FULLY INTEGRATED DASHBOARD FOR CLUSTER NODE AND HUMAN-BUILDING INTERFACE FOR THE EDGE NODE (FIRST VERSION)

Project acronym: COLLECTiEF

Project title: Collective Intelligence for Energy Flexibility

Call: H2020-LC-SC3-EE-2020-2

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Executive Summary

This report consists of the first version of Deliverable (D) 3.8, Fully Integrated Dashboard for Cluster Node and Human-Building Interface for the Edge Node that is a part of Work Package (WP) 3.

The first chapter presents the introduction and status of the Human-Building Interface. The second chapter presents the architecture of the Human-Building Interface including, different functions and data interpreted in the Human-Building interface, including the user login/logout function, a Dashboard, a Scheduling tab, Sensor info tab and Send feedback tab. Each of these features serves a different objective. Finally, the third chapter gives an overview of further development of the Human-Building Interface as future developments.

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List of Acronyms

API	Application Programming Interface
BRiG	Boarder Router Intelligent Gateway
D	Deliverable
KPI	Key Performance Indicator
MQTT	Message Queuing Telemetry Transport
POE	Post Occupancy Evaluation
Partner	The beneficiary in the COLLECTiEF Project
SRI	Smart Readiness Indicator
WP	Work Package

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1. Introduction

1.1. Description of the Task (T3.4 Development of the COLLECTiEF user interfaces)

From the Grant agreement:

"In this task a user-friendly Human-Building interface will be developed by adapting and expanding the functionalities of the existing G2Elab app to (1) provide indication of the state of indoor environmental control devices, (2) inform occupant about the quality of the indoor environment, (3) suggest optimization strategies for optimal control of the environment and energy conservation, (4) notify alarm conditions, show historical data and compare current operation modes (e.g. setpoint temperature, lighting state) with the other users' current behaviour in the building, (5) collect users' feedback, override automatic controls to take manual control, and (6) provide cumulated reports on the indoor environmental quality and consumption trade-off over a given time period. The user-friendly Human-Building interface is incorporated into the IoT Operating System. Furthermore, Fully Integrated Dashboard will be developed to support interactive data management providing digital indicators, gauges, and diagrams to visualize information/knowledge. Virtual will collect requirements for the user-friendly Human-Building interface and enhance/adapt designed digital dashboards toward requirements of the Human-Building user interfaces. CyI will develop the concept of a user-friendly Human-Building interface integrated into the IoT Operating System. The current app for occupant information in the Green'ER small scale pilot can be used as a platform for inspiring the development of the user-friendly Human-Building interface (partner CSTB). The app will be presented by the third party G2Elab. CETMA will provide experience in the development of software platforms (performance evaluation dashboards) for sharing information, where the principles of usability and scalability of the system are respected. NTNU will provide further data on occupant behaviour in the educational buildings collected by sensors currently installed at NTNU campus."

1.2. Scope and Purpose

The scope of the Deliverable (D) 3.8 is to present the fully Integrated Dashboard for Cluster Node and Human-Building Interface for the Edge Node. As mentioned in the description of the Task 3.4, the Human-Building Interface will give a number of monitoring and control functionalities to the COLLECTiEF's users. The interfaces will be adjusted according to the category of user i.e., Edge Node user and Cluster Node user. Table 1 shows the user categories of the fully Integrated Dashboard for Cluster Node and Human-Building Interface for the Edge Node. As a starting point, it's given emphasis on the development of the Edge Node user profile in which the following functionalities are activated: Table 1

- Fetching and visualising data from the BRiG about weather, indoor environment, energy use, state of the systems,

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- Visualising selected Key Performance Indicators (KPIs) as identified and listed in D5.1, such as:
    - indoor environmental quality, which corresponds to thermal comfort, indoor air quality, visual and acoustic comfort
    - energy performance and cost
    - Smart Readiness Indicator (SRI)
- Creating and providing notifications for the user related to monitored data or calculated KPIs.
- Providing predictions on the KPIs
- Scheduling of building's operations based on the following COLLECTiEF system operation modes;
    - **COLLECTiEF** mode, which implements all the COLLECTiEF objective functions in a balanced and predefined manner
    - **Comfort** mode, which maximises indoor environmental conditions
    - **Economy** mode, which maximises cost savings
    - **Energy flexibility** mode, which gives priority to meet the requests for flexibility from the Cluster Node
    - **Climate resilience** mode, which gives priority to meet the requests for climate resilience from the Cluster Node.
    - **Manual** mode, which deactivates the COLLECTiEF system, and gives the option to the user to define set points and schedules
- Visualising analytics on the performance of the COLLECTiEF system based on selected Key Performance Indicators (KPIs) as identified and listed in D5.1
- Visualising analytics about user's feedback provided by the Post-Occupancy Evaluation (POE) questionnaires in relation to indoor environmental data.

Table 1 User categories of the COLLECTiEF's fully integrated Dashboard and Human-Building Interface

User categories										
Edge Node Users					Cluster Node Users					
Occupant	Building Owner		Building Manager		Property Manager		Property Owner		DSO
	Consumer	Prosumer	Consumer	Prosumer	Consumer	Prosumer	Consumer	Prosumer	

It is worth mentioning that the current version of the Human-Building interface runs on a Linux webserver, since the Boarder Router Intelligent Gateway (BRiG) is currently under development. In order to avoid any compatibility issues between hardware and software components, the work carried

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out on the development of the interface has been done considering BRiG's hardware specifications and restrictions. Once the hardware solution is set and ready for a beta version, the developed Human-Building Interface will be transferred to and implemented on the BRiG.

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2. Architecture of the Human-Building Interface Application

2.1. Overview

The front-end of the Human-Building Interface is built based on the JavaScript framework React. React is the most popular and most actively maintained web framework for creating dynamic webapps. The framework allows a certain part of the webpage to be updated without the need for the whole webpage to be updated. The user login step of the Human-Building Interface provides the user access to the interface. It takes the user to the dashboard view. The dashboard view provides some information on the sensors used to monitor and control the conditions of the indoor environment such as: air temperature, relative humidity, and pressure. The dashboard view gives visual representations of the analysed sensor data. Also, the sensor battery percentage will be shown to the users. An indoor building layout view indicates in space where the environmental data and provides analytics about the quality of the indoor environment. Graphical representation of energy consumption, thermal comfort parameters, cost savings, and energy prices visualize information in an interactive manner to share knowledge with users compatibly with access rules specified in the COLLECTiEF Data Management Plan (D1.3 Data Management Plan), while acting as digital indicators of collected sensor data. Moreover, historical data of measured parameters such as air temperature can be visualized over a period of time for the user to observe. The scheduling tab provides an interface to the users for optimizing the controlling the operation of the COLLECTiEF system to improve the building performance with respect to energy consumption and environmental requirements. The sensor info tab will accommodate a table that enables to represent sensor serial information, name of the sensor measurements, sensor measurement values, kind of sensor measurement, type of sensors, information retrieval channel, and the date of information retrieval. The feedback option available in the user interface enables the user to share feedback on things that could be further improved in the app. The Logout option of the application easily allows to user to logout when they no longer need to interact with the application. The successive categories will take a closer look at different components of the user interface.

The data collection, in this stage, focuses on the monitored indoor environmental data collected and provided by the Sphensor multi-sensory units. The collection of data is done over MQTT (Message Queuing Telemetry Transport) that is the planned collective communication protocol for the COLLECTiEF Edge Node. MQTT protocol was chosen as it is a reliable and scalable broker that allows efficient message delivery, in both directions between clients and servers, that makes it ideal and suitable for the COLLECTiEF application. The MQTT server was set up in the first week of June 2022. The data is streamed from the MQTT broker and transferred to a lightweight database currently hosted locally on a private service managed by Virtual. The database selected for the data collection of sensor data is SQLite, which is a very lightweight database that is not dependent on an exclusive database server as MySQL or MongoDB. To easily adopt the database for a more constrained device and to easily adopt to unforeseen performance restrictions, the data collection script, developed by LASTEM, has been developed in such a way that it is highly customisable from a configuration file. From the configuration file, there is the possibility to set a limitation for the maximum allowed Database Size, so that the database does not fill up and run out of all its storage over time. It is possible to set the maximum allowed records to be saved in the database, hence, once this limit has been reached, new records will be added in exchange for the oldest records on the principle of first in first out. The data collection script, developed by LASTEM, also allows filtering the data to be saved in the database based on MQTT protocols. Note that data collection script is a temporary solution that will be replaced by the COLLECTiEF's Application Programming Interface (API). COLLECTIEF's API is currently under development by CETMA.

2.2. Human-Building Interface

Once the user is logged into the Human-Building interface through the login page, the interface consists of the following options:

- User Login/Logout
- Dashboard
- Scheduling
- Sensor info
- Send feedback

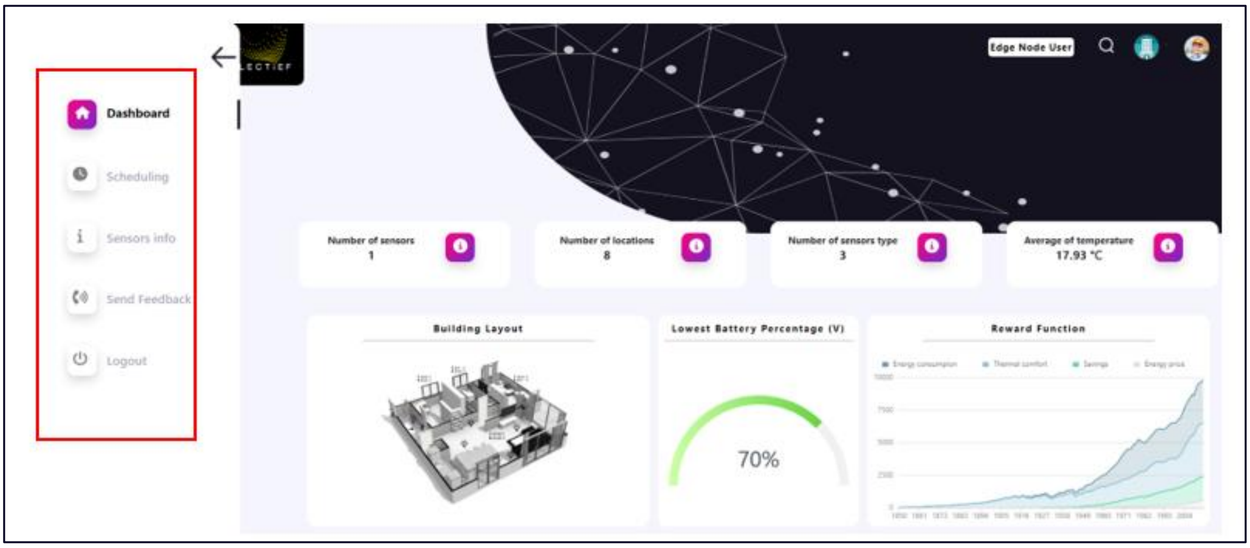

Figure 1 Available options in the Human-Building Interface

Figure 1 depicts the available options in the Human-Building interface (indicated with a red box). This menu could also be collapsed if the user prefers to only navigate using menu icons.

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2.2.1. The User Login/Logout Page

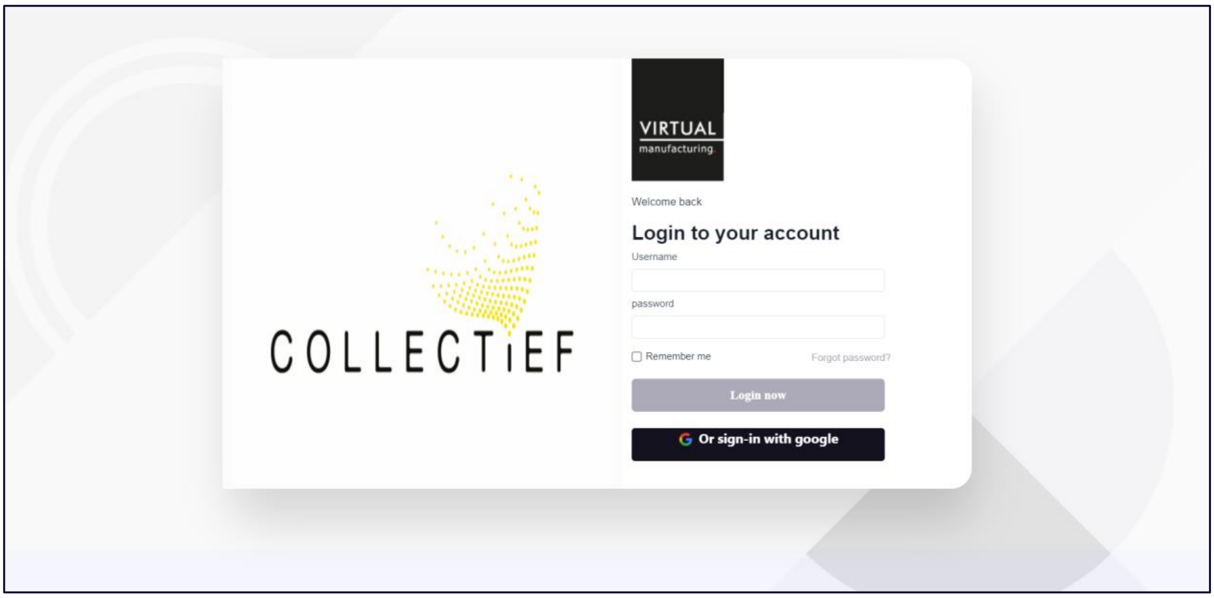

Figure 2 User login page

The first thing the user will see when navigating to the web app is a log in screen. This log in screen will enable the system to connect a user to a certain access level as well as storage for the customization done to the web application. The user login page (see Figure 2) enables the user to access the Human-Building Interface. By entering a username and password.

Figure 3 User login page upon entering login credentials

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As per Figure 3, upon entering the username and password the user can successfully login to the Human-Building Interface (indicated with a red box).

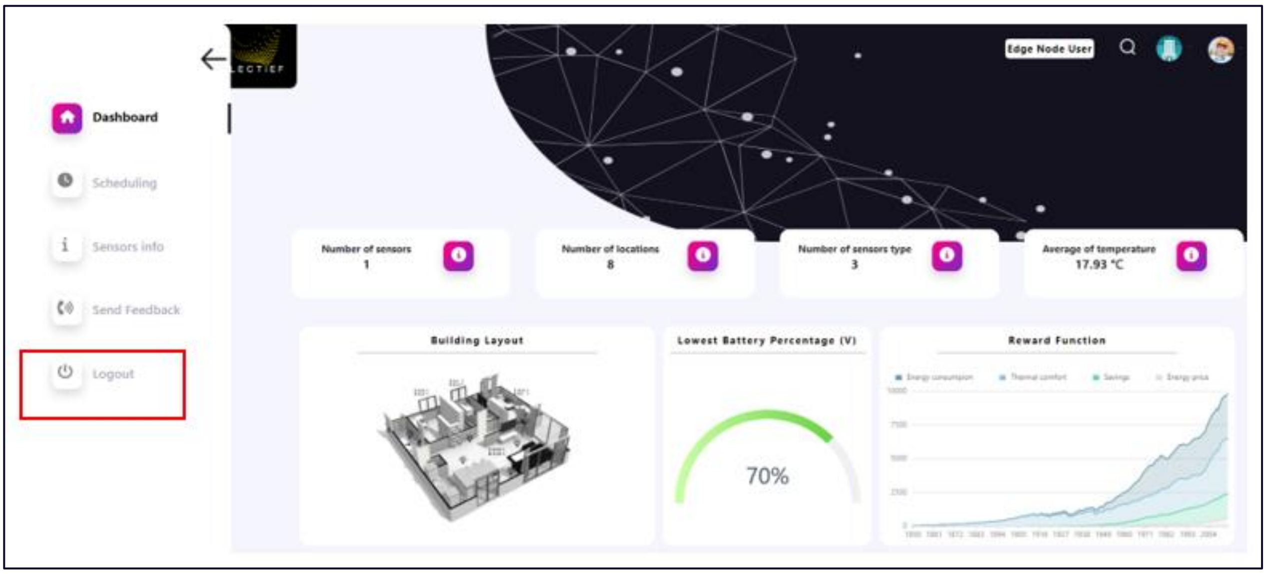

Figure 4 The logout tab

The logout tab (see Figure 4) allows the user to easily logout from the app, after using it and referring to the required information. Figure 5 depicts the currently implemented structure of the Human-Building Interface.

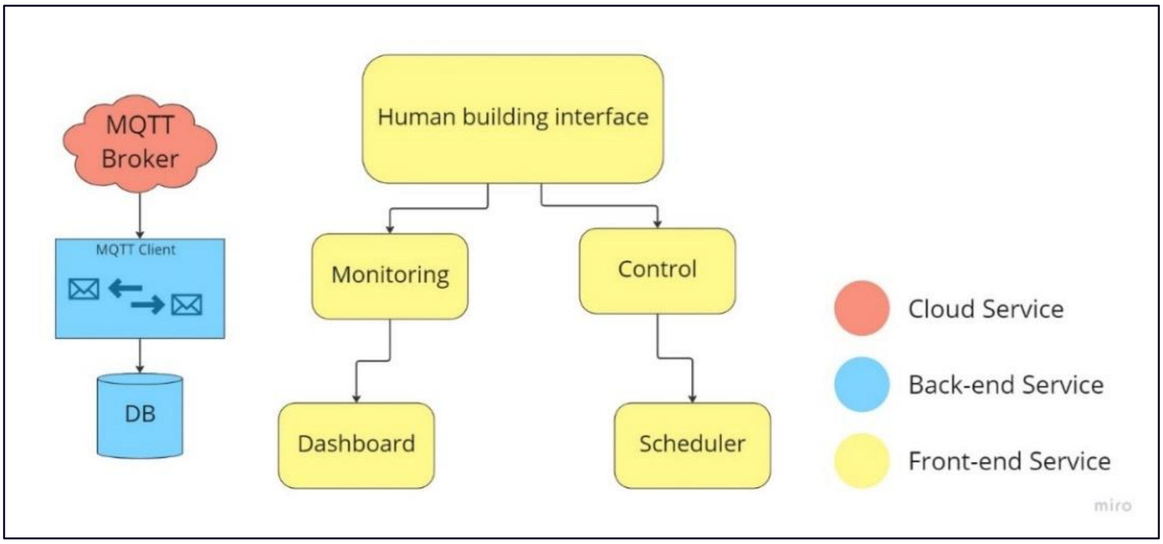

Figure 5 Structure of the Human-Building Interface

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2.2.2. The Dashboard Tab

The data is collected from the SQLite database, where it has been saved by the script as mentioned previously. The dashboard is able to constantly get the latest data points as well as query a series of data to be visualized in a time-series chart for parameters such as, air temperature, relative humidity, pressure or any available parameter of the user's choice. The dashboard consists of several "cards", where each card is holding some information that is displayed to the user. The idea behind this setup is to allow the solution to be very flexible and easy to manage. Our current design allows the development of customized and modified cards by the user, depending on their accessibility criteria.

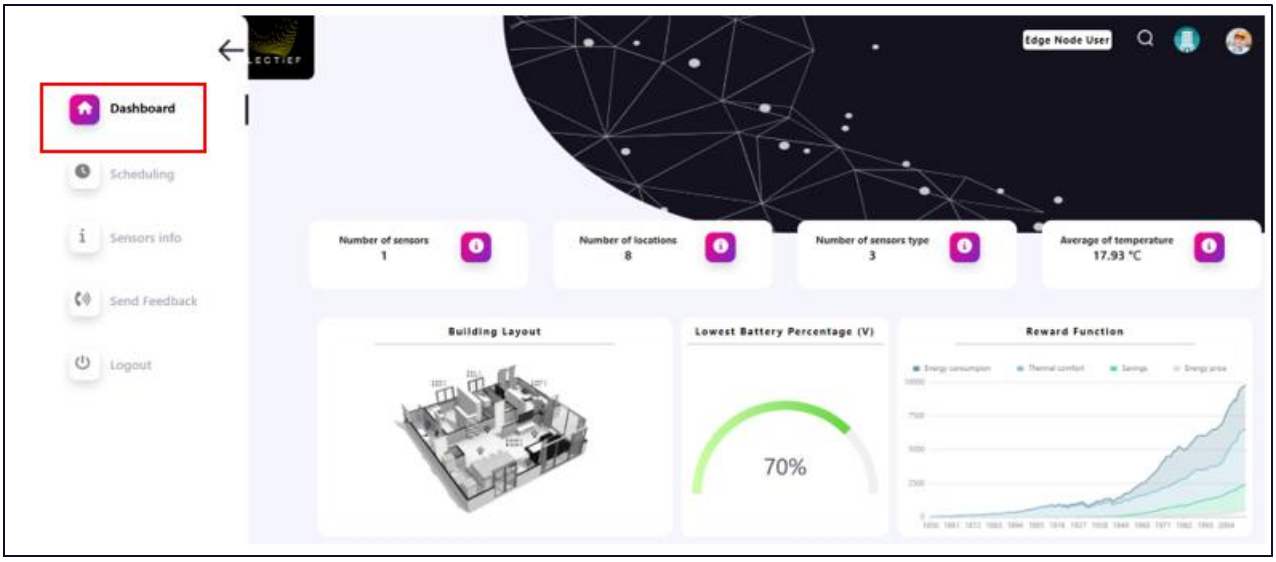

Figure 6 The dashboard tab

The dashboard tab (see Figure 6) is an interactive space where graphical representations of environmental conditions and digital indicators of analyzed data is available, along with information on indoor environmental condition monitoring sensors.

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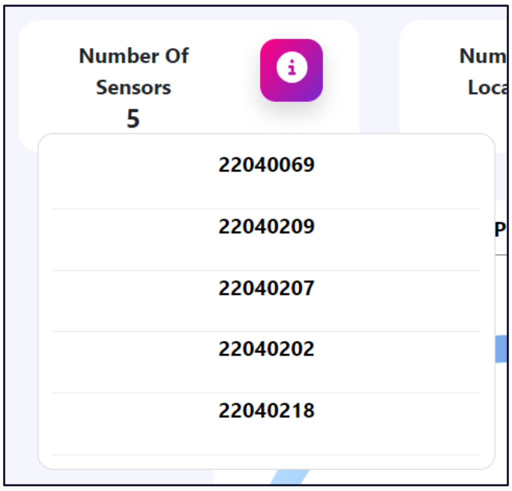

Figure 7 Number of sensors

As represented in Figure 7, information on the number of sensors available in indoor environment control devices are available as a visual representation for user reference. The sensor data are currently obtained from pilot plant laboratories.

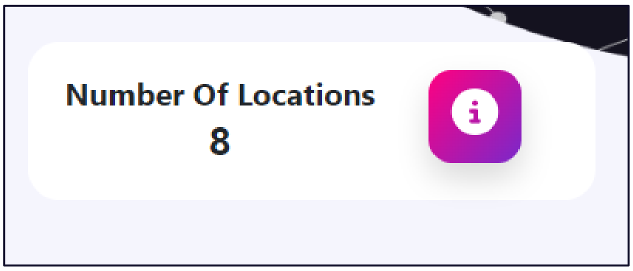

Figure 8 Number of sensor locations

As represented in Figure 8, information on the number of sensor locations available for indoor environment control devices is available as a visual representation for user reference. The sensor data are currently obtained from pilot plant laboratories.

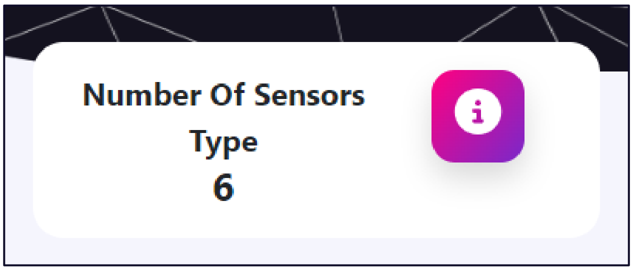

Figure 9 Number of sensor types

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As represented in Figure 9, information on the number of sensors types available as indoor environment control devices is available as a visual representation for user reference. The sensor data are currently obtained from pilot plant laboratories.

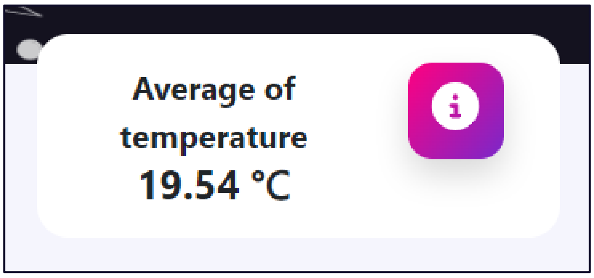

Figure 10 Average of air temperature

As represented in Figure 10, information on the average air temperature recorded from the sensors of available indoor environment control devices is available as a visual representation for user reference. The sensor data are currently obtained from pilot plant laboratories.

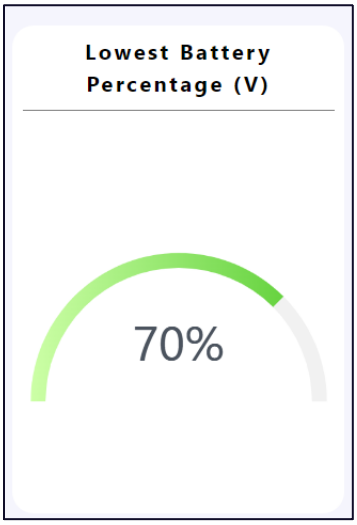

Figure 11 Battery percentage of sensors

Figure 11 depicts the visual representation of the battery percentage of sensors available in indoor environment control devices. This acts as a digital indicator that visualizes sensor information useful to the user.

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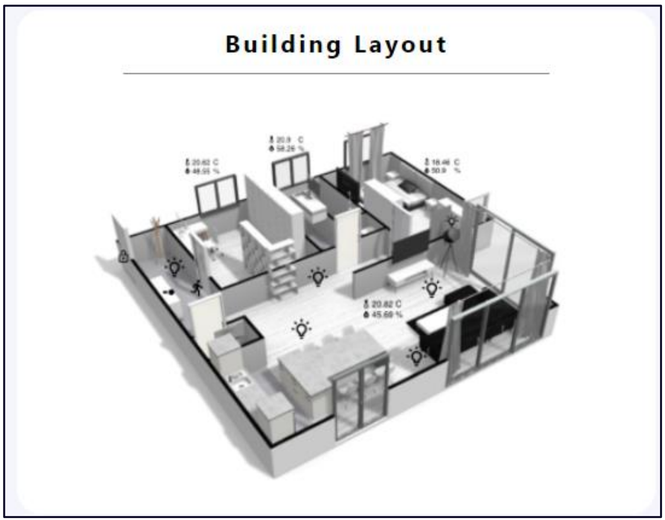

Figure 12 Environmental conditions of the indoor building layout

As depicted in Figure 12, the digital indicator that represents the quality of environmental conditions include useful information such a temperature, relative humidity etc. obtained from the sensors of the environment control devices of different parts of the indoor building layout.

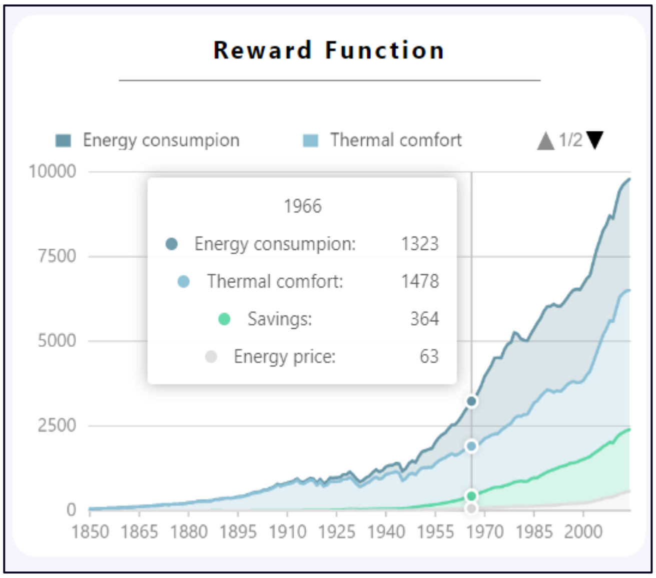

Figure 13 Graphical representation of the reward function

The graphical representation of the energy consumption, thermal comfort, savings, and energy price (see Figure 13), provides a visual representation of useful information to the user, which has been derived from the data analysis of retrieved sensor records. The data for this graphical representation will be obtained through a reward function formula.

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Figure 14 Different forms of graphical representation

As depicted in Figure 14 the interactive graphical representation allows the user to refer to one, two, three or all four graphs at a time, depending on the requirement of the user.

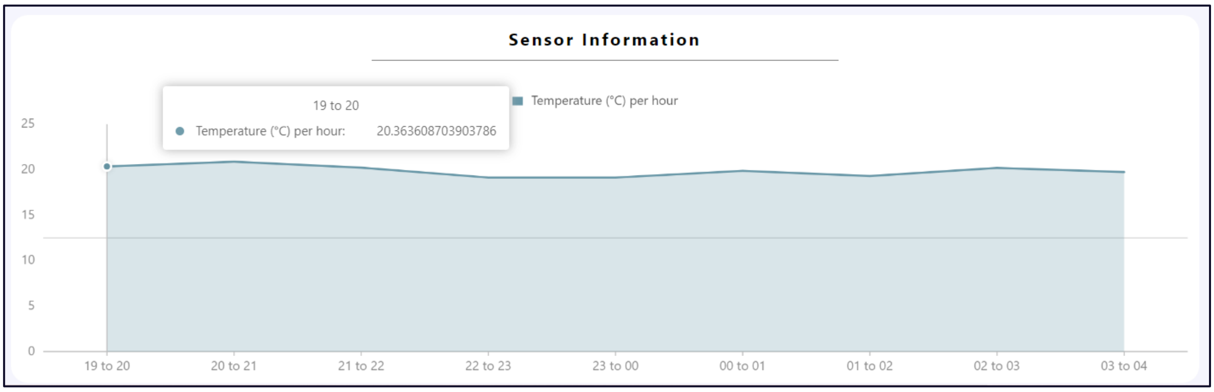

Figure 15 Historical data representation of parameters

Figure 15 represents the graphical representation of historical air temperature data of sensors for a time period of 12 hours. The user can observe how the air temperature varies over the hours.

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2.2.3. Scheduling Tab

The scheduling functionality enables the user to create customized schedules depending on how flexible the user wants to be at a certain time. The Scheduler lets the user select a certain flexibility mode and then select a timeslot where the setting should apply. This lets the user set a weekly schedule with the complete ability to customize each day into different slots.

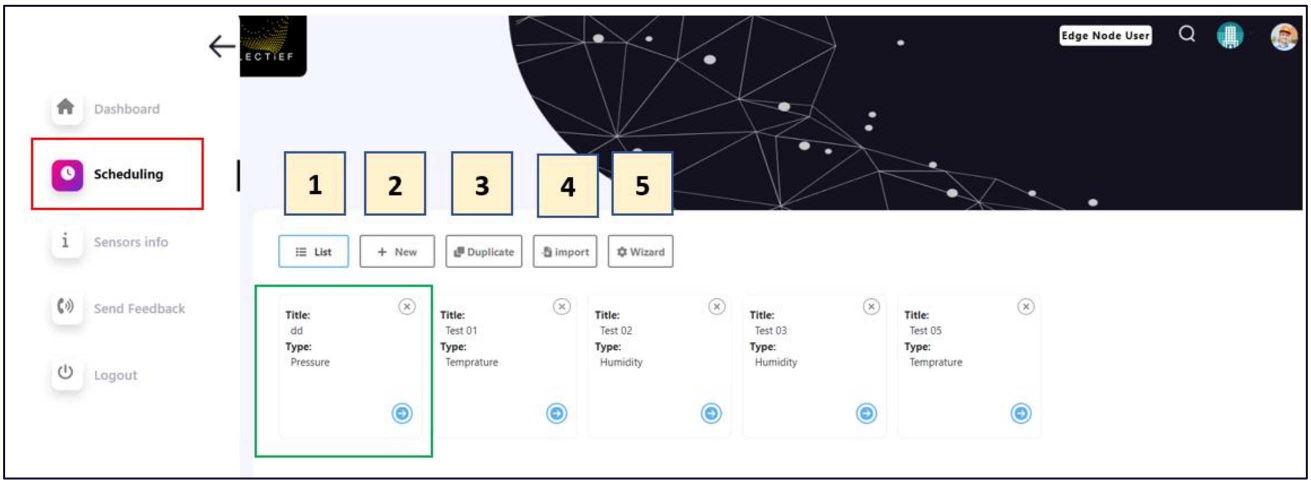

Figure 16 The scheduling tab

The scheduling tab (see Figure 16) allows the user to optimally control the energy and the environmental conditions of the indoor environment to be efficient in an interactive manner. The highlighted numbers in Figure 16 have the following functions.

1- **List**, which represents the saved schedules (as highlighted in green)

2- **New**, which allows the user to create a new schedule

3- **Duplicate**, which allows the user to create a copy of an existing schedule

4- **Import**, which allows the user to import a schedule

5- **Wizard**, which contains predefined information about scheduling for a new user.

When creating a new template, we can either create from an empty template (see Figure 17) or pick from a default template such as temperature template (see Figure 18), pressure template (see Figure 19) and humidity template (see Figure 20). The empty template will allow you to customize all features available from scratch, while the default templates will already have pre-populated data which can also be further adjusted as per the user requirements.

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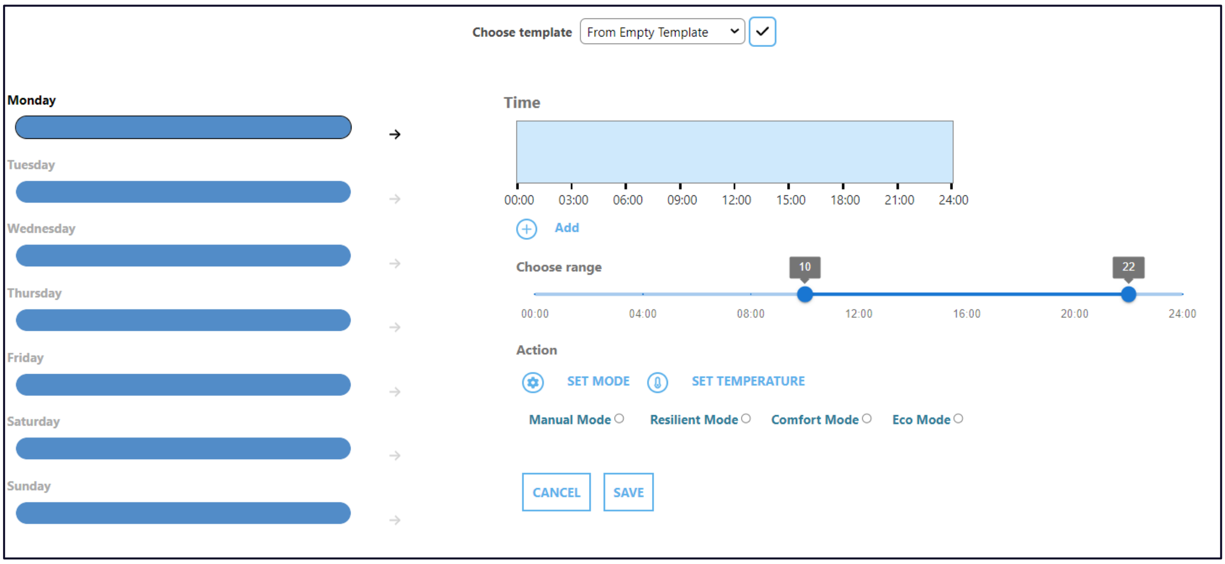

Figure 17 The empty template

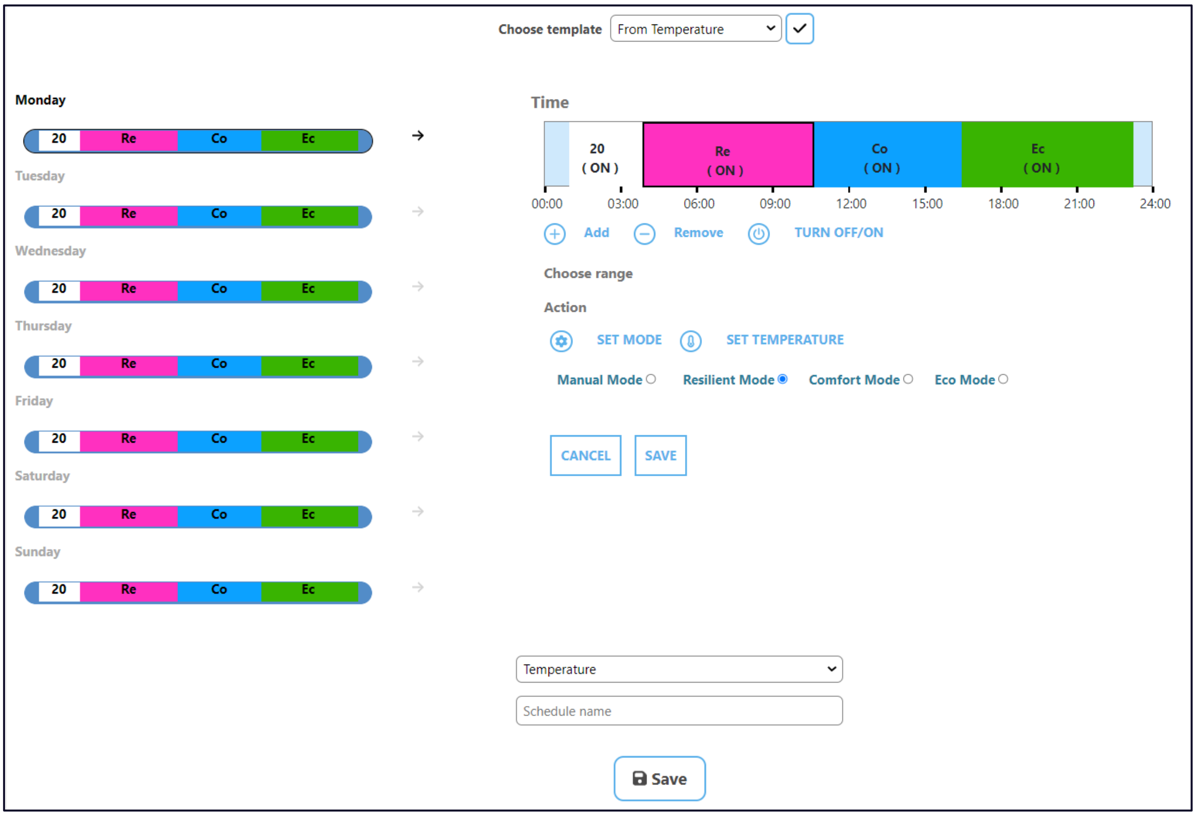

Figure 18 The temperature template

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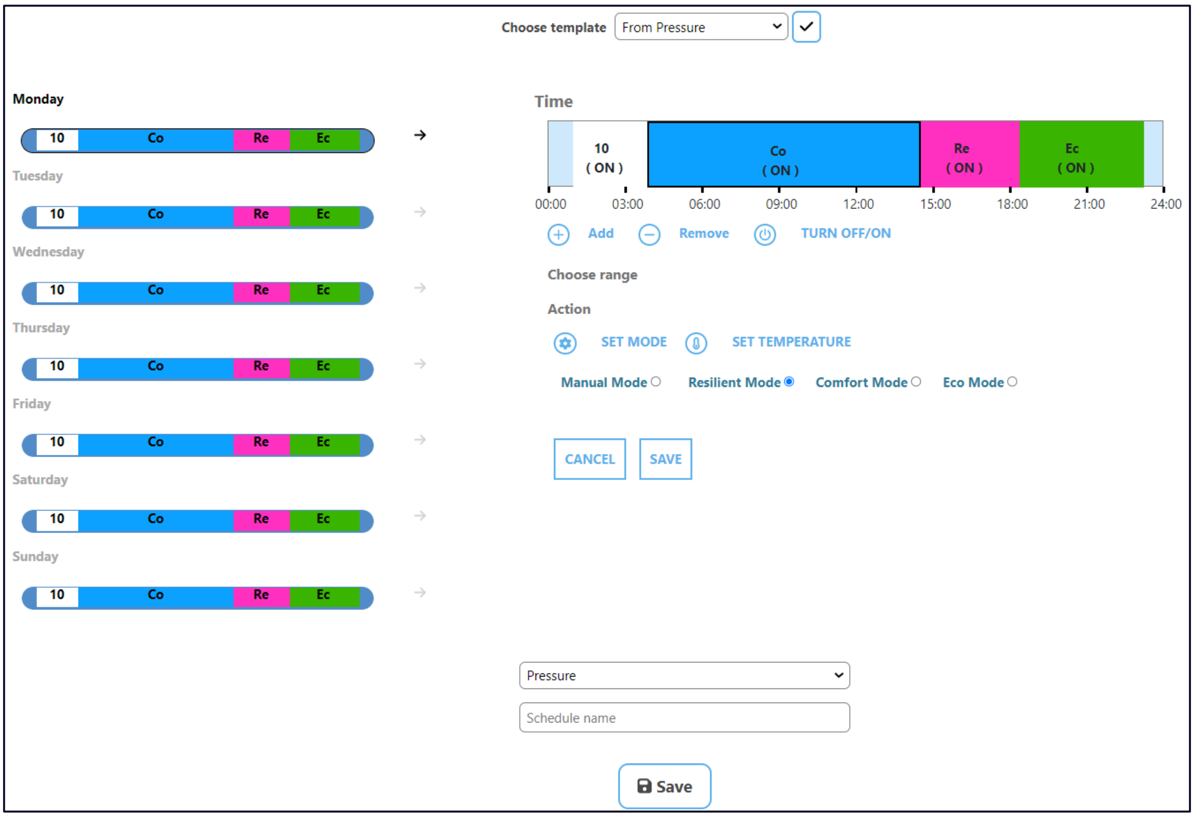

Figure 19 The pressure template

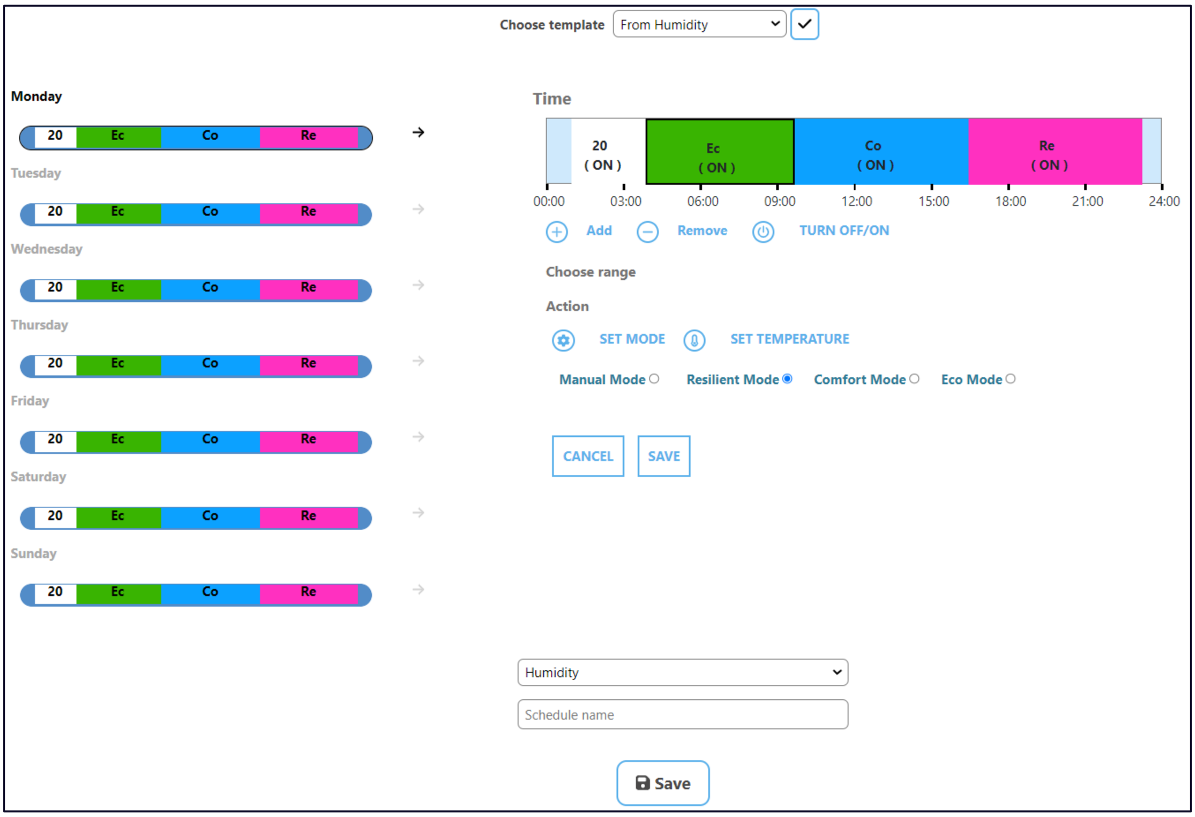

Figure 20 The humidity template

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Further information on different components of the scheduling templates (e.g., for temperature template) is mentioned below, following the highlighted numbers in Figure 21 and Figure 22.

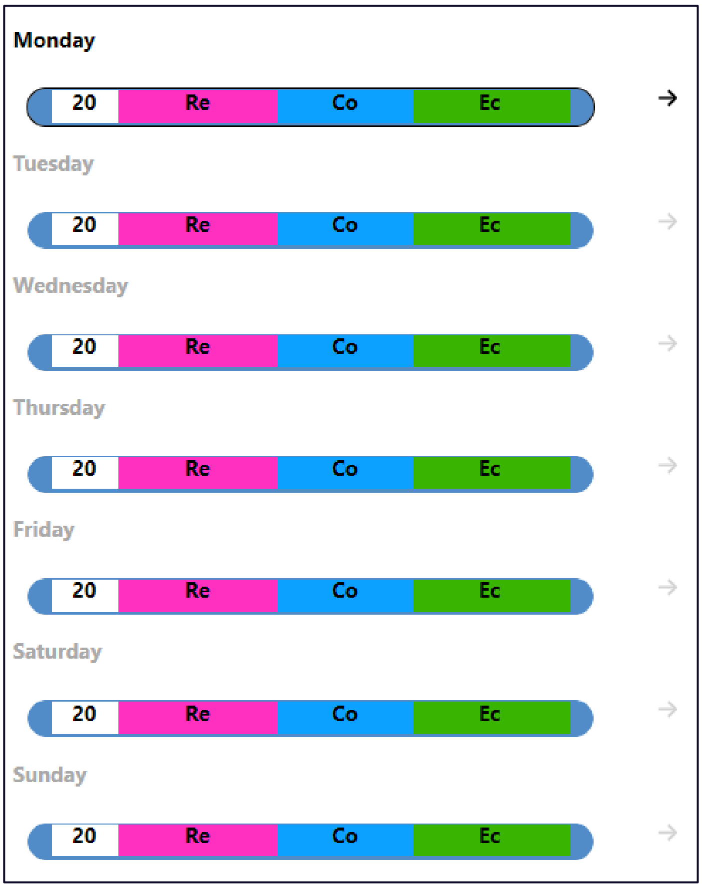

Figure 21 The temperature scheduling template part 1

As shown in Figure 21, the scheduling allows the user to pick the day of the week on which they would like to create a schedule for it.

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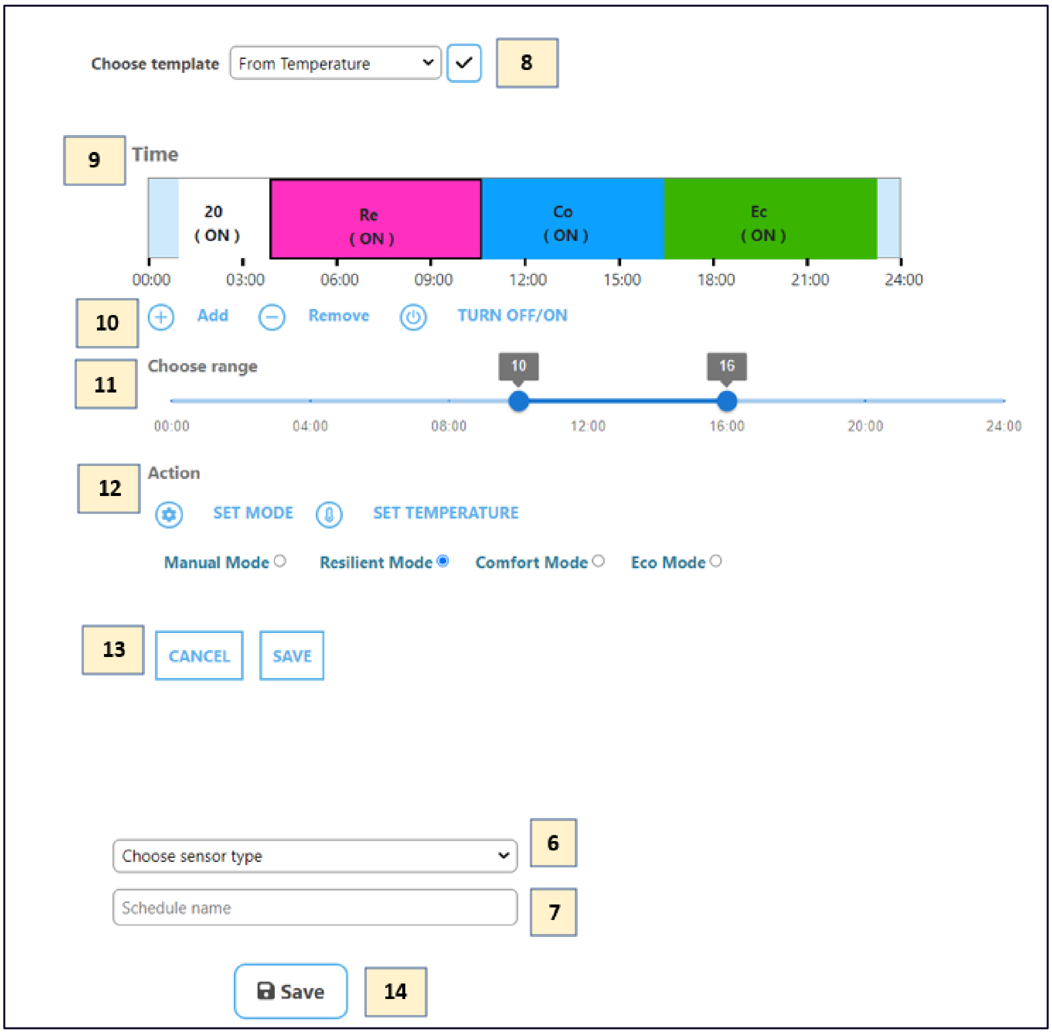

Figure 22 The temperature scheduling template part 2

- 6 – “**Choose sensor type**” option, which allows the user to pick the sensor type from, temperature, pressure, and humidity
- 7 – “**Schedule name**” option, which allows the user to give a name to the schedule
- 8 – “**Choose template**” option, which gives the options to the user to pick from an empty template, temperature, pressure, or humidity template
- 9 –“**Time**” option, which demonstrates all the hours available within a day for the user to schedule an action and it also demonstrates the different modes allocated to each time interval.
- 10 –“**Add/ Remove**” option, which allows to add or remove a certain schedule. The “**Turn Off/On**” function, which lets the user to disable/enable any actions scheduled a priori.
- 11 – “**Choose range**” option allows the user to pick a time period to which the schedule/modes will be applied to

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- 12 – “**Action**” tab, which allows to “set a mode” such as manual, resilient, comfort and eco modes for different time intervals. “**Set Temperature**” allows the user to set a desired temperature
- 13 – “**Cancel**” option, which gives the ability exit the scheduling options, and “**Save**” option that allows the user to save the scheduled settings, and
- 14 - “**Save**” option, which allows the user to save the complete schedule.

2.2.4. Sensor Info Tab

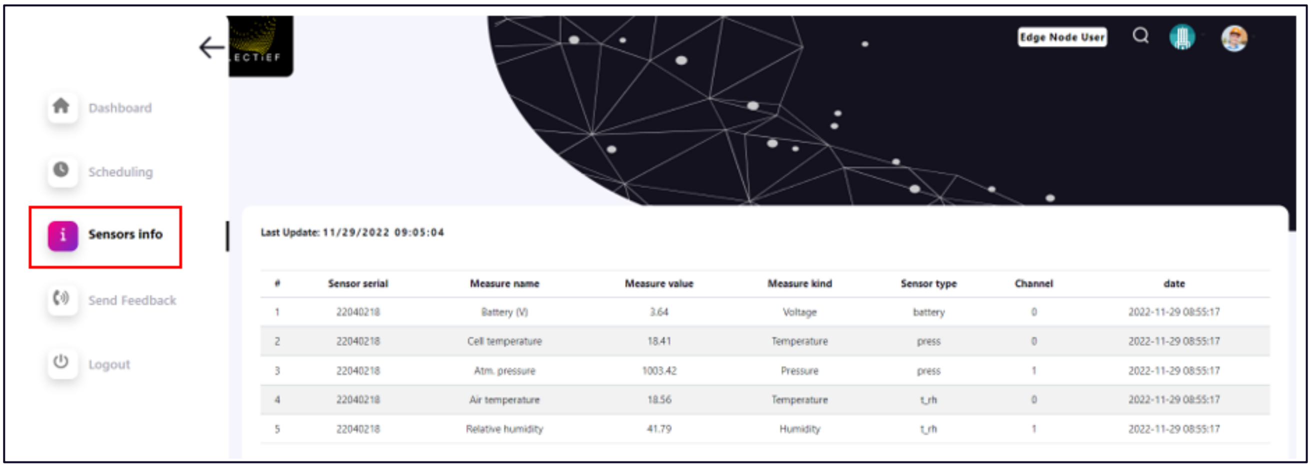

Figure 23 The sensor info tab

The sensor info tab (see Figure 23) provides information to the user about indoor environment monitoring devices in the format of a table. The table contains information such as: sensor serial numbers, measurement name retrieved from the sensor, measurement value of sensors, the kind of measurement retrieved from the sensor, the type of sensor, the channel and the date of data recording. The sensor data are obtained from COLLECTiEF’s French pilot building.

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2.2.5. Send Feedback Tab

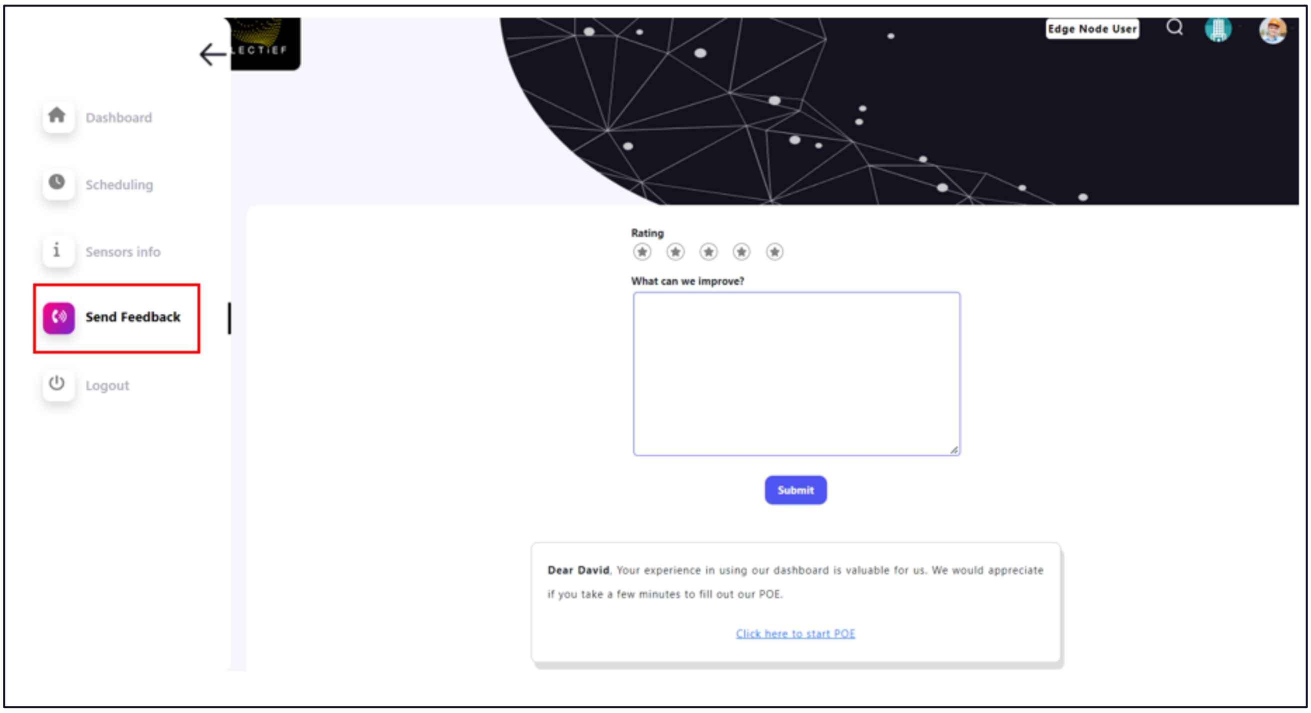

Figure 24 The send feedback tab

The feedback tab (see Figure 24) allows the user to send feedback about the app. They can give a rating and submit their comments or click on the link to complete the POE, which can be used to further improve the COLLECTiEF algorithms and the app, so that users can have a better experience while using the app.

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3. Conclusion and Future Work

The Human-Building Interface has a user login function, a Dashboard, a Scheduling tab, Sensor info tab, Send feedback tab and a Logout feature. Each of these features serve a different purpose. The user login page allows the user to access the Human-Building Interface by entering their login credentials. Note that the credentials will used to identify the profile or type of the user, which will enable the appropriate access permissions. The Dashboard tab acts as a digital indicator of the indoor environment quality and sensor information retrieved from environment control devices, in the form of diagrams, charts etc., which serve as a visual knowledge sharing component. The scheduling tab gives the user to optimally control the energy and environmental conditions of the indoor area, while efficiently prioritizing user requirements. The sensor info tab provides information on indoor environment condition control devices. The feedback tab allows the user to send feedback to further improve the features of the application. The logout feature allows the user to seamlessly leave the app once they have finished interacting with the app.

Moving forward, we will be including a user authentication mechanism at the login page which allows the system to give different levels of access and storage to the Human-Building interface depending on their role as occupant, building owner, building manager etc. Additionally, we envision that the user, in a later version of the Human-Building Interface, will be able to rearrange and customise the cards holding information it best fits the user. The idea is to have a set of default templates based on the type of user and the type of facility the system is integrated into. The user will also be able to compose individualized cards if none of the default ones matches the need of the user. The card will then be built up by selecting the type of visualization that the user wants. The user is then prompted to select the data to be visualized. This could be a single value, a series of values or multiple values to be compared depending on what type of visualization that was selected. The development enables to create a timeseries of all the rooms of the building (at the Edge Node level) and the average of all buildings (at the Cluster Node level) as a visual comparison of the current room/building with respect to the rest of the network. In future will it be possible to click on an area of the indoor building layout and get information such as battery percentage details (such as, highest and lowest battery percentages) and other environmental parameter information obtained from the sensors in that area, such as air temperature, relative humidity, etc. Additionally, a graphical representation of sensor information such as, sensor battery percentages, air temperature and relative humidity over time, will be displayed by each zone/room of the building. The flexible modes available for the user to pick from, in the scheduling tab will be incorporated with algorithms which will give more efficient energy saving solutions based on the 2D models they will be integrated with. When scheduling a parameter in the manual mode, it would be defined as a range rather than a value for a better overview for the user. A calendar function will be incorporated for the user to schedule vacation times or any occasions as per the requirement. The scheduling function will further be open to have weekdays and weekend scheduling which will give more structure for the user to schedule their days. The scheduling function will accommodate any parameters that are supported by environment condition detecting sensors that are used for monitoring, this will give the user an opportunity to efficiently save energy.

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The sensor information tab, which represents information received from sensors setup in different buildings, will be further filtered to confine the information relevant to the type of user logged in (occupant, building owner, building manager etc.). The Human-Building Interface will have options to change visual aspects, such as the color theme, depending on the preference of the user. Hence, these future functionalities will give the user a more unique experience.

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