D7.11 ECF4CLIM IoT Platform v.1 (tested at QUE Lab premises)

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WHO WE ARE

The ECF consortium consists of ten partners. The project is coordinated by Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas-CIEMAT.

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ACRONYMS

Term	Definition
ECF	European Competence Framework
IoT	Internet of Things
OTA	Over The Air
KPI	Key Performance Indication
WSN	Wireless Sensor Network
IAQ	Indoor Air Quality
HVAC	Heating Ventilation Air Conditioning
UI	User Interface
SD	Secure Digital
USB	Universal Serial Bus
PPM	Parts Per Million
PIR	Passive Infrared
VOC	Volatile Organic Compounds

About the Project

Through a multidisciplinary, transdisciplinary and participatory process, ECF4CLIM develops, tests and validates a European Competence Framework (ECF) for transformational change, which will empower the educational community to take action against climate change and towards sustainable development.

Applying a novel hybrid participatory approach, rooted in participatory action research and citizen science, ECF4CLIM co-designs the ECF in selected schools and universities, by: 1) elaborating an initial ECF, supported by crowdsourcing of ideas and analysis of existing ECFs; 2) establishing the baseline of individual and collective competences, as well as environmental performance indicators; 3) implementing practical, replicable and context adapted technical, behavioural, and organisational interventions that foster the acquisition of competences; 4) evaluating the ability of the interventions to strengthen sustainability competences and environmental performance; and 5) validating the ECF.

The proposed ECF is unique in that it encompasses the interacting STEM-related, digital and social competences, and systematically explores individual, organisational and institutional factors that enable or constrain the desired change. The novel hybrid participatory approach provides the broad educational community with: an ECF adaptable to a range of settings; new ways of collaboration between public, private and third-sector bodies; and innovative organisational models of engagement and action for sustainability (Sustainability Competence Teams and Committees).

To encourage learning-by-doing, several novel tools will be co-designed with and made available to citizens, including a digital platform for crowdsourcing, IoT solutions for real-time monitoring of selected parameters, and a digital learning space. Participation of various SMEs in the consortium maximises the broad adoption and applicability of the ECF for the required transformational change towards sustainability.

LEGAL NOTICE

EXECUTIVE SUMMARY

The IoT Ecosystem Framework is designed to deliver real time energy consumption and indoor air quality data gathering of the selected educational institutions to the ECF4CLIM project. These extracted data will be pre-processed, with data cleansing and normalization algorithms. Providing consistent and actual data from the pilot sites that will participate to the calculation of the Key Performance Indicators. It comprises firstly, of an installed Wireless Sensor Network, that securely collects a continuous data stream from the selected buildings. Secondly, includes the IoT Cloud that is responsible for the data cleansing and data transferring to the database of the ECF4CLIM platform.

The information that will be examined is related to the indoor air quality sensing and energy metering characteristics of the pilot sites. By processing the dynamic real time data that the IoT Ecosystem provides, our goal is to examine the environmental effect of the educational community.

The requirements that the IoT ecosystem Framework needs to fulfill in the project are presented in this document alongside with the challenges that were faced to deploy the solution to the buildings.

Following, it is described in detail the specifications and services of the IoT Ecosystem Framework. Secondly it is demonstrated the steps that were implemented to test and validate the IoT devices that will participate in the project. Different IoT devices will be installed in the selected pilot sites since the solution needs to be adjusted for each building infrastructure. Also, the IoT ecosystem is equipped with services and web applications that will produce added value to the project. Aiming towards the engagement of the teachers and students using mobile applications to monitor the effects of their activities. To accommodate the deployment and the supervision of the IoT ecosystem in the educational institutions, web applications will be delivered to the people that will be responsible for these tasks.

Finally, the next steps are presented in the conclusion of the deliverable to give a brief overview of our planning for the coming period.

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1 INTRODUCTION

1.1 Scope and objectives of the Deliverable

The deliverable aims to demonstrate the first steps that have been fulfilled to deliver to ECF4CLIM project the IoT Ecosystem framework. Utilizing this technical solution, the educational community will be able to collect, process and finally evaluate their environmental performance and the carbon footprint that their activities leave to the environment. The IoT solution framework will be deployed in eleven educational institutions. Each educational building will have its own IoT ecosystem, therefore each solution will be tailored made to match the existing building's infrastructure assets.

The main objectives of the deliverable are:

- Provide an overview of the project's requirements that the IoT ecosystem will address as well as the building cases where the solution will be installed.
- Describe the IoT ecosystem framework main components, software and hardware, and its services.
- Demonstrate the IoT ecosystem assessments that took place within the ECF4CLIM project. Those tests include validation process that took place in QUE lab premises in order to finalized the IoT proposed list that will take part in the project.
- Present the next steps that will be included in the updated version of the deliverable.

1.2 Structure of the deliverable

The deliverable is divided into 5 sections:

- In the first section it is described the IoT ecosystem's scope, the objectives of the deliverable, the structure of the deliverable and the relation with other tasks and Work Packages in the ECF4CLIM project.
- In the second section we demonstrate pilot sites that will take part in the ECF4CLIM project as well as the data requirements that will address to the project.
- The third chapter includes the hardware and the software specifications of one of the main components of the IoT ecosystem, the IoT gateway, in addition it is documented the Cloud where all the available data are processed before reaching the ECF4CLIM database, IoT Cloud. These two components are the main part of the IoT ecosystem solution. Finally, they are listed the applications that will facilitate the deployment of the solutions and foster the engagement of the teachers in terms of the ECF4CLIM project.
- In the next chapter, we analyze the steps that were implemented finalize the list of the IoT equipment that will be installed to the pilot sites. This IoT equipment will be proposed to match each building's specifications and to acquire the preferable data to the IoT Cloud.
- Finally, in the last section describes the next steps that will be presented in the updated deliverable.

1.3 Relation to Other Tasks and Deliverables

The task has direct and indirect links with tasks of the ECF4CLIM project.

- Link with task3.5: In this task the results of the Key Performance Indicators (KPIs) that will be calculated directly or from the data provided by the IoT Ecosystem will be included.
- Link with task4.3: In this task the auditing procedure as well as the installation roadmap will be defined in order to deploy the IoT Ecosystem solution to each selected pilot site.
- Link with WP5: A part of the Key Performance Indicators that will be defined in this task will be based on the data extracted from the IoT Ecosystem.
- Link with task7.1: In this task the architecture of the IoT Ecosystem as well as the steps that will grant interface with the ECF4CLIM digital platform will be defined
- Link with task7.3: In this task some KPIs will be created that will be calculated with the help of the IoT Ecosystem.
- Link with task7.6: In this task the testing and validation of the interface between the digital platform and the IoT ecosystem will be presented.
- Link with WP8: The WP8 will demonstrate the results of the IoT ecosystem solution through dissemination events to the public.

2 Building Case Studies & IoT Infrastructure Requirements

2.1 Introduction

The IoT ecosystem comprises of the Wireless Sensor Network, the IoT cloud and the application services that will be described below in detail in Chapter 3, enabling the ECF4CLIM project to extract real time data of the energy consumption and ambient conditions data from the selected educational institutions.

2.2 ECF4CLIM Dynamic Data requirements

The list of the selected academic pilot sites consists of 11 institutions. Every pilot partner who participates in these tasks selects a few intervention spaces that wants to include in the project. In these spaces is possible to examine how the students' activities affect their surroundings in terms of energy consumption and air quality use cases. The IoT ecosystem is going to retrieve real time data with 15 minutes granularity from the respective pilot sites. This data will be used for the dynamic calculation of the KPIs that will be defined in WP4, WP5 and task 7.3. The KPIs will address energy metering and Indoor air quality (IAQ) use cases. The IAQ metrics considered include information regarding the CO_2, Volatile Organic Compounds (VOC) and Part Per Million (PPM) 2.5 concentration, temperature, and humidity. The energy metering aspects will capture the energy and the power consumption of the selected intervention spaces. Through this, the pilot partners will examine the behavioural and environmental routine of the students during school time and correlate their activities to the carbon footprint that they leave to the environment.

2.3 Summary of pilots' building infrastructure

Since the IoT ecosystem will be installed in the chosen educational buildings, as a prerequisite the solution providers, represented by QUE, need to fully understand the existing building characteristics. Therefore, the solution providers, will suggest an equipment list that will match to the building assets of the pilot site, addressing the goal of the projects, without affecting any existing infrastructure system. Firstly, dedicated audit templates were distributed to the pilot partners to provide a detail overview of the existing building infrastructure. Through the auditing process it is possible to obtain the preferable information and provide the most suitable IoT equipment for the building. Since the solution is tailored made and adjustable to each specific case.

By installing indoor air conditions multi-sensors, it is possible to capture air quality and ambient conditions in the selected intervention spaces, therefore such multi-sensors will be installed in all spaces. For gathering energy consumption data from the pilot sites, different smart energy meters will be installed only in the electric circuit boards on site.

Each pilot site has different building aspects, therefore different IoT solutions will be investigated before proposing the appropriate equipment.

2.4 Challenges in Implementation of the IoT ecosystem in demonstration sites

Since the IoT ecosystem solution is going to be implemented in the selected educational sites, an installation roadmap was agreed to organise the procedure, which is documented in detail in [1]. Bottlenecks that have caused delays to the implementation of the installation roadmap are:

- The audits cannot be implemented during the summer period and Christmas holidays as the pilots (universities and schools) are closed. Audit templates could not be fulfilled on time.
- Hardware equipment unavailability is a global issue. The combination of surging demand for consumer products that contain chips and pandemic-related disruptions in production has led to shortages for semiconductors over the past two years.

3 IoT Ecosystem Framework Specifications

3.1 Introduction

To be able to obtain real time data from the selected buildings, pre-process them and provide them to the ECF4CLIM platform, QUE has established an IoT ecosystem which, in a nutshell, is able to gather the required information of the preferred pilot site. Except from the data collection, the IoT ecosystem preprocess the acquired data through machine learning algorithms in order to remove outliers and provide cleansed data.

The IoT ecosystem comprises of the main components:

- The Wireless Sensor Network (WSN)
- The IoT Cloud
- Application services

The WSN combines two device categories. The IoT gateway and the third party of-the-shelf IoT devices. Both categories compose the hardware infrastructure of the IoT ecosystem solution to be installed in the pilot sites. Below are listed the IoT gateway specifications and its description. The second part of the WSN, the third party of-the-self IoT devices, will be documented in the Chapter 4

The EC4FCLIM IoT ecosystem was developed on top of the cloud based IoT and data management platform originally developed in the H2020 project ACCEPT (957781). EC4FCLIM designed and developed the necessary interfaces and extensions to be able to enhance the system with new IoT equipment and their data models. This IoT equipment will be responsible for the energy metering and indoor air quality data gathering of the pilot sites. Secondly, services will be designed that will calculate the building relative Key Performance Indicators (KPIs). Finally, all this information will be transferred securely to the ECF4CLIM platform that is described in more detail in the 3.4 section of this deliverable.

3.2 IoT Gateway Specifications

3.2.1 IoT Gateway description

The IoT gateway is responsible for the constant and safe transmission of the data gathered from the pilot sites to the IoT cloud. It acts as an interface between the physical and the digital word. It has functionalities allowing commissioning and over the air updates, it has a back-up mechanism implemented and a message broker to allow communication. Further details are presented in this chapter.

3.2.2 IoT Gateway Hardware Specifications

The hardware equipment of the IoT gateway includes a Pi 4 model B raspberry computer with its case and power supply, as illustrated in Figure 1.

Figure 1. IoT gateway hardware components

The raspberry Pi computer it's a modular computer device, selected as the basis of the gateway since it provides many advantages. Firstly, it is a non-intrusive device which doesn't exceed the size of a credit card. Secondly, it has great processing power in a combat board. It is enriched with many interfaces such as, Universal Serial Bus (USB) & ethernet ports, Wi-fi and Bluetooth drivers, allowing the communication exchange between the IoT gateway and the third party IoT devices with Wi-fi and Bluetooth protocols. IoT protocols ensure that information from one device or sensor gets read and understood by another device, a gateway, a service.

Expanding the protocols that can be integrated to the raspberry, is necessary to have a robust list of the equipment that could participate in the project. Integrating a Z-Wave antenna to the raspberry Pi it is possible to enhance the equipment list with Z Wave devices creating an interoperable solution. The Z-Wave antenna is presented in Figure 2.

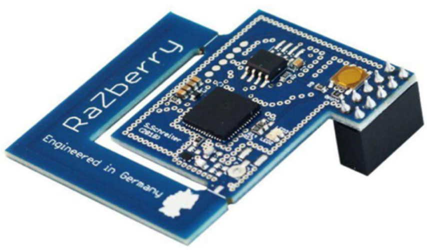

Figure 2. Z-Wave Antenna

Finally, a Secure Digital (SD) card will be inserted to the IoT gateway, Figure 2. The SD card will have encapsulated the firmware that will enable the services that are vital for the proper functionality of the IoT gateway.

3.3 IoT Cloud gateway software specifications

The pre-existing IoT gateway that was used as a basis for EC4FCLIM development activities is briefly described in Annex 6 to offer a better view of the scope and context of the underlying technology.

In the ECF4CLIM project the software components of the IoT Cloud and IoT gateway needed to be enhanced in order to adjust to the new IoT equipment that will be installed in the pilot sites. The data modeling and data handling functionalities of the IoT gateway were enriched to be able to extract constant data and safely streaming them to the IoT Cloud.

3.4 IoT Cloud specifications

The raw data that are collected from the IoT gateway are streamed and stored on the IoT Cloud. The IoT Cloud further acts as a preprocessor that cleanse the data in case any distortion is detected. Handle the outliers of data that may not present the actual representation of the pilot sites. Finally, it fills the gaps of missing data. The software modules are described in detail in 6.1.1.

Security mechanisms have been developed to prevent any leak of sensitive data to non-project related partners. All this effort has been implemented to present consistent, comprehensive real time data of the selected pilot sites. These mechanisms are responsible for the data transmission to the ECF4CLIM database.

3.4.1 Data cleansing and handling processes

Before reaching the ECF4CLIM database, different data analysis methods are applied to the raw gathered data of the pilot sites. Anomalies in the datasets that may occur due to a number of external factors are eliminated. These distortions may produce high peaks in the dataset, and these are unwanted and not representative of the actual energy consumption pattern. To overcome those obstacles black box data cleansing machine learning algorithms are used to detect those outliers. The detection procedure is based on unsupervised learning algorithms. An indicative result for voltage dataset, is illustrated in Figure 3.

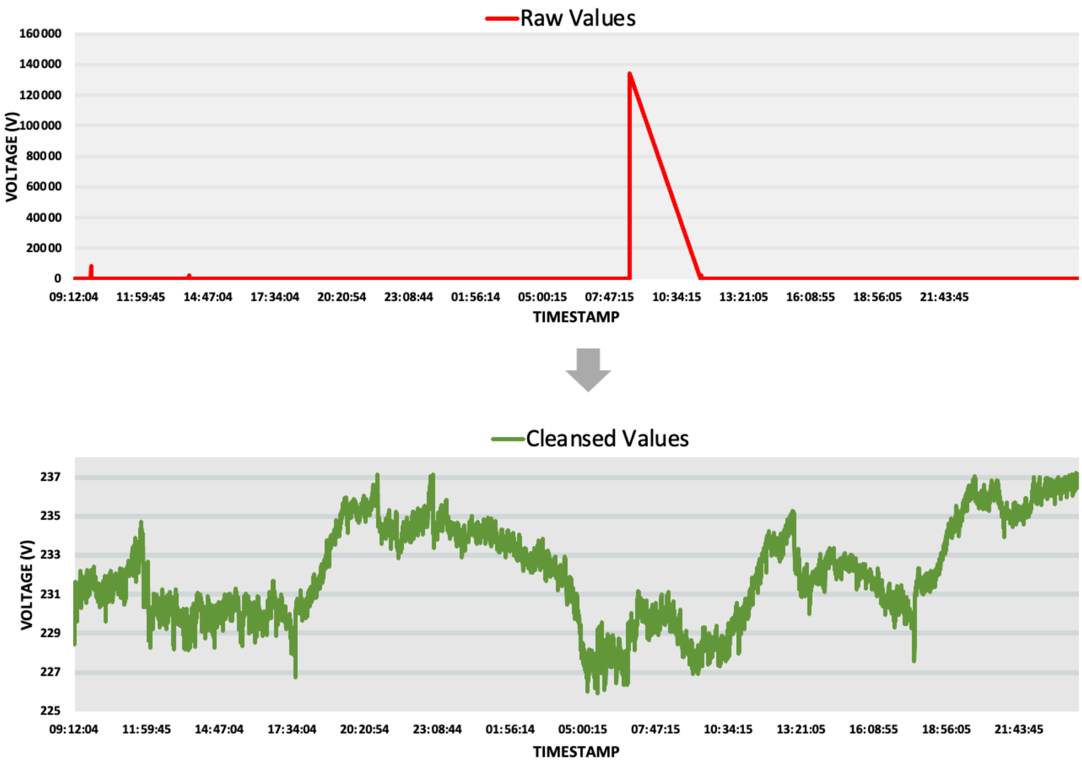

Figure 3. Clustering Cleansing example

In a few cases, data losses may occur due to communication failures between the IoT gateway and the IoT Cloud, for instance if the IoT gateway is unplugged and doesn't transmit any data. Data losses are usually originated from the WSN level, e.g., if a multi-sensor it is unplugged or has been excluded from its network. In these circumstances, the dataset it is filled with the last imported value.

Finally, the IoT Cloud provides functionalities like data aggregation and granularity shifting to deliver data in various measuring frequencies, for example every 1 hour, 1 day etc.

Following, the IoT Cloud validates each message that arrives to the IoT Cloud from the installed IoT devices and allocates it to the respective database.

3.4.2 Common Information Interfaces

Lastly, the IoT Cloud is responsible for the data transmission and acquisition to the other modules of the project. As explained in deliverable [3], presented in Figure 4, the IoT ecosystem shares an interface with the ECF4CLIM platform providing real time processed data of the pilot sites.

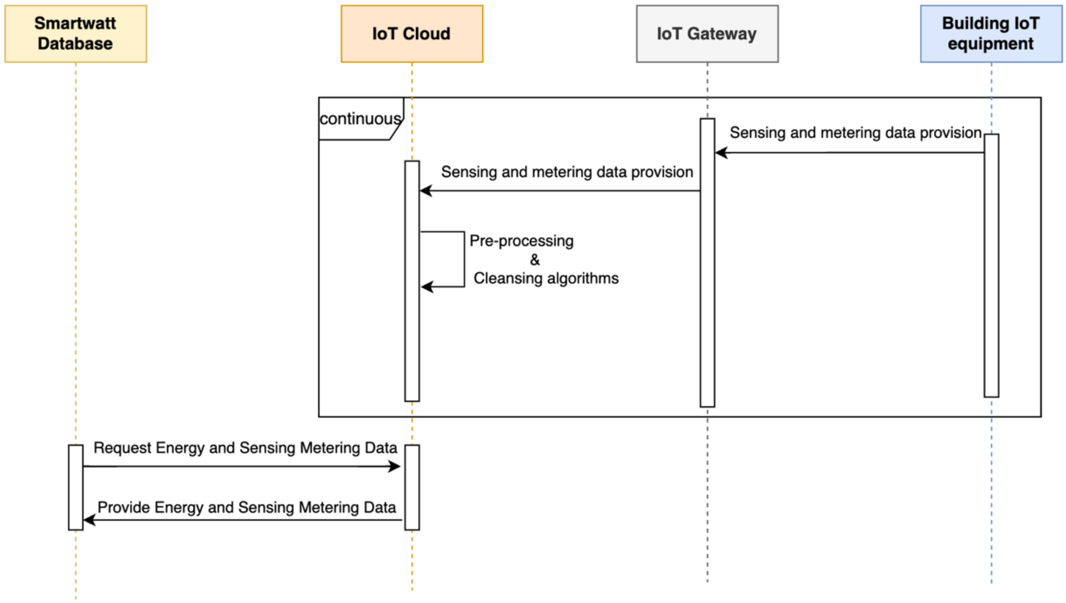

Figure 4. UML diagram for IoT ecosystem interface with ECF4CLIM component

This will be implemented through this subcomponent which acts as the intermediate between the IoT Cloud and the Smartwatt system through authorization and authorization services. Through these servicers all the extracted data will be successfully transmitted to Smartwatt planform, achieving the secure and continuous streaming of data.

3.5 Services for enhancing the overall user-experience

The IoT ecosystem solution isn't going to address only the requirements that were defined in the above sections in the project. Additionally, it will enrich the user experience of the people by providing mobile apps and web application systems. Therefore, those applications that will be developed are going to facilitate the deployment of the IoT Ecosystem in the premises and engage the students towards a more sustainable behavior, establishing an intuitive interaction between the end-users (students and teachers) and the experts (commissioners that will deploy and monitor the solution) with the ECF4CLIM project.

3.5.1 Mobile application for the teachers and students

A user-friendly mobile front-end application will be distributed to the students and the teachers to monitor the extracted data from the installed IoT ecosystem solution. Through this innovative mobile app, the end-users can display the ambient conditions, for example the concentrations of air pollutants, temperature, humidity as well as the actual energy consumption of the selected intervention space. Enabling the monitoring of the impact that the actual actions in the investigated educational establishment have. In addition, through this approach, the end-users could understand the IoT ecosystem scope without interacting with the installed IoT equipment. Therefore, the mobile app is able to engage the end-users and bring them closer to the ECF4CLIM project and its purpose.

3.5.2 Web applications for the installers

Two different services have been developed to facilitate the process of the IoT devices commissioning and the health monitoring of the IoT ecosystem during the operational phase.

The first one is the commissioning application. This service is a User Interface (UI) web application, where the authorized commissioner, is able to commission the devices to the IoT gateway and therefore to the database of the IoT platform. It's a do-it-yourself application, which combined with the training material and dedicated workshops enable the expert commissioner to deploy the solution, with only adequate knowledge of computer systems as prior knowledge requirement.

The second one is called monitoring tool. It is a web application, which facilitates the health monitoring of the system through the operational phase. Through this interface the people who are responsible for monitoring the health of the IoT ecosystem can identify when and which device is disconnected from the system. Therefore, they can restore its prior connection and prevent any further loss of data.

4 IoT Ecosystem Framework Evaluation Procedure

4.1 Evaluation of IoT Ecosystem Framework

Not all the IoT devices in the market are feasible to be integrated to the IoT ecosystem solution. There are standard methodologies that need to be implemented to check the compatibility of the devices with the IoT ecosystem and at the same time to address the requirements of the project.

As described in [1] the IoT ecosystem needs to be adapted to each pilot site respectively. Therefore, QUE needs to know in advance the existing building infrastructure of the selected pilot sites to propose equipment that won't affect the building's system.

4.1.1 IoT Ecosystem prerequisites

There are some selection criteria that the IoT devices needs to reach in order to be included to the suggested IoT equipment list.

- The IoT device should be a reliable solution. Therefore, only devices that are certified and approved for their quality from their manufacturers are suggested.
- They must be off the shelf devices. This means devices that can be easily purchased by the pilot site users and within the budget limits. Not custom devices will be included in the suggested IoT equipment list.
- The IoT device should communicate with the IoT gateway through a well-known and established communication protocol.

4.1.2 Equipment topology

Different IoT solutions were examined to tackle the project requirements and to be integrated to QUE's IoT solution. In the ECF4CLIM project the IoT devices are divided in two categories. Hard wired energy metering devices and Indoor Air Quality (IAQ) plug 'n play solutions.

Since the energy metering will take place in the electric circuit boards of the educational institutions, Din rail energy meters and meters with clamps were examined to identify the most suitable proposal for data gathering.

From the auditing procedure it was identified that there were three- phase and single-phase dedicated circuit breakers in the circuit boards of the selected pilot sites. Through these dedicated circuit breakers, it is possible to capture the consumption of the intervention spaces that will participate in the project. Thus, the characteristics of the dedicated circuit breaker, like maximum Amperage capacity and type of dedicated circuit breaker, have to be kept in mind before proposing the appropriate energy meters. For the proper installation of the energy meters a certified electrician must be chosen. Also, s/he must follow the manufacturer's manual for the appropriate installation.

Concerning the IAQ multi-sensors, task's scope was to propose equipment that will be easily deployed in the classrooms, based on QUE's experience, they were suggested plug 'n play devices. Thus, this was set as a requirement to narrow down the devices from the market. From the manufacturer's manual it is suggested that the IAQ multi-sensor should be located indoors and be placed away from direct sunlight, any cover, or any heat source to avoid false signal for temperature control.

4.1.3 Lab Testing

Different IoT devices were tracked down from the market to fulfil the building requirements as well as the prerequisites that have already been set in the previous chapters. Some IoT Solutions that correspond to the ambient sensing and indoor air quality indoor metrics were examine, like Aeotec multisensor 6, Netatmo Smart Air Quality Monitor, Eurotronics Air Quality Sensor Z-Wave Plus, air-Q, MCO Home A8-9 and MCO Home MH9-CO2-WA. As far as the energy metering use case concerns different IoT metering devices were considered like Aeotec Gen 5, Shelly EM, Shelly 3EM, Qubino ZMNHTD1, Qubino ZMNHXD1, SMA Energy Meter, IAMMETER single and three phase Wi-Fi energy metering devices. Below are presented the final list of the suggested IoT equipment.

In order to be sure that the solution is applicable and can be integrated into the IoT ecosystem offering reliable data, sample equipment was procured to be tested it in QUE's lab premise. The equipment was installed according to the manufacturer's manual and for the hard-wired installation utilized the services of certificated and authorized personnel, for instance an electrician.

After the acquisition of the IoT equipment to be tested, QUE's development team integrated the IoT devices into the IoT ecosystem solution, enabling their easy commissioning, and enhancing the database with information regarding the new IoT devices like their data model, metrics and etc.

Firstly, the energy metering devices were used in small scale testing scenarios, as illustrated in Figure 5.

These testing scenarios include:

- Installation of the IoT devices to Lab's environment
- Inclusion to the IoT gateway's network
- Integration to the IoT Cloud
- Data acquisition
- Data validation

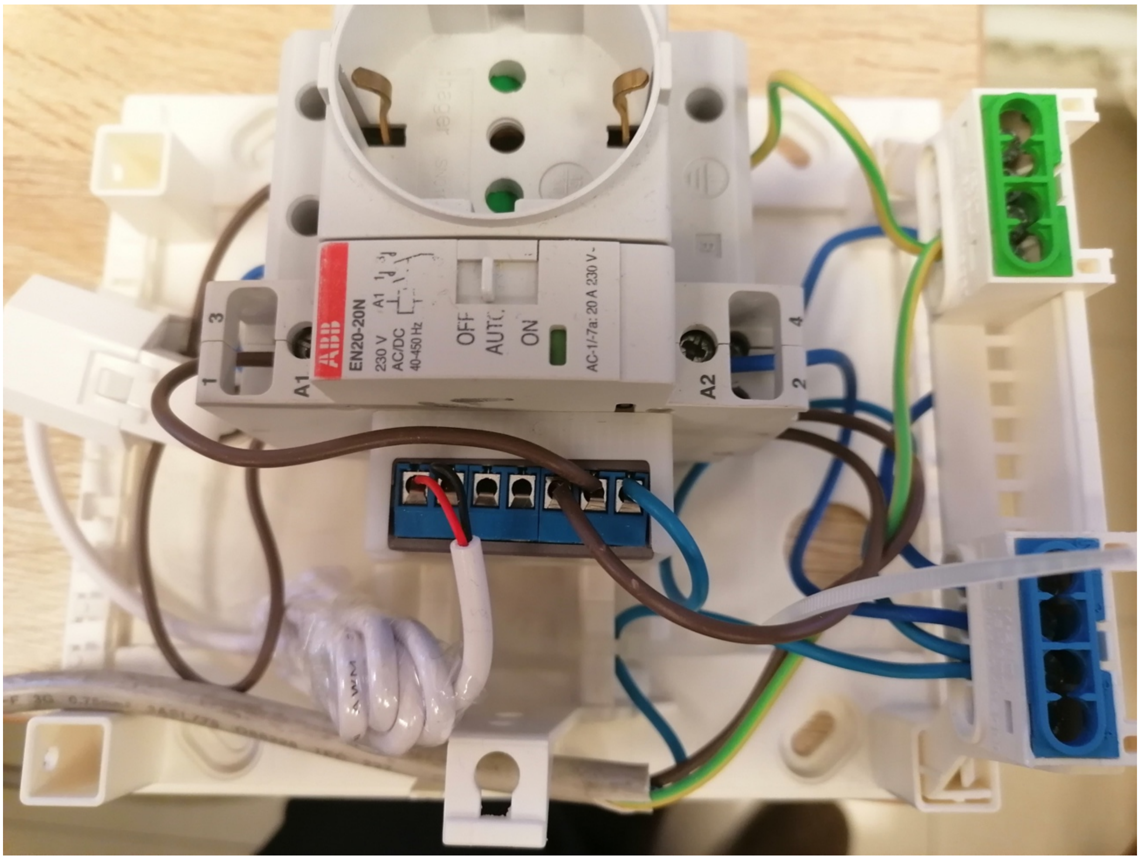

Figure 5. Initial testing case for energy metering

After examining the operational status of the device and its received data, QUE applied larger scale installations to electric circuit boards to fully deploy the solution, as presented in Figure 6.

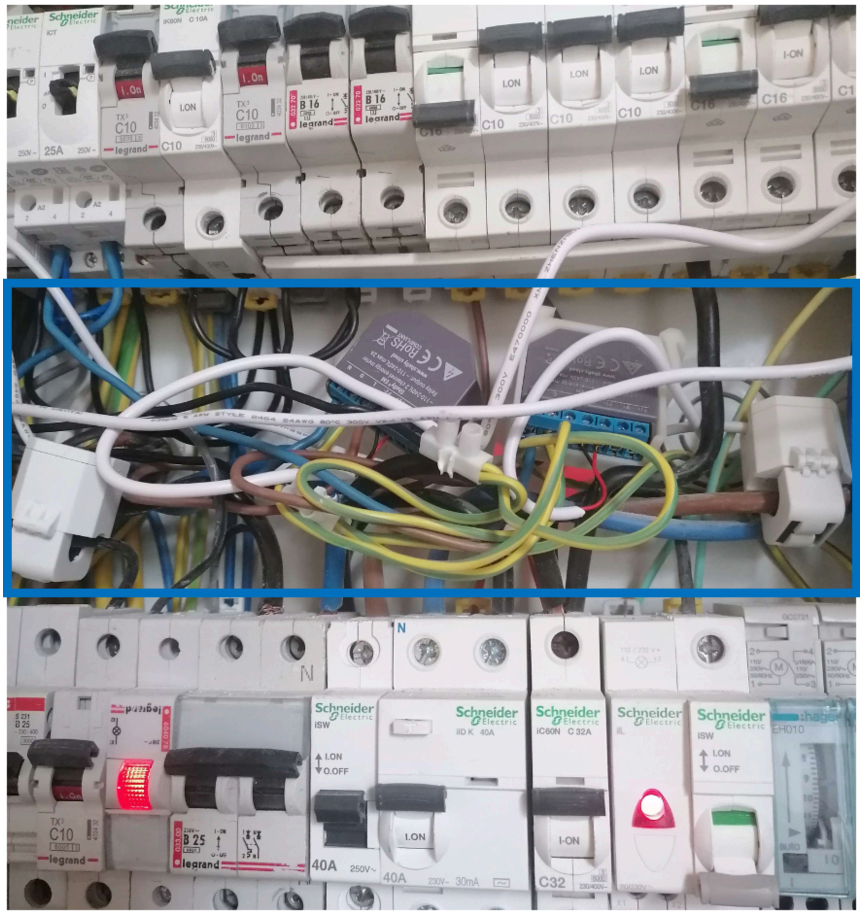

Figure 6. Tested case for single phase energy metering

The same procedure was conducted for the three phase loads as it seen in Figure 7. They were installed in the electric circuit board to test the data quality and granularity.

In these test cases, information regarding total energy consumption and Heating Ventilation Air-Condition (HVAC) loads were examined in order to monitor and validate the data.

Figure 7. Tested case for three phase energy metering

However, for the IAQ multi-sensors the two different IoT off the shelf devices were tested in QUE's lab premises. The first IoT device multi-sensor, presented in Figure 8, could provide metrics, like VOC, CO_2 concentration, temperature and humidity. The second IAQ sensor, as displayed in Figure 9, monitors the same metrics as the previous one plus extra functionalities, for example PPM 2.5 concentration and more accurate values.

Figure 8. First tested case for Indoor Air Quality multi-sensor

In addition, further issues were detected during the testing case of the first IoT device.

- It had inconsistencies compared to a calibrated CO_2 sensor.
- It didn't receive values for a long period of time
- It wasn't as responsive to the drastic change of the CO_2 concentration, in testing activities that were performed as the second multi-sensor.
- With the second IAQ multi-sensor someone can perform calibration processes manually.
- In case the auto calibrated procedure will not be performed correctly the system will receive values that will not respond to reality.

Figure 9. Second tested case for Indoor Air Quality multi-sensor

4.1.4 Proposed list

In this section is presented the proposed IoT device list.

For the energy metering devices, many solutions are proposed to provide a robust solution. One phase smart energy meters, and three phase smart meters are foreseen to be installed in the circuit panel of the buildings to monitor the energy consumption of the selected intervention spaces in the educational institutions. It must be noted that the final equipment selection will be available after a final on-site audit is conducted and pictures of the circuit panel have been made available. Indicative pictures of the equipment planned to be installed are provided below.

The IoT single phase DIN Rail device that will be proposed is illustrated in Figure 10.

Figure 10. One phase DIN RAIL energy meter - Qubino

This IoT device is able to be installed in the circuit board of the pilot site. It addresses to single phase loads up to 65 Amperes and it can communicate with Z Wave devices up to 30 meters indoors. Its size is 36 x 90 x 64 mm.

The Shelly EM is a robust and a single-phase energy metering device that can be used in cases that there is not enough space in the circuit board, and it is demonstrated below Figure 11. It is a single-phase Wi-Fi enabled energy metering IoT device which is able to extract information regarding the electrical energy consumption. It can monitor electric loads up to 50 Amperes. It has dimensions of 39mm x 36mm x 17 mm and it can operate to temperatures from 0 to 40 Celsius.

Figure 11. One phase DIN RAIL energy meter with clamps - Shelly

The IoT Ecosystem as explained above it is designed to tackle cases where the energy consumption of the intervention spaces is being monitored through three phase dedicated circuit breakers. To address those circumstances below is presented the DIN Rail solution in Figure 12.

Figure 12. Three phase DIN RAIL energy meter - Qubino

This IoT device is similar to the Qubino IoT single phase, which is referred above. The main difference of this device with the previous one is that the present is designed to monitor three phase loads instead of one. However, both can extract data from loads that don't exceed 65 Amperes.

Due to the large volume as an alternative, it is recommended the Aeotec Gen 5 solution that works with clamps in Figure 13. The advantage of this solution is that can be mounted to the wall instead of installing it on the Din rail. Therefore, it doesn't depend on the occupied space on the Din Rail of the circuit board. It's a Z Wave device and it can operate in environments from minus 10 degrees to 50 degrees Celsius. It is a Z Wave device which can communicate with IoT devices with the same protocol up to 30 meters.

Figure 13. Three phase energy meter with clamps - Aeotec

Regarding the IAQ multi-sensors the solution that was finally approved is the MCO Home A8-9 multi-sensor, illustrated in Figure 14. In tables **Error! Reference source not found.** and Table 1 are demonstrated the technical specs of the multi-senor and the embedded sensors respectively. It is a plugged device and can operate to environments from minus 20 up to 60 Celsius. It's a compact non-intrusive device and has dimensions of 110x110x32mm. It includes embedded sensors which are demonstrated in Table 1.

Figure 14. IAQ multi-sensor - MCO Home

Table 1. Indoor Air Quality Sensors' specs

IAQ embedded Sensors	
Temperature	0…50°C
Humidity	0%RH … 99%RH
PM2.5	0 …500ug/m3
CO2	0 … 5000ppm
VOC	0 … 64000ppb
PIR (Passive Infrared) Sensing	0 or 1 Presence Detection
Illumination	0…40000Lux
Noise	30dB … 100dB
Smoke	0 or 1

5 CONCLUSIONS AND NEXT STEPS

Summarizing as a prerequisite for the deployment of the IoT Ecosystem framework each existing building infrastructure needs to be examined in detail, since the solution is tailored made and adjustable to each respective pilot site. After establishing the data requirements of the project, the final buildings' that will participate in the project are described in a nutshell, as well as the challenges that were faced to implement this task.

In the third chapter, the main modules that comprise the IoT Ecosystem framework are documented. Starting with (WSN) and its core component, the IoT gateway. It is described in detail the IoT gateway's software and hardware components explaining each layer functionalities. Following, it is listed the definition of the different subcomponents of the IoT Cloud and what specification they offer to the IoT Ecosystem solution. Finally, the extra services of IoT Ecosystem are described and how they provide added value to the project in terms of facilitating the deployment procedure to the experts and its maintenance, through initiative, do-it-yourself web applications. In addition, a user-friendly innovative mobile application will be distributed to the teachers in order to monitor in real time, the ambient air quality conditions of the spaces together with the power consumption.

Except from the IoT gateway each WSN will include the proposed IoT devices which will be utilized to extract energy metering information and IAQ metrics. Those real time data will be used for the calculation of the already defined KPIs in previous tasks examining the carbon footprint that the student society leaves to the environment. Not all IoT devices of the market are applicable to tackle this task. They have to fulfill the requirements of the IoT Ecosystem to be integrated to it and to be tested in QUE Lab's premises for data validation. After advancing these thresholds they will be included in the final list of the devices that could participate in the project. Each pilot site will have dedicated Bill of Materials with equipment that is included in the final list.

In the immediate future, further development effort will be implemented for the finalization of the mobile application to demonstrate a user-friendly interactive view of the educational institutions to the end users, as well as optimizing the monitor tool web application succeeding the appropriate overview of the IoT ecosystem from the maintenance crew.

Additionally, calculation engines will be implemented in the IoT cloud to calculate KPIs based on the data extracted from the IoT ecosystem.

Finally, the extracted data from the respective pilot sites in addition to the building relative KPIs will be streamed to the digital ECF4CLIM database.

REFERENCES

[1] J. Lage, T. Faria, M. Almeida, A. Stratis and P. Andriopoulos, "D4.3 Baseline assessment of the environmental performance," in *ECF4CLIM project, European Competence Framework for a Low Carbon Economy and Sustainability through Education*, 2023.

[2] I. Preto, L. Marques and C. Valente, "D7.2 ECF4CLIM digital platform architecture," in *ECF4CLIM project, European Competence Framework for a Low Carbon Economy and Sustainability through Education.*, 2022.

[3] I. Preto, L. Marques, C. Valente and A. Stratis, "D7.5 ECF4CLIM digital platform - Module 3 - IoT Ecosystem space," in *ECF4CLIM project, European Competence Framework for a Low Carbon Economy and Sustainability through Education.*, 2022.

6 ANNEX

6.1.1 IoT Gateway Software Specifications

The software architecture of the IoT gateway is presented in Figure 15.

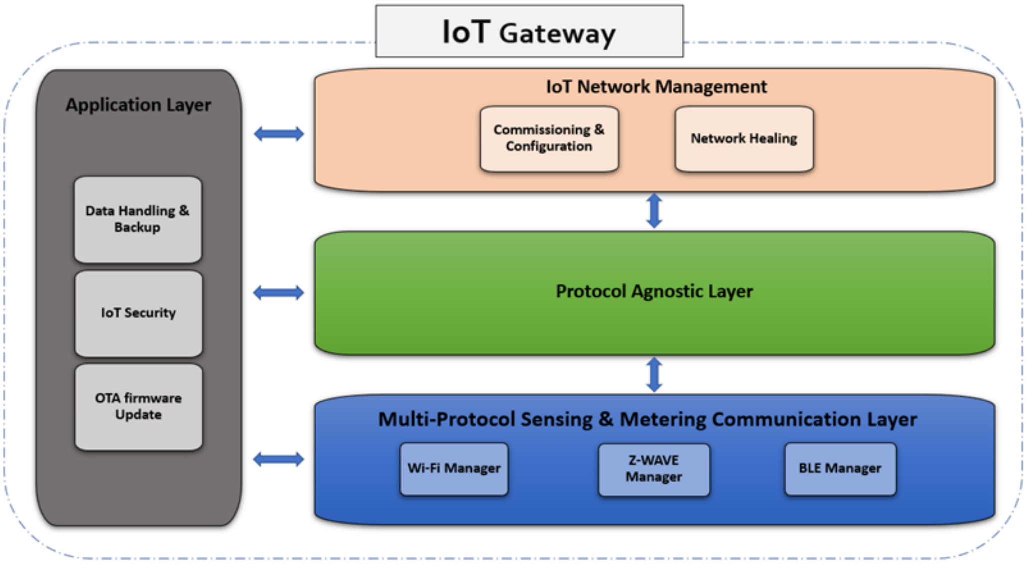

Figure 15. IoT Gateway architecture

The software module is divided in four different layers. The IoT Network Management Layer, The Protocol Agnostic Layer, the Application Layer and the Multi-protocol Sensing & Metering Communication Layer.

6.1.1.1 Multi-protocol Sensing & Metering Communication Layer

The first layer of the IoT gateway is in charge of the communication exchange between the different IoT devices and the IoT gateway. The Multi-protocol Communication Layer includes all the drivers that are important to establish network communication between the IoT gateway and different IoT devices, since it enables communication through different protocols like Z-Wave, WIFI and Bluetooth.

Through this layer the IoT gateway is able to communicate with a variety of different IoT solutions establishing interoperability to the IoT ecosystem, as well as, scalability, since the gateway is able to communicate with a large number IoT devices.

6.1.1.2 The Protocol Agnostic Layer

The Protocol Agnostic Layer provides the capability of unifying the different IoT devices to a common data model. Utilizing this layer all the provided information of the installed IoT equipment is being aligned to the database and not further modification or wrappers are needed to be developed.

6.1.1.3 The IoT Network Management Layer

That sub-component consists of services that configure the whole wireless sensor network, IoT gateway and IoT sensors and meter devices. Through those services the commissioner, whose role is being described in detail in [1], who is in charge to deploy the solution to the pilot sites, lands to a user-friendly web environment where, the commissioner could complete the configuration task with minimum errors. In the same layer there are also services that operates automatically behind the scenes in order to make sure the smooth connectivity operation of the network level. Self-healing techniques and network checking run periodically to achieve the optimal results.

6.1.1.4 The Application Layer

Through the application Layer, the IoT gateway can gather the energy metering/ indoor air quality data and to distribute them to the IoT Cloud. In case the system cannot communicate with the IoT cloud in order to deliver data, the system has been designed to activate the Backup module. This module temporarily stores the data that couldn't been transmitted to the IoT Cloud due to connectivity malfunctions, to be delivered when the connectivity is restored.

Secondly, the Over The Air Updates (OTA) is responsible for receiving updates that will help optimize the operation of the IoT gateway. The software of the gateway is continuously enhanced to solve bugs of the system and to further add services, or optimize the overall system operation, ensuring the health and stability of the on-site installations.

Finally, the IoT Security combines authentication and authorization services and protects all the sensitive information that handled in the IoT gateway. Ensures secure communication between the IoT cloud and the rest of the third party IoT devices, including the other components of the IoT gateway.