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D7.12 ECF4CLIM IoT Platform v.2 (Final Version After Integration is completed and prior to roll out)

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Version	2		

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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.

Name	Country	Logo
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas CIEMAT	ES	
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Universidad de Sevilla **USE**	ES	
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Smartwatt Energy Services SA **Smartwatt**	PT	
QUE Technologies Kefalaiouchiki Etaireia QUE	GR	

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
API	Application Programming Interface
REST	Representational State Transfer
JSON	JavaScript Object Notation

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

This deliverable is an updated version of the deliverable D7.11 [1]. In the deliverable D7.11 is presented the IoT Ecosystem Framework, which is designed to deliver real-time energy consumption and indoor air quality data 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 in the calculation of the Key Performance Indicators. It comprises firstly, of an installed Wireless Sensor Network (WSN), 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 requirements that the IoT ecosystem Framework needs to fulfil in the project are presented in this document alongside with the challenges that were faced in deploying 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's infrastructure.

In the updated version of the deliverable, it is presented the current status of the IoT ecosystem solution and the work that has been carried out until now. Two applications were further developed and introduced to the current version. The first one is the mobile application, which illustrates in a user-friendly interface the energy, indoor air quality metrics of the preferred pilot site, demonstrating the impact that the students' actions leave on their educational environment.

The second application is a web application whose main purpose is to facilitate the health monitoring of the installed IoT devices in educational buildings. Providing a quick overview of the status of the installed equipment.

Additionally, it presents the progress that has been accomplished by the respective partners related to the data transmission between the IoT Cloud and the ECF4CLIM platform.

Furthermore, it demonstrates the bottlenecks that were faced during the deployment of five pilot sites as well as the actions that were taken to overcome those obstacles.

Lastly, the ensuing measures are enumerated, essential for the seamless functioning of the IoT Ecosystem solution and the subsequent deployment leading to the final iterations of the ongoing services.

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1 INTRODUCTION

1.1 Scope and objectives of the Deliverable

The scope of the deliverable is to describe the development that has been carried out for the IoT Ecosystem to tackle the requirements that have been set from the ECF4CLIM project as well as to demonstrate outcomes from the deployment in various pilot sites. The deliverable is an updated version of the deliverable D7.11 ECF4CLIM IoT Platform v.1 (tested at QUE Lab premises) [1]. Therefore, it contains the context of the former's deliverable, as well as an extra development effort that was carried out prior to roll out, demonstrating the latest status of the ECF4CLIM IoT Platform. The second version is focused on the designing and development of mobile and web applications. The main role of the applications is to engage the students towards a sustainable way of thinking by displaying their impact on the energy and indoor air quality metrics and facilitating the overall health monitoring of the IoT ecosystems. In addition, it demonstrates the main issues that were faced during the first deployments of the IoT ecosystem framework in educational institutions, as well as the measures that were implemented to fix those issues and to establish a secure data acquisition.

The deliverable D7.11 ECF4CLIM IoT Platform v.1 (tested at QUE Lab premises) contains information regarding 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 and 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's main components, software and hardware, and its services.
- Describe in detail the latest version of the maintenance web application as well as the current version of the mobile application that will be distributed among the pilot partners.
- Demonstrate the IoT ecosystem assessments that took place within the ECF4CLIM project. Those tests include the validation process that took place in QUE lab premises in order to finalise 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.
- Following two services that were introduced in the first version of the deliverable, are further described in detailed, with their specifications, since they are closer to their final version.
- The updated version also includes the information about the services that are responsible for the secure and constant data transmission between the IoT Cloud and the ECF4CLIM platform.
- In the next chapter, we analyze the steps that were implemented finalize the list of the IoT equipment that will be installed at the pilot sites. This IoT equipment will be proposed to match each building's specifications and to acquire the preferable data for the IoT Cloud.
- In the seventh chapter are listed the obstacles that were faced in the first five installations and the actions that were taken in order to troubleshoot those issues.
- Finally, 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 the tasks of the ECF4CLIM project.

- Link with task 3.5: 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 task 4.3: 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 task 7.1: 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 task 7.6: 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.

1.4 Differences related to the first version

The main differences between version 2 and the former deliverable [1] are associated with the development of both mobile and web applications. Furthermore, the current version is linked with the practical insights gained from deploying the IoT ecosystem framework to educational institutions. Development and adjustments needed to be performed to the services that ensure a constant and safe data transmission between the IoT Cloud and the ECF4CLIM platform.

Finally, since it is an ongoing task, the next steps that will be performed to enhance the IoT ecosystem framework and to ensure the proper operation are demonstrated in the last section.

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 on 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 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 detailed 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 tailor-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 the 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 [2]. 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 of 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 for 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 their descriptions. The second part of the WSN, the third-party of-the-self IoT devices, will be documented in the Chapter 4

The ECF4CLIM 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 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 facilitate to the calculation of the building's relative Key Performance Indicators (KPIs). Finally, all this information will be transferred securely to the ECF4CLIM platform which 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 world. It has functionalities allowing commissioning and over-the-air updates, it has a backup 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, or 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.

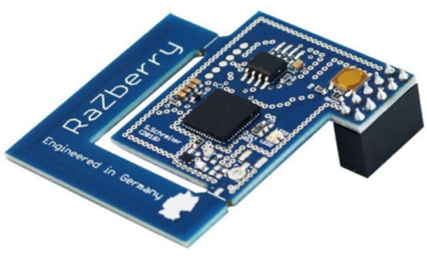

Figure 2. Z-Wave Antenna

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 7 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 7.1.1.

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 several external factors are eliminated. These distortions may produce, for example, high peaks and negative values 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 the voltage dataset is illustrated in Figure 3.

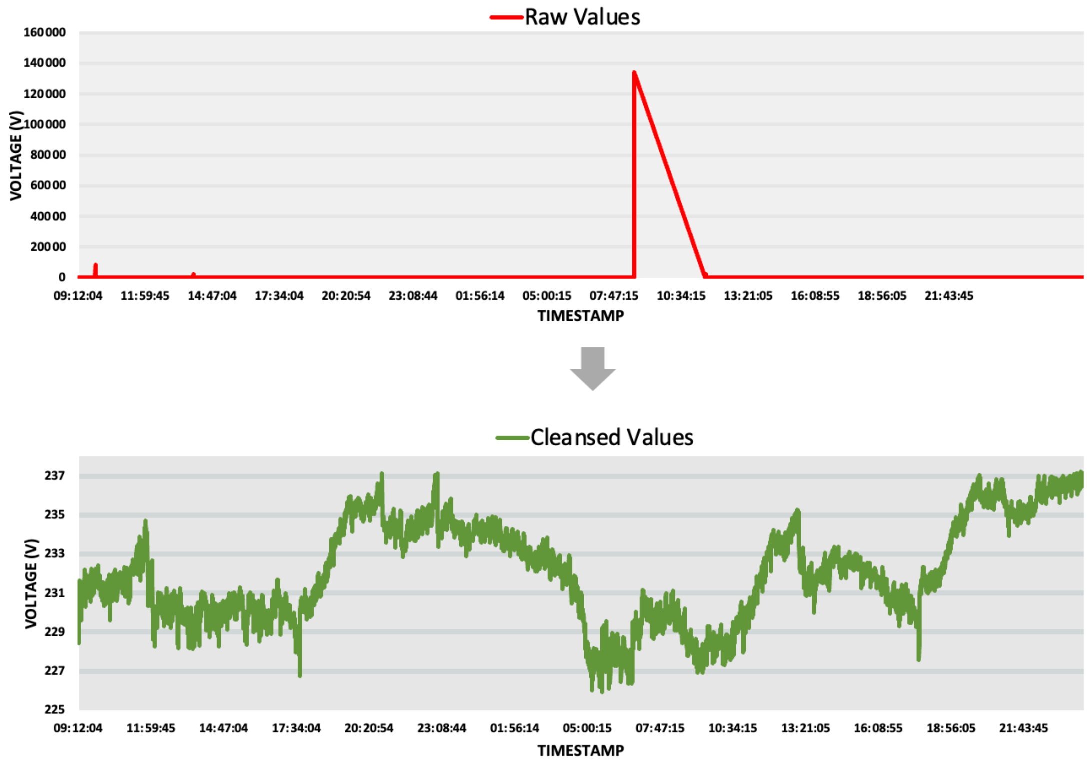

Figure 3. Clustering Cleansing example

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 is unplugged or has been excluded from its network. In these circumstances, the dataset it is filled with the last measured 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 at 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.

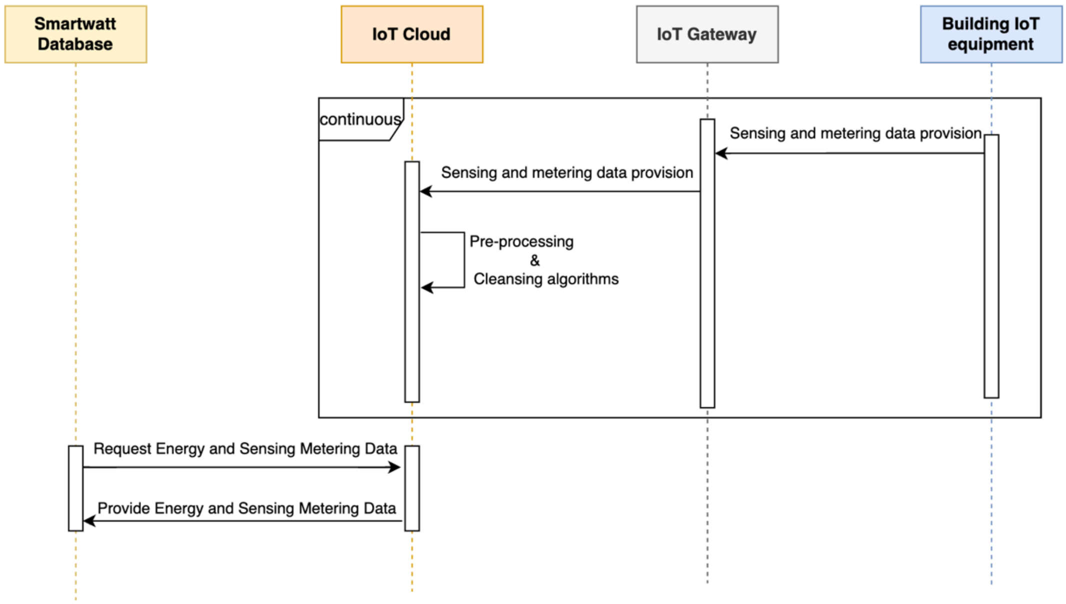

Figure 4. UML diagram for IoT ecosystem interface with ECF4CLIM component

This will be implemented through this subcomponent which acts as the intermediate between the IoT Cloud and the Smartwatt system through authorization and services. Through these services all the extracted data will be successfully transmitted to the Smartwatt platform, 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 of 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 behaviour, 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

3.5.1.1 Introduction

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, and 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.

3.5.1.2 Mobile application overview

In this updated version of the deliverable is demonstrated an overview of the development of the mobile app as well as its main attributes.

As explained in the previous section the mobile app will provide informative metrics to its end users concerning indoor air quality and energy metering data.

The mobile app will consist of four main views. The first one will include information regarding the current date, an indicative image of the user with a welcoming message. The second one will present the energy and power consumption metrics that apply to the whole user, in case the metering topology provides this information. The third one will demonstrate the available rooms that the user could select from this panel. Finally, the last section, which occupies the most space of the monitor of the phone, will illustrate the available metrics per space for each user.

3.5.1.3 Mobile application UI Elements

The mobile application comprises User Interface (UI) Elements to present the information in a more user-friendly, interactive and intuitive way. Those elements are cards, buttons, pop-up windows and typography.

Cards are square boxes which contain information in text, image or other type of information format. They appear in different colours and sizes, and they act as headers, footers or in many cases as placeholders.

Buttons are commonly used to enable different actions in the application by pressing them. Allowing the user to interact with the application and to perform specific operations. For example, selecting different spaces.

Pop-up windows are activated by pressing a button. They appear in front of the main page, usually with blurring visual effects on the background, presenting information in different formats, fonts, colors and sizes.

Finally, the typography element consists of all the information related to texting visualization materials. The text could be illustrated in different colours, fonds and sizes. Therefore, it is mainly focused on the design of the letters, alignment of the words in the application.

3.5.1.4 Mobile application pages

The initial page that appears when users launch the mobile application on their devices is the login page. It is a prerequisite step to access the mobile application and monitor the metrics of their pilot sites. Since this application addresses predefined users, an authentication system has been established to allow only authorized personnel. Therefore, as a first step, they must insert their credentials to access their specific virtual user, granting extra security capabilities to the existing features of the mobile application.

After logging in, the users land on the main page which includes the project's logo, the user's icon and the main features of the mobile application.

The information that is presented in the mobile application is linked to the data that is extracted from the IoT equipment in the respective pilot site.

The view of main page is mostly informative, and its primary goal is to raise the environmental awareness of the students in the pilot sites by illustrating to them the energy and air quality impact of their actions on their classroom.

Not all the data extracted from the WSN will be displayed in the application. Since, not all the information like Voltage, Amperage is comprehensible to the end user. The data that will participate in the application are oriented towards the CO_2, temperature, humidity metrics per classroom and the energy consumption of the whole user.

Finally, the users select their avatar, and a pop-up window will show up with information regarding their user profile.

3.5.2 Web applications for the installers

3.5.2.1 Introduction

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

The first one is the commissioning application. This web application is a User Interface (UI), where the authorized commissioner, can commission the devices to the IoT gateway, configure them and finally link them to the IoT Cloud. It's a do-it-yourself application, which combined with the training material and dedicated workshops provided enables the expert commissioner to deploy the solution, with only adequate knowledge of computer systems as a prior knowledge requirement.

The second one is a 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 maintenance 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.

3.5.2.2 Monitoring tool overview

In this updated version of the deliverable further information will be presented regarding the maintenance monitoring tool and the development that has been implemented so far. The maintenance monitoring tool is a web application whose main purpose is to facilitate the health of each piece of IoT equipment. It will be distributed to each pilot partner to have a clear overview of which devices might be offline and need a troubleshooting procedure.

3.5.2.3 Monitoring tool specifications

Firstly, the authentication page is going to be displayed to the users. The users after the authentication procedure are going to be redirected to the homepage. On the main page, a dedicated section will feature a list of various pilot sites. Next to the name of each pilot site, it will display indications in red, if there are issues detected regarding the respective user. In addition, an extra column will illustrate the number of active equipment per pilot site and the total installed devices.

The homepage acts as a high-level informative view of all the users that the maintenance crew is responsible for monitoring. It is possible through the homepage the maintenance personnel to identify the users that have issues, since not all the equipment is active, as demonstrated in Figure 5. As a result, the maintenance crew could have a glimpse of the inactive equipment for all their respective buildings.

Prosumer Name	Issues Detected	Active Equipment
ECROC01	Yes	2 / 3
ECROC03	Yes	3 / 4
ECROC02	Yes	4 / 6

Figure 5. Example of pilot list with issues

The homepage also illustrates below an indicative map of a wide area of the country of the pilot sites. The app marks different users across the map. By selecting one user it is possible to view details for the specific pilot site. Those locations aren't the real ones, they display random locations inside the boundaries of the respective country since all the applications in the IoT ecosystem are GDPR compliant and the system doesn't obtain geographical information. This feature was designed to enhance the experience of the users.

On the other hand, in case all the equipment is up and running, then the indication will be shown in green and all the equipment will be visible as active, as presented in Figure 6.

Prosumer Name	Issues Detected	Active Equipment
ECFIC03	No	2 / 2

Figure 6. Example of a pilot with no issue

By choosing one pilot site the users could obtain more low-level information regarding the issues on a specific pilot site, as they will be redirected to one new page with details only for the preferred pilot site. The users will have the opportunity to view all the equipment that is installed in the selected user as well as the status of the devices, online or offline. The term online meant that the devices communicate with the IoT Cloud. Finally, the users could check historical data regarding the status of the devices, for up to 24 hours. Providing a more holistic overview of the issues that might occur at the specific pilot site and to understand better the issue before attending the pilot site.

3.5.2.4 Training workshop for health monitoring

Except for the installation of the pilot site, an important step towards the successful data examination of the pilot sites is the health monitoring of the installed IoT equipment. The main purpose for developing the monitoring tool web application is to facilitate the maintenance procedure and to establish a constant connection of the installed IoT equipment to the ECF4CLIM platform. By investigating the health of each IoT ecosystem, it is possible to prevent any loss of data that are is vital to achieve the objectives of the project.

Therefore, all the respective pilot partners will be guided through a dedicated workshop to get familiar with the issues that might occur during the operational phase and to understand the steps that they have to follow to restore the equipment to its prior status.

While, the web application was designed with self-explanatory and comprehensive content, to be user-friendly to the people that are responsible for the maintenance of the WSN of each pilot site, the upcoming workshop will introduce the content and how to properly operate effectively the monitor tool. The material from the dedicated workshop can be served as a maintenance manual not only for the web application but also for the whole maintenance procedure.

3.6 API Services for Cloud-to-Cloud data transmission

In Deliverable D7.5 ECF4CLIM digital platform - Module 3 - IoT Ecosystem space [3],the approach to be adopted for the distribution of the extracted data from the IoT equipment to the ECF4CLIM platform was introduced. To match the project's requirements different services needed to be developed to establish a constant and secure data transmission between the two software Clouds.

As described in [3], the Representational State Transfer Application Programming Interface (REST API) services are web-based software interfaces that allow different applications or systems to communicate and interact with each other over the internet. QUE has created a RESTful API to ensure secure data acquisition from IoT Cloud to different platforms.

Initially, the ECF4CLIM platform needs to utilize the QUE's Authentication and Authorization module to grant access to the preprocessed data from the IoT Cloud. This module is responsible for allowing or denying access to third parties to obtain the extracted data from the pilot sites. By producing authentication and authorization mechanisms, only authorized partners are able to obtain the extracted data from the pilot sites.

Following the authorization and authentication procedures, the respective partners can utilize the APIs that are responsible for the data transmission. As explained in the first version of the deliverable [1], the data that are extracted from the educational pilot sites are related to the energy and power consumption of the respective building, as well as the indoor air quality conditions of the selected spaces. The aforementioned information is formulated in JavaScript Object Notation (JSON) format.

Due to the delay in deploying the IoT Ecosystem solution to the designated pilot sites, as detailed in section 2.4, QUE supplied real-time data from their laboratory premises. This enabled the ECF4CLIM platform to initiate development and align the ECF4CLIM database accordingly.

There was a bilateral communication exchange between the two partners in order to provide the appropriate API documentation and to validate the data acquisition.

After the validation procedure there were adjustments to the provided APIs in order to match the ECF4CLIM platform's requirements. Finally, after the deployment of the five pilot sites, the ECF4CLIM platform successfully verified the accurate extraction of data as originally proposed.

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 into 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 [2] 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 need to reach in order to be included in the suggested IoT equipment list.

- The IoT device should be a reliable solution. Therefore, only devices that are certified and approved for their quality by 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. No 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 into QUE's IoT solution. In the ECF4CLIM project, the IoT devices are divided into 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, the 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 examined, 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 is 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 in QUE's lab premise. The equipment was installed according to the manufacturer's manual and 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, etc.

Firstly, the energy metering devices were used in small-scale testing scenarios, as illustrated in Figure 7.

These testing scenarios include:

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

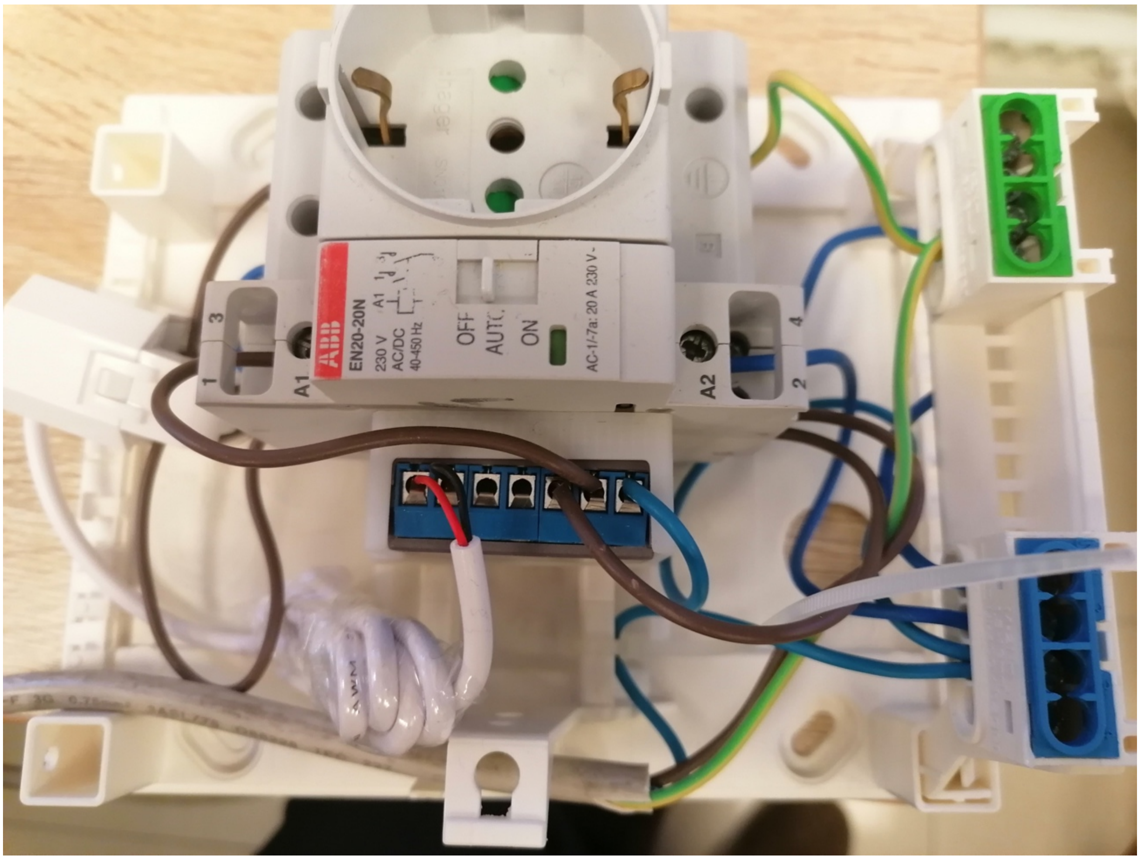

Figure 7. Initial testing case for energy metering

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 8.

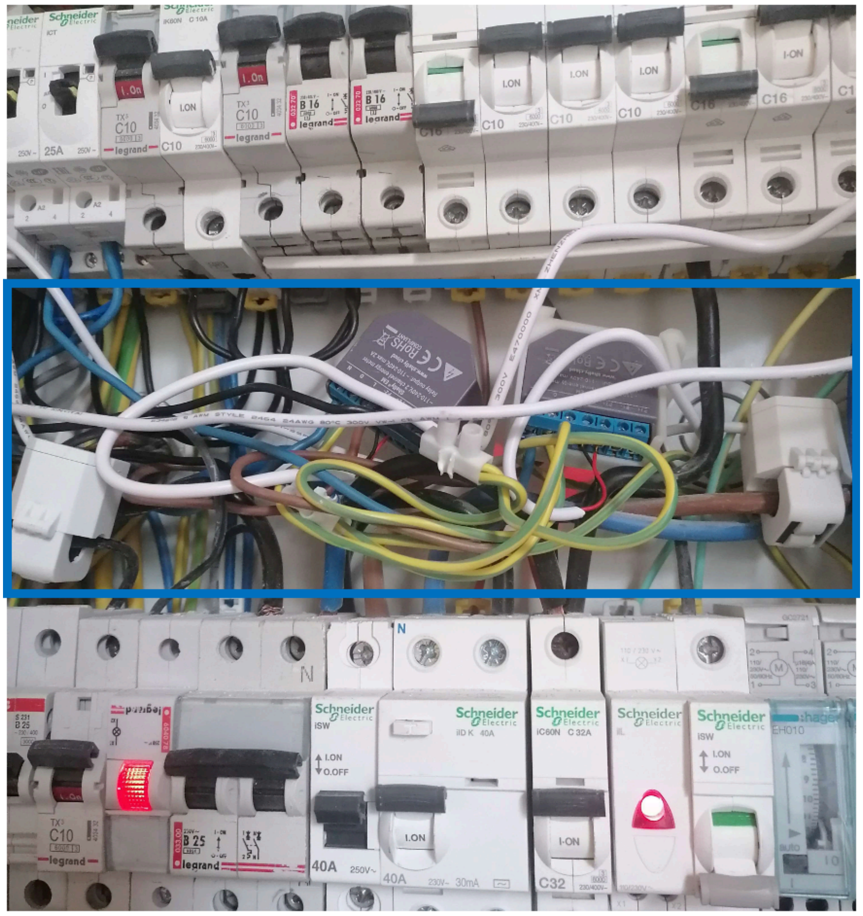

Figure 8. Tested case for single-phase energy metering

The same procedure was conducted for the three-phase loads as is seen in Figure 9. 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-conditioning (HVAC) loads were examined in order to monitor and validate the data.

Figure 9. 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 10, could provide metrics, like VOC, CO_2 concentration, temperature and humidity. The second IAQ sensor, as displayed in Figure 11, monitors the same metrics as the previous one plus extra functionalities, for example, PPM 2.5 concentration and more accurate values.

Figure 10. 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 11. 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 12.

Figure 12. 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 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 single-phase energy metering device that can be used in cases where there is not enough space in the circuit board, and it is demonstrated below in Figure 13. It is a single-phase Wi-Fi enabled energy metering IoT device which is able to extract information regarding 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 at temperatures from 0 to 40 Celsius.

Figure 13. One phase DIN RAIL energy meter with clamps - Shelly

The IoT Ecosystem as explained above 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 14.

Figure 14. 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 15. 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 15. 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 16. 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 16. 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 Building Case Studies & IoT Infrastructure Lessons Learned

5.1 Introduction

In this chapter it is presented the actual outcomes of the deployment of the IoT ecosystem solution so far. Including the bottlenecks that were faced and the actions that were taken to overcome those issues.

5.2 Building Case Studies and proposed equipment assessment.

Since the IoT ecosystem solution hasn't been fully deployed in all the expected pilot sites, the ECF4CLIM project the results are described in this document include three demonstration sites from Romania, one from Seville and finally one from Finland.

The other demonstration sites are expecting to receive the proposed equipment soon. The reasons that lead to this delay in the procurement phase were listed in chapter 2.4.

The IoT ecosystem Wireless Sensor Network for all the users as explained above in chapter 4.1.2, consists of the IoT gateway, which is a plug n play solution. The energy DIN rail metering and IAQ plugged equipment. All those devices are the core of the data extraction system of the IoT ecosystem framework. Without them no information will be collected to the IoT Cloud and monitored through the other services.

5.3 Bottlenecks and difficulties

Prior to the installation and commissioning procedure, different criteria needed to be examined by the team to propose the appropriate equipment that will guarantee seamless data extraction from the chosen educational institutions.

The examination of the existing buildings' infrastructure took place during the auditing process in [2]. All the proposed equipment was successfully installed at the requested pilot sites. Subsequently, tests were performed in order to validate the data that are extracted from the pilot sites.

For the proper operation of the WSN network, described in 3.1, it is imperative that all the IoT devices are connected to the same network with the IoT gateway. This is achieved through two types of networks, ZWave which is utilized for the Indoor Air Quality Sensor and the AEOTEC energy meter, while the other energy metering devices are linked to the IoT gateway via Wi-Fi connection.

Except from the bilateral connection between the respective IoT devices and the IoT gateway, the IoT gateway should be constant connected to a stable network with a good signal. By fulfilling this prerequisite step, it is possible to achieve seamless data transmission between the IoT gateway and the IoT Cloud.

Since the majority of the educational systems use different networking security mechanism, the IoT ecosystem framework had to be adapted to be applied in different networking environments.

Regarding the Finnish pilot site, no issue was detected despite the concerns for the existence of the firewall of the educational institution. On the other hand, the Sevillian pilot site encountered challenges while attempting to connect the IoT gateway to the university network. The issue was originated to the strict security mechanisms of the university's firewall. The internet connection procedure involved different steps in order to be implemented successfully.

Another situation that needed different approach than the ordinary procedure to deploy the IoT ecosystem solution to the Finnish pilot site was that they didn't acquire the proposed raspberry Pi 4 device, presented in 3.2.2. As explained in 2.4, there was stock depletion in Finland regarding the raspberry pi device, therefore they proceed with the acquisition of the previous model, the Raspberry Pi 3.

There are many differences between the raspberry pi 3 and the raspberry pi 4. The main issue that was detected and stalled the commissioning procedure was on the network connectivity of the Raspberry to the respective Wi-Fi.

Finally, regarding the Romanian pilot sites they weren't accessible during the preferable period. In addition, the pilot partners wanted to commission and test the equipment in a different location in order to minimize the time that they have to attend the educational institutions.

5.4 Troubleshooting Actions

To avoid the issue that was caused in the Sevillian pilot site concerning the internet security mechanisms, the pilot partners procured Wi-Fi network antennas. Through this approach it is possible to generate an individual network, different from the university and commission securely the IoT gateway as well as the IoT devices that need a Wi-Fi network, for example the Shelly EM meters. This strategy was followed also by the Romanian partners in order to be as less dependent on the educational institutions' network specifications.

In parallel except for the Wi-Fi network antennas the Romanian pilots first installed the proposed IoT equipment in their lab, configured the IoT gateway and commissioned the IoT devices to the respective IoT gateways. Since the three IoT ecosystems were already fixed with their networks, the only thing that was left to do was just to install the equipment in the corresponding building.

It was a different approach than the one that is recommended, since if the devices got mixed it might need extra development effort from the QUE side to reconfigure the whole IoT ecosystem of each pilot site. Also, the visits to those pilot sites will be more frequent to resolve the issues resulting in the opposite outcome. Therefore, there was constant guidance between the two partners, QUE and Romanian pilot partners in order to facilitate the process and validate the procedure.

The issue that was encountered in the Finnish pilot site was resolved by QUE's development team and the constant assistance from the Finnish pilot partners. Fortunately, the software firmware of the solution was compatible with the previous hardware version. For the minor issue that was faced during the commissioning, the development team had to interfere with the commissioning application to implement the troubleshooting successfully.

6 CONCLUSIONS AND NEXT STEPS

In summary, the deliverable is an updated version of the deliverable D7.11 ECF4CLIM IoT Platform v.1 (tested at QUE Lab premises) [1]and contains content related to it, as well as the current status of the IoT ecosystem framework.

As has been already documented in the first version of the deliverable [1], the required steps to deploy the IoT ecosystem to each respective pilot site are listed. 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 tailor-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.

Following, the main modules that comprise the IoT Ecosystem framework are documented. Starting with (WSN) and its core component, the IoT gateway with its hardware and software components. Following, it is listed the definition of the different subcomponents of the IoT Cloud and what specifications they offer to the IoT Ecosystem solution.

Except for the IoT gateway, each WSN will include the proposed IoT devices which will be utilized to extract energy metering information and IAQ metrics. Not all IoT devices in the market are applicable to tackle this task. They have to fulfil the requirements of the IoT Ecosystem to be integrated into 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 a dedicated Bill of Materials with equipment that is included in the final list.

In this current version of the deliverable are demonstrated the extra applications of the IoT Ecosystem and how they provide added value to the project, in terms of facilitating the maintenance procedure, through initiative, do-it-yourself web applications. Those applications are accompanied by explanatory material as well different workshops will be implemented to facilitate the proper maintenance of the IoT devices. 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.

In addition, the deliverable emphasizes the deployment of the solution to different pilot sites. Since the IoT ecosystem has been deployed in five different pilot sites, different issues that arose are documented as well as the actions that took place to overcome those obstacles.

Finally, the applications that provide extra value to the project in terms of facilitating the maintenance procedure, through initiative, do-it-yourself web applications are documented. 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.

In the immediate future, further effort will be implemented for the development, finalization and finetuning of the mobile application to demonstrate a user-friendly interactive view of the educational institutions to the end users, as well as optimizing and fixing any bugs that may arise in the web maintenance application.

Since there are six more educational institutions to be included in the IoT ecosystem solution, the QUE team need to assist each installation in case any further issue might arise. Each issue needs to be treated with caution and check if the solution needs adjustments to operate efficiently.

An important task that needs to be tackled during the whole project's progress is the health monitoring of the IoT devices in all educational institutions. Except for the installation and commissioning of each IoT device, it must be ensured that the devices are online, and that they extract accurate data. In case an issue is identified then the pilot partners in accordance with the QUE team need to examine the matter and troubleshoot it.

Finally, different services were developed to enable seamless data exchange between the IoT Cloud and the ECF4CLIM platform. The first set of services are focus to the security measures that will be followed between the respective partners. After validating the security protocols, the IoT Cloud grants access to the ECF4CLIM platform to obtain the preferable data. Firstly, those services were tested with actual data from the QUE lab and secondly with the actual data of the installed IoT devices in the educational buildings.

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7 ANNEX

7.1.1 IoT Gateway Software Specifications

The software architecture of the IoT gateway is presented in Figure 17.

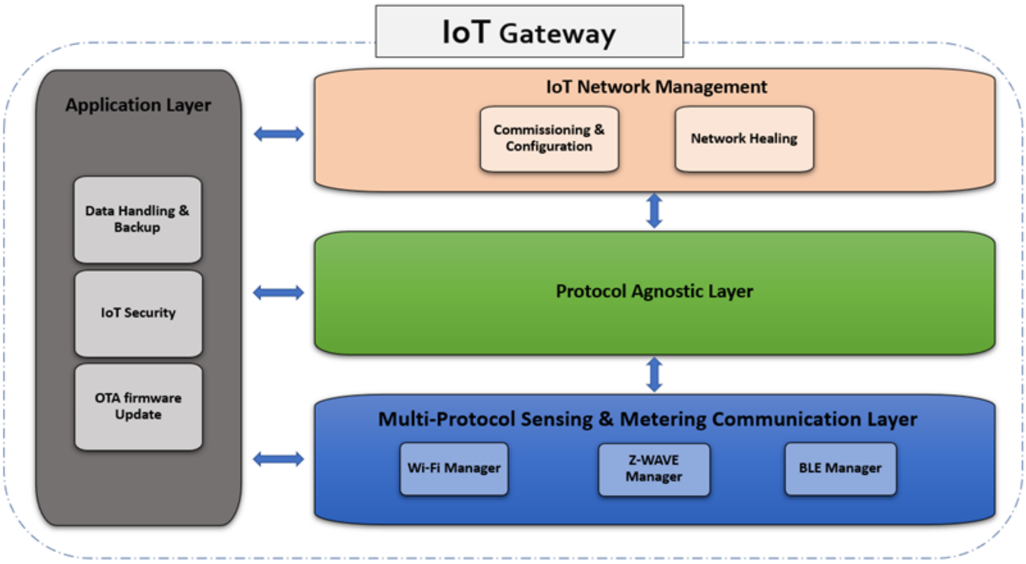

Figure 17. IoT Gateway architecture

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

7.1.1.1 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 of IoT devices.

7.1.1.2 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 aligned to the database and no further modification or wrappers are needed to be developed.

7.1.1.3 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 described in detail in [2], who is in charge of deploying the solution to the pilot sites, lands in a user-friendly web environment where the commissioner can complete the configuration task with minimum errors. In the same layer, there are also services that operate automatically behind the scenes to make sure the smooth connectivity operation of the network level. Self-healing techniques and network checking run periodically to achieve optimal results.

7.1.1.4 The Application Layer

Through the application Layer, the IoT gateway can gather the energy metering/ indoor air quality data and 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.