Platone

PLATFORM FOR OPERATION
OF DISTRIBUTION NETWORKS

Platone

PLATform for Operation of distribution NEtworks

D3.9

Report on main results achieved in the field test

The project PLATform for Operation of distribution NEtworks (Platone) receives funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement no 864300.

Project name	Platone
Contractual delivery date:	31.08.2023
Actual delivery date:	31.08.2023
Main responsible:	Ercole De Luca, areti
Work package:	WP3 – Italian Demo
Security:	P
Nature:	R
Version:	V1.0
Total number of pages:	27

Abstract

The Italian Demo aims to enable network users to participate in the optimized management through the flexibility mechanism. Thanks to the coordination of areti and the cooperation of all the partners involved in the WP3, the Italian Demo will develop an innovative system, enabling distributed resources connected in medium and low voltage grids to provide grid services in different flexibility market models, which will be developed and implemented, allowing the inclusion of all the stakeholders. The solution proposed will allow the development of a new model of cooperation between citizenship and municipality, bringing multiple benefits.

This document mainly focuses on how Italian Demo has been implement and what are the developments carried out during the project activities. As a final report, it gives a clear understanding of the results achieved and which are the future steps to improve the solution proposed. The document illustrates the lessons learned, the Key Project Indicators (KPIs) results and technical platforms' recommendations to implement further methods or easier processes.

Keyword list

Customer-engagement; Light Node; System Architecture; Flow; BeFlexible; RomeFlex; DSO Technical Platform; Aggregator Platform; Blockchain Access Layer; Shared Customer Database; Market Platform

Executive Summary

*"*Innovation for the customers, innovation for the grid" is the vision of project Platone - Platform for Operation of distribution Networks. Within the H2020 programme "A single, smart European electricity grid", Platone addresses the topic "Flexibility and retail market options for the distribution grid". Modern power grids are moving away from centralised, infrastructure-heavy transmission system operators (TSOs) towards distribution system operators (DSOs) that are flexible and more capable of managing diverse renewable energy sources. DSOs require new ways of managing the increased number of producers, end users and more volatile power distribution systems of the future.

Platone is using blockchain technology to build the Platone Open Framework to meet the needs of modern DSO power systems, including data management. The Platone Open Framework aims to create an open, flexible and secure system that enables distribution grid flexibility/congestion management mechanisms, through innovative energy market models involving all the possible actors at many levels (DSOs, TSOs, customers, aggregators). It is an open source framework based on blockchain technology that enables a secure and shared data management system, allows standard and flexible integration of external solutions (e.g. legacy solutions), and is open to integration of external services through standardized open application program interfaces (APIs). It is built with existing regulations in mind and will allow small power producers to be easily certified so that they can sell excess energy back to the grid. The Platone Open Framework will also incorporate an open-market system to link with traditional TSOs. The Platone Open Framework will be tested in three European demos and within the Canadian Distributed Energy Management Initiative (DEMI).

D3.9 "Report on main results achieved in the field test" will highlight the final thoughts on the Italian Demo project activities and provides a comparison between the initial goals outlined for Platone and the final results that have been achieved throughout the project's implementation. In this comprehensive analysis, the document will emphasize the tangible and measurable technological innovations that have been realized, and the importance on the users' involvement activities carried out.

By adopting a comprehensive and transparent approach, the Platone project seeks to pave the way for the widespread dissemination and accessibility of valuable information in the field of energy research and innovation. The project endeavours to not only celebrate its accomplishments but also inspire further advancements in the realm of sustainable energy management. The report therefore wants to present what was the panorama in which Platone (and especially the Italian Demo) has been designed and then developed and what were its actual developments and results. Objectives previously set have been analysed and related results are presented in order to give the idea and let the reader perceive the huge importance of the pilot and its results, not only at project level but also as an opener for further developments at national and international level.

In conclusion, D3.9 document symbolizes a culmination of research, evaluation, and collaboration, offering valuable insights into the transformative potential of the Platone project. As it reaches a wide audience, it is expected to inspire and encourage further research and development, ultimately propelling the global energy sector toward a more sustainable and prosperous future.

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1 Introduction

The "PLATform for Operation of distribution Networks – Platone" project aims to create a two-layer Blockchain-based architecture called the Platone Open Framework. This architecture includes an "Access Layer" connecting customers to the DSO and a "Service Layer" linking customers and the DSO to the Flexibility Market environment. The two layers are connected through a Shared Customer Database with certified data accessible to relevant stakeholders. This framework enhances stakeholder involvement and enables efficient network management. Data from various sources, like weather systems and smart devices, will be processed on platforms for DSOs, TSOs, markets, customers, and aggregators. Additionally, the DSO Technical Platform serves as the framework's core, empowering DSOs to securely and effectively manage the distribution grid. It encompasses tools and services for grid monitoring, control, and enhanced security, reliability, and quality. The platform also handles flexibility requests from the Market Platform and facilitates negotiations. It's directly linked to the DSO's conventional SCADA system through an open API, ensuring seamless communication between the new DSO Platform and the SCADA systems. The innovative Platone architecture contributes to a carbon-free society goal by 2050, fostering new market mechanisms and active grid management [1].

Specifically for the Italian Demo, the man objective was to realise a fully functional system according to the proposed framework of Platone that enables distributed resources connected in medium and low voltage to provide grid services in different flexibility market models which include all the stakeholders (TSO, DSO, aggregators and end-users). This fully functional system has been tested and validated throughout the release of three different versions of the Technology associated with the system. The results corresponding to the three deliveries of the Technology will be now presented and discussed throughout the whole deliverable.

1.1 Associated Tasks

For the incremental development and release of the Italian Demo Technology, five tasks have been identified, three internal tasks related to WP3, and two external tasks related to WP1 and WP2.

Task 3.2 “Development of a standard blockchain-based infrastructure, implementing a Common Access Interface between all the market players” was one of the project tasks composing WP3 – Italian Demo. Task 3.2 was coordinated by areti and performed by areti in cooperation with Apio, Siemens, Engineering and Acea Energia. It includes the following sub-activities:

- HW/SW (Hardware and Software) development of blockchain technologies to include customers in the system, led by Apio;
- Definition of communication protocols, identification of the communication channel and development of the apparatus for meter data exchange, led by Apio;
- Development of Shared Customer Database platform led by areti.

Task 3.3 “Implementation of a technical platform for grid state estimation and flexibility requests validation” was another project task composing WP3 – Italian Demo. It was coordinated by Siemens and performed by Siemens in cooperation with areti. It includes the following sub-activities:

- HW/SW developments related to the real-time state estimation of the grid, led by Siemens;
- Definition of telecommunication infrastructure, led by Siemens;
- Development, testing and implementation of the state estimation tool, led by Siemens.

Thanks to all the data gathered from the hardware/software implemented on the field, the weather forecasts, historical data, and network topology knowledge, the DSO technical platform of the Italian Demo (further evolution of the Sogno Platform [2]) performed the state estimation and indicated any forecasted network operating constraints violation.

Task 3.4 “Solutions to enable Aggregators to provide flexibility: Aggregator platform and customer involvement” was coordinated by areti and performed by areti in cooperation with Siemens, Engineering, Acea Energia and B.A.U.M. It included activities aimed to test a Local Flexibility Market in which end-users can be considered as market actors, thanks also to the role of the Aggregator.

The sub-activities composing the Task 3.4 are reported below:

- Aggregator Platform development and integration, led by Siemens;
- Solutions to enable Local Flexibility Market, led by areti;
- Customer engagement techniques led by Acea Energia in cooperation with B.A.U.M.

These sub-activities ensured an integration at every level of the Aggregator Platform and the acquisition of relevant data from the architecture regarding the flexibility analysis.

1.2 Objectives of the Work Reported in this Deliverable

D3.9 holds significant importance as a "Key Document" within the context of the Platone project. Its primary purpose is to provide a comprehensive comparison between the initial goals set for Platone and the final results that have been achieved. In doing so, the document will highlight and outline the actual and measured technological innovations and the quality of the developed solutions in a quantitative manner.

1.3 Outline of the Deliverable

The introductory chapter explains the Platone reference context, and the specific project task linked to the present deliverable, also providing indications about the objectives and characteristics of the document. Chapter 2 Overview summarizes the structure of the Platone system architecture and the updates regarding the data flows among the platforms. Chapter 3 Updates and Implementations, analyses the achievements and developments within the third release of technology, both on the technical, geographical (demo) side and through some non-functional activities perfomed within the Demo (Platform scalability analyses). Chapter 4 KPIs analyses the ongoing status and updates of WP3 Project KPIs. Chapter 5 Conclusions closes the document with the conclusions part, it is followed by the list of tables, the list of figures, the list of references, the list of abbreviations and the list of technical terms.

1.4 How to Read this Document

The document provides relevant information and updates based on the third release of technology of the Italian Demo. Furthermore, significant links and insights on the evolution of the technology during the project can be made through these Platone Deliverables.

- KPIs in D1.4 [3] “Evaluation of Project KPIs” released by E.DSO on month 36 (August 2022) aims to assess the relevance of project KPIs as DEMOs and other activities progress. It set the stage for the development of deliverable 1.7;
- KPIs in D1.7 [4] “Update of Project KPIs” report released by E.DSO on month 48 (August 2023) is an update of Deliverable 1.2, based on Deliverable 1.4. This report was conducted at the end of the project to ensure that the KPIs remain consistent with the overall project goals and developments;
- D2.2 [5] “Platone platform requirements and reference architecture (v2)” released by Engineering on month 30 (February 2022) as a public report detailed on the Platone Open Framework. Within D2.2, Engineering describes the Platone Open Framework, a relevant element for all Platone Demos including the Italian one;
- D2.5 [6] “Platone Market Platform v3” released by Engineering on month 46 (June 2023) as a public report detailed on the Platone Open Framework;
- Platform framework components in D3.3 [7] “Delivering of technology V1”, released by areti on month 21 (May 2021) as a public report about the detailed work on the release of the first version of the System Architecture;
- Platform framework components in D3.4 [8] “Delivering of technology V2”, released by areti on month 38 (October 2023) as a public report about the detailed work on the release of the second version of the System architecture;
- Platform framework components in D3.5 [9] “Delivering of technology V3”, released by areti on month 46 (June 2023) is the third version of the Technology developed within the Italian Demo;

- D3.6 [10] “Report on first integration activity in the field”, released by SIEMENS on month 23 (July 2021) as a public report about the detailed work on relevant integration activities and data setup that followed the first “Delivery of technology”;
- D3.8 [11] “Report on second integration activity in the field”, released by SIEMENS on month 40 (December 2023) as a public report about the detailed work on relevant integration activities and data setup that followed the second “Delivery of technology”.;
- D6.5 [12] “Periodic report on lessons learned (v2)” was released by NTUA on month 24 (August 2021). The purpose of this deliverable is to collect partners' experiences and lessons learned during the second year of Platone;
- D6.6 [13] “Periodic report on lessons learned (v3)” was released by NTUA on month 36 (August 2022). The goal of this deliverable is to focus on the valuable experiences and lessons learned by partners during the third year of the Platone project;
- D6.7 [14] “Periodic Lessons Learned Report (v4)” was released by NTUA on month 48 (August 2023). The objective of this deliverable is to focus on the valuable experiences and lessons learned by partners during the fourth year of the Platone project.

2 Italian Demo Overview

2.1 Context

Italian Demo activities took place in Rome, Italy's capital city and most populous one with almost 3 million of inhabitants.

Rome is an ever-expanding nucleus towards which a plurality of systems tends to converge, which undoubtedly serves as a center of concentration, a catalyst for businesses and people, traffic and knowledge, planning, resources, and investments. In the last years, Rome has strengthened its national economic weight. With a Gross Domestic Product of € 94 billion, the city produces 6.7% of the national Gross Domestic Product after Milan which provides 10%, and its unemployment rate, lowered from 11.1% to 6.5% between 2001 and 2005, is now one of the lowest rates of all the European Union capital cities. Rome is growing by +4.4% annually and continues to grow at a higher rate in comparison to any other city in the rest of the country.

Within this context, areti manages the electricity distribution grid in Rome, with an extension of 29,000 km, 2.7 million inhabitants fed, and 1.7 million customers connected. Platone activities fell within the continuous improvement of the performance of the electricity distribution network requested by areti.

Moreover, the ongoing energy transition process involves a number of challenges for the entire electricity sector. In particular, the operators of the distribution networks will have to be able to support and manage not only the distributed generation but also the increase in the loads generated by the new uses of electricity and the new ways of end-users' participation in the market of energy. In the context of efficiency and selectivity of investments, the flexibility of distribution networks and electric mobility play a strategic role in the pursuit of these objectives. To enable distribution networks to cope with the spread of distributed generation and the electrification of consumption, innovative management approaches are emerging with the main objective of overcoming traditional approaches that would involve significant infrastructural interventions and long lead times resulting in higher service costs for end users. Platone and areti's involvement in the experimentation are perfectly fitting within this context.

Platone is part of a scenario of the Electricity Sector in which the generation of electricity is increasingly distributed by the integration of renewable sources (small and medium-sized) which are characterized by a variable and difficult to predict production linked to the weather conditions of wind and sun. This unpredictability involves more and more frequent voltage fluctuations due to peak generation. Therefore to a new complexity in the management of the electricity grid has emerged.

2.2 Scope and Objectives

The Platone project aimed to the development of a two-layer platform for the operation of the distribution network and the market, simultaneously creating not only a business opportunity for the system operators but for the consumers, too. Indeed, the main objective of the Italian Demo of the Platone project was to create a Local Flexibility Market where all the electricity market actors are involved and interact among each other.

In areti's pilot, through the development of an innovative technological architecture, based on the application of the blockchain, partners developed a new model of grid management based on flexibility services in the urban area of the capital. This model allowed users to actively participate themselves in the optimized management of the network becoming real "partners", providing flexible services, and helping to ensure a balance between energy supply and demand for the benefit of the whole society.

Within WP3, the partners have been involved in the implementation of a fully functional system that enables distributed resources at medium and low voltage levels to provide flexibility services.

The aim of Italian's Demo was to realize a fully functional system that enables distributed resources connected in medium and low voltage to provide grid services in different flexibility market models which include all the stakeholders (TSO, DSO, aggregators and end-users). The main goals of this WP were:

- Use of BlockChain technology for an efficient, democratic and non-discriminatory market model for exploitation of local flexibility;
- Improve and promote the consumer access thanks to BlockChain infrastructure;
- Use of local flexibility for enhance the grid resilience;

- Increase the grid observability for improve the network management.

This kind of system has been implemented within an urban area where potentially both TSO and DSO could participate (TSO in Platone has been only simulated). The scope was to take a step towards a massive participation in the local market guarantying the involvement of prosumers connected to the distribution network for the optimized management of the grid.

2.3 Technical developments

Developments undergone during the project activities has brought the Italian Demo to the release of 3 different version of the technology designed.

The final version of the System Architecture is depicted in Figure 1 and deeply described in D3.5.

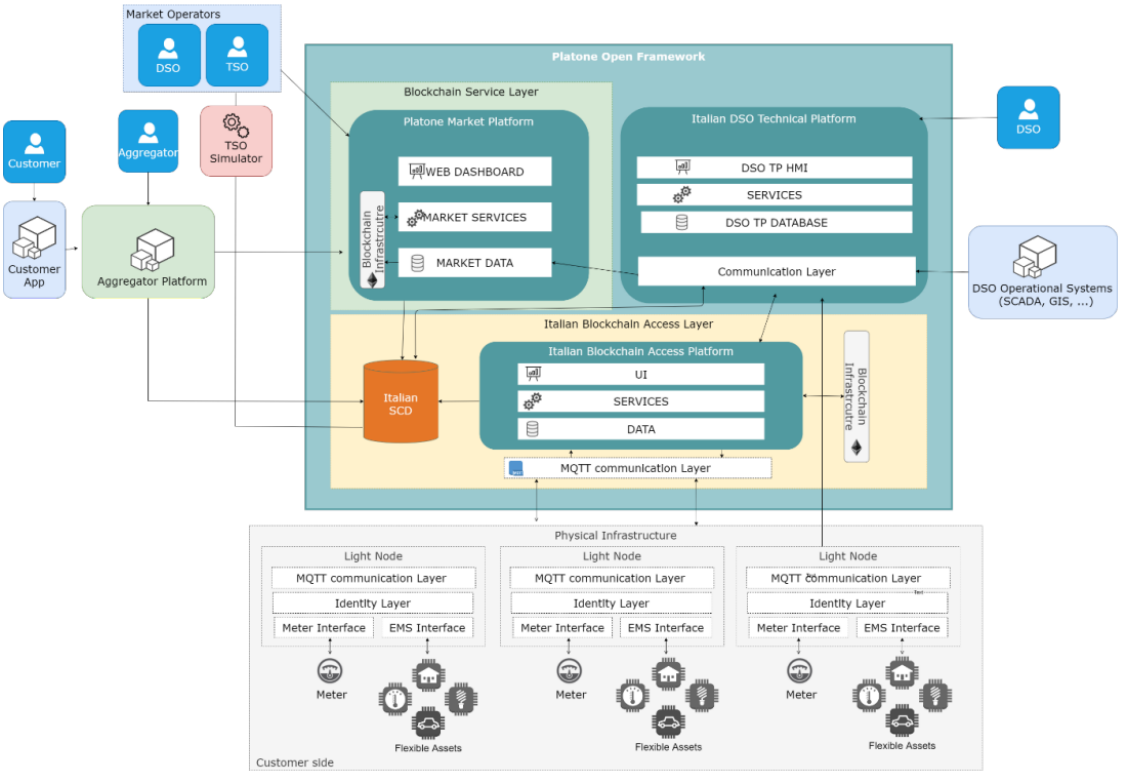

Figure 1 Italian Demo Architecture

Italian Demo partners structured a system architecture made of platforms that communicate and interact in order to enable the foreseen Local Flexibility Market.

These platforms are: I) the Market Platform enabling the management of wide geographical area flexibility requests from system operators and flexibility offers from aggregators, II) the Aggregator Platform facilitating aggregators to manage the flexibility assets, III) the DSO Technical Platform allowing the DSOs to improve reliability and quality of service by exploiting the flexibility made available from Distributed Energy Resources (DERs) connected to their grids, IV) the Access Layer (composed of the Blockchain Access Layer and the Light Node): a data exchange infrastructure among flexible DERs, platforms and stakeholders, and V) the Shared Customer Database: a repository system where all the data related to flexible Point of Delivery (PoDs) are stored and made available to demo platforms and stakeholders.

In Figure 2, the data exchange among platforms developed within the Italian Demo System Architecture has been depicted. The reader can refer to D3.3 [6] for more information about this architecture.

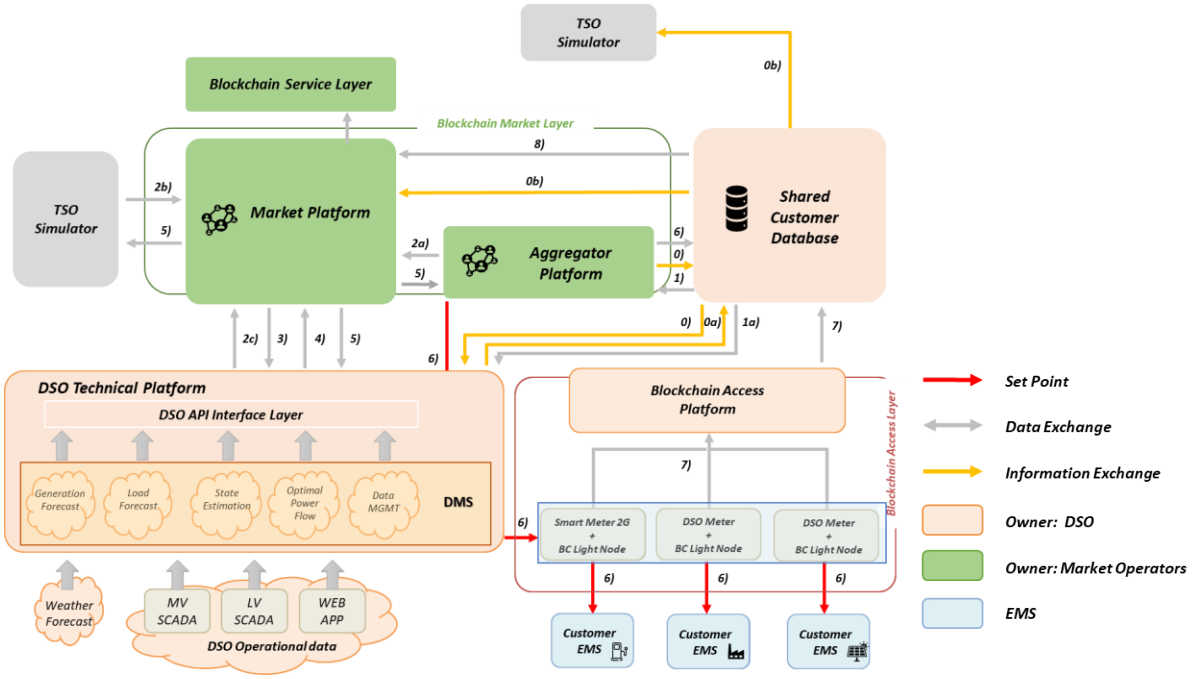

Figure 2 Italian Demo Data Flows

3 Italian Demo Results

3.1 Objective/Results comparison

As previously mentioned in subchapter 2.2, Italian Demo aimed at 4 different main objectives (Obj) within the initial system's design:

- ***Obj 1)*** Use of BlockChain technology for an efficient, democratic and non-discriminatory market model for exploitation of local flexibility;
- ***Obj 2)*** Improve and promote the consumer access thanks to BlockChain infrastructure;
- ***Obj 3)*** Use of local flexibility for enhance the grid resilience;
- ***Obj 4)*** Increase the grid observability for improve the network management.

After the project implementation, the experimentation can be considered extremely positive since for each objective, important results have been achieved.

The main consideration and results achieved for the above-mentioned 4 objectives are reported below.

Results

- ***Obj 1)*** Italian Demo partners used blockchain to create an interface between flexibility market and end-users (Blockchain Acces Layer) which facilitates access and enabling flexibility services offered by customers, certifying their measures and increasing market transparency (role played by the Light Node);
- ***Obj 2)*** end-users were equipped with the enabling device called Light Node in order to standardise the way of access and communication with the market in order to encourage a massive participation of end-users in the market (participation was minimal before this solution). This has led to a democratic form of market participation;
- ***Obj 3)*** provision of flexibility services offered by customers has been tested in order to provide to the DSO an instrument for the resolution of grid issues and in this way ensure continuity and quality of the network service;
- ***Obj 4)*** Light Node collects real-time measurements from flexible resources, allows increased grid observability, and as the number of flexible resources increases linearly will increase the level of observability.

3.2 System architecture developments

The Platone System architecture was developed thanks to the collaboration of many stakeholders creating a complex interaction among an array of technical platforms, to enable the first activation of a Local Flexibility Market in Rome. In Table 1, the first batch of functionalities are reported that were planned for the first version of the Italian Demo System Architecture. These functionalities were released and deeply explained during the Mid Term Conference video [15] .

In the following tables, the functionalities released with the 3 versions of the system architecture and the related platforms dealing with them are reported. Functionalities and their implementations have been fully described in previous deliverables (D3.3 [7], D3.4 [8] and D3.5 [9][9]). Additionally, the following subchapter 3.3 sums up the technical developments corresponding to the release of different components of the Italian Demo System architecture.

Table 1 Functionalities of 1st System Architecture version

First set of system architecture functionalities	Market Platform	Aggregator Platform	DSO Technical Platform	Shared Customer Database	Blockchain Access Layer
Day Ahead Session	X	X	X	X	X
Full Medium Voltage Simulation			X		
Simplified Settlement (by Market Place Reports on Smart Contracts)	X				
Smart Contract for Access Layer					X
Full handling of Medium Voltage (MV) users	X	X	X	X	X

Handling of Low Voltage (LV) users by work-around (as MV PODs)			X		
Measurement Cycle also Using Smart Contract	X			X	X
Activation of all Users Involved		X	X	X	X
Offer Partialization	X	X		X	

The second release of the architecture (Table 2) planned the implementation and improvement of a series of accessory services and tools to complete and increase the potentiality of the overall system architecture of the Italian Demo.

Table 2 Additional Functionalities of 2nd System Architecture version

Second set of system architecture functionalities	Market Platform	Aggregator Platform	DSO Technical Platform	Shared Customer Database	Blockchain Access Layer
Real Time Session	X	X	X	X	X
Full Low Voltage Simulation			X		
Overall settlement and Smart Contract including token	X	X		X	X
App "Flessibili"		X			

During the last phase of the project, the Italian Demo System architecture has incorporated a series of tools and functionalities that weren't planned at the beginning of the project (Table 3).

Table 3 Additional Functionalities not previously foreseen

Additional set of system architecture functionalities	Market Platform	Aggregator Platform	DSO Technical Platform	Shared Customer Database	Blockchain Access Layer
Enhanced Chain 2 with improved data certification and transmission granularity.				X	X
Baseline - standardize processes on the Shared Customer Database to prevent gaming.				X	
Verify TSO actions and coordinate with DSO using a simulator.	X		X		
Improve processes by managing errors in data received from light nodes. (Buffer)				X	X
Report for the validation of data quality in Chain 2.				X	X
Use light node measurement data to enhance forecasting in DSO Technical Platform.			X	X	X
Implement flexible assets with light nodes for flexibility services (batteries).					X
Market uses a traffic light process to prevent network congestion.	X		X		

Complete set of functionalities of the system architecture are reported in Table 4.

Table 4 Overall Functionalities of the System Architecture

Complete set of system architecture functionalities	Market Platform	Aggregator Platform	DSO Technical Platform	Shared Customer Database	Blockchain Access Layer
Day Ahead Session	X	X	X	X	X
Full Medium Voltage Simulation			X		

Simplified Settlement (by Market Place Reports on Smart Contracts)	X				
Smart Contract for Access Layer				X	
Full handling of MV users	X	X	X	X	X
Handling of LV users by work-around (as MV PODs)			X		
Measurement Cycle also Using Smart Contract	X			X	X
Activation of all Users Involved		X	X	X	X
Offer Partialization	X	X			X
Real Time Session	X	X	X	X	X
Full Low Voltage Simulation			X		
Overall settlement and Smart Contract including token	X	X		X	X
App "Flessibili"		X			
Enhance Chain 2 with improved data certification and transmission granularity.				X	X
Standardize processes on the Shared Customer Database to prevent gaming.				X	
Verify TS) actions and coordinate with DSO using a simulator.	X		X		
Improve processes by managing errors in data received from light nodes.				X	X
Validate data quality in Chain 2.				X	X
Use light node measurement data to enhance forecasting in DSO Technical Platform.			X	X	X
Implement flexible assets in light nodes for flexibility services (batteries).					X
Market uses a traffic light process to prevent network congestion.	X		X		

3.3 Technical developments sum-up and final consideration

The Italian Demo System architecture designed during the project activities has been developed and further analysed within the project period and became more than a hypothetical and first-step simple model. Its composition and multi-functional blocks can be easily reproduced and accessible for all the system operators that could be interested in joining the released system.

The simulations performed at the technological level allowed the platforms to be analysed and evaluated for a scalable result different from the one released within the project activities. Indeed, within the WP2 activities, the Italian Demo system architecture has been tested and performed with a scalability analysis in order to evaluate its replicability with a higher volume of consumptions, interactions and resources involved. The scalability analyses were performed over three weeks in the month of May 2023. In the first week, the tests were performed on 10 PoDs, i.e. the actual number of users involved in the Italian Demo experimentations. During the second week, the number of PoDs has been increased by ten times testing 100 PoDs. During the third and last week, the number of PoDs has been increased to the number of users simulated in a possible real-case environment with approximately the 30% of DERs expected in the Italian demonstration geographical area, testing 1500 PoDs. The data related to the three weeks of testing were correctly extracted and are presented in the Deliverable 2.16 [16].

Platform Technical recommendations and results

At the Technical Platforms level, partners summed-up their results and future recommendations as below:

- ***Blockchain Access Layer/ Light Node***

The Blockchain Access Layer and the Light Node were developed in an incremental and iterative way along with the development of the other components of the Italian Demo.

Regarding the Blockchain Access Layer, the first challenge identified was to ensure high availability to allow light nodes to deliver data frequently and without disservices. The choice of the MQTT broker was confirmed to be correct since MQTT brokers are horizontally scalable. Also, the frequency of real-time measurements could have been challenging and to avoid stress on the persistence layer, the use of a Kafka broker that acts as a message broker between the MQTT brokers and the rest of the platform was a correct choice.

The number of messages received from the field and from simulation, created also a challenge on the blockchain layer: writing measurements on the blockchain is not feasible, and blocks cannot be created at the speed of real-time measurements (sub second period in some cases for any number of PODs). The choice of aggregating several messages (not the content of the messages or the measurements, rather their notarization) in time-fixed blocks was the correct solution.

On the Light Node side, the challenges were different. The first one was the deployment of several devices, configured by the producer, while for the second batch of light nodes, it was decided that every light node would be produced with a pre-configured Operative System Image (Latest Debian Linux).

The second batch of Light Nodes also came with a procedure to automate the creation of cryptographic keys that would be securely exchanged with the Blockchain Access Layer as soon as the light node software was booted.

Another lesson learned is that even though Light Nodes are meant to be deployed in apartments and houses in general, these environments can be extremely different in temperature and cellular network coverage, where the latter can cause the inability to communicate with the Platone Platform.

Last, since the communication protocol with the main meter can be upgraded (on the meter's side) over time, it was necessary to have a streamlined way to upgrade the Light Node's firmware which was also conducted via cloud.

In other words, the Light Node is a remotely connected device, and it comes with all the challenges of this kind of solution, from connectivity to stability.

- ***Shared Customer Database***

At the Shared Customer Database side, the first challenge was related to ensuring the correct management of a large number of high-frequency data which in Platone were organized and shared according to the needs of the different stakeholders.

Data sharing to other system platforms were performed using both MQTT brokers and Kafka queues. This choice was successful because it has guaranteed greater flexibility in the use of communications.

For the data management, it was very important to define a coherent unit of measurement fitting for all platforms for different components to allow the receiving systems to acquire data coherently.

It was fundamental to activate measurement acquisition for the monitoring procedures. Indeed, a dashboard has been created in the database to detects possible communication errors that could cause missed acquisitions of the readings.

- ***DSO Technical Platform***

DSO Technical Platform was developed in different stages following the Platone project time plan. As already mentioned for the other Platforms, one of the main drivers for all the activities was an early integration and validation approach. More in detail, for the DSO Technical Platform the crucial points were both on the integration with the other Platforms of the Platone architecture and with the DSO Operational Systems.

The functions that were developed throughout the projects stages involved from the beginning all the necessary capabilities to perform a complete closed loop process involving Power Flows Analysis, Flexibility Requests, Flexibility Technical Validation and Setpoint management (also in terms of basic data flow connecting to the other Platone Platforms). This overall process was evaluated and tested with real network data in different field scenarios adopting an incremental approach overcoming gradually some test boundaries such as number of processed timeslots, number of considered flexible customers, electrical network scenario, combination of technical-economic data, etc.

In the first version of the technology, the DSO Technical Platform enabled the Day Ahead Market session management performing all the above-mentioned calculations on the MV network area of the Platone Project. In the following version, still ensuring the complete closed loop approach, the Real Time Market session management was added together with the Low Voltage network calculations. To be underlined that both for the Medium Voltage network and after for the Low Voltage, a specific integration also with the DSO Operational Systems was implemented; this development has to be considered a fundamental step in terms of quality of the overall processed data since it assures an alignment with the DSO real network state and electrical data.

It is relevant to mention that the described approach brought different advantages since the basic data flow implemented in the first release did not need any relevant modifications and the data model was already flexible enough to accommodate all the functional evolutions introduced in the following releases; another good lesson learned is that, also from the DSO data requirement point of view, a smooth Project evolution can be assured starting from small electrical network areas and using quite raw input data and then refine/extend the data in an iterative way.

The latest version of the DSO Technical Platform included some minor evolutions about data flow monitoring and performance logs to collect the necessary data for the Platone Platforms scalability tests.

This final release of the DSO Technical Platform established a solid base that is already evolving towards the RomeFlex [20] Project requirements in terms of electrical network extension, improved calculation performance, resilience, further integration with DSO Operational Systems and cyber security measures.

- ***Market Platform***

The Platone Market Platform was implemented in three different stages in an iterative way with D2.3, D2.4 and D2.5. At the end of each stage, the Platone Market Platform was integrated in the Italian Demo architecture and validated during an execution on the field. Each validation phase was used to provide insights for improving the platform and implementing additional features.

In the first stage, the Platone Market Platform enabled the creation of day-ahead flexibility market, the validation of the flexibility services and the provisioning of the settlement outcomes. It also integrated blockchain technology, ensuring that market participants can participate to the market in a secure and transparent way, implementing a token-based incentivization for customers engagement.

In the second stage and for the Platone Market Platform, all the functional and non-functional expected requirements were satisfied with a fully functional implementation and concluding the work done in the first stage. The second version included the management of integrated Day-Ahead and Intra-Day sessions as well as a complete integration with the blockchain service layer for the certification of the market data results and for the tokenisation of the settlement phase for the end-customer. In addition, an updated web dashboard was released with new features for the market players. As result of this new implementation, all market results are certified and stored in the blockchain infrastructure, the settlement phase is activated at the end of each Intra-Day Session followed by the validation which provides Platone Token to the end customers.

In the final stage, the Platone Market Platform included the possibility to extract any kind of dataset elaborated during the project and to download it in a standard format. In addition, a new module was created and made available through REST API for the calculation of the KPIs in the Italian demo. Finally, a scalability assessment of the platform was carried out collaboratively by WP2 and WP3, certifying the scalability level of the Market Platform both as a stand-alone platform and at integrated system level.

The Platone Market Platform was recognized within the Engineering company as a valuable asset and renamed “Flexibility Market Platform” in order to be exploited internally and externally as a dedicated

platform for enabling energy flexibility markets. The platform maturation is already started in the ongoing collaboration with areti for implementing the Italian Local Flexibility Market in the RomeFlex [20] context.

- ***Aggregator Platform***

Such as other platforms, the Aggregator Platform has been implemented in several stages. In the first phase and together with the other partners, the needs of platform integrability and scalability were highlighted leading to the choice of certain communication protocols such as Rest-API and MQTT to be used for the different streams. In addition, the Aggregator stream, led by Acea Energia, defined the functionalities necessary for the development of the platform in the context of the project.

In the second phase, the core functionalities defined in the previous phase were developed. The main functionalities can be listed as: DERs' registration management in the flexibility market, calculation of consumption and DERs' production habits, calculation and optimization of the users' flexible capacities through offerings, settlement management towards the user, etc.

The major issues were related to the high number of points to be managed and the underlying items associated with different devices, managed by the platform as "attributes" of individual PoDs.

After the first development, the platform has been continuously updated to improve and add features such as the management of automatic offers to the market platform and the management of the different phases of day-ahead and real time markets.

Due to the complexity of the functionalities and the multiple choices to be taken during the development phase, the platform has been designed in a way to be fully customizable according to the actors involved while maintaining its basic functionalities.

3.4 Lessons Learned

1st Reporting Period	During the first year of the project, the Italian Demo has explored the topic of the flexibility services market. Starting from the current Italian ancillary service market that involves only the TSO, a complementary marketplace has been hypothesized to provide local services (like congestion and voltage management). This has required a careful evaluation of the regulations and laws and of the service products marketed to date. Moreover, the description of the use cases, according to IEC-62559, and the Smart Grid Architecture Model (SGAM) analysis have supported the Italian Demo in identifying all the characteristics necessary for a correct representation of the use cases. The SGAM layers also represent a reference for some future activities (like data exchange and business model). The deepening of the legislative and regulatory framework was necessary not only for technological design, system development activities and administrative aspects (sub-contracting), but also for related activities which foresee the involvement of customers. The need to communicate users' consumption data between partners, in order to ensure full compliance with privacy regulations (EU Regulation 2016/679 and Legislative Decree no. 196 of 30 June 2003, which was modified and integrated by Legislative Decree no. 101 of 10 August 2018) and antitrust provisions (Italian Law no. 287, 10 October 1990). Specifically, the identified potential risk concerned the need, during the pilot testing phase, to communicate and exchange among the Italian Demo partners information relating to users' consumption data directly linkable to personal data, with consequent impacts on privacy-related aspects. This kind of data are already available to the DSO (areti) based on the existing energy transport contract (already in place) with users served by the network managed by areti. It was observed that, without identifying a dedicated prevention strategy, this situation could have caused another potential risk of non-compliance with unbundling and antitrust provisions during the pilot testing execution. This risk concerned the possible exchange between DSO and Aggregator of information that could have been considered as commercially sensitive, with an involuntary undue advantage in favour to the Aggregator. In prevention to these potential risks and misunderstanding of effective aims within the project, dedicated discussion tables and focus boards involving the Legal & Compliance and Regulatory Functions of Acea Energia and areti, together with the Privacy Responsible of Acea

	S.p.A. were activated. This focus led to the definition of an internal governance document which defines the methods and the conduct rules for managing users' personal data exchange during the pilot implementation and during customer engagement activities and is reflected in the Platone data management plan. Throughout the implementation of the activities and the assignment of external activities, one important topic has arisen, the public procurement mechanism and its timeline. Current legislation requires several mechanisms that can significantly lengthen tender procedures. This could lead to possible delays in project activities. For this reason, it was decided to schedule the awarding of contracts in good time to avoid any possible delays and to ensure perfect continuity with the timeline. Moreover, the Italian Demo foresaw the participation of several users to the implementation of its activities. Important value was given to the identification of a strategy for customer involvement since the first year of the project. This strategy identified two different clusters of users, for whom two distinct user engagement workshops were planned: 1) local key-stakeholders and large commercial prosumers (held in June 2020 during the first year of project); 2) residential customers (prosumers and consumers) (held in March 2021 during the second year of project). This strategy was identified as more effective for setting the ground for starting discussions in order to understand users' needs. The participation of several users was crucial for the implementation of the project activities and the success of the trial. For this reason, ENEA - an important national agency for new technologies operating in Rome - was involved. This gave the possibility to involve a niche of people already interested in energy and environmental issues. WP3 partners were able to involve users in the trial thanks to the interaction with ENEA too. In this first phase, the number of users involved were low due to the invasive installation required by the project activities at users' equipment (Micro Photovoltaic, storage system, Light Node). In a second phase, it is possible that only the Light Node will be installed, with a higher number of users involved, in order to recreate a more realistic energy environment. The involvement of several residential customers led to the elaboration of a contractual form regulating the relationship between areti and users. This meant a deep study of the regulatory framework and the implementation of a free-for-loan contract that has allowed the installation of the equipment (Light Node, Micro-photovoltaic and storage system) at the users' equipment. This type of contract gives to the users the opportunity to participate to the project activities. Moreover, areti defined an internal governance document to define the methods for managing users' personal data exchange during the pilot implementation and during customer-engagement activities. This document confirms that areti is the only partner appointed to know user's personal data (already in its availability) and to formally contact the users. Another important phase is related to the sharing of measurement data in the Demo trial, without disclosing the personal data of the users involved. For this reason, areti has adopted a pseudonymization strategy. Therefore, customers who will freely participate in the pilot testing will have to sign a dedicated information document provided by areti, which illustrates project methods and purposes and the use of their consumption data, before starting the activities.
2nd Reporting Period	During the implementation of the Local Flexibility Market, partners from the Italian Demo started to understand some crucial points that have to be considered in future developments. The Local Market is very specific, and all the issues are localized to a limited network area. This means that only a little part of the resources involved can provide flexibility. Therefore, DERs location is crucial for this reason. In addition, another crucial point is the System Operators coordination. Indeed, from the development implemented so far, it emerged that a deep coordination among all the System Operators can largely improve the impact of the flexibility products offered to solve the grid issues. In addition, the participation of users and the crucial role played by them in the project activities, underline the importance of cooperation and networking. For this reason,

	areti involved ENEA in the project discussion and searched for a niche of people already very interested in energy topic and environmental issues. Areti, during the customer-engagement activities, realised that the installation at the single users' place have some criticalities: • Because the customers are spread over a wide area, the installation times and costs have increased compared to what they would be had the customers been closer together; • The installation of components in private environments has required the availability of customers in the planning of intervention; • Maintenance is difficult to do because the intervention on the components always requires the availability of the customer; Moreover, areti decided to test a new type of users during the trial. Indeed, the new type of installation are pursued in order to test the flexibility that a collective self-consumption can offer.
3rd Reporting Period	Throughout the fourth year of Platone even though the activities were in a final stage and the technical tasks were almost done, Italian partners from the Italian Demo were still learning from the implementation of debugging activities, communication, dissemination and exploitation strategy. Indeed, during the very last phase of the project, the activities of the Italian demo were focused on the debugging and fixing of the functionalities already released, the release and implementation of the last functionalities to be included in the last version of the technology, the scalability analysis of the solution proposed, and the real-life replicability of the Platone Italian Demo solution applied to a larger audience (RomeFlex Italian project and Flow / BeFlexbile EU projects). Regarding the scalability analysis, during the tests the partners elaborated a specific process aimed to the monitoring of Platforms and System in order to avoid issues in the computational load when the number of users involved in the environment increase and guarantee a very high level of performance for the entire system. Moreover, since the outstanding results achieved from the Italian Demo and its methodology, areti decided to propose the process developed within Platone in further opportunity. This is the case of 2 more Horizon European projects (Flow [17] and BeFlexible [18]) and the response to the Delibera 352 [19] of the Italian National Regulator ARERA. Indeed, ARERA asked for a pilot project for the supply of local ancillary services, and areti proposed RomeFlex [20] coming from a strong base since partners, solutions and processes are designed taking the Platone's ones as baseline. Regarding the involvement of self-consumption community foreseen and reported in D3.4 and updated in D3.5, has not been finalized. Therefore, there are delays in the installation of the Photovoltaic (PV) generators and the related storages units due to the required authorization permits that are still missing. As a matter of fact, the public offices involved in this activity are overloaded by several requests concerning the incentivization activities promoted by the Italian government such as "Incentivi 110%" concerning energy efficient policy and other initiatives within the so called "Piano Nazionale di Ripresa e Resilienza" (PNRR) supported also by EU funding. This kind of delay was hardly predictable but underline the importance of considering any possible delay in bureaucratic and administrative processes

3.5 KPIs

The Italian Demo partners started to collect data for the calculation of the KPIs once the system architecture had been designed and deployed. Thanks to the implementation and the development achieved during the work on the second and third versions of the technology, areti has been able to design and develop the methodologies and processes for the calculation of several KPIs.

The platforms developed within the WP3 activities have been implemented in order to gather data performing automatic calculations and graphically showing results and trends. Tools like Elastic [21] were used for KPIs calculation and visualization.

KPI PR01 Participants Recruitment:

This KPI analyses the percentage of customers that accepted their participation in the Demo in relation with the total amount of customers contacted to participate in the Demo. This indicator was used to evaluate the rate of customer engagement for the Italian Demo.

$$R = \frac{N_{accept}}{N_{total}} \cdot 100$$

To determine the active participation of users, areti monitored through the Light Node flow of data and the correct activation of the equipment installed. Users were considered active if they were able to keep the activation of the installed devices for at least 90% of the 96 quarterly frames per day. The result of this KPI is 100% as the 11 users (Naccept) were able to keep the flow active for the requested time resulting in 11 (Nactive)

KPI PR02 Active Participants:

This indicator measures the percentage of customers actively participating in each Platone Demo with respect to the total customers that accepted the participation per Demo. This indicator was used to evaluate customer engagement and their participation to provide flexibility services in the Italian Demo.

$$R = \frac{N_{active}}{N_{accept}} \cdot 100$$

To determine the active participation of users, areti monitored through the Light Node flow of data and the correct activation of the equipment installed. Users were considered active if they were able to keep the activation of the installed devices for at least 90% of the 96 quarterly frames per day. The results of this KPI is 100% as all the 11 users were able to keep active the flow of data.

KPI PR03 Flexibility Availability:

The KPI measures the potential flexibility provided by PoDs connected to the grid:

$$Flexibility\ Availability\ Up = \frac{1}{T}\sum_{t=1}^{T}\frac{\sum_{i=1}^{N}\left|Available\_Flexibility\_Up_{i,t}\right|}{\sum_{i=1}^{N}\left|Baseline_{i,t}\right|} \cdot 100$$

$$Flexibility\ Availability\ Down = -\frac{1}{T}\sum_{t=1}^{T}\frac{\sum_{i=1}^{N}\left|Available\_Flexibility\_Down_{i,t}\right|}{\sum_{i=1}^{N}\left|Baseline_{i,t}\right|} \cdot 100$$

In the case of areti, the KPI showed a significant asymmetry between the case of upward flexibility 28,35% and downward flexibility provision 474,38%. This asymmetry could be reduced by refining the KPI baseline calculation through recognized and standardized algorithms including a greater characterization of the flexible assets involved. This refinement should be implemented in view of the scaling up and expansion of experimentations. Other factors impacting the asymmetry between upward and downward flexibility on offered availability were the reduced number of customers involved in the trial and the different combination of flexible assets that prosumers and consumers were equipped with.

KPI PR04 Flexibility Effectiveness:

This KPI targets the measurement of the effectiveness of flexibility provision. The KPI measures the sum of successfully provided flexibility in relation to the requested demand for flexibility.

$$Flexibility\ Effectiveness = \frac{1}{T}\sum_{t=1}^{T}\frac{1}{N}\sum_{i=1}^{N}\frac{\left|Quantity\_provided_{i,t}\right|}{\left|Setpoint_{i,t}\right|} \cdot 100$$

Areti set a target of 70% for this KPI, representing a good value of flexibility that is effectively provided to the grid to solve possible congestion and voltage regulation. The result obtained by the Italian Demo was equal to 73,96% positively exceeding the planned target thanks to the equipment of resources with a storage system that facilitated and improved the planning of the provision of flexibility services. This result could be further improved by increasing the number of available resources and leveraging on a larger calculation period and greater availability of data to improve the estimation of the request setpoints.

KPI IT01 Market Liquidity:

This KPI is targeting to measure the market liquidity. The KPI measures the ratio of the sum of flexibility offered to respond to the requested demand for flexibility.

$$Market\ Liquidity\ Up = \frac{1}{T}\sum_{t=1}^{T}\frac{\sum_{i=1}^{N}\left|Flexibility\_offered\_up_{i,t}\right|}{\sum_{j=1}^{R}\left|Flexibility\_requested\_up_{j,t}\right|}\cdot 100$$

$$Market\ Liquidity\ Down = \frac{1}{T}\sum_{t=1}^{T}\frac{\sum_{i=1}^{N}\left|Flexibility\_offered\_down_{i,t}\right|}{\sum_{j=1}^{R}\left|Flexibility\_requested\_down_{j,t}\right|}\cdot 100$$

The results set for the market liquidity were to have KPIs greater than 150%, the Italian Demo Market Liquidities were equal to 0% for the Market Liquidity Up and 27,41% for the Market Liquidity Down. The Italian Demo Market Liquidity results are lower than the expected target due to the small market size that is unable to cover the wide requests from the DSO. The market Liquidity Up is zero because only downward flexibility offers were tested in the Italian Demo, validating the provision of flexibility services in response to congestion issues arising in a scenario of increasing load electrification,

KPI IT02 Forecast Reliability – Customer Profile:

This KPI evaluates the reliability of the tool performing forecasting of power flow exchanged by each resource with the grid. The indicator is calculated for a forecasted time range (next 24h or next 4h).

$$FC_{Next24h}(\ or\ FC_{Next4h}) = \frac{1}{T}\sum_{t=1}^{T}\frac{1}{N_t}\sum_{i=1}^{N_t}\left|\frac{RL\_profile_{i,t} - FC\_profile_{i,t}}{RL\_profile_{i,t}}\right|\cdot 100$$

The result set for the forecast reliability – customer profile was set to 25%. The Italian Demo result was equal to 131%. The KPI results indicate possible asymmetries in correctly forecasting the power flow exchanged by each resource with the grid. To further improve the KPI result, the algorithm determining the baseline of the forecast should be further refined.

KPI IT03 Forecast Reliability – Grid Profile:

This KPI evaluates the reliability of the tool performing forecasting of power flow in significant assets of the grid. The indicator is calculated for the forecasted time range.

The target result for this KPI was 30% to be assumed as a realistic value that could be fulfilled for the forecasting of the grid. The result obtained was 17,99%, demonstrating a good performance of the DSO Technical Platform in simulating the power flow of the portion of the network being tested. It would be interesting to check the evolution of the KPI with the increase in the size of the examined grid portion.

3.6 Further follow-ups

The activities that have been set during the Platone project allowed for a better understating of what the barriers, the potential developments and the strengths / weaknesses of the defined processes are. It is for this reason that the Italian Demo partners decided to further develop the designed technology of Platone in several other projects that are currently ongoing. Areti is implementing further developments based on the Platone Italian Demo system architecture as a basis to further develop and improve the Local Flexibility Market in Rome throughout two different projects within the Horizon Europe programme and a national project in response to a National Regulator Resolution:

Flow [17]

The project Flow tests, validates, and enhances user-centric Vehicle to X (V2X) smart charging solutions and their orchestrated integration into energy grids that deliver flexibility assets to favour additional

penetration of renewables and alleviate energy grid challenges. Areti participates in the Rome Demo, that aims at implementing a “complete turn-key” technological solution enabling the massive smart charge/V2G services implementation, maximizing the benefits for all the stakeholders (TSO, DSO, charging point operators/mobility system provider, aggregators, Electric Vehicles (EV) drivers) keeping at the center the customer “flexibility experience and satisfaction”. This Demo for areti expands the results developed in Platone with the testing of a smart park equipped with EVs smart charger to test further DERs in the experimental Local Flexibility Market of Rome.

BeFlexible [18]

BeFlexible’s aim is to increase the participation of prosumers to increase the flexibility of the electricity system, and to this end it will work in four areas: markets and regulation, services ecosystem, platforms & architecture, and customer engagement and social co-creation. Areti participates in the Rome pilot by testing three potential businesses: a) Water distribution assets to test the potential of the flexibility water grids; b) areti’s EV fleet: areti investigates the network interaction of his smart park composed of 10 chargin stations with 2 alternating current EV charger(3 and 22 kW) to feed 20 EVs, 40kW PV power plant , 125 kWh energy storage, and an advanced energy management system; c) All kinds of residential and industrial customers, starting from 3kW of contractual power, both as single and aggregate. Areti will have the opportunity to further analyse and develop what has been already done within Platone activities thanks to the application of the Shared Customer Database, the DSO Technical Platform and the Light Node.

RomeFlex [20]

RomeFlex is a project that exploits the technologies developed in Platone in response to the Resolution 352/21 [19] which allows to realize a market of local flexibility in some areas of the territory of the city of Rome. All customers, whose units fall in the identified areas, (regardless of the one connected in low or medium voltage) will be able to modulate their consumption/production and can take part to the project by offering their flexibility services to areti. The customer can then become a provider of flexibility services and actively participate in the management of the electricity grid. In addition, customers who provide the required flexibility services will be awarded with an economic benefit in function of the service rendered and possibly, when provided, an economic value for the availability to the provision of the service.

The main improvements and differences so far between Platone and RomeFlex solutions are:

- The involvement of the Italian Market Operator as a new actor in the market phase;
- The introduction of a long-term auction for the provision of flexibility;
- Introduction of an Ex-ante shared baseline for the calculation of both offers and requests;
- Introduction of an Ex-post shared for the calculation of the settlement phase;
- Introduction of dynamic indications of maximum and minimum flexibility services limits that every resource can reach in the market sessions;
- Definition of a complete flow for the registration of resources;
- Introduction of tests for the resource’s qualifications;
- Introduction and definition of fees for the failure to provide the service;
- Provision and validation of the service for single or aggregated PoDs.

4 Conclusion

The Italian Demo of the Platone project can be considered as a hugely positive experience from different points of view. The partners involved within the project activities were able to compare themselves with an extremely innovative environment making available their know-hows and technologies to improve the distribution energy sector. Industrial actors involved in the activities have been introduced or have participated again in research and innovation activities aimed to the design of a Local Flexibility Market solution, deepening the state of the art of the technologies, national and international regulations, etc.

The final results of the Demo are in line with the initial design of the proposed solutions. The Local Flexibility Market developed within the Italian solution is subject to continuous developments on future projects, ultimatelyleading to a timelier development of all the necessary functionalities and technologies.

The work undergone within the Platone Italian Demo has opened a multiple range of solutions to deepen the developments and improve the architecture designed. Indeed, areti and other WP3 partners are already involved in other projects aimed to the TSO-DSO coordination within the context of ancillary services. In this regard, BeFlexible and Flow, funded within the Horizon Europe programme and other national projects such as RomeFlex could be mentioned. Basically, the design architecture defined in the Platone project represents a strategic asset on which some of the most important developments that will affect the electricity sector in the coming years are based. Furthermore, the DSO Technical Platform and based on the proposed SOGNO architecture has been adopted by areti for the creation of a corporate advanced distribution management system able to orchestrate all the processes and functionalities necessary for a correct and advanced management of the distribution network. The Light Node will be used as enabling flexibility device on Rome distribution grid. Another valuable asset developed within Platone's activities is the Shared Customer Database, a register where all the flexibility data and real-time measurements from the customer side are collected and then shared among all the actors involved in the flexibility activation process.

In short, Platone proposed a multitude of solutions, technologies, and collaborations that will pave the path towards the innovation and creation of an approach which was not sufficiently developed until a few years ago.

5 List of Tables

6 List of Figures

7 List of References

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8 List of Abbreviation

Abbreviation	Term
API	Application Program Interfaces
DEMI	Distributed Energy Management Initiative
DER	Distributed Energy Resource
DSO	Distribution System Operator
EV	Electric Vehicle
HW	Hardware
KPI	Key Project Indicators
LV	Low Voltage
MV	Medium Voltage
Obj	Objective
PV	Photovoltaic
SW	Software
SGAM	Smart Grid Architecture Model
TSO	Transmission System Operator
V2X	Vehicle to X