WP7 Pilots Deployment, Operation and Socioeconomic Evaluation

Document Version:

D7.2 Initial Pilots Deployment, Operation and Validation

1.0

Project Number:	**Project Acronym:**	**Project Title:**
893079	PHOENIX	Adapt-&-Play Holistic cOst-Effective and user-frieNdly Innovations with high replicability to upgrade smartness of eXisting buildings with legacy equipment

Contractual Delivery Date:	**Actual Delivery Date:**	**Deliverable Type* - Security**:**
28/02/2022	28/02/2022	D – PU

* Type: P – Prototype, R – Report, D – Demonstrator, O – Other

** Security Class: PU- Public, PP – Restricted to other programme participants (including the Commission), RE – Restricted to a group defined by the consortium (including the Commission), CO – Confidential, only for members of the consortium (including the Commission)

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Abstract:

This document presents the initial development of all pilots, i.e. their progress in the installed equipment, their integration into the PHOENIX platform and their validation in relation to the operation of the PHOENIX innovations developed so far in WP3 and WP4 and indicates the future work under WP7.

Keywords:

Legacy equipment, Building's upgrade, Integration, Demo-sites, Smartness.

Revision History

The following table describes the main changes in the document since created.

Revision	Date	Description	Author (Organization)
0.1	10/01/2022	Preparation of the skeleton of the document	Aristotelis Ntafalias (VERD)
0.2	27/01/2022	Contribution from Pilots	Maria Vlachou (KaMa) Eoin O' Connor (ARDEN) Pablo Barrachina (MIWenergia) Saguna Saguna (LTU)
0.3	31/01/2002	Contribution and document review	Aristotelis Ntafalias (VERD)
0.4	01/02/2022	Document review and feedback. Contribution to all chapters	Panos Papadopoulos (VERD) Kyriakos Kentzoglanakis (VERD)
0.5	11/02/2022	Contribution from Pilots	Maria Vlachou (KaMa) Eoin O' Connor (ARDEN) Pablo Barrachina (MIWenergia) Saguna Saguna (LTU) Valentina Tomat (UMU)
0.6	11/02/2022	Document review and feedback	Alfredo Quesada Sánchez (OdinS) Alfonso Ramallo (UMU)
0.7	18/02/2022	Contribution on document	Alfonso Ramallo (UMU)
0.8	21/02/2022	Document review	Josiane Parreira (SAGOE) Angeliki Baritantonaki (MERITCH)
0.9	24/02/2022	Detailed review and finalisation	Aristotelis Ntafalias (VERD) Panos Papadopoulos (VERD) Kyriakos Kentzoglanakis (VERD) Sotiris Tsakanikas (VERD) Thanasis Karetsos (VERD) Giannis Georgopoulos (VERD)
1.0	25/02/2022	Final version review and upload to EC portal	Antonio Skarmeta (UMU)

Executive Summary

This deliverable is part of WP7 "Pilots Deployment, Operation and Socioeconomic Evaluation" and represents the initial version of a set of deliverables that will describe the development, operation and validation of pilots in the PHOENIX project.

Herewith, the relevant partners of PHOENIX document the status of pilots in terms of smart readiness, i.e. communication and interoperability through the PHOENIX platform, by providing information on both the legacy equipment and the new sensing and actuating equipment that is being installed.

In addition, this deliverable contains the use cases defined for each pilot and presents the specific Key performance Indicators (KPIs) that will be measured throughout PHOENIX trials in order to validate these use cases. The corresponding data required for the calculation of the KPIs will be available in the updated version of this deliverable where the installations of new devices will be finalized. Moreover, the initial set of trials that each pilot will run the next months to validate the successful integration and interaction with the PHOENIX platform are presented here.

The early operations of the pilots are described in relation to the services and innovations developed in WP3 and WP4 of the PHOENIX project. In the updated version of this deliverable as the pilots' deployment and operation progresses, the validation of the innovations will also include services from WP5 and WP6 to ensure a comprehensive evaluation of the PHOENIX project. In addition, progress indicators are presented as well as specific achievements for each pilot; Figure 1 summarizes the five pilots' progress in electrical design, planned installations, platform requirements for devices integration, field devices integration, as well as definition of trials to be performed to validate the use cases foreseen for each pilot.

Finally, the next steps for pilot development and operation are presented at the end of this document. In addition, the initial trials planning for each pilot is presented, which will be finalized as soon as the PHOENIX platform is fully operational.

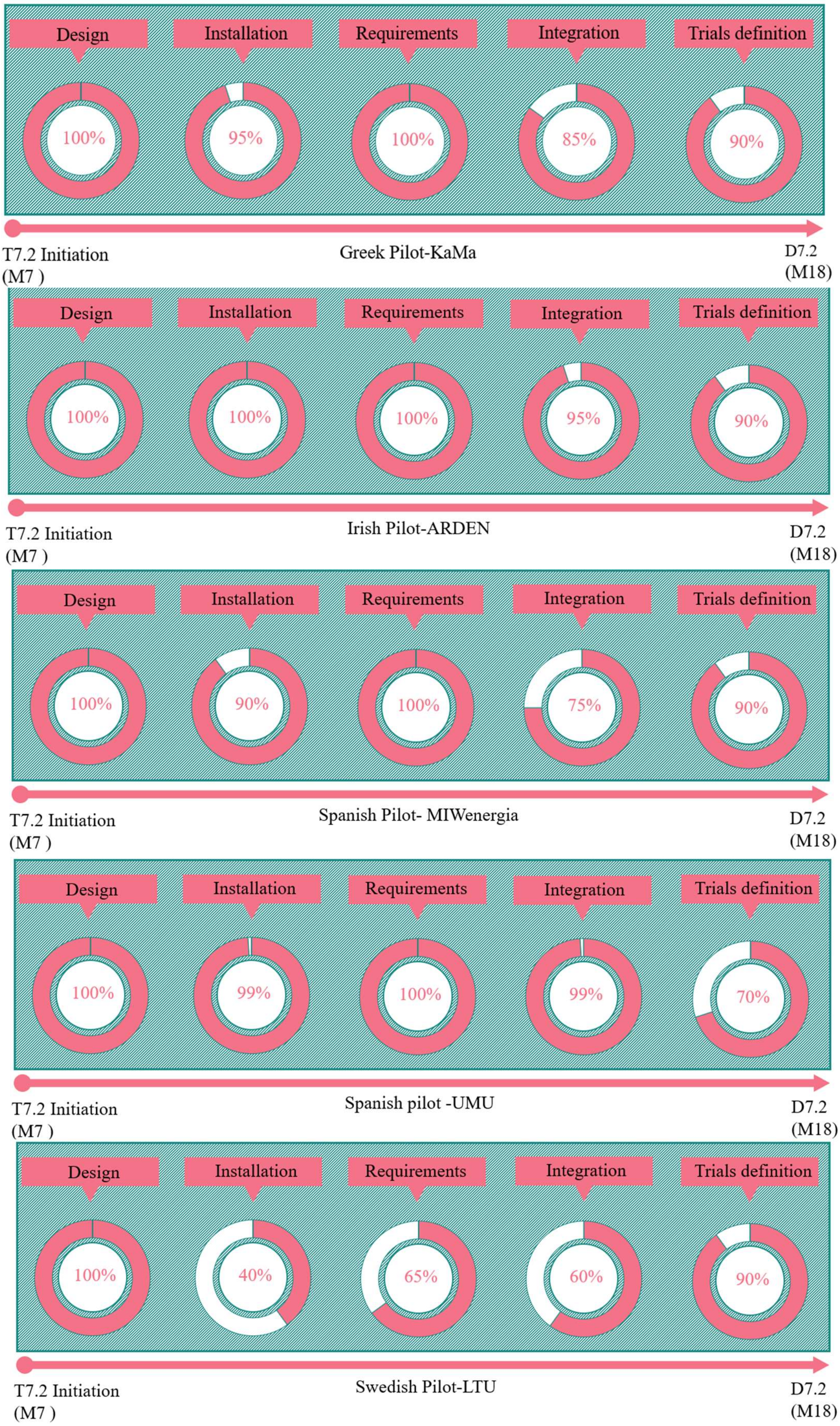

Figure 1 Pilots' progress indicators

Disclaimer

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 893079, but this document only reflects the consortium's view. The European Commission is not responsible for any use that may be made of the information it contains.

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Abbreviations

BMS	Building Management system
CB	Context Broker
D.	Deliverable
DER	Distributed Energy Sources
DoA	Document of Actions
DHW	Domestic Hot Water
DRE	Demand Response Events
HVAC	Heating, Ventilation, and Air Conditioning
KG	Knowledge Graph
KPIs	Key Performance Indicators
PoC	Proof of Concept
PV	Photovoltaic
SRI	Smart Readiness Indicator
ST	Solar Thermal
UC	Use Case
WP	Work Package

1. Introduction

1.1. Scope of the Document

The main objective of Task 7.2 is to describe the adaptation, planning and deployment of the technological innovations and services, developed in PHOENIX project, in relation to the five real-world pilots. The pilots, as described in detail in D7.1 and D3.2, are spread across four European countries (Spain, Greece, Ireland and Sweden) and have different characteristics and level of smartness as they consist of different energy-consuming systems and devices (also referred to as legacy equipment).

In this deliverable D7.2, the initial deployment of the pilots towards their energy upgrade is presented. The legacy equipment of each pilot is detailed with the aim to define their initial level of smartness. These devices will be integrated into the PHOENIX platform through the installation of new smart equipment and communication technologies that will ensure seamless communication between pilots and the platform and will facilitate the operation of the cost-effective and user-friendly solutions developed in the other WPs of the project.

In addition, the objectives of each pilot based on the smart services to be provided by PHOENIX project, as defined in the Document of Action (DoA), as well as the foreseen use cases (UCs) of the pilots defined in D2.2, are presented in this document along with the proposed KPIs that will be used for their validation. The KPIs consist of two categories, the Core KPIs that are specific for each pilot and are necessary to monitor in order to measure progress towards their goals and the Generic KPIs that provide information on the extent of PHOENIX progress in general.

Moreover, in the current deliverable the early operations of PHOENIX innovations developed in WP3 and WP4 are presented from the perspective of each pilot, so that the proposed services can be evaluated in real environments and specific achievements to be introduced. In addition, the progress each pilot has made in relation to its development is illustrated through progress-diagrams as shown in Figure 1.

1.2. Link to other deliverables

This deliverable is related to:

- Deliverable 7.1 in which the description of Proof of Concept (PoC) in UMU and the first lessons about its integration were introduced.
- Deliverables 7.3 and 7.4 which are the updated versions of the current document.
- Deliverable 2.1 in which the use cases are defined
- Deliverable 2.2 in which the project business use cases are defined.

- A set of three deliverables that describe the upgrades and integration of legacy equipment implemented as the project PHOENIX evolves, namely Deliverable 3.1, 3.2 and 3.3.
- Deliverable 4.2 in which the implementation of the Smartness Hub is presented.

1.3. Structure of the document

This document contains five chapters including this introduction. Chapter 2 describes the development of pilots, listing pre-existing equipment as well as newly installed equipment. In addition, the objectives and use cases of each pilot are presented as well as the relevant KPIs and the defined trials that will validate the use cases. Chapter 3 presents the pilots' progress on PHOENIX innovations developed in WP3 and WP4. Chapter 4 describes the validation process of PHOENIX implementations regarding the pilots presenting progress indicators and specific achievements. Finally, Chapter 5 describes the conclusions and future work for each pilot, with an emphasis on solutions and services from WP3-WP6 and presents the initial trials' timeline.

2. Pilots' deployment

This chapter presents the deployment of each pilot towards its energy upgrades. The following sections describe the objectives that each pilot aims to achieve (consisting of the smart services to be provided by PHOENIX as defined in the pilot description in DoA) as well as the foreseen use cases per case as defined in D2.1.

In addition, a list of Generic KPIs is presented providing information on the extent of PHOENIX progress in general. Moreover, the KPIs per pilot (Core KPIs) are listed and a set of the initial trials that each pilot will perform is introduced, to prove the use cases. In essence Generic KPIs are the sum of the Core KPIs from all pilots; in order to enhance the results of the project, each pilot will also try to measure some Generic KPIs (where possible) in addition to their intended Core KPIs.

In addition, both the pre-existing legacy equipment on pilots as well as the new equipment that will upgrade the smartness of the buildings are listed; it should be mentioned here that the newly added devices will be used both for communication and interaction (where relevant) of the buildings with the platform.

The trials on the pilots presented in this chapter, will allow to achieve the Core KPIs per case and the Generic KPIs of the project. The interventions on the pilots will take place thanks to the services being developed in other WPs. These services from WP5 (User-centric services) and WP6 (Grid integration) will be based mostly on the developments from WP3 and WP4.The efforts of integration performed on WP3 are specific for each pilot and can be seen in detail in D3.2.

2.1. Generic KPIs

As presented in the introduction to this chapter, according to the DoA each pilot must measure specific KPIs (Core KPIs) in order to evaluate its goals. In order to have a more complete project evaluation and improved pilot metrics that will add value to project results, a separate calculation of the so-called Generic KPIs (which are essentially the sum of the Core KPIs) will be made by each pilot where possible. That means that a Core KPI for a pilot can be consider Generic for another and vice versa. The list of Generic KPIs is presented in Table 1.

Table 1 Generic KPIs

	KPI ID	Description	Evaluation frequency	Way in which it is going to be measured	Pilot(s) covering it as Generic KPI
Generic KPIs - PHOENIX interest	IoE	Integration of equipment - Energy consumption share integrated	Once per minute	Individual smart meters for each washing machine and each refrigerator in addition to the centrally located smart meter for every apartment	KaMa, UMU, LTU
	SRL	Max, mean and min Level of smart readiness	Once off	SRI tool, questionnaires	KaMa, UMU, MIWenergia, Arden, LTU
	NoS	Number of services	Once off	Via questionnaires	KaMa, UMU,
	PRt	People reached training/awareness	Once off	Via questionnaires	LTU, Arden
	RFF	Revenue from flexibility and trading (around 63€/year/household)	Once per year	Smart meters	UMU,LTU, Arden
	CF	Comfort feedback 95%	Once per year	Via questionnaires	UMU, MIWenergia, LTU, Arden
	RoIC	For commercial buildings 30-40% reduction of imbalance charges	Once per year	Smart meters,	KaMa, UMU, MIWenergia
	SoE	Savings of energy from the Utility point of view of 1500kWh, 27% approx.	Once per year	Smart meters	KaMa, UMU, MIWenergia, LTU, Arden
	RoPD	Reduction on peak demand from utilities point of view (35%)	Once per minute	Smart meters	KaMa, Arden

	KPI ID	Description	Evaluation frequency	Way in which it is going to be measured	Pilot(s) covering it as Generic KPI
	IT	Investment triggered of 16M€ (total project)	Once per year	Via questionnaires	MIWenergia, ARDEN
	CO2 tonnes saved (CO2Sv)	Amount of CO2 reduction due to substitution of fossil power generation by additional RES units inside the distribution network under analysis	Once per year	Smart meters, inverters, questionnaires, electricity bills	KaMa, UMU, MIWenergia,
	ISoB	Improved smartness of buildings as per smart readiness	Once off	SRI tool, questionnaires,	UMU,
	TES	Total target energy saving 20 - 30%	Once per 15 min	Smart meters, inverters, DHW temp., luminance, temperature, questionnaires, weather data	ARDEN, UMU
	SeS	Self-sufficiency in the order of 30-50%	Once per 15 min	Smart meters, inverters, DHW temp.	KaMa, ARDEN, MIWenergia, UMU
	BoS	Blackout support for specific loads with over 90% reliability	Once per year	Via inverters	
	ECR	Energy cost reduction of over 30%	Once per year	Smart meters, inverters, DHW temp., questionnaires, electricity bills	KaMa, ARDEN, MIWenergia, UMU
	IRS	Increased residents' satisfaction	Once per year	Via questionnaires, weather data	LTU, ARDEN, MIWenergia,
	UoEV	Usage of EV charging point of over 10%	Once per 15 min	Smart meter, questionnaires	

	KPI ID	Description	Evaluation frequency	Way in which it is going to be measured	Pilot(s) covering it as Generic KPI
	UA	User acceptance of smart controls and demand response	Once off	Survey	ARDEN,LTU, MIWenergia
	LoS	Load shifted (% and kWh) from high tariff to low tariff and from low renewable generation to high renewable generation.	Once per five minutes/ daily	Smart meters/ SEMO data	KaMa, LTU, MIWenergia
	LoF	Level of communication in real time from to energy providers	Weekly	Smart meter	ARDEN

2.2. Greek Pilot (KaMa) deployment

2.2.1. Objectives and use cases

The key objectives of the Greek pilot focus on two main streams that bring added value to the facilities: enhancement of building's energy efficiency and occupants' comfort. Both streams also aim at the reduction of the energy cost for the operational expenditures for the households. The following objectives are expected to be achieved with the increase in the smartness level of the building.

<u>KaO01: Improvement of the energy management of the building</u>

This objective is concerned with the optimization of energy production and consumption. Photovoltaic (PV) and Solar Thermal (ST) units will cover part of everyday energy needs and the use of battery systems will reduce the grid dependency and allow provision of energy during blackouts.

<u>KaO02: Improvement of the life quality and the comfort feeling of the building occupants</u>

This objective is concerned with several aspects of people's everyday living. The occupants of the Greek pilot will enjoy improved external aesthetics of buildings thanks to the choice of the installed PV units; they will feel more comfortable in terms of lighting and temperature conditions due to automatic shading systems; range anxiety and overall transportation emissions will be reduced via the availability of the EV charging point; they will be able to track in real time the performance of the installed assets they can opt in to get notified of the air quality (CO_2 concentration); and they will be able to enjoy energy availability and consumption during blackouts.

KaO03: Improvement of the cost of energy

This objective is concerned with decreasing the cost of energy for the building occupants. This will be achieved: on the one hand by the renewable energy production (PV and ST units) that covers utility needs; and on the other hand, by the energy consumption monitoring and optimization processes. In addition, financial benefits from the energy exchange could be estimated in a simulated environment. The use cases that describe the Greek pilot's functionalities supported by the PHOENIX framework are the following:

UC01: Adapt & Play integration of domestic appliances, legacy equipment and building systems

This use case relates to the smart hardware that is installed in the Greek pilot in order to increase the level of smartness of the building.

UC03: Services for building occupants to maximize their energy efficiency and increase overall building performance

This use case deals with occupants' engagement in actions that allow monitoring buildings' energy performance and promote energy savings.

UC04: Provision of Comfort, Convenience and Wellbeing services to building occupants

This use case concerns services that aim to improve life quality via simplifying everyday activities.

UC05: Portfolio flexibility analysis and configuration to optimize grid operation

Grid flexibility, by the introduction of power electronics and storage units, is under investigation, since the Greek energy model is static and currently there is no framework in place that embraces the provision of flexibility services. The implementation of this use case could potentially be done in a virtual environment.

UC06: Flexible billing services and smart contracts for the retailer customers

Greek energy retail market is based on static pricing; therefore, this use case could potentially be performed by a simulated concept where retailers react according to energy demands and rates of the energy exchange.

2.2.2. Pilot components

The hardware equipment for the main domains (heating, cooling, lighting, domestic hot water and dynamic envelope) that was pre-existing in the building, along with the interventions are presented in Table 2.

Table 2 Equipment of the Greek pilot

Details of equipment (e.g. capacity, model, power etc)	Pre-existing	Objectives	Use Cases
Heating & Cooling system: Carrier Fancoil 42N, Hitachi Yutaki-M 4NE	YES	KaO01	UC01
Led- Lighting: Various types of led lamps and bulbs	YES	KaO02	UC04
DHW: solar thermal boilers with differential thermostat (Plum ecosol 301 differential thermostats)	YES	KaO01, KaO03	UC01
Renewable energy: 60pcs of Canadian Solar 330Wp, 1pc Fronius Symo 20, 1pc Fronius Gen24 6kW	YES	KaO01,KaO02, KaO03	UC01, UC05, UC06
Energy storage: 1 pcof BYD HVS 5,1 kWh	YES	KaO01, KaO02, KaO03	UC01, UC03, UC04, UC05
Dynamic Envelope: 2m long 1,5 m wide custom-made shading system with actuators	YES	KaO02	UC01, UC04
EV charger: Noark EV wall-mounted charger Ex9EV3 T2 10A, Ampero mod-eth gateway	YES	KaO02	UC01, UC04
Monitoring devices (electrical consumption/ generation): three phase and single-phase smart meters	NO	KaO01, KaO02, KaO03	UC01, UC03, UC05, UC06
Monitoring devices (temperature): building's external/ internal ambient temperature, apartments' temperature, solar thermal boiler water temperature	NO	KaO01, KaO02, KaO03	UC01, UC03, UC04, UC05
Monitoring devices (luminance): luminance sensor	NO	KaO02	UC01, UC04
Monitoring devices (air quality): CO_2 sensor	NO	KaO02	UC01, UC04
IoT devices: smart lamps, smart plugs	NO	KaO02	UC01, UC04
Gateway: Raspberry pi, ModEth modules & Zwave USB	NO	KaO01,KaO02, KaO03	UC01, UC03, UC05, UC06

The connection of the hardware equipment with the objectives and the use cases of the PHOENIX project is also illustrated. Details on how these interventions occurred can be found in Deliverable 7.1. The upgrades are introduced by the PHOENIX project in the Greek pilot include the implementation of various monitoring devices and a gateway to retrieve data from them. The main hardware equipment and the corresponding sensors that are installed for the purposes of the project are all illustrated in the architecture diagram that follows (Figure 2).

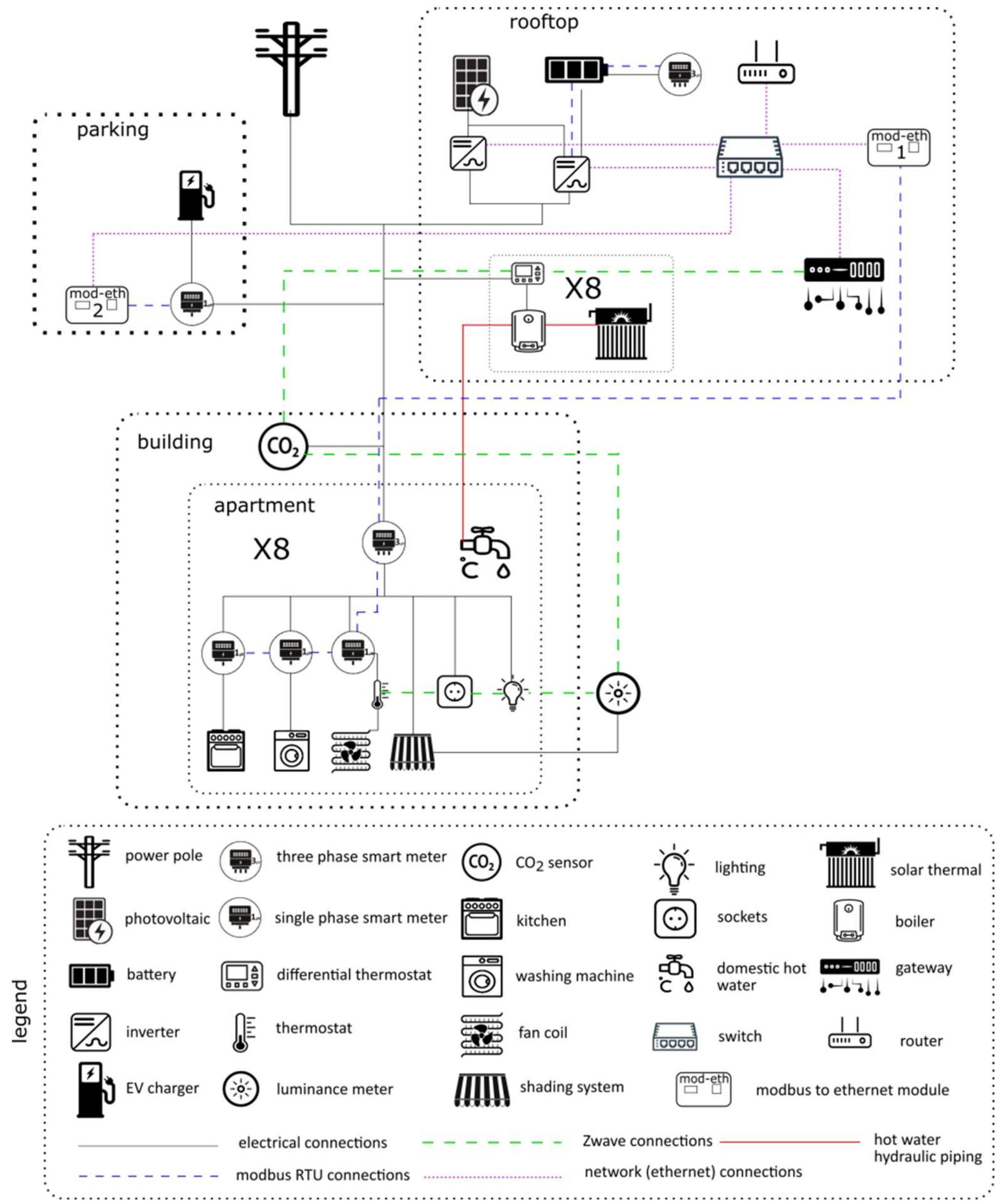

Figure 2 Electrical & architecture diagram of the Greek pilot

There are two types of sensors, as regards their connectivity, that are installed in the Greek pilot: Modbus RTU and Z-wave. The Modbus sensors (dotted blue line) are passing through a ModEth module before the end up to the gateway via Ethernet connection, while the Z-wave (dotted green line) are directly communicating with a Z-stick USB gateway, which is plugged in the gateway (Raspberry pi).

2.2.3. KPIs and trials

Table 3 presents the Greek pilot's monitored KPIs in correspondence with the pilot's objectives and use cases. This table also describes how often the measurements can be assessed by the PHOENIX dashboard and via which methods (means) they can be estimated.

Table 3 KPIs of the Greek pilot

Name (ID)	Description	Units	Evaluation frequency	Means	Objectives	Use Cases
TES	Total target energy saving 20 - 30%	%	15 min	smart meters, inverters, DHW temp., luminance, temperature, questionnaires, weather data	KaO01	UC03
SeS	Self-sufficiency in the order of 30-50%	%	15 min	smart meters, inverters, DHW temp.	KaO01	UC03
BoS	Blackout support for specific loads with over 90% reliability	%	1 year	inverters	KaO01, KaO02	UC04
ECR	Energy cost reduction of over 30%	%	1 year	smart meters, inverters, DHW temp., questionnaires, electricity bills	KaO03	UC03, UC06
IRS	Increased residents' satisfaction	%	1 year	temperature, luminance, CO2, questionnaires, weather data	KaO02	UC04
UoEV	Usage of EV charging point of over 10%	%	15 min	smart meter, questionnaires	KaO02	UC04

Table 4 presents the trials that have been defined in order to ensure and support the interventions' deployment. The trials are basically developed in such a way so as to validate the successful reaching of the targeted KPIs. First, the successful integration of all devices shall be confirmed and validated (Trial No1). Then, the resident's engagement should be measured (Trial No2), because it will reveal whether they are receptive to the PHOENIX dashboard recommendations or not. If not, corrective actions shall be considered, such as training. In connection to this, it shall be assessed whether the recommendations that the residents follow, are in compliance with their preferences and if they bring the desired values for the KPIs, as regards to resident's comfort and energy saving (Trials No7 & 8). Beside those, a few more trials are necessary in order to validate the battery support (Trial No3) and the usage of the EV charger (Trial No4). Lastly, there are two more trials that concern the forecasts and algorithms developed through PHOENIX; one is about the accuracy of the predicted energy production and consumption (Trial No6) and the other about the response of the algorithm to simulated price changes (Trial No5).

Table 4 Trials definition of the Greek pilot

No	Trial name	Description	Trial duration	Acceptance criteria	Success criteria	Use cases	Core KPIs	Generic KPIs
1	Integration of devices	All devices are connected successfully to the gateway	1 week	Receive data from all field devices	no missing data points	UC1, UC3, UC4		IoE, SRL
2	Residents' engagement	Check if the residents follow the suggestions of the dashboard	1 week	Residents react positively to the suggestions	follow 70% of the recommen dations	UC3, UC4	TES, ECR, IRS	IoE, SoE, RFF, RoIC, NoS, CR, UA
3	Black-out support	Induce artificial blackouts to assess whether the battery can supply critical loads, to be tested twice	1 day	Correct battery response	9/10 times the battery works properly	UC4	BoS	
4	Electric vehicle usage	Rent an EV car and provide it to one resident in order to use it as of his own	1 month	The car is being charged	10% usage	UC4	UoE V	
5	Simulated dynamic pricing	The algorithm decides when to store energy, when to consume from the grid and when from the battery, depending on the simulated dynamic pricing	2 months (bimonth ly billing)	Operation at the lowest market (simulated) cost	10% energy cost reduction	UC3, UC5, UC6	ECR	RFF, RoIC, RoPD

No	Trial name	Description	Trial duration	Acceptance criteria	Success criteria	Use cases	Core KPIs	Generic KPIs
6	Forecasting algorithms (production & consumption)	Compare forecasting results to real data as regards energy production and consumption	1 week	Get synchronous real and forecasted data	±10% deviation	UC3, UC5	TES, ECR	IoE, SoE, RFF, RoIC
7	User acceptance of smart controls	Validate that the smart suggestions approved by the residents fulfil the targets in energy consumption reduction	1 week	Pilot residents' satisfaction	30 % energy consumption reduction	UC3	TES, ECR	IoE, SoE, RFF, RoIC, UA, PRt, CF
8	Comfort and convenience	Validate that the smart suggestions approved by the residents fulfil the targets in residents' comfort and convenience	1 week	Temperature & lighting recommendations comply with residents' preferences	30 % energy consumption reduction	UC4	TES, ECR, IRS	IoE, SoE, RFF, RoIC, UA, NoS, CR, CF

2.3. Irish Pilot (ARDEN) deployment

2.3.1. Objectives and use cases

There are three main objectives we wish to achieve at the Arden pilot sites through the PHOENIX project.

<u>ArO01: Improved energy management in the buildings</u>

The first of these is improved energy management in the buildings of each pilot site. This objective will be achieved through improved control in the commercial and residential buildings. For the commercial building, the Building Management System (BMS), with the legacy equipment detailed in Table 5, has been integrated with the PHOENIX platform to allow for optimisation of energy production and consumption. As for the domestic sites, each have been enhanced with a

MyEnergi gateway to allow communication with the PHOENIX platform. We believe there is large scope for improved efficiency through optimised control and ensuring that the various legacy systems are controlled in a co-ordinated manner.

Monitoring and control systems will be integrated in the buildings providing information to building occupants and users, to enable transparency on energy usage and to facilitate improved efficiency and management of energy consumption. This objective ties in with the following use cases: UC1, UC2, UC3, UC7.

ArO02: Demand response and flexibility for grid optimisation

Our second objective is to improve demand response and flexibility for grid optimisation. The roll out of smart metering in Ireland is providing the first price signals and incentives to consumers to shift loads. As generation is increasingly derived from intermittent renewable energy sources there is increasing volatility is spot electricity prices with many periods of negative pricing followed by periods of very high prices. The pilots will demonstrate load shifting to avail of the opportunities provided by these price signals.

This will be enabled through predictive control response of significant loads facilitating load shifting according to time of use pricing. Day ahead market prices will be integrated into PHOENIX and demands optimised according to prices. The presence of solar PV in two out of three of the pilots will also demonstrate how a greater independence from the grid results in grid optimisation. This objective ties in with the following use cases: UC2, UC3, UC4, UC5, UC6, UC7.

ArO03: Improvement of comfort in the building

The final objective Arden has is to improve the comfort of each building. Temperature sensors will allow for improved control and better matching of temperature levels with the requirements of building occupants. This will prevent overheating and energy waste and also underheating. In the residential pilots, the use of heating zone controls can relax the fear of leaving the heating on or using energy unnecessarily to heat up an empty room. The more control a person has over their energy usage, the more comfortable the building becomes. Another aspect of comfort in a building which can be measured is CO_2 level. The commercial site has five CO_2 sensors. These have been connected to the PHOENIX platform and will send real time information to the building manager and occupants. This objective ties in with the following use cases: UC1, UC2, UC3, UC4.

The use cases that describe the Irish pilots' functionalities supported by the PHOENIX framework are the following.

UC01: Adapt & Play integration of domestic appliances, legacy equipment and building systems

This use case will be implemented in all pilot sites. An existing BMS system will be integrated with Phoenix at the commercial pilots and various legacy devices and systems will be integrated at the domestic sites.

UC02: Building knowledge enhancement to upgrade the smartness of buildings

At the commercial pilot, the fully integrated BMS will provide the availability of historical data and enable predictions of load switches. At the domestic pilot sites residents will be provided with information on consumption and energy performance as well as enhanced controls.

UC03: Services for building occupants to maximize their energy efficiency and increase overall building performance

Similarly, to UC02, upgrades and integration with Phoenix will allow monitoring buildings' energy performance and promotion of energy savings as well as providing controls to optimise efficiency.

UC04: Provision of Comfort, Convenience and Wellbeing services to building occupants

The enhanced smart controls and information provided to building managers and occupants at the Irish pilots will improve comfort and convenience. Room thermostats and smart controls will ensure that rooms are heated to the desired temperatures at the correct times. Hot water controls will make hot water available when needed at the lowest possible cost.

UC05: Portfolio flexibility analysis and configuration to optimize grid operation

Demand response and flexibility for grid optimisation will be enabled through predictive control response of significant electrical loads facilitating load shifting according to time of use pricing. In the domestic pilots plug loads and hot water will be controlled to run at times of lowest market cost. In the commercial pilot operation of the heat pump and CHP unit will be optimised according to ½ hourly electricity prices.

UC06: Flexible billing services and smart contracts for the retailer customers

With the utilisation of predictive control response and the implementation of time of use charges in Ireland, we can offer the pilots a lot more flexibility in controlling their bills. Arden Energy will issue bills based in hourly time of use pricing incorporating a comparison to standard bills and savings to the site achieved through load shifting and grid flexibility.

UC07: Advanced energy services to promote self-consumption optimization

The combination of user information, enhanced control and information on electricity pricing signals will promote optimising self-consumption of on-site generation and minimisation of grid imported electricity

2.3.2. Pilot components

The ARDEN pilot is formed by one commercial and two residential buildings. Thanks to the installation of middleware at the commercial site and the domestic sites, the legacy devices at each site are now communicating with the PHOENIX platform and sending data. Table 5 below details the legacy devices connected to the PHOENIX platform and their use cases for the commercial site. All equipment is connected and controlled via a Building Management System (BMS) on site. In order to connect to the PHOENIX platform, the BMS was first updated with Enteliweb software with an API module.

Table 5 Legacy Devices at the Irish Commercial Pilot Site

Details of equipment (e.g. capacity, model, power etc)	Use Cases
Heating system: CHP - Dachs/Senertech G5.5 Generation 1.1 5.5kWe 14.7kWth Condensing 30kW - Manufacturer: Remeha Model: Qunita Pro 30 Heat pump: Neura 20kW Model: L20EuC	UC01, UC04, UC05
LED- Lighting: Various types of led lamps and bulbs	UC04
DHW: As for heating plus solar thermal boilers with differential thermostat	UC01
Renewable energy: Solar PV panels and inverters: GROWatt 2500 (2.5 kW) and Solar Edge SE5K (5 kW)	UC01, UC05, UC06
Monitoring and Control: Delta control BMS with EnteliWeb - Energy Management Software	All
Monitoring devices (electrical consumption/ generation): Three phase smart meter on main incomer and 18 sub metered loads	UC01, UC02, UC03, UC05, UC06
Monitoring devices (temperature): 16 x 10K3A1 -40-150 °C AIC connected to BMS	UC01, UC03, UC04, UC05, UC06, UC07
Monitoring and control Building Management System. Delta Controls/Enteliweb	UC01, UC03, UC04, UC05, UC06, UC07

Table 6 details the legacy equipment at the domestic sites. Each pilot site had a MyEnergi gateway installed to enable connectivity between outputs from electricity meters, EV chargers, hot water boilers and solar PV via and API. This then enables connectivity with the PHOENIX platform.

Table 6 Legacy Devices at the Irish Domestic Pilot Site

Domain	Legacy Equipment and Systems	Use Cases
Heating system	Gas fired boiler	UC01, UC02, UC03, UC04
Domestic hot water	Electric and gas fired	UC02, UC03, UC04
Electricity renewables and storage	Solar PV	UC01, UC02, UC03, UC04, UC07
EVs equipment	EV charging	UC01, UC02, UC03, UC04, UC07

When installed the MyEnergi HUB device is used to monitor the energy consumption of a given household or business, it can be integrated with other smart devices such as EV car charger which can be used to store electricity generated from solar PV or from the grid to charge electric cars. The MyEnergi hub device can be used to manage energy harvested from solar PV and/or wind generation systems, it has the capability to store renewably generated energy in the form of heat or battery stores to improve the household's overall energy efficiency.

All of the MyEnergi devices can be accessed remotely within the MyEnergi app or through use of an API which has the ability to control the MyEnergi devices. For the domestic pilots, Arden decided to install a MyEnergi hub for communication via API and middleware (Figure 3) rather than set up communication to individual devices as was done in other pilots. This will demonstrate the advantages and disadvantages of both approaches to integration of legacy devices. The MyEnergi hub provides read/write access to all connected devices in the home via the API.

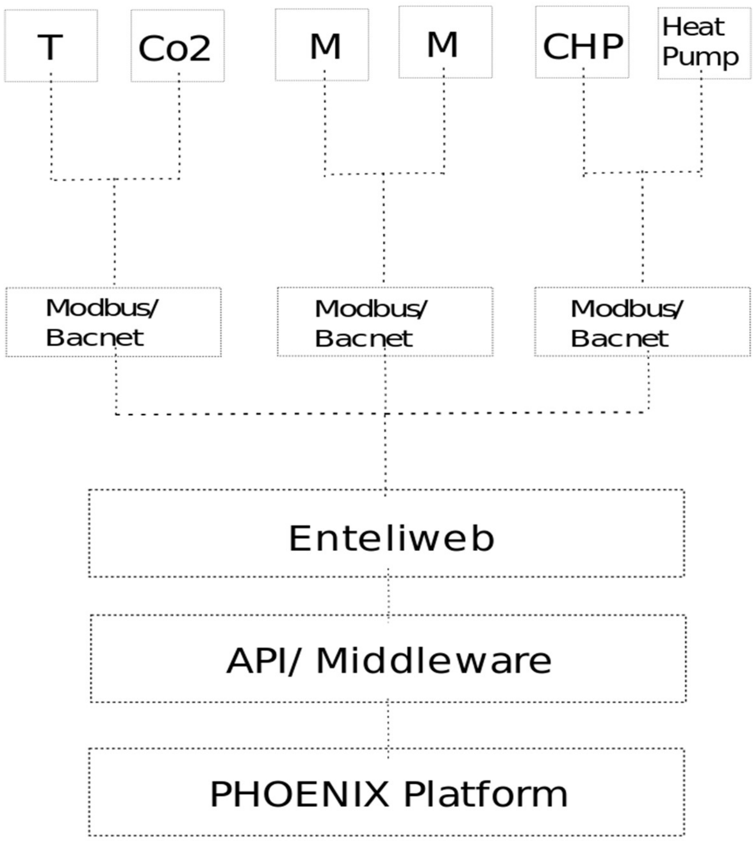

Figure 3 Architecture diagram for Irish domestic pilots

2.3.3. KPIs and trials

In total, Arden has 12 trials planned for the pilot sites. Table 7 conveys the KPIs at the pilot sites while Table 8 conveys the trial names, description and the KPIs associated with each trial.

Table 7 KPIs for Irish Pilots

Name (ID)	Description	Units	Evaluation frequency	Means	Objectives	Use Cases
TES	Total target energy saving 20 - 30%	%	Once per 15 min	smart meters	ArO01	UC03
UA	User acceptance of smart controls and demand response	%	Once off	Survey	ArO01, ArO02	UC04
LoS	Load shifted (% and kWh) from	%/ and kWh	Once per five	Smart meters/ SEMO data	ArO01, ArO02	UC04

Name (ID)	Description	Units	Evaluation frequency	Means	Objectives	Use Cases
	high tariff to low tariff and from low renewable generation to high renewable generation.		minutes/ daily			
ISoB	Improved smartness of buildings as per smart readiness indicator.	%	Monthly	Per device integration	ArO02, ArO03	UC02, UC03
EPM	Energy performance measured via metering of energy use from connected devices compared to baseline with the adequate normalisation (weather, occupancy, etc.).	kWh/ %	Once per five minutes	Smart meters/ SEMO data	ArO01	UC03
IoE	Integration of equipment - Energy consumption share integrated	Number	Once per minute	Baseline comparison before and after devices and meters fully integrated	ArO03	UC01, UC02
LoF	Level of communication in real time from to energy providers	%	Weekly	Arden will monitor consumption	ArO02	UC03, UC05, UC06
NoS	Number of services	Number	Once off	review at end of project	ArO03	UC02, UC04
PRt	People reached training /awareness	Number	Once off	via questionnaires	ArO03	UC04

Name (ID)	Description	Units	Evaluation frequency	Means	Objectives	Use Cases
RFF	Revenue from flexibility and trading (around 63€/year/household)	Millions Euro	Once per year	smart meters	ArO02	UC6
CF	Comfort feedback 95%	%	once per year	via questionnaires	ArO03	UC02,
RoIC	For commercial buildings 30-40% reduction of imbalance charges	kWh	Monthly	Bills	ArO01	UC03
SoE	Savings of energy from the Utility point of view of 1500kWh, 27% apox.	% and kWh	Once per minute	smart meters	ArO01	UC03
RoPD	Reduction on peak demand from utilities point of view (35%)	%	once per minute	smart meters	ArO01	UC03, UC05
CO2 tones saved (CO2Sv)	Amount of CO2 reduction due to substitution of fossil power generation by additional RES units inside the distribution network under analysis	Tones	Yearly	Calculation from reduction in consumption, comparing to benchmarks	ArO03	UC4

Table 8 Trials Mapping

Trial Number	Trial name	Description	Relevant KPIs
1	Validate successful integration of devices	All devices connected successfully to gateway, send data to platform and vice versa	IoE
2	Validation of cost reduction benefits comparison between baseline and PV and thermal storage.	During normal operation cost related KPIs will be monitored and evaluated in order to measure the economic benefits of the RES and storage installation in the demo site. The actual electricity consumption of the site will be measured and compared to the site's electricity demand. The electricity savings due to the PV and battery operation will be translated into energy costs in order to understand the level of cost savings CO_2 emissions' savings will also be calculated during the trial period	ECR
3	Validation of cost reduction benefits comparison between baseline and smart controls	The actual electricity consumption of the site will be measured and compared to the site's electricity demand. The electricity savings due to smart devices operation will be translated into energy costs in order to understand the level of cost savings CO2 emissions' savings will also be calculated during the trial period	ISoB, EPM, IoE, RoPD
4	Validation of cost reduction benefits- comparison with all PHOENIX devices and baseline	The actual electricity consumption of the site will be measured and compared to the site's electricity demand. site will be measured and compared to the site's electricity demand. The electricity savings due to all PHOENIX devices operation will be translated into energy costs in order to understand the level of cost savings CO2 emissions' savings will also be calculated during the trial period	ISoB, EPM, IoE, RoPD
5	User acceptance of smart controls	Prediction of load switches.	TES, UA, PRt, CF
6	User acceptance of smart controls	Information on consumption and energy performance as well as enhanced controls.	TES, UA, PRt, CF
7	User acceptance of smart controls	Devices fully integrated with PHOENIX platform and access granted to occupants of pilot sites.	TES, UA, PRt, CF
8	Smart Billing	Employing time of use tariffs for pilot sites	LoS, RFF, RoPD

Trial Number	Trial name	Description	Relevant KPIs
9	Evaluation of comfort and convenience	The enhanced smart controls and information provided to building managers and occupants at the Irish pilots will improve comfort and convenience	CF, UA
10	Evaluation of flexibility	Optimisation of heat pump and HCP	CF, UA
11	Evaluation of flexibility	Hot water will be controlled to run at times of lowest market cost	RFF
12	Self-consumption evaluation	Self-consumption increase	RFF

2.4. Spanish Pilot (MIWEnergia) deployment

2.4.1. Objectives and use cases

The objectives of the Spanish Pilot site focus on improving smartness and energy efficiency on the buildings while allowing the user to become a prosumer and take full advantages of these improvements. These objectives are described below:

MiO01: Improvement of the efficiency and energy management of the building

This objective concerns the optimization of energy consumption. The use of sensors allows a greater knowledge of energy consumption and the possibility of controlling appliances. This way, it will raise awareness about unsustainable behaviours and energy wastes. The user will be able to improve their efficiency and reduce their energy consumption thanks to better consumption habits. Consumers will also obtain an economic benefit directly in their energy bills from those energy savings.

MiO02: Transform consumer into a prosumer, allowing them to participate in the electricity market

This objective seeks to allow the user to adapt their consumption to the most economical periods, thanks to the deployment of smart devices and to provide more understandable information about the electricity market. It will also foster the participation of small/medium consumers in Demand Response programs. Our goal is to engage consumers in the electricity market by transforming them into prosumers. The benefit to the user is the reduction in their energy costs, as well as bonifications due to participation in programs/actions that take advantage of demand flexibility. Utilities will also make a profit by reducing their costs in the wholesale market and balance its demand/generation portfolio.

MiO03: Provide consumer data to users and improve building intelligence

Thanks to the deployment of measuring devices, users will be able to have real-time access to the data of their consumptions, being able to identify the individual percentage of each type of consumption (lighting, air conditioning, domestic appliances etc.). Comfort measuring devices will also provide information concerning indoor conditions such as temperature, humidity and CO2 concentration. Finally, buildings will increase their intelligence with a better SRI assessment.

The use cases that describe MIWenergia pilot's functionalities supported by the PHOENIX framework are the following:

UC1: Adapt & Play integration of domestic appliances, legacy equipment and building systems

This use case refers to smart hardware that is installed in order to increase the level of building intelligence.

UC2: Building knowledge enhancement to upgrade the smartness of buildings

The installation of these consumer appliance control equipment will increase the intelligence of buildings/homes.

UC3: Services for building occupants to maximize their energy efficiency and increase overall building performance

This use case deals with the participation of occupants in actions that allow to monitor the energy performance of buildings and promote energy savings.

UC5: Portfolio flexibility analysis and configuration to optimize grid operation

The role of the aggregator and the demand response programs to take advantage of grid's flexibility is in full development and it is expected to be implemented in the near future in Spain. Thanks to the implementation of smart devices, consumers will have the possibility to use their flexibility with the support of aggregators, to participate in the electricity market and benefit from those actions. Even if it's not implemented yet in Spain, this use case could be tested in a virtual environment simulating DSO signals.

UC6: Flexible billing services and smart contracts for the retailer customers

The Spanish market will change the tariff structure, and all consumers will have three or more periods daily with different prices. Moreover, there is the possibility of applying a dynamic tariff with an hourly price according to the actual market price. All these mean that the price of electricity is variable depending on the season, the day of the week and the hour. Thus, users are able to save simply by modifying the consumption habits.

2.4.2. Pilot components

The pilot buildings managed by MIWenergia, as it has been stated in D3.2, have no smart devices nor any legacy equipment connected to the internet. Therefore, the equipment installed during PHOENIX project must provide these functionalities and the smart energy and non-energy services to this pilot. Thanks to this upgrade on the smartness level of the buildings and the implementation of the PHOENIX platform, the objectives of this specific pilot will be achieved. Moreover, several use cases have been defined to describe the functionalities that needs to be supported in this pilot in order to meet those objectives. The legacy equipment existing before the start of PHOENIX project can be seen in the following Table 9.

Table 9 Spanish pre-existing legacy equipment

Commercial building	Objectives	Use Cases
Heating & Cooling system	MiO01, MiO02, MiO03	UC01, UC02, UC03, UC05, UC06
Carrier 30RH080-B0127. Heat pump Water chiller - 78 kW IR Thermostat: TAC490		
3 x Johnson PL (75-105-120) IR Thermostat:		
2 x Toshiba Montercarlo Thermostat: RBC-AMT32E(SX-A4EE)		
2 x Fujitsu ABY71-UIA-LV 7KW IR Thermostat: AR-RAH2E		
4 x Midea MUE 71 IR Thermostat: RG70C/BGEF		
Kaysun KAY-26 DN7 IR Thermostat: R51M/E		
LG UU24W U42/CV24 NJ2 IR Thermostat: AKB74075601		
Lighting	MiO03	UC2
Lighting system of the central area has LEDs installed		
In the offices located in the building and along the hallways fluorescent tubes are installed (4 hallways of 60m long each		
Residential building 1-4		
Heating & Cooling system	MiO01, MiO02, MiO03	UC01, UC02, UC03, UC06
B1) Saunier Duval Heat Pump - Thermostat MEITAV M2007	MiO01, MiO02, MiO03	UC01, UC02, UC03, UC06
B2) Daikin Heat Pump - Thermostat Daikin BRC1D52		
B3) Daikin Heat Pump BQSG125C8 - Thermostat Daikin BRC1D52		
B4) Duct heat pump for the whole dwelling		
Lighting Conventional lighting		
Monitoring & Control Smart meter for every apartment that provides hourly data related to energy demand	MiO03	UC2
	MiO01, MiO02, MiO03	UC01, UC02, UC03, UC05, UC06

The new equipment added to provide the new services to the legacy equipment is shown in Table 10. There are two types of sensors as regards as their connectivity, namely Z-wave and WMP. Both types are connected to a gateway (Raspberry pi) through a Z-stick USB for the Z-wave devices and via WiFi for the WMP ones.

Table 10 Equipment added through PHOENIX

Details of equipment	Objectives	Use Cases
Monitoring devices (electrical consumption): Three phase smart meter and one phase. ZWave.	MiO01, MiO02, MiO03	UC01, UC02, UC03, UC05, UC06
Qubino 3-Phase Smart Meter		
Aeotec Home Energy Meter		
Three clamps GEN5"		
Zipato Energy Meter		
Monitoring devices (temperature & Humidity): Temperature and Humidity Zwave sensors - MCOHome MH9	MiO01, MiO02, MiO03	UC01, UC02, UC03, UC05, UC06
Monitoring devices (air quality): CO2 Zwave sensors - MCOHome MH9	MiO01, MiO03	UC01, UC02
Gateway: Raspberry Pi 3 Model B+ with Z-Wave Aeotec Z-Stick Gen5 USB.	MiO01, Mi O02, O03	UC01, UC02, UC03, UC05, UC06
HVAC smarts control devices: Intesis Box WMP - Universal IR	MiO01, MiO02, MiO03	UC01, UC02, UC03, UC05, UC06

The architecture of the system deployed in MIWenergia pilot site is illustrated in Figure 4 where the connection between the utility smart meters, field devices , sensors and the gateway installed with the PHOENIX platform is presented schematically.

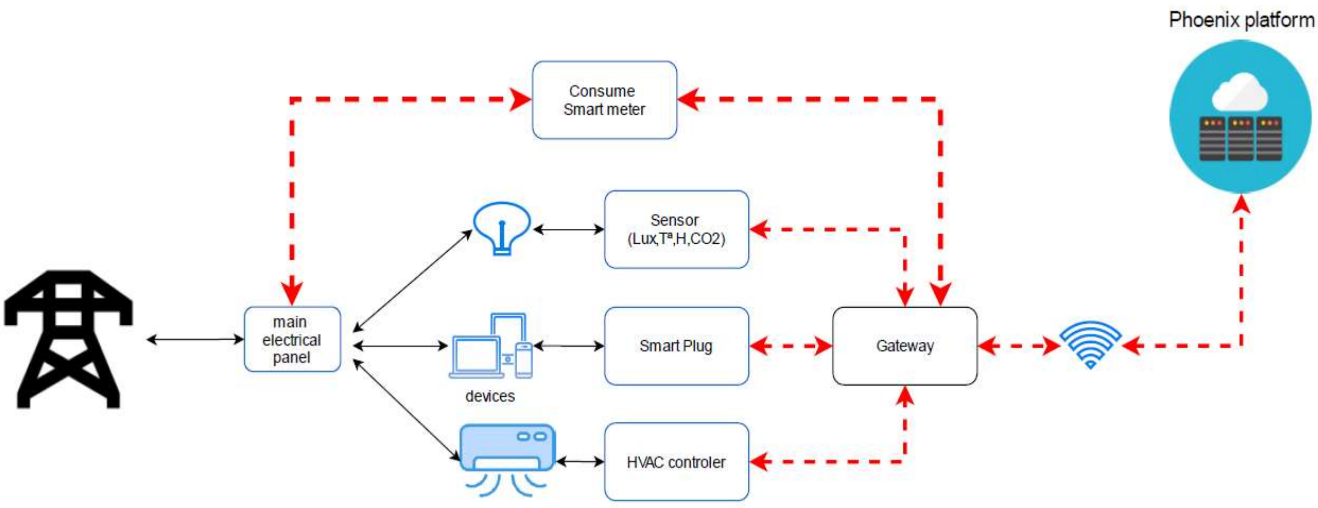

Figure 4 Architecture in MIWenergia pilot

2.4.3. KPIs and trials

The specific KPIs for this pilot are shown in the Table 11 below:

Table 11 KPIs for Spanish pilot

Name (ID)	Description	Units	Evaluation frequency	Way in which this is going to be measured
IoE	Integration of equipment - Energy consumption share integrated	%	every 5 minutes	All devices connected successfully to gateway, send data to platform and vice-versa
PRt	People reached training/awareness	# people	once off	via questionnaires
ECR	Energy cost reduction of over 20%	%	Monthly	smart meters/platform
LoS	Load shifted (15% and kWh) from high tariff to low tariff and from low renewable generation to high renewable generation.	under development	Daily/ Monthly	smart meters/platform
TES	Total target energy saving 20%	%	Every 15 minutes/ Monthly	smart meters/platform
ISoB	Improved smartness of buildings as per smart readiness indicator.	%	once per 6 months	Per device integration
EPM	Energy performance measured via metering of energy use from connected devices compared to baseline with the adequate normalisation (weather, occupancy, etc.).	kWh/ %	Monthly	smart meters/ platform
IT	Investment trigger in sustainable energy	€	End of project	smart meters / RE production

In order to measure these KPIs and evaluate the results in MIWenergia pilot site, a trial road map has been developed and it can be seen in the following Table 12.

Table 12 Spanish Trials

Trial name	Description	Trial duration	Acceptance criteria	Success criteria	Relevant use cases	Relevant KPIs
Validate successful integration of devices	All devices connected successfully to gateway, send data to platform and vice versa	2 weeks	1.Data received from all field devices 2. Platform send set points to devices	>90%	UC1, UC2	IoE, ISoB

Trial name	Description	Trial duration	Acceptance criteria	Success criteria	Relevant use cases	Relevant KPIs
User acceptance of smart controls	Devices fully integrated with PHOENIX platform and access granted to occupants of pilot sites.	monthly / 6 month	1. Data concerning number of interactions with the App 2.Pilot occupant satisfaction collected via questionnaire	1. >8 interaction/month 2. >80%	UC2	PRt
Validation of energy and costs reduction	During normal operation energy and cost related KPIs will be monitored and evaluated in order to measure the economic benefits of explicit and implicit DR actions in the demo site. The actual electricity consumption of the site will be measured and compared to the site's predicted consumption. A baseline must be calculated in order to obtain energy, cost and CO2 emissions savings during the trial period	One-month periods	1.Data received and stored with no problems 2. Platform send set points to devices or specific hours when reduce consumption 3.Able to calculate baseline 4. Able to calculate respective KPIs 5. Able to calculate electricity bills	1.Energy cost reduction by 20% 2. Energy consumption reduction >20% 3. actions done/requested actions>60%	UC1, UC2, UC3, UC4, UC6	TES, ECR
Flexibility extraction	DR actions will be sent to the users (implicit) or device controllers (explicit) to shift consumption from high tariff period to medium or low tariff periods.	One-week periods	1.Data received from all field devices 2. Platform send set points to devices or specific hours when reduce consumption 3. Able to calculate baseline. 4. Able to calculate respective KPIs 5, User acceptance	Load shifted by 15% Number of DR action followed by the user >80%	UC5, UC6	LoS, RFF
Forecasting algorithms (consumption)	During this trial we will validate the load forecasting algorithms by comparing forecasting results to real data from the site	1 week	1.Data received and stored with no problems 2.Reception of forecasted and real time values at the same timestamp	±20% deviation	UC1, UC2, UC3, UC4	

2.5. Spanish Pilot deployment - UMU

2.5.1. Objectives and use cases

The main aim of the UMU pilot is the achievement of better energy management while maintaining occupants' comfort. The increase in energy management considers the needs of the electrical grid, involving the shaving and the shifting of the power peaks. To do so, the objectives have to consider also the flexibility of both the smart building and the users. The increase in the smartness level of the building is essential to achieve these goals. To summarise, the objectives can be expressed as:

UmO01: Improvement of the efficiency and energy management of the building

This objective improves the control and monitoring of electrical consumption. Monitoring devices for the BMS system were already present in the building; hence the improvement will consist in adding specific control of the HVAC system. This objective will also involve the power generation (PV installation control) and the electric vehicles charger circuit.

UmO02: Demand response and flexibility for grid optimisation

This objective will be achieved by assuring an exchange of data with the grid and the insertion of a forecasting algorithm in the PHOENIX platform. In this way, power peaks will be detected, and a Demand Response strategy will be used to obtain a better distribution of consumptions.

UmO03: Improvement of building intelligence through involving users

The smartness of the building is a priority for the UMU pilot, as it is also a way to include users in the loop. Different kinds of data will be available for the occupants, through the insertion of IoT devices such as WiFi smart sockets or devices that monitor the CO2 level.

The use cases that describe the UMU pilot's functionalities supported by the PHOENIX framework are the following:

UC01: Adapt & Play integration of domestic appliances, legacy equipment and building systems

This use case relates to the smart hardware that is installed in the UMU pilot to increase the level of smartness of the building.

UC03: Services for building occupants to maximize their energy efficiency and increase overall building performance

This use case refers to occupants' participation and acceptance of the energy saving strategy.

UC06: Flexible billing services and smart contracts for the retailer customers

The Spanish market has a tariff structure with three or more daily periods with different prices.

The use case is linked to the energy saving achievable by modifying users' consumption habits.

2.5.2. Pilot components

The hardware equipment for the main domains that was pre-existing in the building, along with the interventions in the main domains, is presented in Table 13.

Table 13 Equipment of the Spanish pilot - UMU

Details of equipment (e.g. capacity, model, power etc)	Pre-existing	Objectives	Use Cases
Heating & Cooling system: HVAC of Pleiades Building with actuation support at a split level: • MMY AP3214HT8E (x2) (13,7 kW each) • MMY AP3014HT8E (x2) (11,5 kW each)	YES	UmO01, UmO02, UmO03	UC01, UC03, UC06
DHW: solar domestic home water, including temperature monitoring for both DHW and SOLAR tanks, water consumption and energy consumption of backup resistors for both tanks	YES	UmO01	UC01, UC03
Renewable energy: PV installation adjacent to the Campus' swimming pool: • Sunny Boy inverters (x30) (power not available)	YES	UmO01, UmO02, UmO03	UC01, UC03, UC06
EV charger: located at the Computer Science Faculty's parking: • Circutor Urban	YES	UmO01, UmO02, UmO03	UC01, UC03, UC06
EV chargers' circuit: electrical consumption monitoring and switching the circuit ON and OFF	YES	UmO01, UmO02, UmO03	UC01, UC03, UC06
Monitoring devices (electrical generation): • Pleiades diesel backup generator (Electra Molins)	YES	UmO01, UmO02	UC01, UC03, UC06
Monitoring devices (electrical consumption): some meters directly integrated in the Pleiades BMS; others monitored from IoT Gateways (Pleiades HVAC)	YES (BMS), NO (HVAC)	UmO01, UmO02	UC01, UC03, UC06
Monitoring devices (electrical consumption at a Campus level): electrical consumption available through SCADA for several buildings in the Campus of Espinardo	YES	UmO01, UmO03	UC01, UC03, UC06
Monitoring devices (temperature, humidity, luminosity and motion): integrated in the Pleiades BMS	YES	UmO03	UC01, UC03
Monitoring devices (air quality): CO_2 sensors • MCO Home CO_2 (x4)	NO	UmO03	UC01, UC03
IoT devices: WiFi Smart Sockets • Athom Smart Plug 16A (x20)	NO	UmO01, UmO02, UmO03	UC01, UC03, UC06
Gateways:	NO	UmO01, UmO02	UC01, UC03,

Details of equipment (e.g. capacity, model, power etc)	Pre-existing	Objectives	Use Cases
• ODIN's IoT Gateway (x3) • Raspberry Pi + Zwave USB (x2)			UC06

Figure 5 represents how the devices are connected to the PHOENIX Smartness Hub. There are a number of physical technologies involved in the UMU pilot namely Modbus-RTU for power meters, Modbus/TCP for the Pleiades diesel backup generator, direct inputs/ outputs for ventilation (AHU, a part of the HVAC) and DHW systems in Pleiades and in the EV charging circuit control of UMU Estates as well as Z-Wave technologies for the air quality monitoring devices.

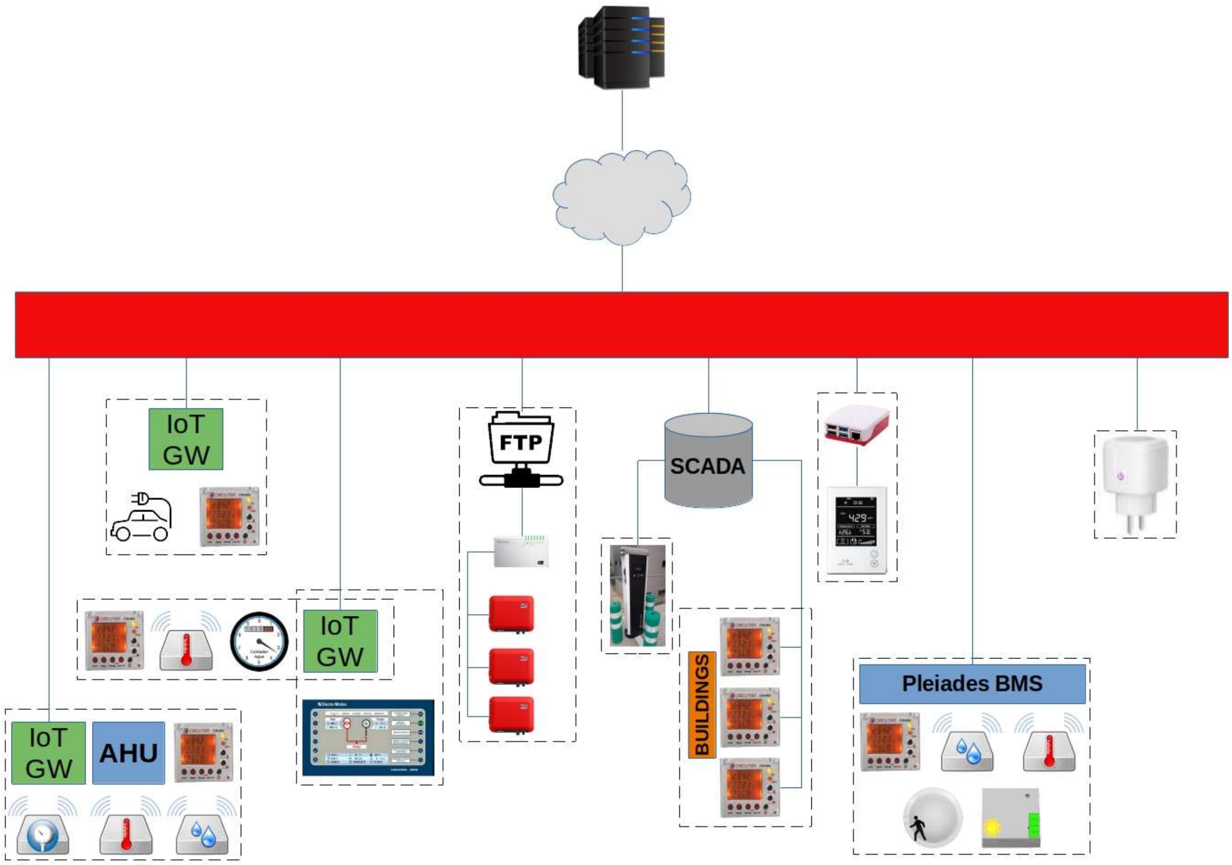

Figure 5 Architecture diagram UMU Pilot

2.5.3. KPIs and trials

Table 14 presents the UMU pilot's monitored KPIs in correspondence with the pilot's objectives and use cases.

Table 14 KPIs of the Spanish pilot - UMU

Name (ID)	Description	Units	Evaluation frequency	Means	Objectives	Use Cases
TES	Target energy saving. Energy savings of 15% are achieved thanks to optimal operation available after retrofitting of controls.	%	Daily/ monthly	Smart meters / platform	UmO01, UmO02	UC03
PRt	People reached training/awareness. Smart services available to users, 100 registered users.	#	At the end of the project	Via questionnaires	UmO03	UC03
IT	Investment triggered in sustainable energy	€	At the end of the project	Via questionnaires	UmO01	UC01
UA	User acceptance of smart controls and demand response	%	At the end of the project	Survey	UmO03	Uc03
LoS	Load and demand shifted (% and kWh). Decreasing of 20% on peak power loads. 18% energy cost reduction due to demand shifting on a variable tariff scheme. Shifting of 15% of demand towards periods of high renewable production.	%	Daily/Monthly	Smart meters/platform	UmO01, UmO02	UC06
EPM	Energy performance measured via metering of energy use from connected devices compared to	%	Hourly	Smart meters/ BMS data	UmO01, UmO02	UC01, UC03

Name (ID)	Description	Units	Evaluation frequency	Means	Objectives	Use Cases
	baseline with the adequate normalisation (weather, occupancy, etc.). Energy performance based on measured data within 90% confidence of real building.					
IsoB	Improved smartness of buildings as per smart readiness indicator (SRI). Devices responsible for 80% of the energy consumption of the building are connected.	%	At the end of the project	Per device integration	UmO01	UC01

Table 15 presents the trials that have been defined in order to ensure and support the deployment of the intervention and to validate the successful reaching of the targeted KPIs. Two different DR strategies were conceived to explore different solutions to the energetic issue. The first one (Trial No1) will be an actuation on the HVAC setpoint, in order to shift consumptions from high demand periods to low demand periods. The experiment will consider also how people react to such a change. The other one (Trial No2) will be more focused on energy saving, without involving the occupants. On days where peak consumption is expected, actuation on appliances will be sent. Actuation can be both a modification of the setpoint of the HVAC or a total switching off for short periods. Trial No 3 will study the users' acceptance of the smart suggestion, related in particular to the proposal of load shifting (Trial No1). The acceptance will be measured directly, through thermal comfort questionnaires, and indirectly, through investigating if they interrupted the actuations during the trial. Trials No 1, No2 and No3 will be repeated during the summer period.

Trial No 4 will concern the air quality of the offices. When a peak of CO_2 will be detected, the mechanical ventilation will be turned on. The information about the amount the CO_2 will be available for the users, so that the trials is related also to people's awareness. Finally, Trial No 5 will be an experiment in which occupants can send a vote with their preferred temperature to the platform, through a very simple dashboard. Then, the setpoint temperature obtained as the equidistant value will be sent to the thermostats. At the end of the trial, the acceptance of the method will be evaluated through questionnaires.

Table 15 Trials definition of the Spanish pilot – UMU

No	Trial name	Description	Trial duration	Acceptance criteria	Success criteria	Use cases	Core KPIs	Generic KPIs
1	DR strategy for flexibility extraction	DR events will be sent to device controllers to shift consumption from high tariff periods to medium or low tariff periods.	3 weeks (winter) + 3 weeks (summer)	Platform sends set points to devices or specific hours	Load shifted by 15%	UC03, UC06	LoS	IoE, ECR, RFF, NoS, SoE
2	DR strategy for energy saving	DR events will be used to obtain energy saving by managing the setpoint temperature of the HVAC	3 weeks (winter) + 3 weeks (summer)	Platform sends signals to devices to turn them on/off	30 % energy consump tion reduction	UC03, UC06	TES	IoE, ECR, RFF, NoS, SoE
3	Occupants' feedback	Validate that the smart suggestions approved by the occupants fulfil the targets in occupants' comfort and convenience	2 weeks (winter) + 2 weeks (summer)	Temperature recommenda tions comply with occupants' preferences	70% of interventi ons accepted	UC03	TES, UA, PRt	IoE, SoE, RFF, RoIC, NoS, CR, CF, ECR, IRS
4	Ventilation control	Ventilation control based on the level of CO2 detected	2 weeks	Platform send signal to the AHU to turn ventilation on/off	Maximu m CO2 level reduced by 10%	UC01, UC06	ISoB, PRt	CO2Sv

No	Trial name	Description	Trial duration	Acceptance criteria	Success criteria	Use cases	Core KPIs	Generic KPIs
5	Crowdsensing	Democratisation of the thermostats: occupants can express their preference for the setpoint temperature	2 weeks	Occupants send signals to the platform correctly	70% occupants satisfied (questionnaires)	UC03	TES, UA, PRt	IoE, SoE, RFF, RoIC, NoS, CR, CF, ECR, IRS

2.6. Swedish Pilot (LTU) deployment

2.6.1. Objectives and use cases

The objectives of the Swedish pilot focus are focussed on energy savings, comfort and convenience as well as improvement of the cost of energy.

LtO01: Improvement of the energy management of the building

LtO01 deals with energy savings by optimization of heating systems in the building. This is done for investigating if energy efficiency in lighting systems and car heaters are possible to improve.

LtO02: Improvement of the life quality and the comfort feeling of the building occupants

The second objective (LtO02) deals with comfort and convenience using sensors for internal environmental conditions. Measuring the indoor environment can improve ambient conditions for the building residents and facilitate the operational control of different systems. This objective is concerned with aspects of people's everyday living. The occupants of the buildings might feel more comfortable in terms of temperature and air quality conditions due to sensor-based improved temperature control. Sensors will be installed in common areas, and in some selected apartments based on consent from the occupants.

LtO03: Improvement of the cost of energy

The last objective is about improvement of the cost of energy. In this objective the goal is the optimization of energy consumption. This will be achieved by improving the regulation of the district heating-based heating system and installing smart thermostats.

There are four key use-cases in the Swedish pilot as listed below:

UC01: Adapt & Play integration of domestic appliances, legacy equipment and building systems

The first use case deals with "Adapt and Play integration of domestic appliances, legacy equipment and building systems". This use case relates to the smart hardware that is installed in the Swedish pilot in order to increase the level of smartness in the building. This impacts the actors namely building occupants and building managers.

UC02: Building knowledge enhancement to upgrade the smartness of buildings

The second use case deals with "Building knowledge enhancement to upgrade the smartness of buildings." This use case also relates to the smart hardware that is installed in the Swedish pilot in order to increase the level of smartness of the building as previous. The actors involved are also the same.

UC03: Services for building occupants to maximize their energy efficiency and increase overall building performance

The third use case is about "Services for building occupants to maximize their energy efficiency and increase overall building performance." This use case deals with occupants' engagement in actions that allow monitoring buildings' energy performance and promote energy savings. The key actors here are mainly the building occupants. The fourth and last use case is about "Provisioning of comfort, convenience and well-being services to building occupants." This use case concerns services that aim to improve life quality via simplifying everyday activities. The key actors here are the building occupants which is same as use case 3.

2.6.2. Pilot components

The pilot in Skellefteå, Sweden as described in previous deliverables focuses on the Heating and Ventilation System (HVAC), domestic hot water (linked to the heating system) and individual apartment's comfort through thermostats and air quality. The legacy systems in the Swedish pilot building included sensors for the HVAC system as well as the DHW system. These sensors are managed by Riksbyggen and the service is provided by KTC. However, these sensors were connected to the KTC proprietary BMS but the data was not accessible outside of KTC's BMS. To provision this access in the PHOENIX project, a new KTC device called IMC was installed by KTC. This device enabled the access of data through the IMC via KTC's new BMS. This data via an API is now received into the LTU IoT platform. Further implementation of a connection from the LTU IoT platform to the PHOENIX IoT platform was done within the PHOENIX project in order to send this data for analytics within the Phoenix platform. This includes 48 different sensors in all.

For monitoring the heating in the individual apartments in the building the Swedish pilot is done using R-Pi gateways with Z-wave connectivity to thermostat sensors and an air quality sensor. These include installation of 14 thermostats and one air quality sensor for each apartment within the Phoenix project. In the beginning, this is installed in one of the apartments owned by the chairman of the building as a demo apartment. These are further planned to be replicated in other apartments for interested residents. A number of other residents have shown interest but will first like to see how the setup looks in the demo apartment. The data from the R-Pi gateways is directly sent to the Phoenix platform via the implementation provided by OdinS within the PHOENIX project similar to other demo sites using the same gateway.

The entire architecture for the Swedish pilot including the legacy and new sensors, devices and connections is shown in the architecture diagram in Figure 6.

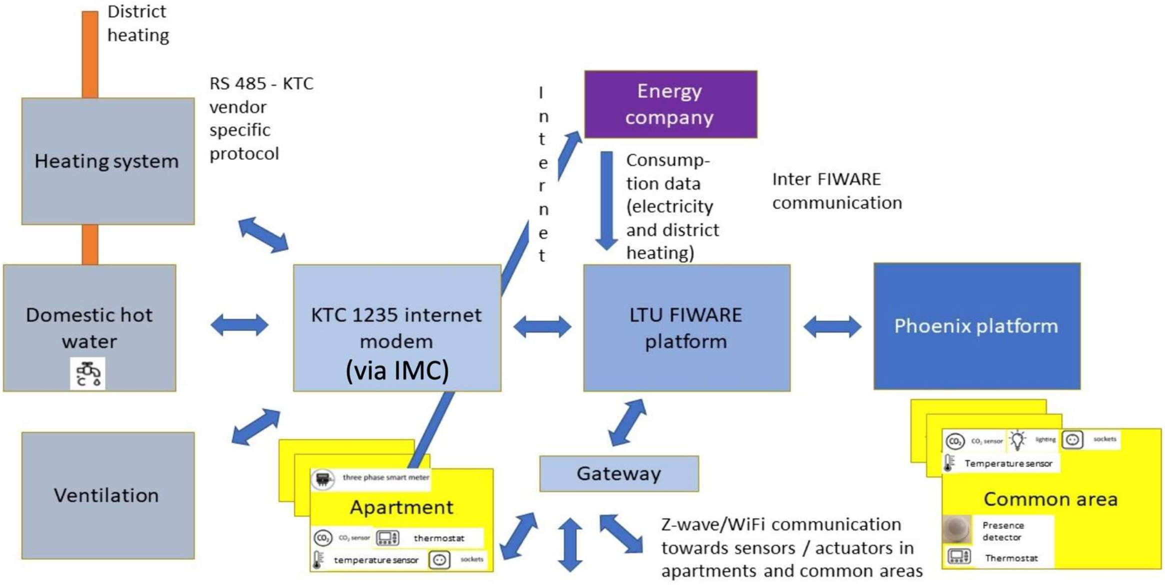

Figure 6 Swedish pilot architecture diagram

The relation between the new sensors and devices as well as legacy equipment with the different objectives and use cases in the Phoenix project are presented in Table 16.

Table 16 Equipment in Swedish pilot

	Details of equipment (e.g. capacity, model, power etc)	Pre-existing	Objectives	Use Cases
Legacy equipment	Heating system: Heat exchanger on the secondary side of the heating system is a Parca Norrahammar, type RL-01 from 1982	YES	LtO01, LtO02, LtO03	UC1, UC2, UC3, UC4
	Ventilation system: FDX system for building ventilation	YES	LtO01, LtO02, LtO03	UC1, UC2, UC3, UC4
	DHW: Linked to the heating system	YES	LtO01,	UC1, UC2,

	Details of equipment (e.g. capacity, model, power etc)	Pre-existing	Objectives	Use Cases
			LtO02, LtO03	UC3, UC4
PHOENIX New Equipment	Monitoring devices (temperature): building's external temperature, apartments' temperature, thermostats	YES	LtO01, LtO02, LtO03	UC1, UC2, UC3, UC4
	Monitoring devices (air quality): CO2 sensor	NO	LtO02	UC4
	Gateway: Raspberry pi, Z-wave USB	NO	LtO01, LtO02, LtO03	UC1, UC2, UC3, UC4

2.6.3. KPIs and trials

In this section we present the KPIs specific to the Swedish pilot along with the generic KPIs identified from the PHOENIX project relevant to this pilot. The specific KPIs with their IDs, description and the way in which these are to be measured are presented in Table 17.

Table 17 Specific KPIs for Swedish pilot

Name (ID)	Description	Classification	Units	Evaluation frequency	Way in which it is going to be measured
EPM	Energy performance measured as actual energy consumption compared to calculated based on predicted consumption (weather, etc. adjusted).	Core KPI	%	60 minutes	smart meters, temperature, questionnaires, weather data
ISoB	Improved smartness of buildings through the ability to adapt its operation mode in response to occupant needs and smartness of buildings as per smart readiness indicator by considering the possibility of one or more of the following: energy savings on site, comfort, convenience, well-being and health, maintenance and	Core KPI	%	5 minutes	smart meters, temperature, questionnaires, weather data

Name (ID)	Description	Classification	Units	Evaluation frequency	Way in which it is going to be measured
	operations, information to occupants.				
TES	Energy savings of upto 20% are targeted	Core KPI	%	1 year	smart meters, temperature, questionnaires, weather data

The trials definition for the Swedish pilot is presented in Table 18.

Table 18 Trial definition of KPIs specific to Swedish pilot

Trial number	Trial name	Description	Trial duration	Acceptance criteria	Success criteria	Relevant use cases	Relevant KPIs
1	Integration of devices	All devices are connected successfully to the gateway	1 week	1. Receive data from all field devices 2. Platform send set points to devices	90%	UC1, UC2, UC3, UC4	EPM, ISoB, TES
2	Residents' engagement	Check if the residents follow the suggestions of the dashboard	1 week	Residents' responses received from all residents	Follow recommendations with a certain acceptable percentage	UC1, UC3, UC4	EPM, ISoB, TES
3	Forecasting algorithms (consumption)	During this trial we will validate the load forecasting algorithms by comparing forecasting results to real data from the site	1 week	1.Data received and stored with no problems 2.Reception of forecasted and real time values at the same timestamp	±20% deviation	UC1, UC2, UC3, UC4	TES

Trial number	Trial name	Description	Trial duration	Acceptance criteria	Success criteria	Relevant use cases	Relevant KPIs
4	User acceptance of smart controls	information on consumption and energy performance as well as enhanced controls.	Constant communication with pilot sites along with training days	Pilot occupant satisfaction	Energy consumption reduction	UC2	IoE, SoE, RFF, UA, PRt, CF
5	User acceptance of smart controls	Devices fully integrated with PHOENIX platform and access granted to occupants of pilot sites.	Constant communication with pilot sites	Data received and stored with no problems	Energy consumption reduction	UC1, UC2, UC3, UC4,	IoE, SoE, RFF, UA, PRt, CF
6	Evaluation of comfort and convenience	The enhanced smart controls and information provided to occupants at the Swedish pilots will improve comfort and convenience	1 week	1. Room thermostats and smart controls will ensure that rooms are heated to the desired temperatures at the correct times	30 % energy consumption reduction	UC4	IoE, SoE, UA, NoS, CF

3. Operation of PHOENIX innovations and validation

This chapter provides an overview of the main activities performed by pilots in relation to WP3 and WP4 services. Each pilot briefly describes its early operations related to WP3 innovations for the adapt-&-play innovations for seamless integration of legacy equipment, the technological standard for interoperability of existing building management systems (BMS), the SRI framework and the creation of knowledge for upgrading the smartness of existing buildings. Another pillar to make possible the creation of the services and their deployment is the work towards developing the algorithms on WP4 from which the services get their intelligence. Although the work done on WP4 can be seen on D4.1 and D4.2 in more detail, in the following we show a brief explanation of the algorithms developments that are tested implicitly on the pilots.

3.1. Developments of algorithms that serve the pilot services

WP4 has two tasks dedicated to the creation of algorithms so that the services can use the calculations and other information provided by them (Figure 7).

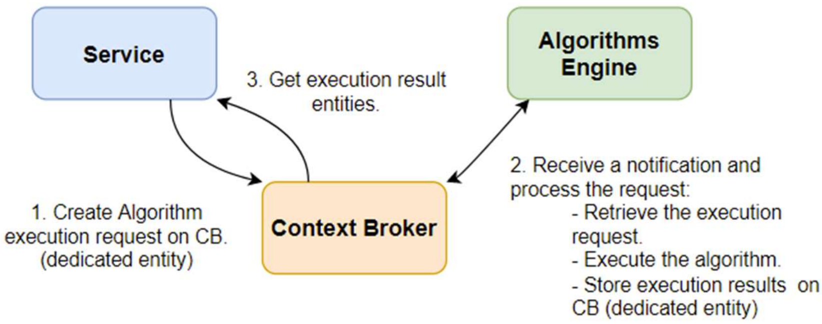

Figure 7 Communication flow with Algorithms Engine

The two distinctive lines of algorithms development are presented below.

3.1.1. Data analytics for user-centric services

Occupancy nowcasting and forecasting for building occupants, the nowcasting occupancy prediction as well as its short-term prediction (between 15 minutes and 3 hours ahead) are of crucial importance for the best interaction of the building occupant with his surroundings and the preservation of his comfort. More specifically when the PHOENIX system needs to make decisions on how to act on some devices e.g., lights, it needs to be aware of the user presence for example the automatic turning off of lights could disrupt the user if the room is occupied.

Default Comfort calculation for building occupants is another crucial aspect of the automated control actions that will improve the thermal, visual and air quality comfort of the building occupant. To that end knowledge of the users' default comfort profiles as well as their relevant short-term predictions is used. The algorithms created here will offer the possibility to the services of "knowing" the comfort of the users, which can be of relevance to other services such as the design of demand response events or energy reduction strategies.

3.1.2. Data analytics for grid integration services

The algorithms developed on this aspect are mainly created to serve the grid flexibility engine, but it can be extended to other calculation engines. The architecture of the grid flexibility engine can be seen on Figure 8.

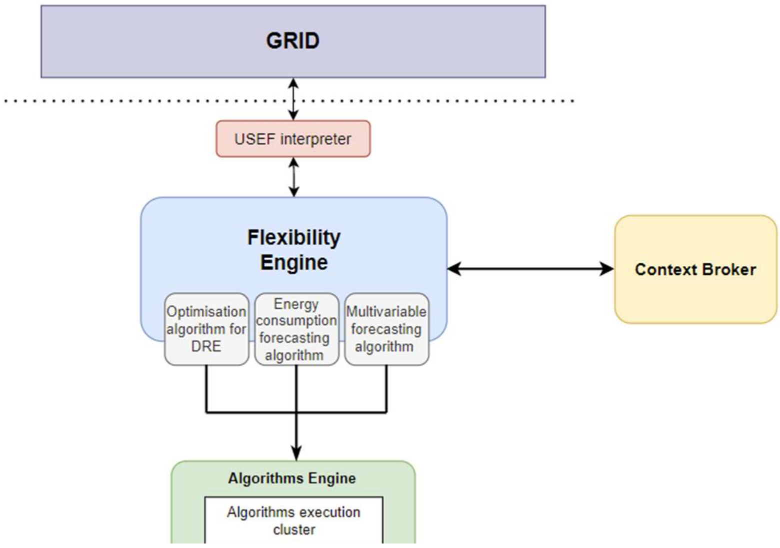

Figure 8 Architecture and components for flexibility

As it can be seen on the diagram of the architecture, there are three main algorithms serving this engine and therefore the services that will come from it.

The optimisation algorithm for Demand Response Events (DRE) is based on a genetic algorithm and it is a heuristic method to allocate the operation of devices so the peaks or the cost can be minimised. Although more about it can be read on D4.2, it is worth noting that the requests to this engine are done by using the Context Broker (CB) with dedicated entities.

The forecasting algorithm is also created within this task and it allows to forecast or benchmark any magnitude reported as a time series on the context broker. This algorithm has a multi-variant version in which the service can request to do a forecasting or benchmarking of several variables at the same time, considering them coupled.

3.1.3. Status update for WP4 solutions

The data used in the analytics methods described in the previous sections are retrieved from context brokers, which are part of the PHOENIX Smartness Hub solution to enable a Knowledge Graph

(KG) at the edge. Sensors are semantically annotated, and services can subscribe to context brokers to retrieve their data. Part of the work within the PHOENIX Smartness Hub is the provision of a cloud KG solution for other data sources such as building models. An initial solution of the cloud KG has been deployed in the PoC. In parallel, PHOENIX is developing the SRI service that makes use of information stored in the cloud KG, based on an SRI model developed in the project. More information can be found in Deliverable D4.2. The next steps within the pilots is to integrate the cloud KG solution, and connect it to the context brokers and services, in order to enable the full fledge PHOENIX Smartness Hub.

The full validation of WP4 solutions will be presented on the update versions of this deliverable. In the next sections the early operations related to WP3 innovations per pilot are presented.

3.2. Greek Pilot (KaMa)

3.2.1. Adapt-&-Play innovations for seamless integration of legacy equipment

There were a few existing legacy pieces of equipment in the Greek pilot that had to be integrated in the PHOENIX platform. All connections of new and legacy equipment are illustrated in Figure 2.

One category of legacy equipment were the inverters for the PV energy production. There existed two inverters, both Modbus TCP/IP. Thus, their connection with the gateway was simple and easy, by Ethernet cabling. The battery of the Greek pilot, which is related to the energy storage produced by the PV installation, is accessed via the hybrid inverter, so no further adjustments were needed for the battery integration.

Another category were the solar thermal boilers for the domestic hot water production. These boilers had differential thermostats between the solar collectors and the storage tanks to ensure optimal and efficient hot water production and storage. The monitoring of the hot water temperature was achieved via the installation of DS18B20 temperature sensors (two for each solar thermal boiler), connected to Z-wave Fibaro smart implants. In this way the existing solar thermal system is wirelessly connected to the gateway.

One more category of legacy equipment that was integrated in the platform is the monitoring of energy consumption of pre-existing home appliances, such as heat pumps, washing machines and fridges, as well as of the total building and the EV charger. For this purpose, Modbus RTU smart meters were installed at all the corresponding electrical lines. All the smart meters are connected via Modbus RTU to Modbus TCP MOD-ETH Gateways, and then, via Ethernet cabling to the final gateway.

Another case of legacy equipment is the heating and the cooling of the apartments, which is achieved via individual heat pumps for each apartment, controlled, originally, by conventional thermostats. The thermostats were replaced with Z-wave ones in order to achieve their connectivity with the gateway.

One last category of legacy equipment that resides in the Greek pilot are the shading systems of the apartments' front view. Their integration required the installation of Z-wave relays in order to have the possibility of remote/ automated movement and adjustment of the shading systems via the PHOENIX platform.

3.2.2. Technological standard for interoperability of existing building management systems

In the Greek pilot case, there is no pre-existing BMS included. The external data sources related to the Greek pilot are only weather data. For this reason, an account was created in the Weatherbit API platform in order for the algorithm that will be developed in WP4 to utilize current weather data and daily forecasts and provide recommendations to the users regarding their everyday activities.

3.2.3. SRI framework for suggestion of upgrading strategies for legacy systems

It is estimated that the PHOENIX upgrades in the Greek pilot will bring an increase in the SRI from 17% to around 50%, by applying interventions in all the domains.

3.2.4. Building knowledge creation for upgrading the smartness of existing buildings

In addition to the aforementioned interventions for the implementation of legacy equipment of the Greek pilot to the PHOENIX platform, a few more interventions from PoC were adopted, that contribute to the increase of the building's smartness. These include a CO2 sensor, a luminance sensor for the building and smart sockets and smart lamps for the apartments.

3.3. Irish Pilot (ARDEN)

3.3.1. Adapt-&-Play innovations for seamless integration of legacy equipment

The legacy devices which Arden has integrated with the PHOENIX platform can be seen in Table5 and Table 6. At the commercial pilot the BMS was updated with an API module to allow communication between the legacy devices on site and the PHOENIX platform. For the residential pilot sites, a MyEnergi gateway was installed to enable communication. Both methods are Adapt-&-Play innovations based on using BMS or home hubs to connect devices and then implementing software for connectivity via APIs and middleware to connect to the Phoenix platform. This aligns with Key Objective 1 of the PHOENIX project, to seamlessly integrate a large number of legacy systems and appliances in existing buildings by using Adapt-&-Play innovations.

3.3.2. Technological standard for interoperability of existing building management systems

For Arden, only the commercial pilot had a BMS. The BMS was not set up for connectivity, so we installed software (Enteliweb) to establish an API interface to the BMS and then developed middleware to provide read/write connectivity with the Phoenix platform. This did not prove to be an easy task for a few reasons. Firstly, a reluctance to engage on the side of the BMS providers slowed down progress. Furthermore, pre-arranged site visits were delayed on some occasions. Difficulties are still arising as we attempt identify and seek to correct errors in data collected by the BMS.

EnteliWEB is a web-based application that connects all facilities and centralizes building management operations, site engineering, and energy analytics. The Enteliweb software provides a wide array of API functions. Arden is employing the API to retrieve real-time consumption data, historical data as well as to activate actuation of devices at the Rediscovery Centre.

Arden also connected electricity market data to the PHOENIX platform. The SEMO API was engaged to send data on a daily basis. This will be employed to enact smart billing trials and forecasting.

3.3.3. SRI framework for suggestion of upgrading strategies for legacy systems

For the commercial pilot site that Arden is managing, the SRI improvements to be made were generated through the installation of middleware to allow communication with the PHOENIX and thus improve control of the energy consumption on site by means of accessibility, actuation and awareness. The BMS had already been installed prior to our research. However, it had not yet been optimised. Furthermore, forecasting via weather APIs and market data will also enhance the SRI of the building.

Similarly, for both domestic sites, offering the occupants more control after the implementation of MyEnergi gateways at each site improved the SRI score of each. Forecasting and smart billing will also provide a boost for their SRI scores.

Arden is providing the pilot sites with a schedule of upgrades and associated improvements in SRI to provide information and to provide a template for action at the pilot sites and for an approach to SRI improvement at other sites.

3.3.4. Building knowledge creation for upgrading the smartness of existing buildings

PHOENIX proposes the creation of a building knowledge to enable the upgrading the smartness of existing building that control, operate and communicate all systems and appliances in the building considering both the well-being of the building's occupants and the energy efficiency of the building.

Through our analysis we are confident that, for similar buildings, we will prove improved efficiency with regards to energy consumption at each pilot site as a result of enhanced smartness. Our studies so far have thought us the main hurdles to overcome with buildings comprised of similar technologies and systems.

3.4. Spanish Pilot (MIWenergia)

3.4.1. Adapt-&-Play innovations for seamless integration of legacy equipment

The focus was to integrate the Heat and Cooling system, frequently the most energy consuming system in the building, and improving largely the monitoring of the legacy equipment.

The integration of the HVAC units in the PHOENIX platform was achieved with the monitoring of their consumption and the installation of the control devices in the office building. Moreover, the ambient devices installed allows to monitor the temperature and humidity of the premises.

The smart metering allows to control the consumption in real time of the building, providing valuable information to the users regarding their energy behaviour.

Another service related with the zone ventilation and well-being of the users, which is implemented through the ambient devices, is the measurement of the air quality with an instant display of the CO2 levels.

3.4.2. Technological standard for interoperability of existing building management systems

There are no pre-existing BMS in MIWenergia pilot sites, so there wasn't any action made for this task.

3.4.3. SRI framework for suggestion of upgrading strategies for legacy systems

During the first months of the project, MIWenergia compiled information about the existing legacy equipment in the pilot. With the support of the technological partners along with the knowledge gained in the PoC, the most adequate devices were selected in order to maximise the SRI of the building. It is expected an increase from around 5% up to 30% by applying interventions in different domains.

3.4.4. Building knowledge creation for upgrading the smartness of existing buildings

As it has been mentioned in the previous section, the PoC was the main reference in order to upgrade the smartness of MIWenergia pilots. The solution will give the users information about their consumption, allowing them to change their behaviour to increase the energy efficiency, and also about the ambient conditions that will facilitate an improvement in their well-being.

3.5. Spanish Pilot (UMU)

3.5.1. Adapt-&-Play innovations for seamless integration of legacy equipment

The integration of legacy equipment is achieved in the UMU pilot on many levels. The integration of the HVAC units in the PHOENIX platform was achieved with the monitoring of their consumption and the installation of the control devices in the office building, through the insertion of WiFi Smart Sockets. A power meter has been added also to the air handling unit with a heat recovery circuit, monitoring the temperature in relevant points of the system.

The solar domestic hot water was another category of legacy equipment. Meters and controllers are integrated to monitor temperature and water consumption. With regard to the electric vehicle, the innovations consisted in monitoring the energy consumed at the charging point through a control panel.

About CO_2 monitoring, sensors have been added and the existing sensors have been integrated into the PHOENIX platform. Finally, the photovoltaic solar installation was already monitored and the intervention in this case consisted in connecting to the PHOENIX platform through a middleware component.

3.5.2. Technological standard for interoperability of existing building management systems

In the UMU pilot, a Building Management System (BMS) was already present before the project. The BMS had direct control over air conditioning units, lighting, presence sensors, etc. To assure interoperability with this system, other systems and devices had to be integrated and connected via Modbus connection. Then, the connectivity to the PHOENIX platform is assured through the creation of the *ocb_updater*.

3.5.3. SRI framework for suggestion of upgrading strategies for legacy systems

It is estimated that the PHOENIX upgrades in the UMU pilot will bring an increase in the SRI from around 6% to around 40%, by applying interventions in all the domains. In detail it is expected: +2.25% for Energy saving on site, +13.74% for Flexibility for the grid and storage, +1.13% for Comfort, +1.87% for Convenience, +1.59% for Health & Wellbeing, +10.06% for Maintenance & fault prediction, +4.66% for Information to occupants.

3.5.4. Building knowledge creation for upgrading the smartness of existing buildings

The UMU pilot's occupants will receive information about the trial and its objectives. In this way, we assure that all participants are engaged in the evolution of the smart building and that they can use the increase of smartness to know more about the building itself and the energy management.

3.6. Swedish Pilot (LTU)

3.6.1. Adapt-&-Play innovations for seamless integration of legacy equipment

In the Swedish pilot, the legacy systems are integrated for the HVAC and DHW systems which are managed by Riksbyggen and KTC. These are integrated by the installation of a device provided by KTC called IMC which enabled communication through an API with the BMS to the LTU IoT platform and further to the PHOENIX platform. This integration shows how two IoT platforms can seamlessly communicate and share data for different types of services and applications.

3.6.2. Technological standard for interoperability of existing building management systems

The integration with KTC Web IMC is done via an API provided by KTC to LTU. This enables receiving of data from the system installed in the building. This data received in the LTU IoT platform is further pushed to the PHOENIX platform from the context broker after the different entities are provisioned in the Phoenix platform.

3.6.3. SRI framework for suggestion of upgrading strategies for legacy systems

The upgrading of the legacy systems and new installations in the building will help increase the SRI from 13% to approximately 49% in the Skellefteå pilot.

3.6.4. Building knowledge creation for upgrading the smartness of existing buildings

The Swedish pilot includes the installation of thermostats in individual apartments where energy savings is envisioned through these smart thermostats. This is done while maintaining the comfort level of the residents both in terms of air quality and indoor temperatures.
The full validation of WP3 solutions will be presented on the update versions of this deliverable.

4. Validation and progress indicators

This chapter presents the validation of the progress in the five pilot sites providing the work that has been done so far to communicate the demonstration sites with the PHOENIX platform. In addition, progress indicators for the first phase of the project are presented, providing visualized information for the development of the pilots.

4.1. Greek Pilot (KaMa)

The validation process of the PHOENIX implementations for the Greek pilot has started with the installation of different sensor types in common areas and in some apartments, in order to establish a smooth and easy way of performing the planned interventions. After the validation that everything works properly and is connected to the PHOENIX platform, the rest of the installations will be performed.

So far, there exist in the Greek pilot the luminance sensor and the CO_2 sensor in common areas in the building, the smart meters of the total apartment energy consumption, smart plugs in two apartments, a thermostat, a relay, temperature sensors for domestic hot water and smart meters for heat pump, washing machine and fridge in one apartment (Table 19). The inverters of the PV installation for solar energy production are also connected. Work is still ongoing to finish and validate all interventions.

Table 19 Validation of Greek pilot sensors installations

KAMA Pilot site Sensors	Controlling area	No of components	Ordered? (Y/N)	Installed? (Y/N)	Connected to platform? (Y/N)	Sending data? (Y/N)
three phase smart meters (modbus RTU) orno we-516	apartment	8	Y	Y	Y	Y
single phase smart meters (modbus RTU) orno we-504	heat pump	8	Y	Y 1/8 N 7/8	Y	Y
three phase smart meters (modbus RTU) Fronius 50kA-3	building	1	Y	Y	Y	Y
single phase smart meters (modbus RTU) orno we-514	washing machine	8	Y	Y 1/8 N 7/8	Y	Y
	fridge	8	Y	Y 1/8 N 7/8	Y	Y
	EV charger	1	Y	Y	N	N

differential thermostats (Z-wave) FIBARO Smart Implant	dwh	8	Y	Y 1/8 N 7/8	Y 1/8 N 7/8	Y
fan coil thermostat (Zwave) MCO Home 4 pipe	heat pump	8	Y	Y 1/8 N 7/8	Y 1/8 N 7/8	Y
luminance meter (Zwave) MultiSensor 6	dynamic envelop	1	Y	Y	Y	Y
Relay (Zwave) Aeotec Nano Switch	dynamic envelop	8	Y	Y 1/8 N 7/8	Y 1/8 N 7/8	Y
CO2 sensor (Zwave) MCOHome MH9 CO2 Monitor 230V	air	1	Y	Y	Y	Y
smart lamps (Zwave) AEOTEC LED Bulb 6 Multi-White	light	8	Y	Y 1/8 N 7/8	Y 1/8 N 7/8	N
smart sockets Aeotec Smart Switch 7	sockets	8	Y	Y 2/8 N 6/8	Y 2/8 N 6/8	N
gateway Raspberry Pi	gateway	1	Y	Y	Y	Y
gateway Zwave USB	gateway	1	Y	Y	Y	Y

4.2. Irish Pilot (ARDEN)

Following the successful integration of legacy devices, the next step was to check and validate the quality of the data and the effectiveness of the sensors. This was an important step as there were no data quality checks on the legacy devices prior to integration. This process identified a number of faults in devices and data acquisition which affected the operation of the pilot sites.

At the commercial site, we noticed that two of the CO2 sensors on site were not measuring the data correctly. We have since notified the occupants who are looking to resolve the issue with the installer. Another discovery was the boilers poor efficiency. This was uncovered by analysing historical consumption and producing calculated efficiency charts. The boiler will be serviced to fix this issue. The heat pump on site was also experiencing issues. From going through historic generation data, it was evident that the heat pump had stopped working for some time. Once again, this issue will be resolved with the installers. Another achievement so far has been advising the occupants of the commercial site to lower the lux of the lights on site.

In terms of progress on performance monitoring, baseline consumptions have been calculated from historical data and Energy performance Indicators defined. This will allow us to track improvements in consumption and generation as the project continues and allow tracking of energy consumption and cost related performance indicators.

Similarly, air quality and indoor comfort data has been collected and faults with sensors have been rectified. This will allow monitoring and reporting of comfort and air quality to the pilot site and is of great interest to the Rediscovery Centre of the Irish Pilot as well, as they want to ensure indoor air quality is maintained throughout periods of varying occupancy levels.

4.3. Spanish Pilot (MIWenergia)

The validation process of the PHOENIX implementations for MIWenergia pilot started with the deployment of the Z-wave sensors and the commissioning into the raspberry pi's through a process developed by OdinS. All devices from this type have been successfully installed and the configuration of the devices have been uploaded in order to include them in the PHOENIX platform.

There was a delay in the purchase of the HVAC control devices because the selected ones (via Modbus) were out of stock and finally it was decided to change them for a WMP (via WiFi) devices from the same manufacturer. The configuration of these devices has been also uploaded and the system is prepared for them to be installed.

OdinS have prepared the final image for the raspberry pi and the configuration of each gateway. In order to validate the performance of the solution, one test has been launched in one of the zones of the office building. Once the validation is finalised and approved, the complete deployment of the new image and the configuration files on all the raspberry pi's will begin. The progress of the integration is presented in Table 20.

Table 20 Integration of smart devices

Pilot site Murcia – MIWenergia	Controlling area	Number of components	Ordered?	Installed?	Connected to platform?	Sending data?
ZIPATO - Micromodulo Contador de energia Z-Wave+	HVAC consumption – Dwelling + Office	1	Yes	Yes	1/1	Yes
WiDom - 1 phase energy meter Z-Wave	HVAC consumption – Dwelling + Office	10	Yes	Yes	No	No
Qubino Smart Meter 3 fases - medidor de consumo eléctrico Z-Wave Plus trifásico para carril DIN	Total consumption Dwelling	3	Yes	Yes	No	No
		26	Yes	Yes	1/26	1/26

Aeotec Clamp Meter 3 phase - Z-Wave	Consumption metering					
MCOHome MH9 CO2 Monitor 230V (MCOEMH9-CO2-230) (CO2 + temp. + hum.)	CO2 + temp + hum	19	Yes	Yes	1/19	1/19
Intesis - ASCII WMP Universal IR	Office building – HVAC	21	Yes	1/21	1/21	1/21
Raspberry Pi + Zwave	Dwelling	4	Yes	Yes	No	No
Raspberry Pi + Zwave	Office Building	11	Yes	Yes	1/11	1/11

4.4. Spanish Pilot (UMU)

The validation process of the PHOENIX implementations for the UMU pilot involved the installation of different types of devices. A detailed description of the devices listed in Table 21 can be found in the PoC.

Work is still ongoing to finish and validate all interventions since not all the devices are already connected to the platform.

Table 21 Validation of UMU pilot sensors installations

UMU Pilot site Sensors	Controlling area/ subsystem	No of components	Ordered? (Y/N)	Installed? (Y/N)	Connected to platform? (Y/N)	Sending data? (Y/N)
Pleiades DHW/ Temperature Solar panels -> solar tank	temperature	1	NA	Y	N	Y
Pleiades DHW/ Temperature Solar tank -> solar panels	temperature	1	NA	Y	N	Y
Pleiades DHW/ Temperature Solar tank -> DHW tank	temperature	1	NA	Y	N	Y
Pleiades DHW/ Temperature DHW tank -> building	temperature	1	NA	Y	N	Y
Pleiades DHW/ Water meter	water	1	NA	Y	N	Y

UMU Pilot site Sensors	Controlling area/ subsystem	No of components	Ordered? (Y/N)	Installed? (Y/N)	Connected to platform? (Y/N)	Sending data? (Y/N)
Pleiades DHW / Solar tank extra resistor power meter Circutor CVM-Mini	power	1	NA	Y	N	Y
Pleiades DHW / DHW tank extra resistor power meter Circutor CVM-Mini	power	1	NA	Y	N	Y
Pleiades / Diesel backup generator	power	1	NA	Y	N	Y
Pleiades Offices / Temperature (BMS)	temperature	18	NA	Y	Y	Y
Pleiades Offices / Humidity (BMS)	humidity	9	NA	Y	Y	Y
Pleiades Offices / Luminosity (BMS)	luminosity	4	NA	Y	Y	Y
Pleiades Offices / Motion (BMS)	motion	5	NA	Y	Y	Y
Pleiades Weather Station (BMS)	multiple values	1	NA	Y	Y	Y
Pleiades Power / Local and global power meters (BMS)	power	8	NA	Y	Y	Y
Pleiades HVAC / Splits (BMS)	hvac	5	NA	Y	Y	Y
Pleiades ATU / Temperature sensors	temperature	3	NA	Y	N	Y
Pleiades ATU / humidity sensors	humidity	3	NA	Y	N	Y
Pleiades ATU / pressure sensors	pressure	2	NA	Y	N	Y
Pleiades ATU / power meters	power	1	NA	Y	N	Y
Pleiades ATU / Actuators	actuation	6	NA	Y	N	Y
Pleiades Climate / Power meters	power	2	NA	Y	N	Y
Pleiades Offices / Smart plugs Tasmota	power / ON-OFF	20	NA	Y	N	Y

UMU Pilot site Sensors	Controlling area/ subsystem	No of components	Ordered? (Y/N)	Installed? (Y/N)	Connected to platform? (Y/N)	Sending data? (Y/N)
Pleiades / Air quality sensors (Z-Wave) MCOHome MH9 CO2 Monitor 230V	air quality	4	NA	Y	N	Y
Pool's parking solar plant / Inverters	generation	30	NA	Y	N	Y
Estates / EV charging circuit	power	1	NA	Y	N	Y
Estates / EV charging circuit actuators	actuation	1	NA	Y	N	Y
Computer Science Faculty parking / EV charging points	power	1	NA	Y	N	Y
Multiple buildings / Global power consumptions	power	NA	NA	Y	N	N

4.5. Swedish Pilot (LTU)

The validation process of the PHOENIX implementations for Skellefteå pilot is done for both legacy equipment for HVAC and DHW where sensors existed but communication of the data was a complex process. The old system did not communicate data to the platform as it is. There was a need to upgrade the modem with an additional device which took considerable time in understanding and researching on the right process. After, communication with Riksbyggen and KTC it was identified that a device called IMC which provided web interfacing to the KTC BMS and the development of an API can enable this communication. This was done and the data was received in the LTU platform. Further API development for platform-to-platform integration was achieved and the data is now sent to Phoenix platform. All 48 sensor values are collected in both the LTU and PHOENIX platform to fulfil and validate this process on an hourly basis.

For the individual apartments in the building the R-pi gateways, 14 thermostat sensors and an air quality sensor are integrated via OdinS support. This is validated by sending data from the gateway to the Phoenix platform. There was a delay due to the unavailability of certain devices as well as the COVID situation for access and communication to the apartments. The test installation for the demo apartment is validated now by seeing all sensors at the Phoenix platform side.

OdinS have prepared the final image for the raspberry pi and the configuration of each gateway. In order to validate the performance of the solution, one test has been launched in one of the zones of the office building. Once the validation is finalised and approved, the complete deployment of the new image and the configuration files on all the raspberry pi's will begin. The progress of the integration is presented in Table 22.

Table 22 Integration of sensors and devices

Pilot site Murcia – MIWenergia	Controlling area	Number of components	Ordered?	Installed?	Connected to platform?	Sending data?
HVAC sensors (48 sensors) + KTC Web IMC	HVAC consumption in entire building	49	Yes	Yes	Yes	Yes
SKE-Building-Flat6-Thermostat (No 1-14) + R-Pi	Apartments	14	Yes	Yes (in process)	Yes	Yes
SKE-Building-Flat6-CO2Monitor	Apartments	1	Yes	Yes (in process)	No	No

4.6. Progress indicators and specific achievements

This section presents the progress each pilot has made in relation to its development and is illustrated through progress-diagrams. In addition, specific achievements for each case are presented offering a holistic view of the evolution of the pilots. It should be noted here that these diagrams present the progress of the pilots regarding the first phase of the project and do not include the validation of the use cases themselves or the success of the specified trials. The diagrams are providing information on the following stages of development:

- Design

  The first step for the communication of demo-sites with the platform is the architectural and electrical design of the pre-existing and new devices that will be used. It is an important step as it determines the basis on which future communication will take place

- Installation
  Provides information on the installation level of new devices such as smart meters, actuators and sensors needed to retrieve real-time data from the demo locations on the PHOENIX platform
- Requirements
  This indicator presents the stage of preparation of field devices for integration with the PHOENIX platform, defining the necessary requirements of the entities associated with the Context Broker
- Integration
  This indicator provides the percentage level of integrated devices that already communicate and send data to the PHOENIX platform
- Trials definition
  This indicator presents the level of determination of the initial trials to be performed by pilot in order to validate the intended use cases as described in chapter 2. The final set of trials will be finalized as soon as the PHOENIX platform is fully operational

4.6.1. Greek (KaMa) Pilot

In the Greek pilot the overall development is evolving smoothly. The architectural design was determined in the early stages of work in T7.2 and the installation of the new equipment began as planned in the pilot buildings. As previously mentioned, Modbus and Z-wave sensors have been successfully installed in public areas. In addition, in two apartments (out of eight in total) some sensors of all kinds were installed and after the validation of the successful integration with the PHOENIX platform, the installations will be finalized in all apartments. At the moment, the integration of already installed devices with the PHOENIX platform is proceeding smoothly and as the pilot data requirements have already been defined, the full integration is expected to take place in the coming months. Finally, the initial set of trials was defined in order to validate the intended use cases and will be finalized after the successful integration of all devices with the platform. The following Figure 9 shows the course of the Greek pilot.

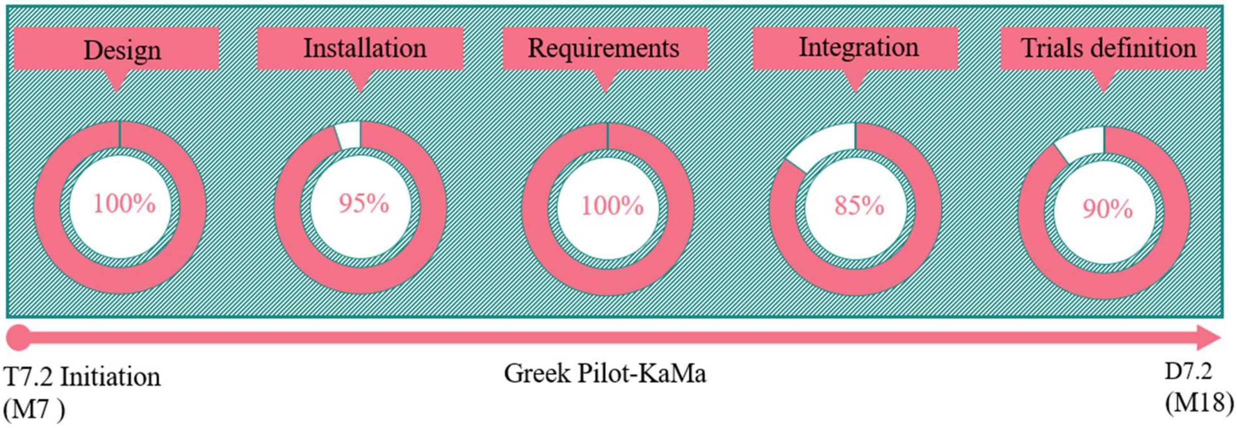

Figure 9 Greek (KaMa) pilot progress Diagram

4.6.2. Irish Pilot (ARDEN)

In the Irish pilot, legacy devices at each location communicate with the PHOENIX platform through the installation of middleware software, as originally planned in the architectural diagram at the beginning of Task 7.2. Data requirements have been successfully defined in order to provide the necessary information and all devices send data to the data broker. Remote device activation will be enabled in the coming months through trials scheduled for the next period, in which additional validation of the use cases will take place. Figure 10 below presents the progress of Irish pilot.

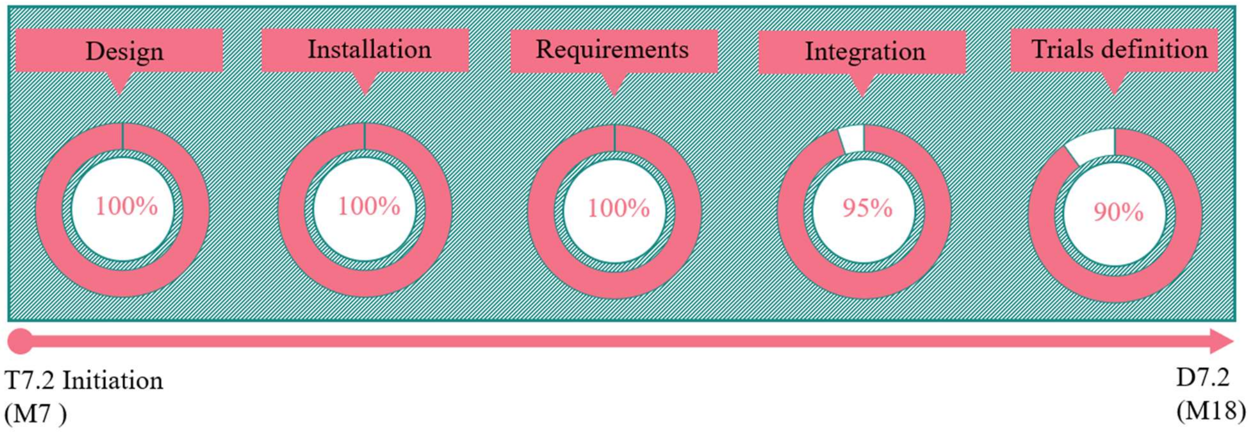

Figure 10 Irish (ARDEN) pilot progress diagram

4.6.3. Spanish Pilot (MIWenergia)

For the Spanish pilots, the architectural design was completed at the beginning of work for T7.2 and the equipment was then procured. At the moment, all the installations in the residential area have been completed and in the commercial site a few devices are pending installation due to delays in the supply chain. The data requirements for integration with PHOENIX platform have been successfully designed and the integration itself is proceeding smoothly. As previously presented, the initial trials plan has been defined and will be finalized in the coming weeks, once the devices are fully integrated with the platform.

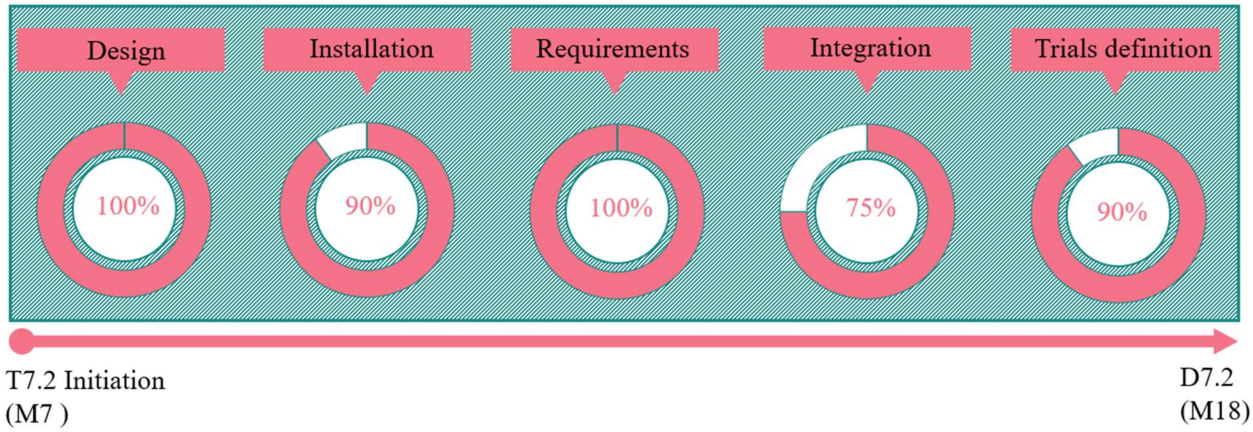

Figure 11 Spanish pilot progress diagram (MIWenergia)

4.6.4. Spanish Pilot (UMU)

The UMU pilot started at the beginning of the project as it was chosen to be the PoC for the other pilots. Thus, most stages of progress have been completed and minor changes to specific equipment are pending. A set of trials was defined in the early stages of the pilot development but more trials are under consideration and will be further defined in the next months. The following Figure 12 presents the progress indicators for UMU site.

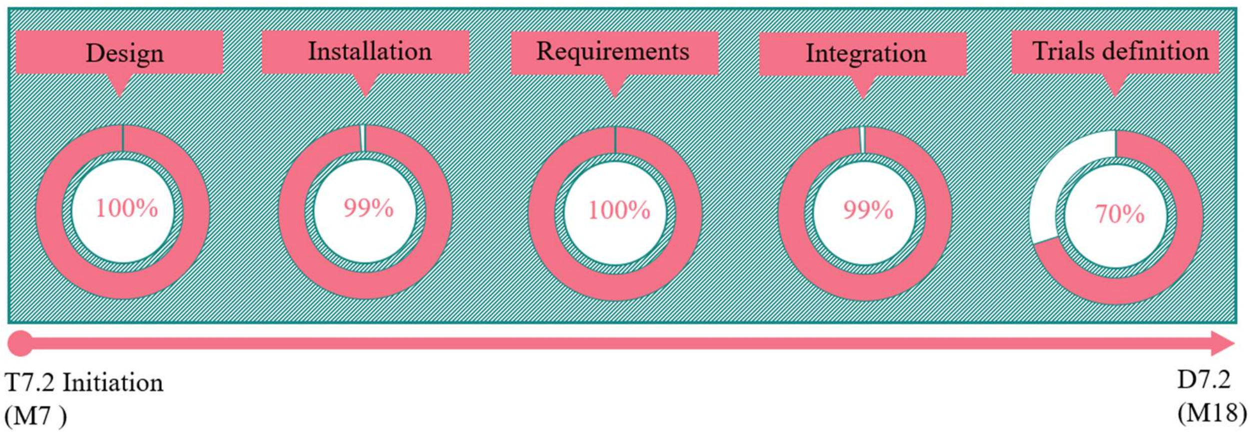

Figure 12 Spanish pilot progress diagram (UMU)

4.6.5. Swedish Pilot (LTU)

In the Swedish pilot the architectural design was defined in the early stages of work on T7.2. Due to restrictions from COVID-19 there have been some delays at the on-site installations which are expected to be completed in the coming weeks. The data requirements are almost complete and the integration with the platform will be achieved through intermediate software. The initial set of trials was successfully defined and presented in the previous chapter. Figure 13 below shows the progress made by Swedish pilots.

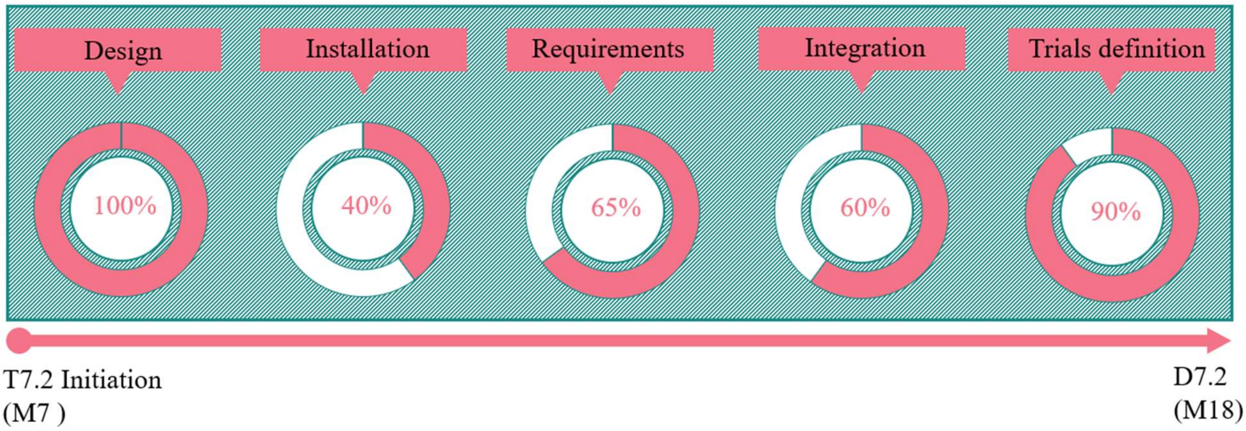

Figure 13 Swedish (LTU) pilot progress diagram

5. Conclusion and next steps

This document described the latest work perform in WP7. We have shown, for each pilot, its progress in terms of equipment installed, their integration to the PHOENIX platform, and their validation. The document also presented the extensive list of use cases and KPIs that will be deployed and tested in the last phase of the project. Apart for a few delays due to COVID-19 pandemic, all pilots are progressing well.

Below we provide a summary of the next steps for each pilot. In addition, the initial trials planning for each pilot is presented, which will be finalized as soon as the PHOENIX platform is fully operational. Through these trials, the calculation of the improved consumption of renewable energy sources and the reduction of energy consumption and costs will be measured and the comfort of the building will be quantified by analysing CO2 data. In addition, in some cases demand response services will be tested by analysing energy consumption trends and prices, while in others black- out support from batteries will be evaluated.

5.1. Greek Pilot (KaMa)

The next month will be devoted to validating all installations that have already taken place in the Greek pilot. After this step is finished with success, all the means and methods that have applied so far will be replicated to the rest of the pilot building (the remaining apartments) (M19-20). It is expected to have some delays in the purchases of the sensors, as they are not in stock from the suppliers. This is the reason why two months are considered as an expected duration for the finalization of all installations at this step. In M21 the trials period could begin, with the sequence that is presented in the trials' description section Table 3. In trials chart found in Figure 14 (Appendix 1), the Gantt chart of the trials planning is presented. The planning of Trials No5 and No6 could begin upon readiness of predicting algorithms (depends on technical partners).

5.2. Irish Pilot (ARDEN)

At this stage we have fully integrated all the legacy devices at each pilot site with the PHOENIX platform. We have also successfully connected the Irish market data source. Our attention will now turn to our trials plan and successfully carrying it out.

We have already analysed the historical data obtained from each site. The continued collection of data will allow us to compare historical data to present day and enable us to calculate improved renewable consumption and a reduction in energy cost through efficient consumption. Furthermore, from the historical data we will be able to calculate improvements in comfort of the buildings when analysing CO2 data and offering improved control of heating.

Over the coming months we will also begin testing load shifting and smart billing. Historical data will be analysed to spot trends in consumption and make predictions. We aim to begin this in April 2022. Data from the Irish Electricity market will be compiled, and variable rates will be offered to the pilot sites. At periods of high cost, the sites will be encouraged to consume generated electricity rather than importing from the grid. This will also be a part of our efforts to implement demand response services at each site.

Once the PHOENIX platform is fully operational, occupants will be given access. Arden plans to help the occupants understand the functionality of the site to improve comfort and enable the site to achieve its full potential. We will be able quantify the comfort of the building by analysing historical data and contrasting it with data collected on the PHOENIX platform after the installation of middleware on site. Irish trials Gantt chart can be found in Figure 15 (Appendix 1).

5.3. Spanish Pilot (MIWenergia)

Next month will be devoted to validating the final configuration and to finalising the deployment of the HVAC devices and the installation of the final image in all raspberry pi devices. Once completed, the successful integration of the devices will proceed for two weeks to finetune the system. Until the end of M20, the pilot manager and the user will test the monitoring and controllability of the solution. If everything goes according to plan, in M21, the rest of the trials will start. Trial No2 will start at M21 and will be performed every 6 months. Trial No3 is planned for M21 and to be run every 4 months. Trial No4 will start the last week of M22 and will be monitored for a week every 2 months. Finally, trial No5 will be tested once in M21 unless any modification or upgrade in the algorithms is performed by the technical partners.

The Gantt chart is shown in Figure 16 (Appendix 1).

5.4. Spanish Pilot (UMU)

During the next weeks, the first part of Trial No1 and Trial No2 will take place in the Pleiades building. In this phase, we will control the setpoint temperature for the heating system, while over summer we will repeat the experiment by controlling the setpoint temperature of the cooling system. During the intervention, the offices' occupants will be asked to fill out a thermal comfort questionnaire, in order to evaluate how the actuation affects their comfort and their acceptance of the DR strategy. Once collected the data, the analysis of the occupants' feedback will compose the Trial No3.

Trial No4 will run over the last two weeks of M20, while Trial No5 over the last two weeks of M21. The trials mapping can be observed in the Gantt chart of 17 (Appendix 1).

5.5. Swedish Pilot (LTU)

The next month will be devoted in the validating process, once the final installation in the apartments is done, in order to finalise the deployment of the R-pi and thermostats. The R-pi images will be updated with the new images provided by OdinS. Once completed, the successful integration of the devices will proceed for one week to validate communication of data from the sensors. Until the end of M20, the pilot manager and the user will test the monitoring and controllability of this system. After this the rest of the trials will start. Finally, the trials for validating and checking data for the KTC equipment for HVAC will also be done in parallel. The first part is to see that all sensors and devices are communicating data correctly. The Gantt chart is shown in Figure 18 (Appendix 1).

Appendix 1

		M21				M22					M23				M24	M25				M26				M27					M28			
		W1	W2	W3	W4	W1	W2	W3	W4	W5	W1	W2	W3	W4	W1-5	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W5	W1	W2	W3	W4
No	Trial name	2/5-6/5	9/5-13/5	16/5-20/5	23/5-27/5	30/5-3/6	6/6-10/6	13/6-17/6	20/6-24/6	27/6-1/7	4/7-8/7	11/7-15/7	18/7-22/7	25/7-29/7	1/8-2/9	5/9-9/9	12/9-16/9	19/9-23/9	26/9-30/9	3/10-7/10	10/10-14/10	17/10-21/10	24/10-28/10	31/10-4/11	7/11-11/11	14/11-18/11	21/11-25/11	28/11-2/12	5/12-9/12	12/12-16/12	19/12-23/12	26/12-30/12
1	Integration of devices (1 week)	■																														
2	Residents' engagement (1 week)		■																													
3	Black-out support (1 day)									■																		* ■				
4	Electric vehicle usage (1 month)						■	■	■	■																			* ■	■	■	
5	Simulated dynamic pricing (2 months)															** ■	■	■	■	■	■	■	■									
6	Forecasting algorithms (1 week)										** ■																					
7	User acceptance of smart controls (1 week)		■																													
8	Comfort and convenience (1week)		■																													

* if necessary
** when the algorithms are ready

Figure 14 Gantt chart of trials planning of the Greek pilot (KaMa)

		M19					M20				M21					M22				M23				M24					M25			
		W1	W2	W3	W4	W5	W1	W2	W3	W4	W1	W2	W3	W4	W5	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W5	W1	W2	W3	W4
No	Trial Name	28/2-4/3	7/3-11/3	14/3-18/3	21/3-25/3	28/3-1/4	4/4-8/4	11/4-14/4	19/3-22/4	25/4-29/4	3/5-6/5	9/5-13/5	16/5-20/5	23/5-27/5	30/6-3/6	7/6-10/6	13/6-17/6	20/6-24/6	27/6-1/7	4/7-8/7	11/7-15/7	18/7-22/7	25/7-29/7	2/8-5/8	8/8-12/8	15/8-19/8	22/8-26/8	29/8-2/9	5/9-9/9	12/9-16/9	19/9-23/9	26/9-30/9
1	Validate successful integration of devices																															
2	Validation of cost reduction benefits comparison between baseline																															
3	Validation of cost reduction benefits comparison between baseline and smart controls (One month)																															
4	Validation of cost reduction benefits- comparison with all PHOENIX devices and baseline (One month)																															
5	User acceptance of smart controls																															
6	User acceptance of smart controls																															
7	User acceptance of smart controls																															
8	Smart Billing																															
9	Evaluation of comfort and convinience															*																
10	Evaluation of flexibility																															
11	Evaluation of flexibility																															
12	Self consuption evaluation																															

*when the platform is ready

Figure 15 Gantt chart of trials planning of Irish pilot (ARDEN)

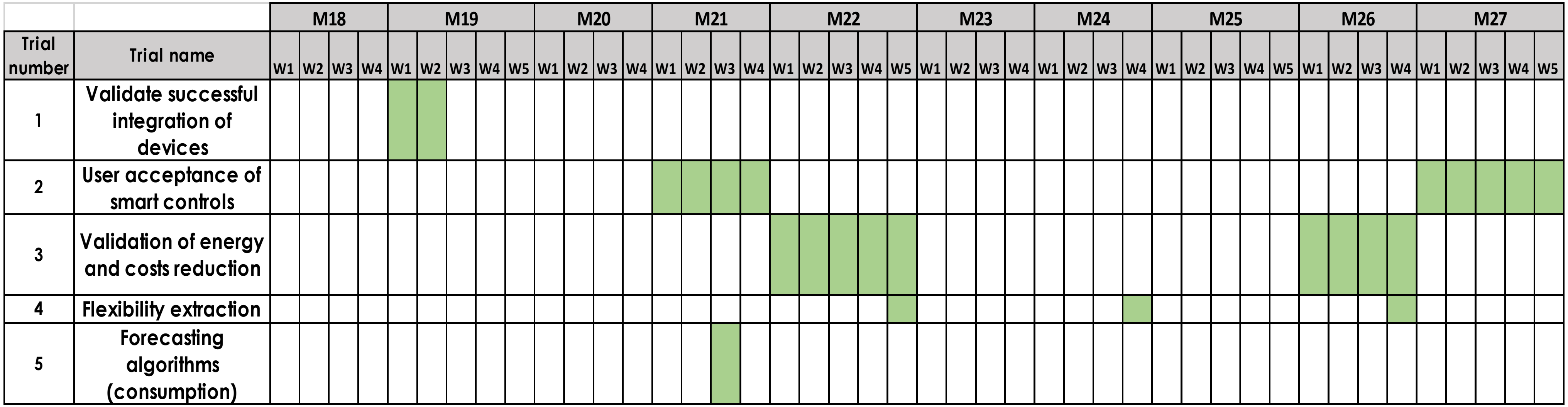

Figure 16 Gantt chart of trials planning of Spanish pilot (MIWenergia)

		M18				M19					M20				M21				M22					M23				M24			
		W1	W2	W3	W4	W1	W2	W3	W4	W5	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W5	W1	W2	W3	W4	W1	W2	W3	W4
Trial number	Trial name	31/1-4/2	7/2-11/2	14/2-18/2	21/2-25/2	28/2-4/3	7/3-11/3	14/3-18/3	21/3-25/3	28/3-1/4	4/4-8/4	11/4-14/4	19/4-22/4	25/4-29-4	2/5-6/5	9/5-13/5	16/5-20/5	23/5-27/5	30/5-3/6	6/6-10/6	13/6-17/6	20/6-24/6	27/6-1/7	4/7-8/7	11/7-15/7	18/7-22/7	25/7-29/7	2/8-5/8	8/8-12/8	15/8-19/8	22/8-26/8
1	DR strategy for flexibility extraction				■	■	■																■	■	■						
2	DR strategy for energy saving				■	■	■																■	■	■						
3	Occupants' feedback									■	■																	■	■		
4	Ventilation control												■	■																	
5	Crowdsensing																■	■													

Figure 17 Spanish (UMU) pilots trials chart

		M18				M19					M20				M21				M22					M23				M24				M25					M26				M27				
Trial Number	Trial name	W1	W2	W3	W4	W1	W2	W3	W4	W5	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W5	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W5	W1	W2	W3	W4	W1	W2	W3	W4	W5
1	Integration of devices																																												
2	Residents' engagement																																												
3	Forecasting algorithms (consumption)																								*																				
4	User acceptance of smart controls																															**													
5	User acceptance of smart controls																															**													
6	Evaluation of comfort and convenience																																				**								

* when algorithms are ready

** constant communication with pilot sites

Figure 18 Gantt chart of trials planning of Swedish pilot (LTU)