BIM4EEB

BIM based fast toolkit for
Efficient rEnovation in Buildings

D6.8 Ambient User Interface

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D6.8 Ambient User Interface

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EXECUTIVE SUMMARY

The main scope of deliverable D6.8 namely Ambient User Interface as stated in the DoA [1] is to provide the specifications, the design principles and proceed with the development of the web-based application dedicated to building occupants (i.e. Owners and Inhabitants) offering three core functionalities: information provision related to occupants' ambient conditions in their apartments, input provision of personalised thermal and visual comfort preferences and energy consumption analytics.

The basis for the design of the application is formed by the occupants' functional requirements specified in the early stages of the project during the WP2 activities and more specifically in D2.5[2]; complemented with technical and non-functional requirements along with feedback received from the BIM4EEB partners and pilot sites' representatives. The overall development and modeling work of the application takes into consideration the definition of the relevant ontologies about occupant behaviour and comfort in buildings, and energy performance of systems defined in WP3; as well as the way the different models are incorporated in the BIMMS in WP4.

In order to avoid having building occupants to access two different applications, the key functionalities of the "Ambient User Interface" app are delivered through the "Occupants 2.0" feature of the BIM4EEB *BIM4Occupants* application. BIM4Occupants integrates the functionalities presented in this deliverable D6.8, as well as in D7.2 [5] into a unique interface, thus making it more appealing and easier for the building occupants to use it.
The functionalities associated with the activities of this deliverable and the "Ambient User Interface app consist of:

- Visualisation of both real time and historical information regarding comfort related parameters (such as indoor/outdoor temperature, humidity, illuminance and indoor/outdoor air quality).The data for the evaluation of the aforementioned parameters are gathered from a set of Wireless Sensor Networks (WSN) installed in the project's pilot sites and provided through the BIM4EEB Building Information Modelling Management System (BIMMS).
- Enabling occupants to provide input regarding their comfort state in relation to the set temperature and Illuminance settings in their apartment. The provided input will be used to complement the Occupant's Profiling Mechanism (developed in D6.7) by continuously updating the generated occupants' profiles, towards the extraction of more accurate context-aware occupant comfort profiles.
- Visualisation of personalised energy consumption information through context analytics dashboards, enabling occupants to efficiently monitor near-real time energy consumption data and analytics of previous periods; thus, contributing in raising occupant's awareness of their energy consumption and their building energy performance.

As such, following a typical software development process and taking into consideration these high-level requirements, the structure of this deliverable is presented as follows:
Section 1 provides the introduction of this deliverable along with the scope and purpose of the app; section 2 presents the requirements analysis and specifications definition along with the application's architecture; in section 3 the design of the application is documented following a modular approach, along with the development principles; and finally section 4 provides a usage walkthrough of the application (focusing only on the aforementioned functionalities) from the building occupants' perspective.

PUBLISHING SUMMARY

The main purpose of this deliverable is to develop a user-friendly web-based application dedicated to building occupants (i.e. Inhabitants and Owners), enabling them to be part of the BIM4EEB project ecosystem. More specifically, the building occupants should be able to provide input regarding their comfort preferences towards the extraction of their accurate comfort profiles, enhancing that way the personalization of the different applications developed in the BIM4EEB project. In addition, through the provision of context analytics dashboards, building occupants can get insights about their personal comfort preferences and further comfort related context analytics; as well as monitor their energy consumption on the way to raise occupant's awareness in energy efficiency and their buildings energy performance.

Upon consideration of the main requirements identified in the project complemented by the BIM4EEB pilot site representatives' partners' feedback; the developed application offers the following three major functionalities for building occupants:

1. Visualisation of both real time and historical information regarding individual comfort related parameters such as indoor/outdoor temperature, humidity, air quality and Illuminance; supplemented with context analytics.
2. Occupants input provision regarding their thermal and visual comfort status against set values of temperature, illuminance
3. Visualisation of energy consumption at apartment level, through a user-friendly dashboard, supplemented with context analytics

Different views are available for the two stakeholder types: inhabitants and owners taking into account the level of details on the available information. Also, the overall framework is developed in a modular approach ensuring the proper visualization of information considering the level of data availability on each building site.

The above-mentioned functionalities are provided with the context of the developed application, named as: BIM4Occupants - An application for building occupants engagement and interaction. Additional views are incorporated in the app (under the context of T7.2) towards setting a holistic building management framework for building occupants and building owners.

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Glossary

Acronym	Full name
BIM4EEB	BIM-based toolkit for Efficient rEnovation in Buildings
BIMMS	Building Information Modelling Management System
CAQI	Common Air Quality Index
DX.Y	Deliverable X.Y
DoA	Description of Action
IAQ	Indoor Air Quality
MVC	Model–View–Controller
ORM	Object Relational Mapping
T	Temperature
WP	Work Package
WSN	Wireless Sensor Network
CQ	Competency Questions

1 Introduction

1.1 Scope of the Document

The main scope of the present deliverable D6.8 namely “Ambient User Interfaces”, constituting part of the activities undertaken in T6.7 is to provide a web-based responsive user-interface (i.e. a user application), enabling interaction with the building occupants, allowing them to continuously provide information regarding their individual comfort preferences. Building occupants input will be utilised for extraction of accurate context-aware comfort profiles, which according to the DoA [1] will be used by the BIM4EEB behaviour profiling mechanism to allow continuous information acquisition towards training occupants’ comfort models and delivering context aware profiles that reflect in a probabilistic manner individual needs and preferences within buildings.

Under this context and towards proving a useful application with added value for the building occupants, while also considering the project’s overall objectives and pilot sites representative partners feedback, the delivered application consists of three key functionalities as identified in D2.5 [2]:

1. Visualization of both real time and historical information of individual comfort related parameters, (such as indoor/outdoor, temperature, humidity, illuminance and air quality metrics) supplemented with context analytics.
2. Input provision from building occupants regarding their thermal and visual comfort status against set values of temperature and illuminance in their apartment.
3. Visualisation of energy consumption (near real-time and historical) through a dynamic, user-friendly dashboard, supplemented with context analytics aiming at raising occupant’s awareness on their energy consumption and buildings performance.

Towards the delivery of these core functionalities of the application, a thorough review of the relevant work is performed in this task to define the modelling aspects for the different features. Additionally, as this application is meant to serve the BIM4EEB project’s pilot sites’ occupants needs, interaction with the pilot site representative took place, to collect their feedback and comments towards setting a user interface that clearly addresses their needs and requirements.

The above-mentioned functionalities are provided within the context of the developed application, named as: BIM4Occupants - An application for building occupants engagement and interaction.

1.2 Relation with other tasks

The current deliverable forms part of WP6 and more specifically of Task T6.7 “Occupants’ context-aware energy behaviour profiling and ambient interfaces for Human-Machine Interaction”. Towards the development of the main output of D6.8, which is a web-based user application intended to serve building occupants, the following interrelations with other tasks undertaken in BIM4EEB have been identified:

- The extracted requirements, main output of D2.5 – “List of owners’ and inhabitants’ needs and requirements for BIM-based renovation processes” are taken into consideration and used as reference points for the requirements definition of the proposed application.
- The outcome of the modelling work performed in WP3 and more specific the early definition of data specifications in D3.6 [3] providing the way for the application’s data requirements.
- In addition to the data specifications, the development of the BIMMS platform in WP4 will provide access to the data required from the application.

- Through the provided application, the occupants' input will be used to "train" the occupants' comfort models and delivering context aware profiles provided by the Occupant Profiling Mechanism which forms the main output of D6.7 [4].

Finally, it should be noted that since the outcome of D6.8 and D7. 2[5] will be delivered in the context of one web based application, namely the BIM4Occupants app; there is close connection and alignment of the activities performed between these two deliverables, as well as with the overall work performed in WP2-WP4.

1.3 Structure of the document

On the way to address all the aspects relevant to the scope of T6.7, the present deliverable has been structured to include the following contents:

- In Section 1 an introduction to the work is provided highlighting the scope of this deliverable, along with its relevance to other BIME4EEB tasks and the deliverable's structure.
- In Section 2 an overview of the system's requirements and architecture is provided, also defining its specifications;
- Section 3, presents the design specifications and development principles of the application;
- In Section 4 we present the user manual for the building occupants' application; by providing a usage walkthrough of the BIM4Occupants applications from an occupant's perspective, focusing only on the functionalities related to this deliverable.

Finally, in Section 5 the main conclusions of this work are reported with the focus to be on the updates to be delivered in the 2nd and final version of the application.

2 Requirement Analysis and Design Specification

As the objective of this section is to report the design specifications for the BIM4Occupants application for building occupants (i.e. owners and inhabitants), we start by presenting the list of BIM4EEB owners and inhabitants requirements as defined in D2.5 [2] and the data models defined in D3.6 [3], focusing on the definition of the system's specifications including the functional, technical and communication needs as modified upon consultation with the pilot site representative partners during WP6 meetings.

2.1 Building Occupants Requirements Elicitation

Towards the definition of the system's requirements, we start by presenting the high-level functionalities to be supported by the occupant's application, as identified in the early stages of the project in D2.5. More specifically, two main functionalities (related to the work performed in the context of T6.7) were identified in D2.5 and presented as follows:

- **Establishment of a comfort and IAQ preserving framework for inhabitants during/post renovation period. (*US-01 & US-02*)**
- **A continuous interaction framework for comfort status monitoring and report for inhabitants (*US-03*)**

In order to better clarify, analyse and organise the system's requirements we make use of the following usage scenarios, where we report in detail the high-level functionalities to be supported by the occupant's application, the functional requirements and the associated mappings with the initial requirements of owners and inhabitants as defined in D2.5.

Table 1 US-01: Establishment of a comfort and IAQ preserving framework for inhabitants during/post the renovation interventions

BIM4EEB usage scenario - 01	
US ID	US-01
US Name	Establishment of a comfort and IAQ preserving framework for inhabitants during/post the renovation interventions
Pilot site	Italy, Poland, Finland
Involved End User(s)	Building occupant (i.e. Inhabitant & Owner)
Description	The ultimate scope when considering undertaking a renovation in a building is to enhance the building's energy performance; this in turn will result in enhanced living comfort conditions for its occupants and users. Nevertheless, during the actual renovation works it is anticipated that the physically invasive processes of the renovation will impact the occupants' comfort conditions and the building's Indoor Air Quality (IAQ). Considering also that people spend 60–90% of their life indoors (houses, offices, etc.) preserving appropriate comfort levels and satisfactory IAQ is critical for their health and particularly for the health of vulnerable groups (children and elderly people), especially if they continue to live inside the building during the renovation works (small scale renovation). In addition, research has clearly recognized that problems with indoor environmental quality (i.e. thermal, acoustic, visual and IAQ) of a building has a direct effect on the comfort, health and productivity of its occupants.

	Consequently, establishment of adequate environments in buildings that can preserve high levels of human comfort and IAQ both during and after the actual renovation process is a key requirement, since these aspects are tightly connected to the real estate value of a building directly affecting the economics and contractual terms for the implementation of such projects. As such, the proposed framework focuses both during and post the renovation period and its objective is twofold: • to establish the building's realistic indoor environmental conditions in terms of physical and measurable parameters; • to provide the means to visualise ambient conditions in a user-friendly manner (such as context-aware dashboards), enabling building occupants to monitor the ambient conditions in their apartments during and after the renovation period.
Supported Functionalities	Based on the above description, there are two main functionalities to be supported: 1. End users (Inhabitants & Owners) to be able to remotely monitor near real time information through visualisation dashboards, regarding ambient conditions (indoor/outdoor temperature, humidity, illuminance, and air quality in their premises. 2. End users (Inhabitants & Owners) to be able to remotely monitor historical information of ambient parameters and related context analytics in their premises.
Requirements Mapping (as per the requirements identified in D2.5**Errore. Il segnalibro non è definito.**)	**1st functionality: Monitoring of ambient conditions** - **Inhabitants** are interested to have a deep knowledge about **indoor environmental conditions** in premises**. (I.04)** - **Inhabitants** are interested to have a knowledge about **temperature, humidity, IAQ** with lower interest about acoustics. (**I.06)** - **Owners** should be able to remotely monitor the building's energy performance/ **Indoor Air Quality (IAQ**) via an app. **(O.10)** **2nd functionality: Visualisation of historical information and context analytics** - **Inhabitants** are interested to **get updates** and have control over **indoor environmental conditions** in building premises. **(I.07)** - **Owner** should be able to receive information about **abnormal conditions/IEQ** during the operation phase of the building.**(O.25)**

Table 2 US-02: Continuous interaction framework for comfort status monitoring and report for inhabitants

BIM4EEB Usage Scenario - 02	
US ID	US-02
US Name	Continuous interaction framework for comfort status monitoring and report for inhabitants
Pilot site	Italy, Poland, Finland
Involved End-User(s)	Building Inhabitants
Description	As explicitly stated in the DoA, one of BIM4EEB's objectives (Obj 3.4) is to enhance user involvement. Towards this direction, a continuous interaction framework about comfort status should be established, enabling users (i.e. Inhabitants) to continuously update their comfort preferences during and post renovation. The main purpose of such a framework is to ensure that the inhabitants' perception of various comfort related parameters is taken into consideration during the initial renovation design scenario; as well as during the actual renovation period, thus contributing in minimising any impact on their comfort zones during the works. Correlating their input (i.e. inhabitants' actual visual and thermal comfort status) with the ambient conditions in their premises, enables the definition of accurate comfort profiles of inhabitants within a building. In the case of BIM4EEB project, the extracted inhabitants' comfort profiles will incorporate all personalised and contextual (environmental, temporal) aspects, focusing on thermal and visual comfort preferences while adhering to hygienic and health boundaries that need to be applied in an indoor environment. Inhabitants comfort needs will be considered through their interaction with the application, while comfort related data will be captured by sensors installed in the project's buildings.
Supported Functionalities	Following the above description there are two main functionalities to be supported: a) End users (inhabitants) providing input regarding their thermal and visual status against the set conditions in their apartments. b) End users (inhabitants) being able to access/monitor historical information regarding their thermal and visual preferences.
Requirements Mapping (as per the requirements identified in D2.5**Errore. Il segnalibro non è definito.**)	**1st Functionality (thermal and visual comfort input provision):** - **Inhabitants** should be able to **provide feedback** on their **(dis)comfort** conditions during the renovation. **(I.020)** - **Inhabitants** should be able to **provide feedback via an app** regarding their (dis)comfort conditions (Temperature, Lighting) post renovation**. (I.22)** **2nd Functionality (comfort preferences visualisation):**

	- **Inhabitants** are interested to have a knowledge about **temperature**, **humidity**, **IAQ** with lower interest about acoustics. **(I.06)** - **Inhabitants** are interested to get updates and have control over indoor environmental conditions in building premises. **(I.07)**

In addition to the above functionalities identified in the early stages of the project and upon consideration of the project's demonstration activities and feedback received from the pilot sites partners an additional functionality to be provided to the occupants is considered:

- **Energy consumption monitoring framework for owners and inhabitants**

Table 3 US-03 Energy consumption monitoring framework for owners and inhabitants

BIM4EEB Usage Scenario - 03	
US ID	US-03
US Name	Energy consumption monitoring framework for owners and inhabitants
Pilot site	Italy, Poland, Finland
Involved End-User(s)	Building owners & inhabitants
Description	Towards increasing energy efficiency of buildings, building occupants his direction, a continuous interaction framework about comfort status should be established, enabling users (i.e. Inhabitants) to continuously update their comfort preferences during and post renovation. The main purpose of such a framework is to raise building occupants (inhabitants and owners) awareness on their building's energy consumption, by informing occupant of their individual energy consumption.
Supported Functionalities	The main functionality to be supported with varying degree of information, depending on the role of the end-user (owner or inhabitant): - End users being able to monitor their energy consumption
Requirements Mapping (as per the requirements identified in D2.5**Errore. Il segnalibro non è definito.**)	**Functionality: Energy consumption monitoring** - **Inhabitants** are interested to get **energy updates** in building premises with focus also on indoor environmental conditions; increased building sustainability and reduced energy impact. **(I.01)** - **Inhabitants** should be able to easily track the impact of renovation in terms of **energy consumption** and IEQ. **(I.23)** - **Owners** should be able to remotely monitor the **building's energy performance/** Indoor Air Quality (IAQ) via an app. **(O.10)** - **Owner** should be able to remotely **monitor building's energy performance**/ special interest about HVAC/lighting systems device performance. **(O.15)** - **Owners** should be able to **receive information** about the impact **(**economic/ **energy/** wellbeing**)** of the renovation process in building premises. **(O.27)**

In order to ensure that all possible need and requirements were taken into consideration, during the early stages of T6.7, a draft version of the application was prepared (through the use of mock-ups) and presented both to the pilot sites representative and project's partners to receive their initial feedback.

On the basis of the mock ups, several discussions over the appearance, accessibility and privacy aspects of the intended application were held at various points during the WP6 activities and online meetings. Based on the feedback received, the initial mock-ups were refined and circulated again to the pilot sites representatives', as well as presented during the project's plenary meetings, where face to face discussions with the pilot partners were held to receive further comments.

Having described above the main functional requirements from the end user (owners and inhabitants) perspective, we proceed with the presentation of mainly non-functional requirements, extracted upon consultation from the pilot site partners.

Table 4 BIM4EEB pilot site specific requirements

Req. ID	Description	Type	Priority
1	The app should be as user-friendly as possible	Look and Feel	High
2	A user manual should be provided to the users	Look and Feel	High
3	The app and the features supported should be as simple & intuitive as possible for non-experts	Look and Feel	High
4	Information provided to the occupants should be presented in an accessible, easy to understand and flexible format that triggers users to interact with the app	Look and feel	High
5	Users will be able to access the Web Interface App from a browser	Accessibility	High
6	The web application needs to be designed in a responsive to ensure access from different devices	Accessibility	High
7	A single app should be provided to the users to demonstration project functionalities	Accessibility	High
8	The app shall only provide access to authenticated users	Privacy	High
9	An easy to adopt authentication process should be available to the users to register	Privacy	High
10	The app should be in line with the anonymization principles as defined in the project	Privacy	High
11	The app will be in line with the security and privacy principle as adopted in the project	Privacy	High
12	User shall be able to set parameters about their profile through a dedicated user settings management section	Functional	Medium
13	The users should be able to have access on the history of data presented via the app	Functional	High

14	The user actions (updates over the app) should not be restrictive for the implementation of project activities	Functional	High
15	Data should be consistent and reliable	Reliability	High

Having presented a non-exhaustive list of systems' requirements we proceed in the following section with the definition of the system's architecture and provide the design details of the application.

2.2 BIM4Occupants Ambient Application Architecture

Within this section the design specifications of the Ambient User Interface are presented. Towards this direction, we consider the aforementioned Usage Scenarios and list of requirements, as well as the main features and functionalities specified in the DoA.

Taking into account the list of key principles and requirements, we present in Figure 1 the reference architecture of the Ambient User Interface app.

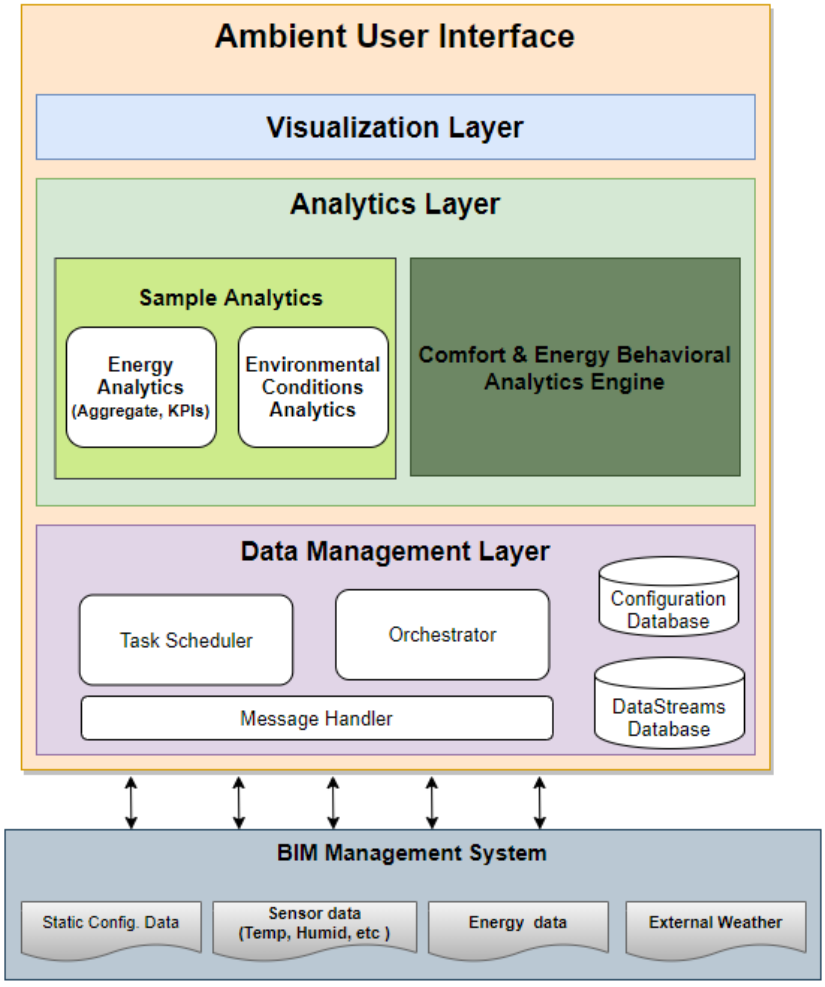

Figure 1 Ambient User Interface app architecture

The Ambient User Interface app follows a typical Model–View–Controller (MVC) software architecture.

MVC is an architecture pattern, commonly used for developing user interfaces; which divides the related program logic into three interconnected elements; the Model, the View and the Controller. As in our case, each of these elements is designed to handle specific development aspect of the application and in more detail:

- The Model (i.e. the Data Management layer) consist of the central architecture component and stores all the data and its related logic. Its role is to orchestrate the data, logic and rules of the application, while also incorporating the data management & analytics services developed in the project. It responds to the request from the Views and also responds to instructions from the Controller to update itself.
- The View (i.e. the Visualization layer) is that part of the application that represents the presentation of data (front end/visualization).
- The Controller (i.e. the Analytics layer); it represents that part of the application that "deals" with the user interaction. It accepts input from the user and converts it to commands for the Model or View. The Controller is responsible for responding to the user input and perform interactions on the data model objects. The controller receives the input, optionally validates the input and then passes the input to the Model.

As further shown in Figure 1, the provided application is not designed as standalone component; in contrary and in fully alignment with the WP4 Reference Architecture; all dynamic information that will be visualized by the application is provided by the BIMMS repository, serving as the central data management system of the project. Such an approach also ensures the security and privacy of the users' data, since it is easier for the platform to handle any request from a user to provide or even delete any piece of information (owned by the user) that is stored within the system.

Having described the high-level overview of the Ambient Users Interfaces architecture, we continue with the detailed design specification of the different layers of the architecture. The analysis remains here at a technical view point as the design details will be presented in the following section.

2.2.1 Visualization layer

The Visualisation layer consist of the front-end layer of the application and its role is the visualization of information. In alignment with the aforementioned requirements and feedback received from the pilot sites and project's partners the high-level principles and guidelines for the design of the application are as follows:

- The user interface (UI) should be **simple, visually appealing and easy to understand**: as typical building occupants (especially in the case of the project's pilot sites) may not be familiar with the provided technologies the focus should be on simple views and on the domains of interest.
- The scope of the tool is to raise building occupant's awareness. Therefore, the application should **focus on both end users (owner and inhabitant)**, providing individual personalized information and building level aggregated information, respectively.
- The **minimum of intrusiveness** of end users is a main prerequisite. The users are prompted to use the application on demand, while inhabitants (through their dedicated screen) are encouraged to provide their thermal and visual comfort status in a simple and appealing manner.

The design principles for the front-end has been fine-tuned after several iterations with the pilot partners of the project. The detailed description of the supported widgets is provided in the following section on the basis of the work flows and requirements (wish list from pilot users).

2.2.2 Data Management layer

As mentioned above, the scope is to provide a tool in order to raise building occupant's awareness in regard to their comfort zones and ambient conditions in their premises during/post the renovation process,

as well as their energy consumption. It is apparent that the application for building occupants cannot stand as a separate tool, rather it relies on data gathered from WSNs installed in the pilot sites and the availability/provision of such data from the BIMMS. Under this context, any data request messages triggered by the application should be received by the BIMMS implementation who will interpret these to the associate response messages.

There are different methods supported by the BIMMS platform to retrieve data (as defined in the DoA, BIMMS platform support both ***REST protocol and RDF- based technologies*** as defined by the consortium) This is actually the main role of the Data Management layer (see Figure 1); to establish a seamless communication between the Ambient User Interface application and the BIMMS platform in order to request specific data attributes required for further analysis and visualization.

The data elements required for analysis are summarized in the following table, also highlighting the business and user perspective in line with the core functionalities as presented above. The definition of the available methods to ensure integration with the BIMMS platform are presented in Annex I.

Table 5 Ambient User Interface - Data specifications

Data Specifications	User Perspective	Mapping with linked data framework
User Configuration Parameters	Inhabitant/Owner	IFC file & Extensions
User comfort related parameters: (thermal, visual)	Inhabitant	Occupant Behaviour Ontology
Ambient conditions related values: (thermal, visual, IAQ)	Inhabitant/Owner	Occupant Behaviour Ontology Indoor Air Quality Ontology
Energy consumption related values: (focus on energy systems operation)	Inhabitant/Owner	Energy Systems Ontology

Further to the definition of the wrapper with the BIMMS platform at the application, an internal data structure is defined to stand as the local data schema. The abstract model of the local data schema is presented in Figure 2. This is a conceptual view of the data model in order to incorporate (a) user specific parameters, (b) comfort and energy related parameters attributes that blueprint the overall design of the application.

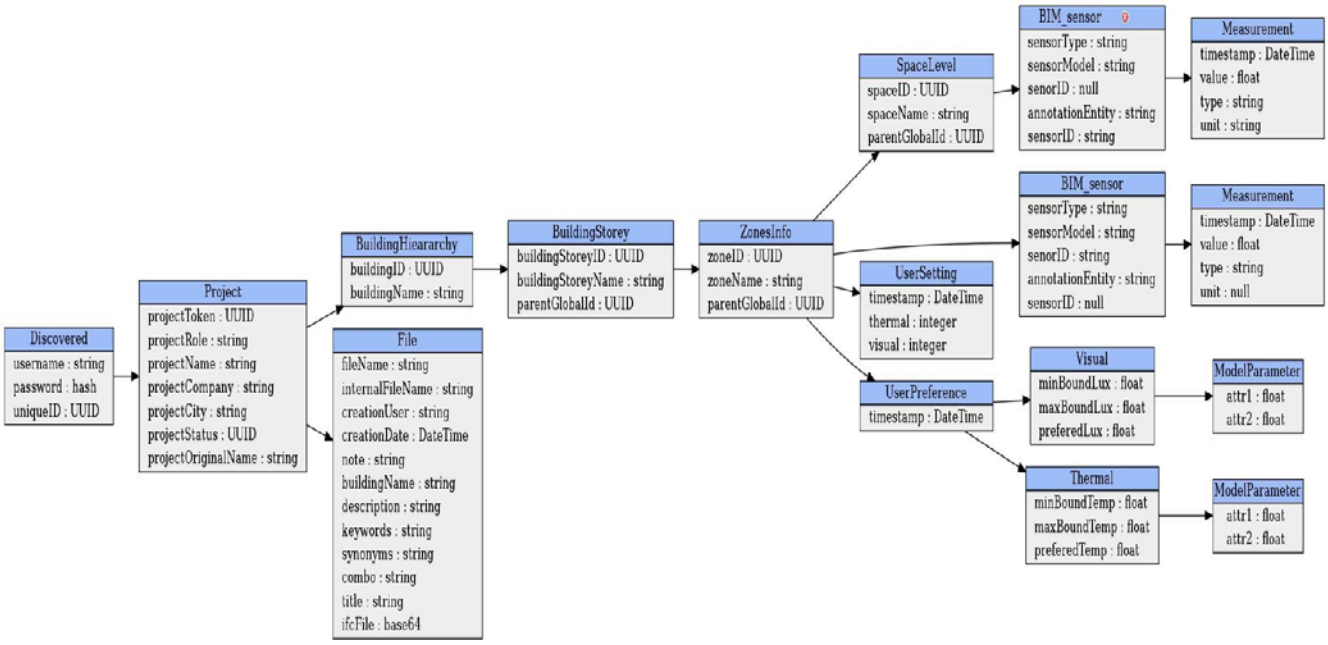

Figure 2 Ambient User Interface Data Model

In addition to the visual representation, the data model structure for the app is presented in Annex I. The definition of the attributes was performed taking into account the different data attributes as were specified in D3.6**Errore. Il segnalibro non è definito.**, with refinements apply in this section considering the progress on the work.

Note: Apart from the core integration work performed in the project, the preliminary evaluation of the relevant ontological models defined in WP3 is performed in this document (as in the rest of software related documents of WP6 and WP7) as a separate activity.

The main focus of this preliminary evaluation is about testing the initial versions of the RDF instances of the different models, with focus on the business perspective of each tool (how the different data available in the BIMMS linked data framework can be retrieved from an external user or an application). The specific tests performed in the context of Occupants Behaviour Application are reported in Annex II. A more thorough evaluation of the BIMMS linked data framework will be performed as part of the work in T 4.6 Testing and validation (D4.9- M24 but mainly in D4.10- M36 where the focus is at testing the different services of the BIMMS platform at the demo sites considering also the demonstration actions to take place in WP8 – as agreed among partners the final evaluation of the BIMMS linked data framework will be reported in D8.5 : Report about the validation results by relevant stakeholders).

2.2.3 Analytics layer

The Analytics layer of the Ambient User Interface app is responsible for incorporating the data analytics part towards the extraction of knowledge from the data streams. Taking into account the list of requirements and usage scenarios, we present the different processes running at the analytics layer of the application:

1. One of the key features supported by the app is the aggregation and simple statistics over the raw data to. This analysis enables end users (owners and inhabitants) to access aggregate and timeseries historical information about the ambient conditions and their energy consumption in their premises.
2. Additionally, the analytics engine for the extraction of the comfort and energy behavioural profiles

is incorporated in this layer. The functionality and the analytics details of the algorithmic process were presented in D6.7 **Errore. Il segnalibro non è definito.**. The technical details on the way to incorporate the analytics engine in the app are presented in the following sections.

Overall, the analytics part is split in two core functionalities, ensuring that way the modularity of the app. The Ambient User Interface app can be offered to provide only sample statistics over the data streams as tracked from the building environment. In addition, the behavioural profiling analytics module is defined as a separate module of the app in order to enhance the overall functionality with fine grained model techniques.

We presented above the design specifications of the Ambient User Interface App. The updated design specifications are based on the list of requirements and user needs as presented in the previous section, along with the definition of the architecture and the development of the data management layer of the project in WP4. In the following section, the design specifications are further transformed into development specifications towards the delivery of the Ambient User Interface app

Note: The outcome of the D6.8, the Ambient User Interface app, will be delivered within the BIM4Occupant application which integrates also the functionalities defined in D7.2. The functionality of the "Ambient User Interface" app is provided through the "Occupants 2.0" feature of the BIM4EEB BIM4Occupants application. In this document, we present the architecture of the Ambient User Interface only.

3 Design Principles and Development

Having defined the design of the architecture we continue with the definition of the design details along with the development/deployment principles of the application.

3.1 Design specifications

Following the definition of the main usage scenarios and requirements for the application, we present the workflow and the particulars towards delivering the defined functionalities. This is the narrative description of the different mock ups discussed with the demo and technical partners of the project, drilling into the design details of the Ambient User Interface application.

3.1.1 Configuration/ Authorization

This the configuration layer of the application as the intro screen a new user will encounter. The process is delivered following the steps:

1. The end user first register to the BIMMS platform as an end user of the BIM4EEB platform; This information is necessary so that the application knows which BIM4EEB instance to contact in order to obtain the application related information.
2. The end user is setting the Unique ID (provided by the BIMMS platform) associated with the building data that belong to the personal account; main prerequisite is the user to have already configured the building gateway and profile in the BIMMS platform in order to have the associated parameters reported in the BIM4EEB framework.
3. This unique token is used in all information-related transactions between the BIM4EEB to identify the specific asset/property. The configuration of each property pre-exists in the central management layer (Middleware) of the BIMMS platform; established in an automated way once the role of building occupant commissioned in the network by a building professional. Therefore, the static configuration parameters for each user may be retrieved by using this unique ID
4. On the other hand, an application specific username/password is defined by the user (linked with the Unique ID) to facilitate the log in process.
5. An early version of terms and conditions should be accepted by the user. Which will be developed in the refined version per demo site at the 2nd release of the application.

It is evident that the configuration process is defined as a single step process; making the overall commissioning as simple as possible. During the registration, no personal information is requested from the users. After the user is registered in the portal, he/she may provide the username/password credentials to log in to the application. The reader is referred also to section 4.1 and 4.2 for the respective screenshots of the application.

3.1.2 Ambient Environmental Conditions visualization

Notably, the physical environment within a building (including the ambient conditions) can affect building occupants' performance. In addition, one of the main objectives of a renovated building is to provide health, and welfare to the occupants.

Under this context and towards an increased information provision, the BIM4Occupants application enables end users (i.e owners and inhabitants) to monitor near real-time but also history of context conditions in their building. Raw sensorial data are received from the BIMMS platform and send to the

application where these are presented an intuitive manner. These raw sensorial data are further mapped to the static building related parameters in order to enhance end user visualization. Along with near real time information, end users of the tool can drill into the history and extract insights about environmental conditions profile.

There are different levels of information about Ambient Environmental Conditions in the different BIM4EEB pilot sites. In more detail the provided application, enables end-users to visualise various comfort related parameters such as indoor/outdoor temperature, indoor/outdoor humidity, indoor/outdoor Illuminance levels as well as outdoor/ IAQ metrics. Based on the available information, the application is adaptive with the appropriate visualizations.

Moreover, as the provided application is intended for both owners and inhabitants dedicated views are provided serving its individual information needs, while also respecting their privacy. In more detail inhabitants can access both near real-time and historical information of its apartment's ambient conditions, while owners are able to see aggregate ambient condition information at building level. The reader is referred also to section 4.1 and 4.2 for the respective screenshots of the application.

3.1.3 Occupants Interaction and Comfort Profiling

In general, building's occupants' feedback, is considered as a rich source of information towards evaluating environmental design practices and building operations. Under this context, this service is about enabling end users (i.e. building inhabitants) to provide real-time information regarding their comfort status against set values of temperature and illuminance in their premises.
An interactive user-friendly approach is provided to gather inhabitants' input through a five-point emoji-based scale. Inhabitants can select the appropriate emoji corresponding to their comfort status. Correlation of inhabitants' feedback with ambient conditions data as gathered from the WSN is further considered towards extracting users' visual and thermal comfort preferences.

Following consultation with the demo partners, this service is provided in the same page with the previously mentioned functionality(ambient condition presentation) in order to: a) provide inhabitants with a "comparison" tool, where they can identify the ambient conditions in the premises and b) urge inhabitants to provide their input when the ambient condition satisfy (or not) their comfort preferences. The reader is referred also to section 4.1 and 4.2 for the respective screenshots of the application.

3.1.4 Energy Behavioural Profiling Analytics

This service is about raising building occupant's awareness of their building's energy efficiency, by enabling them to monitor their own energy consumption. This analysis may be segmented at the level of detail available from each demo site. More specifically, total consumption information, information from the different energy sources, information at device level may be available for visualization. In addition to timeseries information visualization, intuitive statistics are available for visualisation: Typical consumption profile (daily), Total period consumption/per source, etc.

Following consultation with the project's partners and pilot sites representative, the inhabitants are able to monitor their individual apartment's energy consumption; while owners will be able to monitor aggregated information about the building's overall energy consumption. The reader is referred also to section 4.1 and 4.2 for the respective screenshots of the application.

3.2 Development principles

Towards the implementation of the application, various different frameworks were utilised, which are described as follows;

For information exchange with OneTeam (middleware leader) there are different methods supported. The decision was to follow the REST/JSON services as a means of data retrieval stated in the DoA. Therefore, the **data management layer**, acting as the interface layer with the BIMMS platform is based on Django-rest-framework[1]. A Python Celery[2] implementation is available acting as the asynchronous task queue for periodical data acquisition. A Python Flower[3] implementation stands on top of Python Celery, acting as the web-based tool for monitoring and administrating Celery clusters. In addition, Rabbit-MQ [4] is incorporated in order to orchestrate the different tasks at the back end. Along with the data persistence layer as presented above, an internal DB structure is defined mainly for persistency reasons to store the different configuration parameters and thus a Postgres DB [5] is defined per pilot to store only the necessary information. In addition, for sensorial data and in order to ensure the scalability of the app in the future, Elastic[6] has been selected to act as data streams repository.

For the backend, the development as a Python application through the usage of Django[7] which natively support Object Relational Mapping (ORM) integration. Django supports by default the MVC principles and thus the development was performed in accordance with the definition of the architecture.

For the front-end view implementation and considering that the Ambient User Interface consists of a web-based application, typical web technologies (HTML/HTML5/CSS3) were utilised for the design and the most recent JavaScript[8] frameworks for information rendering. VueJS[9] is the framework supported for information visualization, working seamlessly with the Django[7] framework.

To enable also dynamic characteristics on the front end, typical JavaScript libraries have been considered, namely charts.js[10] and apexcharts.js[11] which support a numerous types of visualization widgets. As the requirement is for a responsive visualization, the Vuetifyjs[12] framework is incorporated on top of the VueJS[9]. Vuetifyjs[12] is defined as a Material Design Component Framework and thus it supports the seamless rendering of the different design components in order to address the different visualization requirements (visualization through different communication means).

In relation to the **deployment** of the Ambient User Interface app, this is performed as a dockerized application. The different modules presented above are defined as separate docker containers in order to ensure the reliability of the app.

Overall, the development of the app is performed by exploiting open source and license free technologies and thus no limitations apply at any further commercialization or demonstration of the solution.

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[1] https://www.django-rest-framework.org/
[2] http://www.celeryproject.org/
[3] https://flower.readthedocs.io/en/latest/
[4] https://www.rabbitmq.com/
[5] https://www.postgresql.org/
[6] https://www.elastic.co/
[7] https://www.djangoproject.com/
[8] https://www.javascript.com/
[9] https://vuejs.org/
[10] https://www.chartjs.org/
[11] https://apexcharts.com/
[12] https://vuetifyjs.com/en/

4 BIM4Occupants Ambient User Interface Manual

Since the Ambient User Interface app is intended for the building occupants, i.e. for non-experts in the domain, a User Manual is required. Within this section we provide the manual documentation for the Ambient User Interface delivered within the context of the BIM4Occupants app. A usage walkthrough is provided through screenshots of the respective functionalities of the app, as an outcome of the development process described in the previous sections. The design of the application has been undertaken in a fully responsive manner to enable visibility from different device types.

A demo account is provided and accessible for demonstration purposes: bim4occupants.s5labs.eu
Username/Password: To Be Provided upon request

As previously mentioned, the Ambient User Interface app is delivered within the context of the **BIM4Occupants** application**,** intended for both inhabitants and owners of a building. However, according to the end-user's role, i.e. inhabitant or owner, some functionalities and the appearance of the application varies. Upon presenting the Registration & Authorisation process which is similar for both end users, the sections continue by describing the key functionalities for the inhabitants followed by the owners' view.

Registration & Authorisation View

The scope of this dashboard in mainly to enable occupants to manage their account. In more detail, the occupants can register to the application (Signup, Login) and retrieve their password if it's forgotten.
Overall, the process is delivered in a semi-automatic way; the occupant (Owner or Inhabitant) provides his/her Unique ID (provided by the BIMMS) and upon accepting the terms and conditions he/she sets the parameters at the configuration process. The list of parameters is dynamically retrieved in the background. Username/Password registration process is also supported.

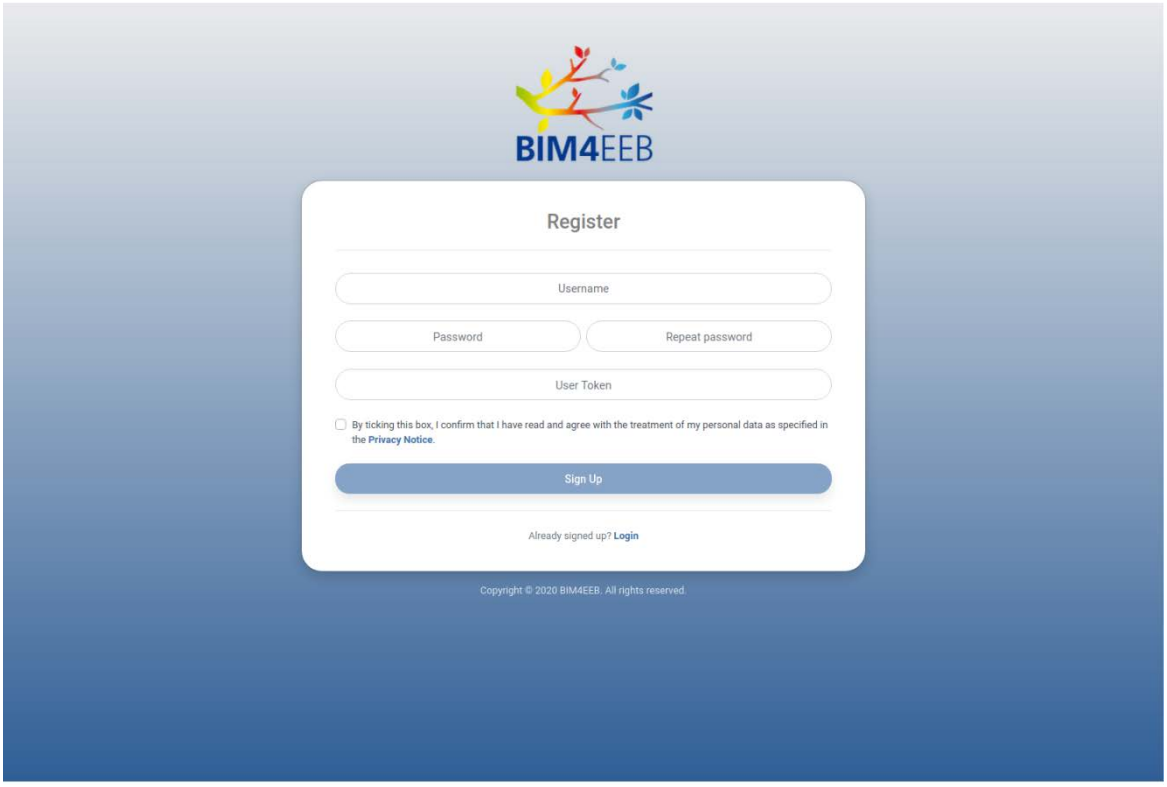

Figure 3 Registration process, Sign Up page

Upon signing up the user can login to the application, by inserting his/her username and password set up in the signup process.

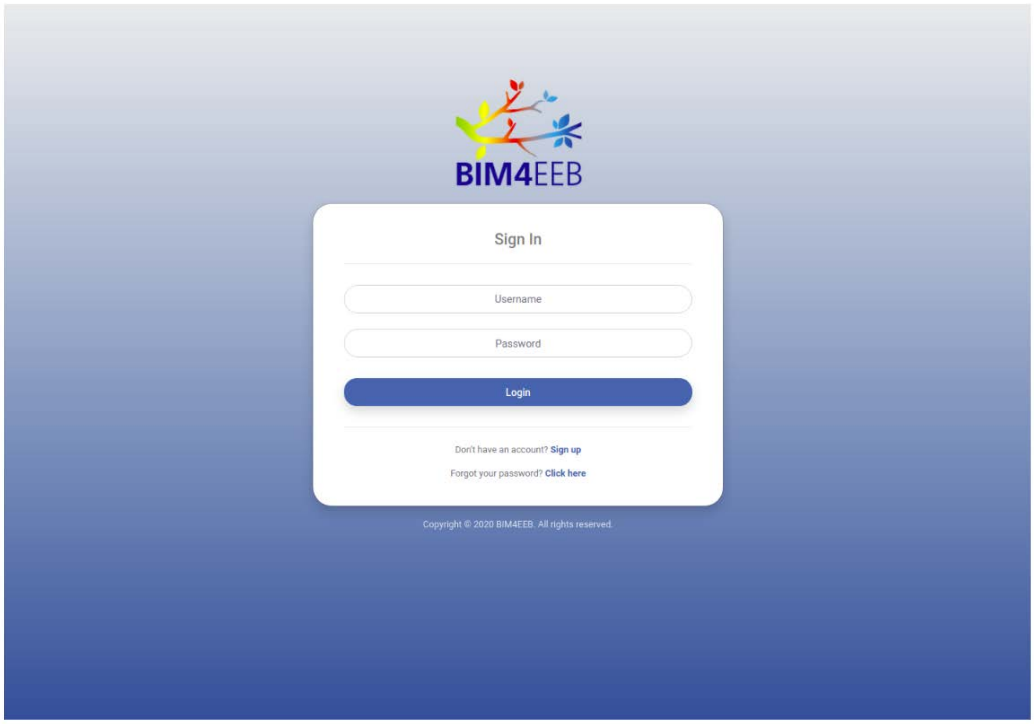

Figure 4 Registration process, Login page

In the event the user forgets his/her password, this can be retrieved as shown in Figure 4, by inserting his/her username and the password set up in the BIMMS platform.

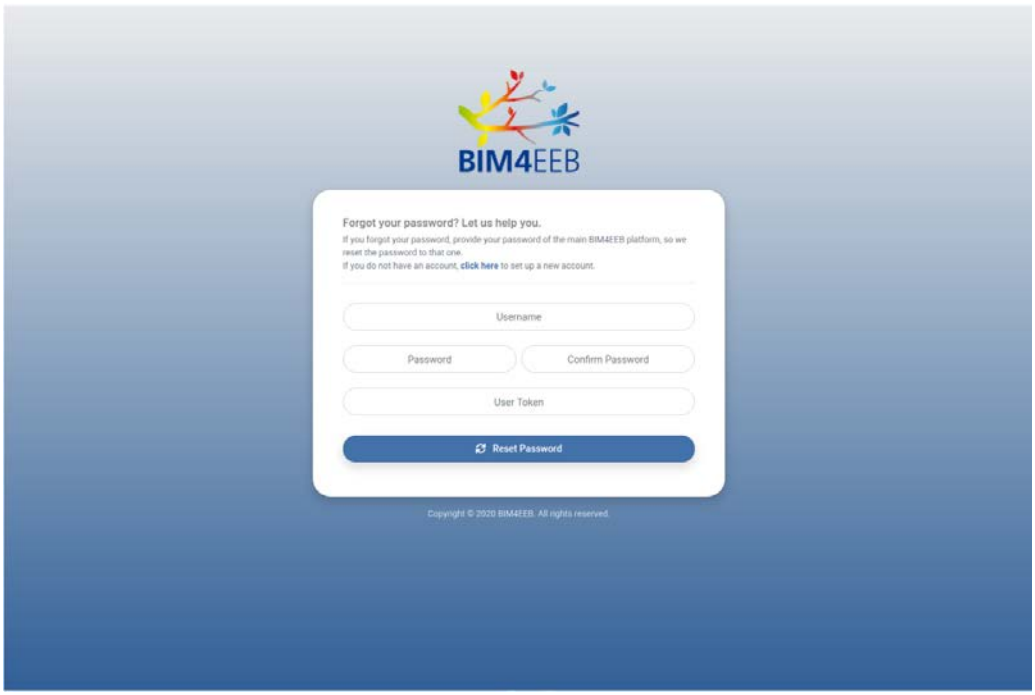

Figure 5 Password retrieval page

Having presented the registration/configuration process for accessing the BIM4Occupants app; we proceed with the presentation of the main functionalities of the app, according to the end user's role (inhabitant or owner); focusing only on the functionalities provided in the context of the Ambient User Interface.

4.1 BIM4Occupants: Inhabitants' view

From the left side drop-down menu, inhabitants can select three main functionalities supported from the BIM4Occupants app:

- **My Overview**: Visualisation of near real-time comfort related information & inhabitants' engagement (input provision)
- **My Ambient Conditions**: Context and Historical Analytics of comfort related information
- **My Energy Analytics:** Visualisation of energy consumption information

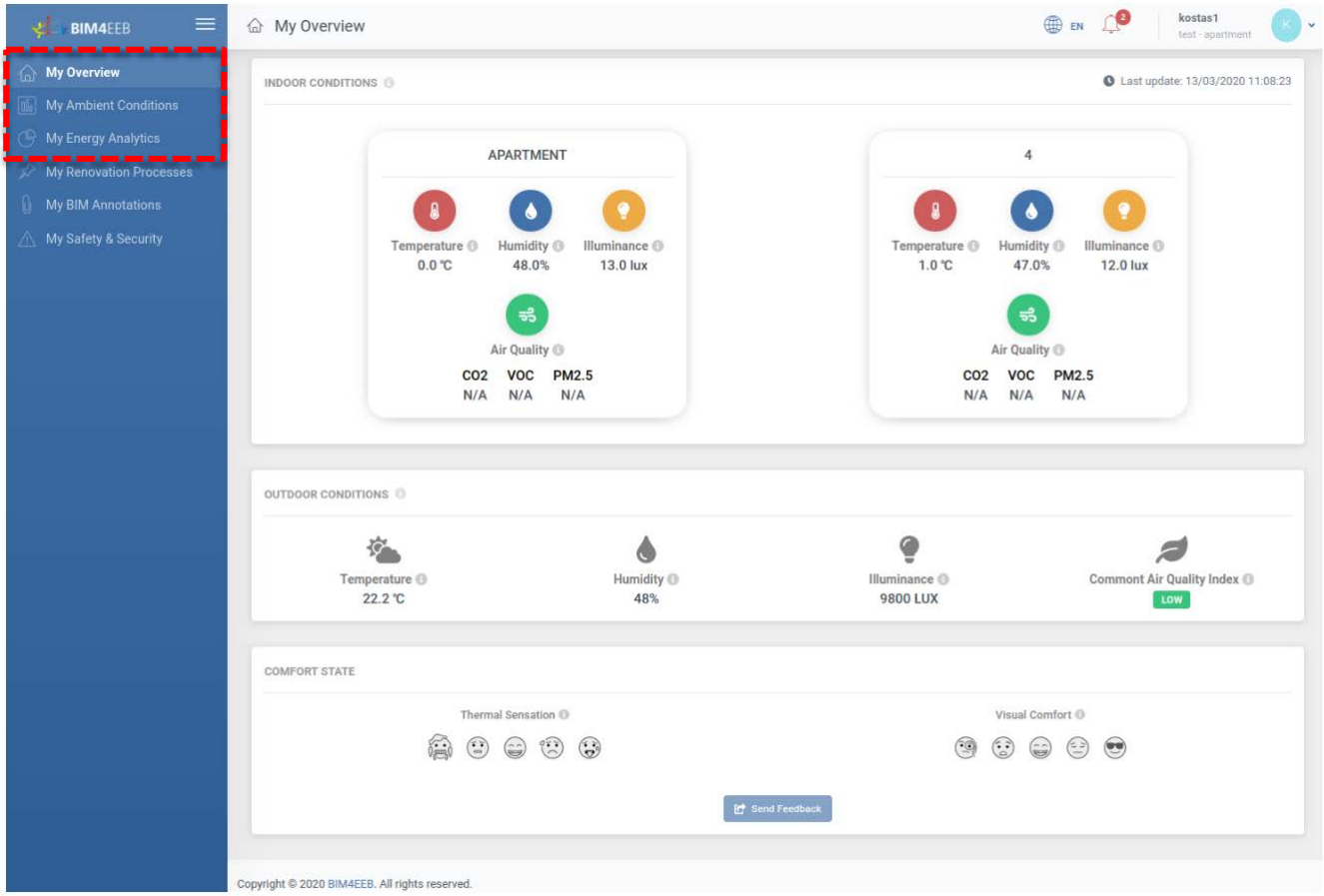

Figure 6 Inhabitants' View - Ambient User Interface menu

An extra section about user profile and assets settings is provided.

- **My Overview:**

Through this view, Inhabitants can visualize in a personalised way, near real-time information regarding the ambient conditions and associated parameters in their premises. This information is periodically updated covering: indoor/outdoor Temperature (ºC), indoor/outdoor Humidity (%), indoor/outdoor Illuminance (lux), IAQ metrics (CO_2, VOC, $PM_{2.5}$, PM_{10}) and the Common Air Quality Index (CAQI) used to present the outdoor air quality. Of course, the visualization is adaptable to the available information from each demo site (considering the installations of sensor and data gathering process).

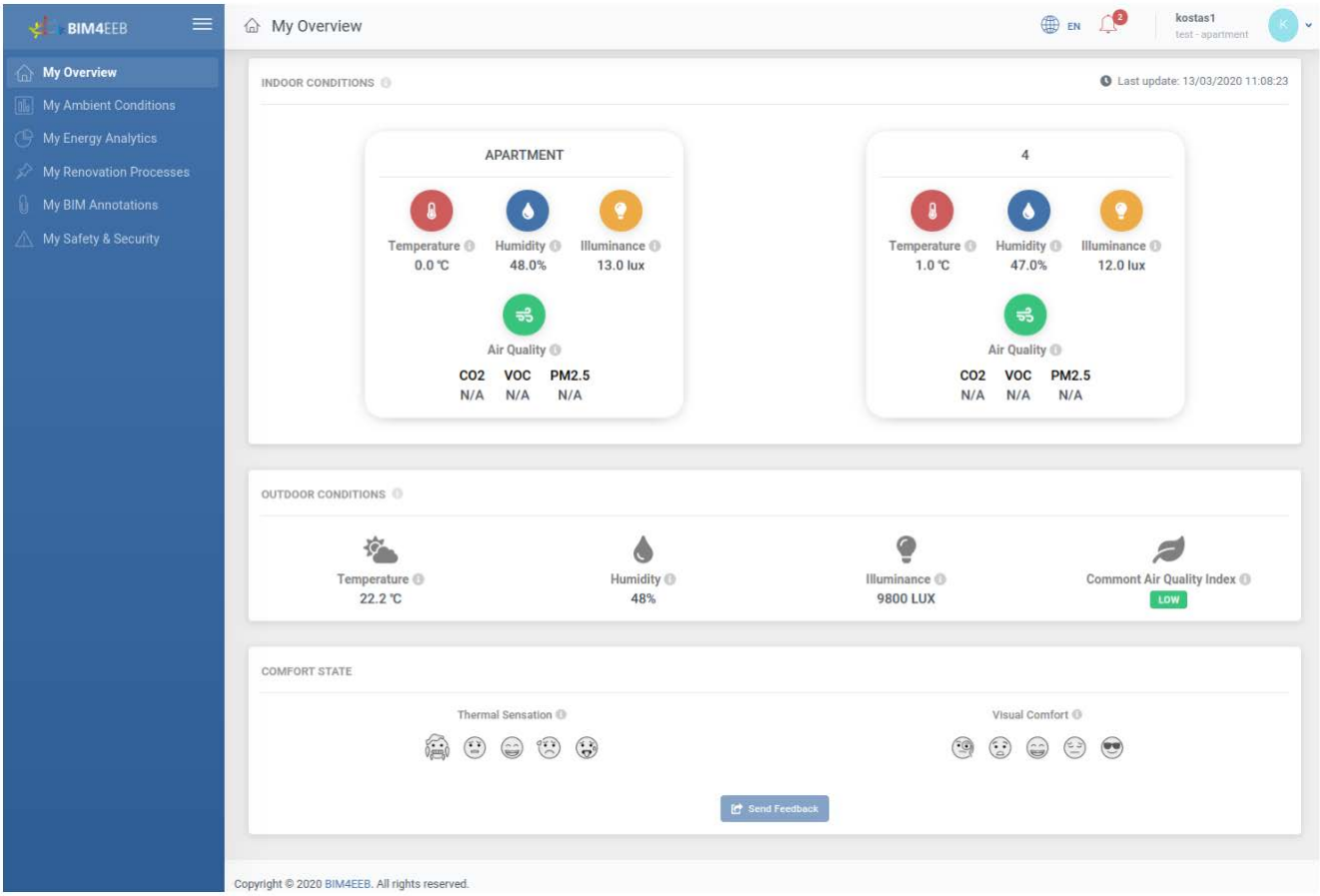

Figure 7 Inhabitants' View – My Overview page

In alignment with the requirements set in the DoA, the application enables interaction with and input provision by the building Inhabitants, aiming at the extraction of accurate context-aware occupant behaviour and comfort profiles. Through this functionality, inhabitants are able to express their comfort state against the set values of temperature and Illuminance in their premises.

Towards an easy to understand, fun and engaging way to capture the inhabitant's perception, we have adopted a 5-point emoji-based scale, where 5 emojis are organised on a single scale representing both positive and negative reactions. This "emoji-scale" ranges from positive through neutral to negative for inhabitants to choose from according to their thermal and visual status.

- **My Ambient Conditions**

Through this functionality, building inhabitants have access to context and historical analytics. Based on the input provided through the previous functionality, inhabitants are able to visualise their thermal and visual preferences through an appealing graph presenting the minimum, average and maximum values of thermal and visual comfort.

In addition, inhabitants have further access to historical information regarding the ambient conditions in their apartments. In more detail, inhabitants can visualize historical information regarding the indoor temperature, humidity, Illuminance, as well as information regarding IAQ metrics.

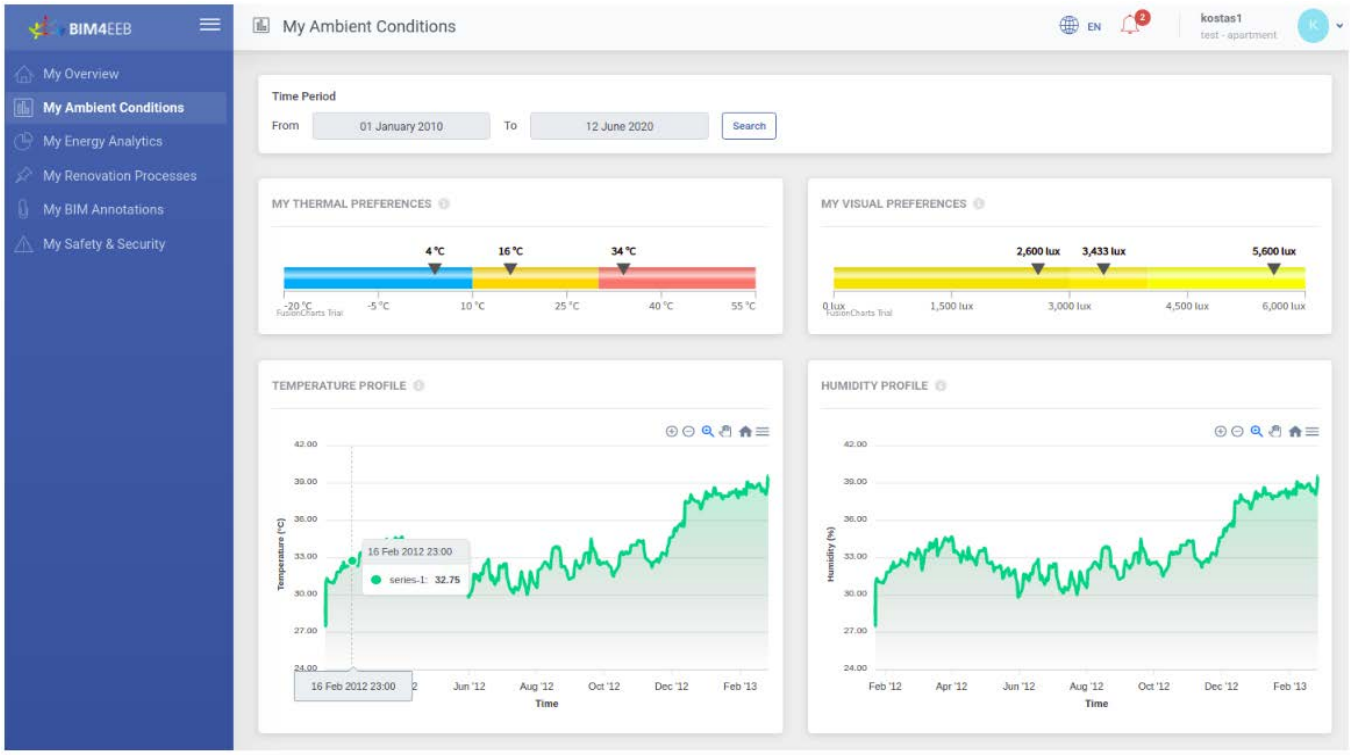

Figure 8 Inhabitants View – My Ambient Conditions (page 1)

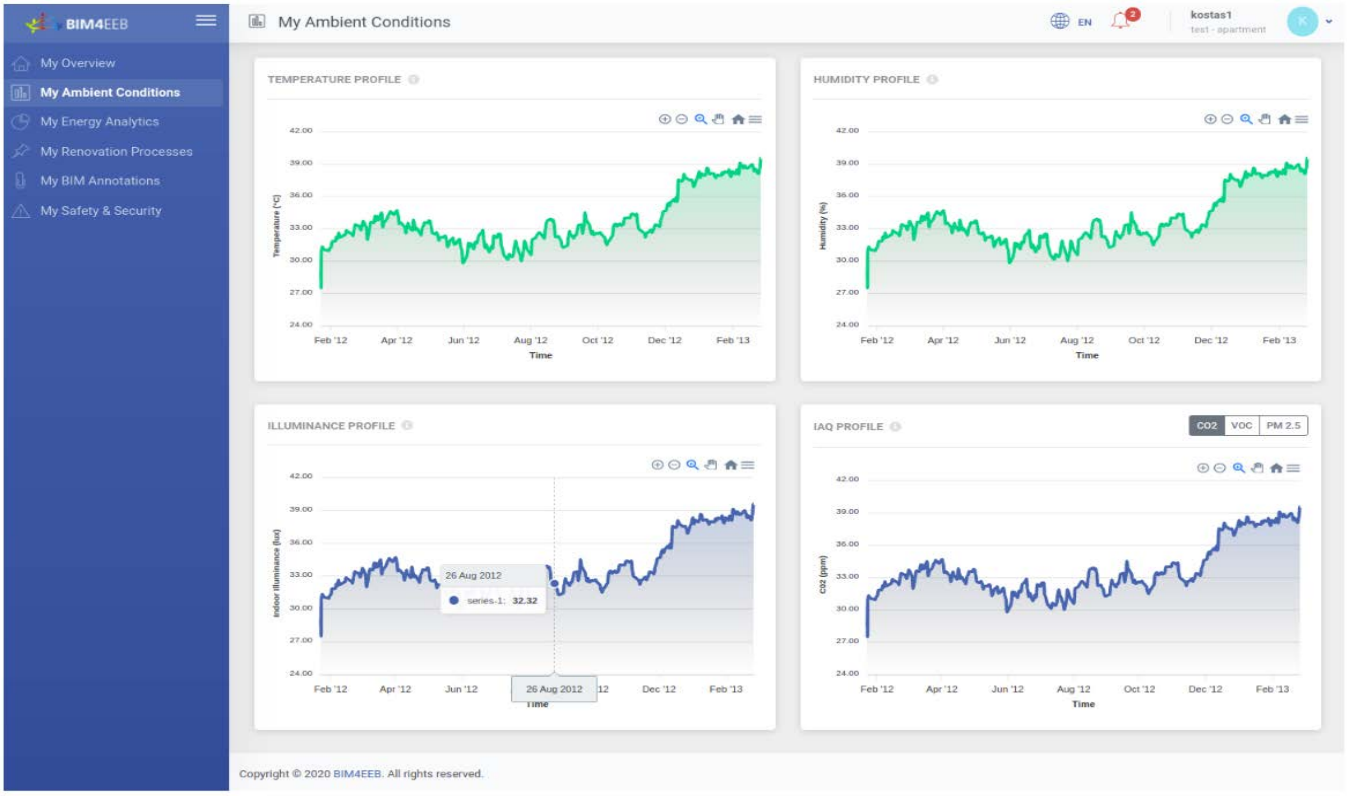

Figure 9 Inhabitants View - My Ambient Conditions (page 2)

- **My Energy Analytics**

Through this functionality and by selecting a time period, building inhabitants can visualize their apartment's energy consumption. Inhabitants are enabled to monitor their energy consumption hourly, daily, weekly and monthly.

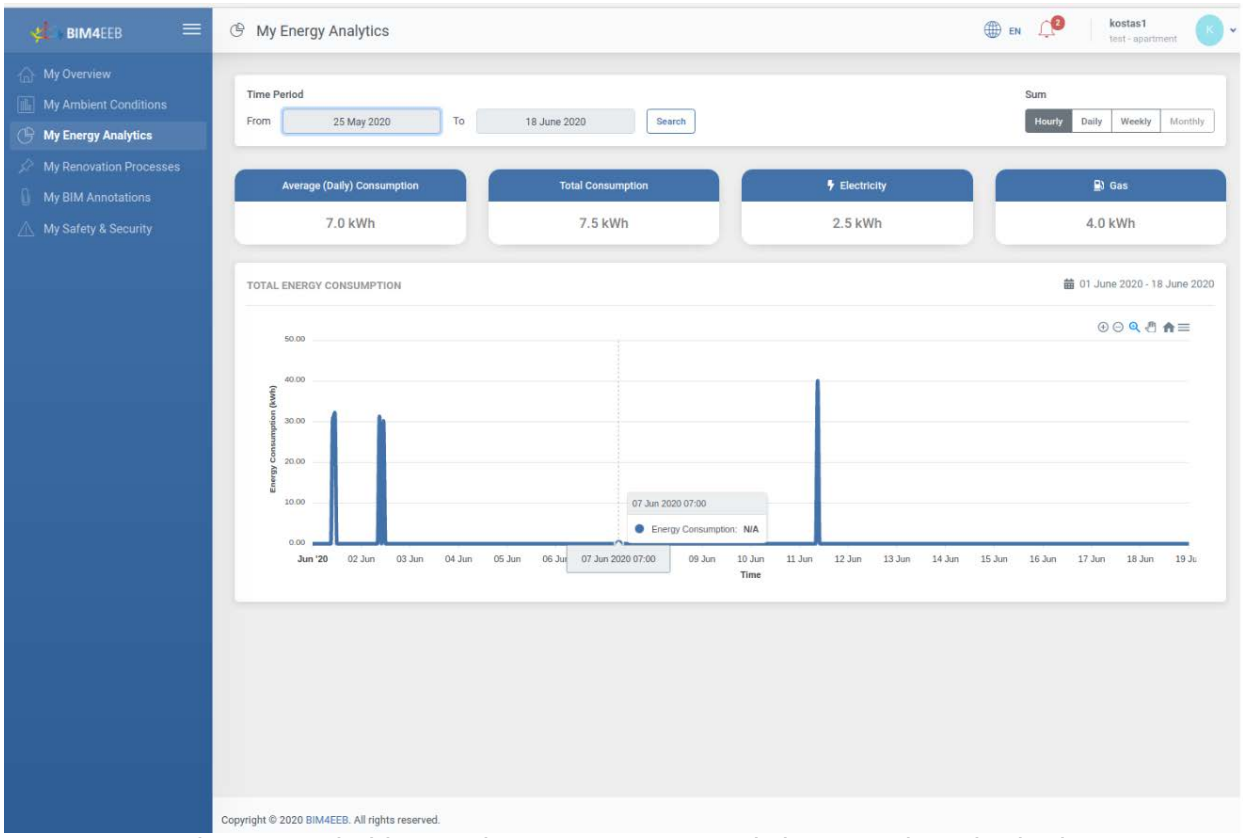

Figure 10 Inhabitants View - My Energy Analytics page (Hourly view)

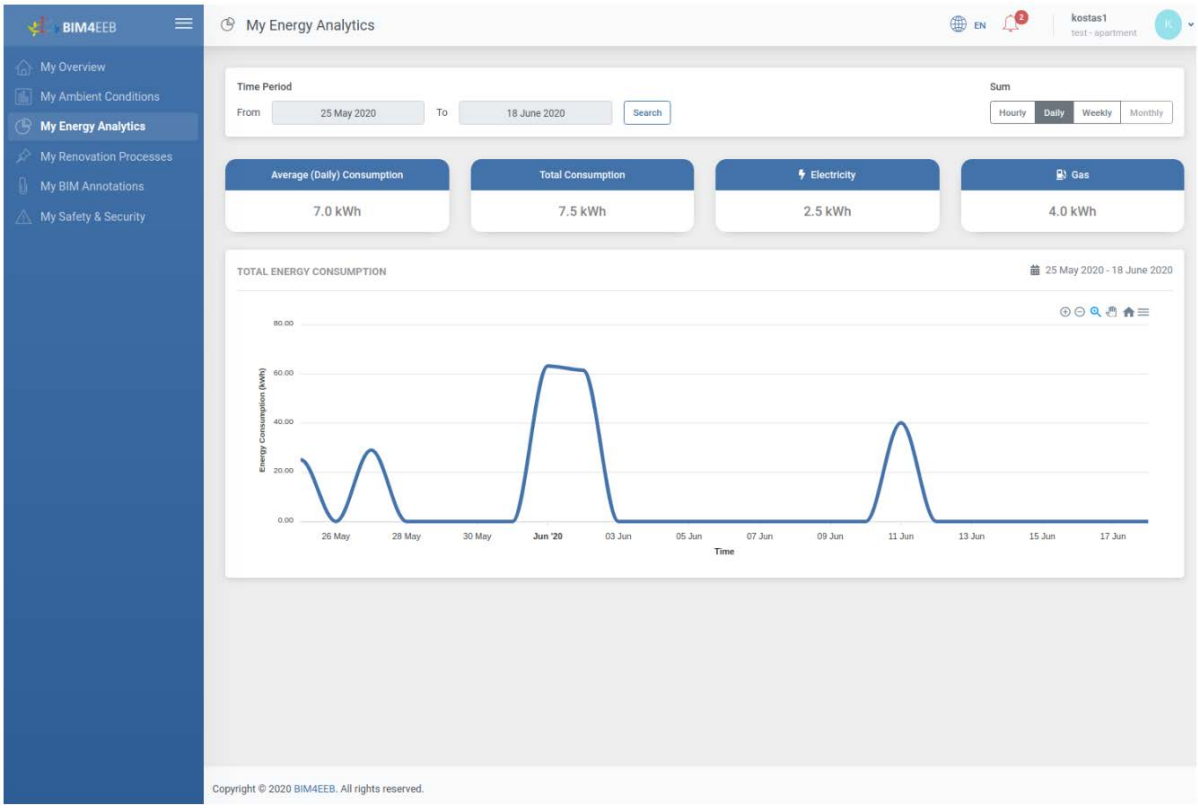

Figure 11 Inhabitants View - My Energy Analytics page (Daily view)

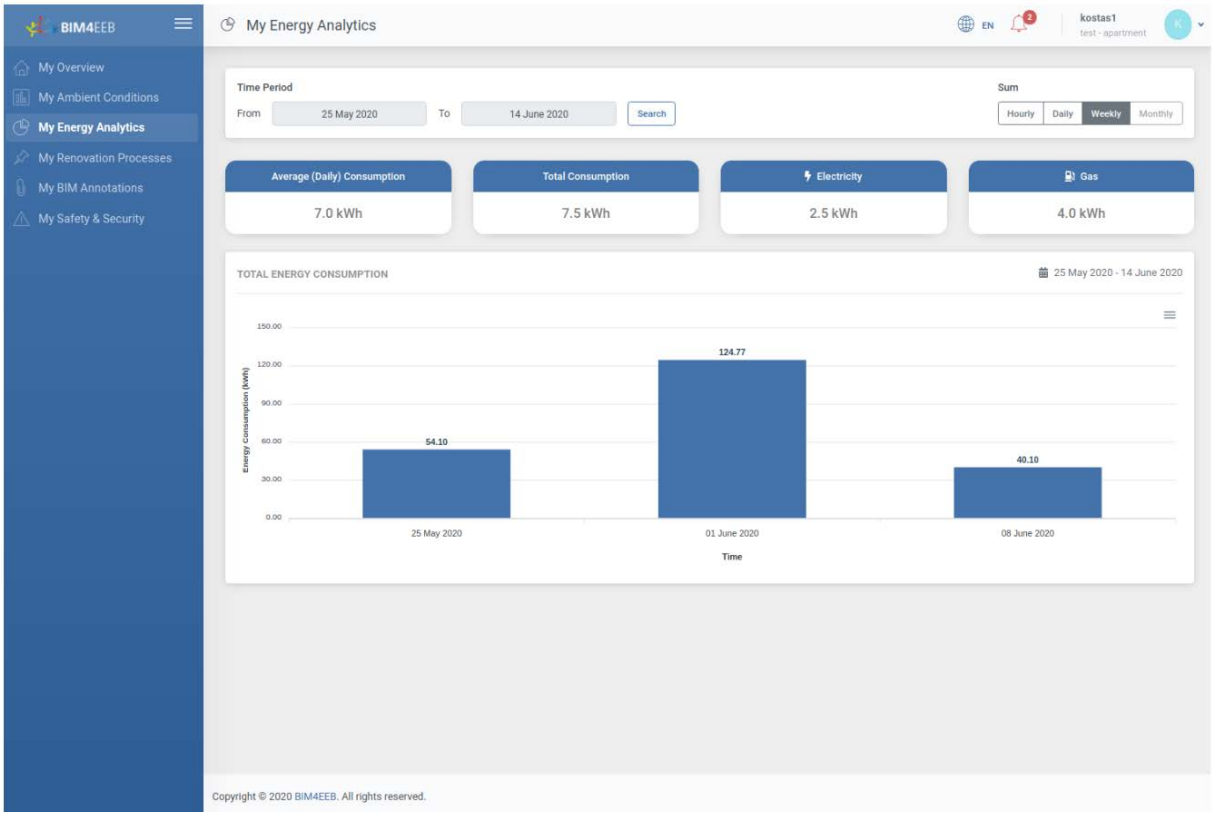

Figure 12 Inhabitants View - My Energy Analytics page (Weekly view)

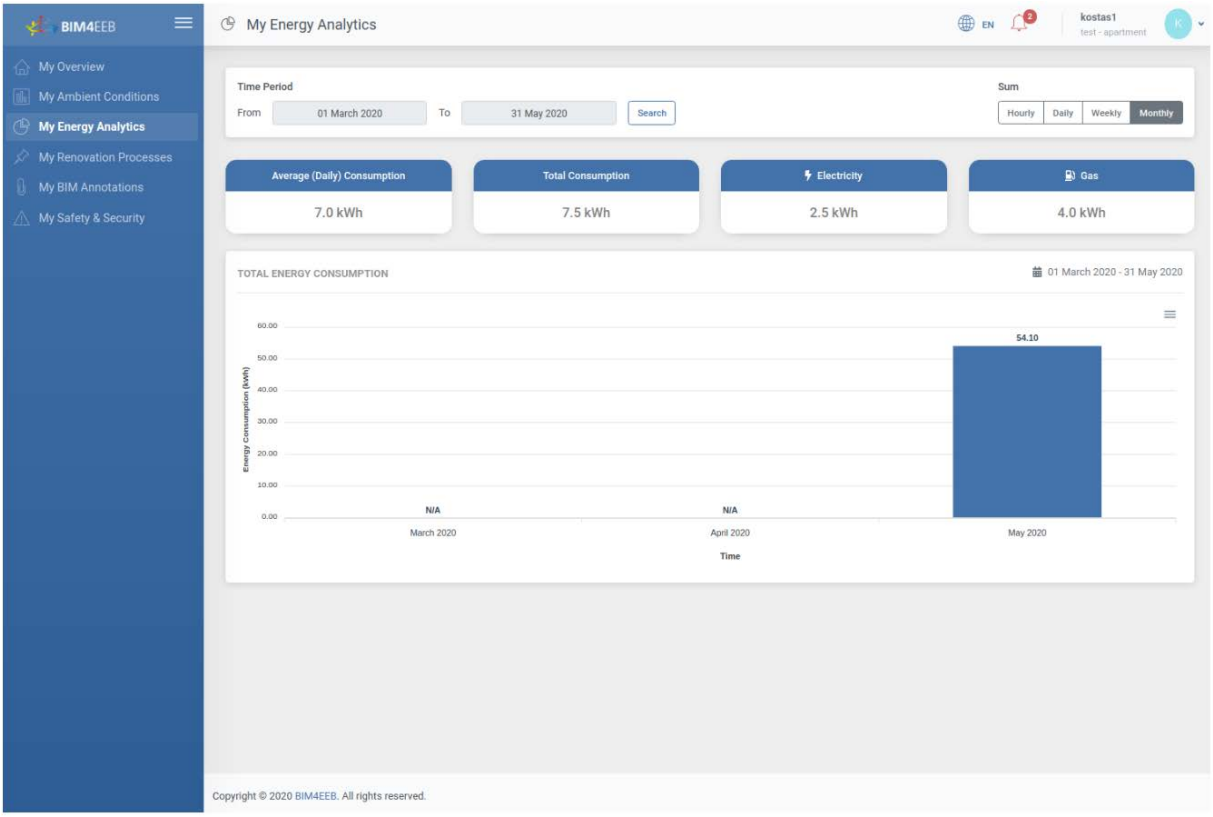

Figure 13 Inhabitants View - My Energy Analytics page (Annual view)

- **User Profile**

In addition to the above functionalities, a User Profile menu is provided, where inhabitants can provide basic information regarding their profile (such as their gender and their age group). This information is further used by the comfort profiling analytics engine towards the initial calibration of comfort profiles. Through this screen, inhabitants can also change their password or delete their account.

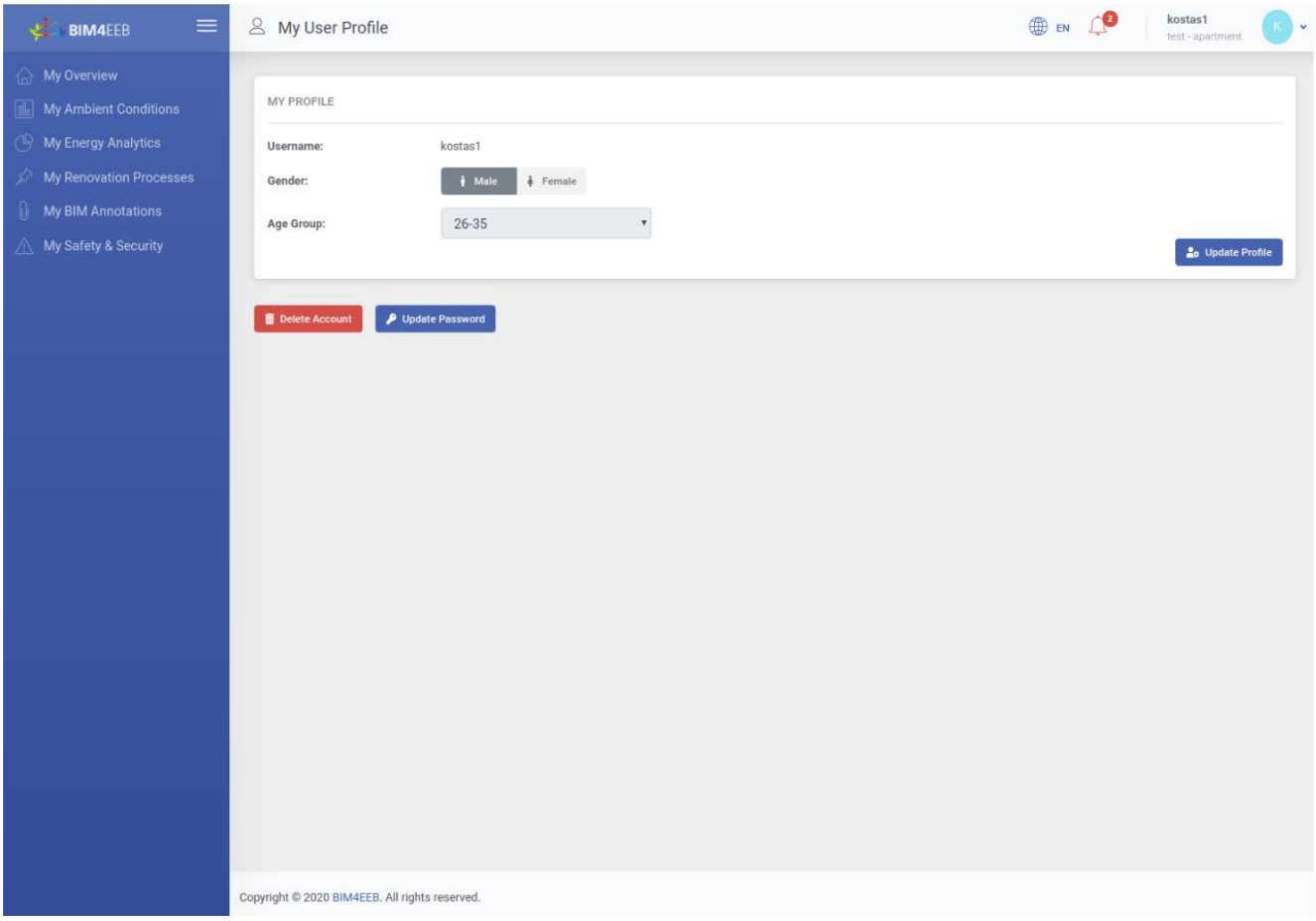

Figure 14 Inhabitants View - User profile

In addition, through the following screen (**User Assets**), inhabitants can get the summary of details about their apartment's composition e.g. zone hierarchy, static information regarding the sensors installed in their premises etc… Also the users are prompted to edit the name of each element for visualization reasons (a user friendly approach defining alias names for the main building elements as extracted from the BIMMS platform)

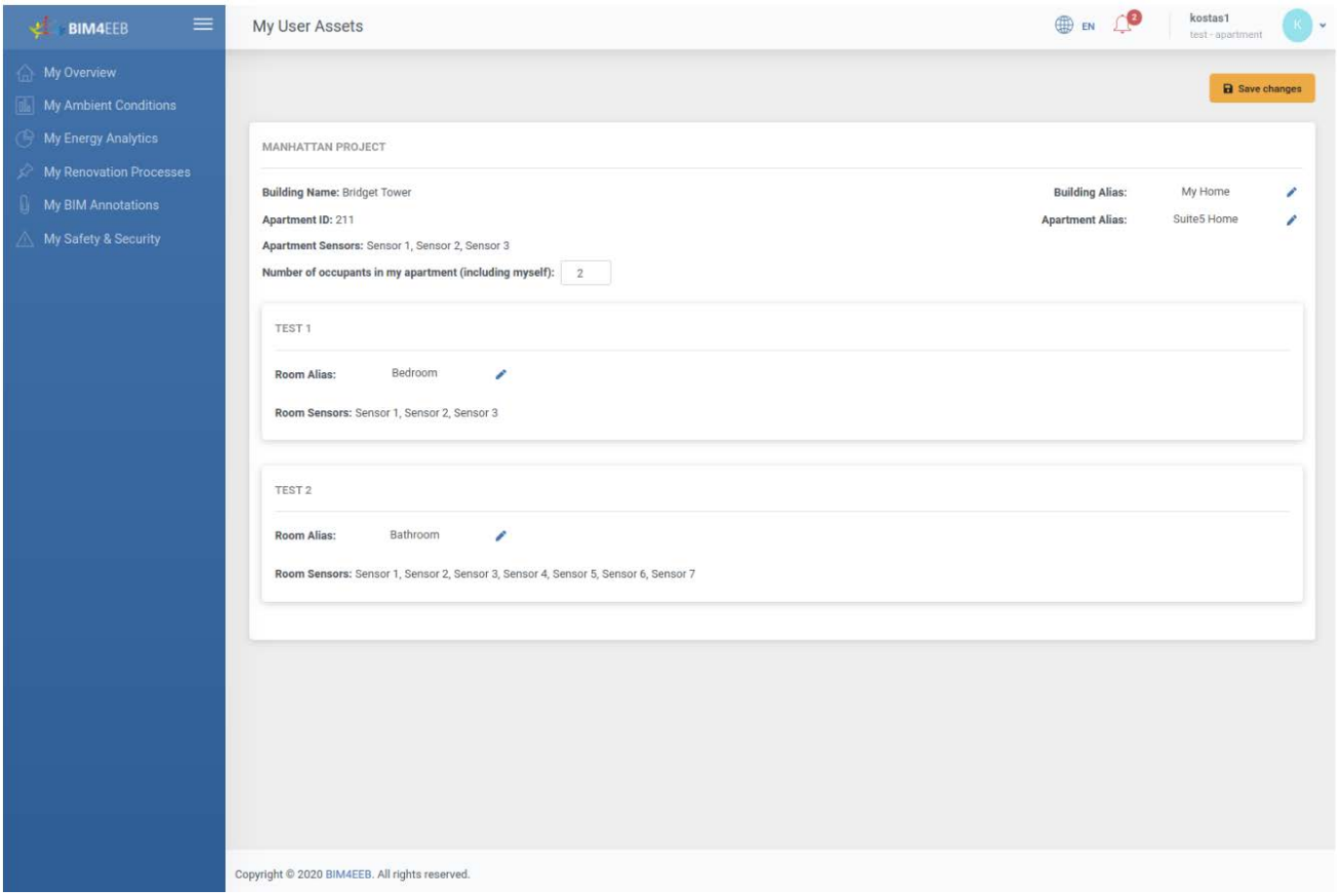

Figure 15 Inhabitants View – User Assets

In the following section the owner's views of the BIM4Occupants application is provided.

4.2 BIM4Occupants: Owners' view

Similar to the approach followed for the building inhabitants in the previous section, we present here the Owner's view of the application. The main difference against the inhabitants' view, is that in the case of owners, aggregated information at building level is provided.

Three main functionalities are provided (in the context of this deliverable) to the building's owners, delivered through the BIM4Occupant application. Such functionalities consist of:

- **Building's Overview**: Visualisation of near real-time comfort related information at building level.
- **Building's Ambient Conditions**: Context and Historical analytics of comfort related information at building level.
- **Building's Energy Analytics:** Visualisation of energy consumption information at building level.

Once again, a user profile and user asset menu for owners is available.

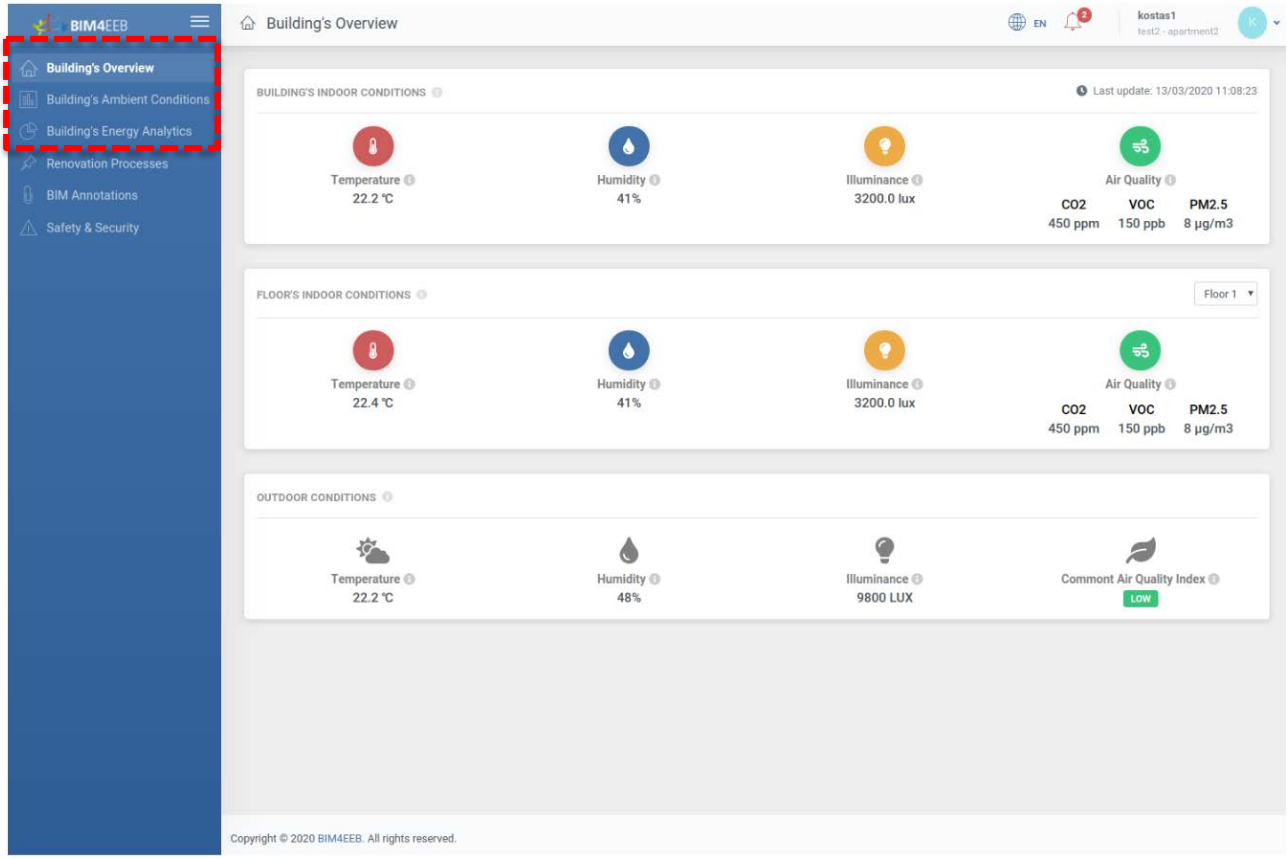

Figure 16 Owners' View – Ambient User Interface app menu

- **Building's Overview**

Through this functionality, owners are enabled to monitor and visualize the ambient conditions in their asset. The main difference against the inhabitants' view, is that in this case, aggregated information at building level is provided. Owners can monitor the building's indoor/outdoor temperature and indoor/outdoor humidity, indoor/outdoor illuminance as well as IAQ and outdoor air quality (CAQI). In addition, owners are enabled to monitor the ambient conditions in each floor of their building.

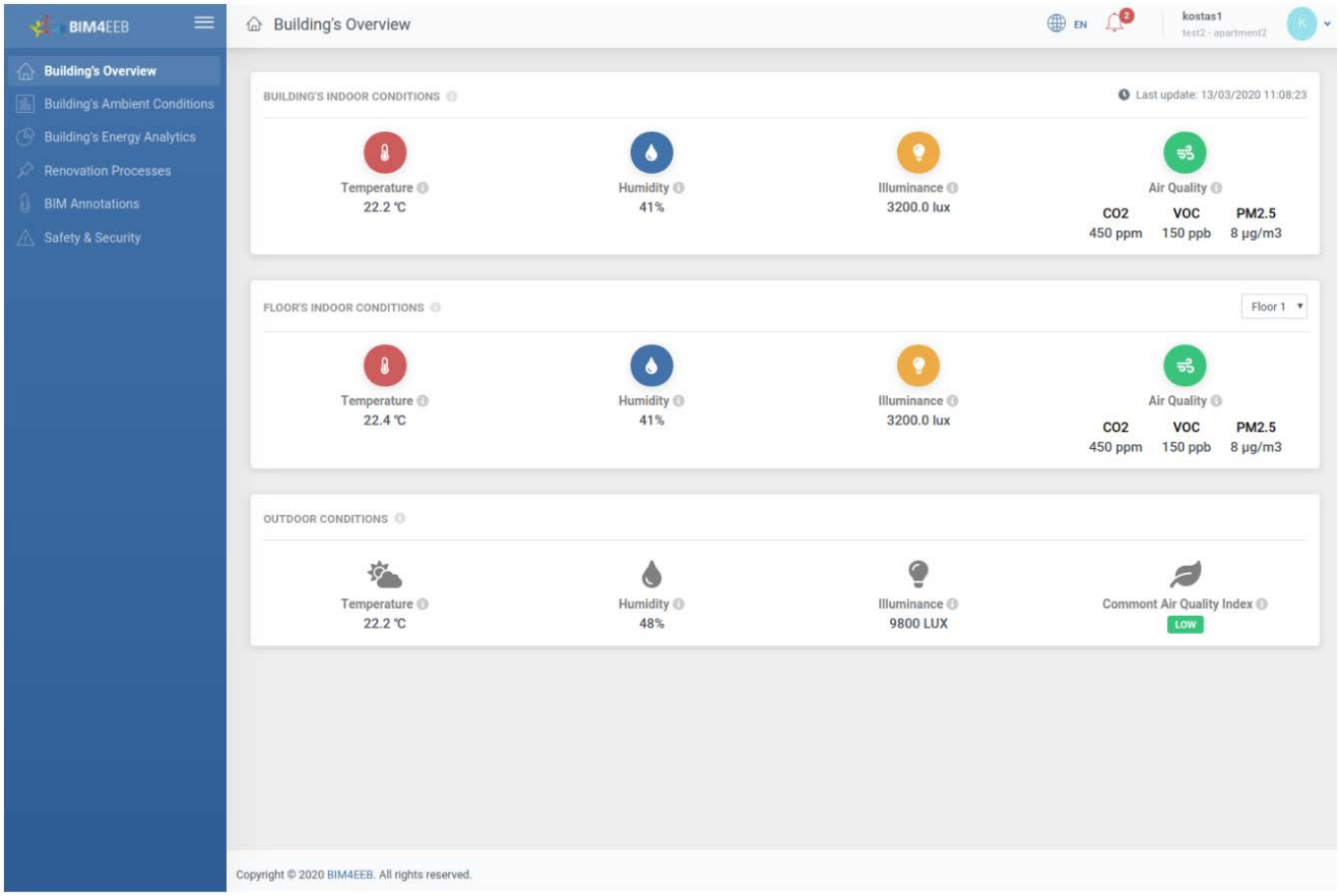

Figure 17 Owners' View - Building's Overview

- **Building's Ambient Conditions**

Through this functionality and associated screen, building owners have access to historical information regarding the ambient conditions in their building. By selecting an appropriate time period, owners can visualise their buildings' temperature, humidity, illuminance and IAQ profile.

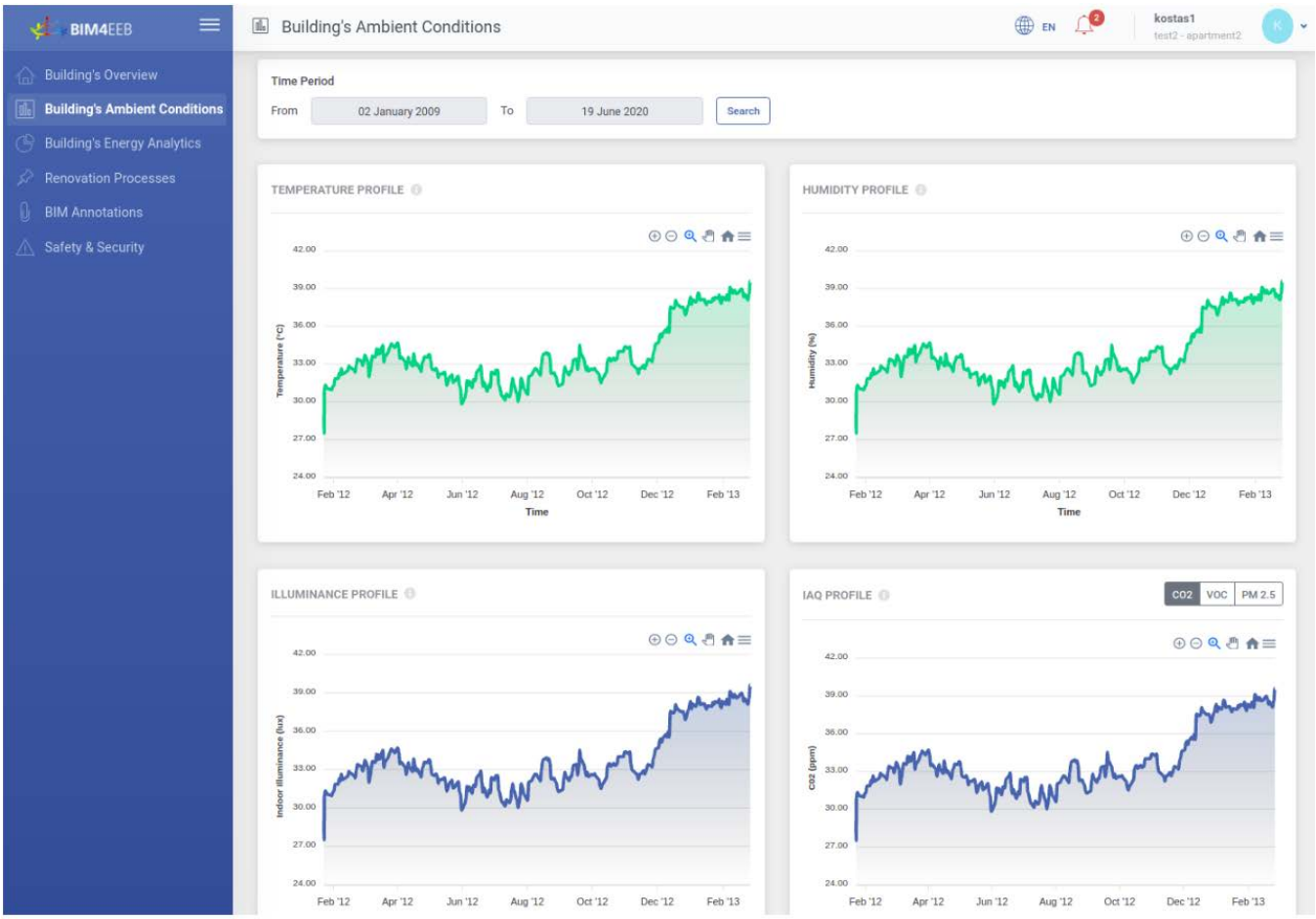

Figure 18 Owners' view - Building's Ambient Conditions

- **Building's Energy Analytics**
  Similar to the approach followed in the previous functionality, building owners will be able to visualize aggregated information regarding the energy consumption of their building. Historical information is also available by selecting an appropriate time period.

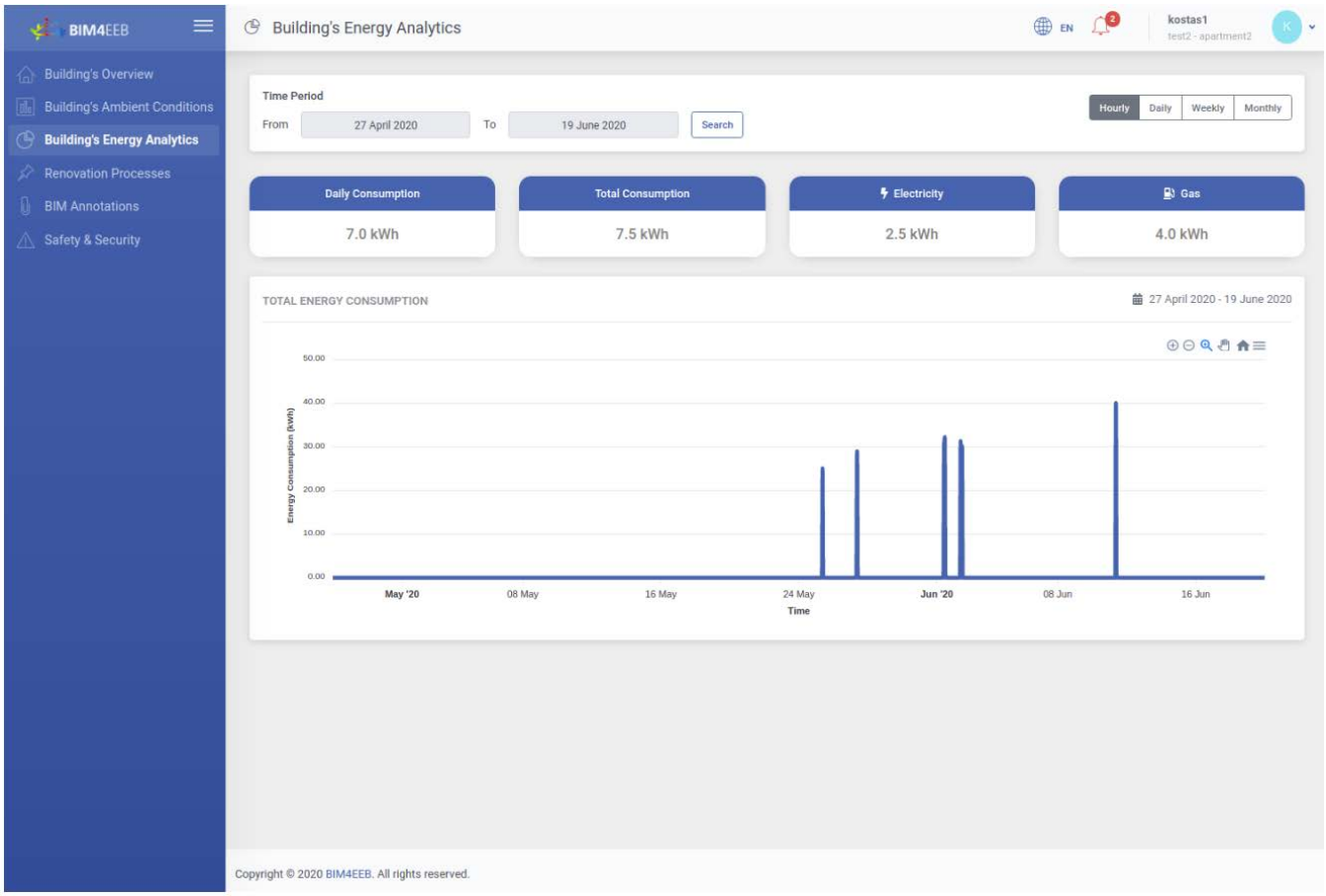

Figure 19 Owners View **-** Building's Energy Analytics (Hourly view)

- **User Profile (Owner)**

Through this screen owners can provide profile information (such as gender and age group), as well as update their password. No need for user profiling settings as the comfort profiling engine is not available for this business role.

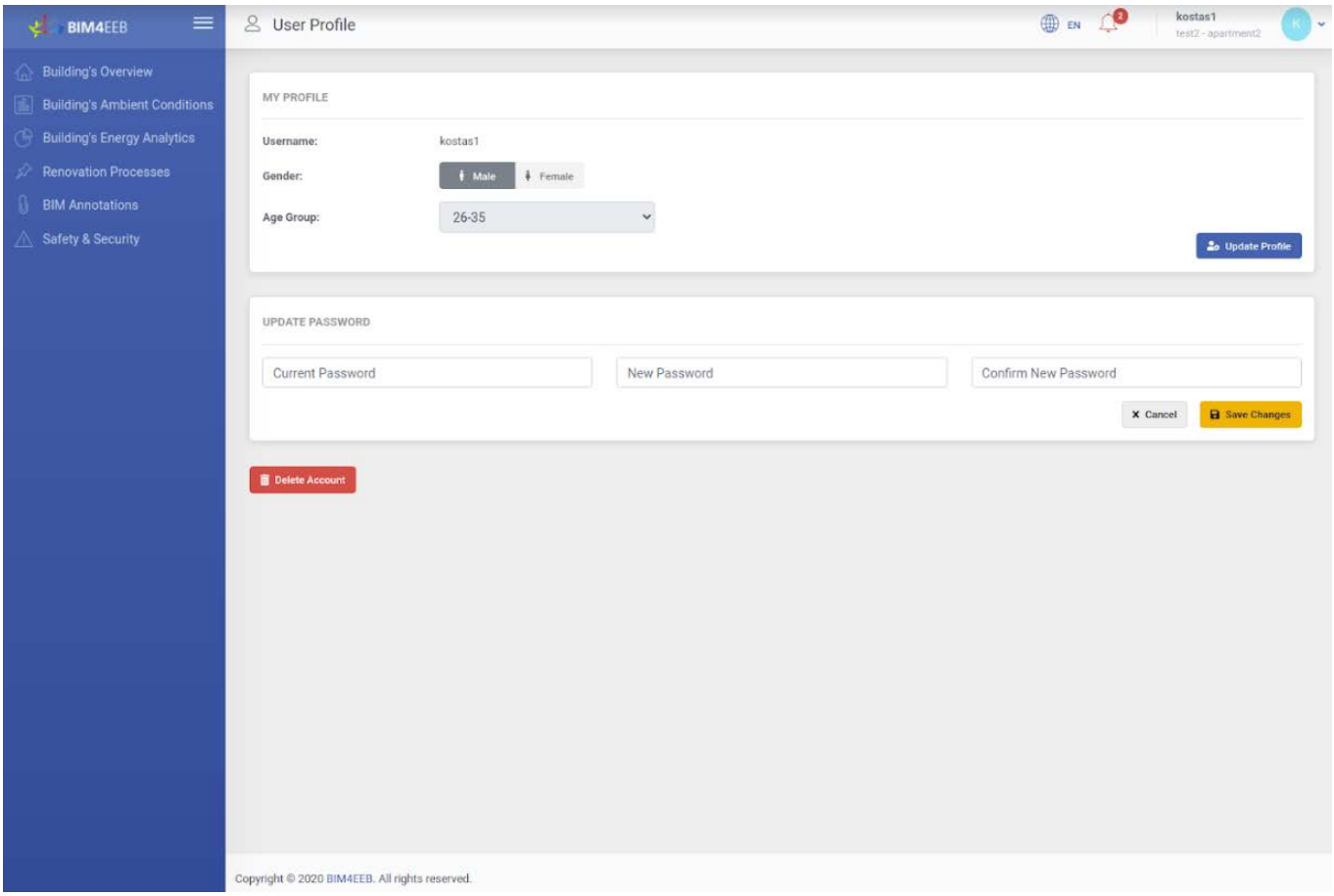

Figure 20 Owners View – User Profile

- **User Assets (Owner)**

Finally, as in the case of inhabitants, building owners can visualise static information regarding their assets. The information level is classified, enabling access on specific level of information which is accessible by the building owner.

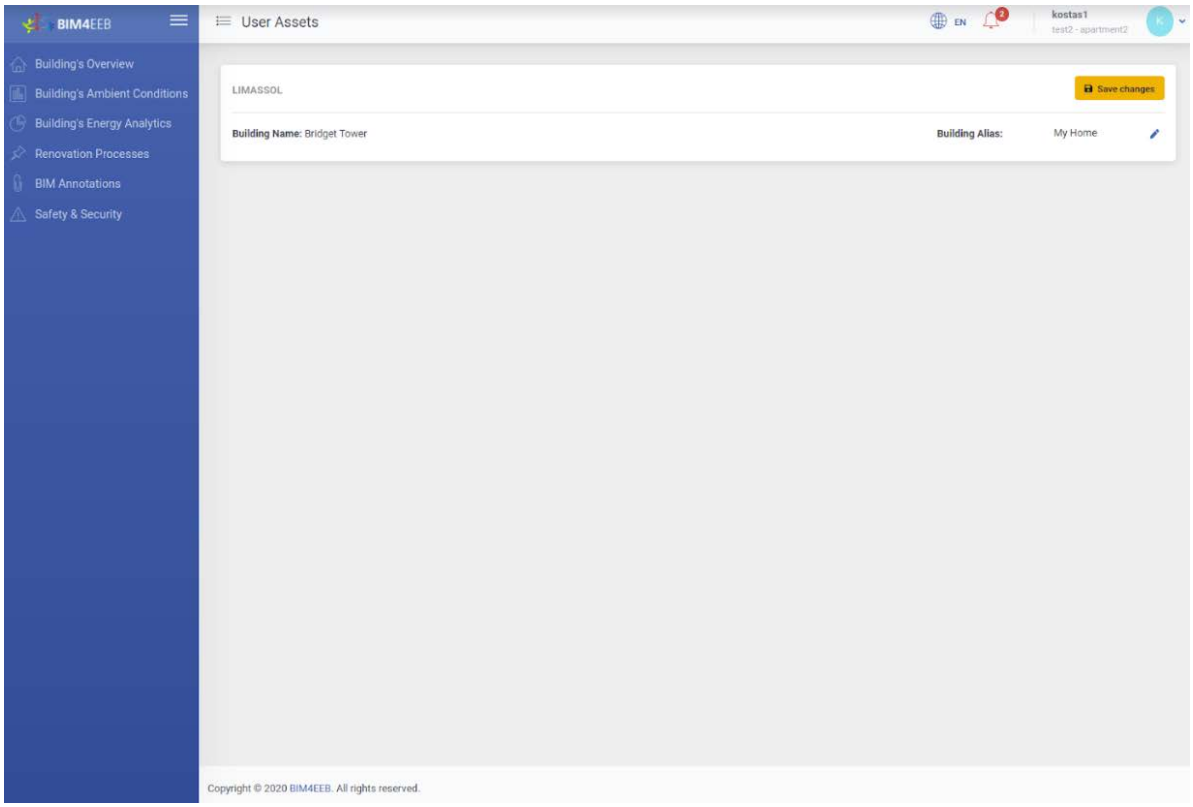

Figure 21 Owners View – User Assets

This is the final version of the Ambient User Interface app, reflecting the different functionalities as defined in the project. The next step of the work is the configuration of the app and further demonstration at the different demo sites. Following the feedback from the demo partners, minor updates may apply to reflect the specificities during the demonstration period.

5 Conclusions

The present deliverable (D6.8) constitutes part of the activities performed in Task 6.7 towards the definition of the Ambient User Interface application intended for the building occupants (i.e. owners and inhabitants). As the supported functionalities are delivered through the BIM4Occupants application (incorporating also additional functionalities defined in D7.2), we summarize in this section the conclusions by reporting the main results from the design process undertaken only for the Ambient User Interface Application.

As explicitly stated in the DoA, the Ambient User Interfaces application for the building occupants complements the Occupants' Profiling Mechanism to enable interaction with and input provision by building occupants through a variety of devices, aiming at the extraction of accurate context-aware occupant behaviour and comfort profiles. Hence, the scope of this application is to enable occupants to visualise in a personalised way both near real-time and historical comfort related information; while on the same time enabling building inhabitants to provide their input in respect to their comfort state against the set values of temperature and illuminance in their premises.

In line with the main objective as presented above, the work undertaken during the reporting period focused both at the design and the definition of the specifications for the Ambient User Interface application. More specifically, as a first step we presented the analysis of the requirements and usage scenarios, as identified in deliverable D2.5 during the activities performed in WP2, from which we extracted the different functionalities to be supported by the application. In addition, the modelling principles as defined in WP3 were also considered in the analysis towards setting the basis for the design of the application. On top of the initial project requirements, the definition of the software architecture was performed and the mock ups for the app were co designed during the task period, drilling into the design details and principles of the Ambient User Interface application.

Following, the main step of the work consisted of the development of the application for the building occupants (owners and inhabitants). The application comprises of the front-end and the back-end system. The front-end is the visualization and occupant interaction layer, in order to deliver the foreseen functionality based on the key functionalities defined for the app. The back end consists of the model that incorporates the functional implementation of the application. More specifically:

- The data management layer has been defined and designed as a collaborative work with BIMMS specifications definition to ensure that any information exchange required for the app is well served by the BIMMS.
- The analytics layer of the application incorporates the sample analytics to support the engagement of the occupants and ensure their active participation in the project. In addition, fine grained analytics techniques as presented in D6.7 are further incorporated in the app (main focus on comfort profiling engine) to serve the functionalities of the Ambient User Interface application.
- The visualization layer is provided as an intuitive and user-friendly UI. The overall design was performed in tight co-operation with the demo partners.

In respect to the technical implementation, the development has been delivered in mature and standardized frameworks (Python based implementation with state of the art JS visualizations that support the easy scalability and the expandability of the main functionalities), while the deployment as a container app is in line with the requirement for a plug and play and fast deployment in different working environments. Out of the list of functional requirements, several key requirements related to privacy and security concerns were also considered at the development of the application, also considering the focus of the project to address any ethics concerns.

The next step of the work is the configuration of the app and further demonstration at the different demo sites. As part of this action, the localisation to the native language of the demo partner will be ensured. Following the feedback from the demo partners, minor updates may apply to reflect the specificities during the demonstration period.

Appendix

[1]. BIM4EEB (2018) Description of Action

[2]. BIM4EEB (2019) D2.5: List of owners' and inhabitants' needs and requirements for BIM-based renovation processes

[3]. BIM4EEB (2019) D3.6: Integrated Linked Data Modelling and Sharing framework

[4]. BIM4EEB (2020) D6.7: Report on BIM4EEB Occupants' Profiling Mechanism

[5]. BIM4EEB (2020) D7.2: Web based responsive user-interfaces

Annex I – Data Model and APIs

In this section, the current version of the data model is presented along with the list of APIs, exposed by the BIMMS platform to ensure data acquisition.


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  "uniqueID": "UUID",
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      "note": "string",
      "building Name": "string",
      "description": "string",
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         "value": "float",
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       "thermal": "integer",
       "visual": "integer"
      }
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   "maxBoundTemp": "float",
   "preferedTemp": "float",
   "modelParameters": {
    "attr1": "float",
    "attr2": "float"
   }
  },
  "visual": {
   "minBoundLux": "float",
   "maxBoundLux": "float",
   "preferedLux": "float",
   "modelParameters": {
    "attr1": "float",
    "attr2": "float"
   }
  }
 }
],
"spaceLevel": [
 {
  "spaceID": "UUID",
  "spaceName": "string",
  "parentGlobalId": "UUID",
  "BIM_sensor": [
   {
    "sensorType": "string",
    "sensorModel": "string",
    "sensorID": "string",
```

```
        "annotationEntity": "string",
        "measurement": [
         {
          "timestamp": "DateTime",
          "value": "float",
          "type": "string",
          "unit": "string"
         }
        ]
       }
      ]
     }
    ]
   }
  }
 ]
}
]
```


The list of methods supported for data integration are presented:

1. GET /user/getUserToken: Get the access token for the given user
2. GET /user/getUserProjects: Get the projects for the given user token
3. GET /user/getUserRoles: Get the roles for the given project and user token
4. GET /project/getProjectIFC: Get the IFC files for the given project and user token
5. GET /ifc/getIFCHierarchy: Get the IFC hierarchy for the given file name, project, and user token
6. GET /ifc/getIFCZones: Get the IFC zones for the given file name, project, and user token
7. GET /sensor/getSensorsFromLocation: Get the sensors for the given location, project, and user token
8. GET /sensor/getSensorData: Get the data for the given sensor, project, and user token

Methods 1-7 are considered for data retrieval for the project hierarchy. The last method is providing access on sensorial data in a periodical (high frequency) manner. The detailed documentation of the methods supported by BIMMS is reported in D4.7 API, Master end user front end as part of the work in T4.5 Development of a dedicated set of applications using the APIs of major BIM and GIS authoring platforms to manage the CDE

Annex II – Initial Evaluation of the BIMMS Linked Data Framework

As stated above, the scope of this section is to provide the early evaluation of the BIMMS Linked Data Framework as specified in WP3 and more specifically in the T3.6 Harmonisation of ontologies to address the requirements of the renovation domain and semantic mapping/ coupling with external data sources and models and T3.7 Definition of harmonised common data exchange formats and integration of open-BIM data standards for sharing information.

The focus of this preliminary evaluation is at the business context of the application developed in this task (related to occupant behaviour analysis and ambient conditions monitoring) and limited to the stage of the project. As the demonstration activities have not started yet, some datasets have been generated in order to fill in the available RDF structures to be considered in the project. The RDF generation was a collaborative work among TUD (delivering the RDF structure following structure defined through the harmonization of the different ontologies defined in the project into the BIM4EEB ontology) and SUITE5 (providing the demo data and the explanation about the different links as defined in the occupants' behaviour ontology)

The test dataset has been then uploaded to BIMMS platform (and more specifically in the BIMMS linked data schema) made further accessible to the external actors and 3rd party companies for experimentation.

Towards the initial evaluation of this RDF structure available in the BIMMS platform, the proper SPARQL queries were conducted (from TUD) in accordance with the list of competency questions (as defined in WP3) expressing the business needs of 3rd party actors.

The overall flow for the work performed towards the evaluation of the RDF schemas as stored in BIMMS is depicted in the following figure

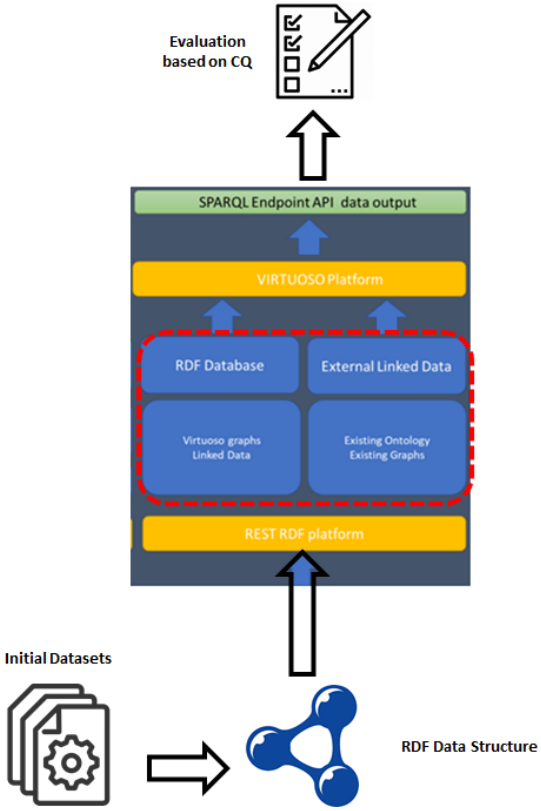

Figure 22 Approach for initial evaluation of BIM4EEB Linked Data Framework

As it can be easily viewed, at the heart of the system we have the BIMMS platform (as reported in D4.3) which handled data inputs, performs the respective validations and transformations, and make the results accessible to 3rd party applications for further utilization.

The input RDF/TTL is available via (https://bit.ly/3dzt0IE) with a screenshot of the model to be available in the following figure:

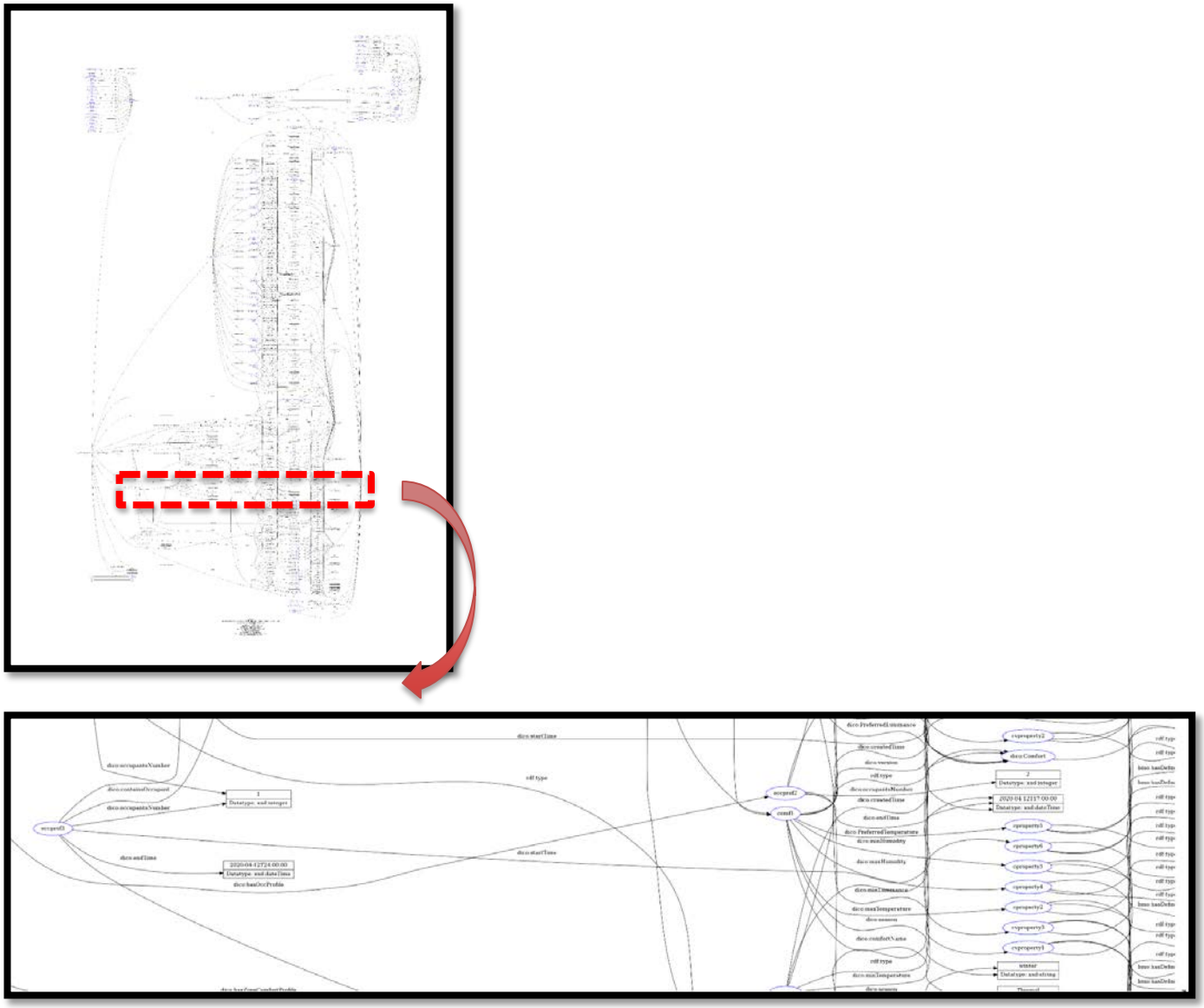

Figure 23 RDF paradigm for initial evaluation of BIM4EEB Linked Data Framework

As a starting point for the RDF model, is a single building zone (e.g. office/apartment zone) where different occupancy and behavioural related parameters are incorporated.

The appropriate SPARQL series were conducted following the early definition of CQs in WP3 in order to retrieve information that is further useful for the business application as presented in this document.

Starting the analysis with occupancy related information in the building environment.

1. What is the number of occupants/personas in the building zone?

```
SELECT ?Occ
WHERE
{
   ?Occ rdf:type dico:Occupant.
}
```

2. What are the characteristics (age) of the occupants?

```
SELECT ?Occ ?age
WHERE
{
   ?Occ rdf:type dico:Occupant.
   ?Occ dico:age?age.
}
```

3. What are the activities performed by the occupants in the building zone?

```
SELECT ?Occ ?Activity
WHERE
{
   ?Occ rdf:type dico:Occupant.
   ?Occ dice:hasActivity ?Activity.
}
```

4. What are the occupancy schedules performed by the occupants in the building zone?

```
SELECT  ?OccProfile ?Occ ?st ?et
WHERE
{
   ?OccProfile dico:containsOccupant ?Occ.
   ?OccProfile dico:startTime ?st.
   ?OccProfile dico:endTime ?et.
}
```

The outcome of this analysis is the extraction of the information about the occupants in place, the activities performed but mainly the occupancy schedules that reflect the level of occupancy in each specific zone.

Along with the occupancy related information, behavioural related information is extracted from the RDF test example.

5. What are the behavioural profiles for the occupants in the building zone?

```
SELECT ?Occ ?OccupantBehaviour
WHERE
{
   ?Occ rdf:type dico:Occupant.
   ?Occ dico:hasBehaviour?OccupantBehaviour.
}
```

6. What is the comfort related characteristics for each behavioural profile?

```
SELECT ?Beh ?Comfort
WHERE
{
   ?Beh rdf:type dico:OccupantBehaviour.
   ?Beh dico:hasComfort?Comfort.
}
```

By defining the list of comfort profiles for each user, we should extract the model parameters for each comfort profile.

7. What are the indoor environmental (temperature, humidity) conditions in a building space or zone?

```
SELECT ?zone ?comfortProf ?TandHValue
WHERE
{
   ?zone dico:hasZoneComfortProfile ?comfortProf.
   ?comfortProf dico:comfortName ?na.
   {?comfortProf dico:minTemperature ?p} UNION {?comfortProf dico:maxTemperature ?p} UNION {?comfortProf dico:PreferredTemperature ?p} UNION {?comfortProf dico:minHumidity ?p} UNION {?comfortProf dico:maxHumidity ?p}
   ?p bmo:hasDefinedValue ?TandHValue.
```

```
    FILTER regex (?na, "Thermal", "i")
}
```

The outcome of the request is the comfort boundaries for thermal comfort for a specific user at the specific building zone.

8. What are the indoor environmental (luminance) conditions in a building space or zone?

```
SELECT ?zone ?comfortProf ?LuminValue
WHERE
{
    ?zone dico:hasZoneComfortProfile ?comfortProf.
    ?comfortProf dico:comfortName ?na.
    {?comfortProf dico:minLuminance ?p} UNION {?comfortProf dico:maxLuminance ?p} UNION {?comfortProf dico:PreferredLuminance ?p}
    ?p bmo:hasDefinedValue ?LuminValue.

    FILTER regex (?na, "Visual", "i")
}
```

The outcome of the request is the comfort boundaries for visual comfort for a specific user at the specific building zone.

In addition to the context related parameters, device related parameters should be retrieved from the RDF structure. The focus is on modeling the HVAC and light devices as directly linked with the thermal and visual comfort analysis as presented above. Therefore, the associate comfort related device types should be extracted from the available dataset.

9. Which is the HVAC system in building zone?

```
SELECT ?sys
WHERE
{
    ?sys rdf:type ssn:System.
    ?sys dico:systemType ?stype.
    FILTER regex (?stype, "HVAC", "i")

}
```

10. Which is the lighting system in building zone?

```
SELECT ?sys
WHERE
```

```
{
   ?sys rdf:type ssn:System.
   ?sys dico:systemType ?stype.
   FILTER regex (?stype, " Lighting ", "i")

}
```

In addition, linkage of the different device types to the activities taking place in building zone are defined.

11. Which are the device systems used in the activities of the building zone?

```
SELECT ?Act ?System
WHERE
{
   ?Act rdf:type dice:Activity.
   ?Act dico:hasArtefact ?System.
}
```

A non-exhaustive list of SPARQL queries was defined in order to initially test the integration with the BIMMS platform. The aforementioned analysis stands as the basis for the extraction of the skeleton parameters required for occupancy and behavioural profiling as defined in the BIM4EEB project. Additional parameters associated with the building structure (e.g. buildings, spaces, zones etc…) can be also retrieved from the IFC model; the evaluation of this integration is out of the scope of this document.

As stated above, this is the initial evaluation of the BIMMS platform. As the project evolves (with the configuration of the system to the different demo sites and data retrieval from sensors installed in demo premises), the model will be enhanced and additional query requests will be made available. The documentation of this detailed evaluation of the BIMMS Linked Data Framework will be performed as part of the work in T 4.6 Testing and validation (D4.9- M24 but mainly in D4.10- M36 where the focus is at testing the different services of the BIMMS platform at the demo sites considering also the demonstration actions to take place in WP8 – as agreed among partners the final evaluation of the BIMMS linked data framework will be reported in D8.5 : Report about the validation results by relevant stakeholders).