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Deliverable D6.3
Report on frESCO demosite activities

Deliverable number	D6.3
Deliverable name	Report on frESCO demosite activities
Lead beneficiary	COMSA
Description	The Deliverable will provide a focus on the commissioning of all demonstration sites.
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Related task(s)	Task 2.4. Data handling plan and Data progress report Task 6.1. System Integration/ Deployment in demo sites. Task 6.3. Pilot roll-out and demonstration Task 6.4. Socio-economic, environmental, and technological impact assessment.
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ABBREVIATIONS

Abbreviation	Name
ARM	Originally Acorn RISC (Reduced Instruction Set Computer) Machine
ASCII	American Standard Code for Information Interchange
APP	Application program
A/C	Air Conditioning
API	Application Programming Interface
BDMP	Big Data Management Platform
BI	Business Intelligence
BSS	Battery Storing System
CA	Consortium Agreement
CIM	Common Information Model
COP	Coefficient of performance
CSV	Comma Separated Values
DB	Data Base
DER	Distributed Energy Resources
DHW	Domestic Hot Water
DV	Deliverable
DIN	Deutsches Institut für Normung
DMP	Data Management Platform
DSO	Distribution System Operators
EB	Energy Box
EC	European Commission
EU	European Union
EV	Electric Vehicle
ESCO	Energy Service Company
GA	Grant Agreement
HMI	Human Machine Interface
HTTP	Hypertext Transfer Protocol
HVAC	Heating, Ventilation and Air Conditioning
H2020	Horizon 2020 The EU Framework Programme for Research and Innovation
ICT	Information and Communication Technology
JSON	JavaScript Object Notation
LTE	Long Term Evolution

Abbreviation	Name
MQTT	Message Queuing Telemetry Transport Protocol
PDF	Portable Document Format
Pub-Sub	Publish-Subscribe
PV	Photovoltaic
QoS	Quality of Service
REST	Representational State Transfer
RTU	Remote Terminal Unit
SASL	Simple Authentication and Security Layer
SSL	Secure Sockets Layer
TCP	Transmission Control Protocol
TSO	Transmission System Operator
UI	User Interface
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
UTC	Coordinated Universal Time
VM	Virtual Machine
VOC	Volatile Organic Compounds
VPN	Virtual Private Network
XML	Extensible Markup Language
WP	Work package

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EXECUTIVE SUMMARY

The purpose of this document is to describe the performance of the solutions, particularly the challenges faced and the hurdles found during the commissioning and demonstration execution of the frESCO project in the three demo sites, in order to ensure that all key local systems, equipment, and communication network were adequately integrated with the entire frESCO ecosystem, such as Big Data Management Platform, APPS, analytics modules, and so on, and that data flows smoothly in the different subsystems.

This document confirms that all scheduled demonstration activities and standard specifications created in previous WPs have been effectively implemented into the various demo sites. In addition, it guarantees minimal disturbance during the validation stage, data connection between the demonstration locations and data collecting Platform was created and tested.

A continuous demonstration execution process has been done to continuously execute demonstration processes in order to improve performance, not only in the physical site but also in the communications to check back-end services. Detailed descriptions of the issues or challenges that were encountered at each demo site are presented.

The Deliverable D6.3 as well focuses on the problems raised during the commission and demonstration execution where the resolution strategies took place: How each demo site addressed these issues, including any solutions implemented, changes made to the project plan, or changes in hardware resources allocated or how them impact on project, how these issues and their resolutions impacted the overall project timeline, budget, and objectives. Datasets started to become available first in Madrid and Greece since December 2022, making up one full year of data series. The deployment of solutions to the issues encountered delayed availability of data assets some months in Greece and Croatia but the system was up and running ensuring coverage of the full summer period, critical in these two seasonal demos.

An overview of the Workshop pilot's demonstration with the users and pilot owners is presented, together with information about the demonstrations themselves, what was shown, interactions with front end, and any feedback or observations made during the demonstration's workshops.

Following the successful commissioning of all demo sites, Deliverable 6.4 collects the impact assessment of the frESCO solutions across all demo sites while taking into account the various

profiles involved at various stages of the pilot roll-out. In order to close the pilot assessment deliverable D6.5 compiles the Lessons Learned with the insights gained from dealing with these issues, recommendations or suggestions for preventing or mitigating similar issues in future projects or phases when scale up solutions.

1 INTRODUCTION

1.1 Purpose and target group.

In summary, the document is a valuable resource for project management and improvement of the implementation activities. It captures the project's hurdles and their management, provides transparency to stakeholders, offers opportunities for process enhancement, and serves as a guide for future projects. It plays a crucial role in ensuring the success and efficiency of commissioning, demonstration, and integration activities in complex integration projects.

Document includes a comprehensive record by pilot of the challenges and hurdles encountered during the commissioning and demonstration phases of a project. These hurdles could include technical issues, logistical problems, budget constraints, and more. Documenting these hurdles is essential for transparency and answerability in project management. The document also outlines how these hurdles were managed or resolved in some cases. One of the significant benefits of D6.3 is its potential to contribute to process improvement. By documenting hurdles and their resolutions, project teams can identify recurring issues and areas where processes can be streamlined or enhanced. This knowledge can lead to more efficient project execution in the future.

The document may also be particularly useful for future extended pilot projects, as it provides insights into the challenges faced during the initial phases and how these challenges were addressed. This knowledge can help in planning and executing extended pilot integrations more effectively, serving as a guide or reference tool for future projects, especially when they involve similar integration, commissioning, or demonstration activities. Project teams can refer to this document to anticipate potential challenges and learn from the strategies employed to overcome them. This information is invaluable for project assessment, as it demonstrates the project team's problem-solving abilities and resourcefulness.

1.2 Scope of the document.

End-to-End Integration: A comprehensive overview of the entire integration process within the frESCO ecosystem. This end-to-end integration encompasses all stages, from data collection at the pilot sites through the gateways to the central data management platform. This holistic view of the process helps readers understand the activities undertaken in each pilot site within the project.

Deliverable D6.3 "Report on frESCO demo site activities" provides the background information that was needed to implement along the commissioning process and data monitoring in preparation for post intervention operations.

A full description of the commissioning of each pilot site is given. A detailed description of how integration is achieved within the frESCO project. This integration process likely involves local sensors and energy meters being connected to various gateways, which act as central hubs for data collection and transmission. The gateways play a critical role in redirecting the data collected by sensors and meters to the central frESCO platform "Big Data Management Platform." This ensures that data from different sources is efficiently gathered and consolidated for further analysis and monitoring.

This document does not include the impact assessment and test results carried out to demonstrate the impact of the different tools and services in the demo sites. This content is included in D6.4 "Socio-economic, environmental and technological Impact Assessment".

1.3 Structure of the document.

The structure of the document is organized per each pilot as follows:

i. **Site Overview**:
   - Introduction to the site, its location, and its purpose.
   - Brief summary of information about the site.
   - Any relevant context that sets the stage for the rest of the document.

ii. **Mapped Devices Installation**:
   - Details about the devices installed (sensors, meters, gateways) at the site.

- Information on the installation integration.
- Any special considerations or challenges faced during installation.

iii. **Assets Available for Flexibility**:

- Listing and description of assets available at the site that contribute to its flexibility.
- Explanation of how these assets can be utilized to meet various needs or adapt to changing circumstances.

iv. **Digital Communications**:

- Overview of the digital communication systems in place at the site.
- Information about data transmission, networking, and any communication protocols used.
- The role of digital communications in the site's operations.

v. **Problems Raised During the Commissioning**:

- Identification and description of any issues or challenges encountered during the commissioning phase.
- Details on how these problems were addressed or resolved.
- Recommendations for future commissioning processes.

vi. **Site Workshop Summit**:

- Information about the workshop that is being submitted or organized in relation to the site.
- Workshop objectives, agenda, and expected outcomes.
- Logistics, including date, time, location, and participant details.

2 CROATIAN PILOT SITE

2.1 Site Overview.

In the Croatian pilot site, two partners are directly involved – Smart Island Krk as the municipal utility company and KONČAR-DIGITAL as the technical support partner. In the Croatian demo site, unlike all other pilot sites, none of the pilot locations are owned by project partners directly. This pilot site targets residential home users and their homes directly.

There are further locational specifics of Krk: the island is a very popular and easily reachable tourist destination, as it is connected to the mainland via a bridge, and it lies in near proximity of the city of Rijeka, and Slovenian and Italian borders.

Less than half of residential buildings in Krk is inhabited throughout the year, with the remainder used in summer season only or as weekend residences. Summer energy consumption in peak tourist season increases along with the island population that increases fivefold.

Krk is at the forefront of energy transition in Croatia and Krk municipalities have a strategy of making Krk net-zero island. This further increases the diversity of the building fleet in Krk. There are close to net zero or even net negative modern buildings with a very good building energy performance, solar panels and heat pumps, but there are also older buildings with single pane windows and low performance insulation. Generally, the thermal performance of the dwelling is highly related to whether the housing is in use throughout the year and to the year of last renovation. It is understandable that a large share of buildings still has comparatively lower performance as improvements in energy performance are more difficult to justify financially when the building in question is used only occasionally.

These site specifics have influenced the technical decision making and the development of the pilot site: with all the buildings residential, the equipment to be installed in living premises of the users must meet the quality and safety conditions, it must be non-invasive, compatible with existing infrastructure in the dwellings, and any control of the equipment in the house is only possible with explicit consent of the homeowner for each activation.

2.1.1 Pilot End Users Selection Process.

The open call for project participants has yielded 19 homeowners that have tentatively accepted to participate in the project.

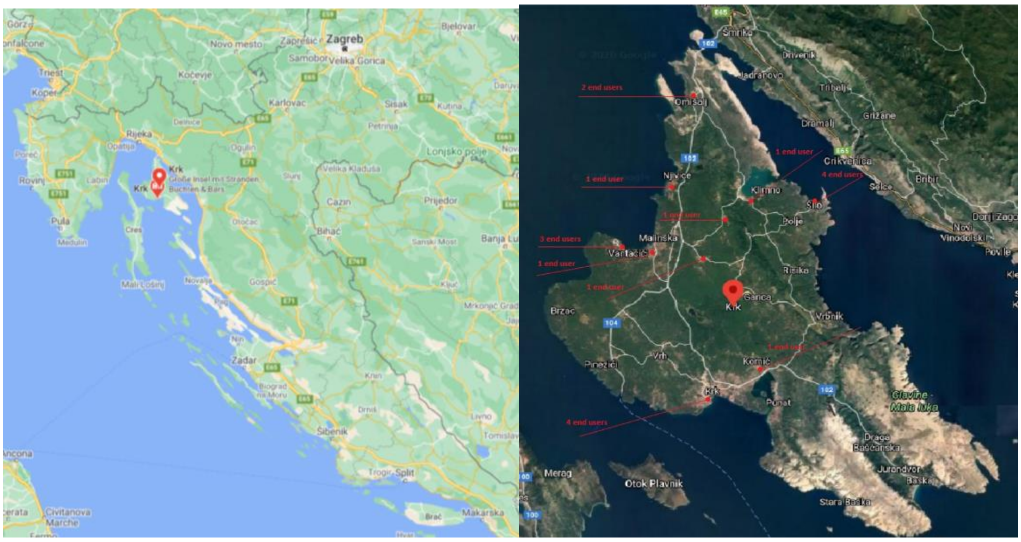

FIGURE 1: [CROATIA DEMO SITE] KRK ISLAND LOCATION AND LOCATIONS OF 19 PARTICIPANTS SPREAD ACROSS THE ISLAND

The users have been divided into four tiers, depending on the dwelling energy performance:

1) *Tier 1 – Households with good insulation and heat pumps*
2) *Tier 2 – Households with good insulation but without heat pump with other sources of heating*
3) *Tier 3 – Households that are mainly weekend users.*
4) *Tier 4 - Households without good insulation and heat pumps.*

The idea has been to cover different types of housing in Krk with “lighthouse” participants. Tentative acceptance is not, however, fully correlated with the later cooperation and the risk of having an unwilling or reluctant end user makes the final user selection a multicriteria problem. To be cost and effort efficient, we wanted to select the minimum number of users that span all the housing types, but a degree of redundancy is needed here as well.

As the pilot installation evolved, there are seven user dwellings that have had the equipment installed and have been actively collecting data and that span the above user set.

Param.	Units	Physical Demo
Dwellings	Un	7
Average User/Dwelling	Un	7 in high occupancy period

		3 in low occupancy period
Total Consumers	Un	7 connection points
Average Electricity	kWh/year	4000 per dwelling
Average Natural Gas	kWh/year	Not applicable
Investment	€	350 in average per dwelling (Range from 250€ to 600€)

TABLE 1: [CROATIA DEMO SITE] SUMMARY PILOT CHARACTERIZATION

2.2 Mapping Devices Installation (sensors, energy meters, gateways, Ebox).

2.2.1 Equipment Selection.

Given the requirements of the end users, and with a very positive experience in other projects, we have decided to use Develco sensors and gateways for the Croatian pilot. The Develco equipment has shown good performance in a remote island of Unije which is considerably hard to visit and the inhabitants are mostly of older age and somewhat reluctant to accept a new technology in their houses. With the supply chain troubles in 2021, there have been very significant troubles with the procurement of the devices so we had to resort to local second-hand purchase for the first round of equipment being purchased.

Equipment specification		
Item	**Link**	**Total**
Air quality sensor	https://www.develcoproducts.com/products/sensors-and-alarms/air-quality-sensor/	9
Prosumer electricity meter	https://www.develcoproducts.com/products/meter-interfaces/prosumer-meter/	3
Smart Plug Mini 2 Schuko socket	https://www.develcoproducts.com/products/smart-plugs/smart-plug-mini-2/	12

Smart Relay power monitor DIN version	https://www.develcoproducts.com/products/smart-relays/smart-relay-16a-din/	2
SquidLink Gateway LTE	https://www.develcoproducts.com/gateways/squidlink-2x/	7

TABLE 2: [CROATIA DEMO SITE] INSTALLED EQUIPMENT SPECIFICATION

In the table below, please note that temperature, humidity air quality sensors are integrated in the same device, the air quality sensor in the table above. To reduce the privacy impact to private dwellings, we decided not to install any motion sensors.

Devices	Units	Physical Demo
Energy Meters	Un	7
Temperature Sensor	Un	10
Air Quality Sensor	Un	10
Motion Sensor	Un	None
Actuator (relay)	Un	2 (within the smart relay) 10 (smart plugs)
Gateways	Un	7
E-Box	Un	Not applicable

TABLE 3: [CROATIA DEMO SITE] LIST EQUIPMENT INSTALLED

2.3 Enabled Assets available for Flexibility.

Flexibility is enabled through interruptible loads. All installed smart plugs have interrupting capabilities, which the meters do not have. The PV systems at one location allows control via the inverter set points, while another location only allows passive readout.

Param.	Units	Physical Demo
HVAC	Un	4
Heating element (floor heating)	Un	1
DHW	Un	n/a

PV System	Un	1
Battery Storing System (BSS)	Un	n/a

TABLE 4: [CROATIA DEMO SITE] COLLECTION OF FLEXIBILITY ASSETS

As mentioned earlier, pilot specifics of the Croatian pilot inevitably apply restrictions on the use of controllable assets. The ownership of the controllable asset and eventual liability for damages is a problem here so we decided early in the project that any actual flexibility actuation would be subject to explicit approval by the homeowner.

There are four possible users where HVAC activation is theoretically possible, i.e. where the existing software and hardware equipment allows the activation of flexibility. Among these four users, one additionally owns a heating element connected through the smart relay – this a resistor-based floor heating and is normally used in early spring and late autumn. Out of these four users, two users have given their explicit consent for the actuation of the flexibility events.

2.4 Digital Communications.

In this chapter, the detailed "as installed and implemented" technical specification of the Croatian pilot is described. The general configuration has been described in the deliverable D6.1 and the high-level configuration is depicted in the following picture.

2.4.1 High-level System Architecture.

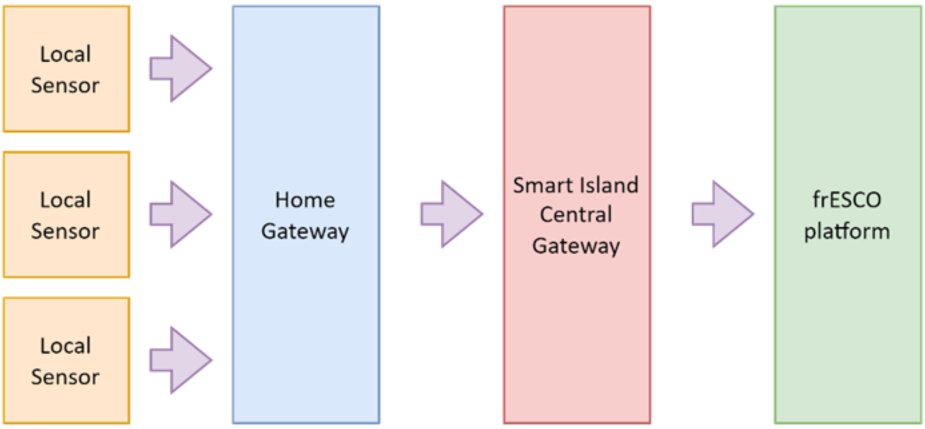

FIGURE 2: [CROATIA DEMO SITE] DWELLING LOCAL IMPLEMENTATION DIAGRAM

Within the participating end user dwelling, there are several sensors installed. Some of the sensors such as the ambient sensors and smart plugs are placed within the environment, while smart relays and three phase smart meters require expert installation. All sensors communicate with the local, in-house gateway via the Zigbee protocol.

The local gateway is a Develco SquidLink hardware device, and collects the Zigbee data, packages the measurement payload into Develco JSON format and posts it to the MQTT message broker – not directly to the frESCO platform.

To increase manageability and ensure the platform receives a correctly orchestrated set of data, there is a Smart Island Krk central data gateway that reads the data from the sensors, then repackages it and prepares it for the submission to the frESCO platform. This central Smart Island Krk gateway aggregates the pilot data and sends the data to the central platform. This interim data orchestration step has three main benefits: reduces the risk of data being lost, cyber-security risks are handed better, and finally the interface with frESCO platform is easier to manage from a central point instead of by visiting the end users.

2.4.2 Data Transmission path from sensors, E-box to BDMP.

The home gateway is a Develco SquidLink 2x device with custom firmware, and it communicates with paired Develco sensors and meters using Zigbee protocol. This is for the most part standard configuration of the Develco equipment.

For two users where there are the PV panels installed, a custom tool in Python has been developed and deployed to the SquidLink gateway. This tool reads the Modbus registers of the inverters. As the Modbus TCP exposed dataset is not standardized across inverter types and manufacturers, it had to be developed and tested manually for the two sites in Croatia.

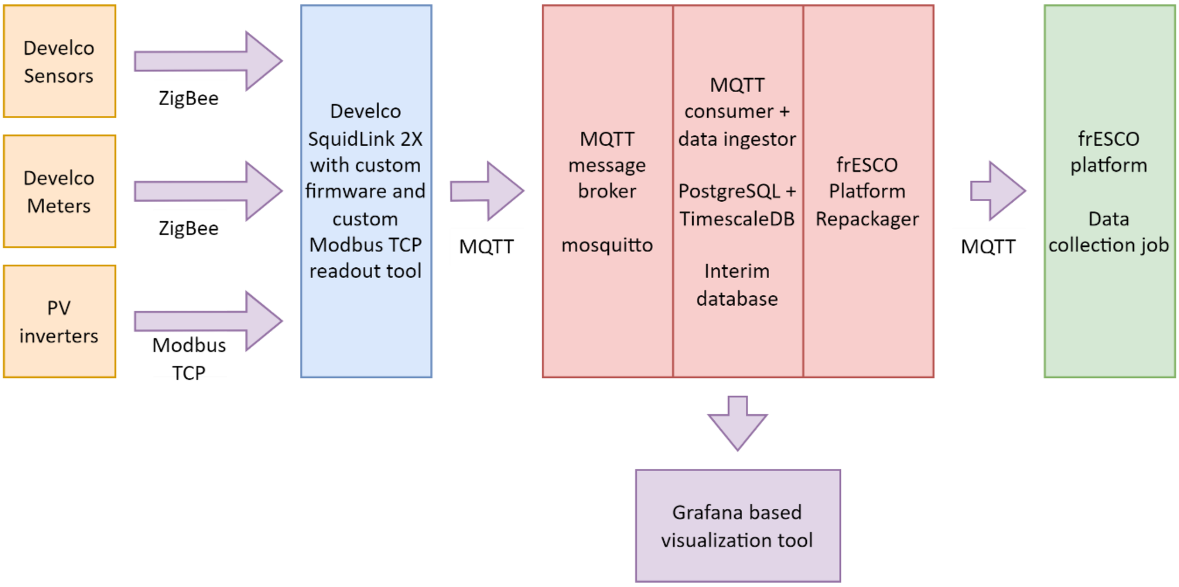

FIGURE 3: [CROATIA DEMO SITE] DETAILED TECHNICAL ARCHITECTURE OF THE CROATIAN DATA COLLECTION AND MANAGEMENT INFRASTRUCTURE

The detailed architectural setup is depicted in the image above. The Smart Island Krk hosted data gateway is not a monolithic component – instead it is composed of four principal components.

2.4.2.1 MQTT Component.

The **MQTT message broker component** is based on a mosquitto software running on Ubuntu 20.04 Linux operating system. It collects the MQTT data from all Develco gateways installed at end user premises, and Develco gateways must be, prior to deployment, configured to point towards this MQTT broker. To minimize the cyber security attack surface, this message broker has a proper SSL certificate, so the traffic is encrypted. It also does not allow logging in without a password. The usernames and passwords are different for each deployed gateway.

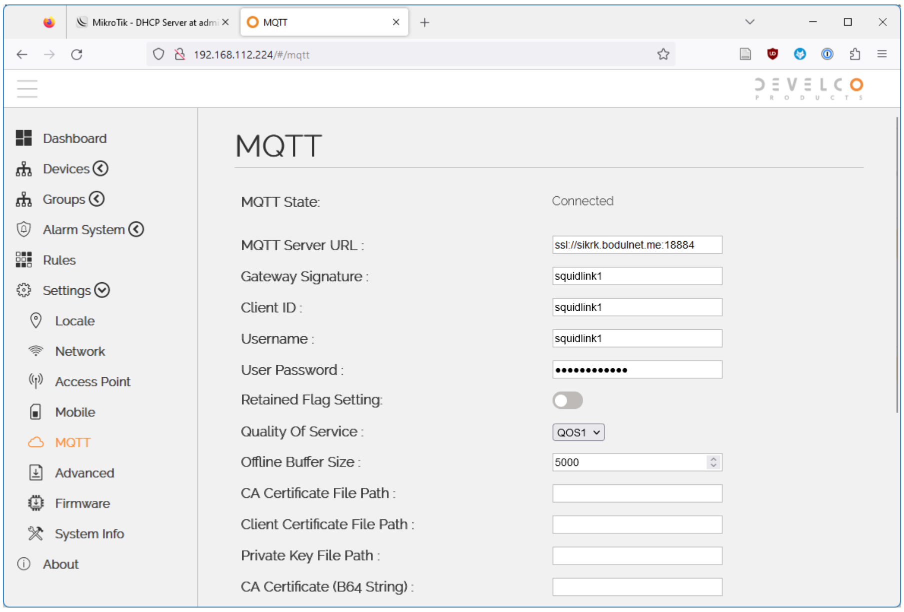

FIGURE 4: [CROATIA DEMO SITE] DEVELCO GATEWAY WEB INTERFACE TO MQTT CONFIGURATION

The second component is the **MQTT consumer and interim database ingestor.** It consists of a MQTT client script subscribed to all relevant MQTT topics that unpacks and stores the numerical payload of the data posted by Develco gateways into the interim database. The interim database is based on PostgreSQL with TimescaleDB time series extensions. It is used for data staging of the numerical time stamped data.

FIGURE 5: [CROATIA DEMO SITE] MQTT CONSUMER COMPONENT INGESTING THE DATA INTO INTERIM DATABASE

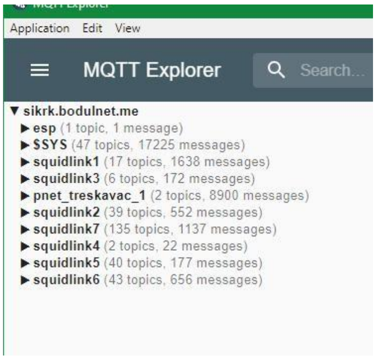

FIGURE 6: [CROATIA DEMO SITE] MQTT EXPLORER TOOL, USED TO DEBUG SQUIDLINK TO MQTT MESSAGE BROKER COMMUNICATION

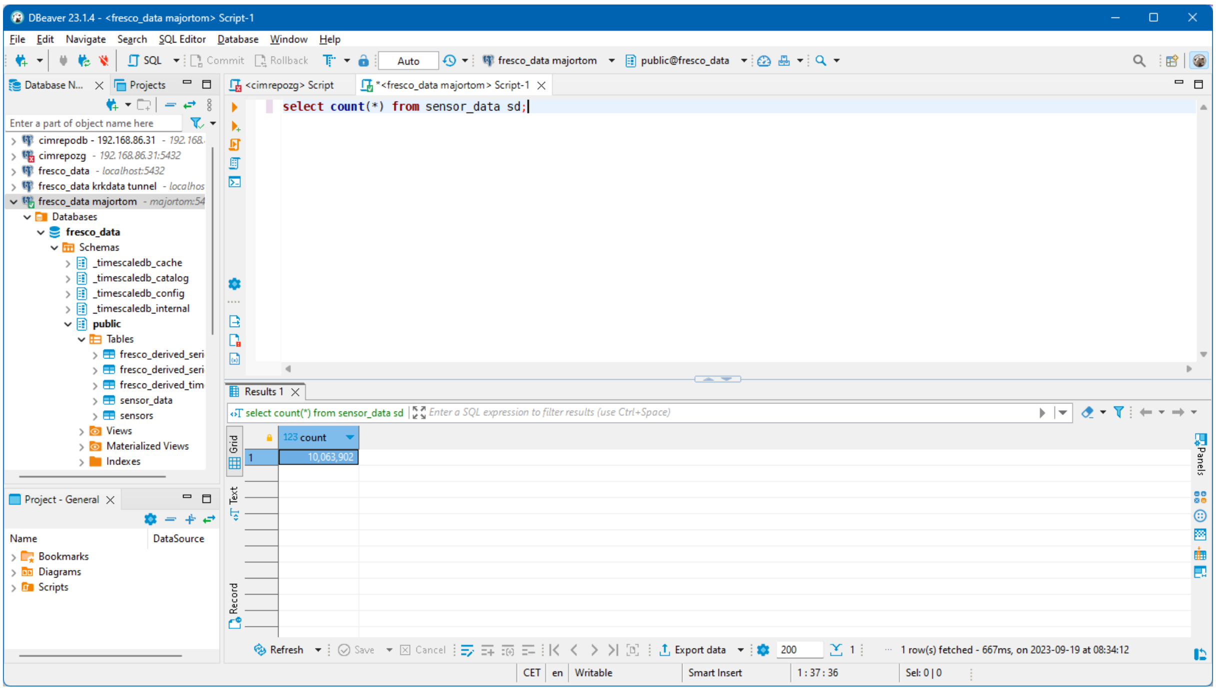

FIGURE 7: [CROATIA DEMO SITE] DBEAVER DATA MANAGEMENT TOOL CONNECTED TO THE INTERIM DATABASE, BASED ON POSTGRESQL WITH TIMESCALEDB EXTENSIONS

The data staging is needed as the Develco data is typically only sent on change, the data that changes slowly such as temperature is not sent periodically. If the temperature in a space is kept constant there will be no messages on temperature. For such values, the “last observation carried forward” approach is used – if the value is unchanged, use the last observed value as relevant. Different interpolation techniques are also much easier to implement if there is missing data.

Using the TimescaleDB functions, it is easier to aggregate the data to a certain time granularity – and this is the task of the **frESCO platform repackager** component. This component aligns the data series to the data format expected by the frESCO platform and submits it to the MQTT data collection job of the frESCO platform periodically. The MQTT collection job of the frESCO platform requires that all the required data is stored in the message payload, while the Develco sensors have a part of the identifiable information associated with the MQTT topic they are posted to. To mitigate this, we have derived unique device identifiers to utilize inside the JSON message payload and these are defined in the Static Data Collection information.

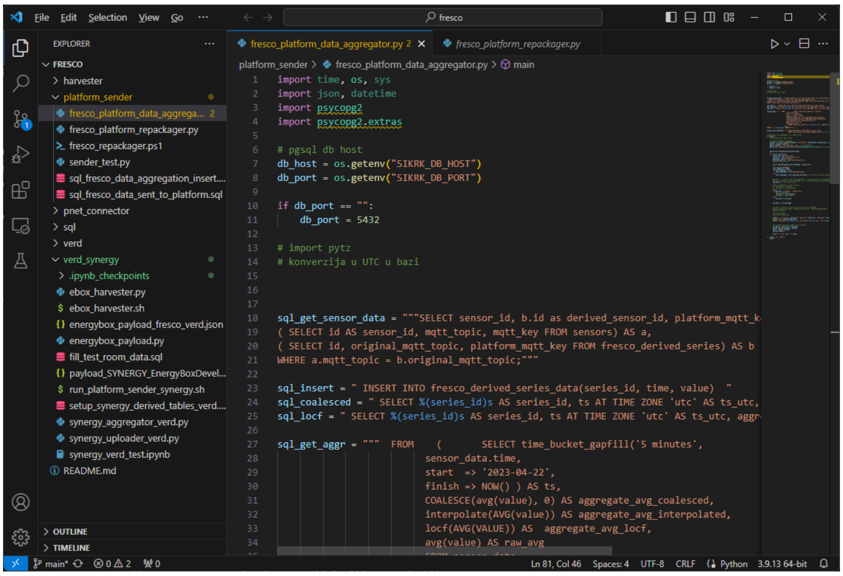

FIGURE 8: [CROATIA DEMO SITE] PYTHON CODES UTILIZING TIMESCALEDB INTERNAL FUNCTIONS TO AGGREGATE AND INTERPOLATE THE DATA

The following table defines the unique identifiers that are used in repackaging of the data that is posted to the frESCO platform.

Unique identifier	Unit	Measured value
krkuser1_voc	ppb	VOC, User 1
krkuser1_humidity	%RH	Rel. humidity, User 1
krkuser1_demand	W	Total demand, User 1
krkuser1_temperature	°C	Ambient temperature, User 1
krkuser2_voc	ppb	VOC, User 2
krkuser2_humidity	%RH	Rel. Humidity, User2
krkuser2_demand	W	Total demand of User 2
krkuser2_temperature	°C	Ambient temperature - User 2

krkuser2_hvac_demand	W	HVAC demand, User 2
krkuser3_voc	ppb	VOC, User 3
krkuser3_humidity	%RH	Rel. humidity, User 3
krkuser3_demand	W	Total demand, User 3
krkuser3_temperature	°C	Ambient temperature, User 3
krkuser4_voc	ppb	VOC, User 4
krkuser4_humidity	%RH	Humidity, User 4
krkuser4_temperature	°C	Ambient temperature, User 4
krkuser5_voc	ppb	VOC, User 5
krkuser5_humidity	%RH	Humidity, User5
krkuser5_heating_demand	W	Floor heater demand (used only in cold months), User 5
krkuser5_hvac_demand	W	Cooling (split system demand), User 5
krkuser5_temperature	°C	Ambient temperature
krkuser6_voc	ppb	VOC, User 6
krkuser6_humidity	%RH	Humidity, User 6
krkuser6_demand	W	Total demand, User 6
krkuser6_temperature	°C	Ambient temperature
krkuser7_voc	ppb	VOC, User 7
krkuser7_humidity	%RH	Humidity, User 7
krkuser7_demand	W	Total demand, User 7
krkuser7_temperature	°C	Ambient temperature, User 7
krkuser7_hvac_demand	W	HVAC (split system demand), User 7
krkuser2_pv_production	W	User 2 location PV production
krkuser6_pv_production	W	User 6 location PV production

TABLE 5: [CROATIA DEMO SITE] COLLECTION OF UNIQUE IDENTIFIERS USED IN REPACKAGING OF THE DATA

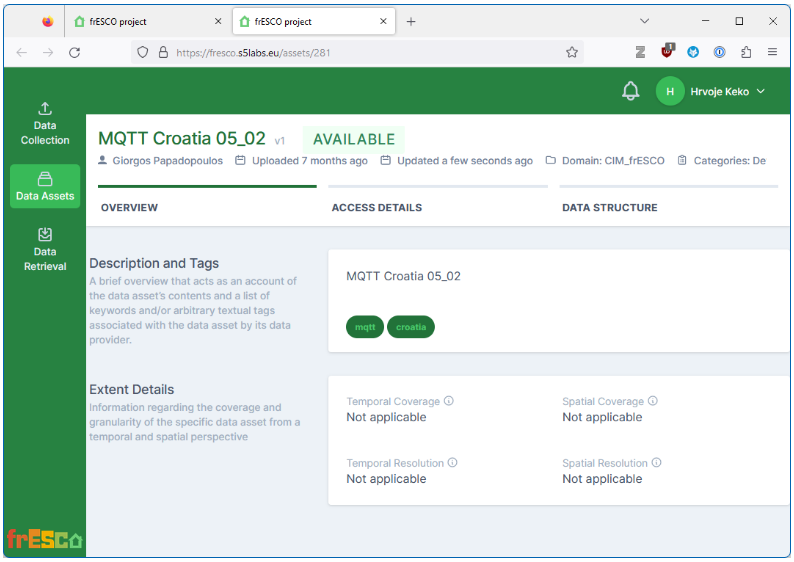

Figure 9: [Croatia Demo Site] frESCO platform data collection job for live data of the Croatian pilot

Finally, as the end users have shown great interest in the raw data, and in order to provide a simpler tool that would allow early detection of errors in the data collection, a Grafana-based tool that interfaces with the interim data has also been deployed in the Croatian pilot. This has been a very effective tool to increase user engagement and at the same time to permit the users to oversee the data collection and warn SIK team if the collection stops working. As the Grafana tool visualizes the data ingested in the interim database, so if the collection fails up to that point, it will be visible in Grafana visualization.

Figure 10: [Croatia Demo Site] Grafana-based data collection process debug tool

There is no personally identifiable data is retained in the interim database – these are scrubbed in the first data collection step and we store no personally identifiable info on the end users, and each end user only see its own data.

2.4.2.2 Data Model Structure, MQTT content, jobs definition.

As explained previously, the Develco sensors utilize the default Develco MQTT payload model. A part of the data is contained in the MQTT topic, and only a part of is carried within the payload. An example of Develco-formatted payload is:

MQTT Topic:

```
squidlink7/update/zb/dev/5/ldev/pmta/data/demand
```

MQTT Payload:


```
{"key":"demand",
 "name":"Instantaneous Energy Use",
  "type":"signed_integer",
  "unit":"W","access":"r",
  "lastUpdated":"2023-09-19T18:44:50.690444+02:00",
   "value":222}
```


From the above, one must utilize the topic to deduce which device this payload refers to. Within the repackaging (and after the process of syncing and aggregation) the above message is repackaged into a message that contains the unique identifier *within* the payload itself. The timestamp is also converted to UTC format. The MQTT payload is as follows:


```
{ "client_device_id": "krkuser7_demand",
                                    "key": "demand",
                                    "lastUpdated":"2023-09-19T16:44:50.690444Z",
                                    "unit": "W", "value": 222 }
```


These data are ingested by a single MQTT-based data collection job in the frESCO platform called **MQTT Croatia 05_02** and illustrated in the platform screenshot in this chapter. The unique identifier of the devices is now contained within the “client_device_id” of the JSON payload of each MQTT message.

2.4.2.3 Availability of Retrieved Data.

Personalized Energy Analytics and Human-Centric Automation tool uses the data from the BDMP as inputs for doing the analytics and running the different services. The first step to collect this data was to show data availability in the platform ready to be consumed.

The Croatian data set MQTT Croatia 05_02 search in the BDMP shows the following as can be seen in the Figure 11.

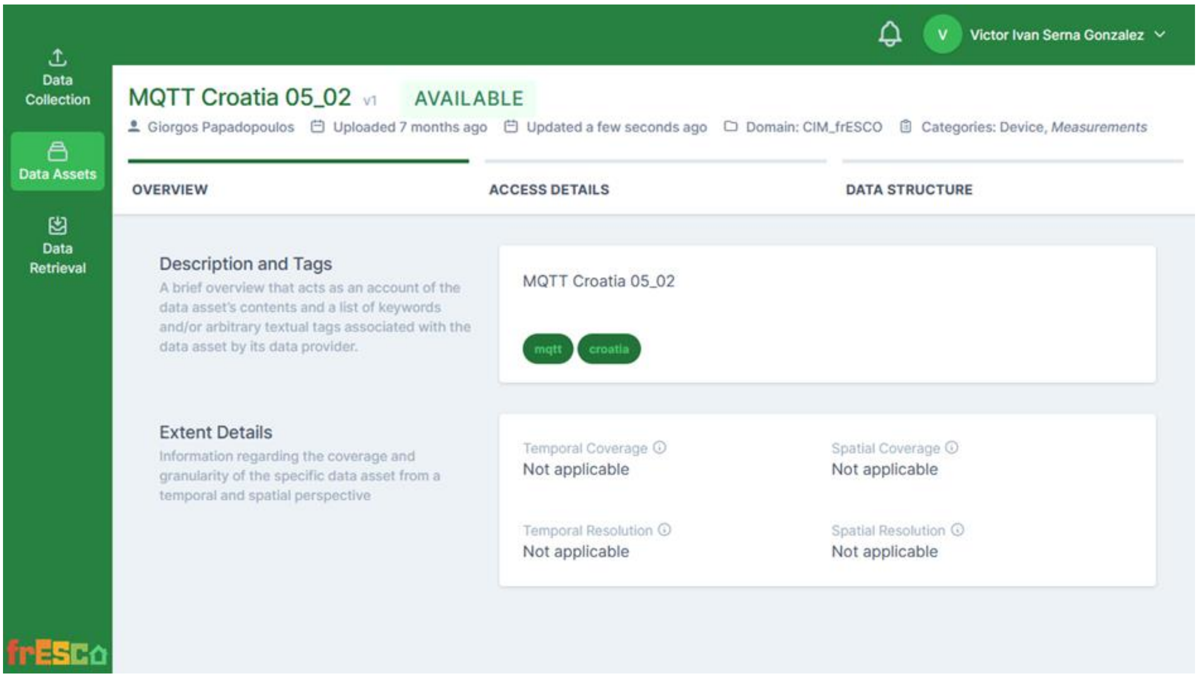

FIGURE 11: [CROATIA DEMO SITE] ATTESTING OF AVAILABILITY OF MQTT CROATIA 05_02 DATASET

Besides, a test for checking that the data is available was done through the data retrieval section in the BDMP as can be seen in the Figure 12.

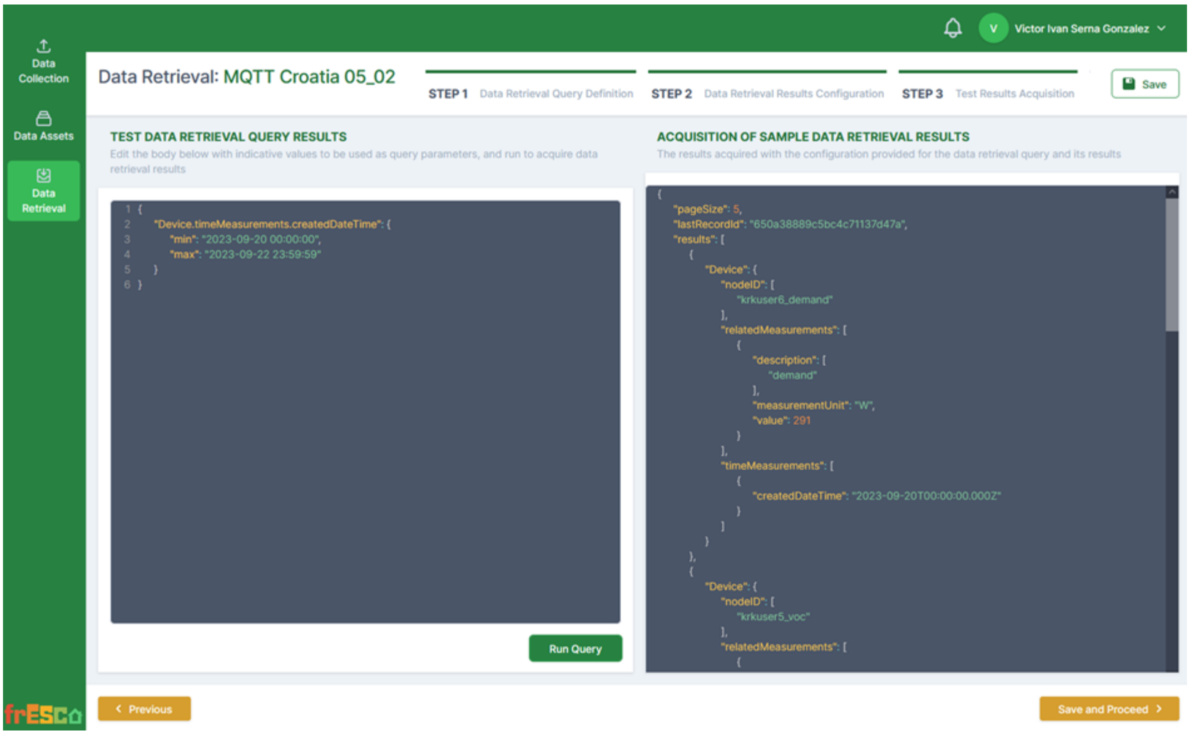

FIGURE 12: [CROATIA DEMO SITE] DATA RETRIEVAL CHECKING FOR MQTT CROATIA 05_02 DATASET

2.4.3 Data Transmission path from BDMP to APP developers.

<u>**Retrieving data for Personalized Energy Analytics and Human-Centric Automation tool**</u>

For retrieving the data form the BDMP for Personalized Energy Analytics and Human-Centric Automation tool, several data retrieval queries were created in the BDMP. In the Figure 13 an example of the creation process for one of the variables needed in the Croatia demosite can be seen.

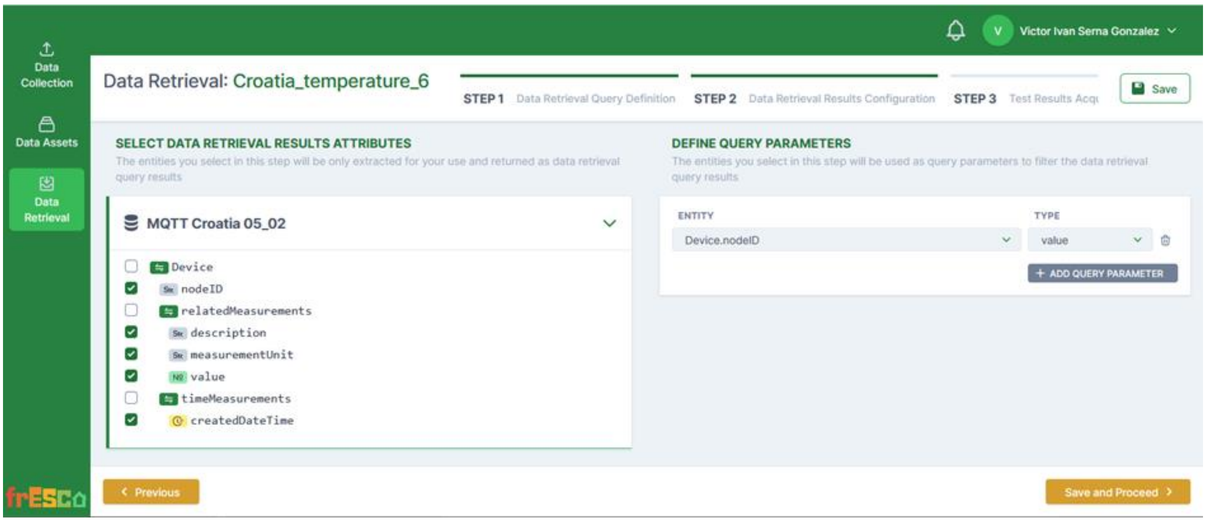

Figure 13: [Croatia Demo Site] Example of a data retrieval creation process for one variable

2.4.3.1 Getting data and Control commands for automation.

The control commands arrive at the designated MQTT topic. At that point a callback is activated at the Energybox to read the message and reroute the command to the appropriate device via Modbus or MQTT. The apps then have to wait for feedback on the data channel to see the outcome of the activation.

2.4.3.2 API Restful.

<u>**API RESTful for Personalized Energy Analytics and Human-Centric Automation tool**</u>

Once this has been configured, the application uses the API generated in the BDMP for accessing to the variable values needed for running the algorithms. The API used in the example is the following:

https://fresco.s5labs.eu/api/query/3c8d6fbb-f198-4fc4-99a8-c0692b6e3fe5?Device.nodeID=krkuser6_temperature&pageSize=2&orderDirection=DESC&orderBy=Device.timeMeasurements.createdDateTime

Configuring all the data retrievals needed, the connection between the application and the BDMP is ensured.

2.4.3.3 Data Model Structure (datasets), retrieval Data Base content.

For the Personalized Energy Analytics and Human-Centric Automation tool, several API were used. In Figure 14 a picture with the list of all APIs created for the Croatian demo site are displayed.

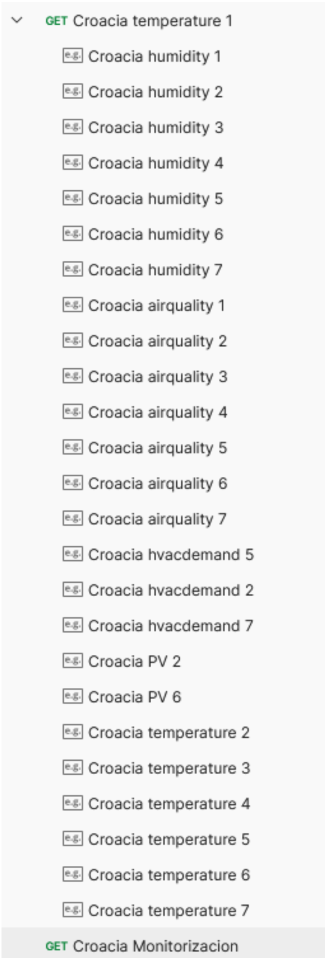

FIGURE 14: [CROATIA DEMO SITE] APIS FOR THE PERSONALIZED ENERGY ANALYTICS AND HUMAN-CENTRIC AUTOMATION TOOL

All the API can be grouped in two sets:

i. API for long term energy consumption monitoring: this API is used to retrieve the last few hours energy consumption data for all the users from the Croatian demo site. The API is called every five hours and the data is stored in a local DB for fast access when the user accesses the tool. The structure of the data is as in Figure 15:

```
-
{
    "Device": {
        "nodeID": [
            "krkuser1_demand"
        ],
        "relatedMeasurements": [
            {
                "description": [
                    "demand"
                ],
                "measurementUnit": "W",
                "value": 0
            }
        ],
        "timeMeasurements": [
            {
                "createdDateTime": "2023-08-20T00:00:00.000Z"
            }
        ]
    }
},
```


FIGURE 15: [CROATIA DEMO SITE] ENERGY CONSUMPTION DATA STRUCTURE

ii. API for status check: these API include humidity, air quality, energy production and HVAC consumption check. All these API retrieve the last one or two data from the different sensors installed in the user's dwelling and are stored in the local DB for fast access when the user accesses the tool and for time tracking. These APIs are called every few minutes. The data structure is as in Figure 16.

```
{
    "Device": {
        "nodeID": [
            "krkuser4_humidity"
        ],
        "relatedMeasurements": [
            {
                "description": [
                    "humidity"
                ],
                "measurementUnit": "%RH",
                "value": 59.5
            }
        ],
        "timeMeasurements": [
            {
                "createdDateTime": "2023-09-26T04:35:00.000Z"
            }
        ]
    }
},
```


FIGURE 16: [CROATIA DEMO SITE] SENSORS' STATUS DATA STRUCTURE

2.4.3.4 Other External Sources (Weather Data, Demo Tariffs)

For the Croatian pilot's requirements, external sources are used to gather weather-related information, which is then utilized for the frESCO applications.

With the Data Collection API method provided by the Big Data Management Platform, a job that collects data every 15 minutes is created. The corresponding dataset created, and its characteristics are displayed in Figure 17 below, while in its data structure and the related concepts and fields used can be seen in Figure 18.

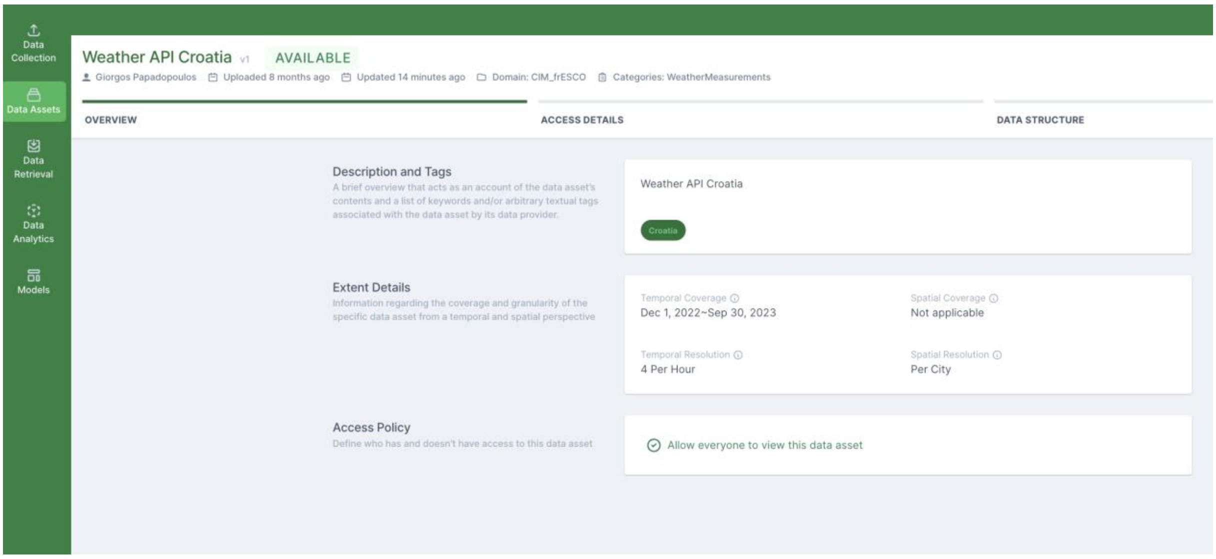

FIGURE 17: [CROATIA DEMO SITE] THE WEATHER DATASET DETAILS

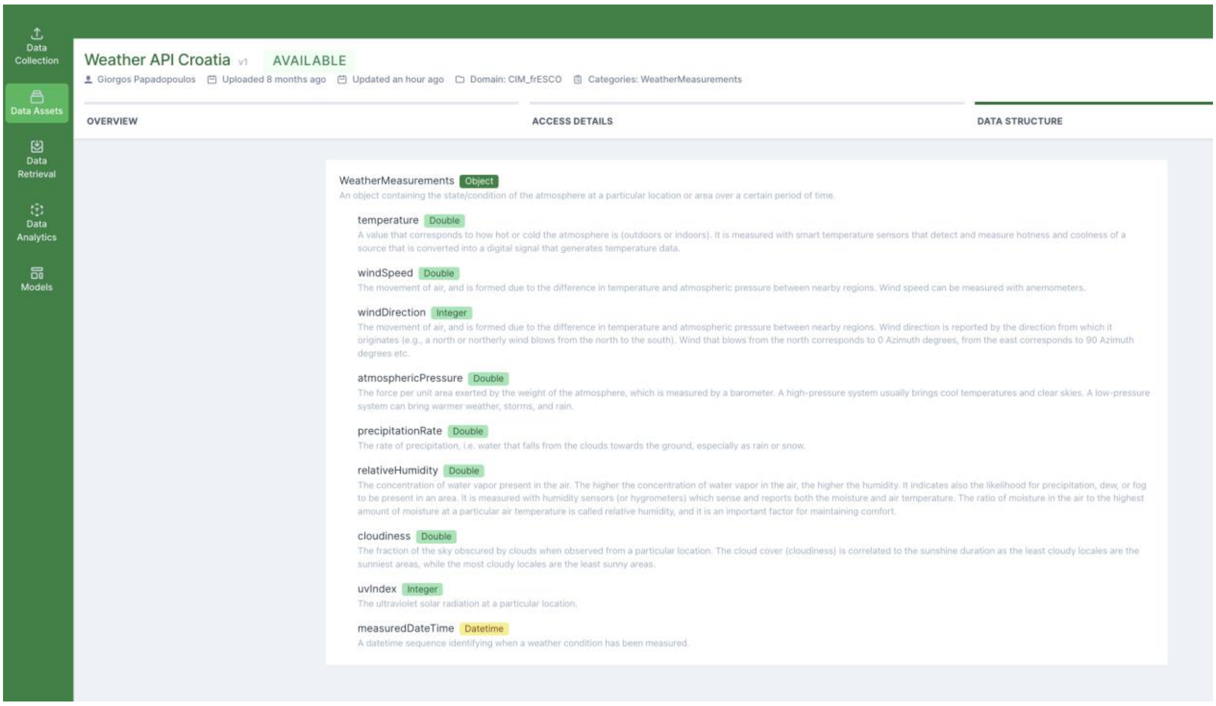

FIGURE 18: [CROATIA DEMO SITE] WEATHER DATA STRUCTURE

To retrieve weather data from the applications, users should make use of the search and retrieval creation functionalities provided by the Big Data Management Platform. Within the platform, users have the flexibility to select the fields they wish to retrieve and define query parameters for the retrieval process. An illustrative example of the data obtained through an API GET request is presented in Figure 19.

```
{
"WeatherMeasurements": {
        "temperature": 8,
        "windSpeed": 3.1111111111111107,
        "windDirection": 130,
        "atmosphericPressure": 208083.8568,
        "precipitationRate": 0,
        "relativeHumidity": 49,
        "uvIndex": 1,
        "cloudiness": 0,
        "measuredDateTime": "2023-01-31T17:20:13.000Z"
}
```


FIGURE 19: [CROATIA DEMO SITE] WEATHER DATA RETRIEVAL USING THE API GET REQUEST

Alongside the weather data collected within the BDMP, the Croatian demo tariffs are also uploaded to the platform using the file collection method. Hourly static values per month can be accessed by the application through the API retrieval functionality. Figure 20 provides an illustrative example, presenting the hourly tariffs for the Croatian demo site throughout the month of January.


```
{
  "TariffProfile":{
    "relatedLocation":[
      {
        "countryName":"Croatia"
      }
    ],
    "creationDate":"2023-06-01",
    "startDateTime":"2023-01-01T00:00:00.000Z",
    "endDateTime":"2023-01-31T00:00:00.000Z",
    "hourlyFixedCost":[
      0.0958,
      0.0958,
      0.0958,
      0.0958,
      0.0958,
      0.0958,
      0.0958,
      0.1338,
      0.1338,
      0.1338,
      0.1338,
      0.1338,
      0.1338,
      0.1338,
      0.1338,
      0.1338,
      0.1338,
      0.1338,
      0.1338,
      0.1338,
      0.1338,
      0.1338,
      0.0958,
      0.0958
    ]
  }
}
```


FIGURE 20: [CROATIA DEMO SITE] TARIFFS DATA RETRIEVAL USING THE API GET REQUEST

2.4.3.5 Keycloak tool as centralized point of access to different users.

In the frESCO project, Keycloak has been used as a common platform for prosumers, ESCOs and aggregators to create and manage users' accounts. Keycloak has been utilized with the objective of having the same authentication credentials and ease the definition of the relationships between users and their characteristics. The users can be assigned to three different roles (*aggregator*, *esco* and *prosumer*) and three countries (*croatia*, *greece* and *spain*). Depending on the role selected, users can access the different dashboards developed in the frESCO project (*Prosumers Dashboard*, *Aggregators Dashboard*, *Smart Contracts Dashboard* and *ESCOs Dashboard*), and once logged in each of them, they will see personalized information related to their user. More information about Keycloak is included in deliverables D5.7 and D5.8 of this project.

In the Croatian pilot site, the *Croatian* option has been selected when defining the users. Nine different users have been created: one aggregator, one ESCO and seven prosumers.

2.4.3.6 Data retrieval proof and Commands for control.

In this section, two screenshots from the database are included. In them, it can be seen how the energy consumption data from one of the users is stored (Table 6) and how the data from the status check is saved (Table 7).

	id	energy_power	year	month	day	hour
1	1	0	2.023	9	25	1
2	2	0,0003333333	2.023	9	25	2
3	3	0	2.023	9	25	3
4	4	0	2.023	9	25	4
5	5	0	2.023	9	25	5
6	6	0,00075	2.023	9	25	6
7	7	0,251	2.023	9	25	7
8	8	0,001	2.023	9	25	8
9	9	0,1620277778	2.023	9	25	9
10	10	0	2.023	9	25	10
11	11	0,0005	2.023	9	25	11
12	12	0,0005	2.023	9	25	12
13	13	0,00075	2.023	9	25	13
14	14	0	2.023	9	25	14
15	15	0,0005	2.023	9	25	15
16	16	0	2.023	9	25	16
17	17	0	2.023	9	25	17
18	18	0	2.023	9	25	18
19	19	0	2.023	9	25	19
20	20	0,001	2.023	9	25	20
21	21	0,001	2.023	9	25	21
22	22	0	2.023	9	25	22
23	23	0	2.023	9	25	23

TABLE 6: [CROATIA DEMO SITE] ENERGY CONSUMPTION DATA IN THE DB

	id	user_notification_id	value_past	value_present	created_datetime	action_recommended	update_datetime
1	41	111	0	261,77	2023-09-26 07:25:00.000 +0200	[v]	2023-09-26 07:36:12.039 +0200
2	40	110	170,06	248,14	2023-09-26 07:25:00.000 +0200	[v]	2023-09-26 07:36:12.033 +0200
3	51	109	0	0	2023-09-26 04:25:00.000 +0200	[ ]	2023-09-26 07:38:43.410 +0200
4	50	108	0	0	2023-09-26 04:25:00.000 +0200	[ ]	2023-09-26 07:38:42.906 +0200
5	49	107	0	0	2023-09-26 04:25:00.000 +0200	[ ]	2023-09-26 07:38:42.406 +0200
6	42	106	2.159,2	2.015	2023-09-26 07:05:00.000 +0200	[v]	2023-09-26 07:37:14.415 +0200
7	43	105	181	181	2023-09-26 04:05:00.000 +0200	[ ]	2023-09-26 07:37:14.422 +0200
8	44	104	112	117	2023-09-26 07:05:00.000 +0200	[ ]	2023-09-26 07:37:14.427 +0200
9	45	103	256,5	242	2023-09-26 07:05:00.000 +0200	[ ]	2023-09-26 07:37:14.432 +0200
10	46	102	66	73,33	2023-09-26 07:25:00.000 +0200	[ ]	2023-09-26 07:37:14.438 +0200
11	47	101	248	243,5	2023-09-26 07:25:00.000 +0200	[ ]	2023-09-26 07:37:14.443 +0200
12	48	100	216	215	2023-09-26 07:25:00.000 +0200	[ ]	2023-09-26 07:37:14.448 +0200
13	52	99	56,5	56,6	2023-09-26 07:05:00.000 +0200	[ ]	2023-09-26 07:40:28.032 +0200
14	53	98	51,2	51,2	2023-09-26 04:05:00.000 +0200	[ ]	2023-09-26 07:40:28.041 +0200
15	56	97	57	57,5	2023-09-26 07:00:00.000 +0200	[ ]	2023-09-26 07:40:28.056 +0200
16	57	96	59,7	60,4	2023-09-26 07:05:00.000 +0200	[ ]	2023-09-26 07:40:28.065 +0200
17	58	95	61,1	61,3	2023-09-26 07:05:00.000 +0200	[v]	2023-09-26 07:40:28.070 +0200
18	54	94	66,6	66,5	2023-09-26 06:40:00.000 +0200	[v]	2023-09-26 07:40:28.045 +0200
19	55	93	60,8	61	2023-09-26 07:05:00.000 +0200	[v]	2023-09-26 07:40:28.051 +0200
20	59	92	24	23,9	2023-09-26 06:40:00.000 +0200	[v]	2023-09-26 07:21:58.954 +0200
21	60	91	23,5	23,5	2023-09-26 03:45:00.000 +0200	[v]	2023-09-26 07:21:58.962 +0200

TABLE 7: [CROATIA DEMO SITE] SENSORS' STATUS DATA IN THE DB

2.5 Problems raised during commissioning.

Though the equipment has been chosen with care and to adapt to the site, a part of the equipment required skilled and certified electricians. For example, the smart meter or a smart relay must be installed in the dwelling switchboard on a DIN rail. This is, naturally, impossible to do without cutting off the main electricity supply to the dwelling.

On the other hand, the software configuration requires skills that are often not available with the electrician teams. The Croatian project team has developed a "checklist" for the installed to work with the installer team, to minimize the effort needed to make the equipment collect the data.

FIGURE 21: [CROATIA DEMO SITE] DWELLING INSTALLATION PROCEDURE AND INSTALLED SMART RELAYS AND SMART METERS

The deployment consisted therefore on installing and powering up the sensors, and then configuring the gateways according to the checklist that verifies whether the gateway is operational and sends the data to the Krk data aggregator.

FIGURE 22: [CROATIA DEMO SITE] DEVELCO SQUIDLINK GATEWAYS INSTALLED AND CONFIGURED

The gateway utilized is the Develco Squid.link 2X. It is using an open Linux platform and supports multiple wireless protocols for communication with sensors, smart plugs, smart meters, thermostats, and more. Within the Croatian pilot, Zigbee communication is used to communicate with the Develco sensors.

2.5.1 Gateway and local (in-dwelling) data flow installation challenges

The gateway has an ARM Cortex CPU and allows building and configuration of its firmware using Buildroot. In the Croatian pilot it runs a customized firmware that adds VPN and remote-control functionality to the devices. A custom tool for Modbus communication for the two user locations where solar panel inverters are available is added as well.

Even with these careful plans and the efforts not to bother site owners, we have had to visit several sites multiple times. In one case there has been a damaged meter, and debugging, final diagnostics and replacement took at least 3 site visits. In another case, the installation of the smart meter had to be corrected and reconfigured. In several cases, the VPN connection of the gateway has not been operational, which required an additional visit to reconfigure and reboot the gateway.

The principal takeaway is that the technology maturity that aims to be used in the end user dwellings must be very high. At the minimum, large scale deployments to end user facilities require the maturity to be at the level of Internet routers. The internet routers typically utilize the TR-069 protocol for their remote management and configuration. Effectively, these routers, or the "customer premises equipment", if the wired connection to the dwelling is operational so there is no need for interventions on its connectivity, require no user input and no manual configuration and collect their configuration from the wire entirely.

This is why the user can receive the router in the mail, connect it the power source and to the wired communication network and start using the Internet connection. Currently, home automation and IoT data collection solutions are not at this level nor is there a standard, especially when controllable assets are added into the equation. While in recent years significant efforts have been made, however the current situation is not quite favourable, and this has been very visible in the management and execution of the Croatian pilot as well.

In one end user case, we have also had a case of damaged equipment with a smart meter that started operating unreliably before it stopped operating entirely. Debugging this issue has been very hard – as it seemed as if the meter drops out of Zigbee connection. After two site visits, the meter stopped responding entirely and was replaced.

2.5.2 Official DSO smart meter data access challenges

Another problem has been with securing the data of the official energy meters in Croatia. The Croatian DSO, HEP ODS, is the only entity that performs metering for all the energy suppliers in Croatia. This means the HEP ODS is the designated metering operator and owns all the assets.

The first of the two problems are numerous electromechanical meters in Croatia. The smart meter rollout is in progress in Croatia but many users still have the electromechanical ones and these, by their nature, only allow manual readout. For the willing participants that have had the technical viability, we have secured the three phase Develco smart meters and installed these on the DIN rails of their switchboards. However, this is prohibitively expensive at scale, both because of the equipment and because of the installation and power cutting costs.

The second problem is related to data access: where the smart meter is actually installed in the dwelling, obtaining the measurements from the meter is challenging, even though AA legislative obligations imply that the DSO *should* allow the users to retrieve the raw data from the meters. At this point, HEP ODS does not a data hub-like solution to retrieve the data and the internal data processing does not allow this.

HEP ODS does have a data portal where the measurement point owner can utilize the credentials for the government site "e-Građani" (e-Citizens in Croatian) and retrieve the measurement data. However, for residential users, the typical frequency of data storage is once per month only, even though the meters do collect 15-minute values. The values in this portal are only available after the billing cycle – essentially, these should be the same values are used to issue the monthly bill by the selected energy supplier to the end user.

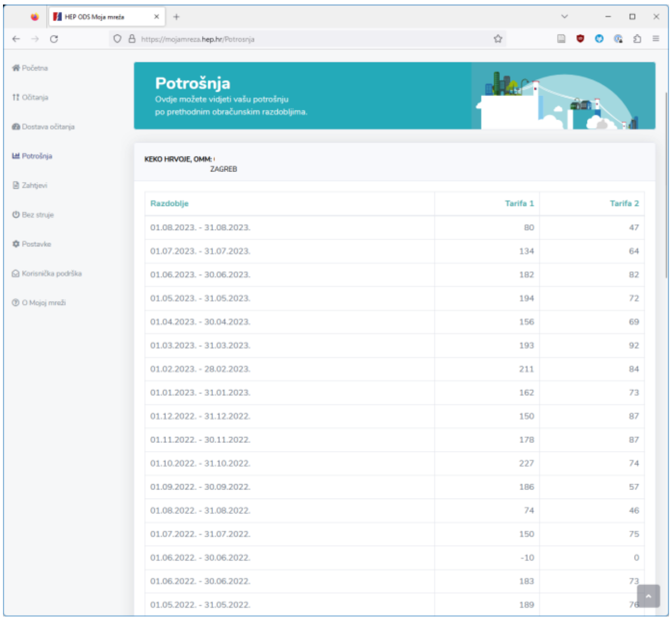

FIGURE 23: [CROATIA DEMO SITE] HEP ODS PORTAL "MOJA MREŽA" SHOWING THE MONTHLY CONSUMPTION

Additionally, to use this data from third party end users there is an additional problem as the portal currently does not allow generating any kind of access token to delegate the data export. The only way to extract the data from the site is to impersonate the actual user, and as the credentials are the same as the ones used for e-Citizenship portal, this is challenging.

However, it must be said that there have been promising developments in the last months on the data availability on behalf of the DSO. As one of user sites is shared with a DSO pilot project where a cost-effective hardware solution reads the user port of the meter directly, and then submits the metering values to the cloud. The DSO is piloting this solution that allows the end user to exfiltrate the data through the meter's data port and is compatible with most of the smart meters deployed in Croatia. It is reasonable to expect that this, if sanctioned by the DSO, would open the data sourced at the DSO meter which would be highly beneficial for frESCO solutions as well – as the important data would be available at virtually no added cost. If deployed at scale, this would be a quite attractive proposition for the frESCO solutions.

Although this technology has not been mature enough to be utilized within the frESCO project, overall the direction the DSO in Croatia is moving regarding the end user data openness can be seen as promising for the frESCO solutions.

2.6 Site Workshop

The Croatian site workshop meeting has been scheduled for July 25th, 2023 – just in time before the peak summer season in August. Due to the increased interest of end users, we have decided to hold the meeting and present the pilot situation to the end users, and have them involved in the process of pilot site completion more actively.

These have been the participants of the meeting:

- Leila Luttenberger Marić, Hrvoje Keko (Končar Digital)
- Mateo Kirinčić, Alen Gržetić, Zdenko Kirinčić (Smart Island Krk)
- User representatives for End Users 1, 2, 3, 4, 5, 6 and 7

The meeting has been held as Teams virtual meeting. As described earlier, the Croatian pilot is specific as the pilot site end users do not participate in the project itself, unlike any other pilot in frESCO. For this reason, in the initial part of the meeting some recapitulation has been presented by SIK and KONČAR teams. The meeting has been orchestrated and moderated by Mateo (SIK).

The frESCO project overall framework and the developments have been presented. Focusing on the pilot specifics, Leila (KONČAR) has presented the process of selection of the end users and the mapping of these pilot users and their usage pattern importance. This has been an important point of this meeting: to refresh the importance of their participation for the project. Hrvoje (KONČAR) has continued the presentation with a focus on the technical specifics of the Croatian pilot.

A significant interest from the end users has been related to data management – so the anonymization and data aggregation has been described in detail. To increase the activity of the end users, and to allow the users to monitor the operation of the pilot equipment themselves, Končar partners have installed a Grafana-based visualization of live collected data. This has also been shown to the end users. This serves as a manual debugging tool for the situations when the data value chain fails so the users themselves detect this and alert Končar and Smart Island Krk. It is a passive tool, just showing a part of the collected data, but still enough to detect if some of the equipment is not operational.

Finally, the materials used by CARTIF and Suite 5 have been utilized to illustrate the developments of frESCO project. Overall, the interest has been notable, especially in light of the recent increase of coverage in the Croatian media on the energy communities, energy sharing and similar topics.

The workshop has been held in Croatian language, with the materials developed by partners mostly in English with explanations provided by Smart Island Krk and Končar teams.

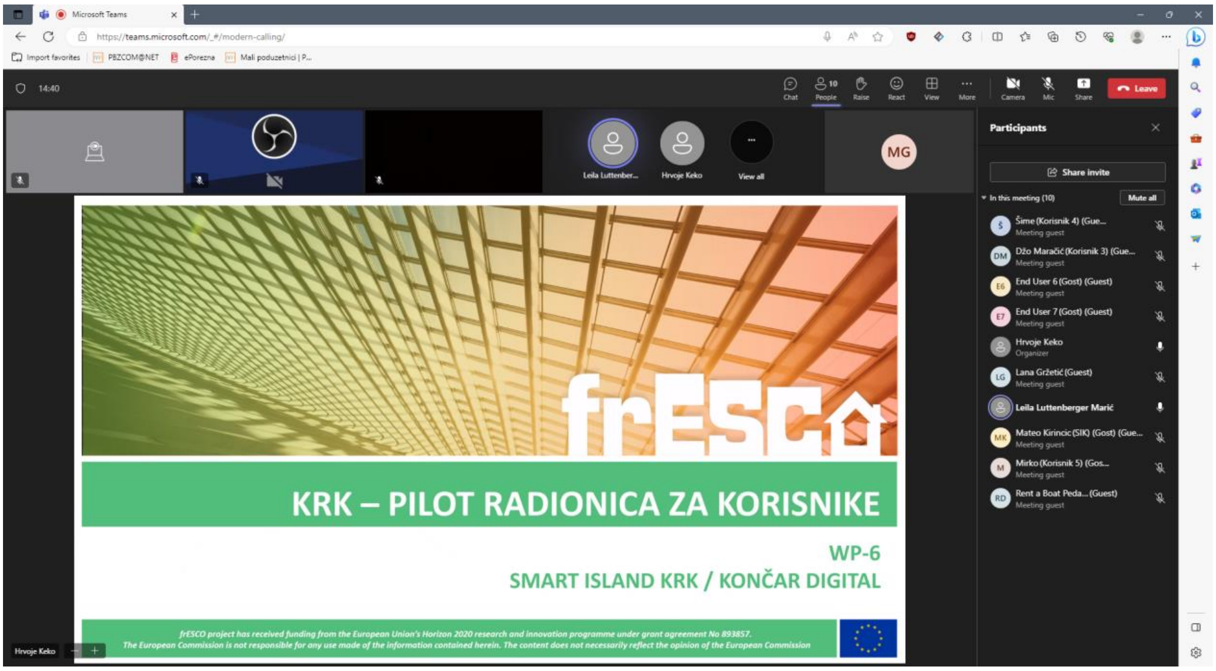

FIGURE 24: [CROATIA DEMO SITE] DEMO WORKSHOP INTRODUCTION

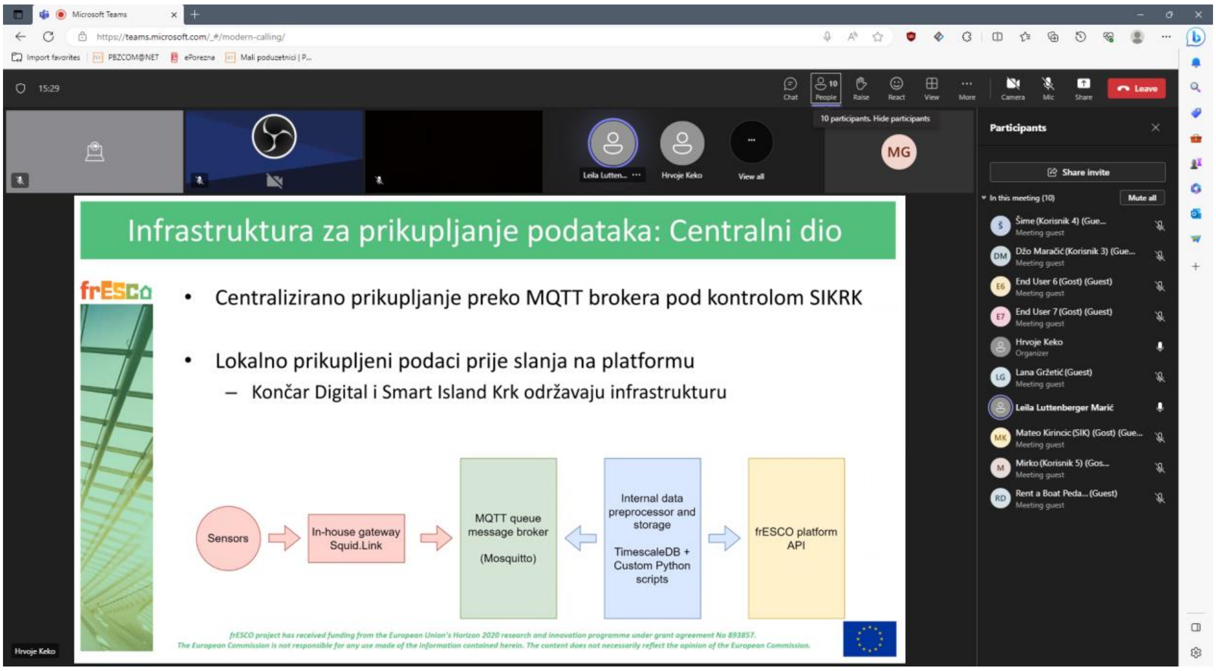

FIGURE 25: [CROATIA DEMO SITE] EXPLANATION OF THE GENERAL SOFTWARE ARCHITECTURE AND DATA MANAGEMENT RESPONSIBILITIES

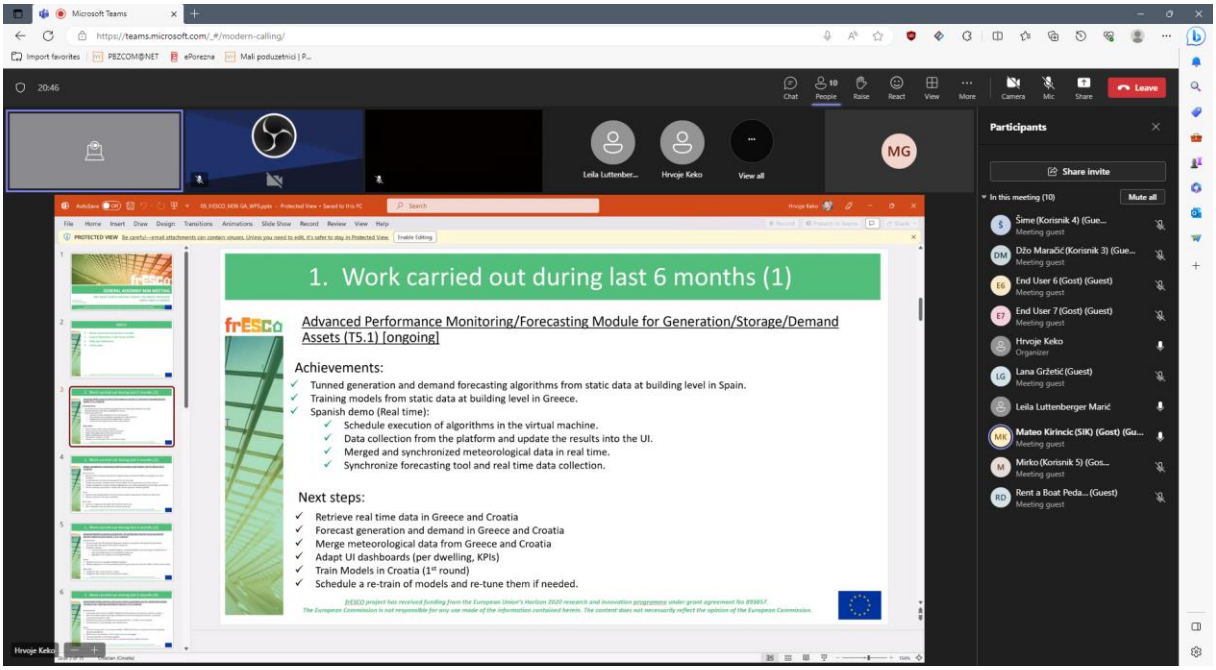

FIGURE 26: [CROATIA DEMO SITE] DEMO WORKSHOP PRESENTATION OF THE WP5 TOOLS

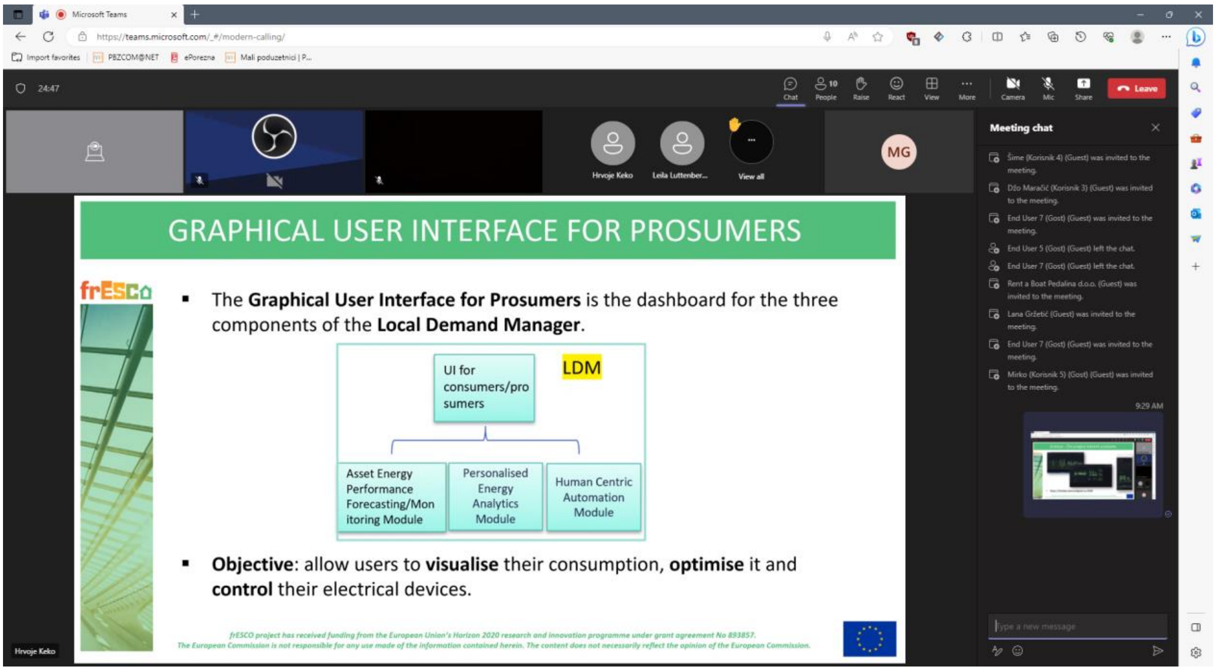

FIGURE 27: [CROATIA DEMO SITE] DEMO WORKSHOP PROSUMER LDM PRESENTATION

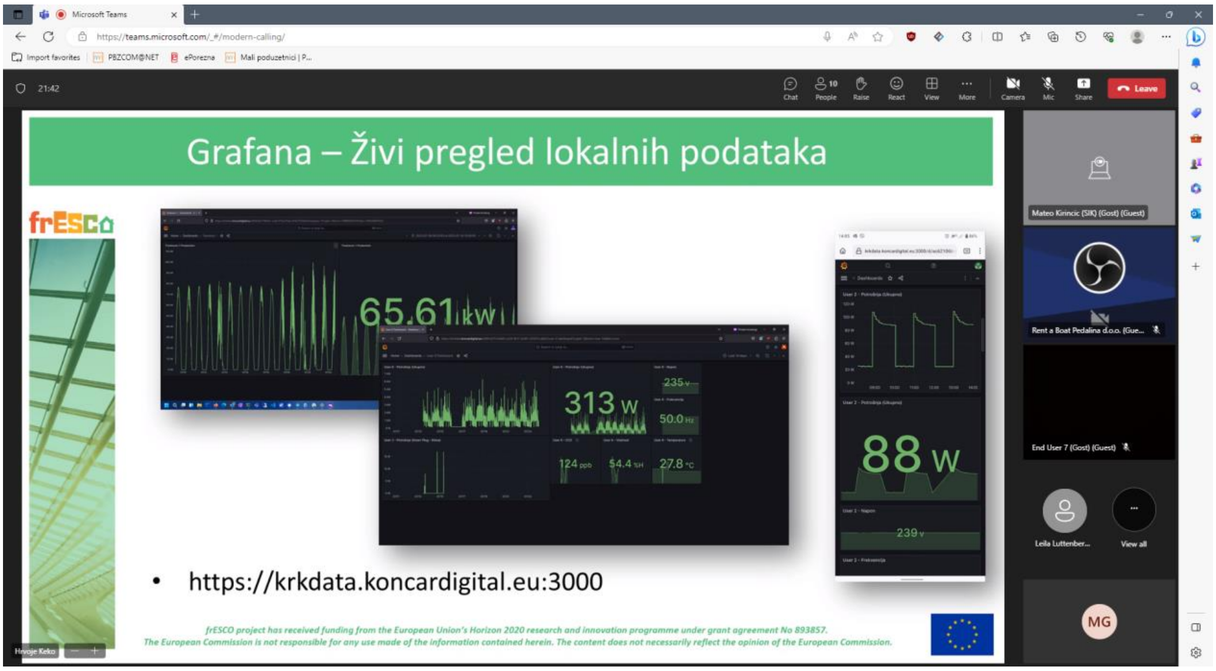

FIGURE 28: [CROATIA DEMO SITE] GRAFANA TOOL TO DEBUG THE DATA INGESTION PROCESS AND VISUALIZE THE RAW DATA DEMONSTRATION

3 GREEK PILOT SITE

The Greek Demo Site is located at a vacation resort in Thasos. Thasos is an island in the north of the Aegean Sea and its coordinates are [40°46'14.4"N 24°43'33.1"E (40.770663, 24.725846)]. Figure 29 shows the location of the resort within Thasos while Figure 30 is a hawk eye view of the resort.

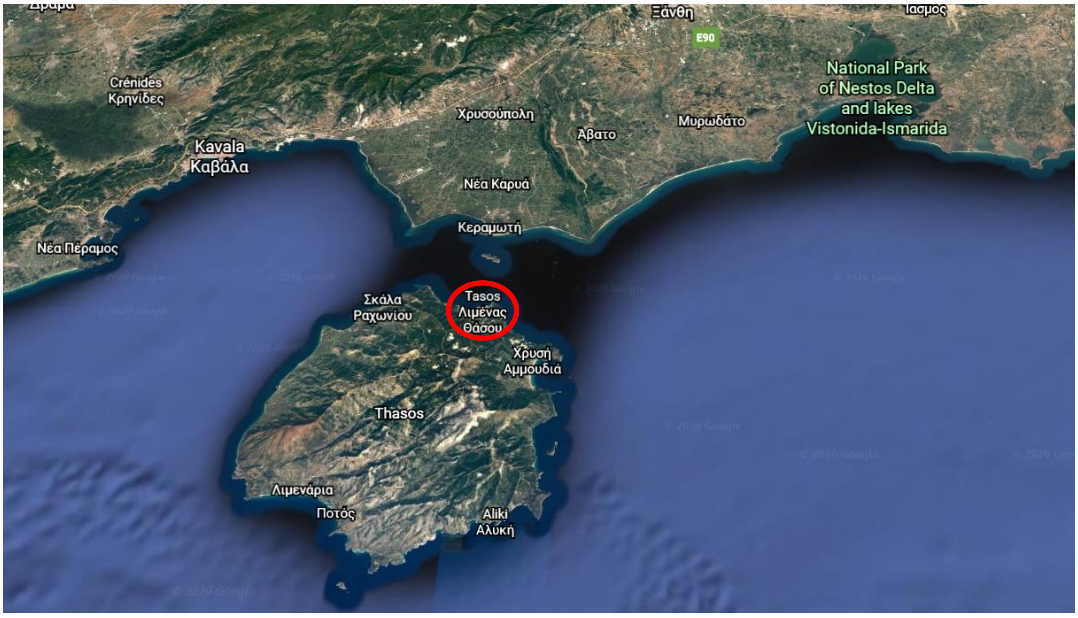

FIGURE 29: [GREECE DEMO SITE] THASOS ISLAND LOCATION

FIGURE 30: [GREECE DEMO SITE] MAKRYAMMOS HOTEL AND BUNGALOWS GENERAL VIEW

Makryammos Bungalows lies on the northern part of the island. The hotel is built on a 35 acres site, with more than 30 detached bungalows and a number of central main facilities / buildings. Three of the bungalows have been recently equipped with photovoltaic plants.

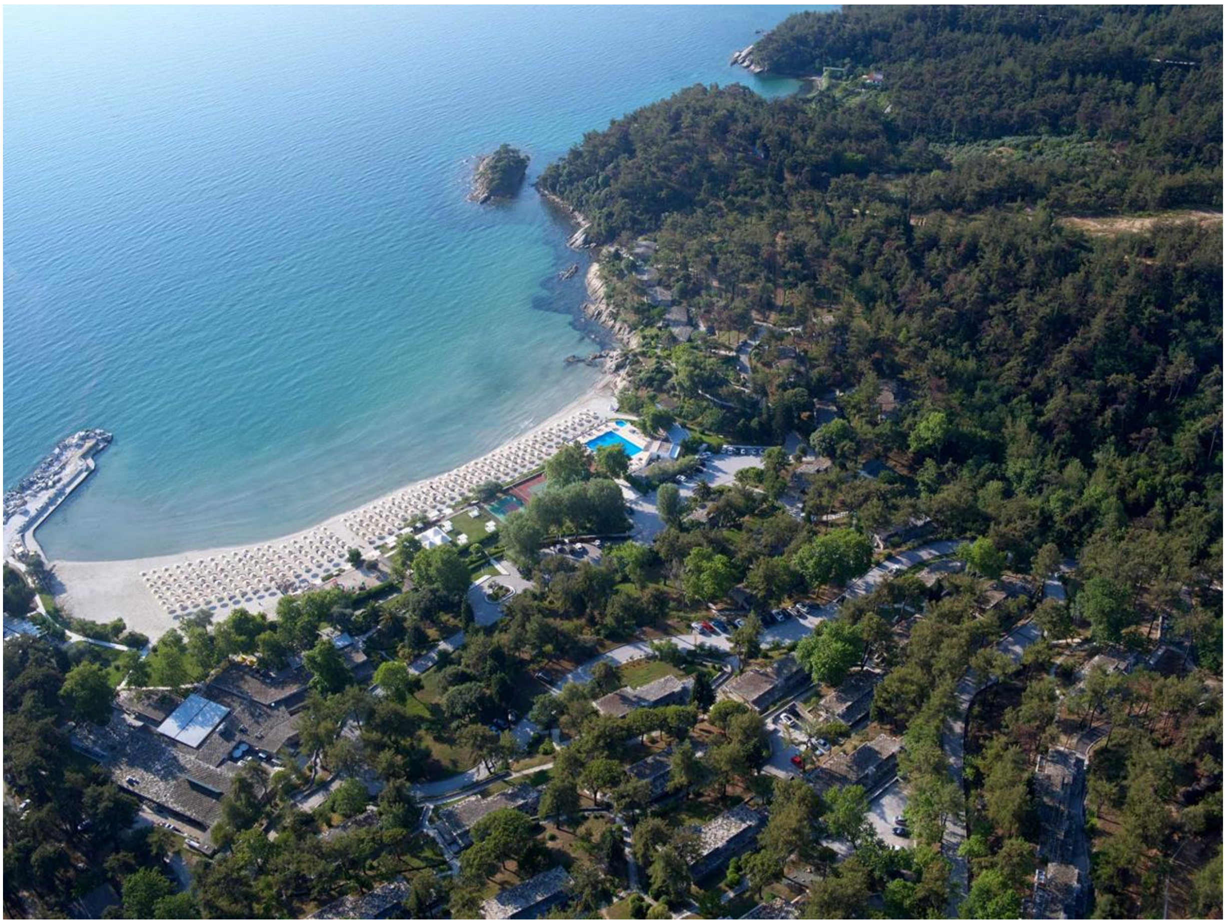

FIGURE 31: [GREECE DEMO SITE] MAKRYAMMOS RESORT VIEW

The hotel is in transition to becoming a green hotel and some challenges are to be addressed:

- Management of the renewable resources including generation and storage with the aim of maximizing the benefit while ensuring the optimal operation of the local grid.
- Management of the local storage capabilities to support the grid in case of blackout risk.

3.1 Site Overview.

The Makryammos hotel resort (Figure 31) has a seasonal schedule at summer season which means an operation of 5 months per year mostly from May to September. The hotel management aspires to transform the demo site into a green environmentally friendly hotel with renewable energy flexibility and distributed resources to minimize the carbon footprint. The hotel is equipped with a 400kVA substation and a number of bungalows, three of which are equipped with PV and batteries. The substation load is monitored along with a double EV charging point which is also installed on the site. The hotel comprises a number of loads that are mainly individual lodge loads, offices and other auxiliary services (e.g. reception building, restaurant, etc.). However, this dedicated 400kVA substation supplies only residential bungalows. The Total PV generation capacity is 50kWp. The available energy storage is composed by 3 Lithium-ion batteries with a combined total peak capacity of 24.9 kWh (Figure 32) and an 95% depth of discharge.

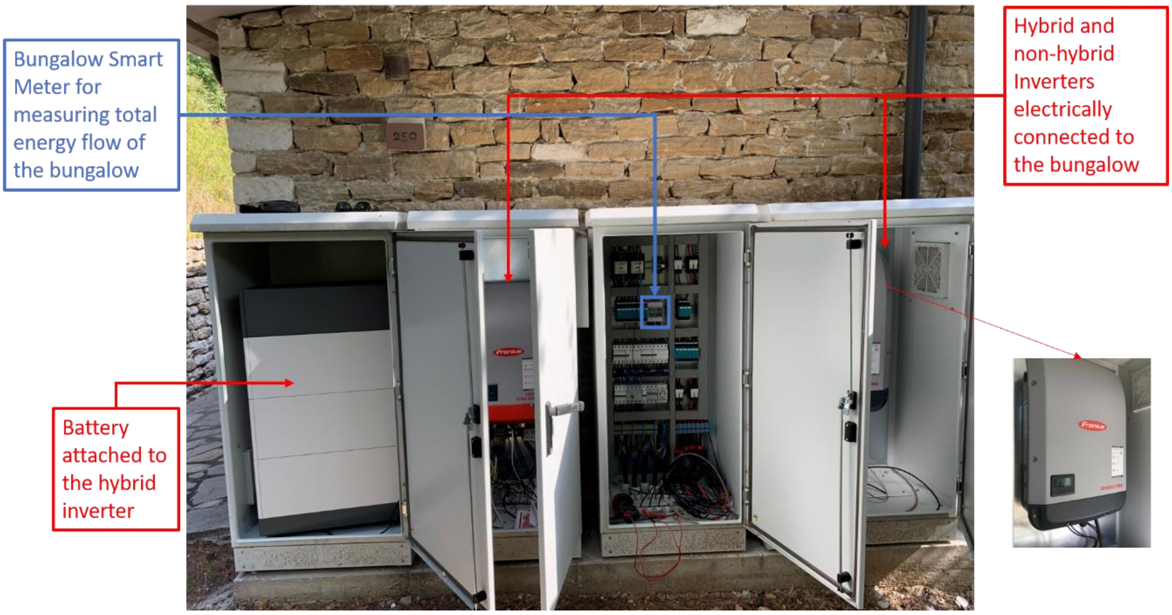

FIGURE 32: [GREECE DEMO SITE] BUNGALOW 250 ENERGY STORAGE AND PV ELECTRICAL BOARDS

These bungalows, allow the simulation of a typical small residence and also contain the advantage of gauging different user approaches on the same infrastructure. Bungalow 250 has been chosen as a reference building for testing the frESCO services. Bungalow 250 is comprised of five distinct apartments. Common facilities like PV system, Battery or DHW, were integrated in the pilot as electrical production/ load assets.

The key electrical assets in Bungalow 250 are divided in three categories.

1. **Consumption Assets:**

- *Electric Cooling System (A/C units):* Decentralized cooling devices of 13,25 kW total power and a nominal efficiency of 6,2 (5 in total 1 for each apartment).
- *Electric Heating System:* A/C unit, it is not expected to be used as a heating device.
- *Electric Domestic Hot Water (w/Thermal Storage):* Currently there are 3 centralized electric domestic hot water systems of 12 kW power each plus a 300 L storage tank. 2 of the Systems serve 2 apartments each (apartments 251-252 and 253-254 respectively) and the last DHW System serves Room 255.
- *Automated Lighting:* The type of lighting used is LED.

2. **Generation Assets:**

- *Rooftop PVs:* 54 PV solar panels of 350 Wp on an area of 88,02 m^2 on the roof of the bungalow, with a total output of 18,90 kWp and an annual production of 17950 kWh/year.
- The PV system is electrically integrated with a Fronius Symo on grid inverter (12 kW) and a Fronius Symo hybrid inverter (5 kW).

3. **Storage Assets:**

- *Battery Storage:* Currently an 8,3 kWh lithium-ion storage system with useable capacity of 7,8 kWh and a max charge/discharge power of 2,6 kW.

The energy produced from the solar panels covers directly the consumption of the bungalow 250 five rooms and any surplus energy is stored in the battery system. In case the battery is full and there still is a surplus of energy, it is directed to another hotel loads or to the grid.

FIGURE 33: [GREECE DEMO SITE] ROOF OF THE BUNGALOW, PV PANEL'S VIEW.

Domestic Hot Water (DHW) is provided by 3 electrical boilers that each contain a 300-liter tank and operated under a 12-kW load. Water can be heated up to 60°C. 2 of the boilers service 2 apartments each while the third boiler services a single apartment. Colling of the apartments is achieved via decentralized AC units with a total cooling power of 2.65 kW each. Additional home appliances are present in each apartment such as refrigerators, roof ventilators, TV appliances and coffee machines.

FIGURE 34: [GREECE DEMO SITE] BUNGALOW 250 GENERAL VIEW

A smart meter is installed on the 250-bungalow premises and monitors consumption in an aggregated view. For the frESCO demo, additional meters as well as other control equipment were installed. Specifically, smart DIN-rail meters were installed in each apartment's electrical board to permit isolation, lights in the apartments were replaced with controllable bulbs and smart relays were applied to the DHW boilers as well as the AC units.

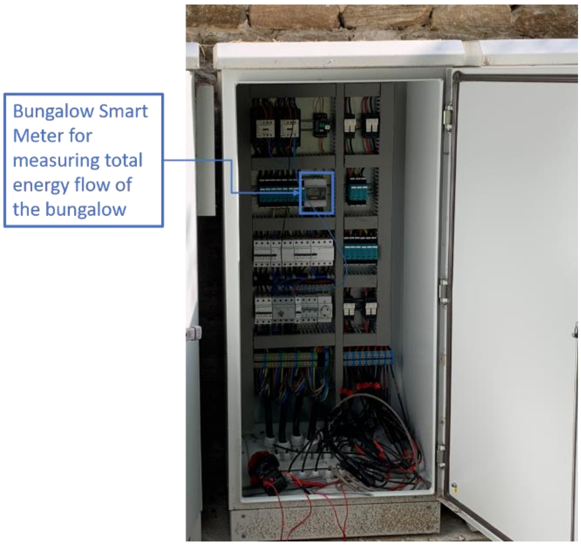

Figure 35: [Greece Demo Site] Bungalow 250. Smart meter installed on it.

Use cases concerning the Greek demo site involve controlling DHW, cooling and lighting devices. The testing goals include Energy Efficiency in seasonal touristic buildings, PV-self consumption optimization, service suitability in touristic facilities with uneven occupancy levels and non-energy services.

Bungalow 250 hosts a significant number of guests per season with an average booking per apartment of 107 nights per season. In every night an average of 2 adult users and 0.5 child users are hosted.

Bungalow 250	Nights	Adults	Children
Room 251	101	212	44
Room 252	109	218	76
Room 253	105	203	44
Room 254	120	245	43
Room 255	99	198	41

Table 8: [Greece Demo Site] Bungalow 250. Average Booking per room

An overview of the main characteristics for Bungalow 250 are the following:

Param.	Units	Physical Demo
Dwellings	Un	5
Average User/Dwelling	Un	2.5
Total Bungalow users	Un	1,324

Avg. Electricity	kWh/year	9,000
Avg. Natural Gas	kWh/year	N/A
Investment	€	3,300
PV System	kWh/year	17,950

TABLE 9: [GREECE DEMO SITE] SUMMARY PILOT CHARACTERIZATION

3.2 Mapping Devices Installation (sensors, energy meters, gateways, Ebox…).

The equipment deployed in the Greek Demo Site is comprised by the following units:

- **Motion & Temperature Sensor:** Motion Sensor Mini – Monitor room activity, light, and temperature (develcoproducts.com)

The wireless Motion Sensor Mini is a compact multi sensor with Zigbee wireless protocol technology, that detects occupancy, light, and temperature. Five (5) such sensors were deployed (one per apartment).

- **Humidity Sensor:** Humidity Sensor – Monitor temperature and humidity (develcoproducts.com)

As the Motion sensor, the Humidity sensor operates under the Zigbee standard. Five (5) such sensors were deployed (one per apartment).

- **Control relays Ex9CH20:** NOARK Electric

NOARK control relays are used to connect the three boilers and five AC units that are at the pilot (One relay per boiler). A total of 8 controllable relays were installed.

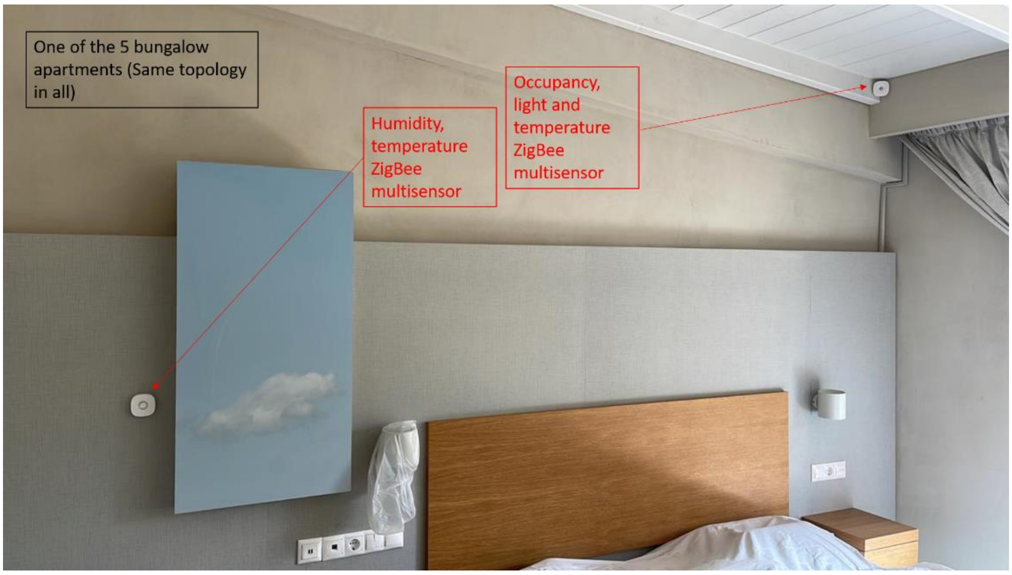

FIGURE 36: [GREECE DEMO SITE] SENSOR INSTALLATION ROOM VIEW

- **Energy Analyzers:** Orno Energy Meter

Device for making indications in kWh with the possibility of remote reading registers of indicators, via a wired network of RS-485 standard. A special electronic circuit, by the flow of current and applied voltage generates pulses in proportion to the energy consumed. Phase energy consumption is signalled by LED flashing. The number of pulses is converted into energy input and its value is indicated on the LCD display. RS-485 port is used for remote reading of electricity. One analyser was installed per room and one additional analyser was installed in the HVAC system of room 253.

- **Zigbee Smart Plugs (**Monitor and Control Electrical appliances**):**

The smart plugs were installed to serve as Zigbee network nodes, in order to increase Zigbee network range to all apartments within the bungalow. The plugs were installed in sockets that never lose power, regardless of guest presence in the room and thus ensure a stable Zigbee node for the other Zigbee equipment.

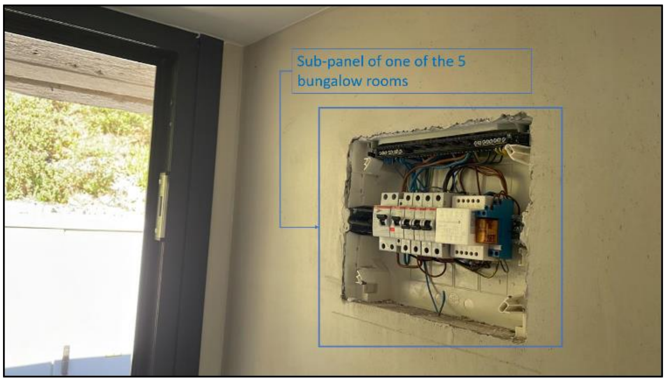

FIGURE 37: [GREECE DEMO SITE] ELECTRICAL PANEL PER ROOM

- **Ampero Modbus relay:** module MOD-8I8RO

The Ampero Modbus relay was installed to interconnect the Noark relays with the Energy Box through the latter's RS485 port with twisted-pair wire. This module communicates with all commercially available PLCs and other devices that support popular Modbus Master protocol.

- **Zigbee Gateway:** Squid.link 2X

Two Develco Zigbee gateways were deployed to improve Zigbee network connectivity issues with the installed Ebox. The Squid.link is an all-in-one gateway that connects IoT devices and enables end-users to monitor and control appliances via their IoT system. The Squid.link 2X is an open Linux platform including multiple wireless protocols for communication with sensors, smart plugs, smart meters and thermostats.

- **General Gateway:** Energy Box

The CIRCE Energy Box is an integrated solution that controls and monitors energy in real time. It is an intelligent multi-user controller capable of managing intelligent devices in real-time use (residential, industrial) to mediate the integration of various communication technologies. it is a Smart Home Gateway/ EMS module, enabling end-to-end interoperable communication between the control centre of the service provider and individual smart home devices (through sensors and actuators). One Energy Box was installed that managed signals from the Bungalow Inverters and Smart Meter, as well as Energy analysers installed in each apartment. A summary of the installed equipment can be found bellow:

Devices	Units	Physical Demo
Energy Meters	Un	6
Temperature Sensor	Un	5
Humidity Sensor	Un	5

Motion Sensor	Un	5
Actuator (relay)	Un	8
Gateways (Develco)	Un	2
E-Box	Un	1
Smart Light bulbs	Un	10 (2 per room)

Table 10: [Greece Demo Site] List Equipment Installed

3.3 Enabled Assets available for Flexibility.

Flexibility events are responses from the demand side to signals from an aggregator according to DSO/ TSO requirements. Infrastructure to support flexibility events include smart plugs and smart relays with control capabilities. Storage can also be used to respond to flexibility events - depending on the battery State of Charge. The Greek demo case included the following assets:

Param.	Units	Physical Demo
HVAC	Un	5 AC units
DHW	Un	3 Boilers
Battery Storing System (BSS)	Un	Not applicable as it refers to the bungalow and not the users

Table 11: [Greece Demo Site] Collection of Flexibility Assets

Due to the type of the facility being a holiday resort and since consent and reaction from temporary guests was not applicable, no flexibility actions are anticipated by the direct end-users. Especially in the case of the boilers that would have a significant impact due to their capacity, the shared asset between rooms increased the complexity. Hotel guests are temporary users that are quite disinterested in sacrificing comfort and ideal conditions for the short time of their stay and leisure.

The DHW infrastructure (3 boilers) as well as the 5 HVAC (5 AC units), were equipped with the necessary control equipment, to support the hotel specific use cases. However, a dedicated energy meter should be added to be able to measure and verify flexibility and build flexibility forecasts.

3.4 Digital Communications

The local system architecture is presented in the following diagram. Various communication protocols are exploited both wired (Ethernet, Modbus TCP and Modbus RTU) and Wireless (Zigbee, Wi-Fi)

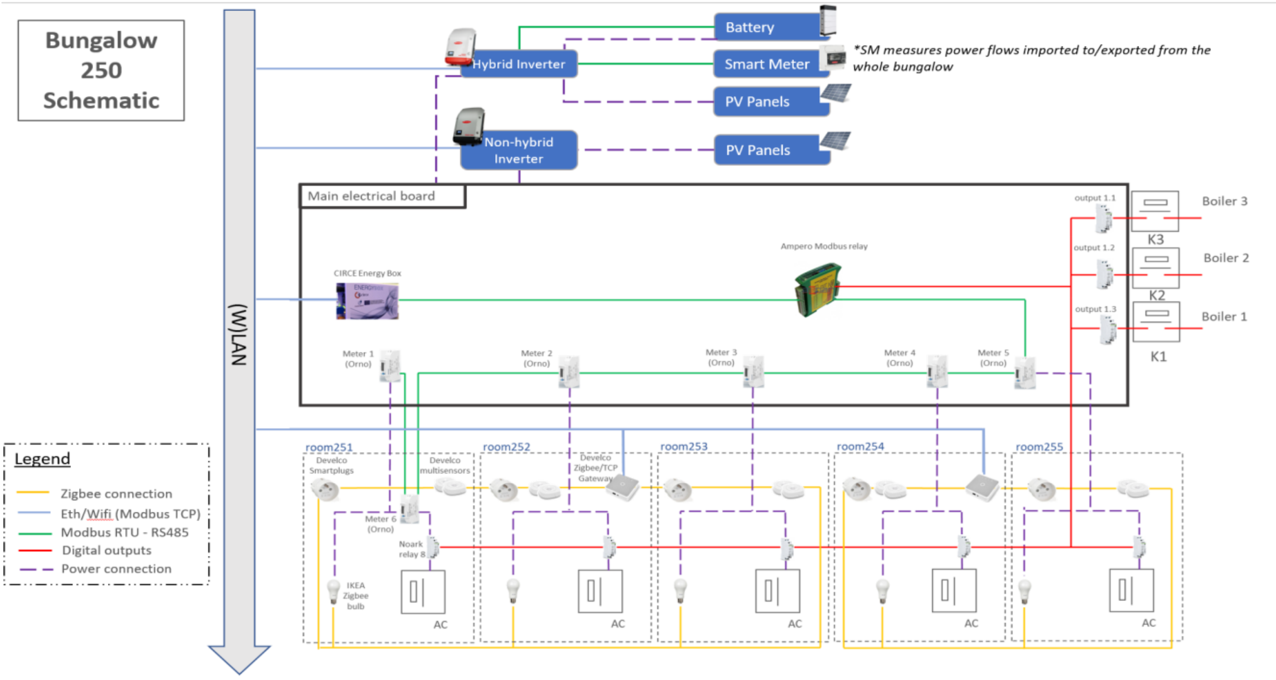

FIGURE 38: [GREECE DEMO SITE] PHYSICAL CONNECTION GENERAL DIAGRAM

3.4.1 Data Transmission path from sensors, E-box to BDMP

The EB has devices connected to it both using Modbus RTU and Modbus TCP. This communication layer is abstracted so that all devices are managed exactly the same way. In practice, the main control loop from the EB reads periodically data from all the devices and stores it in a temporary buffer and into a local csv. At periodic intervals the EB writes the last data from the buffer of each device into the MQTT topic for the BDMP converting it into a standard json file in the process.

3.4.1.1 MQTT Component.

In the case of the EB the MQTT component is part of the communication layer which is almost completely decoupled from the device control layer. You can configure multiple instances of the component each communicating with a different server / topic. The MQTT component queries periodically (configurable) the list of the device controllers to get the latest data, which then communicates using a standardized json format.

3.4.1.2 Data Model Structure, MQTT content, jobs definition

The EB has a standardized json file which identifies the EB which is performing the communications and an array which describes all the devices it is controlling, and gives information about each one of them. The EB is capable of having multiple MQTT communications open, each writing to a different server/topic which is parametrizable however the streamed data content is always standard.

```
{
    "timestamp":2164318000,
    "nameEB":"fresco_Greek_Demo",
    "devices":[
        {
            "nameDevice":"RELAY01",
            "idDevice":"RELAY01",
            "values":[
        },
        {
            "nameDevice":"ANALYZER02",
            "idDevice":"ANALYZER02",
            "values":[
        },
        {
            "nameDevice":"ANALYZER03",
            "idDevice":"ANALYZER03",
            "values":[
        },
        {
            "nameDevice":"ANALYZER04",
            "idDevice":"ANALYZER04",
            "values":[
        },
        {
            "nameDevice":"ANALYZER05",
            "idDevice":"ANALYZER05",
            "values":[
        },
        {
            "nameDevice":"ANALYZER06",
            "idDevice":"ANALYZER06",
            "values":[
        }
    ]
}
```


FIGURE 39: [GREECE DEMO SITE] EXAMPLE OF MQTT JSON FILE STRUCTURE

Similar to the configuration of the Croatian demo described in chapters 2.4.2.1 and 2.4.2.2, the Greek demo also utilizes an instance of interim gateway to repackage the data coming from Develco devices. The MQTT ingestion component of the frESCO big data platform expects all the information on the messages to be contained within the message payload, while the Develco messages carry a part of the data in the MQTT topic.

To resolve this, a replica of the configuration from Croatian demo has been established by KONČAR.

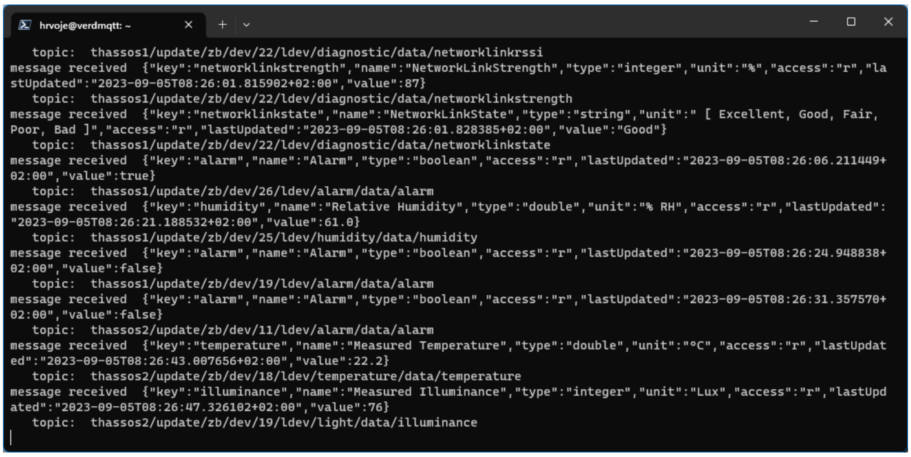

FIGURE 40: [GREECE DEMO SITE] LOG SCREEN OF MOSQUITTO MQTT MESSAGE BROKER

The following figure illustrates the components of the data repackager. It is configured so it runs on a separate instance of a virtual machine to the Croatian pilot, and it has its own SSL certificates to encrypt the data in transit. The Develco gateways installed at the Greek pilot site acquire the data from the Develco sensors via MQTT protocol, then send the data to an instance of Mosquitto MQTT broker installed on the VM. The data is subsequently consumed by a local data consumer, buffered into a TimescaleDB enabled PostgreSQL database, and finally aggregated and repackaged and sent to the frESCO Big Data Management Platform.

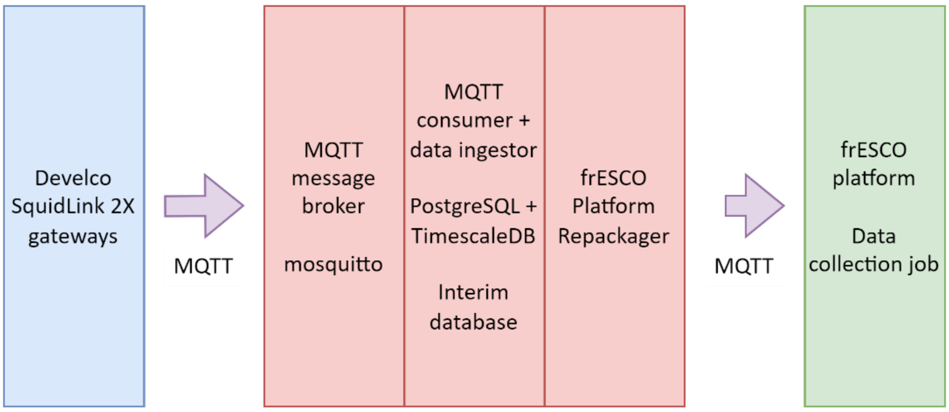

FIGURE 41: [GREECE DEMO SITE] ARCHITECTURE OF FRESCO DEVELCO DATA REPACKAGER

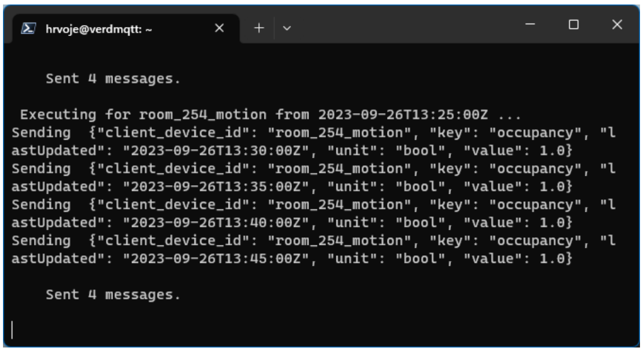

FIGURE 42: [GREECE DEMO SITE] LOG SCREEN OF MESSAGE SENDING TO THE FRESCO BDMP MQTT DATA COLLECTION JOB

3.4.1.3 Availability of Retrieved Data.

Personalized Energy Analytics and Human-Centric Automation tool uses the data from the BDMP as inputs for doing the analytics and running the different services. The first step to collect this data was to attest that the data was available in the platform and could be gathered from them.

For that the MQTT greek develco 20_04 was searched in the data assets and founded as can be seen in the Figure 43.

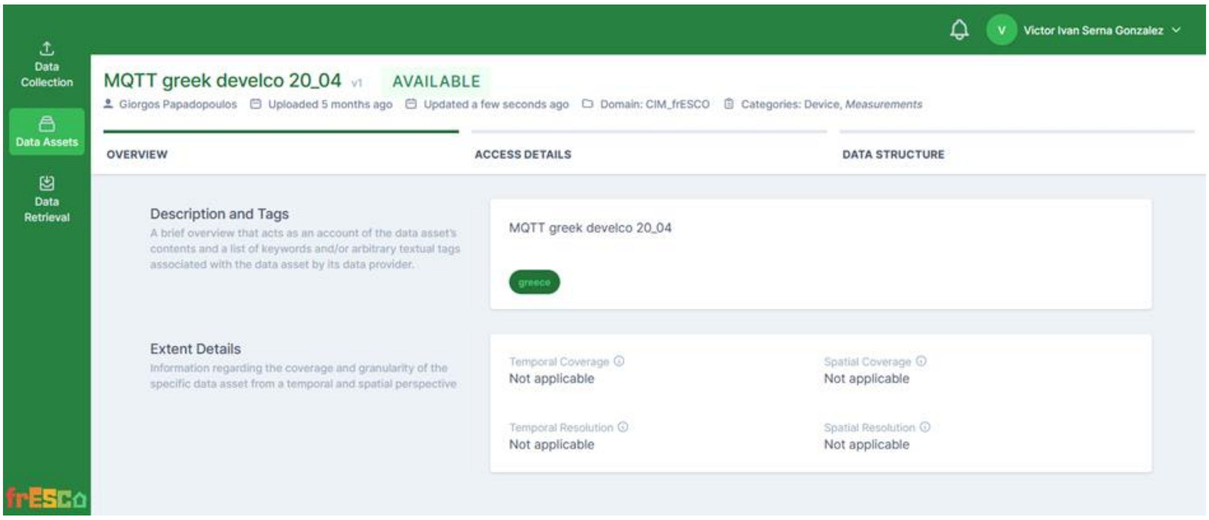

FIGURE 43: [GREECE DEMO SITE] ATTESTING OF AVAILABILITY OF MQTT GREEK DEVELCO 20_04 DATASET

Besides, a test for checking that the data is available was done thought the data retrieval section in the BDMP as can be seen in the Figure 44.

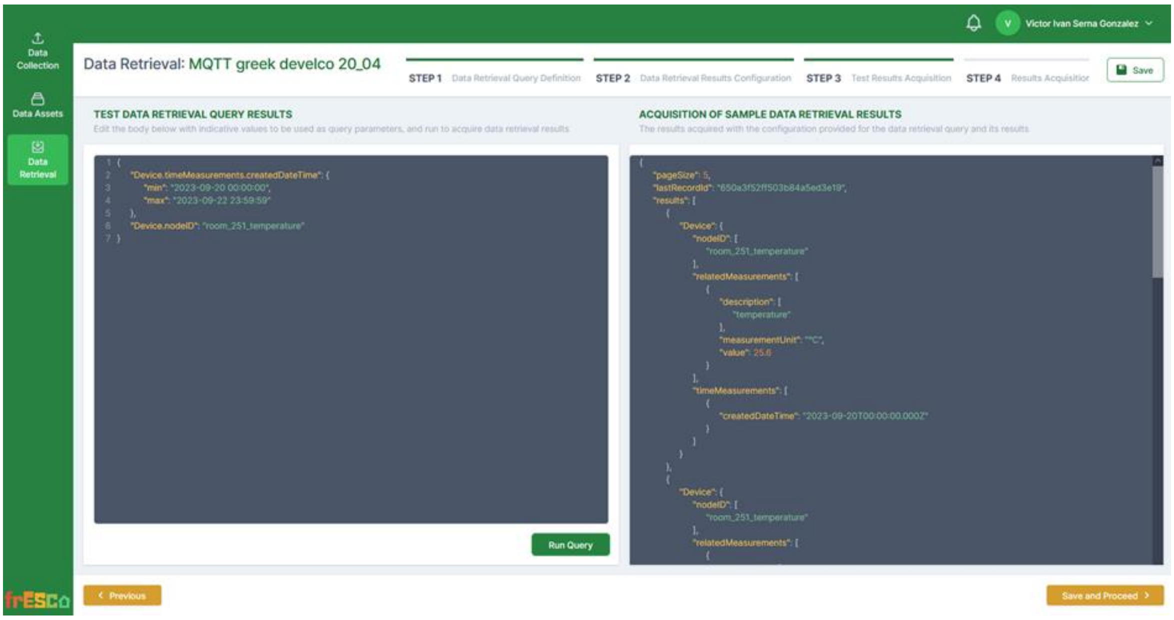

FIGURE 44: [GREECE DEMO SITE] DATA RETRIEVAL CHECKING FOR MQTT GREEK DEVELCO 20_04 DATASET

3.4.2 Data Transmission path from BDMP to APP developers.

In the case of the EB all commands are received via the MQTT command interface. Once a command is posted in the appropriate topic a callback activates in the MQTT component which parses the command and does the appropriate calls in the device controller. For example, setting a new value in a Modbus device will queue this value for update in the corresponding device controller which will be written in the Modbus channel as soon as it is available.

3.4.2.1 Getting data and Control commands for automation.

Retrieving data for Personalized Energy Analytics and Human-Centric Automation tool

For retrieving the data form the DMP for Personalized Energy Analytics and Human-Centric Automation tool, several data retrieval queries were created in the BDMP. In the Figure 45 an example of the creation process for variables needed in the Greece demosite can be seen.

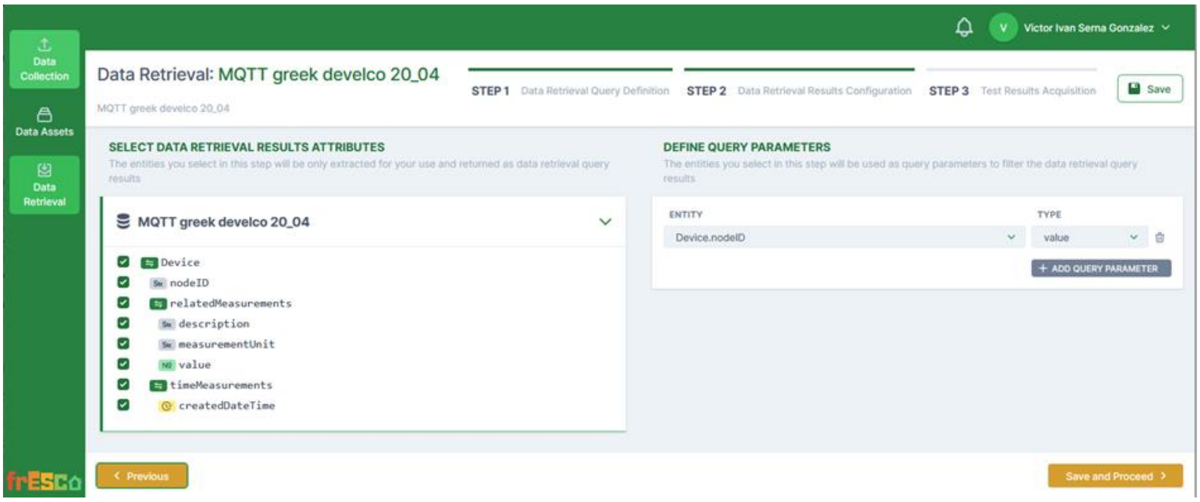

FIGURE 45: [GREECE DEMO SITE] EXAMPLE OF A DATA RETRIEVAL CREATION PROCESS

Sending automation signals from Human-Centric Automation tool

The Human-Centric Automation tool run algorithms taking into account the values collected for the sensors and the preferences configured for the user, in order to send automations signals to the controllers (mainly controlling HVAC systems and Boilers).

The way defined for connecting the controllers is through the MQTT system using a Python script as client, taking advantage of the *paho.mqtt.client* package. For connecting the Greece MQTT endpoint the information used is the following (the payload_dict changes taking into account the variable to be modified and the command to be sent):

```
host="mqtt.fresco.s5labs.eu"
client_id = "id-xxxxxxxxxxxxxxxx"
topic = "86e9957b-XXXX-XXXX-XXXX-XXXXXXXXXXXX"
payload_dict = {"nameEB":"fresco_Greek_Demo", "deviceName":"RELAY01","deviceKind":"default", "idFeed":"Output_5", "value":"true"}
```

FIGURE 46: [GREECE DEMO SITE] MQTT ENDPOINT SET UP.

3.4.2.2 API Restful.

API RESTful for Personalized Energy Analytics and Human-Centric Automation tool

Once this has been configured, the application uses the API generated in the BDMP for accessing to the variable values needed for running the algorithms. The API used can be seen in Figure 47.

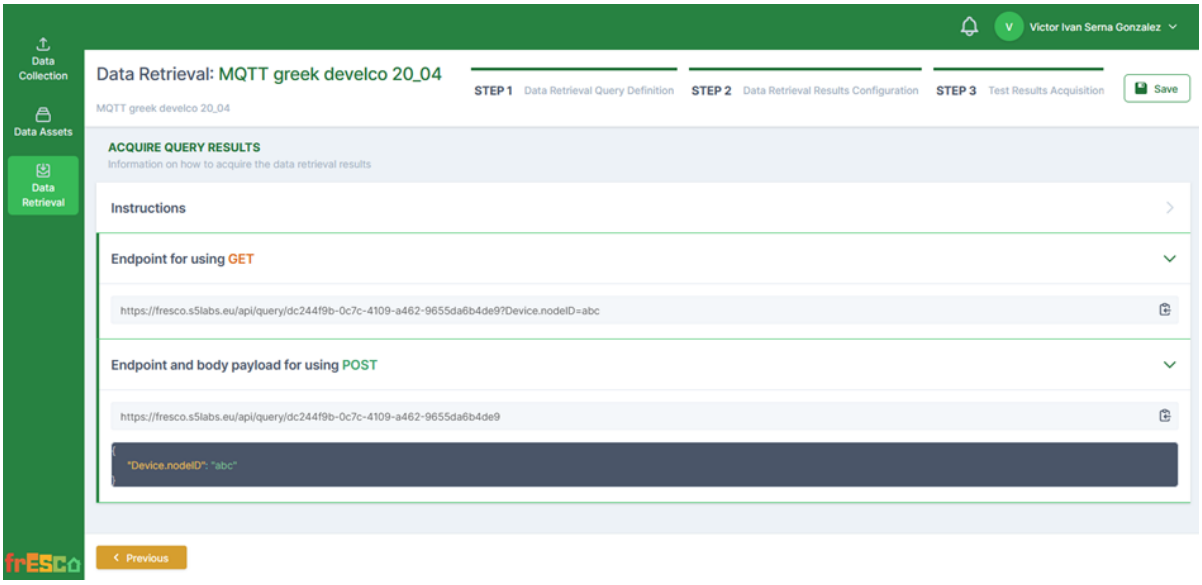

FIGURE 47: [GREECE DEMO SITE] API USED FOR RETRIEVING DATA FROM MQTT GREEK DEVELCO 20_04

Configuring all the data retrievals needed, the connection between the application and the BDMP for Greek demosite is ensured.

3.4.2.3 Data Model Structure (datasets), retrieval Data Base content.

For the Personalized Energy Analytics and Human-Centric Automation tool, three groups of APIs were used:

i. API for long term energy consumption monitoring: this API is used to retrieve the last few hours energy consumption data from each of the facilities monitored in Greece demo site. The API is called every five hours and the data is stored in a local DB for fast access when the user accesses the tool. In Figure 48 an example meant to illustrate the data structure can be seen.

```json
{
    "Building": {
        "id": "GridLocation:greece:thassos:B250:B250FH",
        "relatedEnergyMeasurements": [
            {
                "createdDateTime": "2023-09-26T06:08:19.589Z"
            }
        ],
        "relatedPhotovoltaicPlant": [
            {
                "relatedEnergyMeasurements": [
                    {
                        "power": [
                            1.193
                        ]
                    }
                ]
            }
        ]
    }
}
```


FIGURE 48: [GREECE DEMO SITE] ENERGY CONSUMPTION DATA STRUCTURE

ii. API for status check: these API include humidity, air quality, energy production and HVAC consumption check. All these API retrieve the last one or two data from the different sensors installed in the user's dwelling and are stored in the local DB for fast access when the user accesses the tool and for time tracking. These APIs are called every few minutes. The data structure is as in Figure 49.

```json
"Device": {
    "nodeID": [
        "room_251_humidity"
    ],
    "relatedMeasurements": [
        {
            "description": [
                "humidity"
            ],
            "measurementUnit": "%RH",
            "value": 68
        }
    ],
    "timeMeasurements": [
        {
            "createdDateTime": "2023-04-01T09:15:00.000Z"
        }
    ]
}
```


FIGURE 49: [GREECE DEMO SITE] SENSORS' STATUS DATA STRUCTURE

iii. API for forecasts retrieval: APIs (Figure 50) for PV generation and energy consumption forecasts were created. These APIs are called ones a day and data are used immediately for the platform and not stored in the local DB.

```
{
    "Building_id": "GridLocation:greece:thassos:B250:B250SM",
    "predictions": [
        2.511133909225464,
        4.3006110191345215,
        5.382369518280029,
        6.109615325927734,
        6.0456085205078125,
        5.038473606109619,
        3.706611156463623,
        3.005066156387329,
        2.244811534881592,
        1.2247512340545654,
        0.0943649411201477,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        1.0075218677520752
    ],
    "reportedDatetime": "2023-09-26T05:00:00.000Z"
}
```


FIGURE 50: [GREECE DEMO SITE] PV GENERATION FORECAST EXAMPLE

3.4.2.4 Other External Sources (Weather Data, Demo Tariffs)

External sources are employed to gather weather-related information tailored to the needs of the Greek pilot, and this data is subsequently used to enhance the functionality of the frESCO applications. Through the utilization of the Data Collection API method offered by the Big Data Management Platform, a data collection job is established to gather information every 15 minutes. Figure 51 provides a detailed overview of the resulting dataset and its characteristics, while Figure 52 illustrates the data structure, related concepts, and fields used.

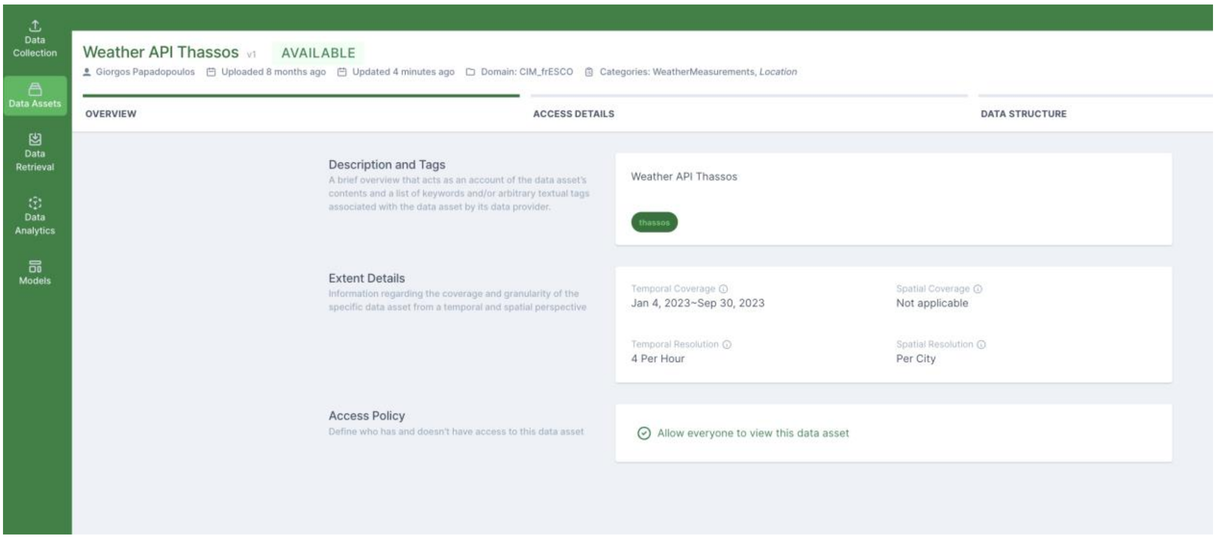

FIGURE 51: [GREECE DEMO SITE] THE WEATHER DATASET DETAILS

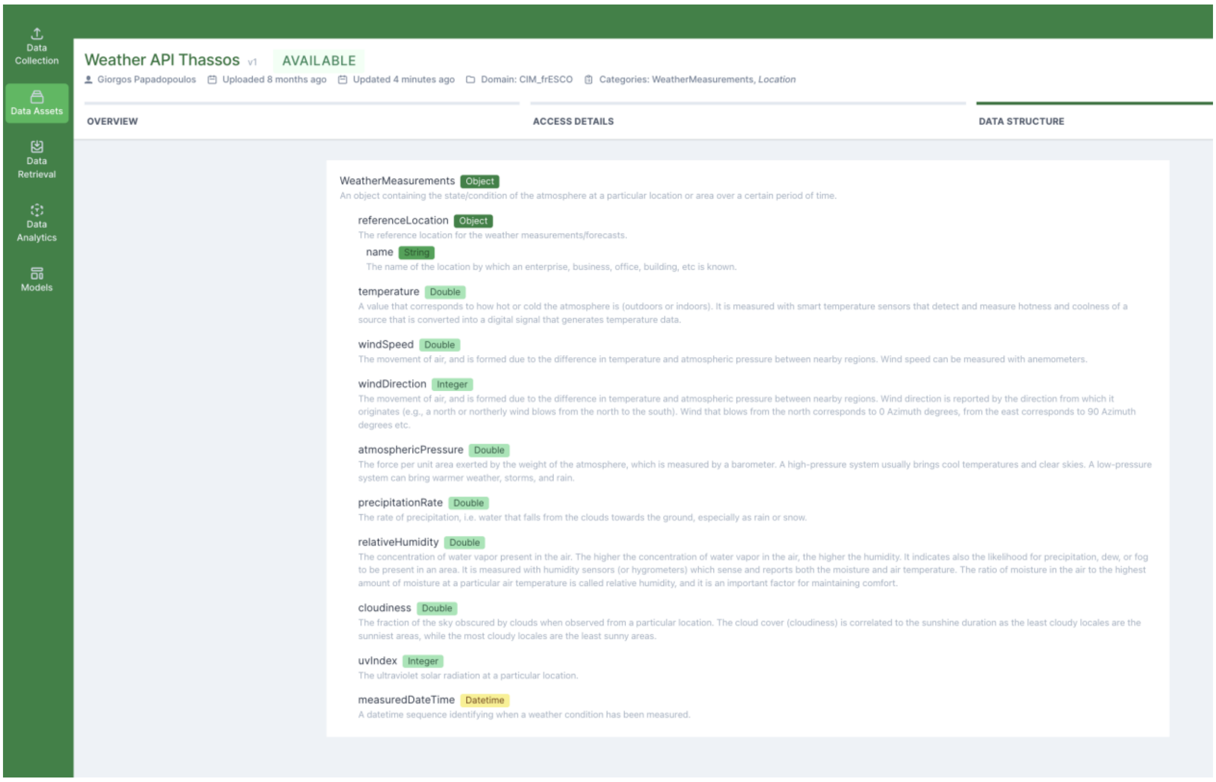

FIGURE 52: [GREECE DEMO SITE] WEATHER DATA STRUCTURE

To access weather data from the applications, users are encouraged to utilize the search and retrieval features offered by the Big Data Management Platform. Within this platform, users enjoy the freedom to specify the fields they intend to retrieve and establish query parameters to fine-tune the retrieval process. Figure 53 offers a concrete example of the data acquired through an API GET request.

```
{
"WeatherMeasurements": {
        "temperature": 21,
        "windSpeed": 4.5,
        "windDirection": 120,
        "atmosphericPressure": 205083.111,
        "precipitationRate": 10,
        "relativeHumidity": 39,
        "uvIndex": 3,
        "cloudiness": 0,
        "measuredDateTime": "2023-02-25T09:20:13.000Z"
}
```


FIGURE 53: [GREECE DEMO SITE] WEATHER DATA RETRIEVAL USING THE API GET REQUEST

In addition to the weather data stored in the BDMP, the Greek demo tariffs are similarly incorporated into the platform via the file collection method. The application can access monthly hourly static values using the API retrieval functionality. An illustrative instance is showcased in Figure 54, offering a detailed representation of the hourly tariffs for the Greek demo site during the month of December.


```
{
        "TariffProfile": {
          "relatedLocation": [
            {
              "countryName": "Greece"
            }
          ],
          "creationDate": "2023-09-01",
          "startDateTime": "2023-12-01T00:00:00.000Z",
          "endDateTime": "2023-12-31T00:00:00.000Z",
          "hourlyFixedCost": [
            0.155,
            0.155,
            0.114,
            0.114,
            0.114,
            0.114,
            0.114,
            0.114,
            0.155,
            0.155,
            0.155,
            0.155,
            0.155,
            0.155,
            0.155,
            0.114,
            0.114,
            0.155,
            0.155,
            0.155,
            0.155,
            0.155,
            0.155,
            0.155
          ]
        }
      }
```


FIGURE 54: [GREECE DEMO SITE] TARIFFS DATA RETRIEVAL USING THE API GET REQUEST

3.4.2.5 Keycloak tool as centralized point of access to different users.

In the frESCO project, Keycloak has been used as a common platform for prosumers, ESCOs and aggregators to create and manage users' accounts. Keycloak has been utilized with the objective of having the same authentication credentials and ease the definition of the relationships between users and their characteristics. The users can be assigned to three different roles (*aggregator*, *ESCO* and *prosumer*) and three countries (*Croatia*, *Greece* and *Spain*). Depending on the role selected, users can access the different dashboards developed in the frESCO project (*Prosumers Dashboard*, *Aggregators Dashboard*, *Smart Contracts Dashboard* and *ESCOs Dashboard*), and once logged in each of them, they will see personalized information related to their user. More information about Keycloak is included in deliverables D5.7 and D5.8 of this project.

In the Greek pilot site, the "*Greece"* option has been selected when defining the users. Three different users have been created: one aggregator, one ESCO and one prosumer.

3.4.2.6 Data retrieval proof and Commands for control.

In this section, two screenshots from the internal database are included. In them, it can be seen how the energy consumption data from one of the users is stored (Table 12) and how the data from the status check is saved (Table 13).

	id	energy_power	year	month	day	hour
697	697	0,0769166667	2.023	6	8	0
698	698	0,0768333333	2.023	6	8	1
699	699	0,077	2.023	6	8	2
700	700	0,0766666667	2.023	6	8	3
701	701	0,0755	2.023	6	8	4
702	702	0,07425	2.023	6	8	5
703	703	0,0744166667	2.023	6	8	6
704	704	0,074	2.023	6	8	7
705	705	0,0744166667	2.023	6	8	8
706	706	0,0746666667	2.023	6	8	9
707	707	0,0745	2.023	6	8	10
708	708	0,07475	2.023	6	8	11
709	709	0,0745833333	2.023	6	8	12
710	710	0,0750833333	2.023	6	8	13
711	711	0,07575	2.023	6	8	14
712	712	0,0753333333	2.023	6	8	15
713	713	0,0741666667	2.023	6	8	16
714	714	0,0745	2.023	6	8	17
715	715	0,0748333333	2.023	6	8	18
716	716	0,0755	2.023	6	8	19
717	717	0,07525	2.023	6	8	20
718	718	0,0764166667	2.023	6	8	21
719	719	0,077	2.023	6	8	22
720	720	0,0776666667	2.023	6	8	23

Table 12: [Greece Demo Site] Energy Consumption Data in the DB

	id	user_notification_id	value_past	value_present	created_datetime
25	62	87	20	20,5	2023-09-26 06:00:00.000 +0200
26	63	86	25	25	2023-09-26 03:45:00.000 +0200
27	39	83	22,2	22,2	2023-09-26 07:05:00.000 +0200
28	38	82	27,7	27,7	2023-09-26 07:05:00.000 +0200
29	37	81	27,4	27,4	2023-09-26 07:05:00.000 +0200
30	36	80	26,6	26,6	2023-09-26 07:25:00.000 +0200
31	35	79	25,6	25,6	2023-09-26 07:25:00.000 +0200
32	34	78	52	52	2023-09-26 07:25:00.000 +0200
33	33	77	60	60	2023-09-26 07:25:00.000 +0200
34	32	76	57	57	2023-09-26 07:25:00.000 +0200
35	30	75	61	61	2023-09-26 07:25:00.000 +0200
36	31	74	61	61	2023-09-26 07:25:00.000 +0200
37	27	73	22,2	22,2	2023-09-26 07:05:00.000 +0200
38	26	72	27,7	27,7	2023-09-26 07:05:00.000 +0200
39	25	71	27,4	27,4	2023-09-26 07:05:00.000 +0200
40	29	70	26,6	26,6	2023-09-26 07:25:00.000 +0200
41	28	69	25,6	25,6	2023-09-26 07:25:00.000 +0200

Table 13: [Greece Demo Site] Sensor's Status Data in the DB

3.5 Problems raised during commissioning.

3.5.1 Seasonality.

The hotel is characterised by seasonality in operations. Business activities typically start in mid-May and the hotel remains operational until approximately mid-October. Maintenance and preparation begin in March prior to the Holiday season window. This creates specific windows were installations and electrical interventions can take place. Intervening during peak months from a business point of view (June, July and August), is practically impossible. In addition to the abovementioned fact, during winter months, access to the facilities depends heavily on weather. It is very often impossible for the ferries to cross the straight from the mainland to Thasos and in case of heavy rain, no work can proceed, since the electrical components (inverters and smart meter), as well as the Energy Box are located in external cabinets. This has caused some delays in the deployment phase, since access to the facility was not always possible. Seasonality also impacts indirectly the actual pilot duration. Due to the fact that the apartments are occupied only in specific periods per year, consumption on an apartment or bungalow level is heavily reliant on the period under consideration. This means that regarding self-consumption optimization and energy savings presume occupancy and energy consumption in the first place. Consequently, the Energy Efficiency Services can only be tested between mid- May to Mid- October.

3.5.2 Zigbee Connectivity issues.

The basic equipment (sensors, meters and relays) was procured in August 2021 and was calibrated by CIRCE with a dedicated Energy Box within the following months. During March 2022 the equipment was initially installed electrically, and the initial Zigbee Network was set up. Unfortunately, the Zigbee module of the Energy Box failed a few weeks after the initial installation and had to be replaced with a newly calibrated Energy Box in June 2022. The Zigbee network proved unstable and sensors frequently lost connectivity to the Energy Box most probably due to signal attenuation caused by multiple thick walls separating the E-box from IoT wireless devices and the fact that the E-box was enclosed within a metallic pillar for safety reasons. In order to overcome this technical obstacle, extra equipment had to be deployed (smart plugs) and connected to sockets that would not switch off when the guests left the apartment taking entry card with them.

FIGURE 55: [GREECE DEMO SITE] DEVELCO GATEWAY VIEW

Unfortunately, this mitigation plan was proven unsuccessful to address frequent disconnections. To ensure the stability of the network, additional gateways were deployed in two intermediate apartments (Develco SquidLink). These intermediate devices served as the Zigbee gateways and communicated with the Energy box via the Wi-Fi infrastructure.

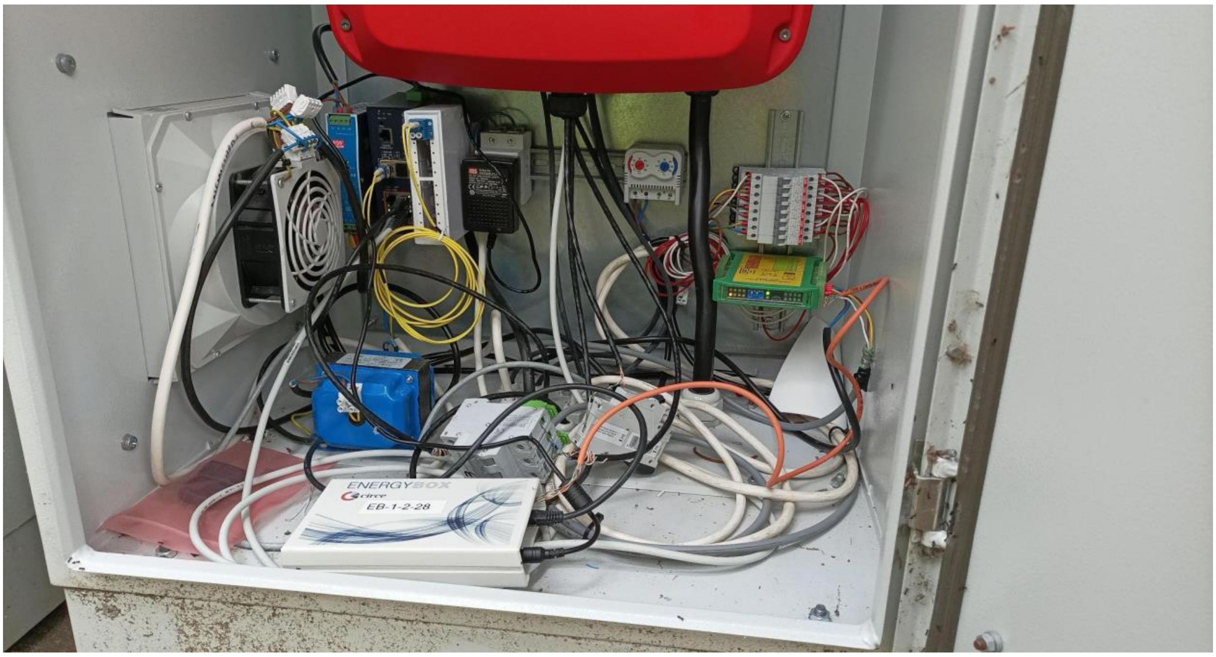

FIGURE 56: [GREECE DEMO SITE] BUNGALOW CABINET WITH ENERGY BOX AND AMPERO RELAY

3.6 Site Workshop.

The Site Workshop for the Greek pilot took place on May 18th, in the sidelines of the M36 General Assembly meeting and relevant site visit. During that period, the applications were not fully deployed and integrated with the data coming from the demo sites, but the Greek demo workshop served as a first user acceptance test regarding the features and the information provided to the end user.

The hotel itself presented different use cases in comparison to the other demo sites, since the end user in this case is the hotel management and not the guest, for the reasons described in chapter 3.3.

FIGURE 57: [GREECE DEMO SITE] SITE WORKSHOP VIEW

The aim of the workshop was to present the functionalities of the applications and receive initial feedback from the Hotel management and relevant staff.

The ESCO toolkit was presented by UBITECH. In the Greek demo site, VERD (now MOH) undertakes the role of the ESCO, regarding energy management and savings. Discussion revolved around direct presentation of savings (in €) as a KPI explicitly presented. In addition to the direct savings, a methodology was discussed that included the usage of the PV production, the forecasts of production and consumption and the State of Charge (SoC) of the storage system, in order to maximize self-consumption optimization via leveraging different Time-of-Use (ToU) tariffs. This methodology was realized and deployed across the ESCO toolkit. The Aggregator toolkit was also presented, with a focus of smart contract creation, execution, and monitoring.

FIGURE 58: [GREECE DEMO SITE] SITE WORKSHOP HELD IN THASOS

The prosumer toolkit was presented by CARTIF. The prosumer toolkit, is the interface between the frESCO solution and the end user, allowing the latter, not only to monitor consumption and production levels (in case of a prosumer), but also schedule and control devices. Services deployed specifically for the hotel use case are AC automatic control or scheduling, boiler automatic control and scheduling and temperature monitoring services.

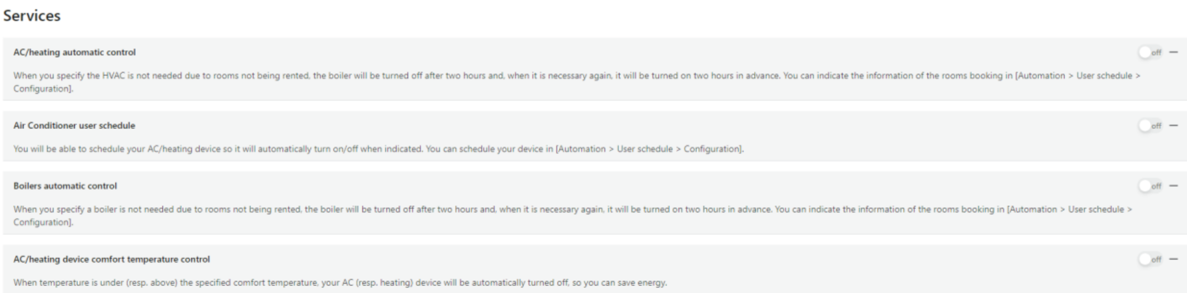

FIGURE 59: [GREECE DEMO SITE] HOTEL SERVICES - PROSUMER TOOLKIT.

Three Hotel participants took part in the workshop (from both operations as well as technical perspectives).

Feedback was directly received from the end-users regarding functionalities and platform navigation concerns. Finally, a representation of the cost of energy by the utilization of actual consumer tariffs was agreed in this first frESCO Workshop and is now fully adopted across pilots.

4 SPANISH PILOT SITE

The demo site is a multi-apartment-building located in a residential neighbourhood called Almendrales, in the city of Madrid, at a distance of 4.70 km from the city centre (Plaza Mayor) at an elevation of 575 m above sea level.

The building, built in 2019, contains a total of 17 apartments that can be reached via a central staircase. Community areas consist of a kitchen and an area for events, room for children recreation, car park, garbage collection and laundry room. The building has the shape of a quadrilateral, with the Northern and Western sides adjacent to other buildings.

In particular, the apartments involved (about 61 to 83 square meters each) are owned by members of the Eco-social cooperative Entrepatios and are part of multi-family building (4 floors, 2 apartments/floors) 17 apartments housing 32 adults and 23 children.

The community aspires to transform the demo site into an energy efficient building, maximizing PV production, reducing consumption and testing the flexibility of energy demand, showing the potential of saving energy and reducing costs with the frESCO tools. They expressed their interest in fitting the building with data collection systems and monitoring.

4.1 Site Overview.

Over the 17 dwellings that conforms the whole apartments building, a total of 12 dwellings were committed to participate in the demo site, allowing to install sensors, energy meters and retrieve data from their residences.

Three common areas were included in the trial as well, known as Kids room, Laundry and Kitchen room.

The heating and cooling of the dwellings are provided by individual split-type air-to-air heat pumps with an indoor and outdoor unit. The outdoor units are located on the top of the building. The heat pumps use ecological refrigerant R32 and have a COP of 4.3-4.6 (for heating) and 4.2-4.5 (for cooling).

A common facility provides hot water by means of a split-type air-to-water heat pump with two central storage tanks with 930 litres capacity each (located in the basement). The system operates with an electric power of 6.25 kW and a COP of 4 which can deliver 25 kW of nominal power.

A photovoltaic system of 30 kWh, integrated by 90 polycrystalline PV panels, covers 180 m^2 on the roof. The panels are oriented with a 5° eastern azimuth and 15° tilt and run with 19.1% efficiency. The system is composed by two PV sets, each provides a nominal power of 16.65 kWp and uses a SMA 15000 TL inverter of 15k W. Simulations by Design Builder estimates that the whole photovoltaic system generates 57 MWh per year of which 23.3 MWh will not be consumed by the building. The surplus energy generation is expected to occur in the summer months when energy consumption by the apartment is at its lowest and production at its maximum.

Param.	Units	Physical Demo
Dwellings	Un	12
Average residents per dwelling	Un	3
Total Residents	Un	36
Avg. Electricity (Building)	kWh/year	52,232 Includes Common areas
Avg. Electricity (Dwelling)	kWh/year	1,900
Avg. Natural Gas	kWh/year	No gas consumption
Investment in smart eq.	€	11,506
PV System	kWh/year	24,500

TABLE 14: [SPAIN DEMO SITE] SUMMARY PILOT CHARACTERIZATION

4.2 Mapping Devices Installation (sensors, energy meters, gateways, Ebox).

Several sensors, energy meters, actuators, E-box (gateways), etc… have been installed in the dwellings and common areas. Below you will find a summary table of the total equipment installed.

Devices	Units	Physical Demo
Energy Meters	Un	17
Temperature Sensor	Un	13
Air Quality Sensor	Un	4
Motion Sensor	Un	4

Actuator (relay)	Un	16
E-Box (main gateway)	Un	17

TABLE 15: [SPAIN DEMO SITE] LIST EQUIPMENT INSTALLED

Not in all dwellings and common zones the same number of sensors have been installed. Please refer to the below table to have an accurate picture about the type of sensors installed in each building area.

Zone/Dweling	Actuator (HVAC Relay)	Temperature Sensor	Air Quality	Motion Sensor	Energy Meter	Energy Box
Common: Kits Room	No	Yes	No	No	Yes	EB-01-03-15
Common: Laundry	No	Yes	No	No	Yes	EB-01-03-08
Common: Kitchen Room	Yes	Yes	No	No	Yes	EB-01-03-09
Apartment 1	Yes	Yes	No	Yes	Yes	EB-01-3-10
Apartment 3	Yes	No	Yes (VOC; T; HR)	No	Yes	EB-01-3-11
Apartment 4	Yes	Yes	No	Yes	Yes	EB-01-3-12
Apartment 5	Yes	Yes	No	No	Yes	EB-01-3-13
Apartment 7	Yes	Yes	No	No	Yes	EB-01-3-14
Apartment 8	Yes	No	Yes (VOC; T; HR)	Yes	Yes	EB-01-3-16
Apartment 9	Yes	Yes	No	Yes	Yes	EB-01-3-17
Apartment 10	Yes	Yes	No	No	Yes	EB-01-3-18
Apartment 11	Yes	No	Yes (VOC; T; HR)	No	Yes	EB-01-3-19
Apartment 12	Yes	Yes	No	No	Yes	EB-01-3-20
Apartment 13	Yes	Yes	No	No	Yes	EB-01-3-21
Apartment 14	Yes	Yes	No	No	Yes	EB-01-3-22
DHW (water tanks)	Yes (2 Reles signal)	No	No	No	Yes	EB-01-3-07
PV System	No	No	No	No	Yes	N/A

TABLE 16: [SPAIN DEMO SITE] MAPPING DEVICES INSTALLED

Following an example of the apartment lay-out, the distribution of the different equipment installed in the dwelling is as follows.

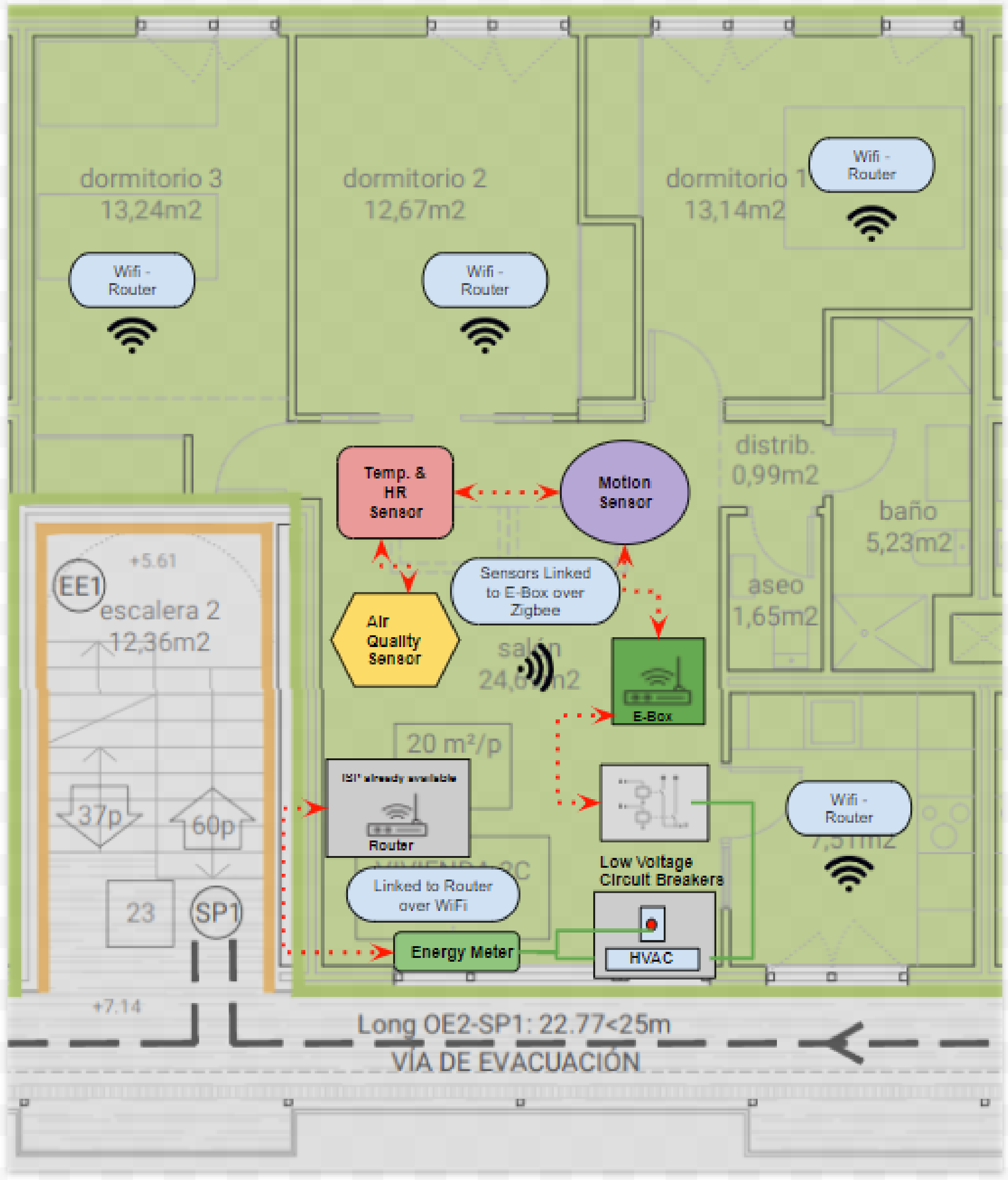

FIGURE 60: [SPAIN DEMO SITE] EXAMPLE LAYOUT EQUIPMENT DISTRIBUTION DIAGRAM

4.3 Enabled Assets available for Flexibility.

One of the services to be tested is the amount of flexibility that can be offered by users or dwellings to the system. Thus, the aggregated flexibility can be sold to the electrical system. Due to the expected small amount of demand flexibility in residential buildings it is needed to aggregate a lot of small devices to make them available and then get potentially a certain value of aggregated flexibility.

Even though markets for aggregated demand flexibility are not completely open in Spain yet, it is an interesting exercise to study all the devices that should be implemented to enable the flexibility resource from the single device level.

In this demo site, at the end, we just considered HVAC flexibility from all the devices existing in the dwellings, as HVAC has the highest energy consumption, if we compare with lighting or other appliances. It is worth to remember that this building has a common washing machine room, so no washing machine exists in the dwellings. Therefore, at the end, no big loads exist in the dwellings but the HVAC.

The building has a PV system, around 30 kWp installed, which offers energy for the community (example to use in the production of DHW) as well as for the dwellings. Actually, the building has just one fiscal meter, and all the loads (common and those belonging to dwellings) are connected to the main meter without any specific method or metrics of distribution. Building owners share the cost of the energy billing which is not high after the PV energy remuneration is compensated.

In that specific demo site, the way we found easy and less impact in budget to enable the different assets for flexibility purpose was installing a bunch of relays to control remotely those assets. By means of these relays on the HVAC feeding circuits, flexibility events can be simulated sending automation commands in the domain of ON/OFF functions, to switch on and off the devices. Someone could find this approach a quite vast way for having a good management of flexibility amount, but for testing purposes can be justified just to extract an approximate quantity of offered flexibility in legacy equipment.

Flexibility assets.	Units	Physical Demo
HVAC	14	Mainly in the apartments.
DHW	2	DHW Tanks
PV System	2	15kWp Each

Table 17: [Spain Demo Site] Collection of Flexibility Assets

4.4 Digital Communications.

The upcoming chapters will outline the different channels through which digital information and data travel coming from the ICT. Starting with the sensors and energy meters, which are the main sources of data that should be gathered, to be ending with the Big Data Management Platform, where the data is stored in Datasets ready to be accessed by an algorithm or app that is constantly running and processing data to provide one of the many frESCO services that are available to end users.

Two communication protocols (API Restful and MQTT) have been used to transfer data from the IoT smart devices and the frESCO BDMP.

The choice between RESTful APIs and MQTT often depends on the specific requirements of the project. There may not be a single "one-fits-all" standard for IoT communication protocols because different use cases have different needs. Many IoT integrations use a combination of protocols to address the diversity of devices and systems they need to connect. For example, RESTful API is use for retrieving configuration data or performing occasional updates, while MQTT could be used for real-time telemetry data.

4.4.1 Data Transmission path from sensors, E-box to BDMP.

According to the device mapping outlined in chapter 4.2 - Mapping Devices Installation (sensors, energy meters, gateways, Ebox).- and in particular Table 15, the data comes from the sensors and energy meters installed in each dwelling and communal area. Energy meters have their own system, which means that energy devices installed in homes are connected to the main router through Wi-Fi, which links the devices with a private cloud server that uses the internet to send the data. In the case of sensors like temperature (which includes humidity), motion, and air quality devices, these devices are linked with the Energy Box using a Zigbee protocol. Figure 61 below shows a representation diagram.

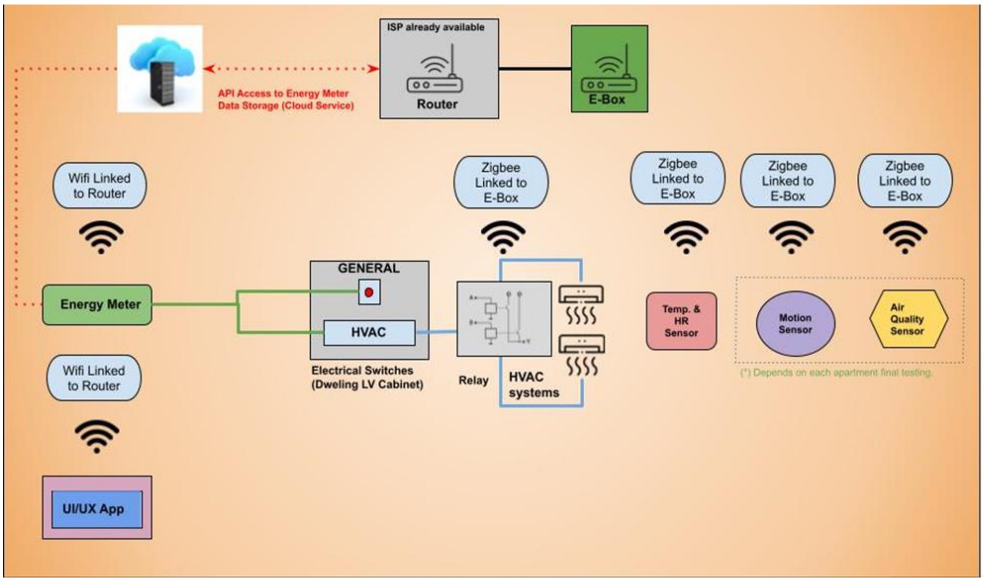

FIGURE 61: [SPAIN DEMO SITE] DWELLING LOCAL SYSTEM INTEGRATION ARCHITECTURE

Therefore, in the Madrid demo site, we implemented two ways for gathering the data up to the Big Data Management Platform. A first pathway it is been to use API Restful calls for gathering all the data from the energy meters and already stored in a private server belonging to the Wibeee company, which offered us the possibility to consume the data through an API developed by them. Here you can access to the Wibeee Nest API Website http://nest.wibeee.com/swagger-ui.html

For the sensors installed in the dwellings and common areas, we use the second mechanism to gather the data coming from the sensors (temperature, motion, air quality, etc..) linked with the Energy Boxes through Zigbee protocol, that is using the known Message Queuing Telemetry Transport protocol (MQTT). MQTT is a lightweight, binary, simple, open, and easy-to-implement publish/subscribe messaging protocol. In that case, all the data stored in an intermediate buffer implemented in the Energy boxes is sent periodically to a MQTT broker. In the Energy Box it isa public code library with the necessary software is embedded to act as MQTT client.

For both data transmission mechanisms it is needed to create in the platform's MQTT broker their respective "jobs", which are the internal processes that the BDMP has to configure the way in which data will be received and stored. These "jobs" ultimately lead into the creation of the datasets where the information, is finally stored and available to make later the respective queries.

4.4.1.1 API RESTful (Meters), MQTT (Sensors) and Jobs Definition.

To configure calls using the Restful API for the case of energy meter data collection, it is necessary to know which functions offer the developer of the devices. RESTful APIs use HTTP methods (verbs) to perform CRUD (Create, Read, Update, Delete) operations on resources. It is based in a Client-Server Architecture, where the client and server are separate entities that communicate over a network. This separation allows for independent development, scalability, and flexibility in client and server implementations.

The principle behind REST, as the name suggests, is transferring the (server's) state in a representational manner (to the client).

Here, it is worth highlighting two key points. First, the server is stateless. It doesn't store the current status of whether a client connection was made. The client is allowed to build a stateful application based on the distinct states it receives from the server using just the transitory state that is sent to it. Second, the server can deliver the resources to the client in a variety of representational representations.

Each and every piece of data that a client may access via REST is referred to as a resource, and it can be accessed by using a particular URL, or Uniform Resource Identifier (URI). Each resource has a unique URI. The resources can be kept on the server in any kind of storage (a database, CSV file, or object-oriented class). The resources can still be sent as binary, JSON, XML, YAML, or other representational forms like JPEG. In other words, the client only has access to the representation and not the actual resource.

The communication should take place between a client and a server. As previously mentioned, the client is the seeker, and the server is the provider of information. As an example, a client asks the server for the temperature, and the server responds with a message containing the temperature in JSON format. It is essential to mention two crucial components that the client's request should contain a URI and HTTP method. The HTTP methods are actions that are requested from the client to the server, there are six standard HTTP methods (GET, PUT, POST, DELETE, HEAD, and OPTIONS) and each one is used in a specific situation. As examples, GET should be used to receive the state of a resource, PUT to update a resource, POST to create one, and DELETE to delete a resource.

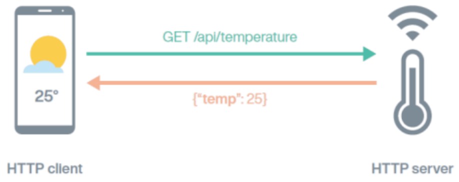

FIGURE 62: [SPAIN DEMO SITE] EXAMPLE APPLICATION HTTP METHOD

In our case the server will be the Wibeee platform and the client will be the Big Data Management Platform. The several methods offered by Wibeee can be found in http://nest.wibeee.com/swagger-ui.html website.

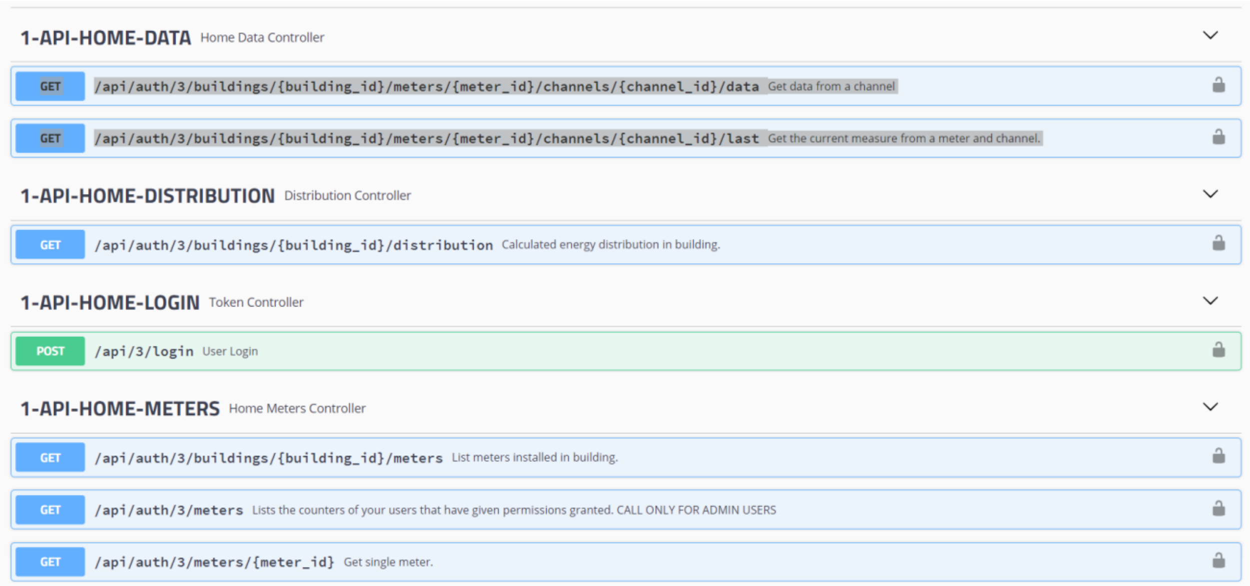

FIGURE 63: [SPAIN DEMO SITE] EXAMPLE OF WIBEEE HTTP METHODS

Thus, for example to get the data for a specific meter we use the following URL Request:

FIGURE 64: [SPAIN DEMO SITE] GET METHOD TO READ VALUES

Whereas you need to hand over certain parameters, such as the building ID, the channel ID and the meter ID. In Spanish case we worked with meters that has two channels. Meter ID is given by the manufacturer and is unique by each device.

The API allows querying data in minutes, quarters of an hour, hours, and days granularity. In the case of minute granularity the maximum limit in a time interval is up to 7 days. For 15-minute granularity the maximum limit time interval is up to 105 days.

<u>Other useful definitions</u>

User: A person whose house is being measured and is registering on the platform nest.wibeee.com.

Building: A location or house where one or several energy meters are installed. A user may have one or several buildings.

Meter: An energy meter that is permanently transmitting measurements.

Channel: Energy load sensor that belongs to a meter.

Appliance: Element that consumes energy in a Building.

Nevertheless, before making any call of a method you need to get a TOKEN to get Authorization, and then LOGIN into the platform.

The new authorization is granted through a user token that expires after 24 hours; this is generated in the 1-API-HOME-LOGIN tag through the POST /login method.

The token generated is the one we will use for authorization and thus have access to all the methods of the API.

As token expires after 24hrs it is needed to create a dynamic procedure to renovate tokens. That was programmed in the Big Data management platform:

Header Authorization

```
{
"url": "https://nest.wibeee.com/api/3/login",
"raw_url": "https://nest.wibeee.com/api/3/login",
"method": "post",
"headers": {
"Content-Type": "application/json",
"Accept": "application/json"
{
"email": "proyectos@comsa.com",
"password": "******"
}
```

In the Spanish demo site were installed 17 energy meters along all the dwellings and common areas, since each meter has 2 channels that means we created (17x2) jobs with the corresponding URL_Request HTTP method.

A complete collection of jobs created for gathering Real Time Energy Data and its correspondence URL_Request are listed below.

BIG Data Management Platform Job Name	URL_Request
Madrid_RT_EM_Kids_Room_CH1_ID_122408	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/122408/channels/1/last
Madrid_RT_EM_Kids_Room_CH2_ID_122408	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/122408/channels/2/last
Madrid_RT_EM_WS_CH1_ID_122409	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/122409/channels/1/last
Madrid_RT_EM_WS_CH2_ID_122409	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/122409/channels/2/last
Madrid_RT_EM_WS_CH3_ID_122409	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/122409/channels/3/last
Madrid_RT_EM_AP1_CH1_ID_113459	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113459/channels/1/last
Madrid_RT_EM_AP1_CH2_ID_113459	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113459/channels/2/last
Madrid_RT_EM_AP3_CH1_ID_113462	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113462/channels/1/last
Madrid_RT_EM_AP3_CH2_ID_113462	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113462/channels/2/last
Madrid_RT_EM_AP4_CH1_ID_113465	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113465/channels/1/last
Madrid_RT_EM_AP4_CH2_ID_113465	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113465/channels/2/last
Madrid_RT_EM_AP5_CH1_ID_113467	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113467/channels/1/last
Madrid_RT_EM_AP5_CH2_ID_113467	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113467/channels/2/last
Madrid_RT_EM_AP7_CH1_ID_113471	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113471/channels/1/last
Madrid_RT_EM_AP7_CH2_ID_113471	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113471/channels/2/last
Madrid_RT_EM_AP8_CH1_ID_113466	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113466/channels/1/last
Madrid_RT_EM_AP8_CH2_ID_113466	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113466/channels/2/last
Madrid_RT_EM_AP9_CH1_ID_113473	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113473/channels/1/last
Madrid_RT_EM_AP9_CH2_ID_113473	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113473/channels/2/last
Madrid_RT_EM_AP10_CH1_ID_113468	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113468/channels/1/last
Madrid_RT_EM_AP10_CH2_ID_113468	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113468/channels/2/last
Madrid_RT_EM_AP11_CH1_ID_122407	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/122407/channels/1/last
Madrid_RT_EM_AP11_CH2_ID_122407	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/122407/channels/2/last
Madrid_RT_EM_AP12_CH1_ID_122405	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/122405/channels/1/last
Madrid_RT_EM_AP12_CH2_ID_122405	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/122405/channels/2/last
Madrid_RT_EM_AP13_CH1_ID_113474	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113474/channels/1/last
Madrid_RT_EM_AP13_CH2_ID_113474	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113474/channels/2/last
Madrid_RT_EM_AP14_CH1_ID_122410	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/122410/channels/1/last
Madrid_RT_EM_AP14_CH2_ID_122410	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/122410/channels/2/last
Madrid_RT_EM_Meeting_Room_CH1_ID_113472	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113472/channels/1/last
Madrid_RT_EM_Meeting_Room_CH2_ID_113472	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113472/channels/2/last
Madrid_RT_EM_Laundry_CH1_ID_113469	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113469/channels/1/last
Madrid_RT_EM_Laundry_CH2_ID_113469	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/113469/channels/2/last
Madrid_RT_EM_PV System_CH1_ID_112214	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/112214/channels/1/last
Madrid_RT_EM_PV System_CH2_ID_112214	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/112214/channels/2/last
Madrid_RT_EM_PV System_CH3_ID_112214	https://nest.wibeee.com/api/auth/3/buildings/131378/meters/112214/channels/3/last

TABLE 18: [SPAIN DEMO SITE] DATA COLLECTION JOBS CREATED IN THE BDMP

Once the “jobs” are processed by the BDMP the corresponding Data Sets were created. Website link https://fresco.s5labs.eu/.

FIGURE 65: [SPAIN DEMO SITE] SCREENSHOT OF DATASETS CREATED IN THE BDMP

There is another data coming from sensors such as temperature, motion, air quality, relay status, that will be gathered using MQTT protocol. A Message Queuing Telemetry Transport (MQTT) is a lightweight, binary, simple, open, and easy-to-implement publish/subscribe messaging protocol. Recently it has conquered the industrial IoT market, especially in areas where constraints like small code footprint and limited network traffic are required.

The MQTT clients (both publisher and subscribers) interface to the MQTT broker. MQTT clients may subscribe to a particular topic, as example can be a humidity value coming from a sensor. The broker recollects that, and once the publishing MQTT client delivers some data value to the broker, the broker transmits that message to all the subscribed MQTT clients. In our case, the Energy Boxes will act as publishers that integrates an open source library with a MQTT client code, it will be configured to point to an URL where a MQTT Server set up by Suite 5 will collect all the data. The Big Data Management Platform will act as a client subscriber, with the purpose of storing all data in the respective created Data Set.

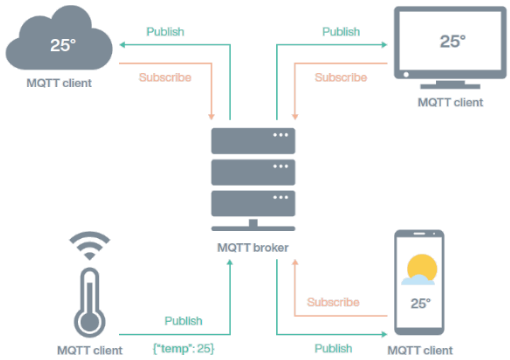

FIGURE 66: [SPAIN DEMO SITE] EXAMPLE APPLICATION MQTT PUBLISHER-SUBSCRIBER

Each message sent through the wire consists of (apart from header metadata) a topic and a payload. The topic is the data with which the broker can channel through messages and to which subscribers subscribe. Topics can comprise of different levels, for case:

- "home/sensor1/identification" consists of three topic levels and,
- "home/sensor2/data/temperature" consists of four topic levels.

Each topic level is separated by a forward slash and the topic structure is case-sensitive. Topics can also include wildcards on individual and multiple levels.

This is a feature called Quality of Service for defining the delivery assurance for each message. The idea behind is to define different levels of security that the message will arrive at the subscriber side. Those levels are: QoS 0 (at most once), QoS 1 (at least once), and QoS 2 (exactly once). In our application will use QoS 1.

As same to API Restful calls, we need configure de MQTT client providing a username and password, as well as the topic to be published.

```
options = {
    "version": 5,
    "transport": "tcp",
    "port": 1883,
    "topic": "9dd8d76b-67e8-4faa-8616-caa8acdbde08/python/mqtt",
    "username" : "9dd8d76b-67e8-4faa-8616-caa8acdbde08",
    "password" : "KTY6vKiaSSYWmate0FUNEmHYceLKpVAc",
    "broker": "localhost",
    "client_id": "Madrid",
    "clean_session": False,
    "qos": 1
}
```

4.4.1.2 Data Set. Data Model Structure for API Restful and MQTT content.

Although many data gathering jobs are defined for energy meters, using the HTTP method provided by the API, all of them return the same data model structure and the response in JSON format follows that pattern:


```
{
        "pageSize": 5,
        "lastRecordId": "63bda4298dc3b7db9045a5b4",
        "results": [
                {
                        "EnergyMeasurements": {
                                "apparentPower": [
                                        -0.151
                                ],
                                "rmsCurrent": [
                                        0.69
                                ],
                                "rmsVoltage": [
                                        0.22811
                                ],
                                "power": [
                                        0.40
                                ],
                                "createdDateTime": "2023-07-26T16:45:10.000Z",
                                "relatedDevice": {
                                        "nodeID": [
                                                "113459"
                                        ],
                                        "code": "1"
                                }
                        }
                },
```


Where “nodeID” is the “meterID” given by the manufacturer, and the “code” is the channel that we are getting the data. In this case it is referencing the meterID= 113459, which is an energy meter located in the apartment 1, and the given values corresponds to the channel 1, which is measuring the global consumption of the referred dwelling.

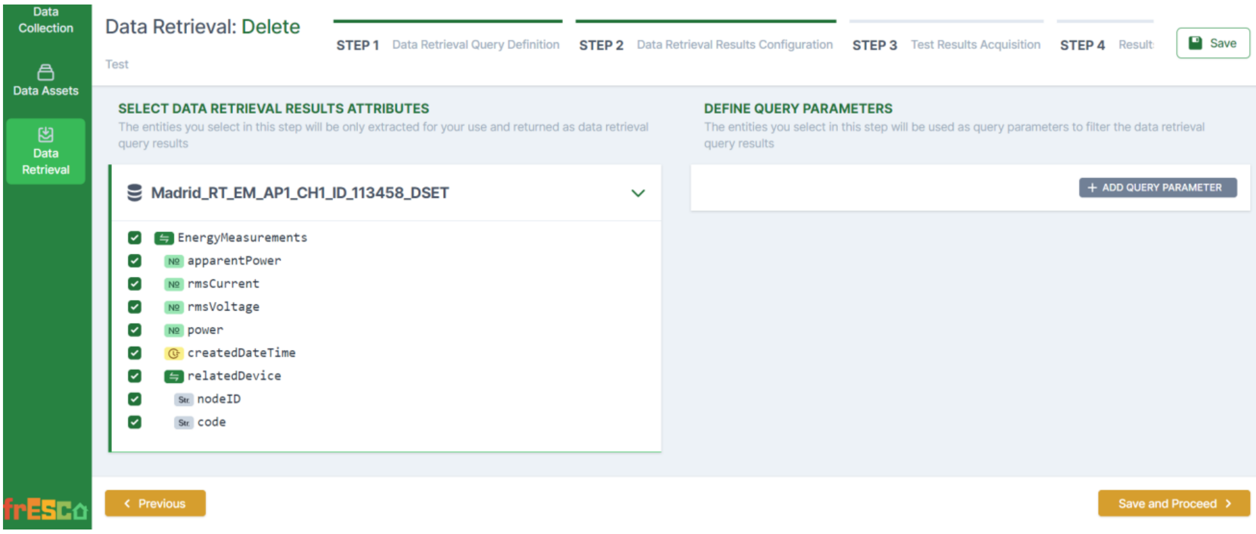

FIGURE 67: [SPAIN DEMO SITE] EXAMPLE OF DATA SET CONTENT HTTP API RESTFUL - DATA MODEL STRUCTURE.

The other data coming from the different sensors through MQTT pathway have the following Data Model Structure.

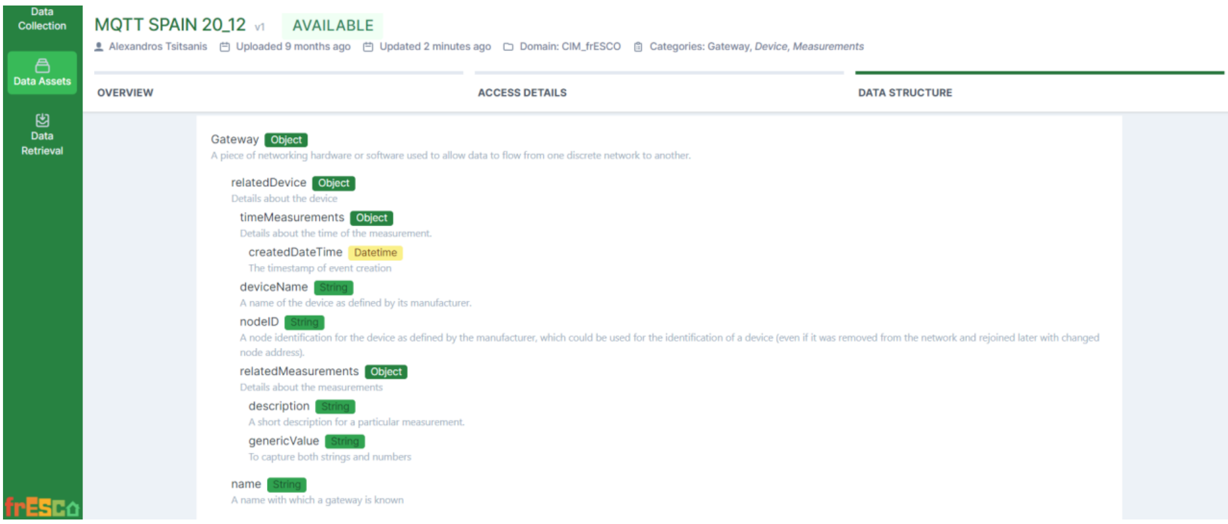

FIGURE 68: [SPAIN DEMO SITE] EXAMPLE OF DATA SET CONTENT MQTT - DATA MODEL STRUCTURE.

This is a single Data Set, called MQTT_SPAIN_2012, that collects in a JSON file all the sensors (temperature, motion, air quality, relay, etc..) available in the pilot. The collection of the sensors and its related measurements are listed below. Keep in mind that a humidity sensor can offer two variables: humidity itself and temperature. The case of the Air Quality sensors, may offer three variables, VOC (Volatile Organic Compounds), temperature, and %HR.

Gateway.name	.deviceName	.relatedMeasurements.description		
fresco_apartamento1	apartamento_1_humidity	TEMP_MEASUREDVALUE	HUMIDITY_MEASUREDVALUE	
fresco_apartamento1	apartamento_1_motion	OCCUPANCYPIROCCUPANCY		
fresco_apartamento1	apartamento_1_rele	ONOFF_ONOFF		
fresco_apartamento3	apartamento_3_air_quality	TEMP_MEASUREDVALUE	HUMIDITY_MEASUREDVALUE	VOC_MEASUREDVALUE
fresco_apartamento3	apartamento_3_rele	ONOFF_ONOFF		
fresco_apartamento4	apartamento_4_humidity	TEMP_MEASUREDVALUE	HUMIDITY_MEASUREDVALUE	
fresco_apartamento4	apartamento_4_motion	OCCUPANCYPIROCCUPANCY		
fresco_apartamento4	apartamento_4_rele	ONOFF_ONOFF		
fresco_apartamento5	apartamento_5_humidity	TEMP_MEASUREDVALUE	HUMIDITY_MEASUREDVALUE	
fresco_apartamento5	apartamento_5_rele	ONOFF_ONOFF		
fresco_apartamento7	apartamento_7_humidity	TEMP_MEASUREDVALUE	HUMIDITY_MEASUREDVALUE	
fresco_apartamento7	apartamento_7_rele	ONOFF_ONOFF		
fresco_apartamento8	apartamento_8_air_quality	TEMP_MEASUREDVALUE	HUMIDITY_MEASUREDVALUE	VOC_MEASUREDVALUE
fresco_apartamento8	apartamento_8_motion	OCCUPANCYPIROCCUPANCY		
fresco_apartamento8	apartamento_8_rele	ONOFF_ONOFF		
fresco_apartamento9	apartamento_9_humidity	TEMP_MEASUREDVALUE	HUMIDITY_MEASUREDVALUE	
fresco_apartamento9	apartamento_9_motion	OCCUPANCYPIROCCUPANCY		
fresco_apartamento9	apartamento_9_rele	ONOFF_ONOFF		
fresco_apartamento10	apartamento_10_humidity	TEMP_MEASUREDVALUE	HUMIDITY_MEASUREDVALUE	
fresco_apartamento10	apartamento_10_rele	ONOFF_ONOFF		
fresco_apartamento11	apartamento_11_air_quality	TEMP_MEASUREDVALUE	HUMIDITY_MEASUREDVALUE	VOC_MEASUREDVALUE
fresco_apartamento11	apartamento_11_rele	ONOFF_ONOFF		
fresco_apartamento12	apartamento_12_humidity	TEMP_MEASUREDVALUE	HUMIDITY_MEASUREDVALUE	
fresco_apartamento12	apartamento_12_rele	ONOFF_ONOFF		
fresco_apartamento13	apartamento_13_humidity	TEMP_MEASUREDVALUE	HUMIDITY_MEASUREDVALUE	
fresco_apartamento13	apartamento_13_rele	ONOFF_ONOFF		
fresco_apartamento14	apartamento_14_humidity	TEMP_MEASUREDVALUE	HUMIDITY_MEASUREDVALUE	
fresco_apartamento14	apartamento_14_rele	ONOFF_ONOFF		
laundry	laundry_humidity	TEMP_MEASUREDVALUE	HUMIDITY_MEASUREDVALUE	
fresco_kids_room	Kids_room_humidity	TEMP_MEASUREDVALUE	HUMIDITY_MEASUREDVALUE	
kitchen_room	kitchen_humidity	TEMP_MEASUREDVALUE	HUMIDITY_MEASUREDVALUE	
kitchen_room	kitchen_rele	ONOFF_ONOFF		
fresco_DHW_room	DHW_room_rele1	ONOFF_ONOFF		
fresco_DHW_room	DHW_room_rele2	ONOFF_ONOFF		

TABLE 19: [SPAIN DEMO SITE] MQTT COLLECTION DEVICES AND RELATED MEASURES

4.4.1.3 Availability of retrieved Data.

Personalized Energy Analytics and Human-Centric Automation tool uses the data from the BDMP as inputs for doing the analytics and running the different services. The first step to collect this data was to attest that the data was available in the platform and could be gathered from them.

For that the MQTT_SPAIN_20_12 dataset was searched in the data assets and founded as can be seen in Figure 69.

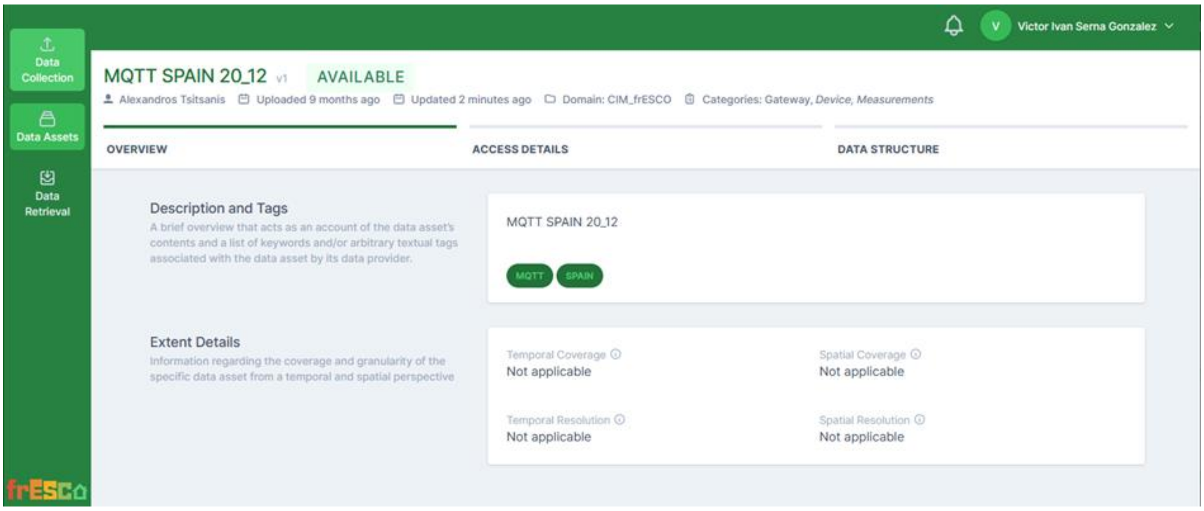

FIGURE 69: [SPAIN DEMO SITE] ATTESTING OF AVAILABILITY OF MQTT_SPAIN_20_12 DATA SET

Besides, a test for checking that the data is available was done thought the data retrieval section in the BDMP as can be seen in the Figure 70.

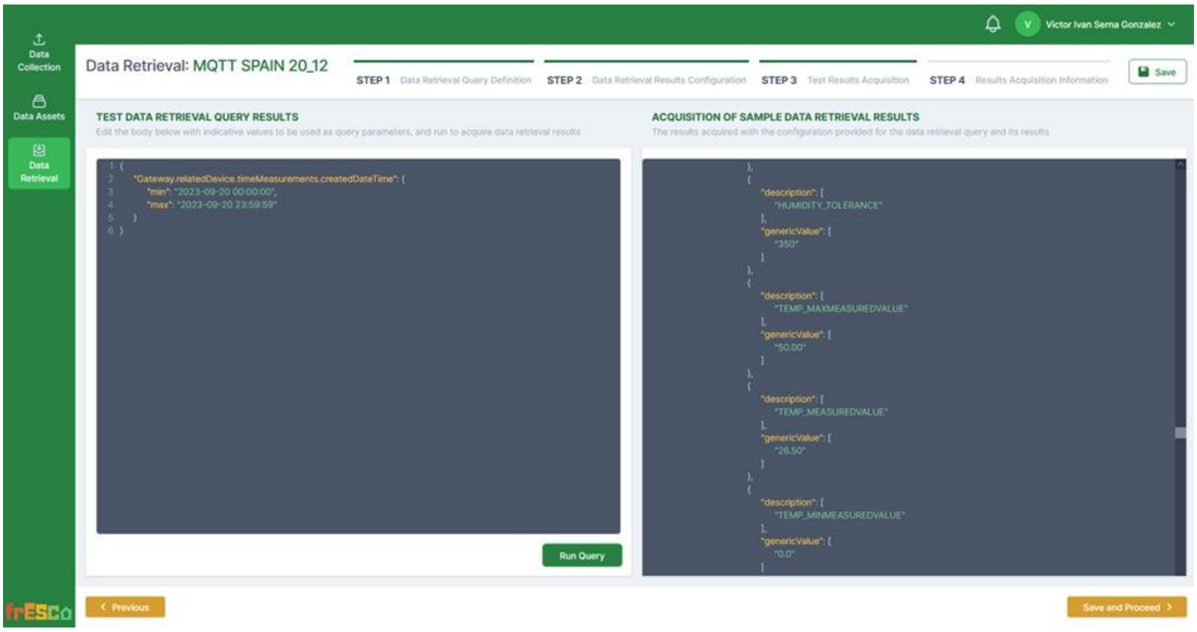

FIGURE 70: [SPAIN DEMO SITE] DATA RETRIEVAL CHECKING FOR MQTT_SPAIN_20_12 DATA SET

4.4.2 Data Transmission path from BDMP to APP developers.

In the case of the EB all commands are received via the MQTT command interface. Once a command is posted in the appropriate topic, a callback activates in the MQTT component which parses the command and does the appropriate calls in the device controller. In the case of the Madrid (Spain) demo, all controllable devices are based on Zigbee. In this case the device controller will try to send the command as soon as the ZigBee chip is available for transmission.

4.4.2.1 Getting data and Control commands for automation.

Retrieving data for Personalized Energy Analytics and Human-Centric Automation tool

For retrieving the data form the DMP for Personalized Energy Analytics and Human-Centric Automation tool, several data retrieval queries were created in the BDMP. In the Figure 71 an example of the creation process for variables needed in the Spanish demo site can be seen.

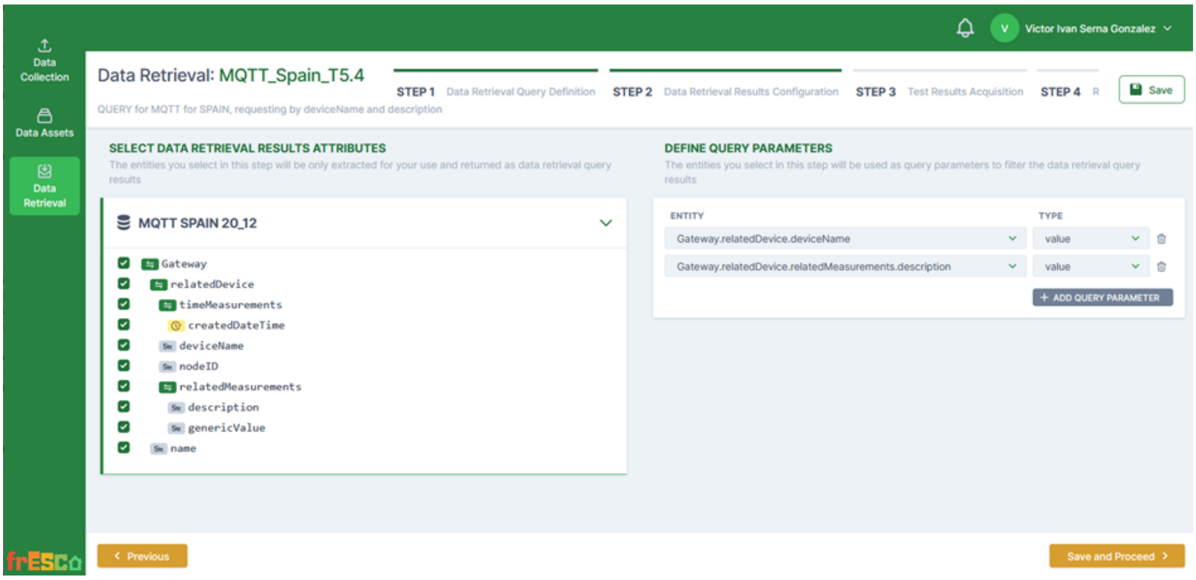

FIGURE 71: [SPAIN DEMO SITE] EXAMPLE OF A DATA RETRIEVAL CREATION PROCESS

Sending automation signals from Human-Centric Automation tool

The Human-Centric Automation tool run algorithms taking into account the values collected for the sensors and the preferences configured for the user, in order to send automations signals to the controllers (mainly controlling HVAC systems and Boilers).

The way defined for connecting the controllers is through the MQTT system using a Python script as client, taking advantage of the *paho.mqtt.client* package. For connecting the Spain MQTT endpoint the information used is the following (the payload_dict changes taking into account the variable to be modified and the command to be sent):

```
host="mqtt.fresco.s5labs.eu"
client_id = "id-xxxxxxxxxxxxxxxx"
topic = "86e9957b-XXXX-XXXX-XXXX-XXXXXXXXXXXX"
payload_dict = {"nameEB":"kitchen_room", "deviceName":"kitchen_rele","deviceKind":"zigbee", "command":"disable"}
```

FIGURE 72: [SPAIN DEMO SITE] API USED FOR RETRIEVING DATA FROM FOR MQTT_SPAIN_20_12 DATASET

4.4.2.2 API Restful

<u>**API RESTful for Personalized Energy Analytics and Human-Centric Automation tool**</u>

Once this has been configured, the application uses the API generated in the BDMP for accessing to the variable values needed for running the algorithms. An example of the API used can be seen in the Figure 72.

Configuring all the data retrievals needed, the connection between the application and the BDMP for Spanish demo-site is ensured.

4.4.2.3 Data Model Structure (data sets), retrieval Data Base content.

For the Personalized Energy Analytics and Human-Centric Automation tool, three groups of APIs were used:

i. API for long term energy consumption monitoring: in Spain Pilot, an API for the retrieval of the last few hours of energy consumption data is called every five hours. The data is then stored in a local DB for fast access when the user accesses the tool. In Figure 73 an example meant to illustrate the data structure can be seen.


```
{
    "EnergyMeasurements": {
        "power": [
            0.115
        ],
        "createdDateTime": "2023-08-07T00:01:11.000Z",
        "relatedDevice": {
            "nodeID": [
                "113465"
            ],
            "code": "1"
        }
    }
},
```


FIGURE 73: [SPAIN DEMO SITE] ENERGY CONSUMPTION DATA STRUCTURE

ii. API for status check: these API include humidity, air quality, energy production and HVAC consumption check. All these API retrieve the last one or two data from the different sensors installed in the user's dwelling and are stored in the local DB for fast access when the user accesses the tool and for time tracking. These APIs are called every few minutes.

iii. API for forecasts retrieval: APIs for PV generation and energy consumption forecasts were created. These APIs are called once a day and data are used immediately for the platform and not stored in the local DB. In Figure 74 an example of a json with the energy consumption forecast can be seen.


```
{
    "datetime": "2023-09-26T05:00:00.000Z",
    "hour": 5,
    "predictions": [
        0.314251810312271l,
        0.3850751519203186,
        0.3865625560283661,
        0.4388916492462158,
        0.42066967487335205,
        0.3674651086330414,
        0.4364018440246582,
        0.402953177690506,
        0.3927438259124756,
        0.339789479970932,
        0.3862937390804291,
        0.31555095314979553,
        0.3189796805381775,
        0.2711678445339203,
        0.2759131193161011,
        0.24443915486335754,
        0.2525583505630493,
        0.24249811470508575,
        0.27854716777801514,
        0.23259560763835907,
        0.2729406952857971,
        0.23645555973052979,
        0.23231828212738037,
        0.24393627047538757
    ]
}
```


FIGURE 74: [SPAIN DEMO SITE] ENERGY CONSUMPTION FORECAST EXAMPLE

4.4.2.4 Other External Sources (Weather Data, Demo Tariffs)

Like the Croatian and the Greek demo sites, external sources are leveraged to procure weather-related information customized to meet the requirements of the Spanish pilot. This data is then applied to augment the capabilities of the frESCO applications. Employing the Data Collection API method made available by the Big Data Management Platform, a data collection job is initiated to retrieve information at 15-minute intervals. Figure 75 demonstrates the resultant dataset and its attributes, whereas Figure 76 offers the data structure, associated concepts, and utilized fields.

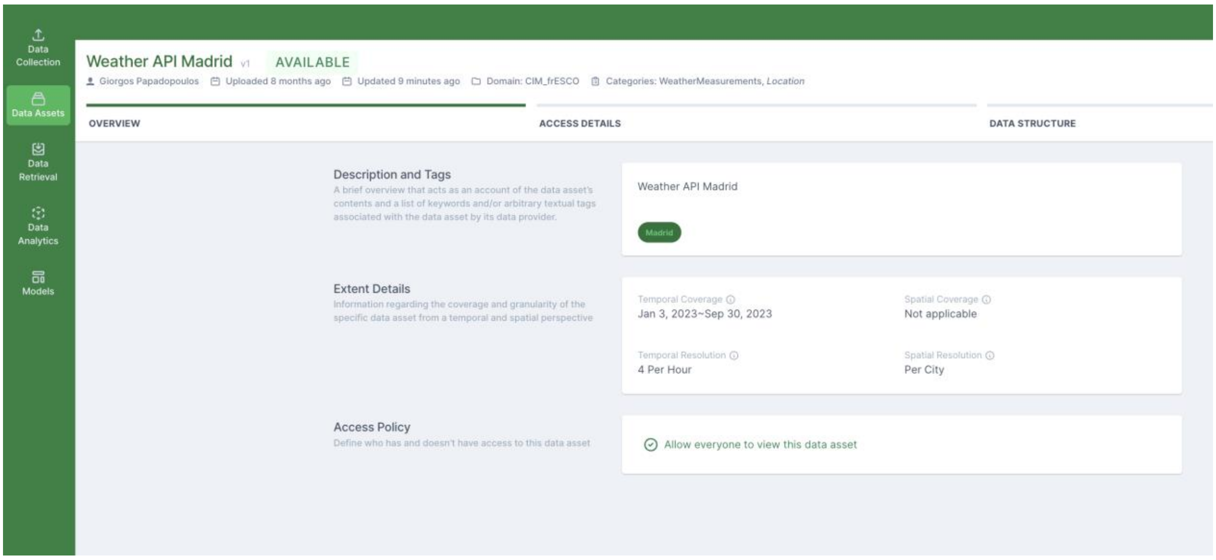

FIGURE 75: [SPAIN DEMO SITE] THE WEATHER DATASET DETAILS

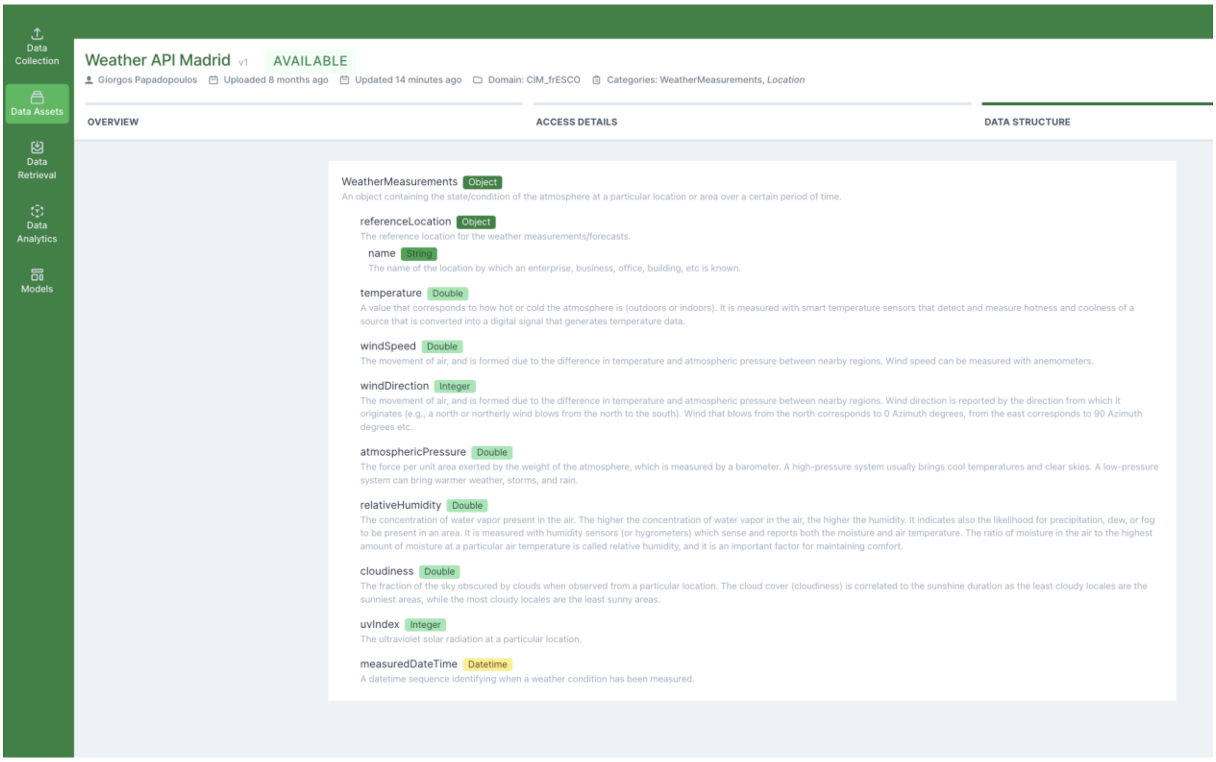

FIGURE 76: [SPAIN DEMO SITE] WEATHER DATA STRUCTURE

For obtaining weather data from the applications, users are encouraged to make use of the search and retrieval functionalities provided by the Big Data Management Platform. Within this platform, users have the flexibility to specify the fields they wish to access and define query parameters to refine the retrieval process. A practical illustration of the data obtained through an API GET request is presented in Figure 77.


```
{
"WeatherMeasurements": {
        "temperature": 25,
        "windSpeed": 0.5,
        "windDirection": 100,
        "atmosphericPressure": 205563.111,
        "precipitationRate": 56,
        "relativeHumidity": 28,
        "uvIndex": 2,
        "cloudiness": 13,
        "measuredDateTime": "2023-06-13T10:00:13.000Z"
}
```


FIGURE 77: [SPAIN DEMO SITE] WEATHER DATA RETRIEVAL USING THE API GET REQUEST

Incorporated alongside the weather data housed within the BDMP, you'll find the Spanish demo tariffs ingested through the file collection method within the platform. This empowers the application to retrieve monthly hourly static values seamlessly via the API retrieval functionality. Figure 78 serves as an illustrative instance, offering hourly tariffs for the Spanish demo site during the month of December.


```
{
        "TariffProfile": {
          "relatedLocation": [
            {
              "countryName": "Spain"
            }
          ],
          "creationDate": "2023-06-01",
          "startDateTime": "2023-06-01T00:00:00.000Z",
          "endDateTime": "2023-06-30T00:00:00.000Z",
          "hourlyFixedCost": [
            0.1827,
            0.1827,
            0.1827,
            0.1827,
            0.1827,
            0.1827,
            0.1827,
            0.1827,
            0.2132,
            0.2201,
            0.2201,
            0.2201,
            0.2201,
            0.2201,
            0.2132,
            0.2132,
            0.2132,
            0.2132,
            0.2201,
            0.2201,
            0.2201,
            0.2201,
            0.2132,
            0.2132
          ]
        }
      }
```


FIGURE 78: [SPAIN DEMO SITE] TARIFFS DATA RETRIEVAL USING THE API GET REQUEST

4.4.2.5 Keycloak tool as centralized point of access to different users.

In the frESCO project, Keycloak has been used as a common platform for prosumers, ESCOs and aggregators to create and manage users' accounts. Keycloak has been utilized with the objective of having the same authentication credentials and ease the definition of the relationships between users and their characteristics. The users can be assigned to three different roles (*aggregator*, *esco* and *prosumer*) and three countries (*Croatia*, *Greece* and *Spain*). Depending on the role selected, users can access the different dashboards developed in the frESCO project (*Prosumers Dashboard*, Aggregators Dashboard, *Smart Contracts Dashboard* and *ESCOs Dashboard*), and once logged in each of them, they will see personalized information related to their user. More information about Keycloak is included in deliverables D5.7 and D5.8 of this project.

In the Spanish pilot site, the *spain* option has been selected when defining the users. Sixteen different users have been created: one aggregator, one ESCO and fourteen prosumers.

4.4.2.6 Data retrieval Proof and Commands for control.

To prove the storing of data in the local DB, two screenshots are included. In them, it can be seen how the energy consumption data from one of the users is stored (Table 20) and how the data from the status check is saved (Table 21).

	id	energy_power	year	month	day	hour
1	1	0,065	2.023	4	3	0
2	2	0,08175	2.023	4	3	1
3	3	0,06925	2.023	4	3	2
4	4	0,08575	2.023	4	3	3
5	5	0,053	2.023	4	3	4
6	6	0,0665	2.023	4	3	5
7	7	0,08825	2.023	4	3	6
8	8	0,35425	2.023	4	3	7
9	9	0,09725	2.023	4	3	8
10	10	0,098	2.023	4	3	9
11	11	0,1305	2.023	4	3	10
12	12	0,11475	2.023	4	3	11
13	13	0,708	2.023	4	3	12
14	14	0,142	2.023	4	3	13
15	15	0,137	2.023	4	3	14
16	16	0,08025	2.023	4	3	15
17	17	0,09325	2.023	4	3	16
18	18	0,0665	2.023	4	3	17
19	19	0,107	2.023	4	3	18
20	20	0,102	2.023	4	3	19
21	21	0,0805	2.023	4	3	20
22	22	0,101	2.023	4	3	21
23	23	0,06525	2.023	4	3	22
24	24	0,087	2.023	4	3	23

Table 20: [Spain Demo Site] Energy consumption data in the DB

	id	user_notification_id	value_past	value_present	created_datetime
1	24	2	21,6	21,6	2023-03-16 16:28:05.000 +0100
2	16	3	21,3	21,3	2023-05-07 08:58:26.000 +0200
3	17	4	23,4	23,3	2023-09-26 07:15:32.000 +0200
4	1	6	22,3	22,3	2023-01-23 21:27:12.000 +0100
5	2	7	24,3	24,3	2023-09-23 11:13:09.000 +0200
6	18	8	27,2	27,3	2023-06-20 11:07:33.000 +0200
7	19	9	28,2	28,3	2023-06-18 03:55:05.000 +0200
8	13	11	28,4	28,4	2023-06-20 11:03:18.000 +0200
9	20	12	27,5	27,5	2023-06-20 11:10:19.000 +0200
10	21	13	24,7	24,7	2023-06-20 11:11:58.000 +0200
11	4	14	28,1	28,1	2023-06-20 11:12:41.000 +0200
12	22	15	25,1	25,1	2023-09-24 12:32:32.000 +0200
13	23	16	25,5	25,5	2023-05-04 12:50:18.000 +0200
14	15	20	51	51	2023-03-29 19:27:29.000 +0200
15	3	21	40,2	40,2	2023-01-23 21:27:12.000 +0100
16	5	22	50	50	2023-09-23 11:13:09.000 +0200
17	12	26	47	47	2023-09-26 06:48:22.000 +0200
18	6	32	56	56	2023-01-23 21:27:12.000 +0100
19	10	34	60	65	2023-06-20 11:08:58.000 +0200
20	7	39	11	0	2023-09-26 07:30:08.000 +0200
21	14	40	11	0	2023-09-26 07:34:19.000 +0200
22	8	53	0	0	2023-09-26 07:31:15.000 +0200
23	9	58	0	0	2023-09-26 07:31:15.000 +0200

Table 21: [Spain Demo Site] Sensors' status data in the DB

4.5 Problems raised during commissioning.

Even though the hardware was carefully chosen, and the devices were from first-brand manufacturers, certain issues were discovered during the configuration of the devices during the commissioning stage.

4.5.1 Pairing sensor problems with ZigBee network

It was discovered that in field conditions the capabilities of the EnergyBox Zigbee communication protocol were sometimes insufficient to reach reliably some of the sensors due to distance and physical barriers. Although reliability was somewhat improved with better management of the Zigbee channels, some sensors fade in and out of communications range creating data gaps.

Therefore, particularly for Spanish demo-site, some sensors showed problems and not are always available due to Zigbee connectivity with the EB. For that, some of the functionalities could be affected.

4.5.2 Energy meters migration

Several energy meters, in total 6 units, showed problems after some weeks of normal operation once the first commissioning was done.

Once the problem detected, it was communicated to the manufacturer's assistance service. And after carrying out some local checks, and given the impossibility of recover the devices, it was decided to send the hardware to the manufacturer's technical service, which concluded that all six devices were determined to have a similar defect. LEDs would not light due to a rare writing data error to the device's flash memory. This prevented the microprocessor from executing the correct code, resulting in the devices malfunctioning.

6 new meters were sent by the manufacturer to replace the damaged ones. These new meters have their own ID which entails the need to create new jobs, since each meter has 2 channels that means we created (6x2) jobs in the BDP with the corresponding URLRequest HTTP method.

That general situation made us lose a lot of precious time and substantial delays in the final commissioning.

A technical report from the hardware manufacturer is attached as an annex 1.

4.5.3 Integration Difficulties in Legacy Equipment

There were technical problems while trying to communicate the legacy PV inverter and the EB using the standard data protocols (Modbus, serial, etc..) through the physical build-in ports. Since the priority was to get more stability in the Zigbee communications, it was decided that it was more cost effective to extract the PV production data using a new three-phase energy meter. It was commissioned and installed in early 2023.

4.5.4 Time Response Issues when Retrieving Data

The time response for collecting data from the Datasets related to Spanish sensors is high (60-80 seconds approx.). With this time response, the applications that have to provide real time functionalities showing problems for providing the results on time. This is due cause all the data coming from the sensors are stored in a unique Dataset. As a consequence, the Dataset is a large file which is not fast giving queries.

4.5.5 Lack of heterogeneity in data retrieving.

Actually, this a general problem found in all pilots, not just in the Spanish trial. Thus, in each pilot the way to retrieve the data from sensors and other systems is different. For this reason, different mechanisms for collecting the data have to be applied adapted to each pilot.
For instance, some differences that have been identified are:

i. Some sensors have different units (W vs kW)
ii. For some pilots the information regards the PV are in one dataset only, on other pilots the information is kept in several Datasets.
iii. For some pilots the information for the energy meters is in one Dataset on other pilots the information resides in different Datasets.
iv. For some pilots the information for the sensors is in one Dataset on other pilots the information lies different Datasets.
v. For the Greek pilot a single user must have access to all the sensors and meters.

4.6 Site Workshop.

On the 20th of June 2023, the frESCO consortium organized a hybrid event in a form of a webinar and with a local presentation onsite, to present the frESCO pilot advances implemented, the APPs' user interface, and features to the end users.

The main purpose of the workshop was to inform about the frESCO services and kick off officially the usage and interaction of end users with the toolset provided for energy efficiency and monitoring.

Following the successful integration, a general implementation guide of the use of frESCO dashboard (frond end) was presented to the users. The document is included at the end of this deliverable as annex II.

4.6.1 Workshop Overview.

Las Carolinas is a residential building that its owners are quite involved in testing and applying several technologies or processes to improve sustainability, and has the ambition to become climate neutral. Actually it is constructed under the "Passivhaus" or Passive Houses approach, that means they are basically sustainable and self-sufficient homes, capable of reducing up to 80% of the demand for heating and cooling and that are committed to the use of renewable energy sources such as solar or aerothermal energy. Hence, this is a very efficient building with little chance to gain further energy savings.

Las Carolinas building property, working on the preparation and future implementation of energy efficiency projects to cut CO_2 emissions generated and for having a better control on the energy costs.

The main focus areas were:

• More than 12 Dwellings in the same building willing to collaborate.

• Local renewable energy installation, a common PV system installed,

• A common aerothermal facility system to heat the water and supply for the users,

• A facility to treat the sewage water "gray water", with the aim to reuse the resource for irrigation, or other secondary uses (out of scope of frESCO).

The frESCO project aims to support this transition by exploring and testing different services and business models for the creation of smart systems based on cloud services laid on the P4P pay for performance philosophy.

frESCOs' pilot arose from a joint initiative between the Las Carolinas property and LCTE who contacted the different stakeholders involved in the building and started to promote a model of collaboration within the scope of EU frESCO project.

The long-term ambition of Las Carolinas is to support the creation of an energy management system who help the energy responsible to manage all the apartments, and common areas, including PV system and aerothermal heat water production, but as well to know energy cost related wastewater treatment plant. For doing so, it is very important that all local users and actors understand the benefits of this new energy model as this will ensure their active collaboration and involvement in this transition.

Therefore, Las Carolinas workshop was designed to raise awareness of the frESCO project and the P4P models and services that can offer, among a wide audience of stakeholders, including contributions from users and promoting the resolution of possible doubts and concerns. The event had a hybrid format to help UBITECH to participate and their apps and, for those attending physically the session, it included a snack.

4.6.2 Participating organizations and their roles.

The following frESCO partners contributed to the preparation of the event:

• CIRCE – frESCO Coordinator partner, developing a piece of user Apps and supplying part of the system data communications infrastructure through its own development energy box. As well, analyzing viable business models and doing global project coordination.

• COMSA – frESCO technology partner, engineering firm supporting design and supervising the pilot implementation and operation.

• LCTE – frESCO partner, energy retail company which supplier energy to the building. Act as a local partner supporting the pilot implementation and coordination with users.

• CARTIF – frESCO technology partner, developing the optimal design of the user APPS through detailed algorithms and providing the necessary platform for HMI management and operation.

• UBITECH – frESCO technology partner, developing the optimal design of the Aggregators/ESCO APPS through detailed algorithms and providing the necessary platform for HMI management and operation.

The workshop was attended by more than 8 users and main project partners involved, as listed above, representing important pilot actors. This demonstrated high interest from the community Las Carolinas in the frESCO project and its future potential upscaling and replication throughout the frESCO network.

FIGURE 79: [SPAIN DEMO SITE] VIEW OF THE ROOM WHERE WORKSHOP SESSION EVENT WAS HELD

FIGURE 80: [SPAIN DEMO SITE] SOME PARTNERS PRESENTING RESULTS IN THE WORKSHOP.

COMSA and LCTE act as a pilot smart service provider of the building. frESCO partners CIRCE and COMSA, coordinate the preparation, implementation and operation of the pilot and bring in technical knowledge and engineering skills. The apps and services were developed and implemented by other project partners, such as CARTIF, UBITECH, and S5, who leads the development of the Big Data Management Platform within frESCO.

At the local level, the successful deployment of energy system requires the involvement of several stakeholders including technical experts, the end users, and the main energy supplier or local grid operator for Demand Response events when necessary.

Among the technical experts, a local retailer company (LCTE) has the responsibility to keep the relationship with the users and help engineering company (COMSA, CIRCE) to implement the local infrastructure for automation systems and data infrastructure connecting the whole system with the cloud Platform. Additionally, other local contractors are involved in the pilot preparation for the installation of the devices.

4.6.3 Main presentations, topics, and discussion points

Through several presentations provided by frESCO partners, the event aimed to raise awareness to dwelling users on the Las Carolinas state of the art and its activities implemented in the field of energy innovation within the frESCO project. Participants, including the main property actors, had the possibility to engage with the speakers, ask questions and clarifications.

Main topics presented:

- Presentation Tool ESCOs and user interface by UBITECH.
- Presentation Tool end users and interfaces by Cartif.
- Presentation DashBoard User Manual by Cartif (See Annex II).
- Presentation forecasting Tool monitoring by CIRCE.

Summary of the discussion

The property was worried about what happens with the data at the end of the project. So, they would like to send the sensor data to a storage of his own. As well as redirect MQTT clients to a new property MQTT broker.

Property asked if a double MQTT data delivery can be operated simultaneously to start receiving sensor data before the end of the project.

Property asked about the cost of a DEVELCO gateway.

Property representatives say they were also interested in common areas consumption not just in dwelling consumption. Some debates were celebrated to explain that project objectives are more focused on private dwellings.

LCTE distributed the system user manual soon including the user credentials again.

Property requested scripts of AI analytics. It is not possible to share this with them.
Property asked about an alternative monitoring interface. Grafana is open source to replace Microsoft's Power BI for data management. Grafana is able to connect with Databases as well as API Rest Json files calls.

So, in summary, the Madrid Pilot site event was a great success, as it was attended by most of the building residents and confirmed their interest in the energy services offered by the project.
This workshop not only made users be aware of the frESCO pilot project state of the art, but also provided an opportunity to respond to their questions and concerns. This demonstrated the property commitment to respect the interests of its users, while facilitating further engagement with the community and their future participation/collaboration in the pilot project activities.

Meeting ended at 19.30h thanking all attendees for their attention, time and comments. Snack and face to face discussions followed.

5 FRENCH PILOT SITE

The French pilot is placed in the city of Rennes in the Brittany Region, at the West coast of France, comprising a set of mainly individually owned apartments.
Britany is the most western region in France, with an area of 28,000 km2 and a population of over 3 million people. The region has an oceanic climate, with an average temperature of 6 degrees in winter and 19 degrees in summer.

5.1 Site Overview

The households involved made part of Voltalis's customer base, that was expanding its current client portfolio in the region and was currently negotiating with property managers new service contracts for residential consumers.
The apartments themselves are 40 year-old apartments (from 1986 but renovated in 2015), with medium to good thermal insulation and electric heating.

All sites should be equipped with Smart Meters (smart meters are currently deployed in France and will cover soon 95% of the population). There is no special ICT infrastructure required inside the building/houses as Voltalis boxes connected to HVAC devices includes all the communication/ICT infrastructure. Further sensors/actuators should be installed in the households to measure the most relevant parameters and act on the main energy assets of the house. Next Table presents the parameters initial definition of the French demosite.

Param.	Units	Physical Demo
Dwellings	Un	30
Average residents per dwelling	Un	3
Total Residents	Un	90
Avg. Electricity (Building)	kWh/year	225.000
Avg. Electricity (Dwelling)	kWh/year	7.500
Avg. Natural Gas	kWh/year	No gas consumption

TABLE 22: [FRANCE DEMO SITE] EXPECTED DEFINITION OF DEMOSITE

Finally, at the time of the French demo site cancelation in December 2022, only one apartment had been fully installed and was participating in the demo site with no hopes to involve any more dwellings in the demonstration activities, despite the efforts made by the demonstration partner, including economic incentives for the targeted users.

5.2 Devices installation and data infrastructure

One apartment was equipped in the new Rennes building and the following schematic was provided by Voltalis to represent the intended data flow from the temperature and smart plugs to the frESCO BDP using REST API data transfer protocols. The first attempts to send data from the Volt Box were successful but no more progress could be made.

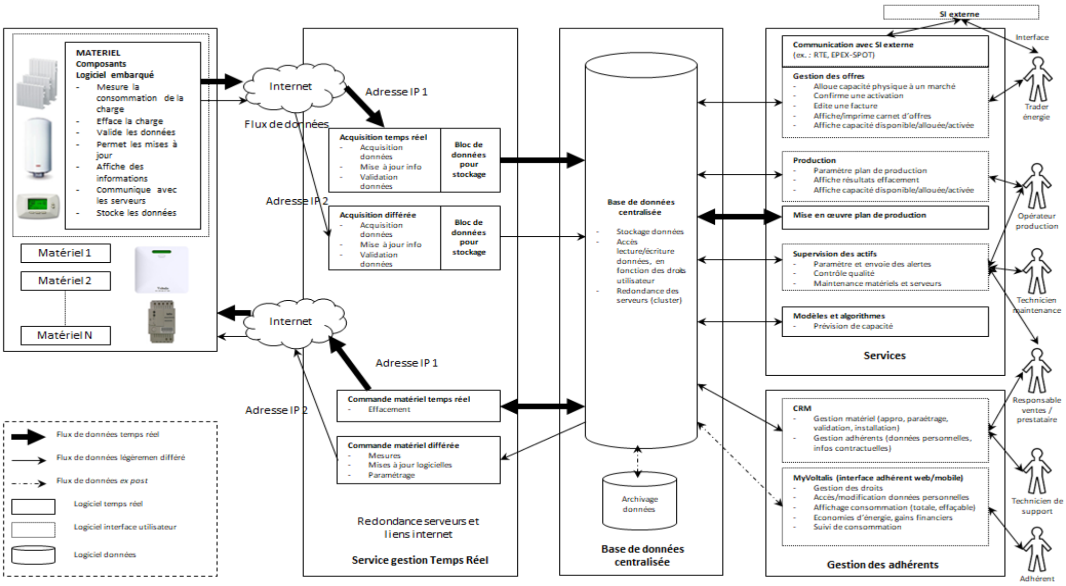

FIGURE 81: [FRANCE DEMO SITE] SCHEMATICS OF THE FRENCH DEMO SITE BUILDING DATA FLOW

5.3 End of the French Demosite in frESCO Project

The initial demo site building in Bordeaux was replaced by a new social housing building in Rennes (Brittany) in early 2021. One apartment was fitted with a Volt box gateway, designed by Voltalis, and a smart plug with temperature sensor feeding the electric resistance heating. The electric heating is the flexible load involved in eventual flexibility events. The problems to engage more users in the building and get simple basic data from the building to characterize it at that late stage of the project, adding the impossibility to look for yet another suitable building for the French demonstration activities led the consortium to decide the drop of the French demonstration in December 2022. Task 6.3 had been running for 8 months at that time with no results worth reporting from the French demosite, being this the main reason why the exit of the French demosite was deemed as necessary at that time.

6 CONCLUSIONS

The purpose of this document is to describe the commissioning process for three pilot projects that aim to demonstrate the feasibility and benefits of a smart energy management system. The document will cover the following aspects of the commissioning process:

- The integration of various components, such as hardware, firmware, sensors, and connectivity solutions, to create a functional system at each pilot site.
- The challenges faced and the solutions implemented to address hardware and software issues, data access and transmission problems, environmental factors, and compatibility issues.
- The success achieved in ensuring that data flow from the pilot sites to the processing applications (APP) was seamless and reliable.

Prior to commissioning, integration plans were developed for each pilot site. These plans detailed how the various components, including hardware, firmware, sensors, and connectivity solutions, would be brought together to create a functional system.

Each site was thoroughly assessed to identify potential challenges and requirements unique to the location. Site-specific factors such as infrastructure, environmental conditions, and existing equipment were considered in the integration plans. Even though, during the commissioning process, several challenges were encountered:

a. Hardware Problems: Some hardware components experienced issues, including malfunctions and damage. Firmware errors in some commercial hardware led to equipment replacement and data losses, in some cases.

b. Smart Meter Data Access (DSO): Challenges were faced in accessing data from smart meters due to the complexities of interfacing with the Distribution System Operator (DSO). A full own independent metering system had to be implemented.

c. Random ZigBee Connectivity Issues: Connectivity issues arose with ZigBee devices, requiring troubleshooting to ensure reliable data transmission. Random connectivity issues were identified between the gateway custom firmware and some external sensors' code. New Develco gateways were integrated. These intermediate devices served as the Zigbee gateways and communicated with the Energy box via the Wi-Fi infrastructure.

d. Seasonality: Seasonality also impacts indirectly the actual pilot duration. Due to the fact that the apartments are occupied only in specific periods per year, consumption on an apartment or bungalow level is heavily reliant on the period under consideration.
e. Webeee Energy Meters server Migration: The migration of Webeee energy meters current platform to a newer one forced by the manufacturer introduced compatibility issues with the firmware. Firmware in the Energy Meters were updated.
f. Lack of Integration: Some legacy equipment lacked compatibility

ANNEXES

Annex I: Smilics Technologies Energy Meter Technical Report.

Annex II: frESCO Dashboard User Manual.

H2020-LC-SC3-EE-2019

EUROPEAN COMMISSION

European Climate, Infrastructure and Environment Executive Agency

Grant agreement no. 893857

ANNEX 1

Smilics Technologies Energy Meter Technical Report

Informe técnico RMA

Diagnostico y reparación

Contents

1 | Diagnósticos

1.1 | Información del producto

Producto	Código de producto	S/N	MAC
Wibeee BOX (WBB)	0800050	222422180021	A848FACB1593
Wibeee BOX (WBB)	0800050	222422180006	A848FACB0A0E
Wibeee BOX (WBB)	0800050	222422180007	A848FACAD766
Wibeee BOX (WBB)	0800018	223631860011	BCFF4DE992FD
Wibeee BOX (WBB)	0800050	222422180012	A848FACC1D74
Wibeee BOX (WBB)	0800050	222422180004	A848FACC11A8
Wibeee BOX (WBB)	0800050	SIN ETIQUETA	A848FACC918F
Wibeee BOX (WBB)	0800050	222422180009	A848FACB090D

1.2 | Inspección preliminar

1.2.1 | Inspección física externa

MAC	Sin manipulación	Etiquetas	Sin Tierra	Sin Óxido/Sin quemaduras
A848FACB1593	✓	✓	✓	✓
A848FACB0A0E	✓	✓	✓	✓
A848FACAD766	✓	✓	✓	✓
BCFF4DE992FD	✓	✓	✓	✓
A848FACC1D74	✓	✓	✓	✓
A848FACC11A8	✓	✓	✓	✓
A848FACC918F	✓	×	✓	✓
A848FACB090D	✓	✓	✓	✓

Después de esta inspección inicial, se realizó una evaluación para determinar si hubo alguna manipulación.

En el caso del BOX con MAC: "A848FACC918F", no se encontraron marcas en la carcasa que indiquen que la cubierta ha sido abierta. Sin embargo, se observó que falta la etiqueta con el número de serie, la cual contiene la fecha de venta. Después de revisar el caso, se llegó a la conclusión de que se debe activar la garantía para este equipo.

En cuanto al resto de los BOX, no se encontró evidencia de manipulación de ningún tipo, por lo tanto, se considera que estos equipos están cubiertos por la garantía.

1.3 | Inspección detallada

Uno de ellos (MAC: "BCFF4DE992FD") arrancó correctamente y tuvo el comportamiento esperado después del reinicio. Este dispositivo venía con la versión de firmware 4.6.164. Se verificó que los valores medidos eran correctos y luego se actualizó a la última versión disponible de firmware (4.6.169) utilizando FOTA (Firmware Over The Air). Posteriormente, se calibró y se verificó que la comunicación con la plataforma era correcta.

La imposibilidad de iniciar cualquiera de los otros dispositivos sin quitar la cubierta llevó a la necesidad de abrirlos y leer el contenido de la memoria flash utilizando PICK-it. En seis de ellos se observaron errores poco comunes en la escritura. Luego, se insertó la última versión validada del firmware en los dispositivos utilizando PICK-it (conexión directa a la placa), lo que eliminó los errores. Posteriormente, los dispositivos BOX se calibraron utilizando la fuente de alimentación MTE y se verificó que la comunicación con la plataforma era la esperada.

Por último, en el caso del dispositivo con MAC: "A848FACB090D", se intentó seguir el mismo procedimiento que se aplicó a los seis dispositivos BOX anteriores, pero se observó que no arrancaba incluso al conectar la tensión directamente en los buffers del micro. Se determinó que esto se debía a un posible cortocircuito en algún punto de la placa o a un micro defectuoso.

Otras verificaciones:

Todos los componentes presentes	Libre de óxido	Libre de quemaduras	Componentes bien soldados
✓	✓	✓	✓

1.4 | Diagnóstico

Se determinó que seis dispositivos tenían un defecto similar, donde los LED no se encendían debido a un error poco común en la escritura de datos en la memoria flash del dispositivo. Esto evitaba que el microprocesador ejecutara el código correcto, lo que resultaba en un mal funcionamiento de los dispositivos.

Después de grabar la última versión validada del firmware en los dispositivos WIBEEE utilizando la herramienta PICK-it, se confirmó que funcionaban correctamente. Posteriormente, se calibraron y se pusieron a disposición para su devolución.

Finalmente, se tomó la decisión de enviar nuevos equipos de reemplazo con el objetivo de prevenir cualquier posible error similar en el futuro.

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ANNEX 2

PROSUMER'S DASHBOARD: USER MANUAL

Author: CARTIF
Contributors: CIRCE, UBITECH,

TABLE OF CONTENTS

1 GENERAL INFORMATION

This user manual explains how to use the prosumer's dashboard of the frESCO project. The aim of this dashboard is showing information and enabling the management of the Personalized Energy Analytics Module and the Human Centric Automation Module.
The Personalized Energy Analytics module focuses on the implementation of those frESCO services giving users recommendations that, if followed, will carry along energy and economic savings.
The Human Centric Automation module focuses on the implementation and automation of those frESCO services in charge of establishing the best control signals for managing controllable devices, mainly the AC/heating and domestic hot water tank. For doing this, it is necessary to automatically send the signals to the actuators responsible of the devices control. It is important to note that the service would be enabled only if the infrastructure related is available (mainly sensors and actuators installed and configured)

2 DASHBOARD STRUCTURE

The prosumer's dashboard can be accessed through this link: https://fresco.cartif.es/. Your energy company should provide you with your credentials to access the dashboard.
After successfully logging in, all the information can be viewed along the five existing tabs: *Monitored data*, *Recommendations*, *Automations*, *Notifications* and *Generation and demand* (Figure 1). Lastly, the configuration options can be established in the Settings section.

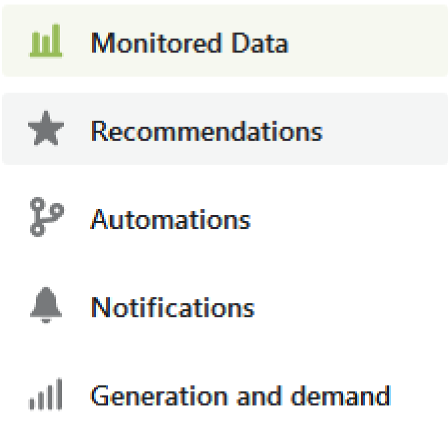


Figure 1: Tabs available in the dashboard

All the mentioned sections are explained below.

2.1 Log-in

The first screen that appears when entering the dashboard web is the log-in page (Figure 2). Here, the username and the password must be introduced to access the prosumer's dashboard.

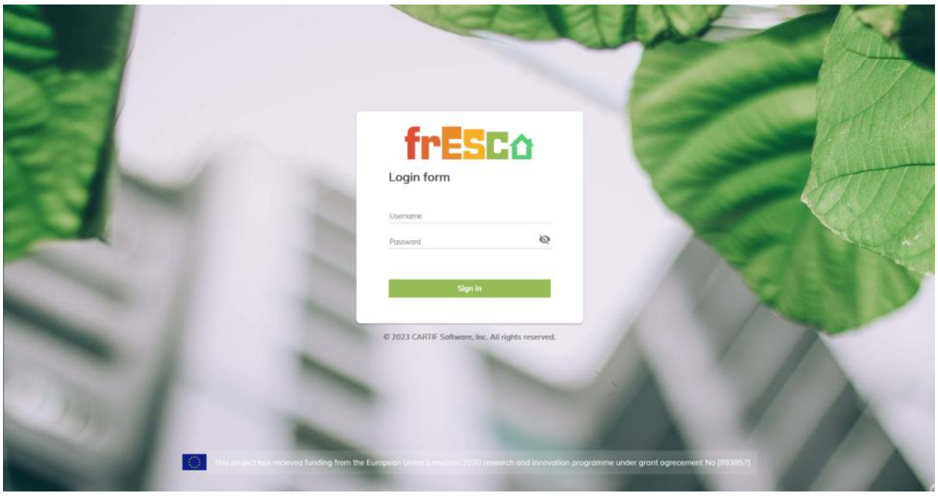


Figure 2: Log-in page.

To log-out, place the cursor over the user's name in the top right and click on *Log-Out* button.

2.2 Monitored data

In this tab, the electricity consumption of the dwelling (in kWh), the prices (in €/kWh) and the total cost (in €) can be viewed in three diagrams in that order (Figure 3).

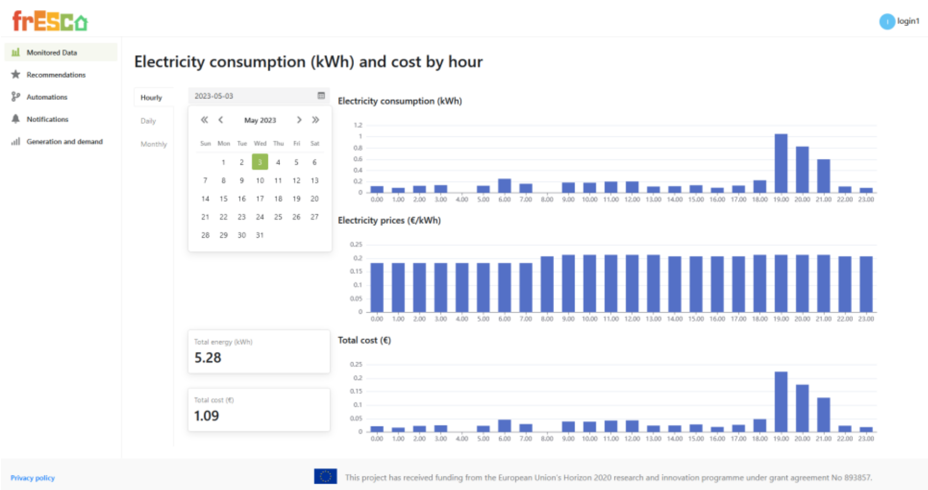


Figure 3: Monitored data page.

The information can be displayed hourly, daily and monthly, and you can select the day, month or year to be shown.

Besides, the application shows the total energy and total cost. This information is related to all the periods shown in the graphs. So, in the hourly view both values indicate the total in the whole day selected, in the day view they are related to the month selected, and in the month view related to the year selected. It is important to note that the total costs are indicative and do not include a possible compensation of energy with the PV system, but also do not consider the fixed costs of the energy tariffs.

2.3 Recommendations

In *Recommendations* (Figure 4), the best usage schedule for the non-automatable appliances (DER) specified by the user can be found. This schedule is calculated by optimization, and the specification of DERs can be accessed through the *Configuration* green button. This button redirects to *Appliances* tab in the *Settings* where you will be able to include the DER you are interested to schedule.

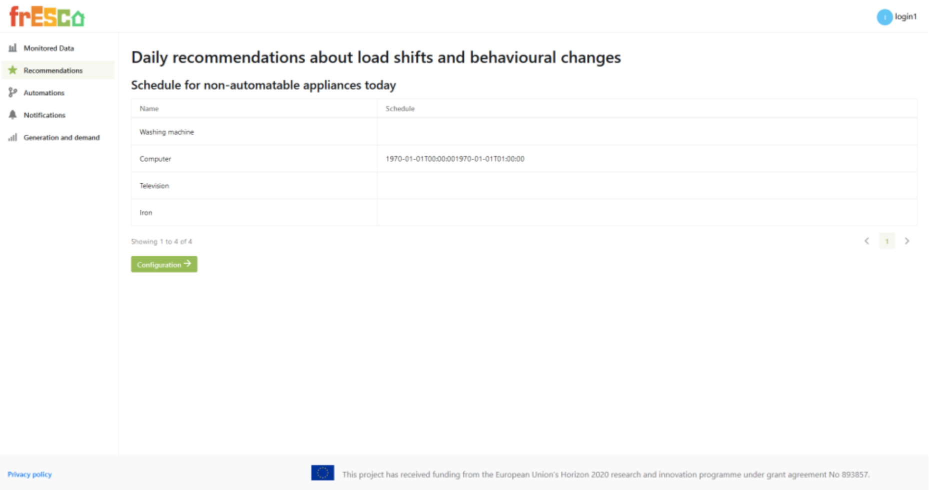


Figure 4: Recommendations page

The table shows the name of the DERs and the time of the day when the appliances should be used to save money as much as possible. The electricity prices are considered.
The service associated to the schedule optimization is still in progress.

2.4 Automations

To access the automations section, you just need to click on the *Automations* button in the lateral menu. In this section, all information regarding automatic actions is included. Two different tabs can be accessed, the *Automations schedule* and the *Presence simulation*.

2.4.1 Automations schedule

Here users can see a table with relevant information (see Figure 5). On the *Appliances* columns, the different appliances that were configured to be automatable are displayed. In the second column is shown the current status of the appliances, OFF or ON. In the *Schedule next automation* column, it is shown the hour of the current day at which the status of the device will be switched to *Next status*.
Lastly, in the *Force ON/OFF* column a button is available that fulfill two different requirements, first it allows to manually switch ON or OFF the appliances whenever the user needs it, and second, it provides information about flexibility events (see section 3.7 for detailed information). When a flexibility event is being carried, the light on the button is red to alert the user of the situation, otherwise, it is green. Moreover, by putting the mouse on top of the button, a short message is displayed to alert the user and guarantee that if he or she alters the status of the specific appliance it will interfere with the flexibility event.

If you forcefully change the state of an appliance, you need to take into account that it is possible that any of the active automation services (see section 3) will change it again shortly after. If you do not want this to happen, you should deactivate the services. In section 2.7.3 you can see how.

Automations schedule

Appliances	Current status	Schedule next automation	Next status	Force ON/OFF
Air conditioner - Kitchen Room	OFF			off
Room 254 - renting	OFF			off

Showing 1 to 2 of 2 ‹ 1 ›

Configuration →

Figure 5 Automations schedule table

All the scheduled changes on the Appliances are triggered by one or more automation services, but users can include their own scheduling if they so wish for. Below the table, there is a *Configuration* button that will redirect you to the *User automatic schedule* in *Settings* where users can include their own schedules for the different appliances. More information can be found on sections 2.7.4 and 3.

2.4.2 Presence simulation

Presence simulation (Figure 6) represents an energy efficiency service not fully implemented in the demo sites due to the absence of lights control actuators. The aim of this service is to configure lighting schedules when nobody is at the dwelling, in order to simulate presence for security reasons.

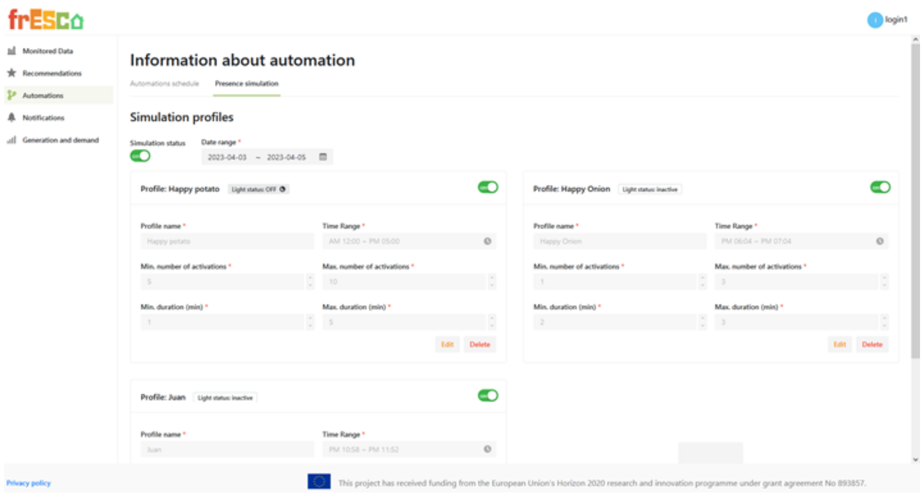


Figure 6: Presence simulation tab

First, *Simulation status* button must be on and the dates in which the presence must be simulated has to be specified. Then, a new schedule can be created pushing the *Add profile* button and establish it on. Six characteristics need to be configured: the schedule profile name, the time range in which actuate, the minimum and the maximum number of activations of the lights, and the minimum and maximum duration of these activations. After that, the algorithm calculates when the controlled light should be on or off, and its status will be displayed.

2.5 Notifications

In this tab, the alarms generated can be checked by the user (Figure 7). The alarms that the user can check are those that have been configured taking into account the sensors available and configured for the user.

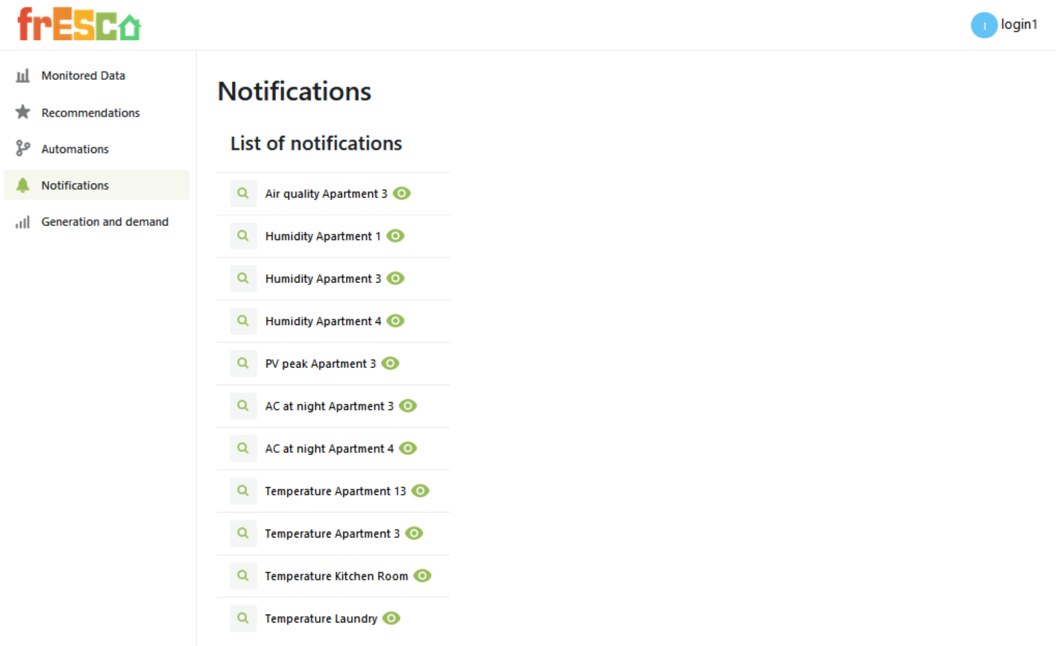


Figure 7: Notification page

The user can indicate one or more email addresses in order to receive the notifications directly. This functionality is explained in section 2.7.2.

Besides, the notification service can be configured by the user in the corresponding service setting. Please consult section 3, for more information about the configuration of each notification service.

When the user clicks on one of the elements of the list, he/she is able to see the last alarm generated by the service, as can be seen in the Figure 8.

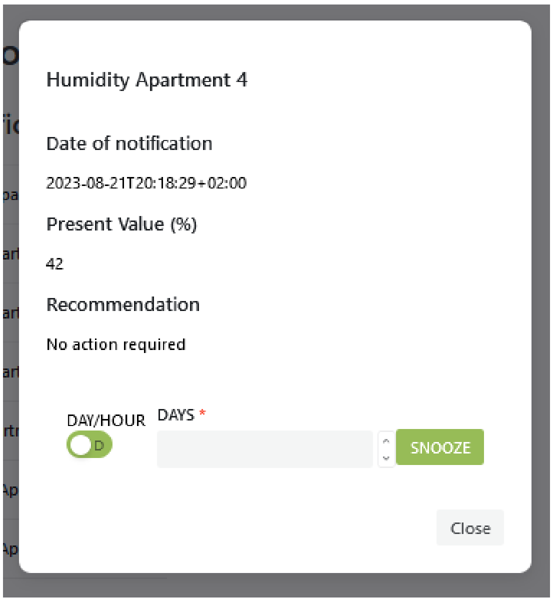


Figure 8: Alarm screen

If the user wants to stop receiving notifications in their email during a period, he/she can indicate the period as it is shown in Figure 9, in hours or days as desired. After that he/she has to click in the SNOOZE button. In this way the user would not receive emails notifications in this period.

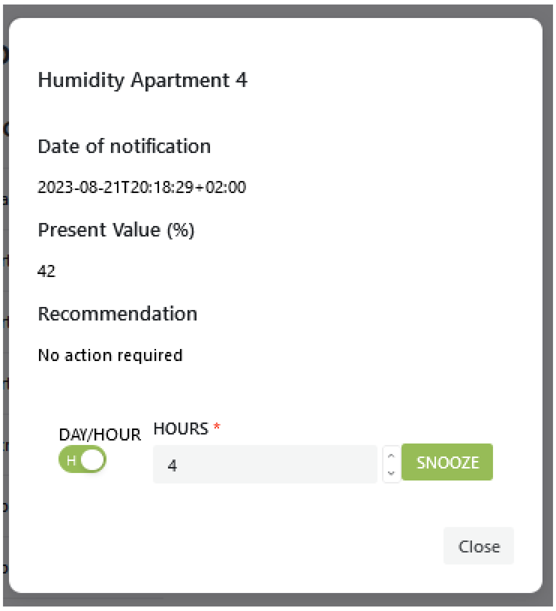


Figure 9: Alarm screen prepared to be snoozed

In the list of notifications, the alarms that have been snoozed will appear with a "closed eye" icon, as shown in Figure 10.

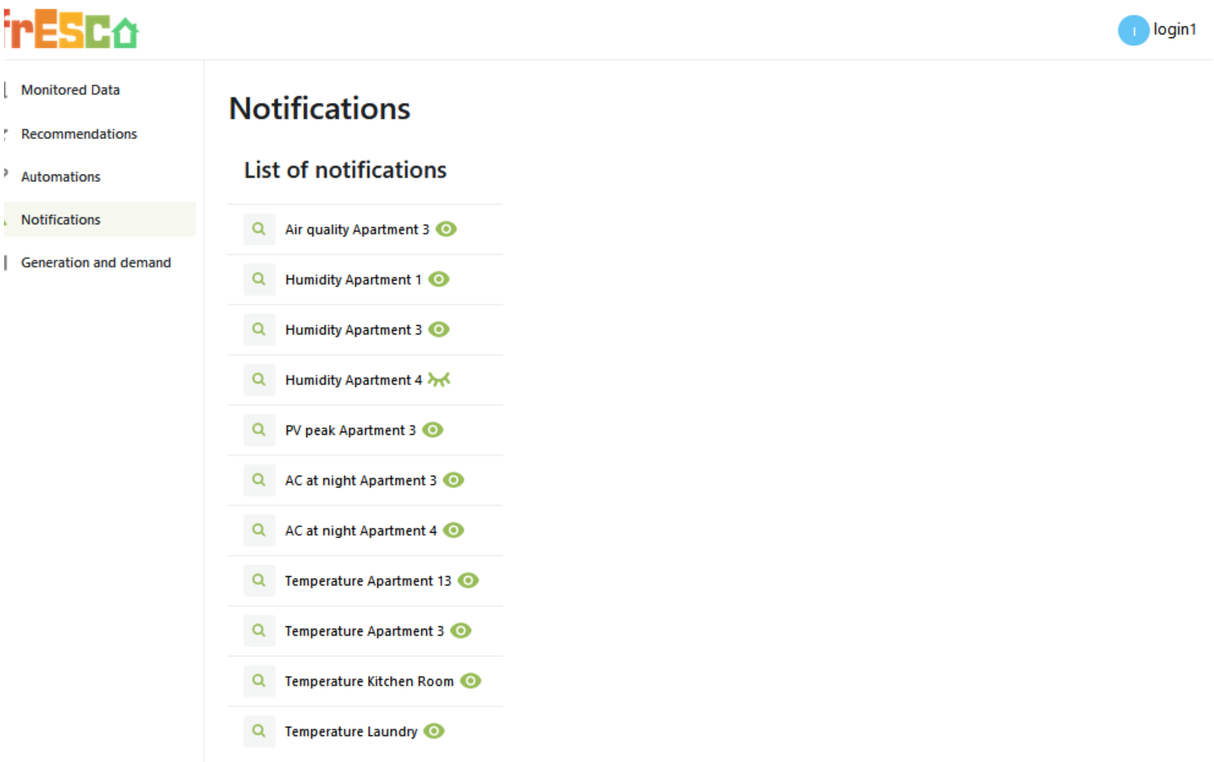


Figure 10: Notification page with Humidity Apartment 4 notification service snoozed

The user can deactivate the muting of notifications at any time, receiving emails again from then on. For that the user has to click in the notification that would like to unmute and once the pop-up with the specific information of the notification appears, he/she has click in the WAKE button, as you can see in the Figure 11.

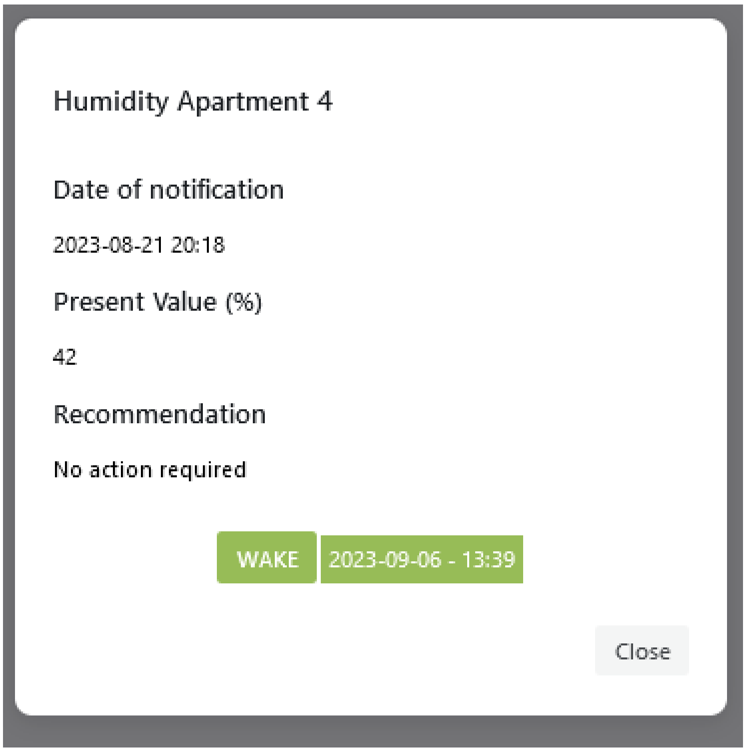


Figure 11: Alarm screen with snoozed period indicated, available to be woken up

2.6 Generation and demand

This tab gives the user access to the dashboards related to the generation and demand analysis at the *dwelling level*. It provides updated information in terms of monitoring and forecasting in the long term. The main screen of the tool, which allows users to navigate through the rest of the panels, is displayed below (Figure 12). The contents of each of the dashboards that each button leads to will be described in the following subsections

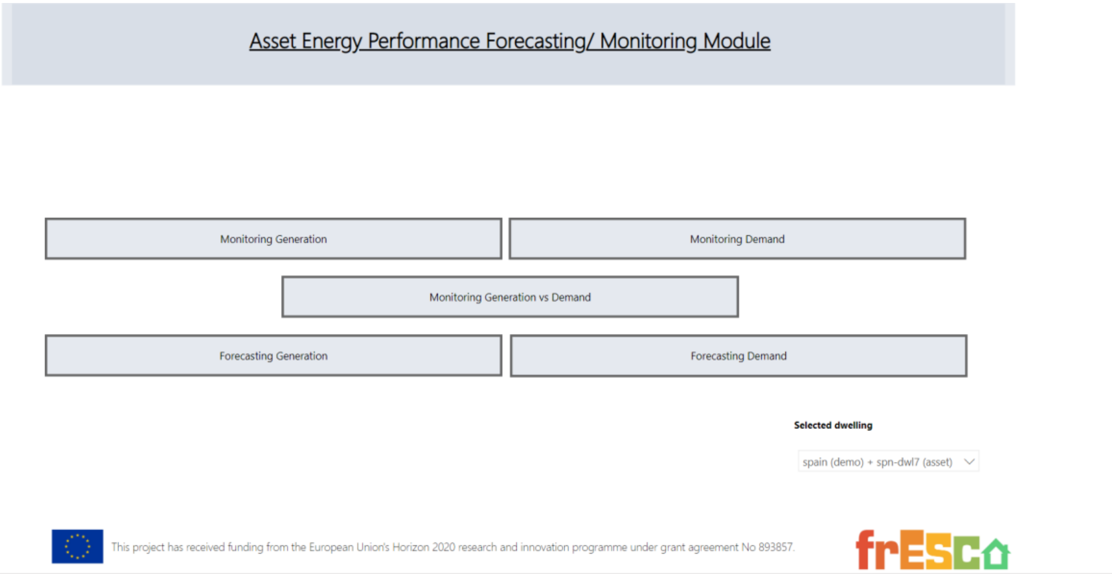


Figure 12: Main navigation Dashboard

2.6.1 Monitoring Generation

The main controls and features on this dashboard are shown in Figure 13 and described below.

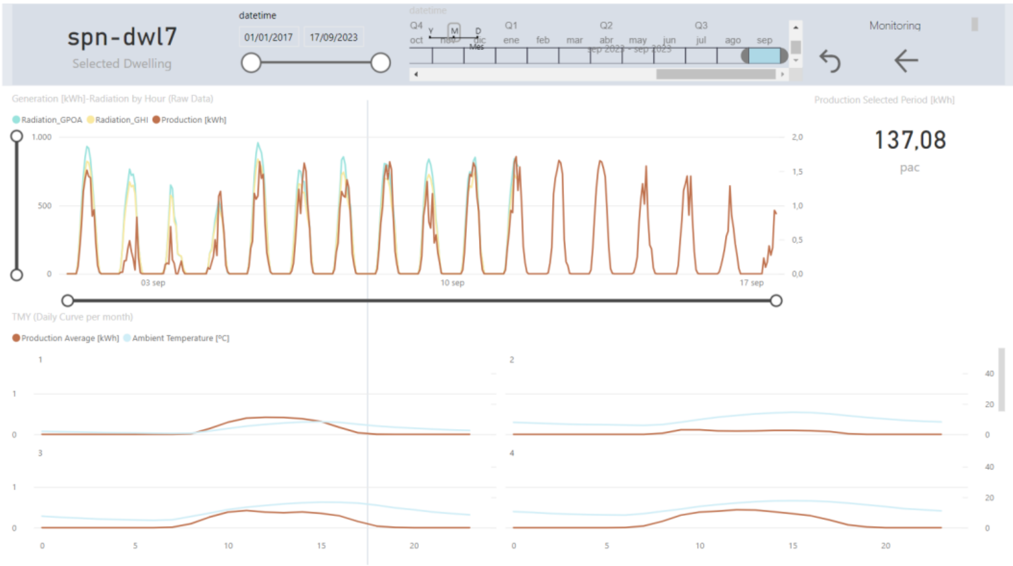


Figure 13: Monitoring Generation Dashboard

- Period Selection: This feature consists of 2 selectors at the top of the screen. The left one allows you to limit the volume of data queried from the database. The selector on the right enables you to choose data blocks more precisely. It allows for monthly granularity (by default) but also offers annual or daily options.
- Generation [kWh]-Radiation by Hour (Raw Data): This graph displays the solar generation curve for the selected period. It also includes global radiation and radiation on the plane of the array, if available.
- Production Selected Period [kWh]: This card displays the cumulative solar generation for the selected period.
- TMY (Daily Curve per month): These graphs depict the typical daily solar generation curve by month, based on historical data.

2.6.2 Monitoring demand

The main controls and features on this dashboard are shown in Figure 14 and described below.

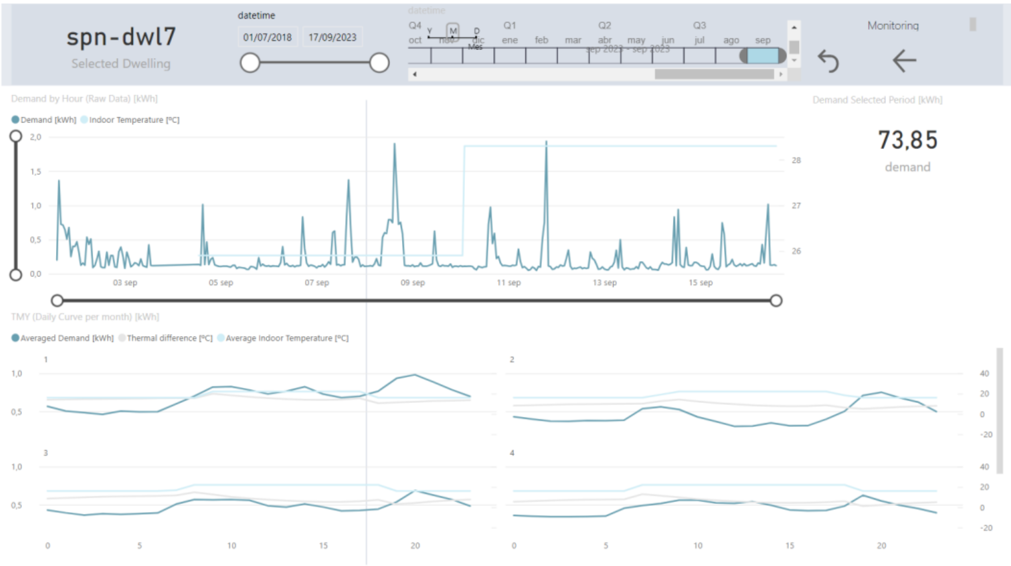


Figure 14: Monitoring Demand Dashboard

- Period Selection: This feature consists of 2 selectors at the top of the screen. The left one allows you to limit the volume of data queried from the database. The selector on the right enables you to choose data blocks more precisely. It allows for monthly granularity (by default) but also offers annual or daily options.
- Demand by Hour (Raw Data) [kWh]: This graph displays the demand curve for the selected period. It also includes indoor temperature, if available.
- Demand Selected Period [kWh]: This card displays the cumulative demand for the selected period.
- TMY (Daily Curve per month [kWh]: These graphs depict the typical daily demand curve by month, based on historical data.

2.6.3 Monitoring Generation Vs Demand

The main controls and features on this dashboard are shown in Figure 15 and described below.

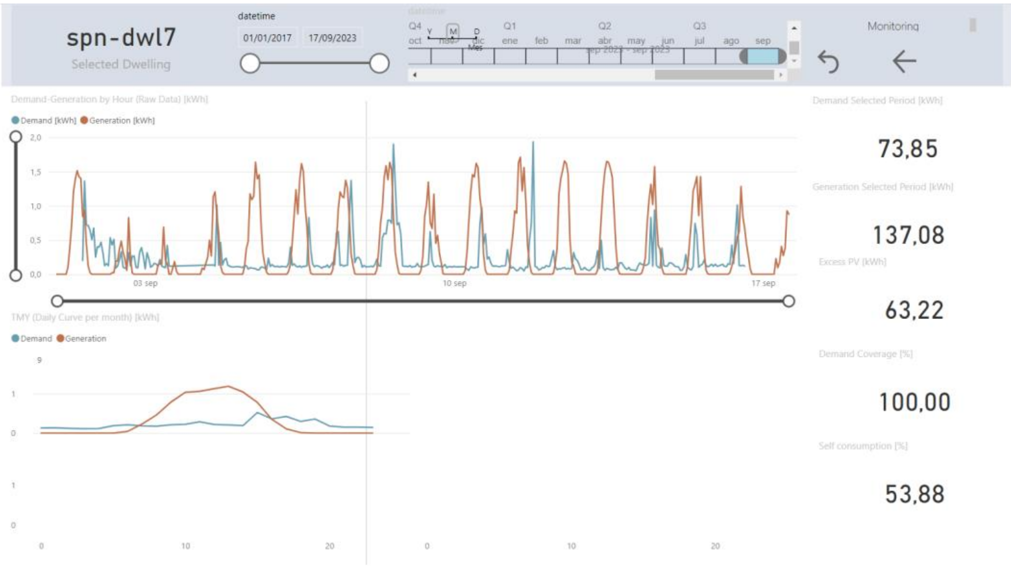
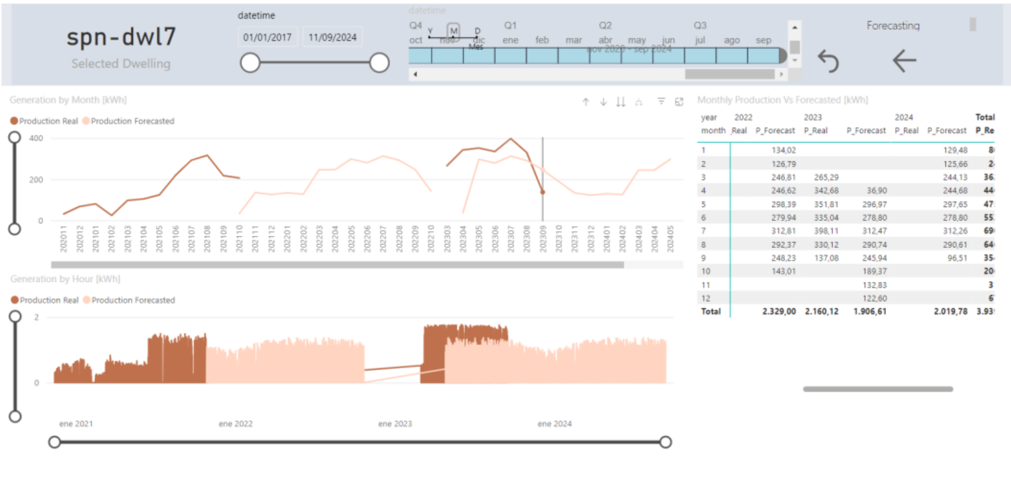


Figure 15: Monitoring Generation Vs Demand Dashboard

- Period Selection: This feature consists of 2 selectors at the top of the screen. The left one allows you to limit the volume of data queried from the database. The selector on the right enables you to choose data blocks more precisely. It allows for monthly granularity (by default) but also offers annual or daily options.
- Demand-Generation by Hour (Raw Data) [kWh]: This graph displays the demand curve and the solar generation curve for the selected period.
- TMY(Daily Curve per month)[kWh]: These graphs depict the typical daily demand curve and typical daily solar generation curve by month, based on the selected period.
- Demand Selected Period [kWh]: This card displays the cumulative demand for the selected period.
- Generation Selected Period [kWh]: This card displays the cumulative solar generation for the selected period.
- Excess PV [kWh]: This corresponds to the surplus solar energy generated during the selected analysis period (generation - demand). It would correspond to the maximum excess energy that could be utilized by an energy storage system if one were in place.
- Demand Coverage [%]: This corresponds to the maximum possible demand coverage rate achievable through the use of solar photovoltaic energy generated (generation/demand). Under optimal conditions, assuming the existence of an ideal energy storage system.
- Self consumption [%]: The amount of solar energy generated and utilized to meet the demand (demand/generation). Under ideal conditions, assuming the existence of an energy storage system that enables the utilization of all available solar generation.

2.6.4 Forecasting Generation

The main controls and features on this dashboard are shown in Figure 16 and described below.



Mid-Long Term Forecast GENERATION

Figure 16: Forecasting Generation Dashboard

- Period Selection: This feature consists of 2 selectors at the top of the screen. The left one allows you to limit the volume of data queried from the database. The selector on the right enables you to choose data blocks more precisely. It allows for monthly granularity (by default) but also offers annual or daily options.
- Generation by Month [kWh]: This graph displays the solar generation and the forecasted generation every month for the selected period.
- Monthly Production Vs Forecasted [kWh]: This table displays the solar generation and the forecasted generation every month for the selected period.
- Generation by Hour [kWh]: This graph displays the solar generation and the forecasted generation on an hourly basis for the selected period.

2.6.5 Forecasting demand

The main controls and features on this dashboard are shown in Figure 17 and described below.

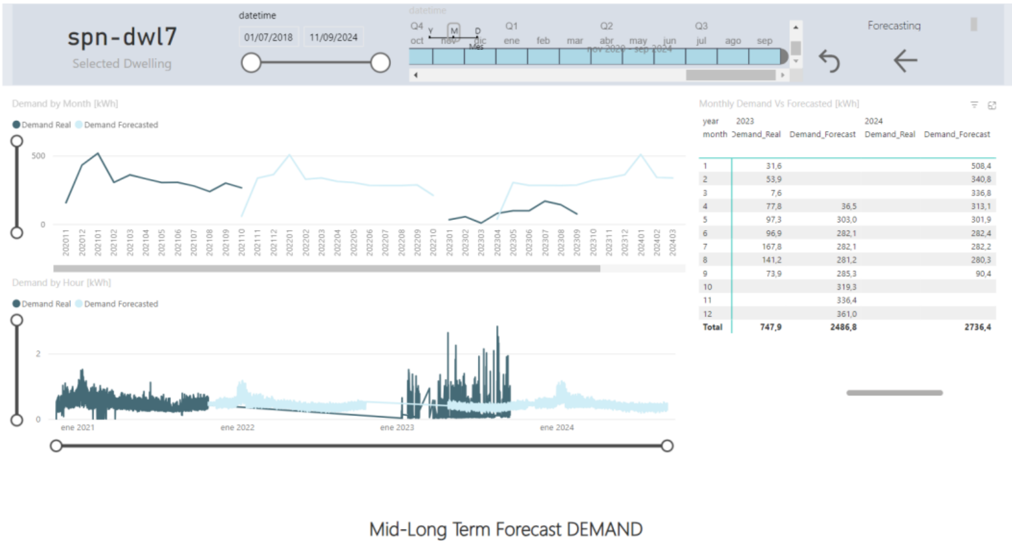


Figure 17: Forecasting Demand Dashboard

- Period Selection: This feature consists of 2 selectors at the top of the screen. The left one allows you to limit the volume of data queried from the database. The selector on the right enables you to choose data blocks more precisely. It allows for monthly granularity (by default) but also offers annual or daily options.
- Demand by Month [kWh]: This graph displays the demand and the forecasted demand every month for the selected period.
- Monthly Demand Vs Forecasted [kWh]: This table displays the demand and the forecasted demand every month for the selected period.
- Demand by Hour [kWh]: This graph displays the demand and the forecasted demand on an hourly basis for the selected period.

2.7 Settings

To access this section, the cursor must be placed over the user's name and click on *Settings*. Once in this section, five different tabs can be found, which are *Appliances*, *Notifications*, *Services*, *User automatic schedule* and *User preferences*. They are explained below.

2.7.1 Appliances

The first tab of the settings is *Appliances*. Here, users will configure the devices for the recommendation service. But currently this service is not available.

2.7.2 Notifications

In the *Notifications* settings (Figure 18), those emails addresses which will receive messages each time any service triggers a notification can be established. The services notifications are sent by email and can also be viewed at the *Notifications* tab.

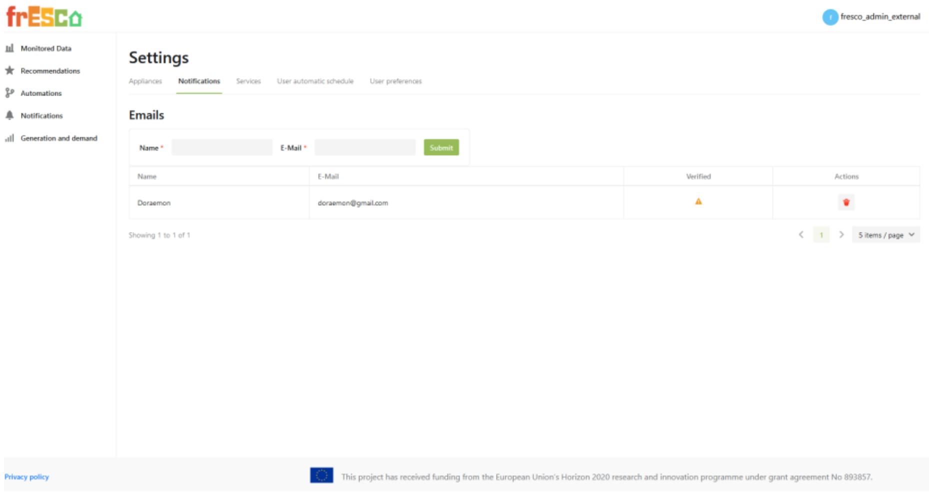


Figure 18: Notifications settings

The email addresses need to be verified by answering the message that the dashboard sends to them the first time they are submitted. An email address can be deleted from the dashboard at any time clicking on the red button.

2.7.3 Services

In the Services Settings tab the user can see the list of services that are available for him/her. Some services are available or not, depending on the infrastructure (sensor and actuator) that the user has.

For each service, it is shown its name in bold and a brief description (that can be hidden or displayed with the "-" or "+" icons, respectively). Besides there is a slice button for activate or deactivate the service. In the Figure 19 and Figure 20, two examples of the Services' Settings screen from different users are shown.

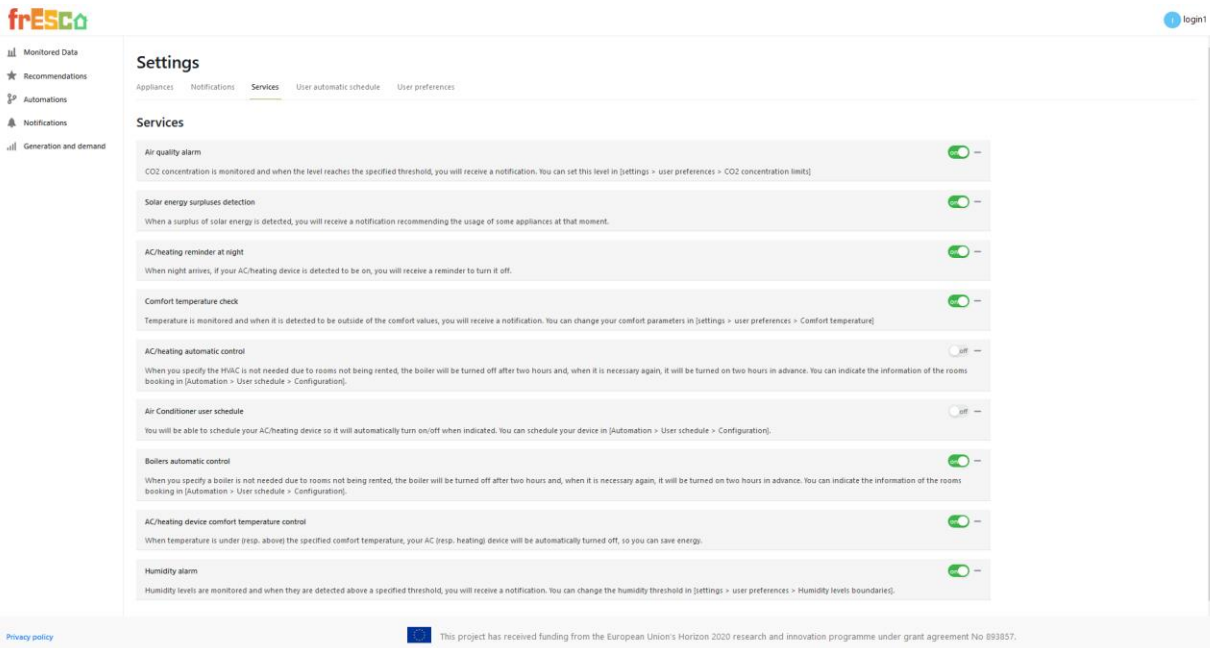


Figure 19: Services settings view, example 1

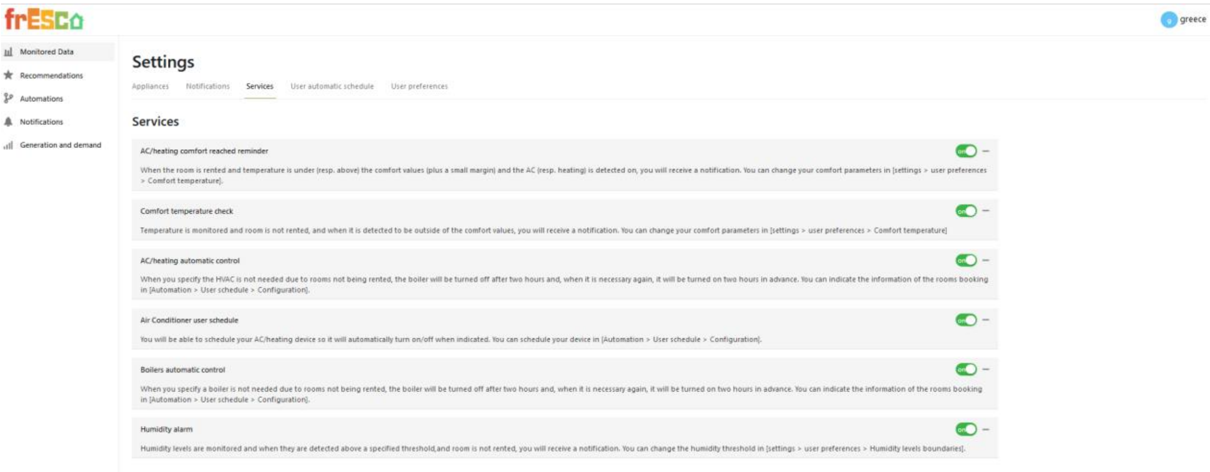


Figure 20: Services settings view, example 2

2.7.4 User automatic schedule

On the User automatic Schedule (see Figure 21), users can indicate different schedules for their automatable appliances. For each of them, a dropdown menu is available. When clicking on it, a scheduler appears in which users will introduce dates or hours.

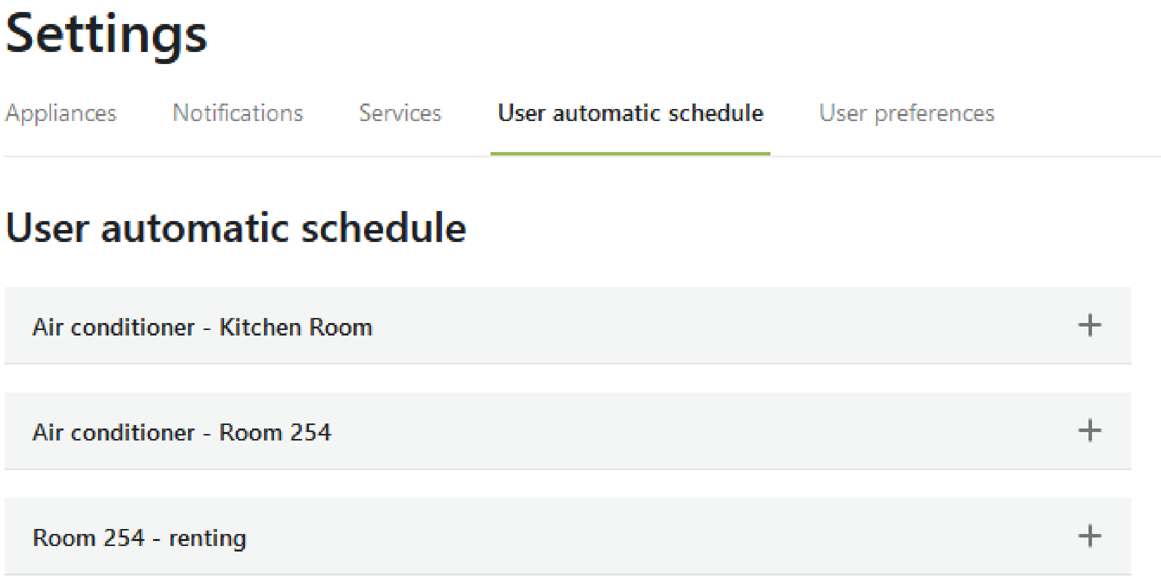


Figure 21 User automatic schedule

Two different schedulers are available depending on the automatization nature. The first one is the weekly schedule (see Figure 22). This scheduler allows to introduce daily schedules and by activating the option 'Repeat weekly' at the bottom of the table, the hours introduced will remain for next week and so on. The button with the picture of a trash bin allows to remove a range of hours from one day.

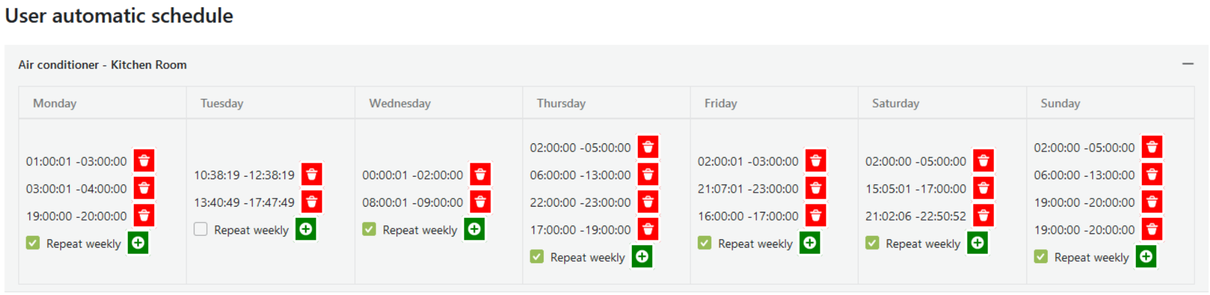


Figure 22 Weekly scheduler

More information related to the Weekly schedules might be found in section 3.10.
By clicking on the button with the '+' symbol, an interface will appear where a new range of hours can be included as shown in Figure 23. Users only need to click on the hours and write a date or choose it from the menu that will appear. Lastly, click on 'Confirm' to save the changes.

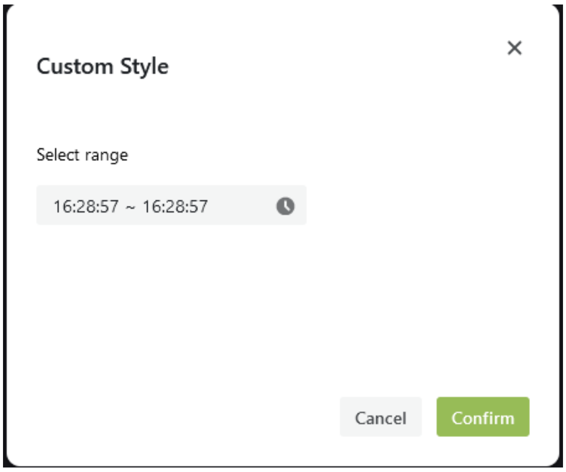


Figure 23 New weekly schedule frame

The second type of scheduler is the calendar schedule (see Figure 24). This time, users can choose a range of dates on a calendar. Again, clicking on the trash bin will delete a range of dates and clicking on the Add Schedule button opens a menu that allows to choose dates on a calendar or manually write the dates.

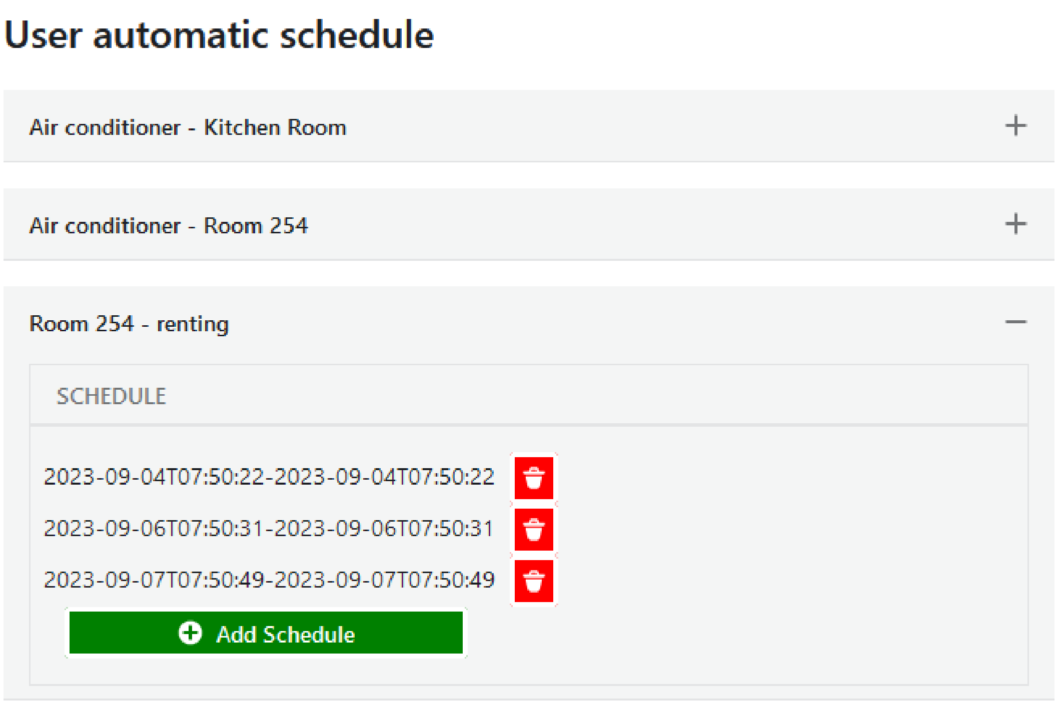


Figure 24 Calendar scheduler

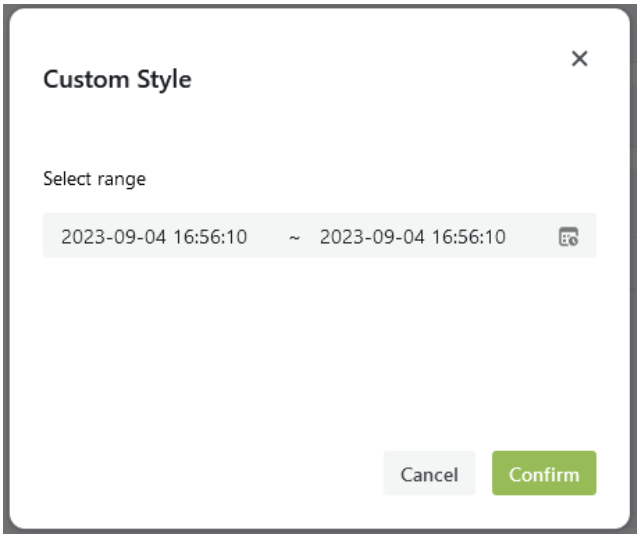


Figure 25 New calendar schedule frame

More information related to the Calendar schedules might be found in section 3.8.

2.7.5 User preferences

In *User preferences* settings (Figure 26) the comfort parameters of the user can be configured. These values are used by several services, so it is important to keep them updated.

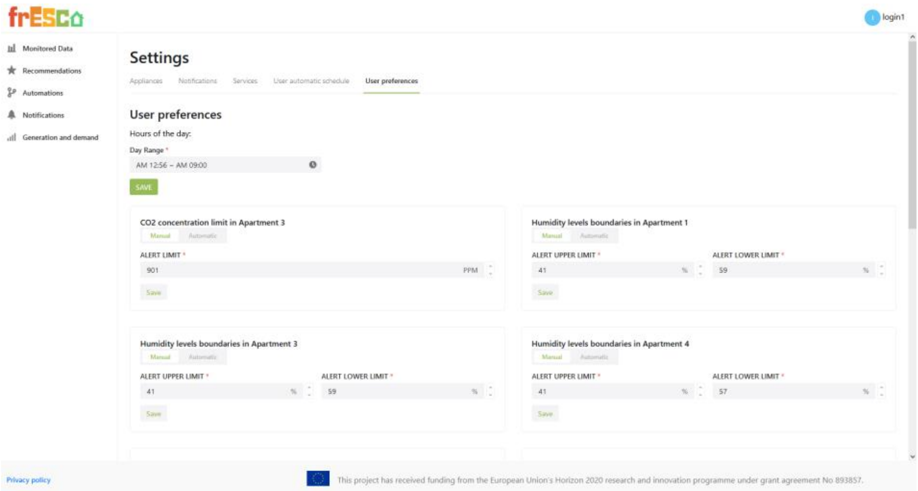


Figure 26: User preferences settings.

Three parameters can be configured: Hours of the day, temperature (used in services 3.1, 3.6 and 3.12), humidity (3.2) and CO_2 concentration (3.3). In the first you will introduce an hour range. For the next two parameters, the minimum and the maximum value allowed must be specified when the *Manual* option is activated. Regarding CO_2 concentration, only the maximum value is required.
The parameters introduced in this section will be used in some of the services explained in section 3: With the hours of the day, you can specify the hours of the day you will be or typically are active during the day, this will affect the AC/heating behavior as explained in 3.5, 3.6. The temperature range introduced will affect the trigger for the services in sections 3.1, 3.6 and 3.12. The same way, humidity limits and CO_2 concentration work for services in sections 3.2 and 3.3 each.

3 SERVICES

The Personalized Energy Analytics module and the Human Centric Automation module include ten services that can be used for increasing the energy efficiency of the user's dwelling.
These services can be separated in two different groups: Notifications and Automations.
Notification services include those services that help you to be aware of the possibilities you have to save energy and money by providing you with recommendation and information to change your current energy consumption; for example, to turn off your AC/heating devices when the temperature is stable. The notification services are: *Comfort temperature check, Humidity alarm, Air quality alarm*, *Solar energy surpluses detection*, *AC/heating reminder at night* and *AC/heating comfort reached reminder.*
Automation services are those that will change automatically change the state of the devices to reduce your energy consumption. As different automation services are offered, so they do not interfere with one another, in case of two different automation services colliding due to different criterion in their decision making, it was decided to stabilize a priority within this group of services. The automation services appear explained bellow in decreasing order of priority: *Flexibility events*, *Boilers automatic control*, *AC/heating automatic control*, *Air conditioner user schedule, AC/heating device night shutdown* and *AC/heating device comfort temperature control*.
All the services are explained below.

3.1 Notifications: Comfort temperature check

Comfort temperature check service generates a notification each time the temperature monitored in real time is outside of the specified comfort values. The temperature comfort limit values can be modified at the *User preferences* settings, as indicated in section 2.7.5. The notifications can be seen through the graphical user interface, and they can also be received by e-mail.
For more information about how to configure the e-mail notification, please see section 2.7.2.
For more general information about the notification services and how to temporally disable the e-mail notification, please see section 2.5.

3.2 Notifications: Humidity alarm

Humidity alarm service generates a notification each time the humidity monitored in real time is outside of the specified comfort values. The humidity comfort limit values can be modified at the *User preferences* settings, as indicated in section 2.7.5. The notifications can be seen through the graphical user interface, and they can also be received by e-mail.
For more information about how to configure the e-mail notification, please see section 2.7.2.
For more general information about the notification services and how to temporally disable the e-mail notification, please see section 2.5.

3.3 Notifications: Air quality alarm

Air quality alarm service generates a notification each time the CO_2 concentration monitored in real time is higher than the specified comfort value. The CO_2 concentration comfort limit value can be modified at the *User preferences* settings, as indicated in section 2.7.5. The notifications can be seen through the graphical user interface, and they can also be received by e-mail.
For more information about how to configure the e-mail notification, please see section 2.7.2.
For more general information about the notification services and how to temporally disable the e-mail notification, please see section 2.5.

3.4 Notifications: Solar energy surpluses detection

Solar energy surpluses detection generates a notification each time a surplus of solar energy is detected, with the objective of informing users of when it is a good time to use electrical appliances or systems. The notifications can be seen through the graphical user interface, and they can also be received by e-mail.
For more information about how to configure the e-mail notification, please see section 2.7.2.
For more general information about the notification services and how to temporally disable the e-mail notification, please see section 2.5.

3.5 Notifications: AC/heating reminder at night

AC/heating reminder at night generates a notification when the night arrives, and the AC/heating device is detected to be on (analysing the energy that the device is consuming). So, the user could decide to switch off the AC/heating device, manually or using the

automations screen of this application. The notifications can be seen through the graphical user interface, and they can also be received by e-mail.
You can configure the light hours that affect this service in the user preferences section in settings [Settings > User preferences] and introduce de hour range in 'Hours of the day').
For more information about how to configure the e-mail notification, please see section 2.7.2.
For more general information about the notification services and how to temporally disable the e-mail notification, please see section 2.5.

3.6 Notifications: AC/heating comfort reached reminder

When the room is rented and temperature is under (resp. above) the comfort values (plus a small margin) and the AC (resp. heating) is detected on, you will receive a notification alerting you of the situation and recommending you to turn it off.
You can change the comfort temperature and the margin in [settings > user preferences] and change de values in the 'Comfort temperature' box.

3.7 Automations: Flexibility events

A flexibility event is a coordinated response initiated by the aggregator to adjust energy consumption patterns within the electricity grid. This adjustment is essential to ensure the efficient and effective operation of the grid, especially during times when there's a specific demand response (DR) request.

The aggregator initiates this response by determining the necessary duration and extent of energy reduction. An advanced system, known as the optimal VPP configuration module, then calculates the best strategy to achieve this reduction. This module considers various factors, such as the agreements each prosumer has with the aggregator and the comfort settings of devices. Based on these considerations, the module formulates a plan detailing which devices, like HVAC systems, should reduce their energy consumption and by how much.

Once this plan is in place, the human centric automation module ensures the devices adhere to the specified adjustments. For instance, it may momentarily turn off an HVAC system. It's crucial to note that all adjustments made during a flexibility event are designed to stay within comfortable limits and always respect the agreements prosumers have established with the aggregator.

By participating in these flexibility events, prosumers not only play a vital role in supporting the broader electricity grid, ensuring its stability and efficiency, but they also receive compensation for their successful participation in these DR events. This compensation serves as a token of appreciation for their contribution to the grid's optimal functioning.

The user could see when a flexibility event is being carried in the automation section of the platform, associated to the device. When a flexibility event is being carried, the light on the button is red to alert the user of the situation, otherwise, it is green. Moreover, by putting the mouse on top of the button, a short message is displayed to alert the user and guarantee that if he or she alters the status of the specific appliance it will interfere with the flexibility event.

3.8 Automations: Boilers automatic control

This service is designed for hotels and similar business. When you specify a boiler is not needed due to rooms not being rented, the boiler will be turned off after two hours and, when it is necessary again, it will be turned on two hours in advance. You can indicate the information of the rooms booking (not directly the boiler usage) in [Automation > User schedule > Configuration] and introducing the information with the calendar scheduler. See the details of the calendar scheduler in 2.7.4.

3.9 Automations: AC/heating automatic control

This service is designed for hotels and similar business. When you specify the AC/heating is not needed due to rooms not being rented, the boiler will be turned off after two hours and, when it is necessary again, it will be turned on two hours in advance. You can indicate the information of the rooms booking (not directly the AC/heating usage) in [Automation > User schedule > Configuration] and introducing the information with the calendar scheduler. See the details of the calendar scheduler in 2.7.4.

3.10 Automations: Air conditioner user schedule

You will be able to schedule your AC/heating device so it will automatically turn on/off when indicated. You can schedule your device in [Automation > User schedule > Configuration] and include your schedules using the weekly scheduler. See the details of the weekly scheduler in 2.7.4.

3.11 Automations: AC/heating device night shutdown

AC/heating device night shutdown switches off the AC/heating system when night-time arrives. Besides, the AC/heating system is switched on when day-time arrives. Not comfort restriction are applied so, simply the service will make sure that during the night period the device is turned off.
For more information about this service, please check section 2.4.

3.12 Automations: AC/heating device comfort temperature control

When temperature is under (resp. above) the specified comfort temperature, your AC (resp. heating) device will be automatically turned off, so you can save energy.
You can change the comfort temperature and the margin in [settings > user preferences] and change de values in the 'Comfort temperature' box.