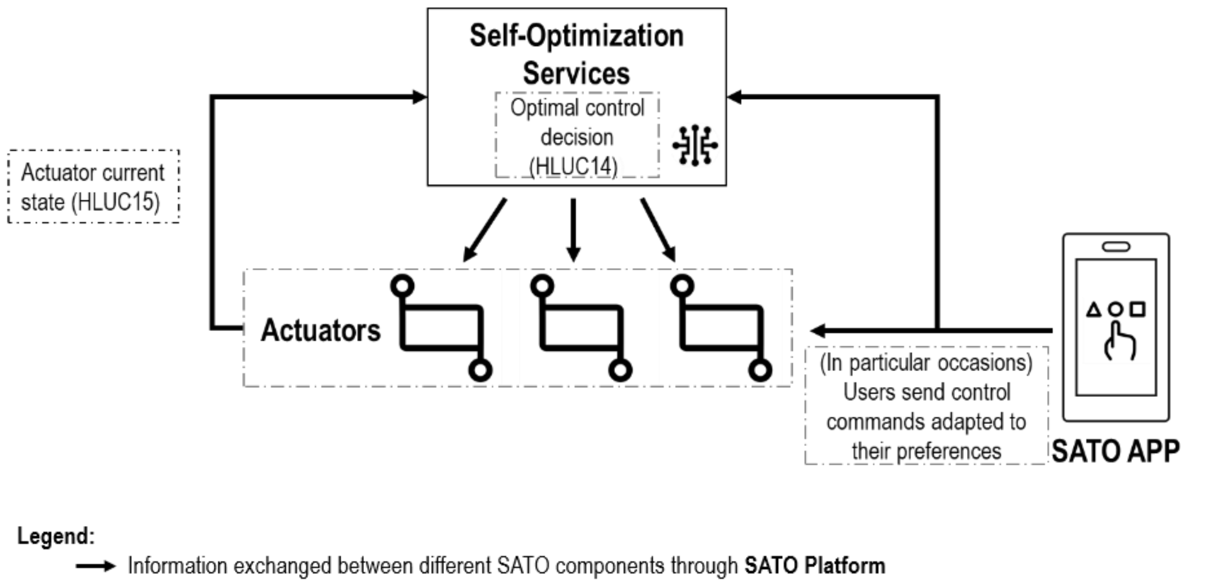
1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
HLUC01 – Monitoring is a prerequisite for the definition of smart-optimization strategies and hence, the application of those strategies. HLUC14 – The optimal control decision will solve conflicts between competing strategies developed by **SATO Self-Optimization Services** and send the optimal control.
Level of depth
Defines the level of depth of the use case: **HLUC** - Cloud managing of legacy and smart appliances and equipment PUC15.1: Cloud managing of legacy appliances and equipment PUC15.2: Cloud managing of smart appliances and equipment PUC15.3: Cloud managing of electric vehicles chargers and batteries
Prioritisation
This HLUC is considered of top priority to SATO as other HLUC depend on this to receive/send data to appliances/equipment by which the **SATO Self-Optimization Services** will be validated. PUC15.1 should be applied in the Seixal and Milan residential pilot sites, with the goal to achieve a low-cost replicable solution that can be retrofitted to any residential building. PUC15.2 should be applied to all residential and service pilot buildings that already have communication capacities. PUC15.3 will be applied in the Lisbon Service Building pilot site.
Generic, regional or national relation
Generic Use Case
Nature of the use case
Technical Use Case
Further keywords for classification
Cloud, sensor, actuator, smart management, smart control, smart/legacy appliances and equipment

2 Diagrams of use case

For clarification, in general it is recommended to provide drawing(s) by hand, by a graphic or as UML graphics. The drawing should show interactions which identify the steps where possible.

Diagram(s) of use cases



3. Technical details

3.1 Actors

Actors		
Actor Name	*Actor Type*	*Actor Description*
Facility/building managers	Human actor	This actor as an indirect role in this HLUC. His role is to adapt the building conditions to occupants' preferences when the SATO system is not able to meet these preferences. This indirect participation enables the system to react better to future scenarios.
Building occupants	Human actor	This actor as an indirect role in this HLUC. His role is to adapt the building conditions to their preferences when the SATO system is not able to meet these preferences. This indirect participation enables the system to react better to future scenarios.
SATO Platform	Software/ systems/ applications/ devices	**SATO Platform** will provide the selected optimal management strategy defined in HLUC14 and retrieve the actuators status
SATO APP	Software/ systems/ applications/ devices	**SATO APP** will allow to send new commands to the building equipment and appliances.
SATO APL	Software/ systems/ applications/ devices	***SATO APL*** *will allow connection and implementation of control strategies in the actuators.*
SATO BMS	Software/ systems/ applications/ devices	***SATO BMS*** *will allow connection and implementation of control strategies in the actuators.*
SATO Self-Assessment Framework	Software/ systems/ applications/ devices	**SATO Self-Assessment Framework** will receive data regarding current controls, which can be analysed and used to produce the assessments that generate the energy efficiency strategies.
SATO Self-Optimization Services	Software/ systems/ applications/ devices	**SATO Self-Optimization Services** running on the cloud will generate the smart management strategies and send them directly to the actuators.

3.2 References

References						
No.	**References type**	**Reference**	**Status**	**Impact on use case**	**Originator/ organization**	**Link**
1	Internal Document	SATO KPI tool reference list	n/a	Provision of KPI to be included	AAU	KPI tool
2	Internal Document	SATO actors reference list	n/a	Provision of actors to be included	EDP NEW	Use Case Short Description V6.xlsx
3	Technical document	Re:dy website	n/a	Detailed about Re:dy system	EDP Comercial	https://www.edp.pt/particulares/servicos/redy/
4	Technical document	SIEMENS TWIN website	n/a	Detailed about SIEMENS TWIN system	SIEMENS	

4. Step by step analysis of use case

4.1 Overview of scenarios

Scenarios conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
1	Implement real-time cloud-based control actions	The actuators in the building will perform control-actions received from the **SATO Platform**.	**SATO Platform**	The actuators will receive control actions whenever the **SATO Platform** finds it necessary. Additionally, a constant timestep is necessary between two consecutive control actions for the same device.	Availability of control over appliances and equipment.	Control actions are deployed, changing the state/setpoint of the appliance and equipment.

4.2 Steps – Scenarios

Scenario								
Scenario name:	***Implement real-time cloud-based control actions***							
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirements, R-IDs***
1.1	Submission of control actions by the **SATO Platform**	Send control actions to actuators	**SATO Platform** send specific control actions for individual actuators, appliances and equipment.	REPORT	**SATO Platform**	**SATO BMS or SATO APL**	IE1	R-SEC-1; R-SEC-2; R-SEC-3; R-QoS-1; R-QoS-2
1.2	Implementation of control action by actuators	Applies the controls received into the actuators	The control actions received from the **SATO Platform** are implement in the equipment/appliance's actuators through **SATO BMS** or **SATO APL**	EXECUTE	**SATO BMS or SATO APL**	Actuators	IE2	R-SEC-2; R-SEC-3; R-COMP-1
1.3	Submission of control actions	Send actuators state	The **SATO Platform** sends a request to the actuators to know its state/setpoint	GET	Actuators	**SATO Platform**	IE3	R-SEC-1; R-SEC-2; R-SEC-3; R-QoS-1; R-QoS-2

(*) Available options are:

- *CREATE means that an information object is to be created at the Producer.*
- *GET (this is the default value if none is populated) means that the Receiver requests information from the Producer (default).*
- *CHANGE means that information is to be updated. Producer updates the Receiver's information.*
- *DELETE means that information is to be deleted. Producer deletes information from the Receiver.*
- *CANCEL, CLOSE imply actions related to processes, such as the closure of a work order or the cancellation of a control request.*
- *EXECUTE is used when a complex transaction is being conveyed using a service, which potentially contains more than one verb.*
- *REPORT is used to represent transferal of unsolicited information or asynchronous information flows. Producer provides information to the Receiver.*
- *TIMER is used to represent a waiting period. When using the TIMER service, the Information Producer and Information Receiver fields shall refer to the same actor.*
- *REPEAT is used to indicate that a series of steps is repeated until a condition or trigger event. The condition is specified as the text in the "Event" column for this row or step. Following the word REPEAT, shall appear, in parenthesis, the first and last step numbers of the series to be repeated in the following form REPEAT(X-Y) where X is the first step and Y is the last step.*

5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE1	Smart management controls	Control actions sent by the SATO Service	R-SEC-1; R-SEC-2; R-SEC-3; R-QoS-1; R-QoS-2
IE2	State of control actions	Current control actions being implemented by the actuators	R-SEC-2; R-SEC-3; R-COMP-1
IE3	State/Setpoint of actuators	State/setpoint of the actuators deployed in the building	R-SEC-1; R-SEC-2; R-SEC-3; R-QoS-1; R-QoS-2

6 Requirements

Requirements		
Categories ID	***Category name for requirements***	***Category description***
R-CONFIG	Configuration	Reflect the typical, probable, or envisioned communication configurations that are relevant to the use case step. These configuration issues include numbers of devices and/or systems, expected growth of the system over time, locations, distances, communication types, network bandwidth, existing protocols, etc., but only from the user's point of view. In some cases, only one of the possible choices is reasonable, while for other situations, more than one choice is reasonable.
R-SEC	Security	Assess how different security measures applied to different items can potentially interact and either leave security holes or make user interfaces very laborious and possibly unworkable. Security must not only protect against the very harmful but quite rare deliberate attacks, but also against the far more likely inadvertent mistakes, failures, and errors. At the same time, it is necessary to try to identify the requirements and the concerns for implementing security measures.
R-COMP	Compatibility	Compatibility with other functions.
R-QoS	Quality of Service (QoS)	Address availability of the system, such as acceptable downtime, recovery, backup, rollback, etc. QoS issues also address accuracy and precision of data, the frequency of data exchanges, and the necessary flexibility for future changes.
R-DATA	Data Management	Covers both the management of the data exchanges in each Use Case step and the management of data at either end if that management is impacted by data exchanges. An example of the first type of data management is the initial setting up and on- going maintenance of what data needs to be exchanged, say between a Geographic Information System and the many different applications that use its data. An example of the second type of data management is the need to backup data or ensure consistency of data whenever it is exchanged, such as if new protection settings are issued to multiple field devices, these settings need to be reflected in Contingency Analysis functions. It should not address database design but should concentrate on the user requirements for the interfaces to databases and other data handling applications.
Requirement R-ID	***Requirement name***	***Requirement description***
R-SEC-1	Data privacy	Ensuring confidentiality, avoiding illegitimate use of data, and preventing unauthorized reading of data, is quite important
R-SEC-2	Authentication	Ensuring that data comes from the stated source or goes to authenticated receiver is important.
R-SEC-3	Data security	Ensuring that data cannot be stolen or deleted by an unauthorized entity is important.
R-QoS-1	Availability of information flows	Continuous availability not required but must be available at specific times or under specific conditions.
R-QoS-2	Accuracy of data requirements	Age of data needs to be known; Quality of data characterization is important.
R-COMP-1	Compatibility with the data sent by **SATO Platform**	The optimal control strategies for every timestep coming from the holistic optimal control must be compatible with the actuator they target. Ensure compatibility with HLUC14.

7 Common Terms and Definitions

Common Terms and Definitions	
Term	*Definition*
Actuator	Device with the capacity to receive and apply a control command to equipment/appliances
CTM system	Centralized technical management system
HEM system	Home energy management system
V2G	Vehicle-to-grid