Ref. Ares(2022)7809036 - 11/11/2022

The PARITY project has received funding from the EU's Horizon 2020 research and innovation programme under grant agreement No 864319

Project Acronym:	**PARITY**
Project Full Title:	**Pro-sumer AwaRe, Transactive Markets for Valorization of Distributed flexibilITY enabled by Smart Energy Contracts**
Grant Agreement:	**846319**
Project Duration:	**42 months (01/10/2019 – 31/03/2023)**

DELIVERABLE D8.4
Pre-pilots deployment and testing

Work Package:	**WP8 – System Integration, Demonstration and Impact Assessment**
Task:	**T8.4 – Pre-validation activities (nZEB - DIH testbed facility & small-scale test deployments)**
Document Status:	**Final v1**
File Name:	**PARITY_D8.4_Pre-pilots deployment and testing_R1_V1.0_CERTH**
Due Date:	**April 2022**
Submission Date:	**November 2022**
Lead Beneficiary:	**CERTH**

Dissemination Level	
Public	X
Confidential, only for members of the Consortium (including the Commission Services)	

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Version History

Version	Author	Date	Status
0.1	Stylianos Zikos, CERTH	July, 2021	Initial draft (TOC)
0.5	Stylianos Zikos, CERTH	April, 2022	Content in introduction and pre-validation plan
0.7	Stylianos Zikos, CERTH	October, 2022	Additional content in section 3 and section 4
0.9	Stylianos Zikos, CERTH	November, 2022	Final draft for internal review
1.0	Stylianos Zikos, CERTH	November, 2022	Final version ready for submission

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Executive Summary

The present document describes the pre-validation activities that have been performed prior to the final deployment of PARITY solutions to the four pilot sites, as well as the main outcomes of the tests that shall be considered and addressed prior to the final validation. The objective of the pre-validation phase is to support the experimental evaluation and validation of the PARITY solutions that have been developed within WP5-WP7 throughout the project. The pre-validation results have helped to perform bug fixes and improvements for the developed solutions, resulting in reduced integration risks.

Initially, background information on the types of software testing along with the pre-validation plan is presented, in addition to the descriptions of the different locations of the testing environments. These include the controlled environments at CERTH/ITI nZEB - DIH and HYPERTECH office building, as well as the small-scale pilot deployments in selected locations of the Swiss and Spanish pilot sites. The tests that have been performed per software component or combination of components are presented, along with any identified issues and corrective actions. Moreover, tests of the installed IoT equipment as well as tests of the D-STATCOM device are described.

The vast majority of the designated tests were successful, while corrective actions have been performed to handle the test cases and usage scenarios that did not produce the expected results. The corrective actions are related to the configuration and deployment of software solutions, improvements in data handling and implementation of the defined communication interfaces, as well as improvements in user interfaces and presentation of information. In all cases of initially unsuccessful tests, identified problems have been resolved and correct operation was confirmed through subsequent tests.

As far as the deployment of the system is concerned, the steps to follow for the configuration of the software components after their deployment for a new site, were clarified. The deployments made for the Swiss and Spanish pre-pilots will be extended to form the final full-scale deployments for these pilots and will be used as a guide for the full-scale deployments at the pilots in Greece and Sweden.

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List of Acronyms and Abbreviations

Term	Description
ANM	Active Network Management
BaaB	Building-as-a-Battery
D-STATCOM	Distribution Static Synchronous Compensator
DER	Distributed Energy Resource
DIH	Digital Innovation Hub
DSO	Distribution System Operator
EV	Electric Vehicle
IML	Information Management Layer
IoT	Internet of Things
IR	Infrared
JSON	JavaScript Object Notation
LEM	Local Energy Market
LFM	Local Flexibility Market
nZEB	nearly Zero-Energy Building
OCPP	Open Charge Point Protocol
P2H	Power to Heat
UC	Use Case
UI	User Interface
VPP	Virtual Power Plant
WP	Work Package

1. INTRODUCTION

1.1 Scope and Objectives of the Deliverable

This document describes the pre-validation activities that have taken place prior to the final deployment of PARITY solutions to the four pilot sites, along with their results. In particular, it presents the pre-pilot locations and deployments, tests performed per component or combination of components, any issues found and corrective actions, as well as preliminary feedback received from a limited number of selected pilot participants.

The objective of the pre-validation phase is to support the experimental evaluation and validation of the WP5-WP7 contributions throughout the project. Pre-validation results will help to perform bug fixes and improvements for the developed solutions. As a result, integration risks are expected to be reduced. In particular, the goal is to perform the pre-validation phase of the PARITY solutions in real buildings after testing them in controlled lab environments. To this end, the infrastructures of CERTH/ITI nZEB – DIH testbed facility, Hypertech's office premises, and small-scale test beds available in the Spanish and Swiss pilot sites have been utilised.

Special focus has been given to the validation of main functionalities provided by critical back-end components, user interfaces, and the interoperability with off-the-self equipment. Moreover, the small-scale validation of the local market by utilizing real data will contribute to the avoidance of severe integration issues at the full-scale deployments.

Finally, feedback that has been received from selected pilot participants will allow to make any further improvements to PARITY components before the final full-scale deployments and validation.

1.2 Structure of the Deliverable

Section 2 initially provides background information on the types of software testing and presents the pre-validation plan that has been developed to be applied within PARITY. Furthermore, it provides descriptions of the different locations of the testing environments. Section 3 presents the tests of several PARITY components that were performed in the controlled environments at CERTH/ITI nZEB - DIH and HYPERTECH office building. Section 4 presents the tests that were performed at the small-scale pilot deployments that took place in selected locations of the Swiss and Spanish pilot sites, by utilising real data from assets available on-site. The results and corrective actions that have been applied are presented. Finally, section 5 summarises the outcomes of the pre-validation activities.

1.3 Relation to Other Tasks and Deliverables

Relevant inputs were received from the following tasks of the project, in order to plan, prepare and execute the pre-validation tests.

- T8.1 - PARITY System Integration
- T8.2 - Community engagement, pilot participant recruitment and integration into local flexibility market
- T8.3 - Procurement of hardware infrastructure and deployment/integration in pilot sites
- T3.3 - PMV methodology definition
- WP5-WP7 component development tasks

The outputs of the pre-validation activities that are presented in this document will be useful for improving the PARITY solutions and also for activities to be taken place within the following WP8 tasks:

- T8.1 - PARITY System Integration
- T8.5- PARITY system roll-out and demonstration in 4 pilot sites

2. PRE-VALIDATION PLAN

2.1 Pre-validation plan and objectives

The pre-validation process includes a number of selected tests on the developed software components. Different types of software testing exist. The most common are shortly described below.

Unit testing: Unit testing is the initial stage in the test life cycle of software. The functionalities of an individual software unit are tested to ensure that the requirements are met before integration.

Integration testing: Integration testing refers to two or more separate software units that interact with each other. The goal is to examine if these combined units can interact as expected without problems. If this is not the case, corrections are then made to the corresponding unit(s) to solve the detected errors.

System testing: A system test is used for evaluating the operation of all software units as a whole. It takes place after unit and integration testing.

Common tests used for performing a system evaluation are depicted in Figure 1. These are divided into two main categories: functional tests and non-functional tests [1].

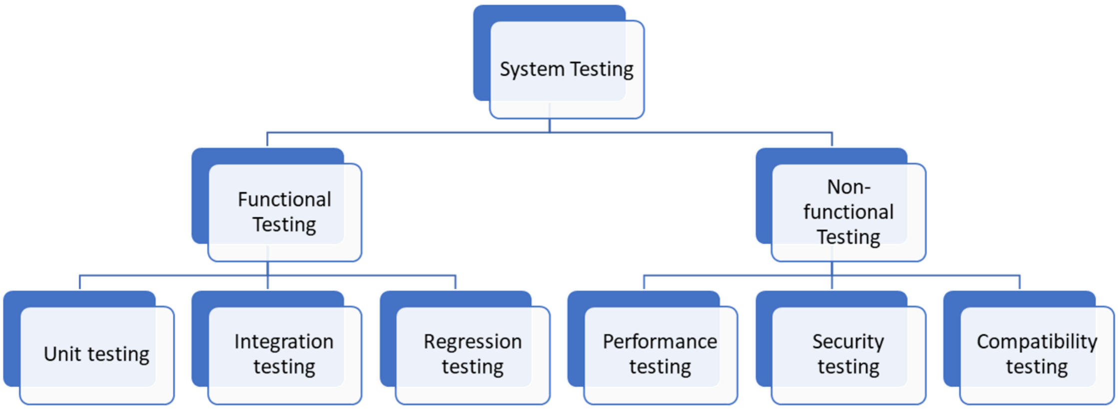

Figure 1. Common tests used for performing a system evaluation.

System testing includes several sequential steps, as shown in Figure 2, starting from the test plan. If errors have been detected during the result analysis step, these are resolved at the debugging step. Afterwards, the cycle is repeated until all errors have been resolved and no other errors are detected.

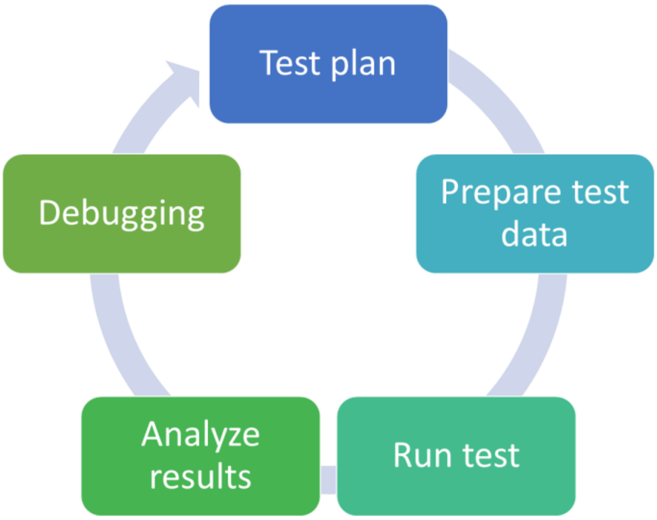

Figure 2. Steps of system testing.

The pre-validation plan that has been designed and followed within PARITY consists of the following points and activities:

1. Determination of the locations that are most suitable for the pre-validation in terms of available equipment and ease of deployment
2. Selection of software components to test and functionalities to test per each component
3. Specification of functionalities to test that depend on several software components
4. Specification of the tests to be performed at each location
5. Analysis of the test results & user experience, and implementation of corrective actions

In the project, there are two small-scale test beds, in Switzerland and Spain. In each case, various tests conducted to examine the functionality of the following components.

Table 1. Components deployed during the pre-validation phase for the small-scale test beds.

Component Name	Related WP
LEM/LFM Repository and off-chain component	WP5
Blockchain Platform	WP5
IoT network/IoT Gateway & IML Cloud	WP5
Oracle	WP5
DSO Toolset	WP6
D-STATCOM	WP6
Aggregator Toolset (Prosumer Flexibility Manager, VPP Manager, UI)	WP7
Demand Flexibility profiling and P2H	WP7
Prosumer Applications (BaaB App, Smart marketplace UI)	WP5, WP7

A set of properties have been defined for describing each test and its result. These include a numeric ID, the title of the tested functionality, the names of the involved PARITY component(s), whether pilot participants were involved or not, the related use cases, and the outcome. The related use case(s) are denoted by using their ID, according to Figure 3. The outcome can be 'Successful' or 'Failed' and include details about the identified issue and the corresponding corrective actions.

UC	Title
1	Building-level P2H/BAB flexibility estimation & automated provision to aggregator for LFM participation
2	Aggregated P2H flexibility estimation and provisioning for market participation pre-qualification
3	EV profiling and aggregated EV flexibility estimation for market participation
4	Human-centric and contract-safeguarding energy and flexibility transactions in LFM, on the basis of context-aware flexibility profiles
5	Forecasting, scheduling and dispatch of DER flexibility for coordinated management of the LFM grid
6	Smart grid management using enhanced PQ services for grid instability limitation
7	Ancillary services provision by STATCOM to TSO for overlay network stability
8	Congestion management by DSO through operation of LFM to increase DER penetration
9	Provision of ancillary services to overlay ancillary service market operated by TSO
10	Participation of LFM-enabled flexibility to national wholesale energy market
11	Red light (emergency) grid management using automated control of distributed DER (through smart contracts)

Individual and aggregated flexibility estimation
P2P energy and flexibility transactions in 'green' state
Smart Grid monitoring and control by DSO
DSO as flexibility buyer ('yellow' state)
LFM flexibility provision to TSO or BRP (through Aggregator)

Figure 3. List of use cases.

The following paragraphs provide a synoptic description of the main functionality tests that have been planned to be implemented on PARITY's Swiss and Spanish pilots.

Starting from the Tesserete Municipality building, in Switzerland, the pre-validation plan includes tests to examine the LEM's functionality in the green state, by using data from assets. The included components will be: IoT Gateway, IML Cloud, LEM/LFM Repository, Blockchain Platform, Oracle, Prosumer Flexibility Manager, Aggregator Toolset, BaaB App, Smart marketplace UI. In this case, the pilot participants will also get involved to provide the requested feedback.

The second test case in Switzerland, will be applied to residential customers to examine LEM's operation in the green state by using data from assets (combined with municipality building). The included components will be the identical to those in the previous test case (IoT Gateway, IML Cloud, LEM/LFM Repository, Blockchain platform, Oracle, Prosumer Flexibility Manager, Aggregator Toolset, BaaB App, Smart marketplace UI). Additionally, the feedback of residential customers will be considered.

The Spanish URBENER building will be used to test the platform's flexibility profiling functionality. In this test case, the IoT Gateway, IML Cloud, LEM/LFM Repository, and Prosumer Flexibility Manager modules will be involved, while the pilot's participants will not take part in the testing operations. In the same pilot building, the assets control and information visualisation functionality will also be tested. In particular, the process will include the IoT Gateway, the IML Cloud, the LEM/LFM Repository, the BaaB App, and feedback from the pilot participants.

Lastly, the Cuerva's grid, in Spain, will be utilised to test two extra functionalities. The DSO Toolset grid monitoring and grid status estimation-forecasting will be tested. Two components will be involved: the DSO Toolset (along with its UI) and the LEM/LFM Repository. Typically, there will be no participant feedback, but if necessary, a DSO partner will provide it. The second functionality test is related to D-STATCOM ANM and involves the D-STATCOM and DSO Toolset components. This test case will not involve any pilot participants.

2.2 Locations

CERTH/ITI nZEB – DIH: CERTH/ITI Smart House is a nearly zero-energy building (nZEB) which is used as a rapid prototyping testbed. It is equipped with a vast variety of sensors (power meters, environmental, occupancy etc.), actuators, smart home appliances, an EV charger and other devices. The consumption of the entire building is monitored through smart power meters, while automated algorithms that have been developed allow the application of building automation and building efficiency scenarios. The building can operate as a microgrid by utilising an adjacent PV plant of approximately 10KWp and a stationary battery unit of approximately 5KWh.

Hypertech building: Hypertech Energy Labs laboratory set-up is hosted at the company's headquarters and is used to serve the functional testing requirements of a wide variety of projects. Its main objective is to test the functionality of newly developed services before releasing them to real life environments to proceed with their beta testing. The IoT equipment installed at the fully fledged lab facilities comprise a wide range of indoor conditions sensing equipment, home displays & thermostats, energy metering devices, status monitoring & actuating devices, as well as several gateways. For testing purposes, different loads including two air-to-air heat pumps and a small electric water heater are available on site, with a total flexibility potential of about 6 kW.

Small-scale pilot deployments

The small-scale pilot deployments in the Swiss pilot site involve the following areas:

- Tesserete Municipality Building
- 2 residential customers that are part of Luggagia community

Furthermore, the small-scale pilot deployments in the Spanish pilot site involve the following areas:

- Offices in URBENER building
- Offices in ACESA building
- Cuerva's grid

3. TESTBEDS IN CONTROLLED ENVIRONMENT

3.1 CERTH/ITI nZEB – DIH

The first controlled environment is used to test the functionalities provided by the LEM/LFM Repository and the off-chain component. The VPP manager component uses the pilot to execute several tests, focusing on the red state scenario. The installed EV charger infrastructure enables communication testing activities via the OCPP protocol. Lastly, the building's advanced IoT network facilitates the collection of data to test the occupancy estimation and forecasting functionalities.

3.1.1 Test of LEM/LFM Repository and off-chain component

Table 2. Summary of tests in controlled environment (LEM/LFM Repository and off-chain component).

ID	Tested functionality	Involved component(s)	Pilot participants involved	Related use case(s)	Outcome
1	Handling of multiple simultaneous or sequential requests	LEM/LFM Repository, Off-chain component	No	All UCs	Successful. Automatically tested via the use of a script for 24 hours
2	Retrieval of past day weather data for given location and storage in the database for future use	LEM/LFM Repository	No	UC-1, UC-2, UC-5	Successful
3	Automated calculation of irradiance metrics for given location based on cloud coverage (for use in PV generation forecasting)	LEM/LFM Repository, PV Manager	No	UC-1, UC-2, UC-5	Successful
4	Authentication and authorisation (user authentication and token-based access control)	LEM/LFM Repository	No	All UCs	Successful

3.1.2 Test of EV profiling and smart charging

Tests of the developed algorithms for EV profiling within the EV profiling and smart charging component have been performed by using also real-life data about EV charging sessions that were provided by the pilot partners (BFS). The data consist of EV charging sessions gathered from two charging outlets, with 209 and 86 recorded sessions each, totalling at 295 recorded charging sessions. In the whole data range, only two occurrences of overnight charging were spotted due to the usage of the EV charging station, as can be seen in Figure 4 below. The metered data consisted of: Transaction ID (charging session's unique identifier), Charger ID (EV Charger's unique identifier), Account ID (EV owner's unique identifier), Start Time (time at the beginning of the charging session), End Time (time at the end of the charging session) and Charge Amount (amount of total energy transferred to the EV during the whole charging session, metered in kWh).

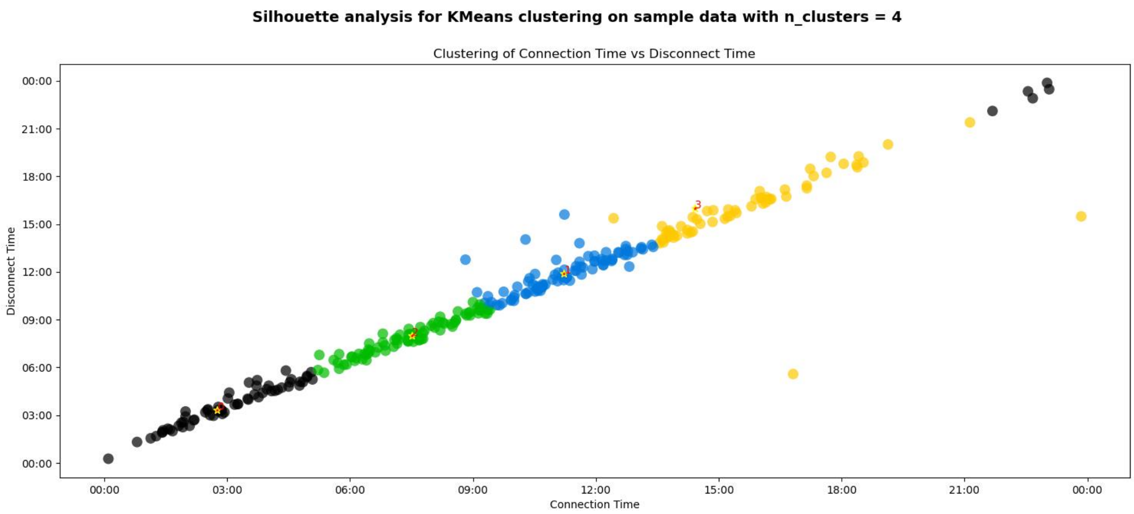

Figure 4. Clustering past EV charging sessions based on connection and disconnection times.

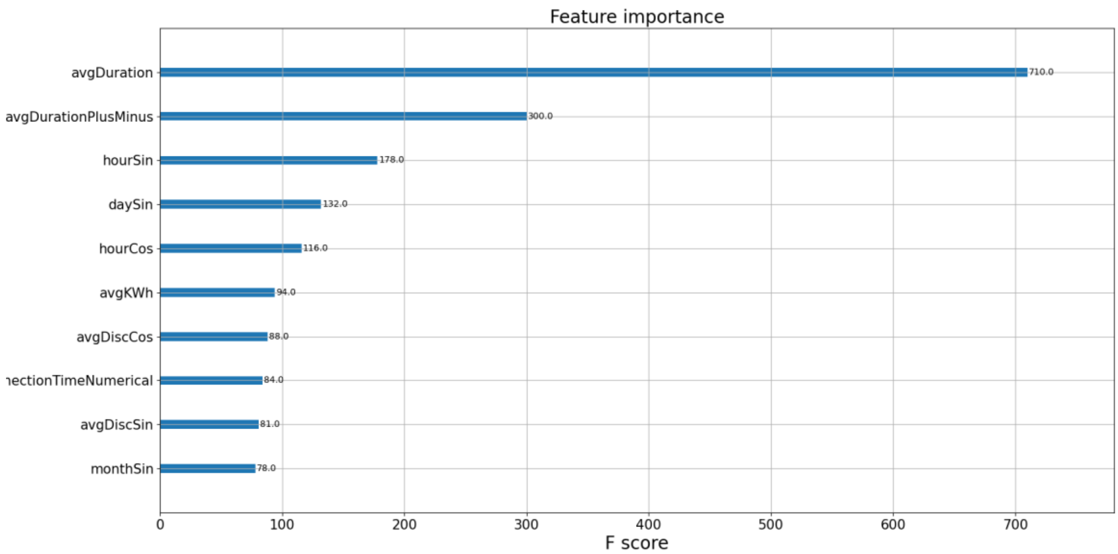

Figure 5. Feature importance results.

MAE of final model = 0.113

MAPE of final model = 0.199

Coefficient of determination (R2) of final model = 0.313

RMSE of final model = 0.154

Table 3. Summary of tests in controlled environment (EV Profiling and Smart Charging).

ID	Tested functionality	Involved component(s)	Pilot participants involved	Related use case(s)	Outcome
1	Prediction of EV departure time	EV Profiling and Smart Charging	No	UC-3	Successful
2	Clustering past EV charging sessions	EV Profiling and Smart Charging	No	UC-3	Successful

3.1.3 Test of Aggregator Toolset

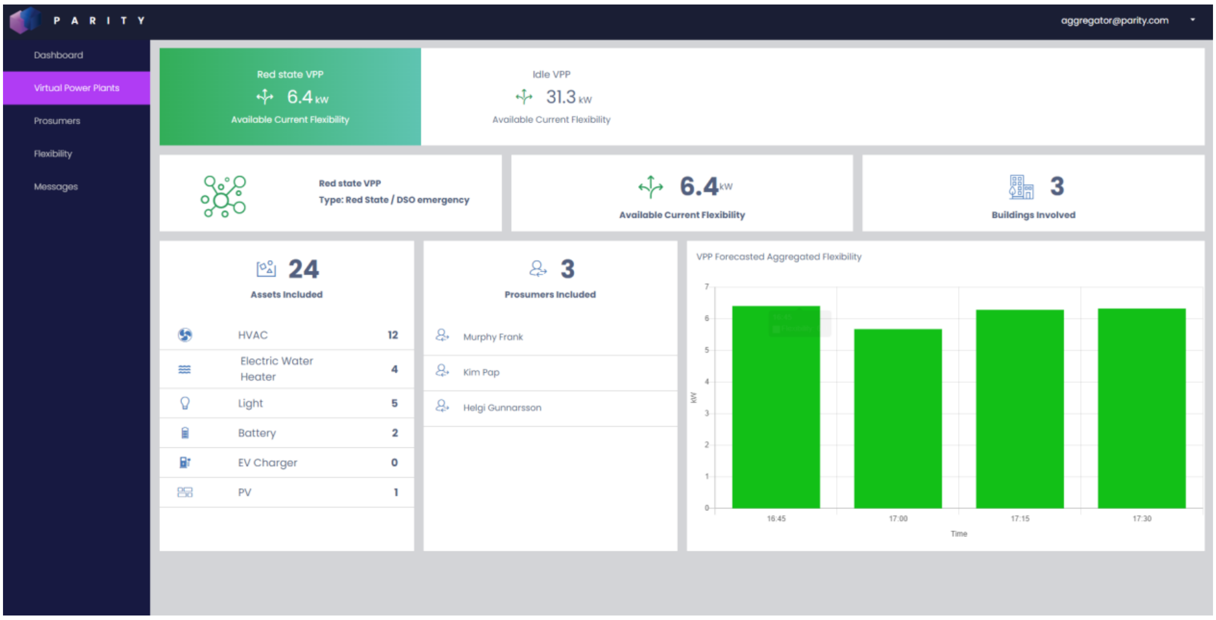

Figure 6. Formulated dynamic VPPs visualization through the Aggregator Toolset UI.

Table 4. Summary of tests in controlled environment (Aggregator Toolset).

ID	Tested functionality	Involved component(s)	Pilot participants involved	Related use case(s)	Outcome
1	Aggregation of BaaB flexibility bundles of prosumers	Aggregator Toolset	No	UC-2	Successful. Improvements required on how virtual battery characteristics are set.
2	Flexibility activation	Aggregator Toolset	No	UC-5	Successful
3	Dynamic VPP formation in emergency 'red' grid state	Aggregator Toolset	No	UC-11	Successful

3.1.4 Test of Prosumer App (Marketplace UI)

Table 5. Summary of tests in controlled environment (Marketplace UI).

ID	Tested functionality	Involved component(s)	Pilot participants involved	Related use case(s)	Outcome
1	Display of current state of grid and active markets in the dashboard	Marketplace UI , LEM/LFM Repository	No	All UCs	Successful
2	Retrieval and presentation of prosumer's past transactions information	Marketplace UI, LEM/LFM Repository, Oracle	No	UC-4, UC-5, UC-8	Successful
3	Retrieval and presentation of prosumer's SLAs information	Marketplace UI, LEM/LFM Repository	No	UC-4, UC-5, UC-8, UC-9, UC-10, UC-11	Successful
4	Presentation of received text messages	Marketplace UI, LEM/LFM Repository	No	UC-9, UC-10, UC-11	Successful

3.2 HYPERTECH Building

In Hypertech labs, the Oracle and Blockchain Agent components have been deployed for testing. The components are deployed at four gateways and they perform market operation trials in collaboration with HIVE, using two prosumers, one DSO, and an Aggregator (4 nodes in total). Additionally, the IML Cloud and the P2H component are deployed on Hypertech's server. The latter utilises the lab set-up at Hypertech's premises to conduct multiple operation tests.

3.2.1 Test of IoT network

As the IoT network deployed and demonstrated in PARITY is an extended version of Hypertech's solution, the testing performed on site was generally focused on assessing the usability and reliability of new devices implemented in the project. In addition, functional tests were performed to ensure the remote control functionalities of the actuating devices available on site. The testing outcomes are summarized in the following table.

Table 6. Summary of tests in controlled environment at Hypertech labs (IoT equipment).

ID	Tested functionality	Involved component(s)	Pilot participants involved	Related use case(s)	Outcome
1	WiFi Energy meter compatibility with IoT Gateway	Shelly EM energy meter & IoT Gateway	No	All UCs	Successful. Despite the success of the test, further development work was necessary for the full incorporation of the device in the commissioning process.
2	Load controllability through the mobile UI	IoT Gateway & Prosumer application	No	N/A	Failed – the HVAC set-point was not properly updated in the prosumer app. The problem was solved by modifying the way the asynchronous message exchange worked.
3	Load controllability through control automation	IoT Gateway & Control dispatch and monitoring (PFM)	No	UC-6, UC-9, UC-10, UC-12	Successful

3.2.2 Test of Oracle

Table 7. Summary of tests in controlled environment at Hypertech labs (Oracle component).

ID	Tested functionality	Involved component(s)	Pilot participants involved	Related use case(s)	Outcome
1	Request/Receive Prosumer Balance from Blockchain Platform	Oracle, Blockchain Agent	Yes	UC-6	Successful
2	Provide Prosumer Balance to the LEM/LFM Repository	Oracle, LEM/LFM Repository	Yes	UC-6	Successful
3	Request/Receive Metering Data from IML	Oracle, IML Cloud	Yes	UC-6	Successful
4	Calculate KPIs from Metering Data	Oracle,	Yes	UC-6	Successful
5	Provide KPI Data to Blockchain Platform	Oracle, Blockchain Agent	Yes	UC-6	Successful

3.2.3 Test of Flexibility profiling and P2H

Table 8. Summary of tests in controlled environment at Hypertech labs (Flexibility profiling and P2H component).

ID	Tested functionality	Involved component(s)	Pilot participants involved	Related use case(s)	Outcome
1	Request/receive building-level data from the IML Cloud	IML Cloud	Yes	UC-1, UC-2, UC-4	Successful
2	Train P2H models	-	Yes	UC-1, UC-2, UC-4	Successful
3	Perform optimisations for building-level flexibility forecasts	-	Yes	UC-1, UC-2, UC-4	Successful

In more detail, the following tests were performed at the Hypertech labs:

The Flexibility Profiling and P2H module requested historical sensor and metering data from the IML cloud – the data are gathered from the IoT devices deployed at the Hypertech offices. Data on implicit and explicit control actions[1] performed by the users are also retrieved and analysed to deduce useful information on the comfort preferences of occupants.

The data were then used to train the P2H models (Figure 7) and produce profiling data for the Hypertech building, its devices and the occupants in the offices. Below, the comfort profile of an occupant produced is given (Figure 8). The profile is considering the occupancy profile of the occupant, as well as their thermal comfort preferences.

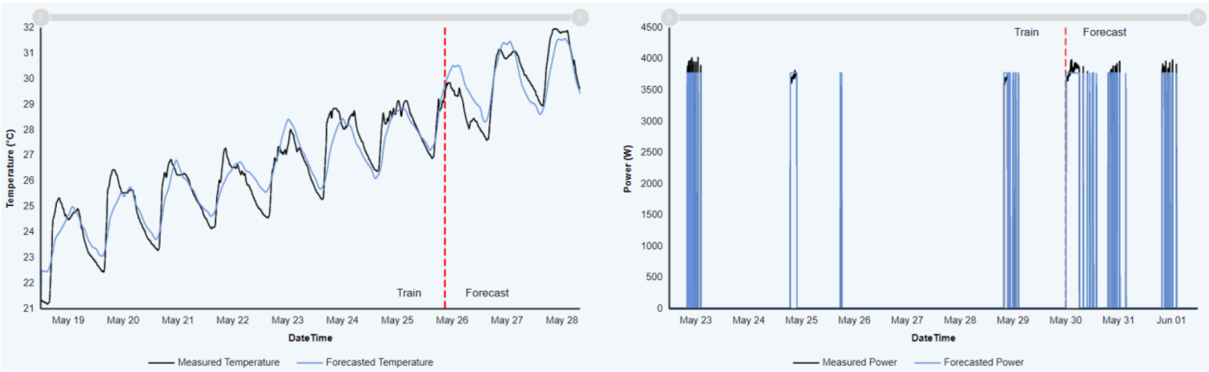

Figure 7. Forecasted vs measured space thermal conditions and HVAC consumption during and post-training of P2H models.

Figure 8. Occupancy and thermal comfort profile of an occupant at the Hypertech labs.

Once the different P2H models were sufficiently trained, the optimizer of the BaaB component utilizing these models, forecasted the power required for the operation of the HVAC system at the labs to ensure that the occupant is kept at maximum comfort (baseline scenario, Figure 9), as well as the available upwards and downwards flexibility that the HVAC system can offer without compromising the occupant's comfort (Figure 10, Figure 11).

[1] Explicit events refer to comfort and discomfort events that are extracted from control actions that the occupant performs to adjust, for example, the HVAC systems' operation to his/her preferences. Implicit events refer to comfort events that can be implicitly extracted when there are no actions to the HVAC controllable elements for a long period. For instance, when the occupant is present and does not react to current conditions or shows tolerance and acceptance of the current conditions, it is inferred that he/she feels thermally comfortable.

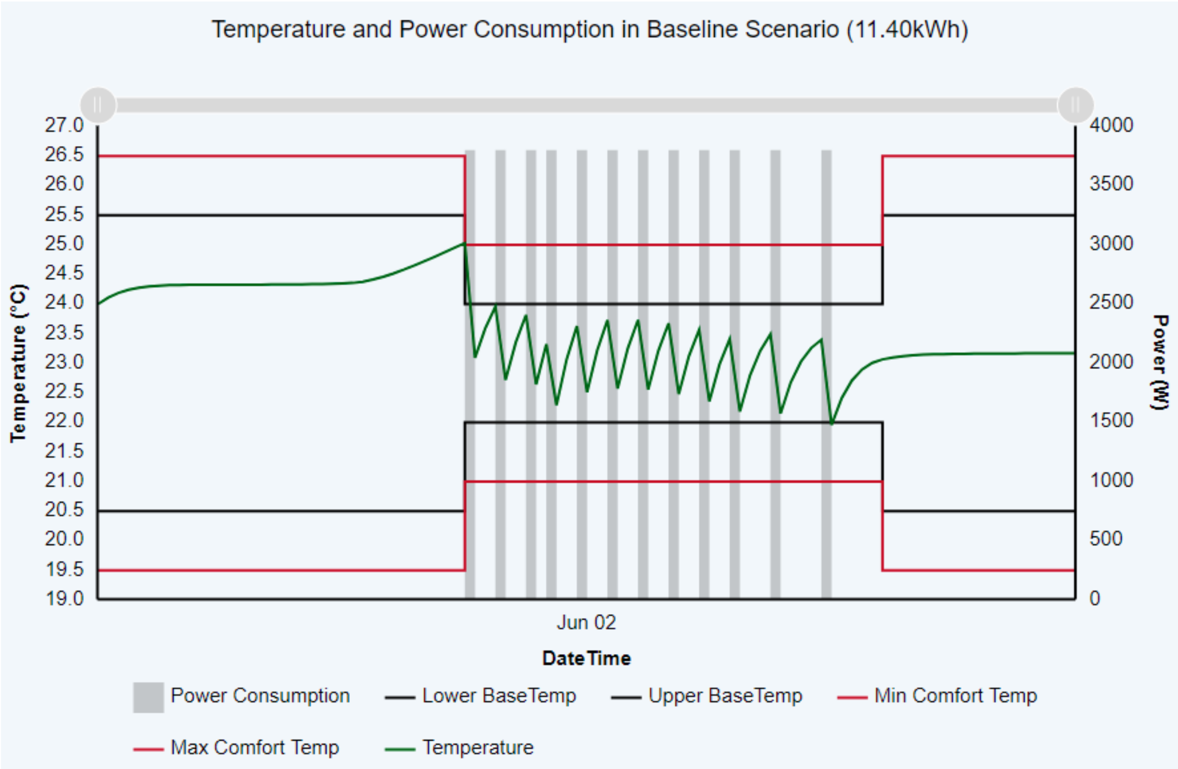

Figure 9. HVAC baseline consumption for maximum occupant comfort.

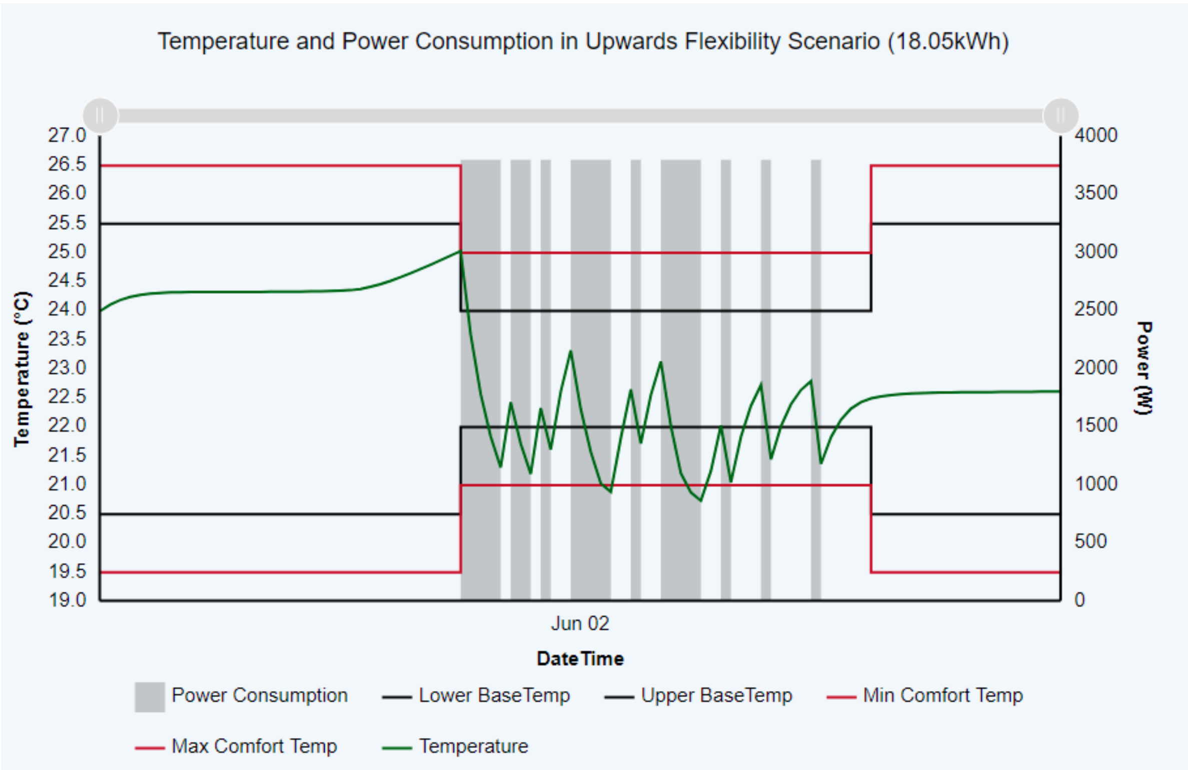

Figure 10. Upwards flexibility forecast for the lab HVAC system.

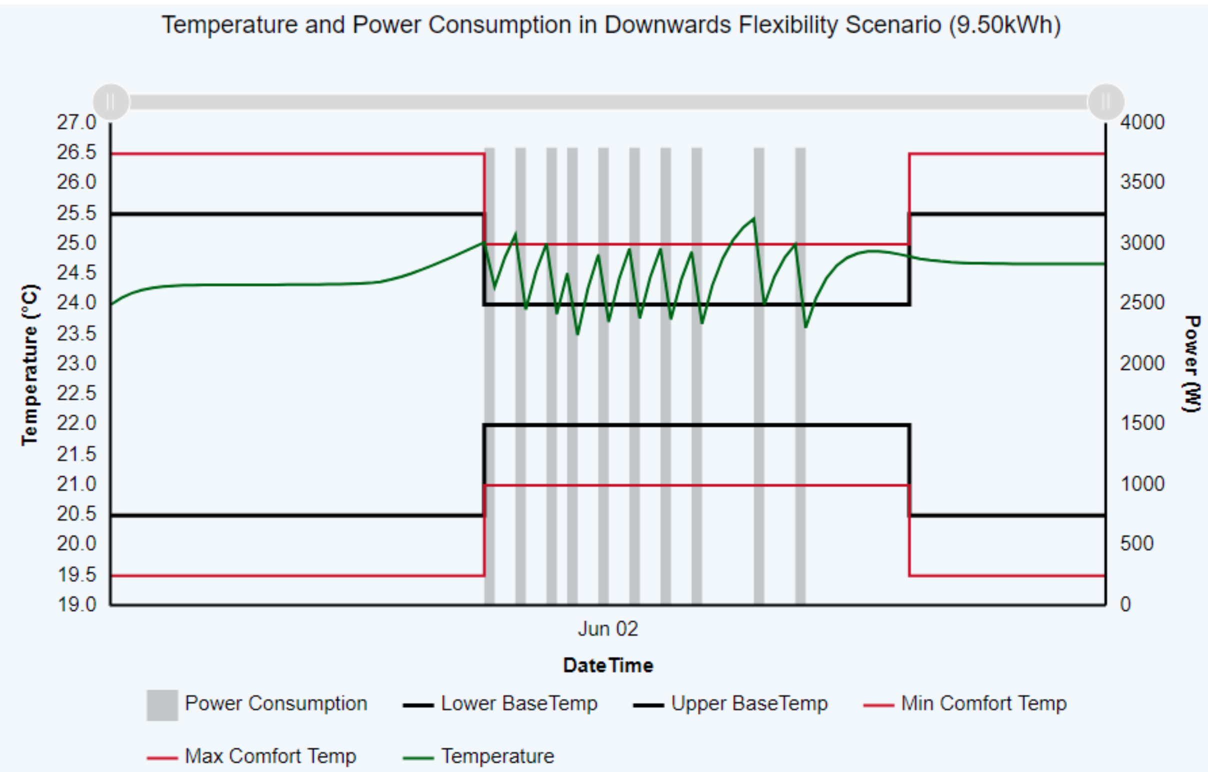

Figure 11. Downwards flexibility forecast for the lab HVAC system.

3.2.4 Test of Aggregator Toolset

The Prosumer Flexibility Manager module of the Aggregator Toolset was tested at the Hypertech labs, but also using data from an actual pilot participant from the Greek demo.

The test included the retrieval of flexibility forecasts from available controllable loads at the participant's premises, as well as PV forecasts from the participant's PV installation. No EV forecasts were available, as the participant does not have an EV.

The PFM module, upon successful retrieval of the aforementioned flexibility and PV forecasts, calculated (under a day-ahead assumed scenario) the prosumer-level flexibility forecast. Following this calculation, an implementation of a self-consumption scenario was also tested successfully. The results of this implementation can be found in Figure 12.

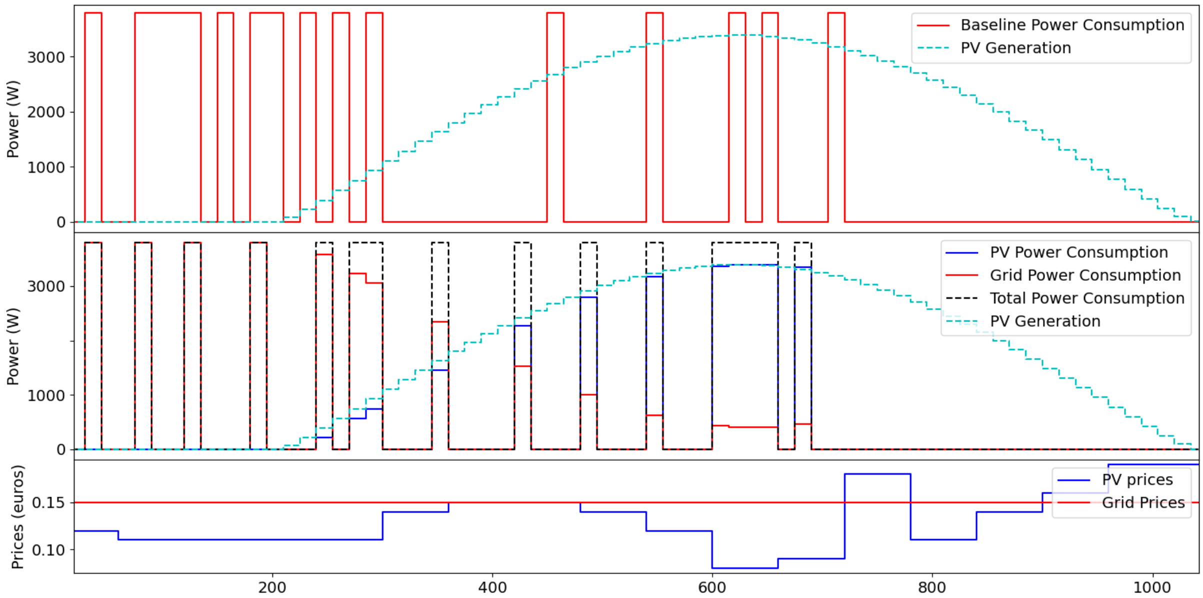

Figure 12. Implementation of self-consumption scenario by the PFM module of the Aggregator Toolset [2].

Table 9. Summary of tests in controlled environment at Hypertech labs (Aggregator Toolset).

ID	Tested functionality	Involved component(s)	Pilot participants involved	Related use case(s)	Outcome
1	Retrieve flexibility forecasts from prosumer-level assets	Prosumer Flexibility Manager (Aggregator Toolset), Building-as-a-Battery module, PV Manager, EV Profiling and Smart Charging module	Yes	UC-1, UC-5, UC-8, UC-9, UC-10	Partially Successful (the retrieval of EV flexibility forecasts was not possible, as there were no EV chargers/EVs available)
2	Calculation of prosumer-level flexibility	Prosumer Flexibility Manager (Aggregator Toolset)	Yes	UC-5, UC-8, UC-9, UC-10	Successful
3	Implementation of a self-consumption optimisation scenario	Prosumer Flexibility Manager (Aggregator Toolset)	Yes	-	Successful

3.2.5 Test of Prosumer App (BaaB App)

Prior to the release of the functional version of the Prosumer App for mobiles, a mock-up interactive version of the application was shared within the PARITY consortium. With the assistance of UDEUSTO, who provided the consortium with a detailed feedback form which allows users to provide feedback consistently, the user experience was evaluated against its usability, functionalities, performance, and user friendliness. The feedback was then used as an input for the development and refinement of the final version of the Prosumer App.

The mobile Prosumer App was partially tested at the available pre-validation sites. More specifically, at the Hypertech labs and a couple of pilot users of the Greek pilot, the BaaB App module of the Prosumer App toolkit was tested. Table 10 summarizes the key tests of the BaaB App that were performed.

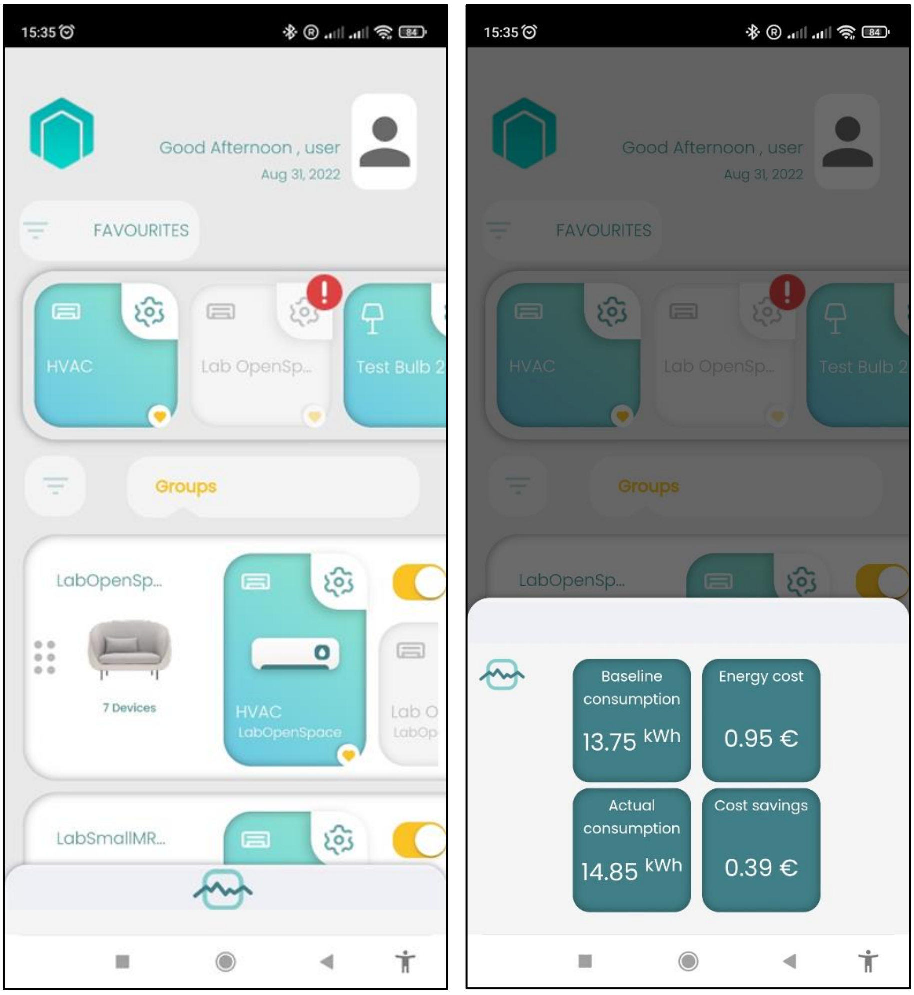

Figure 13. Information on appliances and energy consumption/cost via the BaaB App.

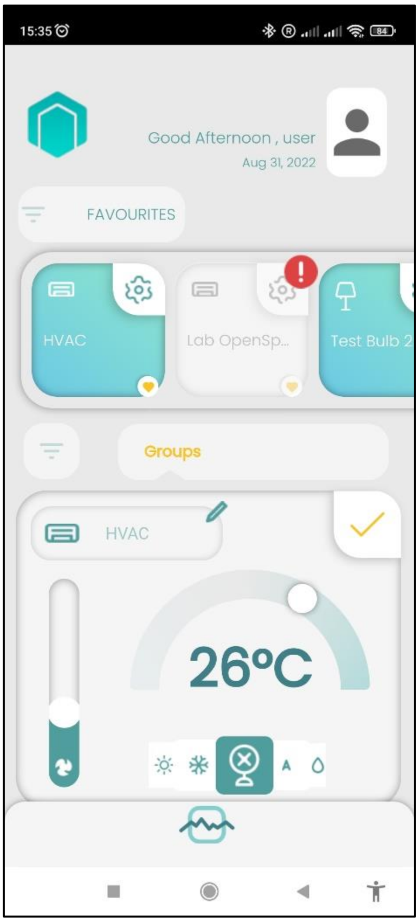

Figure 14. Remote control of selected appliance via the BaaB App.

Table 10. Summary of tests in controlled environment at Hypertech labs (BaaB App).

ID	Tested functionality	Involved component(s)	Pilot participants involved	Related use case(s)	Outcome
1	Retrieval of IoT data	IoT gateway, BaaB app module	Yes	-	Successful
2	Prosumer login	BaaB app module	Yes	-	Successful
3	Display of prosumer-level information	BaaB app module	Yes	-	Successful
4	Remote control over available controllable devices	BaaB app module, IoT gateway	Yes	-	Successful

3.3 Results and Corrective Actions

Testing of the Oracle component at the Hypertech labs, as well as the Blockchain Agent, revealed the need for the implementation of an OpenVPN solution to avoid problems with changing IoT gateway IPs of the participating prosumers. The latter would affect the communication between the gateway and other PARITY solution components.

The testing of the BaaB application by actual end-users at the Greek pilot helped a lot with the debugging of the application prior to its wider release to all PARITY users. During the installation and testing of the application, the two users were involved in testing the main functionalities of the application (e.g., visualisation of ambient conditions, status of devices, etc, and remote control over controllable devices), reporting possible bugs and providing feedback. Based on the outcomes of the tests, fixes were implemented in a newer release of the BaaB app, which will be deployed to all relevant PARITY pilot users.

In general, the tests of the IoT equipment and the software components that were conducted in the controlled environments of CERTH/ITI nZEB building and labs in Hypertech building, helped to validate that supported functionalities and algorithmic approaches have been implemented correctly, as well as to identify issues related to the stability of the system, and the integration and data exchange between the PARITY components during the operation of the LEM/LFM. In all cases of initially unsuccessful tests, identified problems have been resolved and correct operation was confirmed through subsequent tests.

4. SMALL-SCALE PILOT DEPLOYMENTS

The small-scale pilot deployments at the Swiss and Spanish sites have been performed in order to test functionalities of specific use cases that require the operation of several PARITY components in an integrated manner. Special focus has been given in the validation of a small-scale local market operation, by using actual data from consuming/producing assets that are available on-site.

4.1 Luggagia Innovation Community, AEM Pilot Site, Switzerland

This pilot case is used to demonstrate the LEM operation at the 'green' state in a grid. The sidechain ruling the LEM, based on Cosmos technology, is basically running at the Swiss pilot (Lugaggia). There are four key components involved, including Blockchain, Blockchain Agents, LEM/LFM Repository, Oracles, and Smart Marketplace UI. Data from 9 prosumers are used to test the functionalities of the above mentioned components.

The sidechain balances data are updated every quarter of hour on the Repository via Parity Oracles that take the data from the Blockchain Agent REST API. A prosumer can logon to the Marketplace UI to view current and historical information related to his/her participation in the market. Figure 15. Flow of informationFigure 15 illustrates the main flow of information.

Figure 15. Flow of information.

A PARITY sidechain must be constituted of a DSO node, an Aggregator node and a set of Oracles/prosumers nodes, as presented in Figure 16. This demo is comprised of a total of 11 nodes, as 9 oracles are installed in the Lugaggia pilot. Table 11 presents the technical characteristics of each node type.

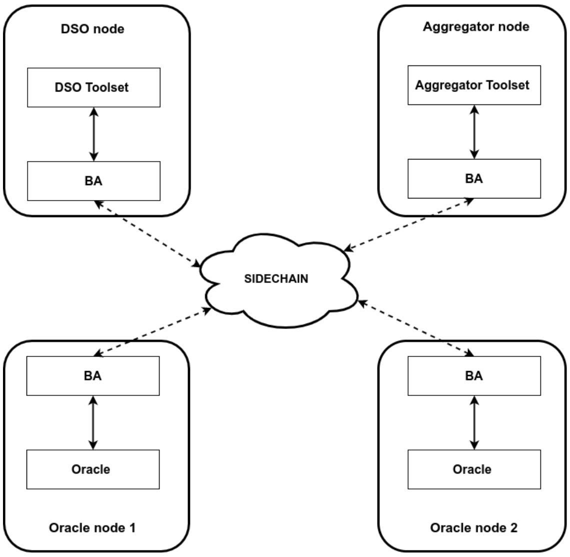

Figure 16. PARITY Sidechain.

Table 11. Node characteristics.

DSO node (dso)	• Runs on lab.fcirce.tech CIRCE VM • Validator node • 8 cores KVM, 8 GB RAM, 32 GB HD
Aggregator node (agg)	• Runs on CERTH VM • Validator node • 4 cores i7, 8 GB RAM, 32 GB HD
Oracle nodes	• Run on Strato device, based on Raspberry Pi3 board • Simple node • 4 cores ARMv7, 1 GB RAM, 32 GB HD

Figure 17 demonstrates the metering configuration. The device inside the green rectangle is the Smart Meter. The Strato device is in the red rectangle, while the blue rectangle includes the connectivity dongle meter. Finally, the Optical reader between the Strato and the meter the Violet circle is indicated with the violet circle.

Figure 17. Metering Configuration.

Moreover, additional IoT devices that have been deployed and utilized during the pre-pilot testing in the Swiss pilot are shown in the following figures.

Figure 18. Energy meters connected to the AC units power cables.

Figure 19. From left to right: IoT Gateway installed in the Municipality building, IR universal control for air condition automatic management, and multisensor installed on desk in office room.

Figure 20 illustrates the LEM Operation procedure. According to coloring code used in this schema, the DSO is represented with an orange rectangle, the aggregator with a green, while the rest of the colors are used to represent the rest of the prosumers.

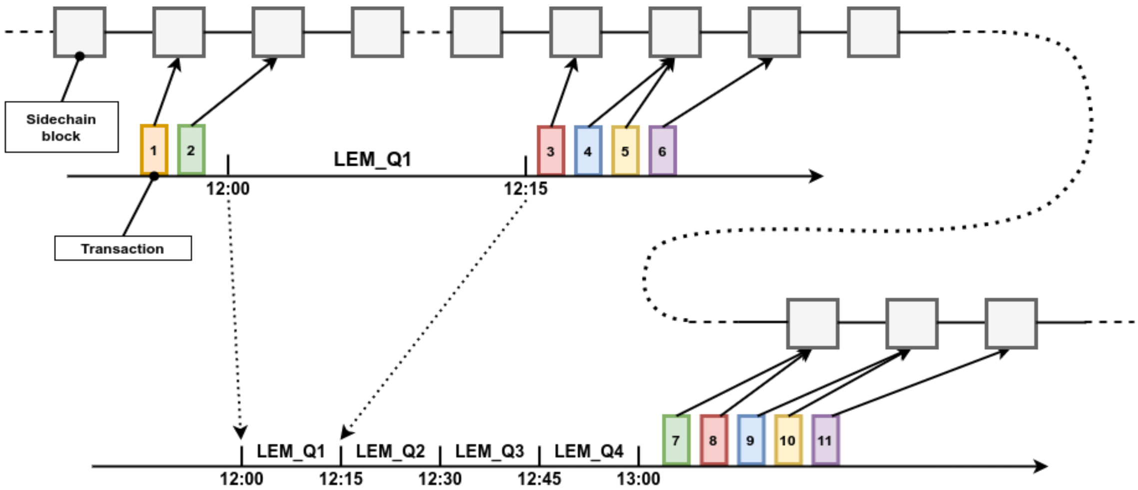

Figure 20. LEM Operation schematic diagram.

4.1.1 Test of IoT network

Before its deployment at the Swiss pilot sites, the IoT network setup was extensively tested at Hypertech's testbed to ensure the equipment's uninterrupted operation and seamless communication. As no additional, pilot specific devices were deployed, the only testing performed on-site was the validation of the received data to ensure the correct devices' installation, and the testing of the communication with the actuators installed locally. Any issues identified at this point were solved on spot by the commissioner. However, as these tests comprise the validation considered as part of the standard system installation process they are not further reported in this section.

4.1.2 Test of LEM/LFM Platform and Blockchain

Table 12. Summary of small-scale pilot tests (LEM/LFM platform and Blockchain).

ID	Tested functionality	Involved component(s)	Pilot participants involved	Related use case(s)	Outcome
1	Return responses in JSON format regardless of the content's size	LEM/LFM Repository	No	All UCs	Failed in cases where large number of events are found. Solved by configuring the application server to use more heap memory
2	Stability of operation	LEM/LFM Repository Off-chain component	No	All UCs	Failed occasionally. Optimization in the host operating system was made to solve excessive disk usage
3	Oracle updates the amount of tokens of each prosumer periodically in LEM	LEM/LFM Repository, Oracle	No	UC-4, UC-5, UC-8	Successful

4.1.3 Test of Prosumer App

Table 13. Summary of small-scale pilot tests (Marketplace UI).

ID	Tested functionality	Involved component(s)	Pilot participants involved	Related use case(s)	Outcome
1	Data retrieval and visualisation to the Dashboard	Marketplace UI, LEM/LFM Repository	Yes	UC-4, UC-5, UC-8, UC-9, UC-10, UC-11	Successful

2	Presentation of the current amount of prosumer’s tokens dynamically	Marketplace UI, LEM/LFM Repository	Yes	UC-4, UC-5, UC-8, UC-9, UC-10, UC-11	Successful
3	Calculation and visualisation of daily performance metrics based on past transactions data	Marketplace UI, LEM/LFM Repository	Yes	UC-4, UC-5, UC-8, UC-9, UC-10, UC-11	Successful. Further improvements in the presentation of information (graphs) to be made.

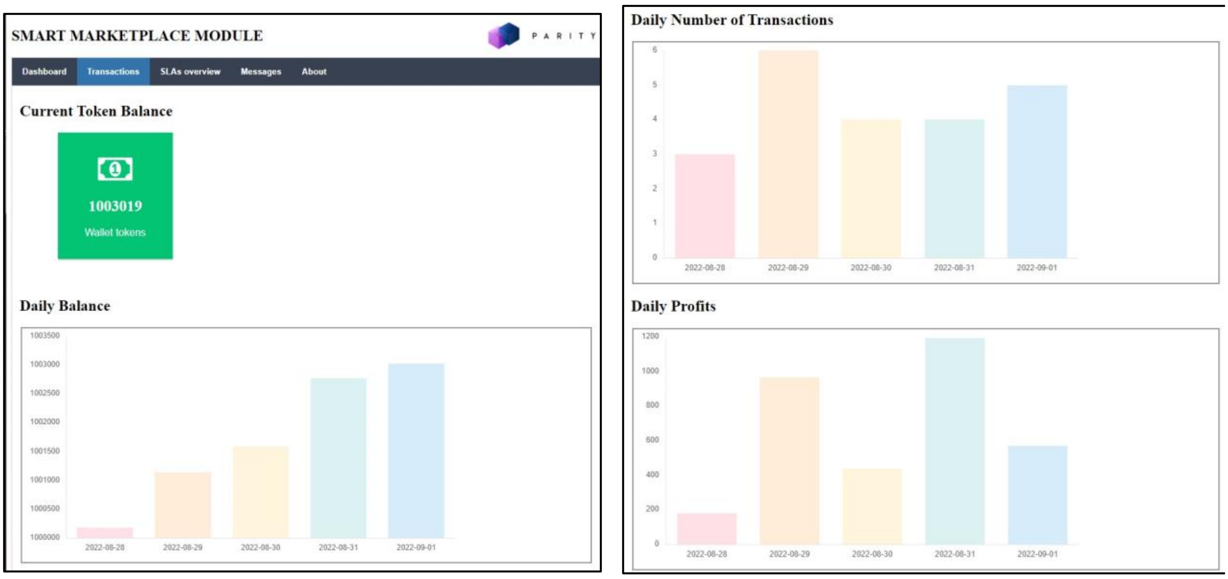

Figure 21. Marketplace UI.

4.2 Escuzar Area and Office Buildings, CUERVA & URBENER Pilot Site, Spain

The small-scale test bed at the Spanish pilot includes the grid network model of CUERVA (topology and power data) as well as selected spaces within the URBENER and ACESA office buildings. Indicative photographs of the deployed equipment (sensors, power meters, IoT Gateway) in the latter case are shown in the figures below.

Figure 22. Deployed equipment (from left to right): Aeon Labs Multisensor, Aeotec clamp power meters, Raspberry Pi 4 model B as IoT Gateway.

4.2.1 Test of IoT network

As in the case of the Swiss pre-validation site, part of the Spanish pilot and more specifically the URBENER headquarters are also part of the PARITY pre-validation activities. However, in the case of the URBENER building, additional site-specific equipment was deployed necessitating additional testing activities on-site to ensure its correct operation and integration with the PARITY system. More specifically, to remotely monitor and control the air-to-air heat pump available on site, a dedicated gateway was installed, namely an Intesis gateway for the integration of Hitachi VRF systems into Home Automation systems. Due to the lack of previous experience with the specific system, and the difficulty in testing the system at Hypertech's lab set-up as the specific HVAC system was not available, the equipment had to be commissioned and tested remotely through coordinated activities of Hypertech and URBENER. The testing included the device's functionality, reliability and communication with the PARITY system. Details of the conducted test activities are summarized in the following table.

Table 14. Summary of small-scale pilot tests (IoT network).

ID	Tested functionality	Involved component(s)	Pilot participants involved	Related use case(s)	Outcome
1	Communication of Intesis gateway with IoT Gateway	Intesis Gateway & IoT gateway	No	UC1, UC2, UC4, UC5, UC6, UC8, UC10,UC11	Successful
2	Individual HVAC indoor unit controllability through control automation	Intesis Gateway & IoT gateway	No	UC6, UC9, UC10, UC12	Successful

4.2.2 Test of DSO Toolset

The pre-validation testing of the DSO Toolset has been focused on the functionalities related to grid state estimation and forecasting according to the traffic light concept, the communication with the LEM/LFM Repository, and the presentation of information via the developed UI.

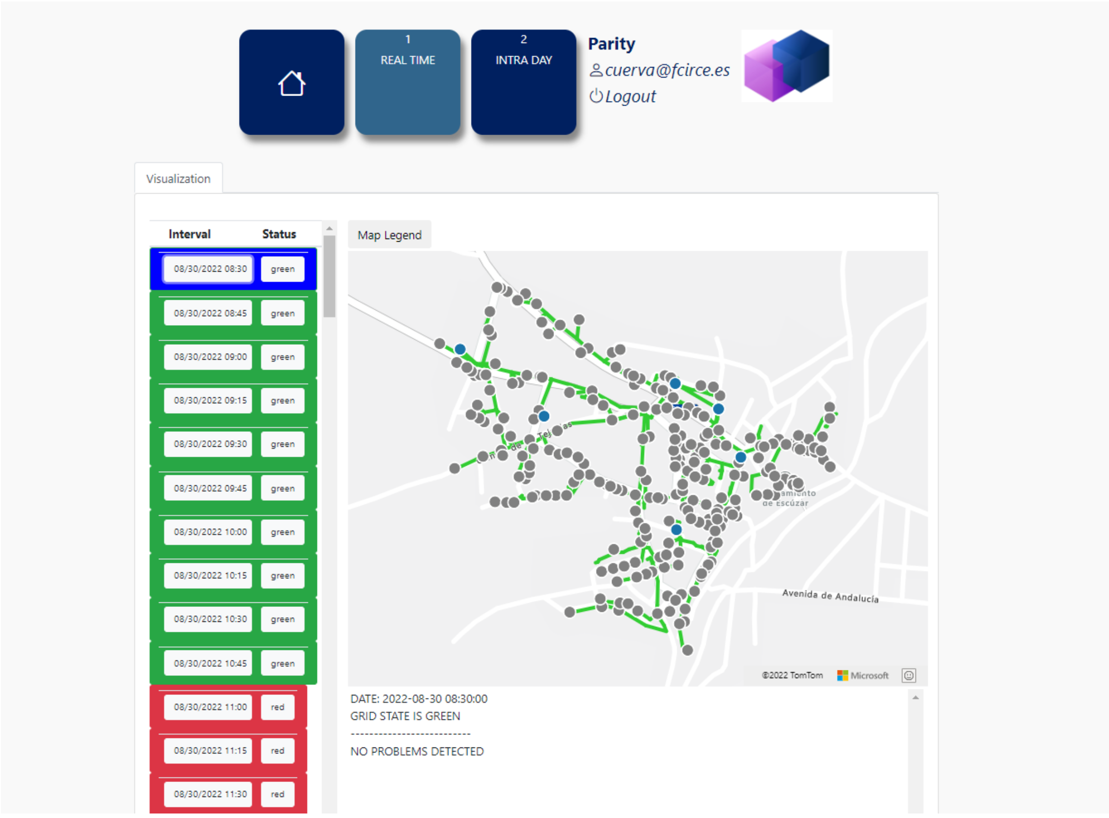

Figure 23. DSO Toolset UI when operating using data of the Spanish pilot grid.

Table 15. Summary of small-scale pilot tests (DSO Toolset).

ID	Tested functionality	Involved component(s)	Pilot participants involved	Related use case(s)	Outcome
1	Forecasting of the grid state according to the traffic light concept	DSO Toolset	No	UC-6, UC-7, UC-8, UC-11	Successful
2	Communication with the LEM/LFM Repository to store and retrieve data in JSON format	DSO Toolset, LEM/LFM Repository	No	UC-6, UC-7, UC-8, UC-11	Successful
3	Calculation and extraction of grid-related constraints	DSO Toolset, LEM/LFM Repository, Aggregator Toolset	No	UC-11	Successful
4	Presentation of grid state and detected/forecasted congestions in the UI	DSO Toolset	No	UC-6, UC-7, UC-8, UC-11	Successful

4.2.3 Test of D-STATCOM module

The assembled D-STATCOM module is presented in the figure below.

Figure 24. D-STATCOM module.

Prior to the deployment and operation at the pilot site of CUERVA, pre-validation tests have been performed at the lab, in order to make sure that it will operate properly at the pilot and to minimise the chance of integration problems.

Table 16. Summary of small-scale pilot tests (D-STATCOM).

ID	Tested functionality	Involved component(s)	Pilot participants involved	Related use case(s)	Outcome
1	Control loop	D-STATCOM	No	UC-6, UC-7, UC-8, UC-11	Successful
2	Control and functional tests at different operating points	D-STATCOM	No	UC-6, UC-7	Successful
3	Maximum power tests	D-STATCOM	No	UC-6, UC-7	Successful
4	Thermal tests	D-STACOM	No	UC-6, UC-7	Successful
5	Communication tests	DSO-Toolset, D-STATCOM	No	UC-6, UC-7	Improvements were required

4.3 Results and Corrective Actions

The vast majority of the designated tests at the small-scale pilots were performed successfully without any issues. For the tests and usage scenarios that did not produce the expected results, corrective actions have been performed. These include improvements in (a) the configuration and deployment of software solutions, in (b) data handling and implementation of the defined communication interfaces, and (c) in the design of user interfaces and information visualization. After the application of the corrective actions, the tests were repeated in order to confirm that the detected issues have been resolved.

In addition to the targeted tests that were performed at the small-scale pilot deployments during the pre-validation phase, received feedback by selected pilot participants for individual technology solutions will be reviewed and analysed in order to identify any aspects that need to be improved. This is achieved via the presentation of the solutions and their functionalities using multimedia material (slides, videos) and hands-on experience sessions.

Through this procedure it is possible to evaluate aspects that are related to:

- Usefulness of the solution for improving productivity and performance
- Usability and user experience
- Presentation of all necessary information to the users
- Adequate measures for user privacy

Special attention has been given to improve the user interfaces (if applicable) of the solutions in order to (i) make them simple to use and navigate, (ii) visualise the information using graphical elements and explanations where possible, and (iii) provide notifications to the user about occurring events as well as data handling and privacy.

As far as the deployment of the system is concerned, the feasibility of distributed deployment across different networks and locations was tested allowing to better understand the deployment requirements. The trials allowed to confirm the installation of components that are hosted on the same physical or virtual machine. Moreover, the steps to follow with regard to the configuration that need to be made for each component after the deployment on a new site, were clarified. Lastly, deployments already made for the Swiss and Spanish pre-pilots will be used as the basis and will be extended to form the final full-scale deployments for these pilots.

5. CONCLUSIONS

This document presented the pre-validation activities that have been performed prior to the final deployments of PARITY solutions. The pre-validation activities include the deployment of components in controlled environments of CERTH/ITI nZEB - DIH and HYPERTECH office building, as well as at the pilot sites in Switzerland and Spain, as well as the execution of defined tests and evaluation from the developers and test users. A pre-validation plan was created in order to select the functionalities to be tested, and the involved location for each test. The small-scale pilot deployments were used to test the functionality of the local energy/flexibility market as well as other use cases that employ multiple PARITY components intended to be used by different stakeholders (Aggregator, DSO, Prosumers).

Based on the reported outcomes, the vast majority of the tests were successful. Through the pre-validation tests it was possible to identify problems and then proceed to corrective actions in order to resolve them. These actions included further improvements/additions in software components as well as modifications in the configuration related to installation and deployment, to ensure smooth operation. In particular, measures to make data exchange more reliable have been applied, as well as improvements in user interfaces and presentation of information. Subsequent tests allowed to ensure that the identified problems have been resolved and confirm that operation using real-life data is as expected. Additionally, feedback from users will allow to perform refinements on the user interfaces to further improve usability.

Regarding system deployment, details on the configuration of the software components after their deployment for a new site were clarified. The deployments made for the Swiss and Spanish pre-pilots will be extended to form the final full-scale deployments for these pilots and will be used as a guide for the full-scale deployments at the pilots in Greece and Sweden.

6.REFERENCES

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