Report on pilot preparation

Deliverable D6.2a

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Technical References

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[1] PU = Public
PP = Restricted to other programme participants (including the Commission Services)
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Summary

1.1 Summary of Deliverable

This document must be considered a report on pilot activities carried out to characterize end-user energy behaviour, building technical facilities and energy consumption, necessary to deploy ebalance-plus platform on site. Therefore, this document summarises all the tracked activities from September 2020 to July 2021 to prepare ebalance-plus demo site to deploy the new technologies: flexibility equipment, system architecture, management units and other additional devices to communicate or supply the corresponding devices. This document is structured in the following sections:

- **Introduction of the ebalance-plus architecture** and flexibility solutions proposed
- **End-user energy behaviour** for those demo site in which the user interaction will be considered and evaluated.
- **Demo site tracking**: general description collected after technical visits, use case assessment (detection of preparation activities needed), track control of preparation activities (timeline, progress, managers, deadlines, etc).
- **Fog server description**: main server as core of the ebalance-plus platform, explaining the processes to deploy services.
- **Gantt Chart** of the preparation activities per demo (updated until June 2022).

Several activities are still on progress due to the covid-19 delays and the electronic market supply chain problems; thus, the final version of this document will be restated after that accordingly.

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1 Introduction

1.1 The ebalance-plus energy balancing platform

The ebalance-plus project is a 42-month collaborative research and innovation action at European level with the participation of 15 organisations from 10 different countries, which will develop smart-grid solutions (flexible loads and ICT devices) to increase the energy flexibility and the electric grid observability, providing new services for grid operators, transmission system operators, energy retailers and the customers, who are empowered with more functionalities to interact with the grid and manage the energy flows with high-quality standards. The project is aligned with a variety of EU strategies and roadmaps promoted in the last years to reduce CO_2 emissions, increase the energy efficiency at different levels and engage the customers in this kind of innovative solutions. The aim of the project is to increase the flexibility and resilience of electric grids (power system), by means of an energy balancing platform, which will integrate smart production, storage and consumption technologies. This energy balancing platform is based on a fractal-like hierarchical architecture (see Figure 1-1) that replicates the existing grid topology with a bidirectional communication framework, assuring the scalability of the solutions.

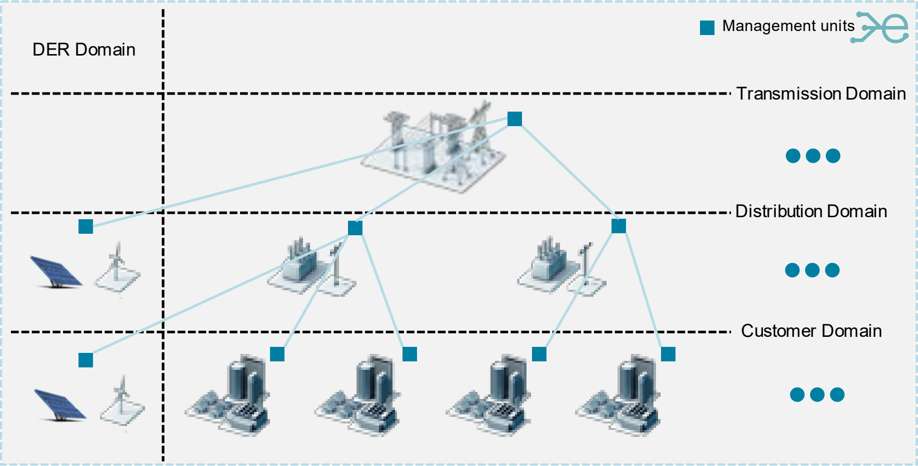

Figure 1-1 Fractal-like hierarchical ebalance-plus architecture

The ebalance-plus innovative services are based on the following technologies:

- **Grid management units.** These ICT devices compose the whole system architecture and allow monitoring and control the downstream domains.
- **Data-exchange middleware.** Software solution that assures the interoperability of heterogeneous communication protocols and databases.
- **Security and privacy technology**. The system architecture protects the privacy and user's data against attacks and manipulation with the latest encryption technology.
- **Prediction models**. To manage energy flexibility as commodity in new energy markets and services, it is necessary to develop more accurate prediction algorithms that capture the variability of end-user behaviour, renewable energy generation and electric vehicle charging infrastructures.
- **Smart-storage solutions for buildings**. The straightforward way to increase the energy flexibility of buildings is deploying smart batteries that allow deploying services based on energy arbitrage.

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Silicon-carbide high-efficient power converters. New semiconductors like silicon carbide offer the possibility to manage distributed energy resources that usually work at DC voltage in a cost-effective manner and with a high level of energy efficiency and reliability.

Vehicle-to-grid (V2G) infrastructure. This facility takes advantage of the batteries of electric cars to use them as flexible storage and support grid operation and/or minimize energy costs using available RES.

During the first months of the project (February to November 2020), 11 use cases were defined combining these technologies to impact the flexibility and energy distribution market with innovative solutions. These were clustered in three groups in turn:

ICT architecture: use cases related to communication infrastructure, interoperability with existing systems and energy management systems (EMS), privacy and security, distributed control and management units.

- UC.01 ebalance-plus hierarchical energy communication platform
- UC.02 Interoperability solutions to integrate existing BEMS within demand response markets

Grid reliability and resilience: all the mechanisms, technologies and algorithms to increase the grid observability and restore the power system stability quickly against unexpected events (resilience).

- UC.03 Application of IEN 50160 for voltage quality
- UC.04 Fault Detection, Isolation & Restoration (FDIR) services
- UC.05 Volt/VAr optimization with increasing RES generation
- UC.06 Intentional islanding after cascading failures
- UC.07 Secondary substation transformer monitoring (health and voltage quality)

Flexibility mechanisms: use case related to unlock the energy flexibility at customer premises, district or neighbourhood level (DER facilities), ancillary services (frequency and non-frequency), energy demand optimization and market mechanisms.

- UC.08 Flexibility measures I: Virtual Power Plant (VPP) services based on district solutions (variable PV generation, storage and V2G)
- UC.09 Flexibility measures II: Virtual Power Plant (VPP) services based on building solutions (IoT devices, PV and storage)
- UC.10 Flexibility measures III: Price/CO2 based optimization (demand response)
- UC.11 Ancillary services and market mechanisms based on residential power-to-heat-control (DTU's research)

This document describes the preparation activities to implement the corresponding use cases in every demo site: Smart Campus of University of Málaga (UMA), University of Calabria (UNC), JUNIA-Institute Catholic of Lille (JUNIA-ICL), summer houses in Denmark and in-lab demo in Germany (IHP's laboratory). The ebalance-plus solutions are composed of electronic devices (management units and gateways), software and equipment (power converters, smart electric batteries and V2G charging points) that require adapting the existing facilities with additional. This activity was planned from November 2020 until January 2022 but due to the covid-19 restrictions and other international problems (e.g., supply chain of electronic devices), this activity has continued in parallel with the platform installation and commissioning (September 2022).

The allocation of use cases in the corresponding demo sites is as follows (Table 1-1):

Table 1-1 Allocation of use cases and demo sites

Use Case	UMA	UNC	JUNIA-ICL	Denmark	In-lab
UC.01	●	●	●	●	●
UC.02	●	●	●	●	●
UC.03	●	●			
UC.04					●
UC.05	●	●			
UC.06					●
UC.07	●	●			
UC.08	●	●			
UC.09	●	●	●		If necessary
UC.10				●	
UC.11				●	

Moreover, this document describes the working methodology applied to prepare the corresponding demo site, the end-user-behaviour characterization based on the use cases defined and the UMA's fog server specifications (server in which the ebalance-plus will be deployed).

Remark: UC.11 is a simulated use case thus, it is not part of this document.

1.2 Working methodology

The working methodology adopted by the consortium to carried out the pilot preparation comprises four main activities and the coordination:

- **Coordination**: every demo site (UMA, UNC, JUNIA, DTU) has proposed a working team that manages the pilot preparation together with the corresponding facility managers. The working team holds weekly follow-up meetings (about half an hour) with the project coordinator to make decisions and corrections over the original plan, mitigating potential risks and delays.
- **Inspection**: apart from the first inspection at the beginning of the project to perform the data collection, building and technical facilities has been visited by technical staff to clarify doubts and check the suitability of setups and prototypes to be installed.
- **Analysis**: The technical staff evaluates the conditions and restate, if appropriate, the requirements of the platform or flexibility solutions provided by ebalance-plus.
- **Preparation and deployment plan**: the preparation and deployment plan include the devices, locations, configurations, integration, administrative procedures (e.g., tenders and procurements) and commissioning of elements necessary to deploy the ebalance-plus platform and flexibility solutions.
- **Control and supervision**: in the last step, following the deployment plan, the corresponding working groups together with the project coordinator, perform the supervision of deployment and apply the corrections needed when appropriate.

Moreover, the inspection and analysis of facilities aims at identifying the following points:

- **Flexibility sources**: identification of facilities and equipment that can significantly increase or reduce the energy consumption and their operation can be controllable under security conditions.
- **Internet access**: identification of new or additional communication infrastructure to connect flexibility sources and management units. Management units requires Internet connection or local area network to be connected each other in a hierarchical manner.

- **Identification of management unit location**: ebalance-plus management units must be connected closely to flexibility sources, with access to Internet or local area networks and energy supply (230 V_{AC} or 24 V_{DC} in case of grid management units).
- **Room adaptations and reinforcements**: depending on the size and the weight of some equipment (e.g., electric batteries, power converters…) it is necessary to evaluate the size of available spaces to deploy the corresponding solutions.
- **Data acquisition and store**: existing and ebalance-plus devices will generate data that must be store in the management units to run the algorithms and evaluate the impact at the end of the project. With this information, the data management plan will be updated accordingly.
- **Administrate procedures and legal authorisation**: depending on the country, some devices are required to fulfil specific technical rules that must be identified in advance to reduce additional delays.

2 End-user energy behaviour

Energy usage is a phenomenon that is not only technical but also psychological and social. Therefore, aspects of end-user engagement are so crucial to the success of any energy innovation. Developments in energy generation and optimisation technologies have not eliminated the need for end-user involvement and in some cases have even increased it. For example, from the perspective of building managers, previously their efforts were focused on building thermal comfort into poorly insulated buildings; now, with efficient and more airtight buildings, they need to protect themselves from the risk of overheating through good ventilation maintenance and intelligent use of curtains and blinds. From the residents' perspective - whereas previously engagement was about adjusting the thermostat or air-conditioning - it may now require giving them the extent of their flexibility (when using a smart washing machine or dishwasher) or deciding when to cook a meal using cheaper electricity.

Obtaining demand flexibility and the ability to shift the load therefore also requires gaining the acceptance and commitment of end-users. In some cases, this requires more cognitive effort on the part of residents to keep everything in mind and act rationally. This brings new questions and challenges. Obtaining the involvement of residents is sometimes difficult because we are dealing with an unfavourable context. In particular, the technical side of buildings, with the latest generation of smart buildings, is fuelling notions of ease of use, automatic background operation and energy efficiency.

Today more than ever, the development of technical and energy solutions imposes the search for a solution on two fronts:

- obtaining acceptance of the changes on the part of the users, some of whom do not want to change established habits, considering that the effects are sufficiently effective in terms of performance and user comfort
- obtaining specific properties of the proposed solutions. When a new device is developed, it is not immediately integrated into everyday practice. This occurs during an often long and multi-stage process. In order to facilitate this adoption, solutions must be proposed that end users can easily understand and use. Thus, the closer the solution is to the goals, skills, intelligence but also values of the end-users, the more likely it is to be accepted and used as envisaged by the design and as required by the specification.

In the ebalance-plus project, to maximise the chances of end-users adopting the technology, the introduction of the new solution in the demo-sites sites is preceded by activities to describe the current context of use. As part of the project, interviews were carried out with cleaning staff at the Junia campus, interviews with electric car users at the University of Malaga campus and a workshop with residential students at the University of Calabria. The main results of which we present in the following chapter.

2.1 University of Málaga – Smart Campus

2.1.1 Planned interventions

As part of the ebalance-plus project intervention, it is planned to install EV charging stations in the car park in the surroundings of the Ada Byron building. The charging stations will operate in Vehicle-to-Grid mode.

2.1.2 Current status

Currently there are electric car charging stations (Grid-to-Vehicle) installed on the University of Malaga campus. The use of the charging stations is free, there are no fees. From conversations with electric car owners working at the University of Malaga, this is a very attractive solution. By charging the car at work, journeys are virtually free. Some employees have decided to replace their fuel car with an electric one precisely because free charging is possible.

The increased interest in free charging is resulting in more and more cases where a charging station is occupied by someone else. A feature of the electric car is the relatively short range (compared to a fuel car). The energy cannot be stored in an extra battery (like, for example, extra fuel in a canister). Hence, there is a very high sensitivity to the lack of charging capability. For some users, not being able to connect to a charging station when arriving at work means not being able to drive home.

Discussions with users revealed potential barriers to this technological solution:

- The Vehicle-to-Grid charging concept may not be understood by everyone. It is a reversal of the previous paradigm that the charging station charges (increases the amount of energy in the battery).
- A consequence of the V2G concept is that the car will not be charged as quickly as it could be. This reduces the attractiveness of charging in this way, as the driver's constant concern is to have the battery as charged as possible. The car's large potential range means freedom and no worries about 'will I get home'.
- The above uncertainty could be solved by a clear and transparent contract - which the driver would be informed of at the time of connection. The contract would need to state that the station can draw energy from the battery to some extent, and an assurance of a minimum level of energy in the battery below which the battery will not be discharged.
- Concern for battery life also appears to be a major barrier. To users to opt for the V2G charging option, they need to be assured that this does not harm the battery. Certificates from the manufacturer would work best here.
- The use of the V2G charging concept is certainly encouraged by the free electricity. This is still the main perceived advantage and motivator. As long as, in the long term, the balance of energy supplied by the charging station exceeds the energy withdrawn, the whole concept remains attractive to potential users.

2.2 UNC Smart Campus

2.2.1 Planned interventions

As part of the ebalance-plus project, it is planned to install an automatic air conditioning system in the rooms occupied by students in the Monaci dormitory. The air-conditioning system is to flexibly adjust the room temperature depending on the availability of energy produced by the University's photovoltaic plants.

It is also planned to install smart appliances (e.g., smart washing machines, smart dishwashers) in the students' rooms, which, when loaded, will run themselves automatically during periods of more availability of electricity from the photovoltaic plants.

It is planned to install and use IoT devices such as Smart Plugs, humidity, temperature and lightness sensors. They are respectively useful to control and monitor the loads, monitor the room status in term of temperature and light so to valuate and so provide flexibility services.

2.2.2 Current status

Actually, the students living in the student residence (Monaci) do not have any air conditioning system installed. This means that from their point of view, any air conditioning system would be a step towards increasing their comfort.

Regarding washing machines - there is currently a common room in the Monaci building where washing machines are made available to students. They are activated by a coin fee. There is no set schedule for using the laundry facilities - students use when it is convenient for them. The procedure requires that they load the washing machine with laundry, select the appropriate programme, and pay for the service with coins. Students usually wait on site until the whole laundry operation is completed.

2.2.3 Feedback on the planned intervention

Flexible air conditioning

The flexible variation of room temperature by an automatic system is not seen as a significant disadvantage. If the range of fluctuations is small, according to the students, flexible temperature changes may even go unnoticed. The perceived temperature is always a very subjective matter. Even the same temperature can be subjectively felt differently on different days.

Washing machines

Students were approving of the plans to install washing machines in the rooms. Interestingly, they did not see having to wait for the washing machine to start automatically as a disadvantage. Currently, they have to wait for the washing cycle to finish in the common room anyway. When using a smart washing machine in the room, the entire cycle will be started and completed automatically, which was welcomed.

Based on statements from potential end-users, it can be concluded that the planned interventions will not encounter major barriers. Both functionalities improve the comfort of the students compared to the current state.

2.3 JUNIA

2.3.1 Planned interventions

For the French demo-site, 5 types of equipment are planned to be installed and tested within ebalance-plus project:

Table 2-1 Building facilities in ICL and Junia related to user behaviour

Target facility	Interaction – End User	Interaction – Facility Manager
BESS		●
HVAC	●	●
DHW boilers	●	●
PV production		●
Charging points for students and staff (for mobile phones, laptops, etc.)	●	●

Of the five planned equipment types, three will be used by end-users at the university. Since for one of them (the boilers) the interaction goes beyond simple use, the following analysis focuses on describing the behaviour of the cleaning service using the water heating boilers.

2.3.2 Exploration of demand response potential on the Lille Campus: the case of domestic hot water

Facilities and reasons for use

The table details the areas where hot water is used and the rate of use, in the three Lille Campus buildings.

Table 2-2 Domestic hot water (user behaviour) in ICL and Junia demo sites

Entity	Junia	Lille University	
Buildings	**School of Advanced Studies in Engineering (HEI)**	**Rizomm building**	**Academic Hotel**
Floors and tables in offices and classrooms	1 time per week	1 time per week	1 time per week
Cleaning the toilets	Every day	Every day	Every day
Small dining room	Quick washing-up	Quick washing-up	Quick washing-up

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Entity	Junia	Lille University	
Buildings	**School of Advanced Studies in Engineering (HEI)**	**Rizomm building**	**Academic Hotel**
Biology laboratory	-	Course and sample materials	-
Shower	-	1 to 3 per day	-

Many 15-liters boilers, a few 50-liter boilers and a few 100-liter boilers are spread on the campus. The boilers constantly heat the water up to 60° C, day and night. The washes are with hot water, the rinses with cold water. The boilers have a thermostat to restart the heating and maintain the temperature.

No indication of the quantity of water available, nor of the water temperature is available.

Terms of use of hot water tanks

The common points between the buildings are the fact, that usage is regular. There is little variation outside regarding level of contamination or scheduled events, which increase footfall and cleaning needs. In each building cleaning staff always works on an assigned area (generally a floor or half a floor) and has its own reservoir (boiler), the size of which corresponds to the needs.

It was also observed that staff generally do not draw large quantities of hot water at a time to avoid handling a heavy load. For this reason, it is very rare that a lack of hot water in the tank is indicated.

Cleaning staff working patterns

- At the University buildings, cleaning staff works all day long, with presences spread out from 5 a.m. to 4 p.m. On Junia, the organization is more classic, with a morning cleaning then a permanence by 1-2 people during the day.
- At Rizomm (University), non-cleaning uses are more intense: washing handling materials for biology classes and the use of showers. But these uses are programmed (because of lessons schedule) or regular (i.e., lunch break).

Rizomm building and Academic Hotel: consumptions for cleaning

- Cleaning staff cover the whole day with different hours. Most arrive from 5 to 9 am, then less attendance from 4 pm.
- Generally, one boiler of hot water per person and per sector is available, so staff has usually detailed knowledge of the capacities and limits of the used boiler.
- There is observable habit of never making a large draw from boiler, for a matter of weight or not to have too much hot water which cools purposeless in the bucket, and which must be handled to empty and risk the shortage. This means that usually there are small volumes taken (max 5 liters) repeatedly. The water intakes vary depending on attendance and current season / weather (summer versus winter; rainy vs. dry weather).
- The permanent functioning of the cumulus is sufficient to ensure sufficient DHW throughout the day.

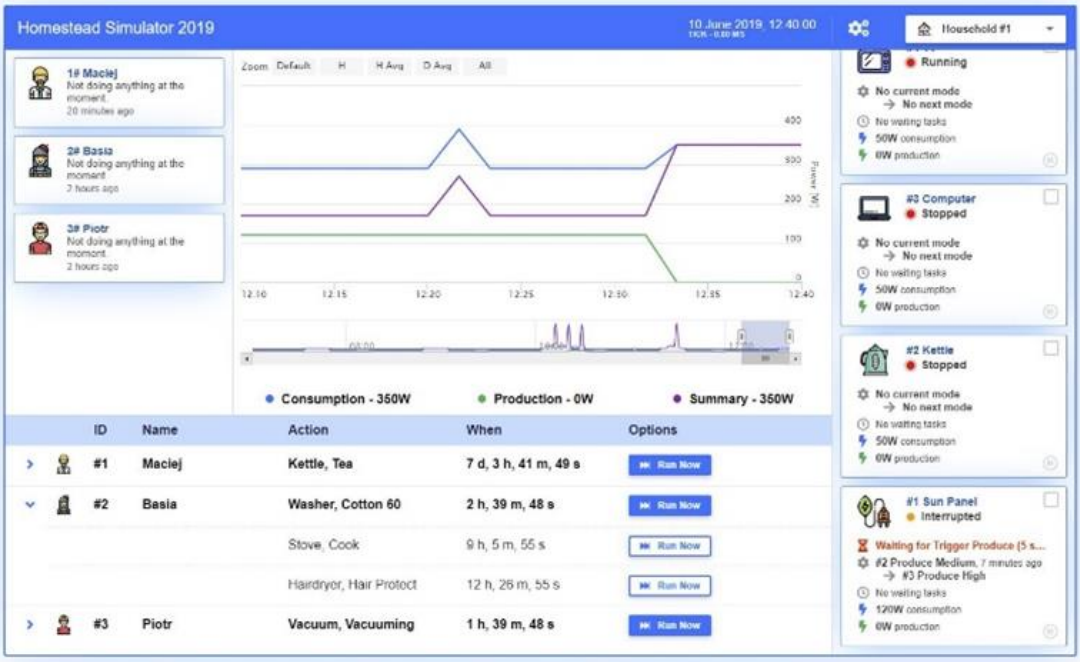
- The operation of the hot water tank is not explained but understood by logic, with the red light indicating permanent heating of the water. Knowing the remaining volume is not an explicit request among cleaning staff. At a minimum, interest rather for the heating time of a given volume.

Suggestions for changes in the future

- There is no need for heating during the night.
- 15-liter tanks, the most numerous, leave little room for maneuver and elasticity. Those of larger size are to be preferred, with the essential precaution of knowing the practices of pulling and the possible offsets between them.
- The demand for knowledge of the volume drawn and remaining is not general.

2.4 In-Lab demonstrator

The In-Lab demonstrator follows a different approach towards user involvement. Within this tool it is possible to model specific user behaviour and evaluate how its change influences the energy profile of the household or neighbourhood. This is happening in the behaviour simulator, where the descriptive language is used to express the typical energy related schedule of a particular user defining how she uses the appliances of given type. Combining the behaviour description with specific set of appliances makes it is possible to generate the energy profile for that user within the given household. A household can be composed of multiple persons and their energy usage schedules are combined to create the household profile. The output of the behaviour simulator drives the physical energy consumption and production elements of the emulator to induce real energy flows within the In-Lab emulator. The graphical interface of the behaviour simulator is shown in Figure 2-1.



ID	Name	Action	When	Options
#1	Maciej	Kettle, Tea	7 d, 3 h, 41 m, 49 s	Run Now
#2	Basia	Washer, Cotton 60	2 h, 39 m, 48 s	Run Now
		Stove, Cook	9 h, 5 m, 55 s	Run Now
		Hairdryer, Hair Protect	12 h, 26 m, 55 s	Run Now
#3	Piotr	Vacuum, Vacuuming	1 h, 39 m, 48 s	Run Now

Figure 2-1 The graphical interface of the behaviour simulator – part of the In-Lab demonstrator

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3 Building technical facilities preparation

3.1 UMA Smart Campus

The UMA demo site is composed of four buildings distributed in two independent electric distribution networks. After the preliminary selection done and presented in the deliverable D6.1, the following ebalance-plus architecture and flexibility technologies have been selected to be integrated.

Computing Science School

This building is composed of 4 modules and supplied by 5 MV/LV transformers (two of them supplying one module) and a PV canopy of 100 kW. To monitor the energy consumption can be done by the smart meter located in the MV distribution cabinet (DSO dwelling), in every transformer or in every main electric panelboards. . The PV canopy facility is completed with 4 PV inverters and 4 Smart Grid meters, and 4 Smart dataloggers. Each couple of components [PV inverter- Smart Grid meter] allows the monitoring and reading of the PV plant production and consumption corresponding to each of the 4 modules in which the building is divided. Each couple [PV inverter- Smart Grid meter] use MODBUS RTU communication protocol to communicate with a Smart datalogger which acts as a gateway between both components and the Network Management System (NMS).

This building does not present any flexible load. The HVAC system is totally distributed, and its complexity makes expensive the load control. There is one room available for installing the BESS provided by AMP in the building module 4, together with the power backup system. This will be installed as close as possible to the main electric panel board to avoid energy losses. The power control of PV inverters is not totally clear, and its final integration and thus, the DERMU installation, will be decided on the last stage.

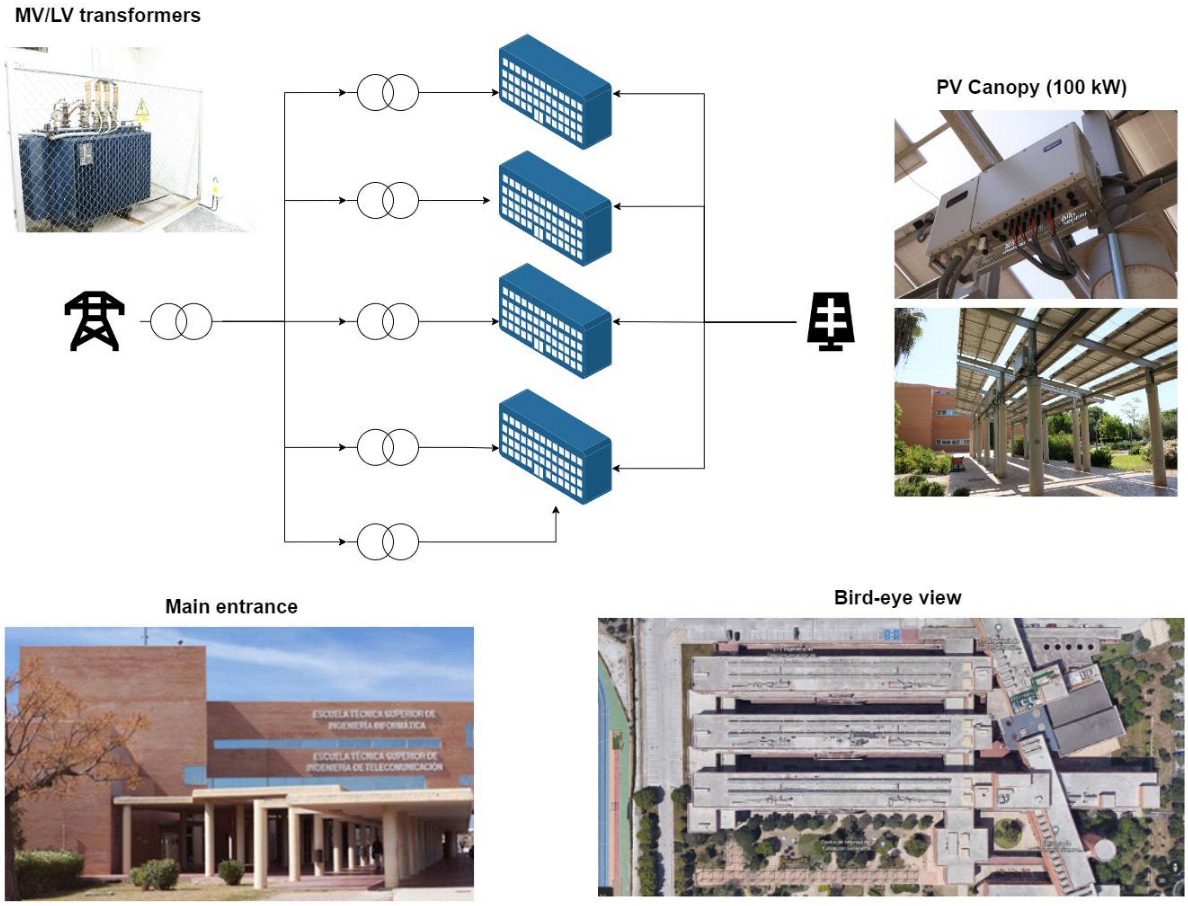

Figure 3-1 General Schemes and pictures of the Computing Science School in UMA Smart Campus

The technologies and devices to be installed and integrated are shown as follows in Table 3-1.

Table 3-1 UMA Computing Science School

Device	Number	Brand	Measurements	Comm. Protocol	Location
Power analyzer	1	To be defined	Electric	Modbus TCP	Main Electric Switchboard 1
Power analyzer	1	Carlo Gavazzi WM30	Electric	Modbus TCP	Main Electric Switchboard 2
Power analyzer	1	Carlo Gavazzi WM30	Electric	Modbus TCP	Main Electric Switchboard 3
Smart Circuit Breaker	1	Carlos Gavazzi WM20	Electric	Modbus TCP	Main Electric Switchboard 4
CMU	1	SOF		TCP/IP	UMA Network
LVGMU	2	EMT	Electric	TCP/IP	Secondary sub room
MVGMU	1	EMT	N.A.	TCP/IP	Virtual
SEMS BUFFER	1	AMP	BESS parameters	REST API	Maintenance room

As example of project progress in Figure 3-2, the first setup of the LVGMU is presented

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Figure 3-2 First LVGMU setup by EMTECH and UMA in Computing Science School (LVGMU at left and current coils wiring at right)

Sport Centre

This building is supplied by 2 MV/LV transformers. To monitor the energy consumption can be done by the smart meter located in the MV distribution cabinet (DSO dwelling), in every transformer or in the main electric panel board.

This building does not present any flexible load. The HVAC system is totally distributed, and its complexity makes expensive the load control. There is one room available for installing the BESS provided by AMP in the technical room, together with the HVAC system. Probably, this room requires structural reinforcements. This will be installed as close as possible to the main electric panel board to avoid energy losses.

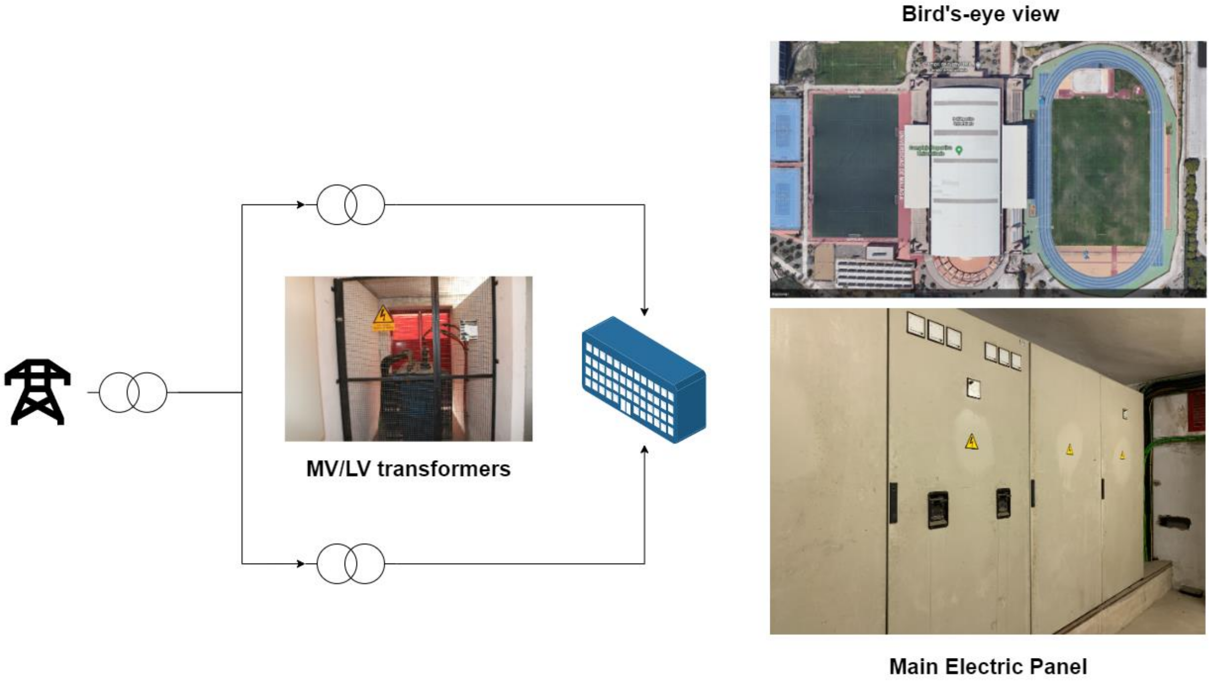

Figure 3-3 General Schemes and pictures of the Sport Centre in UMA Smart Campus

The technologies and devices to be install and integrated are shown as follows in Table 3-2.

Table 3-2 UMA Sport Centre

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Device	Number	Brand	Measurements	Comm. Protocol	Location
Power analyzer	2	Carlo Gavazzi EM24DINAV23XE1PFA	Electric	Modbus TCP	Main Electric Switchboard
SEMS BUFFER	1	AMP	BESS parameters	REST API	Maintenance room
CMU	1	SOF	N.A.	TCP/IP	UMA Network
LVGMU	2	EMT	Electric	TCP/IP	Secondary substation

Ada Byron

This building is supplied by 1 MV/LV transformer. To monitor the energy consumption can be done by the smart meter located in the transformer (owned by the DSO), in the transformer or in the main electric panel board.

This building does not present any flexible load. The HVAC system is partially centralized, what makes it potentially suitable for load control: two air handling units (AHU) supplied by a heat pump for cooling and heating. There is one room available for installing the BESS provided by AMP in a technical (store) room close to the main electric panel board (this room must be cleaned and adapted).

Additionally, the outdoor car park of the building will be partially used to deploy the PV canopy solution with V2G charging points. This facility will be connected to the existing MV/LV secondary substation, connecting both the building and the ebalance-plus smart hub solution.

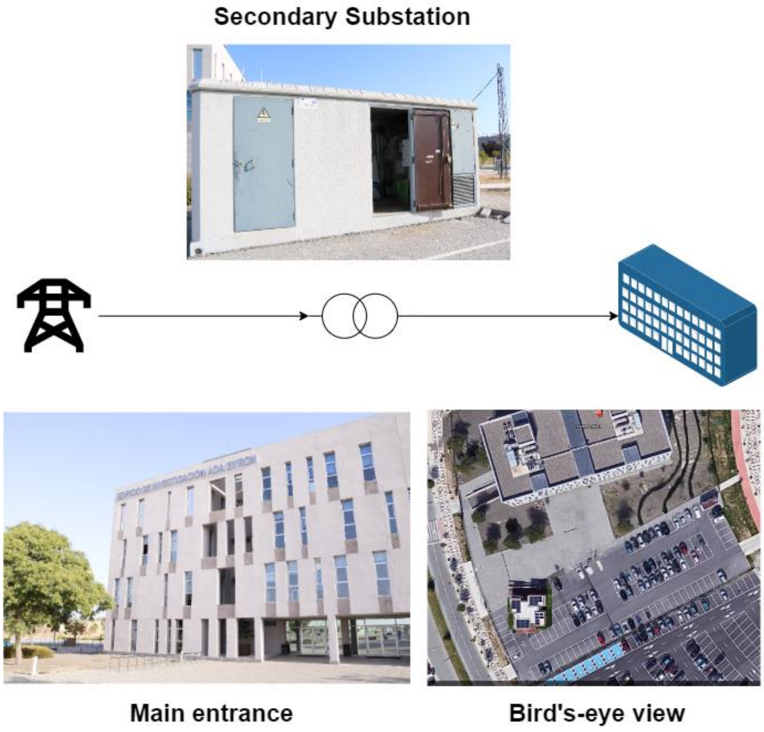

Figure 3-4 General Schemes and pictures of the Ada Byron Research Centre in Smart Campus

Table 3-3 Ada Byron Research Centre

Device	Number	Brand	Measurements	Comm. Protocol	Location
Power analyzer	1	Carlo Gavazzi	Electric	Modbus TCP	Main Electric Switchboard

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Device	Number	Brand	Measurements	Comm. Protocol	Location
HVAC control	1	Loxone	Electric, indoor conditions	Cloud (Modbus)	Building control
SEMS BUFFER	1	AMP	BESS parameters	REST API	Maintenance room
CMU	1	SOF	N.A.	TCP/IP	UMA Network
LVGMU	1	EMT	Electric	TCP/IP	Secondary substation
MVGMU	1	EMT	N.A.	TCP/IP	Virtual
MIMO converter	1	TPS	Electric	Modbus TCP	Outdoors
PV canopy	1	Tender	No	No	Outdoors
External BESS	1	Xolta	BESS parameters	Modbus TCP	Outdoors
V2G Charging point	5	MGC	Electric	Modbus TCP	Outdoors
DERMU	1	EMT	Electric	TCP/IP	Secondary Substation

Psychology Faculty

This building is supplied by 2 MV/LV transformer. To monitor the energy consumption (PV inverters and power analyzer) can be done by the BEMS through API. The building BEMS is relatively modern (documentation is on progress) and the integration cannot be guaranteed, thus the flexible loads (PV system, HVAC) will not be considered, and the building facilities will be just monitored

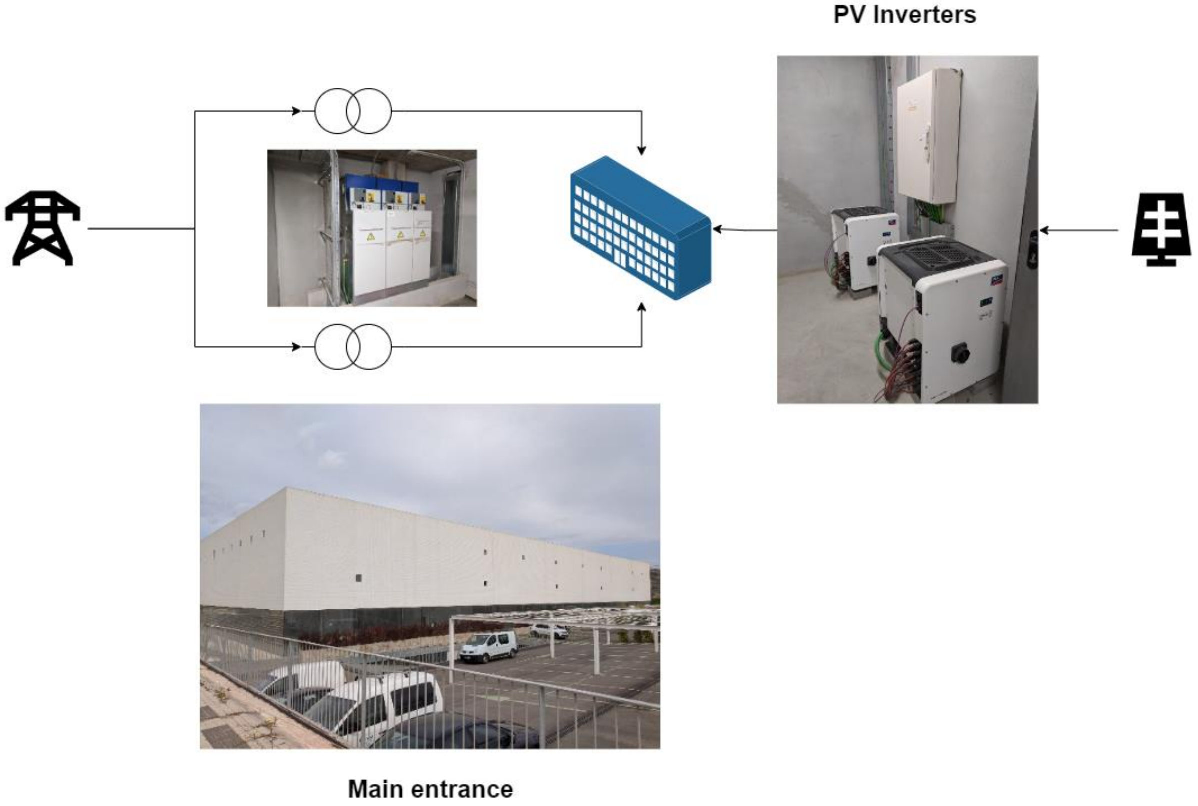


Figure 3-5 General Schemes and pictures of the Psychology Faculty in UMA Smart Campus

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

The technologies and devices to be install and integrated are shown as follows in Table 3-4.

Table 3-4 Psychology Faculty

Device	Number	Brand	Measurements	Comm. Protocol	Location
BEMS	1	TBD	General building parameters, PV generation, EV status	REST API	Indoor
CMU	1	SOF	N.A.	TCP/IP	UMA Network
LVGMU	2	EMT	Electric	TCP/IP	Secondary sub room

3.1.1 Use case assessment

Table 3-5 UMA use case assessment

Use Case	**Technologies**	**Data**	**Requirements**	**Preparation activities**
UC3	LVGMU Electric measurement devices	Electric parameters from secondary substations	Access to transformer supply lines under security conditions (without voltage or totally isolated)	• Selection of suitable spaces to install the devices. • Purchase and installation of electric measurement devices (Rogowski coils) • Purchase and installation of auxiliary components (boxes, cables, assembly elements…)
UC5	LVGMU Electric measurement devices PV power converters	Electric parameters from secondary substations and PV facilities	UC3 requirements Integration of communication and control of PV power inverters	• UC3 activities. • Collection and analysis of specifications of PV power converters (integration and configuration)
UC7	LVGMU Electric measurement devices (PMU)	Electric parameters from secondary substations	UC3 requirements	• UC3 activities
UC8	CMU DERMU DC Power Converter BESS V2G charging points	Electric parameters Weather forecasting Load forecasting BESS SoC	UC3 requirements Equipment supporting outdoor conditions Pole-mounted EV charging points	• UC3 activities • Tender procedure to deploy energy equipment (PV, EV charging points, Power

Use Case	Technologies	Data	Requirements	Preparation activities
	PV canopy facility	V2G SoC	PV facility rated power lower than 100 kW	Converter, BESS) • Internet connection available • Local DSO involvement • Agreement to use V2G electric vehicles from Nissan • Installation works
UC9	CMU Smart meter or power meter BEMS DERMU BESS	Electric parameters Weather forecasting Load forecasting BESS SoC	Power supply Open access to smart meter or available space in electric panelboards BEMS communication enabled Available space close to electric panel board to deploy BESS	• Integration and configuration of DSO smart meters • Room preparation (cleaning and reinforcement if needed) • Inspection of panelboards to deploy power meters • Internet connection available (network points) • BEMS integration (adapters) • PV inverter integration (adapters) • Installation works

3.1.2 Preparation activities

Activity	**Smart meter Integration (DSO infrastructure)**
Validation criteria	☐ Energy parameter readings (at least) every 15 minutes
Start	01/09/2020
Deadline	31/01/2022
Status	Cancelled
Manager	UMA
History of changes	**23.03.21 Deadlock**. The information received confirms that regional DSO blocks smart meters and cannot be read them by the DSO and the customer at the same time. As the communication to the DSO cannot be interrupted, UMA and CEM agree to apply the alternative (power meters). **08.03.21** Implementation in Python to read smart meters (without success) **12.01.21** New attempts to obtain electric readings from the smart meters without success. UMA is assessing the standard and test some scripts. They are looking for alternatives. **01.12.20** Energy readings not received yet (in progress). Test developed in CEMOSA and UMA premises (same models) without success. Additional smart meter purchased to test on laboratory. **27.10.20** API development to integrate data (UMA) **13.10.20** First readings with optical port in one of the models (using third-party software)
Conclusions & lessons learnt	Not all the smart meters are prepared for an easy and stable integration to deploy flexibility mechanisms. These devices are in general ready to send data once a day and store the information of last 6 months. However, for a continuous monitoring only specific models are ready and, in case like this, the DSO blocks the communication access to avoid interruptions. **Lesson learnt**: Not all the DSO use open protocols. The customer can install their own smart meter or power meters. In this case, as the UMA is a large

	customer of the regional DSO, it was not possible to replace current smart meters for other model with better connectivity (permission deny).

Activity	**DSO involvement**
Validation criteria	☐ Technical and legal support
Start	01/09/2020
Deadline	n.a.
Status	Standby
Manager	UMA
History of changes	**30.09.21** Some inputs from other local DSO but without commitment. **17.02.21** Some inputs (technical advice) received from local DSO but not willing to participate. **12.01.21** No answers from any DSO. **10.11.20** Iberdrola's feedback: evaluating their participation as External Advisory Board. **20.10.20** Endesa's contact regarding UMA has change. Looking for the new contact. Alternative: Iberdrola (large Spanish DSO). **13.10.20** No answer from Endesa (regional DSO)
Conclusions & lessons learnt	**Lesson learnt**: Large DSO are reluctant to support research projects. Local DSOs are more open to participate but are in general overburden with daily activities.

Activity	**Energy metering: selection and purchase**
Validation criteria	☒ Energy parameter readings (at least) every 15 minutes ☒ Ada Byron building (general energy consumption) ☐ Ada Byron HVAC energy consumption ☐ Computing Science energy School consumption ☐ Sport Centre energy consumption ☐ Current coils (panelboards and transformers) ☒ Psychology Faculty energy consumption
Start	01/11/2020
Deadline	31/01/2022
Status	Delayed
Manager	UMA
History of changes	**14.06.22** Connectivity issues with Loxone remains (the technical provider cannot find a stable solution to avoid circuit breaker activation). Power meters for Sport Centre expected 19th July. By end of July all the circuit breakers must be installed. **16.02.22** Psychology faculty opening delayed: expected September 2022. **14.01.22** Power meters for measuring HVAC in Ada Byron ready but some problems (unexpected energy supply interruptions). **23.11.21** Power meters supply: electric panels and BEMS controlling HVAC (Loxone) in Ada Byron building delayed. **14.09.21** Power meter supply delayed (**problems in supply chain**). Psychology faculty opening expected beginning 2022. **15.06.21** Looking for alternatives (e.g., sensor integrated in the circuit breakers). **08.06.21 Conflict detected:** Ampere requires access to panelboards to install power meters with a data acquisition rate of 1 second. It makes no sense to duplicate sensors and there is not available space for both setups. **01.06.21** Procurement process to purchase power meter launched **25.05.21** The AHU of Ada Byron is operative again (fixed). Next step: study its integration through API. **18.05.21** Selection of power meters still ongoing (CEM sends several examples and brands). UMA will invest 40 k€ to update the Ada Byron's BEMS (out of the project). **27.04.21** Some panelboards has power meters: to assess if they can be

	integrated as well. **23.04.21** Technical inspection: some panelboards have current coils that can be used to deploy power meters. **23.03.21** Decision about PV control: in case that the PV system can be controlled, the DERMU is the preferable unit. Otherwise, just monitoring and integration with the CMU. **19.01.21** PV facility readings integrated in the CEM's FTP server. UMA has requested specifications to Huawei. The Air Handling Unit of Ada Byron seems broken. **12.01.21** They have applied changes in the BEMS that control the HVAC of Ada Byron and it seems that can be integrated in ebalance-plus for evaluating UC09. The FTP server from PV system is running. **01.12.20** PV facility (Computing Sciences) readings confirmed using FTP **10.11.20** PV facility in Computing Science School: Huawei gateway with several communication possibilities. Start data collection using FTP.
Conclusions & lessons learnt	3-phase electric panel with previous monitoring makes difficult to be monitored (lack of available space). Large buildings blocks can present complex configurations that requires many metering devices (expensive) and extend the existing communication network (additional time). The case of UMA is especially different in some cases due to combination of internal MV/LV transformers and distribution electric panels feeding different facilities. **Lesson learnt**: Smart circuit breakers, independent current and voltage sensors can be a better solution for a better and faster deployment. It is important to check supply chain conditions (exceptional situation due to international delivery issues). Dependencies with external cloud providers can be tricky, support is slow (externalized), disconnections.

Activity	**Purchase and installation of auxiliary components**
Validation criteria	☐ Project elements can be connected (electricity and communications) ☐ Project elements can be deployed and protected according to regulations
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	UMA
History of changes	**28.04.22** First box with energy supply and communication ready to install LVGMU **14.09.21** GPS Antennas to synchronise EMT's management units is not possible in some cases and some alternatives with 5G solutions are discussing. **13.10.20** First readings with optical port in one of the models (using third-party software)
Conclusions & lessons learnt	Technical solutions must facilitate mounting/assembly devices. **Lesson learnt**: assembly instructions must be prepared in advance.

Activity	**Tender procedure for district pilot**
Validation criteria	☒ MIMO converter specifications (mechanical, electrical, communications) ☒ V2G charging points (mechanical, electrical, communications) ☒ PV canopy design (rated power and model reference selection) ☒ Wiring design (type, section…) ☒ Allocation of components in car park environment ☒ Tender draft ☒ Tender publication ☐ Tender evaluation and selection ☐ Deployment

	☐ Commissioning (electricity, communication, legal rules)
Start	01/09/2020
Deadline	31/07/2021
Status	Delayed
Manager	UMA
History of changes	**12.07.22** Technical evaluation ready. Economic evaluation next week. Estimated start time first of September. **21.06.22** Tender evaluation (technical). Three companies participated. **23.05.22** Tender launched **March 22.** Tender and project ready to be launched. Tender awaiting in the administrative queue. **21.01.22** Deadline to submit the tender: end of January 2022. **14.01.22** UMA's internal problem. The tender procedure is stopped since November and nobody informed. It must be restated because it needs preliminary project and project management services. **23.11.21** UMA confirms if there are not new comments, the tender can be launched in February 2022. **14.09.21** Tender procedure: internal conflicts with other research groups. **07.09.21** Tender draft sent to UMA Procurement Services. **27.04.21** Budget estimation to undertake the setup. **23.03.21** Definition of the final setup (under discussion). **12.01.21** Contacting electric provider to design the whole setup (Schneider). Just a few market solutions for DC/DC. **20.10.20** Financial limit to avoid tenders: up to 30.000 € with three offers. Not suitable in our case and the tender procedure is needed in any case. **13.10.20** Collection of internal procedures to launch tenders (UMA must book the budget in advance to address the tender procedure).
Conclusions & lessons learnt	The setup is delayed 3 months. It is recommended to ask for an extension to be on the safe side or demonstrate at the end of the project. **Lesson learnt**: Try to breakdown subcontracting activities to avoid delays. Check all the components in the market firstly (availability and specifications). Check legal rules firstly (storage systems account as generation systems in Spanish regulation)

Activity	**Network (Internet) connection**
Validation criteria	☒ Network infrastructure deployed and configured ☐ Project elements can be connected (communications)
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	UMA
History of changes	**08.06.21** Ada Byron transformer ready. **25.05.21** Installation started. **10.11.20** Fibre installation validated. Deployment will start in January 2021 (two phases and about six months). **27.10.20** Checking if there are available space in indoor spaces to deploy fibre. **20.10.20** It is suitable (confirmed) to deploy fibre for all the setups **13.10.20** Infrastructure network department must evaluate the project deployment (IP addresses, VPN, fibre installation, etc.)
Conclusions & lessons learnt	It has been very positive to address this issue from the very beginning. The task will continue after the submission of this deliverable. **Lesson learnt:** prepare a whole communication plan/design from the very beginning as well.

Activity	**Rooms preparation (cleaning, reinforcements…)**
Validation criteria	☐ Project elements are connected (electricity and communications) ☐ Project elements are deployed and protected according to regulations
Start	01/09/2020

Deadline	30/09/2022
Status	On progress
Manager	UMA
History of changes	**21.01.22** Sport centre and Computing Science School cleaning and preparation started. **14.01.22** Rooms cleaning started **07.09.21** Maintenance manager is back **23.04.21** Visit to plan installation works **13.10.20** Maintenance manager on sick leave
Conclusions & lessons learnt	It has been very positive to address this issue from the very beginning. The task will continue after the submission of this deliverable. **Lesson learnt:** technical providers must provide a clear preparation and deployment plan (technical visit, blueprints and instructions).

Activity	**V2G electric vehicles (agreement)**
Validation criteria	☐ Obtain at least three V2G vehicles (Nissan Leaf)
Start	01/09/2020
Deadline	31/12/2022
Status	Under discussion
Manager	UMA
History of changes	**26.05.22** Nissan asks for the maximum available budget **06.04.22** UMA recovers the contact with Nissan and they could provide 3-4 Nissan Leaf cars for demo but hiring (not for free). **28.12.21** Nissan closes the R&D department in Spain. This was the main contact for the project (risk). **13.10.20** Start involvement of UMA staff providing additional EV for the demonstration.
Conclusions & lessons learnt	V2G projects are in general a risk because the chance in the market to get EV with these functionalities is low. **Lesson learnt**: Try to involve the manufacturer as partner, recruit users of V2G or emulate the V2G functionality somehow.

3.2 University of Calabria Campus

The University of Calabria demo site is composed of four office buildings, one residential building (students) and a laboratory DC/AC microgrid with different flexible loads. Additionally, some electric grid components (primary and secondary substations) are considered in the demo site to test the grid reliability use cases (UC3, UC5 and UC7). The grid topology of University of Calabria is a MV ring as shown in Figure 3-6. The buildings and facilities colour-highlighted are the target of the demo site:

- **Cubo 18B and Cubo 44B**: office buildings to monitor energy consumption, PV generation and increase flexibility with BESS.
- **Cubo 31B and Cubo 41B**: office buildings monitor energy consumption and PV generation.
- **Monaci**: residential building to deploy IoT technologies and home appliances in 5 apartments, monitor energy consumption and monitor PV generation.
- **Chiodo-2** (experimental laboratory microgrid to test DC-based setups).

All the buildings are connected to the MV grid through secondary substations that will be also monitored and integrated in the reliability use cases of ebalance-plus. The MV/MV primary substation is also on the focus of this evaluation and some grid technologies will be also deployed.

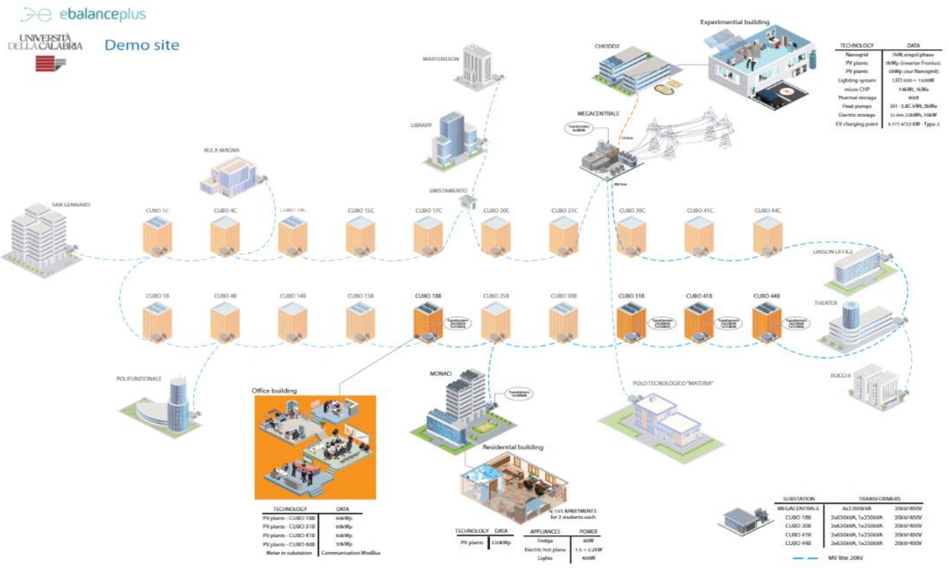


Figure 3-6 University of Calabria's grid infrastructure, buildings and facilities

Office buildings: Cubo 18B, Cubo 44B, Cubo 31B and Cubo 41B

Office buildings are connected to the MV ring through 2 or 3 transformers and are also supplied by PV roof facilities (Figure 3-7). The energy consumption monitoring was decided to be addressed by smart power meters sending the data to AWS and two buildings (Cubo 18B and Cubo 44B) have been selected to deploy 3-phase BESS developed by Ampere Energy. The DERMU will be installed in case that PV power inverters allows modulating power generation, otherwise, just CMU and LVGMU will be installed as components of the ebalance-plus platform.

Every Cubo generally consists in a set of offices, laboratories and classrooms, although the number of offices is prevalent. For each Cubo there are generally from 30 to 60 offices in which there are from 1 to 3 people. Although centralized air conditioning is present, the air conditioning of the rooms is now carried out through individual air conditioners for each room.

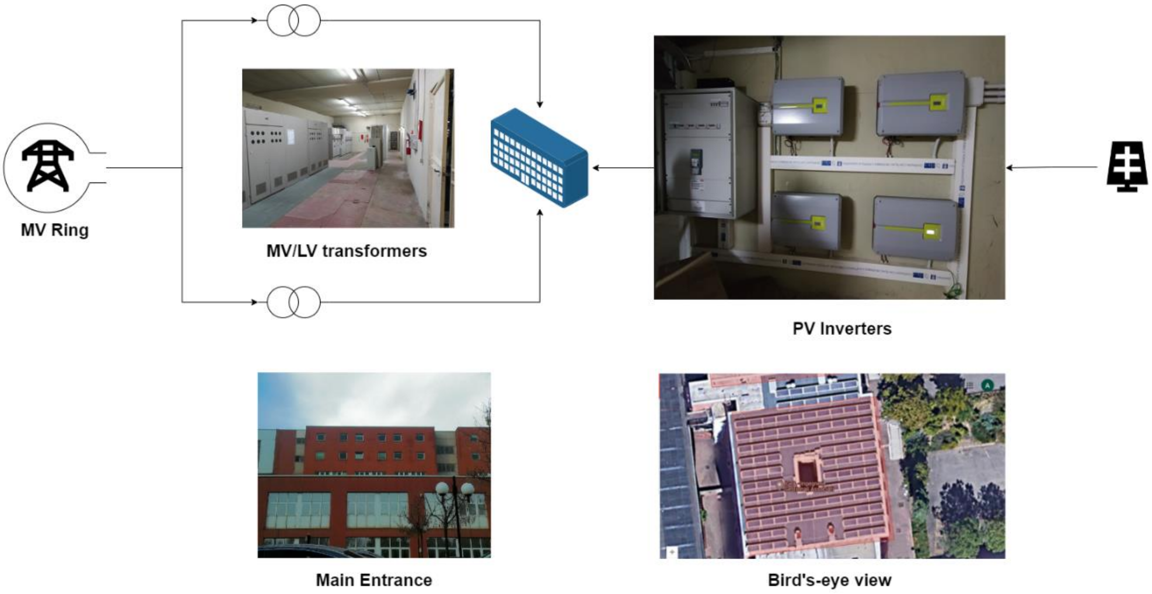


Figure 3-7 University of Calabria's office buildings' configuration

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

The technologies and devices to be installed and integrated preliminary are shown as follows in
Table 3-6Table 3-1.

Table 3-6 Office buildings in UNC

Device	Number	Brand	Measurements	Comm. Protocol	Location
CUBO 18					
Power analyzers	2 or 3	CRETA ES	Electric consumption (general and lighting)	Amazon Database	Main Electric Switchboard
SEMS BUFFER (9 /18)	1	AMP	BESS parameters	Cloud	Technical room
CMU	1	REE	N.A.	TCP/IP	Technical room
LVGMU	2	EMT	Electric	TCP/IP	Secondary sub room
DERMU	1	EMT	PV generation	TCP/IP	Technical room
CUBO 31B					
Power analyzer (2-3)	2 or 3	CRETA ES	Electric consumption (general and lighting)	Amazon Database	Main Electric Switchboard
LVGMU	2	EMT	Electric	TCP/IP	Secondary sub room
DERMU	1	EMT	PV generation	TCP/IP	Technical room
CUBO 41 B					
Power analyzer (2-3)	2 or 3	CRETA ES	Electric consumption (general and lighting)	Amazon Database	Main Electric Switchboard
LVGMU	2	EMT	Electric	TCP/IP	Secondary sub room
DERMU	1	EMT	PV generation	TCP/IP	Technical room
CUBO 44B					
Power analyzers	2 or 3	CRETA ES	Electric consumption (general and lighting)	Amazon Database	Main Electric Switchboard
SEMS BUFFER	1	AMP	BESS parameters	REST API	Maintenance room
CMU	1	REE	N.A.	TCP/IP	Technical room
LVGMU	2	EMT	Electric	TCP/IP	Secondary sub room
DERMU	1	EMT	PV generation	TCP/IP	Technical room

As example of project progress in Figure 3-8, the power meter setup is presented. These smart power meters provide energy consumption information every 5 seconds and 15 minutes through Amazon Web Services.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

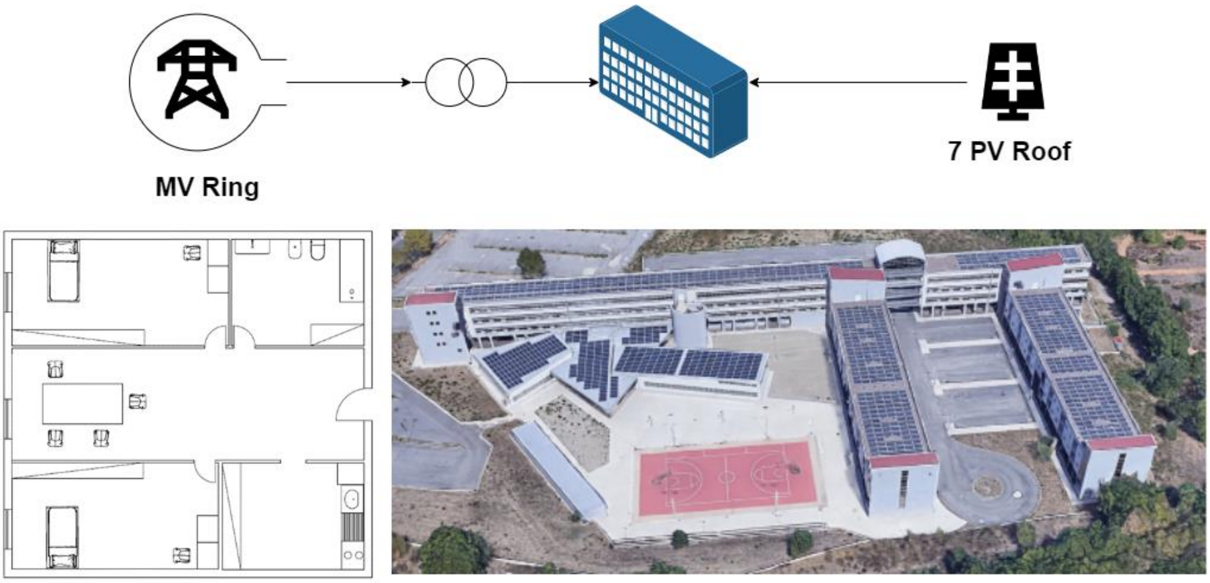
Figure 3-8 Smart power meter setup in the office buildings (Cubo #B)

Monaci

Residential Building (Monaci) consists of 100 apartments. Generally, each apartment is occupied by two students; there are the bedroom, a single room between living room and kitchen and a bathroom. Although the internet connection is present, to be independent and more reliable it will be made through a 3G modem with SIM.

These buildings will be equipped with IoT devices (mainly energy-related sensors), smart home appliances and single-phase BESS to increase as much as possible the energy flexibility and obtain the user experience of the entire solution.

The building block is also supplied by PV systems through 7 power converters. In case these power converters can be controlled, the DERMU will be installed, otherwise, the CMU (in this case the IoT gateway) will be the main management unit of the ebalance-plus platform.



Apartment distribution

Bird's-eye view

Figure 3-9 Monaci building block configuration

The technologies and devices to be installed and integrated preliminary are shown as follows in Table 3-7
Table 3-6Table 3-1.

Table 3-7 Monaci buildings in UNC

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

Device	Number	Brand	Measurements	Comm. Protocol	Location
Smart meters	5	CRETA-ES	Electric consumption	Amazon Database	Main Electric Switchboard 1
BESS (3/3 kW/kWh)	5	Ampere	BESS parameters	REST API	-
CMU	5	REE		TCP/IP	UMA Network
LVGMU	2	EMT	Electric	TCP/IP	Secondary sub room
DERMU	1	EMT	PV generation	TCP/IP	Technical room
Smart appliances	TBD	Teka, Samsung, others	Electric	REST API	Apartments

As example of project progress in Figure 3-8, the smart power meter setup is presented. These smart power meters provide energy consumption information every 5 seconds and 15 minutes through Amazon Web Services.

Figure 3-10 Power meter setup in the residential buildings (Monaci)

Chiodo-2

This building is an experimental AC/DC Microgrid that consists of three nano-grids installed and connected to a common DC bus operating as a unique hybrid AC/DC microgrid. This microgrid integrates two PV plants, one Stirling engine (micro-CHP), a lithium battery energy storage, several electric loads and some controllable loads. Moreover, one heat pump with a thermal storage is installed. An experimental local energy management platform has been implemented and installed for optimal management of RES plants and storage systems to reduce energy costs and CO_2 emissions. This experimental laboratory microgrid will be used to test mainly the UC.08.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

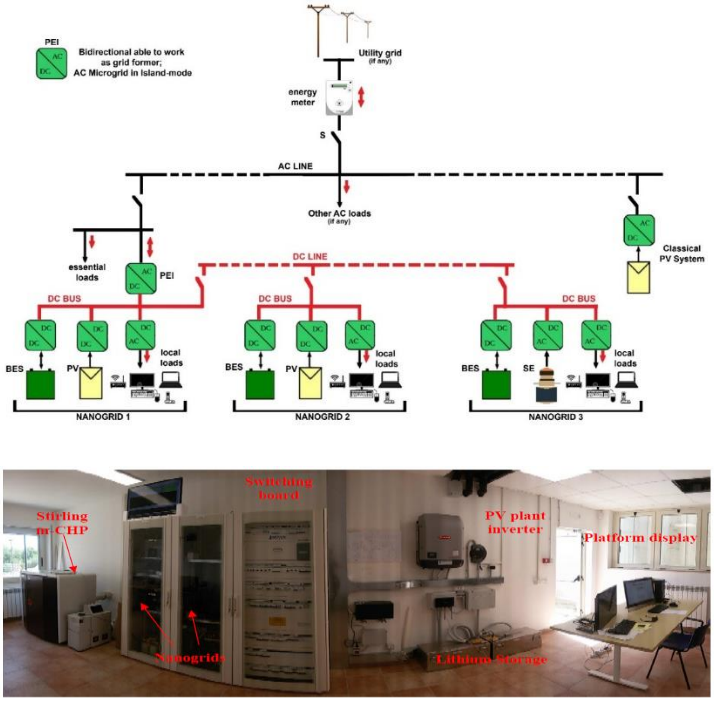


Figure 3-11 Chiodo-2 experimental laboratory

The technologies and devices to be installed and integrated preliminary are shown as follows in Table 3-8
Table 3-6Table 3-1.

Table 3-8 Chiodo-2 Experimental Laboratory in UNC

Device	Number	Brand	Measurements	Comm. Protocol	Location
Smart meter	1	CRETA-ES	Electric consumption	Amazon Database	Main Electric Switchboard 1
BESS	1	Archimede Energia	BESS parameters	Amazon Database	Technical Room
PV inverter	1	Fronius	Electric generation	Amazon Database	Technical Room
DERMU	1	EMT	PV generation	TCP/IP	Technical Room

Megacentrale

The Megacentrale is the primary substation (8 MW) of the University of Calabria. It belongs to the DSO and UNC partially. This primary substation feeds the electric ring with a specific line for a centralized chiller (district cooling). The Megacentrale will be monitored to deploy the reliability use cases UC03, UC05 and UC07. Indeed, a MU will be installed to the Point of common coupling to monitor the exchange of power with the grid.

3.2.1 Use case assessment

Table 3-9 UNC use case assessment

Use Case	Technologies	Data	Requirements	Preparation activities
UC3	LVGMU Electric measurement devices	Electric parameters from secondary substations	Access to transformer supply lines under security conditions (without voltage or totaly isolated)	• Selection of suitable spaces to install the devices. • Purchase and installation of electric measurement devices (Rogowski coils) • Purchase and installation of auxiliary components (boxes, cables, assembly elements…)
UC5	LVGMU Electric measurement devices PV power converters	Electric parameters from secondary substations and PV facilities	UC3 requirements Integration of communication and control of PV power inverters	• UC3 activities. • Collection and analysis of specifications of PV power converters (integration and configuration)
UC7	LVGMU Electric measurement devices (PMU)	Electric parameters from secondary substations	UC3 requirements	• UC3 activities
UC8	DERMU	Electric parameters Weather forecasting Load forecasting BESS SoC	UC3 requirements Integration with existing EMS	• UC3 activities • Internet connection available • Installation works
UC9	CMU (IoT Gateway) Smart meter or power meter BEMS DERMU BESS IoT devices	Electric parameters Weather forecasting Load forecasting BESS SoC IoT devices status	Power supply	• Room preparation (cleaning and reinforcement if needed) • Inspection of panelboards to deploy power meters • Internet connection available (network points) • BEMS integration (adapters) • PV inverter integration (adapters) • Installation works

3.2.2 Preparation activities

Activity	**Network (Internet) connection**
Validation criteria	☒ Network infrastructure deployed and configured ☐ Project elements can be connected (communications)
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	UNC

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

History of changes	**12.07.22** EMT confirms that they can manage dynamic IP address finally, so there is not any additional adaptation to apply. **14.06.22** Management units requires static IP address, but the communication company does not allow to. Look for an alternative. **20.10.20** Infrastructure network department confirms that there is not issue regarding Internet connection (suitable to connect all the ebalance-plus elements).
Conclusions & lessons learnt	**Lesson learnt:** The system architecture must consider IP configuration to avoid commissioning issues at the end.

Activity	**Energy metering: selection and purchase**
Validation criteria	☒ Energy parameter readings (at least) every 15 minutes ☒ Cubo buildings (general energy consumption and PV generation) ☒ Monaci building (general energy consumption and PV generation) ☒ Chiodo-2 building (general energy consumption and PV generation)
Start	01/11/2020
Deadline	30/09/2021
Status	Done
Manager	UNC
History of changes	**14.09.21** Integration in AWS database completed (two monitoring ways: every 5 seconds and 15 minutes aggregation). **15.06.21** Installation started. **16.04.21** Procurement process started. Preliminary inspection for installation done. **23.03.21** Smart meters, they are waiting for authorisation, installation soon. Starting from the office buildings. They will be integrated in their EMS. **09.03.21** Administrative procedure ongoing for the office buildings. For the apartments it is better to know previously the IoT appliances to be installed previously in case they can provide monitoring functionalities. **20.10.20** Confirmed 1-2 months needed for procurement process.
Conclusions & lessons learnt	Data integration in external (cloud) database facilitate the preliminary studies. Access through API is recommended for further integration. **Lesson learnt**: Some IoT devices may provide electric monitoring and this functionality can save deployment time (and money).

Activity	**Purchase and installation of auxiliary components**
Validation criteria	☐ Project elements can be connected (electricity and communications) ☒ Project elements can be deployed and protected according to regulations
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	UNC
History of changes	**16.11.21** UNC does not authorise the integration of the lighting system. **15.06.21** First approach regarding number of management units to be deployed. Some doubts regarding the PV integration: in some cases, it seems controllable through analogic/digital communication. **25.05.21** Evaluation of Lighting systems in office buildings to be integrated in the project. **09.03.21** Integration of Chiodo-2 EMS (the building is not operative the full year) **20.10.20** Planning additional components (building and grid level). Collection of additional specifications, especially Ampere (batteries) and Emtech (management units) and Reengen/Softcrits (CMU).
Conclusions & lessons learnt	It is necessary to know the size of equipment at the very beginning, type of energy supply (AC or DC) to purchase electric adapters. Check regulations and CE certificates regarding National scope. **Lesson learnt**: In the residential side, the equipment noise is relevant (e.g., bedrooms).

Activity	**DSO involvement**
Validation criteria	☐ Technical and legal support
Start	12/01/2021
Deadline	n.a.
Status	Done
Manager	UNC
History of changes	**12.01.21** Some inputs from a national DSO but without commitment. **19.01.21** Some inputs received by a questionnaire **12.01.21** No answers from any DSO.
Conclusions & lessons learnt	**Lesson learnt**: Large DSO are reluctant to support research projects but are in general overburden with daily activities.

Activity	**Selection of IoT devices**
Validation criteria	☐ Project elements can be connected (electricity and communications) ☐ Project elements can be deployed and protected according to regulations
Start	01/10/2020
Deadline	30/09/2022
Status	On progress
Manager	UNC
History of changes	**29.06.22** Final selection of IoT devices: 5 air conditioning, 5 dishwashers (to be confirmed with Teka), smart thermometer (15), smart plugs (40), light sensors (15). **09.03.22** Teka confirms the reception of smart home appliances in Spain and the delivery in Italy. **09.11.21** Teka confirms that they are going to develop IoT home appliances and will be ready about September 2022. **14.09.21** The working group start defining the IoT setup for every room. Series of meetings discussing and checking the suitability of sensors for flexibility management until **May 2022**. **15.06.21** The ebalance-plus system integration must be considered. It is unclear if it is done through the IoT gateway or requires further implementation. **25.05.21** Specific sensors to measure indoor conditions are missing. It necessary to restate the list. For the moment, only smart home appliances are considered. **19.01.21** Preliminary list of IoT devices to discuss. Too general, it requires further discussions. **24.11.20** Evaluation of submetering (electricity consumption by device: advantages and drawbacks) **10.11.20** Detected issues to deliver some IoT devices due to lockdowns (some devices are not available, and they don't indicate the supply service restore) **27.10.20** The working group starts discussing the selection of IoT devices.
Conclusions & lessons learnt	IoT and smart home appliances interoperability remains a big challenge. Most of home appliances manufacturers develop cloud-base solutions, thus any system must be designed accordingly. After contacting the main European home appliance manufacturers and the European association, the only willing to participate was Teka. There are plenty of small IoT devices and sensors in the market but not all of them are stable of offer communication guarantee. According to the experience of UNC, Shelly devices has been selected for the demo site. **Lesson learnt**: Residential IoT sensor and home appliance market is still not ready for demand response solutions and require further development to be integrated. It is necessary that some open approaches are implemented at European level like standards or manufacturer alliances (e.g., Matter).

Activity	**Rooms preparation (cleaning, reinforcements…)**

Validation criteria	☐ Project elements are connected (electricity and communications) ☐ Project elements are deployed and protected according to regulations
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	UNC
History of changes	**28.03.2022** Visit to prepare the installation work of CMU and verify the internet connection. First meeting with the managers of the technical office and the campus energy manager to plan the smart power meter installation work **14.09.2021** Visit to evaluate the installation works **19.04.2021 second** meeting with the managers of the technical office and the campus energy manager to plan the CMU installation works **10.09.2020** Visit to prepare the installation work of CMU and verify the internet connection Meeting with the managers of the technical office and the campus energy manager to plan the smart power meter installation work
Conclusions & lessons learnt	It has been very positive to address this issue from the very beginning. The task will continue after the submission of this deliverable. **Lesson learnt:** technical providers must provide a clear preparation and deployment plan (technical visit, blueprints and instructions).

Activity	**BESS deployment planning and preparation**
Validation criteria	☐ Project elements are connected (electricity and communications) ☐ Project elements are deployed and protected according to regulations
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	UNC
History of changes	**14.09.21** Confirmed number and rated power of smart batteries for residential pilot. Preparation of electric wiring and auxiliary components start. **15.06.21** Ampere confirms that the equipment's noise is suitable for living rooms but not tested in dormitories. Therefore, the disability room is not considered anymore. **25.05.21** Available space is confirmed for office buildings. Question about noise in residential apartments. **24.11.20** 41 and 44 B were selected for the Ampere batteries according to the energy profile, but the 41B is not suitable, but it is better to be installed in 18 B. So finally, the 18 B and 44 B. **27.10.20** Collection of energy profiles of office buildings to select most suitable buildings.
Conclusions & lessons learnt	Battery design requires a deep analysis of building energy profile (power, energy, usage, etc.) **Lesson learnt:** noise is not one of the specifications regarding smart batteries but it good to consider in case of residential sector (dB similar to fridge compressors).

3.3 Institute Catholic of Lille

The Institute Catholic of Lille is a 19th Century Campus composed of three buildings (Figure 3-12) with different progress of renovation and modernization (intelligence): Academic Hotel, HEI and RIZOMM. This block of buildings share PV roof system, centralised BESS, district heating and a common EMS full operative but with continuous improvement process. The main objectives are (1) to implement and synchronize the ebalance-plus platform to turn the system into a demand side management platform providing flexibility to local energy aggregators, and (2) test the interoperability potential of solution through a comprehensive integration of different EMS and an additional IoT network to extend the granularity level of device control. These objectives are mainly aligned with use cases UC2 and UC9. The Figure 3-13 presents the electric configuration of the JUNIA-ICL demo site.

Figure 3-12 Bird's eye view of the JUNIA-ICL demo site.

The three buildings are connected to a common electric feeder (single contract) and the electricity distribution is done and measured internally. At the point of view of grid level, the three buildings are a single customer but given the complexity and consumption level, they will be considered a district with a common EMS. Every building will be provided by one CMU to deploy the ebalance-plus platform.

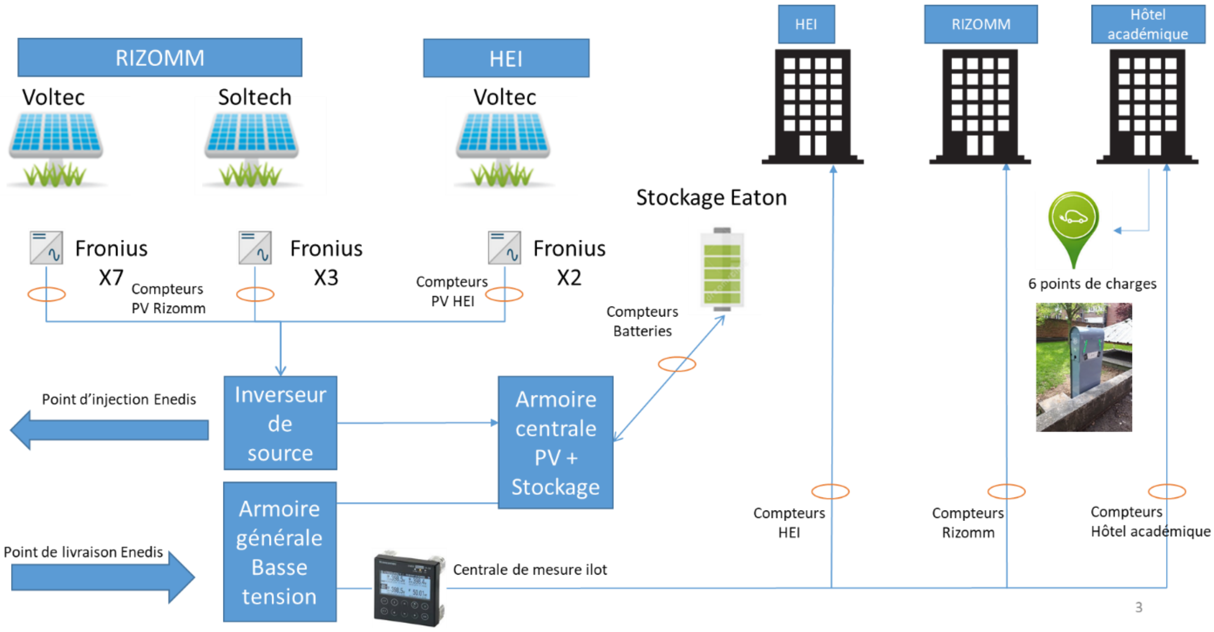


Figure 3-13 JUNIA-ICL demo site: electric configuration and measurement points

Recently, in July 2022, the possibility to test the UC8 with V2G technology is under discussion.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

3.3.1 Use case assessment

Table 3-10 JUNIA use case assessment

Use Case	Technologies	Data	Requirements	Preparation activities
UC9	CMU (IoT Gateway) Smart meter or power meters BEMS BESS IoT network and devices	Electric parameters Weather forecasting Load forecasting BESS SoC IoT devices status	Power supply Internet access	• Inspection of panelboards to deploy power meters • Internet connection available (network points) • Deployment of IoT network • EMS integration (adapters) • API implementation • Installation works

3.3.2 Preparation activities

All the preparation activities are related to the BEMS integration and IoT infrastructure presented as follows. This activity is linked to WP4 (algorithm development) and WP5 (platform integration and development of adapters).

Activity	**BEMS (HVAC, boilers, PV system, storage system and electric chargers) integration and IoT network infrastructure**
Validation criteria	☐ BEMS communicates with ebalance-plus platform (e.g., API) ☐ BEMS receives commands from ebalance-plus platform
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	JUNIA-ICL
History of changes	**21.07.22** HVAC system presents unexpected behaviour when airflow dumpers are activated with algorithms **20.06.22** Junia receives CMU to be deployed with REE support. **08.06.22** Technical visit to clarify issues (see summary of technical visit below). **19.01.22** (1) IoT network with raspberry devices: Prototyping of boxes for the control of boilers (ongoing). Mapping of sensor deployment in the HEI building (ongoing). (2) API integration: working on the link between PV inverters and Fast API to test with WP5 by early February. (3) Equipment: working on the RIZOMM building, in order to identify the variables to recover for optimization and piloting. **19.10.21** Difficulties (covid lockdowns) regarding recruitment process. Some developments are delayed. **13.10.21** First full system integration approach considering user interaction (see Figure 3-14). **06.09.21** Working on grey-box models for the HVAC control and optimisation. **14.06.21** Interview with cleaning staff to know the behaviour of electric boilers (in progress). They want to identify which electric boilers are suitable for optimization and modelling. EV charging stations: pending meeting with Total Energy (this company have developed a solution to predict the charging conditions). The meeting is to define the constraints based on previous research and finds the way for collaboration.

	31.05.21 List of parameters ready to be considered in the adapters (WP5). HVAC systems suitable to be integrated identified. Recruitment of engineer for the API development in progress. **10.05.21** Preliminary ideas to control electric boilers without temperature monitoring. **12.04.21** The HVAC system is more complex than expected. The modern building Rizomm has a combination of air and water systems (high-efficient). **29.03.21** Working on the optimisation problem and integration through an API with the collaboration of SOF. Definition of mobile start inputs and functionalities expected. **05.03.21** First model presented (PV, battery, AHU, storage, EV chargers and laptop chargers). IoT Raspberry network on progress. **15.02.21** Mapping IoT connections. Modelling of equipment started (students recruited). **18.01.21** They are testing Swagger to create an API for the PV power converters. They are deploying a Raspberry Network to integrate IoT devices: coding developing. Their objective is to make boilers, ventilators and heat pumps controllable. They have been contacting manufacturers to collect technical details and costs, so if they must implement drivers. Occupancy is based on schedule. **11.01.21** Idea to create an IoT network to communicate the whole set of electric boilers and integrate into the current BEMS. Working on data exchange and infrastructure. Identification of main parameters and variables in progress. **07.12.20** Yncrea has started to work on AHU control (data dictionary) **26.10.20** Possibility to integrate existing EV chargers (under evaluation). The main issue to explore is the prioritization of the system (two levels: EMS vs. ebalance-plus). Market prices are not available at first. Yncrea has started recruitment to research on the corresponding activities (difficulties due to the pandemic and continuous lockdowns). **19.10.20** The system has two different parts: common facilities (PV system, battery, district heating and electric supply). One building distributes the electricity. The electric battery is only for research. The building has AHU with variable ventilation.
Conclusions & lessons learnt	Most of tasks are progressing but some delays are present, especially regarding testing and algorithm development. Data is integrated in the common EMS and the integration of adapters with ebalance-plus is on progress and with minor delays according to the original plan. **Lesson learnt:** Complex blocks of buildings are a challenge to deploy flexibility mechanisms, since some systems are shared and don't belong to specific buildings, BEMS are running in a continuous process of optimization (no room for flexibility) and system reliability is not guaranteed (high fault tolerance). It is paramount to know how systems work to find suboptimal solutions suitable for flexibility mechanisms.

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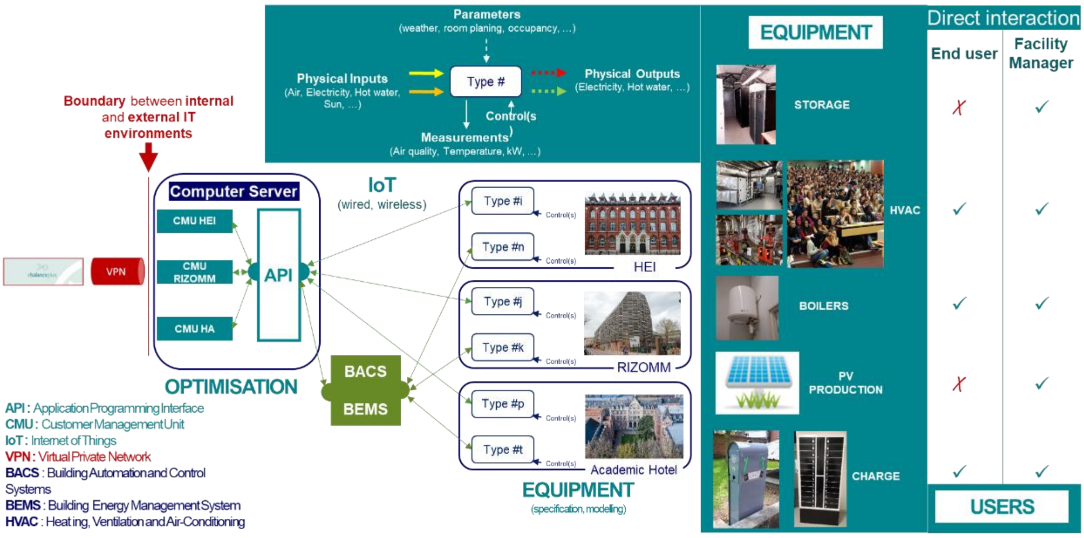

Figure 3-14 Full system integration approach in Junia premises

Especial issue: technical visit to JUNIA-ICL premises (7-8th June 2022)

API developments

Discussion based on sequence diagrams to activate the flexibility:

1. Validate how to use the equipment’s availability data: Planned unavailability and live information

- Provide an endpoint that returns information for planned unavailability
- For unexpected unavailability:
  - Use the return REST-values to inform the caller that the equipment is not available
  - Include the timestamp of “reading-time” in each reading so that the algo can check it and indirectly determine if the equipment is still running
- It’s difficult to think of all the possible scenarios, it could happen for example 1 minute before, but general idea is that every 15min in advance the algo must be aware if the equipment will be ok for the flexibility”

2. Clarify the inverters’ commands needs; it is necessary an unique endpoint for the 10 inverters plants: algorithm in charge of harmonizing (fluctuations regarding cloudy days and accuracy prediction). Producing more than consuming, thus injecting power on the electric grid is not allowed. Therefore, increase the monitoring sample seems to be needed.

3. Agreement on the API’s response schema: “synchronous” is the chosen option: the CMU sends commands; the command is executed, and the feedback (including implicit acknowledgement) is sent back to CMU. Response time can be counted in seconds depending on the equipment.

4. System architecture: 3 CMU will be deployed (one per building) but Rizomm will be the coordinator since the largest PV system is installed there. LVGMU (to be deployed in fog server) must be connect to these CMU, thus public/private IP address and proxy settings must be clarified.

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5. Allocation of algorithms and pilots: HVAC and boilers algorithms in HEI, PV/Battery algorithms in Rizomm, and boilers in HA.

Flexibility modelling

- Water tank modelling: the monitoring data shows a pattern in the consumption, so it is suitable to estimate and manage the flexibility. It is related to cleaning staff schedule. Grey-box models can be used but it is not necessary since the pattern demonstrate the suitability of forecasting. Junia will resume the activity implementing the algorithm.

- HVAC modelling: One floor or room to be tested and decided depending on response time between "temperature/co2 setpoint" and pump/ventilator reaction. Junia will develop their own optimization models and can be compared to the ones provided by CEM.

- Discussion: during a trigger of flexibility if there is an unexpected maintenance occurring or a sudden unavailability of an equipment: set error event and flexibility is rejected.

- Available historical data to calibrate grey-box models for AHU control. Junia is storing the data for further assessment and calibration of algorithms.

- Agreement about flexibility estimation and French market usability (30 minutes instead of 15 min.)

3.4 Danish Summer Houses

Fifteen summer houses are composing the ebalance-plus demo site in two locations (Fredericia and Blåvand) in Denmark. These summer houses have indoor swimming pools heated by heat-pumps or electric boilers to keep water temperature in comfort conditions the whole year. The water heat capacity and the volume of the swimming pools are interesting as buffer to decarbonise their energy consumption and support the grid balancing with power-to-heat services. Novasol is the company that manages these houses and previous deployment like sensors and actuators will be used and integrated into the ebalance-plus platform. This demo will allow testing the use case UC10 (CO2/price-based optimization).

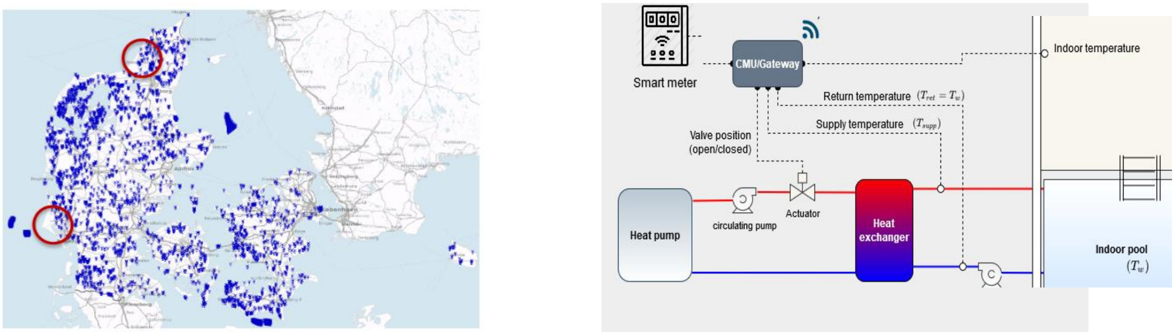

Figure 3-15 Location of Danish pilot (left) and control diagram of the swimming pools and facilities

3.4.1 Use case assessment

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

Table 3-11 Danish summer houses use case assessment

Use Case	Technologies	Data	Requirements	Preparation activities
UC10	CMU (IoT Gateway) Smart meter or power meters BEMS BESS IoT network and devices	Electric parameters Weather forecasting Load forecasting BESS SoC IoT devices status	Power supply Internet access	• Room preparation (installation of additional equipment) • Inspection of houses to install devices and sensors. • Internet connection available (network points) • EMS integration (adapters) • API implementation • Installation works

3.4.2 Preparation activities

All the preparation activities are related to the summer houses integration (electric boilers and communications) are included in the activity “Data platform integration and control”. This activity is linked to WP5 (platform integration and development of adapters).

Activity	**Data platform integration and control**
Validation criteria	☒ Houses are sending data ☒ Electric boilers are controlled remotely ☐ System integrated with ebalance-plus platform
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	DTU
History of changes	**14.06.2022** 13 houses are included and monitored. **22.03.2022** 9 houses are monitored and two controlled under testing. **15.06.2021** Demo is recovered but only with electric boilers. The new facility manager does not agree to provide heat pumps for testing. **24.05.2021** Demo sites algorithms (swimming pools). The contact person managing the swimming pools facilities has left the company and accessing the demo site is not possible anymore. Low of engagement of Novasol even in the other project Smarten (DTU participating). **16.04.2021** They are testing the two-way communication with the current units and identifying the units that has to be replaced. **05.03.2021** Issues with Novasol, as it is not taking part in the project, the engagement is getting an issue. DTU and ENF are looking for alternatives if finally, the summer houses are not available. **20.10.2020** Two approaches, from Nord pool to users or with the aggregator in the middle. The difference is regarding the type of house and its own characteristics. The algorithm will be the same but will depend on its own boundaries. **13.10.2020** Testing two houses (communication and control)
Conclusions & lessons learnt	**Lesson learnt:** involved owners in demonstrator activities from the very beginning. Heat pumps in Denmark are old models that makes difficult its integration and participation in flexibility mechanisms. Electric boilers are more suitable (quick reaction time) but less efficient.

3.5 In-lab demonstrator

In the In-Lab demonstrator the energy grid is emulated by a defined combination of hardware elements that represent specific functionalities of the grid and their interconnection defines the topology of the grid to be emulated. There exist real energy flows between these elements. And there are four classes of blocks that are used to build up the topology: transmission line (TL), primary substation (PS), secondary substation (SS) and prosumer block. All of these, except the transmission line include the management unit (MU) and, by that own their own instance of the smartDSM middleware and can also have services of the energy management platform installed.

In order to support the use cases UC.04 and UC.06 chosen to be executed only in the In-Lab demonstrator a topology was defined to expose the most interesting scenarios for these resilience use cases. This topology is shown in **¡Error! No se encuentra el origen de la referencia.** – the grid matrix reflects the final structure of the In-Lab demonstrator, i.e., the emulator blocks are placed on a special table that allows mounting a grid of **5 x 9 blocks**, just as shown in the topology figure. The in-lab table with several blocks mounted is shown in Figure 3-17. The screen attached to the wall on the right from the table will be used to provide the graphical user interface (GUI).

To optionally support the UC.09 there will be an additional setup of the In-Lab emulator with a simple topology consisting of a primary substation, secondary substation and a small number of (between one to five) prosumer blocks.
Use cases UC.01 and UC.02 are executed on the In-Lab demonstrator by default and their execution will be detailed monitored.

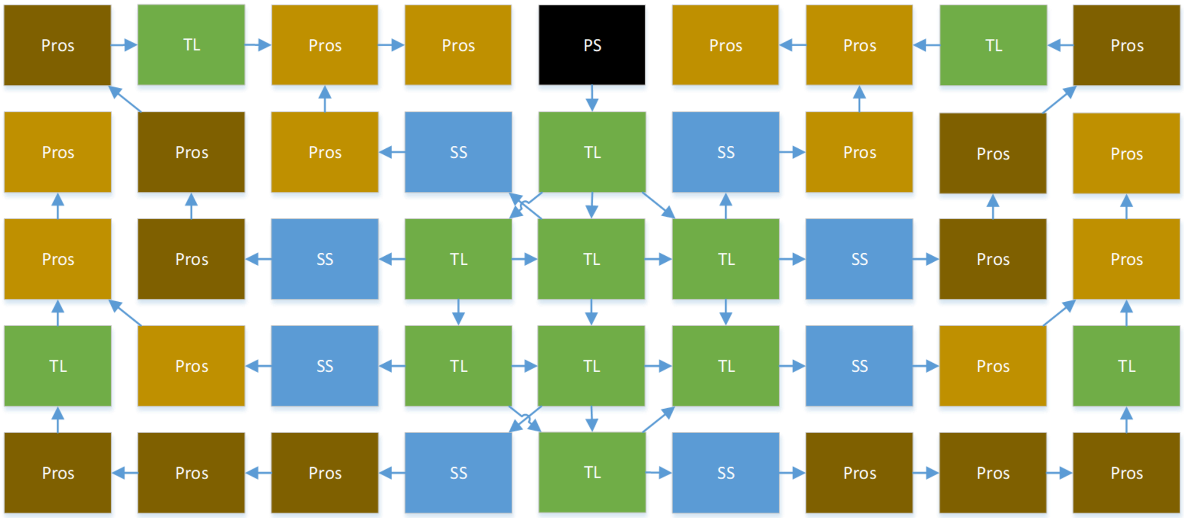

Figure 3-16 The In-Lab demonstrator topology chosen for use cases UC.04 and UC.06

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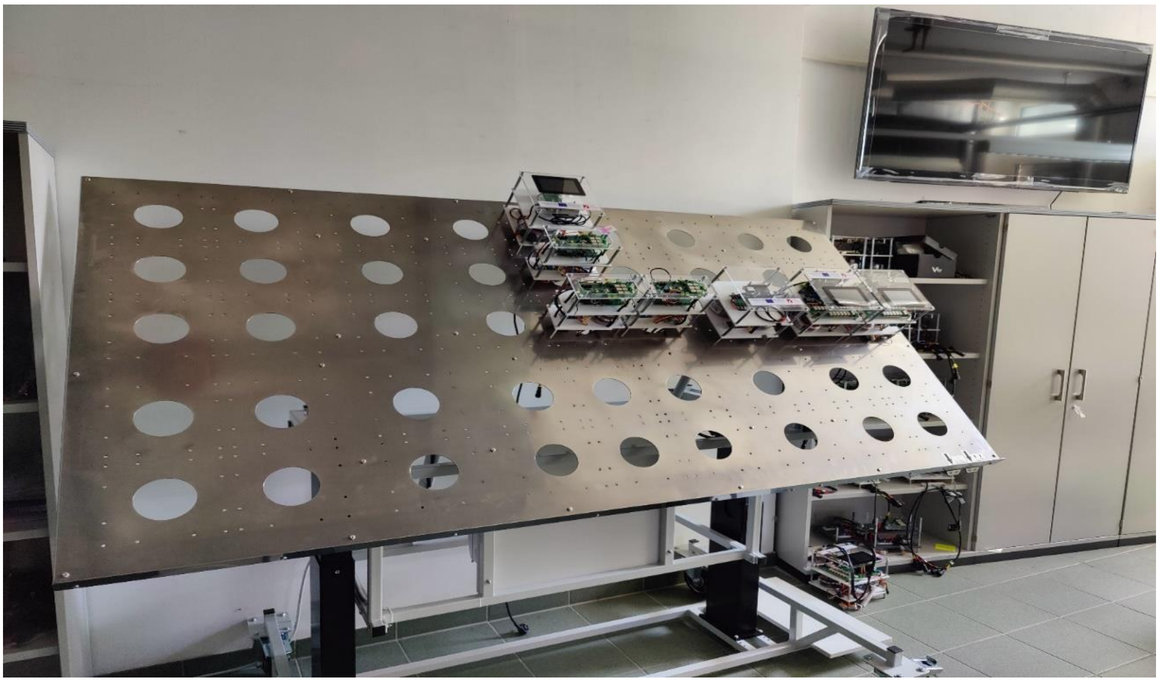

Figure 3-17 The In-Lab demonstrator table

3.5.1 Use case assessment

Table 3-12 In-lab use case assessment

Use Case	Technologies	Data	Requirements	Preparation activities
UC4, UC6, UC9	CMU, LVGMU, MVGMU, metering and acting infrastructure, Behaviour simulator, energy consumption and production devices on the prosumer blocks	Electric parameters Weather forecasting Load forecasting BESS SoC IoT devices status, other	Power supply Internet access	• Physical integration of the emulator block components • Implementation of mechanisms to support emulator deployment and configuration • Collection and preparation of user behaviour data for the simulator • Collection and preparation of appliance description data for the simulator • Implementation and preparation of the software (firmware) to control the metering and acting infrastructure components • Installation and connection of the In-Lab emulator deployments • Implementation of the simulator adapter for the middleware • Configuration and installation works • GUI software implementation • Integration with energy management platform (algorithms)

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3.5.2 Preparation activities

The following tables summarize the progress acquired at the synchronisation meetings discussing the progress and issues. The most recent happened on the 20.07.2022 and its summary if reflected in the status.

Activity	**Physical integration of the emulator block components**
Validation criteria	☐ Right amount of each kind of emulator blocks physically integrated
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	IHP
History of changes	20.07.2022 Status of the integration of current versions of block components collected (in progress)
Conclusions & lessons learnt	Still collecting input on that.

Activity	**Implementation of mechanisms to support emulator deployment and configuration**
Validation criteria	☐ Emulator deployment mechanisms defined, implemented and available
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	IHP
History of changes	20.07.2022 Mechanisms to support software module installation (Linux packages) and scripts for their configuration defined
Conclusions & lessons learnt	Still collecting input on that.

Activity	**Collection and preparation of user behaviour data for the simulator**
Validation criteria	☐ User energy usage schedules collected and translated into the simulator user description language
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	IHP
History of changes	20.07.2022 Definition of user profiles in preparation (early stage)
Conclusions & lessons learnt	Still collecting input on that.

Activity	**Collection and preparation of appliance description data for the simulator**
Validation criteria	☐ Energy profiles for different appliances and a diversity of modes collected and translated into the simulator appliance description language
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	IHP
History of changes	20.07.2022 Summary of available measurements to be converted in device description language collected
Conclusions & lessons learnt	Still collecting input on that.

Activity	**Implementation and preparation of the software (firmware) to control the metering and acting infrastructure components**
Validation criteria	☐ Firmware for individual components of the emulator blocks available and tested
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	IHP
History of changes	20.07.2022 Summary of current progress collected
Conclusions & lessons learnt	Still collecting input on that.

Activity	**Installation and connection of the In-Lab emulator deployments**
Validation criteria	☐ The blocks constituting the deployment are installed on the table and connected together
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	IHP
History of changes	20.07.2022 The topology and block deployment details confirmed
Conclusions & lessons learnt	Still collecting input on that.

Activity	**Implementation of the simulator adapter for the middleware**
Validation criteria	☐ Adapter to connect the behaviour simulator with the smartDSM middleware implemented and tested
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	IHP
History of changes	20.07.2022 Identification of functionalities to be covered by the simulator and to be accessible via the adapter started
Conclusions & lessons learnt	Still collecting input on that.

Activity	**Configuration and installation works**
Validation criteria	☐ All blocks configured (MU relations, MU-sensing/acting relations, simulator definitions) according to the defined energy grid topology
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	IHP
History of changes	20.07.2022 Definition of a concept for automated block configuration
Conclusions & lessons learnt	Still collecting input on that.

Activity	**GUI software implementation**
Validation criteria	☐ User interfaces (end-user, DSO, Aggregator) implemented and tested
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	IHP
History of changes	20.07.2022 Initial design of the GUI defined

Conclusions & lessons learnt	Still collecting input on that.

Activity	**Integration with energy management platform (algorithms)**
Validation criteria	☐ Energy management platform elements (algorithms) deployed within the In-Lab demonstrator
Start	01/09/2020
Deadline	30/09/2022
Status	On progress
Manager	IHP
History of changes	20.07.2022 First concepts on EMP interfaces defined
Conclusions & lessons learnt	Still collecting input on that.

4 Fog Server description

Ebalance-plus presents a hierarchical architecture including Edge devices, Fog nodes, Management Units and Cloud computing. The use of these technologies is justified due to the requirements that the involved actors and technologies present to obtain an efficient behaviour of the Smart Grid.

In the case of Cloud computing, it offers easier scalability of services and allows the delivery of on-demand computing services. The different actors can store and process data over the Internet remotely without owning any computing infrastructure or data centre and paying only for the used resources increasing the cost savings and workloads. Cloud computing integrates resources through internal networks improving the robustness, load balancing and storage capability. Besides, it helps to recover from the blackout condition and enables the performance of monitoring and information collection. However, Cloud computing can present timing issues such as latency or network bandwidth limitations.

A Fog layer between the cloud and the endpoints can provide real-time services by processing requests closer to where the data are generated reducing the amount of data delivered to the cloud. Fog computing offers high security because the data are processed by multiple nodes in a complex distributed network. Pieces of information are aggregated at separate points rather than sent through a channel to a single hub eliminating the problem with bandwidth. Fog computing eases some of the challenges present in cloud computing such as latency, real-time processing, the fault-tolerance, security, and network bandwidth constraints.

The Fog server at UMA provides an HW/SW environment for the development of critical applications with low latency requirements. Among the more relevant features, there is the GPU acceleration, which boosts the speed of execution for large volumes of data performing similar functions simultaneously, and the capacity to provide edge nodes and computing servers.

HW infrastructure overview

The Fog computing infrastructure provides a HW/SW environment for the development of critical applications with low latency requirements. Among the HW features, its 364 cores provided by Intel Xeon SP G6230R processors (26 cores, 2.1GHz), 448GB of graphics memory provided by NVIDIA V100 cards (5120 Cuda cores, 32GB RAM), 384GB of RAM and a total of 12.8TB of storage stand out. To sum up, the HW infrastructure comprise:

- **7 Fog nodes** with 104 cores, 2 Nvidia NVIDIA V100 cards (5120 Cuda cores, 32GB RAM), and 384GB of RAM.
- **2 Edge nodes** with an Intel Xeon D2187NT processor (16 cores, 2GHz), an Nvidia T4 graphics card and its support for Wi-Fi and LTE/4G wireless communications.
- Total of 364 CPU cores, 448GB of GPU, 2688GB of RAM and 12.8TB of storage.

SW infrastructure overview

The infrastructure provides a production environment through **Kubernetes** for the development of critical applications with low latency on top of Docker containers. These applications can make use of GPU acceleration for processing-intensive techniques such as machine learning. The infrastructure is currently being used in the context of several national and international research projects, including monitoring the structural health of civil infrastructures, digital twins of agricultural infrastructures and analyzing smart grids. Technologies in operation include tools such as Apache Kafka, InfluxDB, Eclipse Hono and RabbitMQ, and developed frameworks such as Kafka-ML, which allows the orchestration of data streams and machine learning frameworks. The main features of the infrastructure are:

- Management and monitoring of production-ready applications through **Kubernetes.**
- Easy portability and deployment of applications through **Docker containers.**
- Fault tolerance, scalability and high availability.
- Logical separation of applications by using namespaces.

The use of containers is a lightweight method to create virtual environments. They can be easily deployed, and don’t comprise an entire operative system, only the relevant application and its dependencies are bundled into a package, being a good solution for minimizing limitation problems of resources capacity. The orchestration tool to deploy and manage containers and their resources is *Kubernetes* (K8s), an open-source orchestration platform for containers-based applications.

When Kubernetes are deployed, a cluster is set up, Figure 4-1 a set of worker nodes (one or more), that run containerized applications, orchestrated by a master node that is responsible for managing and controlling the cluster.

The worker node hosts Pods, the fundamental unit of Kubernetes, and each pod contains one or more containers (services or applications) that share storage and a unique IP address. In this architecture, the selected container runtime is Docker, the software responsible for running containers[1].

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[1] http://kubernetes.io/docs/concepts/overview/components/

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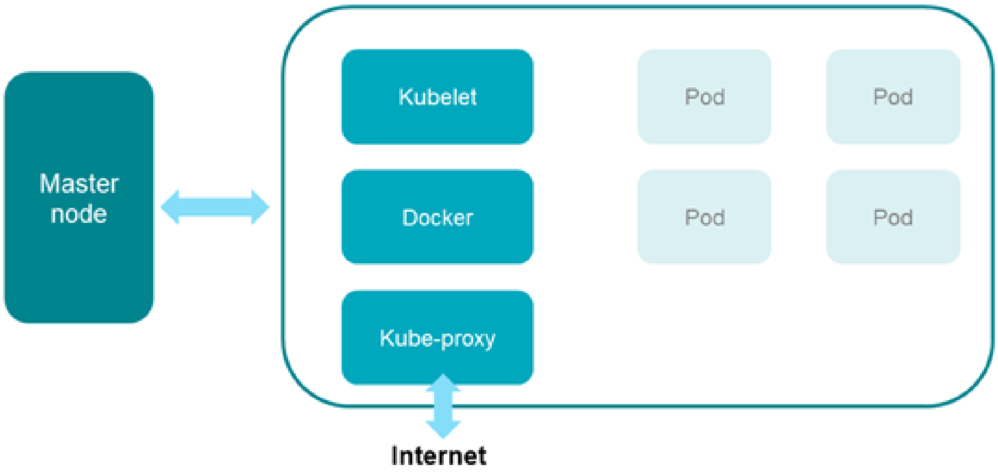


Figure 4-1 Kubernetes cluster

The first approach to the virtual infrastructure of the ebalance-plus communication platform consists in:

Virtualization of the MUs that are not physically presented in demo sites: TLGMU and MVGMU. The Services deployment that will connect with the rest of the platform, physically MUs.

One of the main deployed components in the project to guarantee the communication in the platform is the middleware that is integrated into the MUs. This includes also the MUs that will be deployed in the Fog server as containerized services. The middleware is responsible for allocating and distributing the application logic in the architecture maintaining the application state and replication through a set of orchestration and synchronization services.
The services deployment in Fog server allows an easy replication of them if a new MU is included, Additionally, when a system failure takes place in a node of the ebalance-plus architecture, the orchestration and synchronization services detect the failure minimizing the repair or replacement time of this node (MU, final device or energy system).

For that, the source code of deployed component in Fog server (Services, TLGMU, MVGMU) will be translated into Docker images for their deployment as containers into the Kubernetes cluster.

Some of the advantages of Fog server usage are the easier and faster deployment and replication in different geographical locations as well as the improvement of the resilience when a fault is detected. On the other hand, this solution allows the evaluation of the correct behaviour of the platform before the real deployment. The in-lab demonstrator enables the testing of use cases and scenarios that are not repeatable in the real grid, such as an outage.

Attending the project needs, this solution will have into account several challenges such as minimizing the delay in the communication between the Fog services geographically distributed in different locations, guaranteeing the networking between them, as well as the resource provisions for the application in each FOG node.

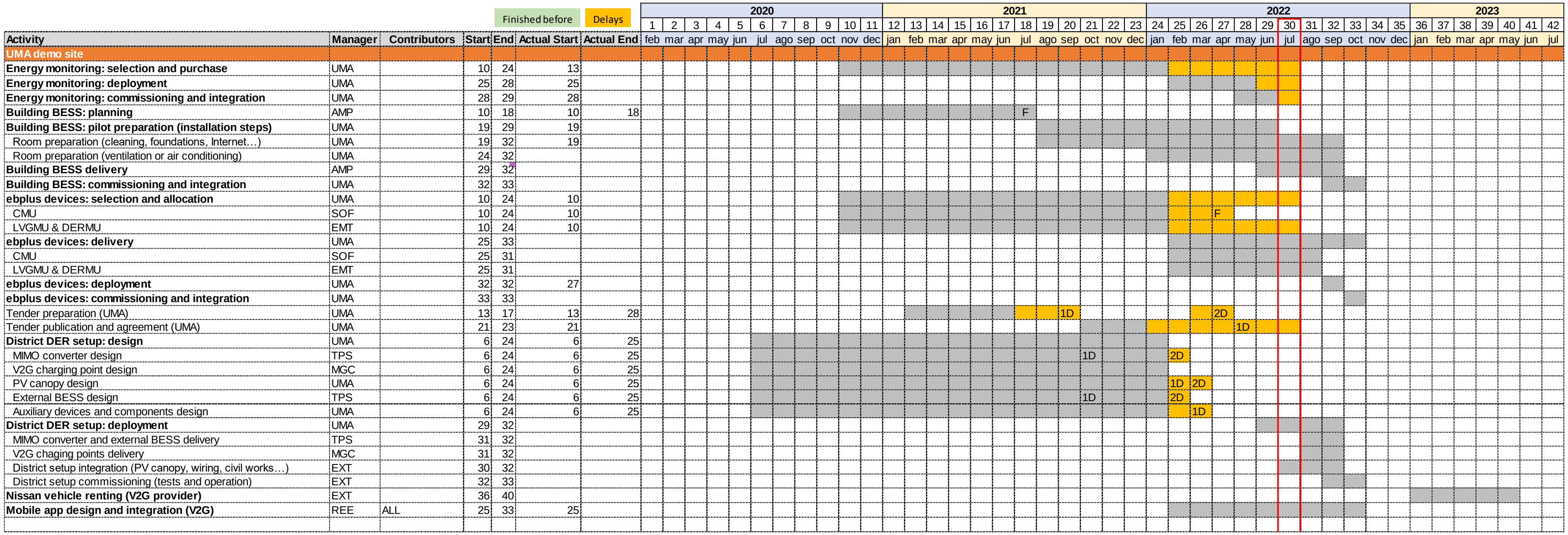
5 Next steps

To mitigate the delays presented in the project due to covid-19 (lockdowns) and electronic market (unavailability of components), the following activities have been agreed between partners:

- Adopt the **Agile methodology and Hardware in the loop** to implement the first prototype in the fog server. This prototype consists of all the ebalance-plus architecture levels (CMU – LVGMU – MVGMU – TLGMU), the mobile app, the smart battery application, and the basic configuration of UC.09. This activity is on progress.
- Tests equipment before delivery. Some equipment is connected remotely to test communication and operation before the final integration.
- Run algorithms and flexibility mechanisms in different periods and prioritising the season (winter or summer), availability of devices and end user schedule.
- Include V2G technology in Junia demo site.
- Weekly follow-up meetings of main developments: mobile app, algorithms tests, platform communication and deployment of equipment.

Annex 1

A.1 Planning (Gantt Chart updated June 2022)



Activity	Manager	Contributors	Start	End	Actual Start	Actual End
UMA demo site						
Energy monitoring: selection and purchase	UMA		10	24	13	
Energy monitoring: deployment	UMA		25	28	25	
Energy monitoring: commissioning and integration	UMA		28	29	28	
Building BESS: planning	AMP		10	18	10	18
Building BESS: pilot preparation (installation steps)	UMA		19	29	19	
Room preparation (cleaning, foundations, Internet…)	UMA		19	32	19	
Room preparation (ventilation or air conditioning)	UMA		24	32		
Building BESS delivery	AMP		29	32		
Building BESS: commissioning and integration	UMA		32	33		
ebplus devices: selection and allocation	UMA		10	24	10	
CMU	SOF		10	24	10	
LVGMU & DERMU	EMT		10	24	10	
ebplus devices: delivery	UMA		25	33		
CMU	SOF		25	31		
LVGMU & DERMU	EMT		25	31		
ebplus devices: deployment	UMA		32	32	27	
ebplus devices: commissioning and integration	UMA		33	33		
Tender preparation (UMA)	UMA		13	17	13	28
Tender publication and agreement (UMA)	UMA		21	23	21	
District DER setup: design	UMA		6	24	6	25
MIMO converter design	TPS		6	24	6	25
V2G charging point design	MGC		6	24	6	25
PV canopy design	UMA		6	24	6	25
External BESS design	TPS		6	24	6	25
Auxiliary devices and components design	UMA		6	24	6	25
District DER setup: deployment	UMA		29	32		
MIMO converter and external BESS delivery	TPS		31	32		
V2G chaging points delivery	MGC		31	32		
District setup integration (PV canopy, wiring, civil works…)	EXT		30	32		
District setup commissioning (tests and operation)	EXT		32	33		
Nissan vehicle renting (V2G provider)	EXT		36	40		
Mobile app design and integration (V2G)	REE	ALL	25	33	25	

Figure A.1 Gantt Chart – University of Málaga

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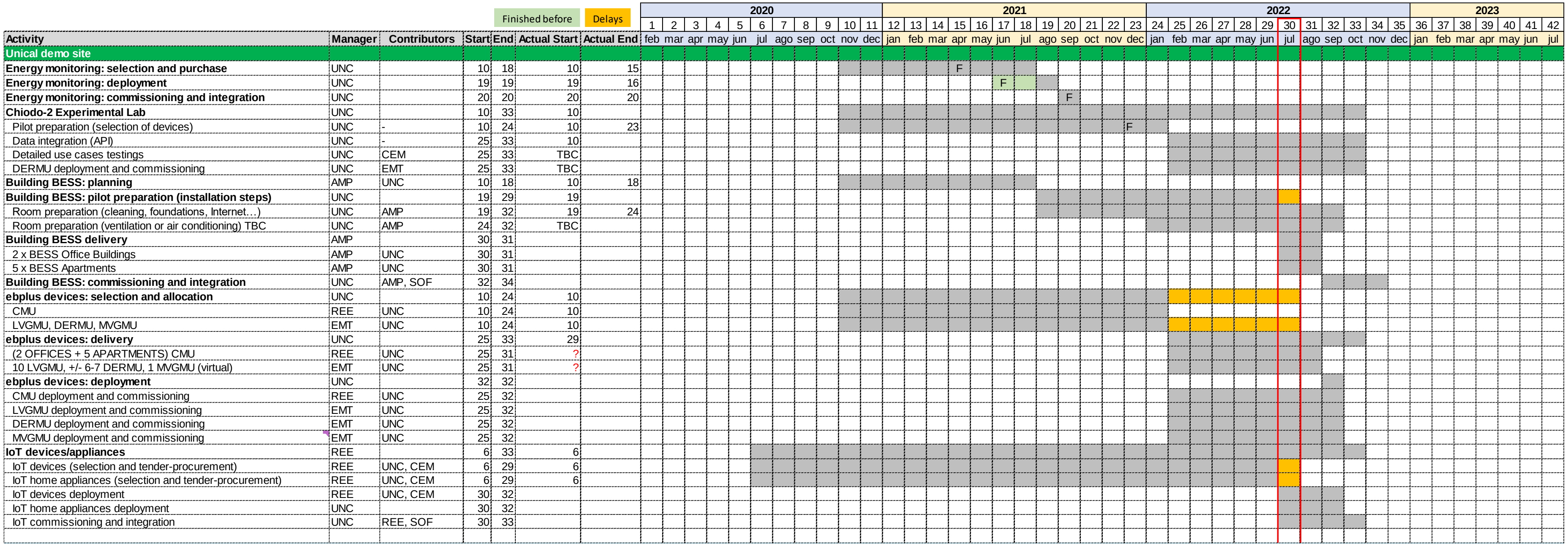

Activity	Manager	Contributors	Start	End	Actual Start	Actual End
Unical demo site						
Energy monitoring: selection and purchase	UNC		10	18	10	15
Energy monitoring: deployment	UNC		19	19	19	16
Energy monitoring: commissioning and integration	UNC		20	20	20	20
Chiodo-2 Experimental Lab	UNC		10	33	10	
Pilot preparation (selection of devices)	UNC	-	10	24	10	23
Data integration (API)	UNC	-	25	33	10	
Detailed use cases testings	UNC	CEM	25	33	TBC	
DERMU deployment and commissioning	UNC	EMT	25	33	TBC	
Building BESS: planning	AMP	UNC	10	18	10	18
Building BESS: pilot preparation (installation steps)	UNC		19	29	19	
Room preparation (cleaning, foundations, Internet…)	UNC	AMP	19	32	19	24
Room preparation (ventilation or air conditioning) TBC	UNC	AMP	24	32	TBC	
Building BESS delivery	AMP		30	31		
2 x BESS Office Buildings	AMP	UNC	30	31		
5 x BESS Apartments	AMP	UNC	30	31		
Building BESS: commissioning and integration	UNC	AMP, SOF	32	34		
ebplus devices: selection and allocation	UNC		10	24	10	
CMU	REE	UNC	10	24	10	
LVGMU, DERMU, MVGMU	EMT	UNC	10	24	10	
ebplus devices: delivery	UNC		25	33	29	
(2 OFFICES + 5 APARTMENTS) CMU	REE	UNC	25	31	?	
10 LVGMU, +/- 6-7 DERMU, 1 MVGMU (virtual)	EMT	UNC	25	31	?	
ebplus devices: deployment	UNC		32	32		
CMU deployment and commissioning	REE	UNC	25	32		
LVGMU deployment and commissioning	EMT	UNC	25	32		
DERMU deployment and commissioning	EMT	UNC	25	32		
MVGMU deployment and commissioning	EMT	UNC	25	32		
IoT devices/appliances	REE		6	33	6	
IoT devices (selection and tender-procurement)	REE	UNC, CEM	6	29	6	
IoT home appliances (selection and tender-procurement)	REE	UNC, CEM	6	29	6	
IoT devices deployment	REE	UNC, CEM	30	32		
IoT home appliances deployment	UNC		30	32		
IoT commissioning and integration	UNC	REE, SOF	30	33		

Figure A.2 Gantt Chart – University of Calabria

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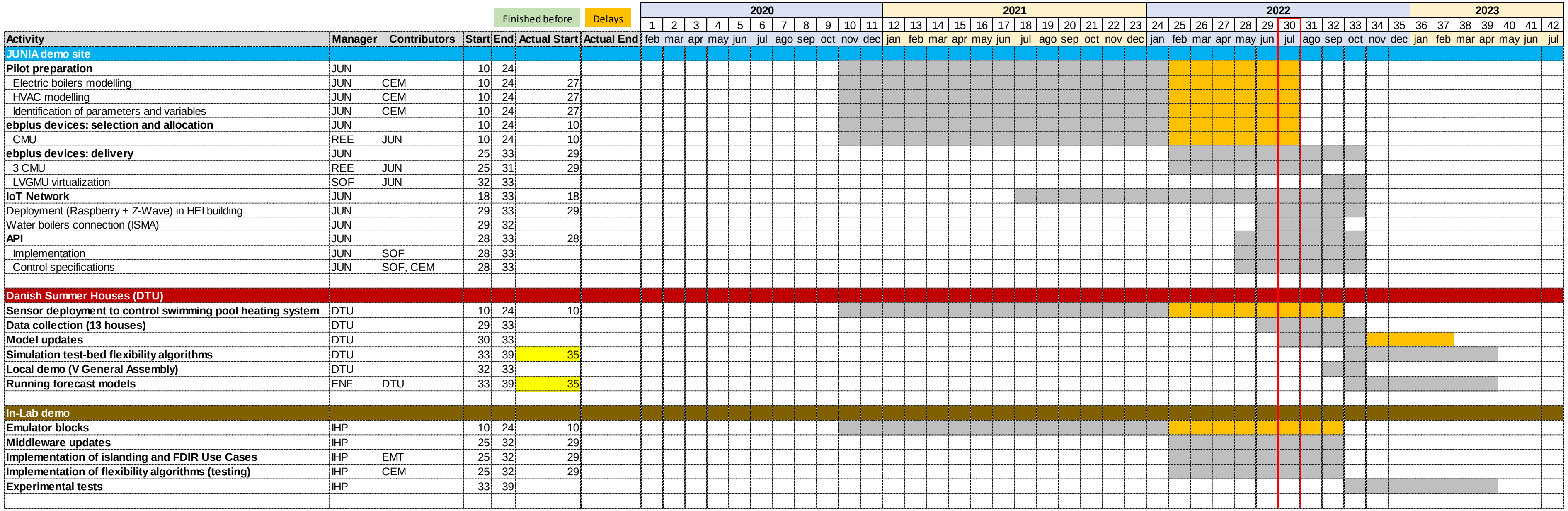

Activity	Manager	Contributors	Start	End	Actual Start	Actual End
JUNIA demo site						
Pilot preparation	JUN		10	24		
Electric boilers modelling	JUN	CEM	10	24	27	
HVAC modelling	JUN	CEM	10	24	27	
Identification of parameters and variables	JUN	CEM	10	24	27	
ebplus devices: selection and allocation	JUN		10	24	10	
CMU	REE	JUN	10	24	10	
ebplus devices: delivery	JUN		25	33	29	
3 CMU	REE	JUN	25	31	29	
LVGMU virtualization	SOF	JUN	32	33		
IoT Network	JUN		18	33	18	
Deployment (Raspberry + Z-Wave) in HEI building	JUN		29	33	29	
Water boilers connection (ISMA)	JUN		29	32		
API	JUN		28	33	28	
Implementation	JUN	SOF	28	33		
Control specifications	JUN	SOF, CEM	28	33		
Danish Summer Houses (DTU)						
Sensor deployment to control swimming pool heating system	DTU		10	24	10	
Data collection (13 houses)	DTU		29	33		
Model updates	DTU		30	33		
Simulation test-bed flexibility algorithms	DTU		33	39	35	
Local demo (V General Assembly)	DTU		32	33		
Running forecast models	ENF	DTU	33	39	35	
In-Lab demo						
Emulator blocks	IHP		10	24	10	
Middleware updates	IHP		25	32	29	
Implementation of islanding and FDIR Use Cases	IHP	EMT	25	32	29	
Implementation of flexibility algorithms (testing)	IHP	CEM	25	32	29	
Experimental tests	IHP		33	39		

Figure A.3 Gantt Chart – JUNIA, DTU and in-lab demo

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