PLATFORM FOR OPERATION OF DISTRIBUTION NETWORKS

Platone

PLATform for Operation of distribution NEtworks

D6.7

Periodic report on lessons-learned (v4)

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Abstract

This deliverable reports on the lessons learned through the field trials activities of Platone during the fourth and final year of project activities. The lessons are divided into two subjects: standards, which is the major topic of WP6 and general topics, including regulatory issues. A summary of previous years lessons-learned is also included for each partner.

Keyword list

lessons-learned, standards, regulation, legislation, data privacy, Demonstration, Demo application, use cases, KPIs, customer engagement,

Executive Summary

The Platone project's core part were the Demos that are currently developed in Italy, Greece, and Germany. During the implementation of innovative projects that cover a variety of applications, a significant body of experience is gained. Such lessons are learned via the process of development and implementation, and it is important to keep track of them and present them to the community. Thus, an extra value is added by projects like Platone which serve as a source of valuable information for future projects that try similar approaches. This deliverable reports the lessons-learned during the 4th and final year of Platone. Reporting is split in two categories: one for general topics and a dedicated category for the applicable standards. The Platone project developing a two-layer Blockchain architecture for data acquisition to enhance connectivity in distribution networks, focusing on customer engagement, flexibility in market operations, and smart network management. This innovative system supports the goal of a carbon-free society by 2050 and will be tested in three European Demos and Canada's Distributed Energy Management Initiative. Within the project's WP6, the emphasis lies on standardization and legislation, assisting Demo leaders in their field trials, with Task 6.2.3 specifically collecting feedbacks from these leaders about their experiences with standards and regulatory challenges.

In the fourth year of the Platone project, the Italian Demo focused on debugging existing functionalities, finalizing the latest technology additions, scalability, and replicability of the solution to broader audiences, such as the RomeFlex Italian project. They implemented specific processes to ensure optimal performance as user numbers grew. However, challenges arose due to unforeseen bureaucratic delays in installing PV generators and storage units, emphasizing the importance of accounting for potential administrative setbacks. Meanwhile, no new experiences with standards were recorded since all technical implementations had been completed in the third year. Summarizing from previous years: in the first year of the Italian Demo, the project outlined a system architecture targeting a Local Flexibility Market with an emphasis on addressing grid issues and integrating platforms like blockchain. The team also explored regulations, especially concerning user data privacy, culminating in a governance document for data management. In the second year, the focus was on deploying and integrating this architecture in two Rome districts. Flexibility was favoured over rigid standard adherence, and engagement strategies were developed to understand user needs amidst concerns about privacy. The third year saw technological advancements in data collection and communication, with an emphasis on the Light Node's compatibility and efficient blockchain measurements. Challenges in distributed cloud communication were addressed, and the Local Flexibility Market's introduction underscored the importance of location and coordination in operational efficiency.

In its final year, the Greek Demo concentrated on completing the installation of Phasor Measurement Units (PMUs) and the integration of data for tools developed by the NTUA. Lessons from PMU installations highlighted the challenges in connection to the LV grid, emphasizing the device's non plug-and-play nature and the need for further design for large-scale installations. Meanwhile, the systems' integration aspect revealed challenges in software licensing, data transfer, and data formatting, emphasizing the need for early prediction of IT solutions. Efforts for customer engagement were hampered by regulatory constraints, but workshops and questionnaires showcased a potential positive response to future variable Distribution Use of System (DUoS) tariffs. Furthermore, the National Regulatory Authority (NRA) of Greece has introduced a new regulatory framework focusing on revising network usage tariffs. The framework emphasizes shifting from primarily variable-based revenue to a fixed price system tied to capacity during peak load hours, promoting the widespread adoption of remote electricity meters. This allows consumers to adjust consumption during peak hours, benefiting both users and the distribution service operators (DSO) by enhancing grid stability and reducing costs. Ultimately, this change gears towards a grid with greater observability and flexibility, pointing towards future integration of innovative solutions tested in Greece. Regarding lessons from previous years, in the first year, the Greek Demo, in partnership with NTUA and HEDNO, focused on the strategic alignment of the Platone architecture with Greek DSO needs, understanding smart grid technology standards, and identifying regulatory gaps, particularly regarding Blockchain in the energy sector. During the second year, the Greek Demo concentrated on installing Low-Cost Phasor Metering Units in the Mesogeia area while deepening their understanding of Greece's national laws, the dynamics between TSO-DSO, and emerging concepts like the 'Aggregator'. In the third year, the emphasis shifted to practical deployment of the Platone concept, discussing regulatory adjustments and emphasizing data

protection, while also addressing challenges with PMU installations, software tool utilization, and identifying regulatory and data gaps for machine learning applications.

In the fourth year, the German Demo concentrated on enhancing algorithms for "Virtual Islanding" and tested "Bulk-based energy supply" in the field, using rule-based and schedule-based control approaches for balancing local generation and consumption. Evaluations revealed that many communities, including the field test community in Abbenhausen, displayed a high surplus of generation, leading to power exports. While the rule-based and schedule-based controls both demonstrated their strengths and weaknesses in energy export/import reductions, it was observed that the bulk-based energy principle could potentially isolate LV communities from the MV-grid, though a broader evaluation is required for more conclusive results. Regarding previous years: Year 1 of the German Demo saw the inception of the energy management system concept, with AVACON focusing on compatibility and integration into the Platone framework. They grappled with disparate battery storage system standards, underscoring the need for uniformity. Additionally, they established a robust data management process in line with data privacy standards. In Year 2, AVACON continued its German Demo development, seamlessly incorporating the Energy Management System into the Platone framework. The community of Abbenhausen became central to their study, revealing significant energy surplus challenges and the potential for improvement with more localized weather data. Engaging with local communities posed challenges, but with local authority collaboration, progress was made. In Year 3, AVACON centred on household battery energy storage system standards and their integrations. They encountered standardization issues, particularly with vendor-specific protocols. However, from their use case studies, they recognized the efficiency of their system setup and noted the significance of accurate forecasting for improved battery control.

Other partners also contributed to lessons-learned reporting. Acea Energia, acting as the aggregator in the Platone Italian Demo, faced challenges in user engagement due to scepticism about device installations and in managing data exchanges while ensuring compliance with privacy and antitrust regulations. Collaborations with national regulatory authority improved user participation, while dedicated focus boards helped define guidelines for secure data management. In the Platone project's early stages, E.DSO played a vital role in WP1, focusing on creating consistent operation specifications for the aggregator/customer flexibility market system across Demo sites. They produced Deliverable 1.3, identifying regulatory challenges, and found a legislative gap between EU directives and their implementation at the state level. E.DSO's continuous collaboration efforts, like the April 2021 workshop and monthly calls, enriched knowledge sharing among Platone project partners. In the project's later stages, E.DSO led WP1 "DSO Operation Strategies and Harmonization," emphasizing harmonization and integrating with the European regulatory framework. They undertook Task 1.3, assessing Key Performance Indicators (KPIs) and revisiting them as the project evolved, ensuring their alignment with project goals and WP7's Scalability, Replicability, and Cost-Benefit Analysis activities. This approach ensured the KPIs maintained relevance and reflected the project's broader implications. Additionally, RWTH was actively involved in different Work Packages (WPs) of the project playing two important roles: coordination and management at the project level and the technical support of the Platone solutions at the Demo level. The major lessons learned regarding the first role can be shortly listed as: The need for early definition of KPIs, accompanied by periodic updates, to be able to track quantitatively the achievement of the project objectives; The importance of actively disseminating and exploiting project results in the context of similar research projects within and outside EU to reach broader audience; And the urge to look at the bright side of the situation which was enforced due to the pandemic by making use of the new opportunities brought by the new shift towards remote working. With respect to the second role of RWTH, the major lessons learned are: The important role of open source developments for the digitalization of the energy sector, The huge impact that the intermittent behaviour of renewables can have for the provision of flexibility and the need for the usage of advanced forecasting methods (provided that sufficient data is at the disposal of stakeholders); And the great opportunity that the modular design of the low cost PMUs provide to increase the technology readiness of them by their deployment and installation in real grid scenarios and in close contact with grid operators.

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1 Introduction

The project "PLATform for Operation of distribution Networks – Platone" aims to develop an architecture for testing and implementing a data acquisition system based on a two-layer Blockchain approach: an "Access Layer" to connect customers to the Distribution System Operator (DSO) and a "Service Layer" to link customers and DSO to the Flexibility Market environment (Market Place, Aggregators, …). The two layers are linked by a Shared Customer Database, containing all the data certified by Blockchain and made available to all the relevant stakeholders of the two layers. This Platone Open Framework architecture allows a greater stakeholder involvement and enables an efficient and smart network management. The tools used for this purpose will be based on platforms able to receive data from different sources, such as weather forecasting systems or distributed smart devices spread all over the urban area. These platforms, by talking to each other and exchanging data, will allow collecting and elaborating information useful for DSOs, transmission system operators (TSOs), Market, customers and aggregators. In particular, the DSOs will invest in a standard, open, non-discriminatory, blockchain-based, economic dispute settlement infrastructure, to give to both the customers and to the aggregator the possibility to more easily become flexibility market players. This solution will allow the DSO to acquire a new role as a market enabler for end users and a smarter observer of the distribution network. By defining this innovative two-layer architecture, Platone strongly contributes to aims to removing technical and economic barriers to the achievement of a carbon-free society by 2050 [1], creating the ecosystem for new market mechanisms for a rapid roll out among DSOs and for a large involvement of customers in the active management of grids and in the flexibility markets. The Platone platform will be tested in three European Demos (Greece, Germany and Italy) and within the Distributed Energy Management Initiative (DEMI) in Canada. The Platone consortium aims to go for a commercial exploitation of the results after the project is finished. Within the H2020 programme "A single, smart European electricity grid" Platone addresses the topic "Flexibility and retail market options for the distribution grid".

In WP6 the emphasis is mainly on the standardization and legislative side of the project. WP6 assists the Demo leaders in the implementation of their field trials by analysing the applicable standardization ecosystem and the regulatory framework, by providing suggestions and support and by recording their efforts to assist future similar projects. It is this last point in particular that the series of annual deliverables on lessons-learned wants to address.

1.1 Task 6.2.3

Task 6.2.3 aims at concentrating feedbacks from the Platone Demo leaders regarding their activities that are affected by standards, the standardization ecosystem in general and legislative and regulatory topics. This task delivers an annual report on the lessons learned through the Demo implementations. These annual lessons-learned reports have an open format that allows the Demo leaders to record their valuable experiences that came as a result of the project activities on the aforementioned topics.

1.2 Objectives of the Work Reported in this Deliverable

The objective of the work reported in this deliverable is to concentrate the valuable experience and lessons obtained by partners during the 4th year of Platone. The Demo leaders are encouraged to report their experience on general topics and, if applicable, to standardisation. Apart from Demo leaders, other partners are encouraged to report any valuable insights on their respective fields. The result is a record of how they encountered and handled any interesting problems or observations. Moreover, an extensive summary of lessons-learned from previous years is included for each partner in order to provide a total comprehensive reporting on the topic.

1.3 Outline of the Deliverable

Chapters 2,3 and 4 discuss the lessons learned as were gained by the activities of the Italian, Greek and German Demo, respectively. In these chapters, first a summary of lessons-learned in previous years is presented. Then, the lessons learned in the fourth year of the projected are discussed, including lessons on standards and more general. Chapter 5 includes the corresponding insights from other partners, apart from the Demo leaders. Chapter 6 concludes this report.

1.4 How to Read this Document

This document aims to record the experiences the Demo leaders and other partners gained during the last year of the project from the work on the implementation of the Demonstrations and other activities of Platone. In addition, a summary of the same topic from the previous year reporting is included for each partner. Reading the corresponding reports from years 1 to 3 will provide to the reader more details on the raised topics [2][3][4]. Moreover, regarding year 4, the reader is referred to the corresponding report from the Demo leaders that summarise Demo activities, namely [5][6][7].

2 Italian Demo

The following subchapters report the lessons learned from the Italian Demo in the fourth and the previous years of the project.

2.1 General lessons-learned

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 debugging activities as well as the communication, dissemination, and exploitation ones.

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, the partners elaborated a specific process aimed to the monitoring of platforms and systems in order to avoid issues in the computational load when the number of involved users increases and to guarantee a very high level of performance for the entire system.

Moreover and due to the outstanding results achieved from the Italian Demo and its methodology, areti decided to propose the approach and the architecture developed in the project to take part in other European and Italian initiatives. In this regard, in Flow [8], an Horizon Europe project, the market mechanism and the main components (Light Node, DSO Technical Platform, Shared Customer Database) are used to develop a solution to unlock the flexibility of the electrical vehicles, moreover in Beflexible [9], another Horizon Europe project, the TSO-DSO coordination is analysed starting from the traffic light mechanism implemented into Platone Italian pilot, at last Romeflex project [11], an experimentation promoted by Italian NRA to test a local flexibility market, based on the architecture of the Italian demo [10].

Regarding the involvement of self-consumption community which was foreseen and reported in D3.4 and updated in D3.5, this activity has not been finalized. This was due to the delays in the installation of the PV generators and the related storage units which needed 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.

2.2 Lessons learned on standards

Since all technical implementations were already completed in year 3 with no additional implementations of hardware components or new IT services in year 4, no additional experiences with standards were gained that can be reported on in this deliverable. A summary of past years lessons-learned is presented below.

2.3 Summary from previous years

2.3.1 First year – Italian Demo

In the beginning of the project, the Italian Demo outlined its system architecture to implement a Local Flexibility Market, identifying: the actor involved, and the role owned; the functional and technical requirements of the components; the market criteria for the clearing mechanism; the short term market sessions; the TSO-DSO coordination schemes; the data format and the media and protocols for the data exchange. This solution, based on market approach, aimed at providing flexibility coming from the Distribution Energy Resources (DERs), to solve congestion issues in local and global network, avoiding the violation of local grid constraints. The plan aligns with a set timeline in WP3, which encompasses the describing use cases, and establishing preliminary KPIs. Key smart grid protocols and standards have been documented for potential use in the Demo. As the project delves into platforms and blockchain technology, the upcoming period will solidify the technologies, standards, and protocols to be adopted,. Overall, the first year has provided foundational insights into components and functions, setting the stage for subsequent standard and protocol determinations.

Moreover, the Italian Demo delved into the flexibility services market, envisioning a supplementary marketplace to the current Italian ancillary service market governed by the TSO catering to local services like local congestion. In this regard, the existing regulations, laws, and the nature of services on offer have been thoroughly examined. Utilizing the IEC-62559 description of use cases and the SGAM analysis helped pinpoint characteristics essential for accurately representing the use cases, with SGAM layers serving as a guide for subsequent undertakings such as data exchange. An in-depth study of the legislative framework was also essential not just for technological and system development but also for customer involvement. A paramount concern herein was ensuring full compliance with privacy regulations when communicating user consumption data, especially considering the potential risk of sharing personal user data during pilot testing. The DSO, areti, already possesses such data due to existing energy transport contracts with users. A lack of a preventive strategy could risk non-compliance with unbundling, antitrust provisions, and inadvertently provide the Aggregator with undue commercial advantage. Second year – Italian Demo.

2.3.2 Second year – Italian Demo

During the second year, the Italian Demo emphasized the deployment and integration of the previously designed platforms. This phase allowed for a deeper understanding of components, integration patterns, and the architecture's overall functioning. Two specific districts in Rome, EUR – Tor di Valle District and Centocelle District were chosen for trial implementation. With the introduction of deliverables D3.3 [12] and D3.6 [13], the Italian Demo began its operational phase. D3.3 details the Italian Demo's architectural components, their respective roles, and the intricate data flows established for interaction. To ensure a comprehensive function definition, the architecture's development was segmented into distinct streams. These streams eventually began inter-communication and integrated their respective functionalities. Despite listing potential standards in D6.2 [14], the Italian Demo opted for lesser-standardized protocols to maintain flexibility. Consequently, they introduced a unique data model, particularly for components like energy market communications. While certain standards provided general guidelines, they were not adhered to rigidly. Notably, due to its nascent stage, the Blockchain Technology hasn't been entirely standardized. Similarly, products related to Energy Storage System weren't certified per traditional standards because of their recent inception. AMI maintained full standard compliance. In the end, to interface the platforms respecting the timeline and guaranteeing the flexibility request by the architecture, the demo use a different solution respect to standards defined in the beginning.

During the project's progression, the Light Node (a device installed in the customer property that enables the end users in the Local Flexibility Market, gathering the real time measurements from the main meters and receiving the flexibility command from the DSO), procurement caused a significant timelines extention, due to requirements fixed by the Italian legislation for the pubblic tender mechanism, this issue has been monitoring and managed in the risk analysis of Platone. Thus, proactive scheduling was adopted to ensure alignment with the project's timeline. The Italian Demo incorporated a dual-faceted user-engagement strategy, segregating users into two groups (retail and business) and arranging dedicated workshops for each to better understand their needs. The collaboration with the Italian research body Enea, allowed the involvement of a segment already keen on energy topics, although initial user involvement was limited due to the intrusive nature of the required installations. The engagement of multiple users necessitated the development of a specific contractual framework between Areti and the users, facilitating equipment installations and participation. Additionally, Areti crafted an internal governance document detailing personal data exchange guidelines, emphasizing pseudonymization to protect user privacy. Participating customers were required to acknowledge and sign the document, clarifying the project's intentions and data usage.

2.3.3 Third year – Italian Demo

In the third year of the project, WP3 partners significantly updated the technology especially enhancing the capabilities of the Light Node. This update improved its compatibility with the CHAIN2, a channel that connect the customers with the main meters, enabling more complete and granularity data collection from 2nd generation of smart meters. Moreover, the adoption on the Light Node of the MQTT protocol streamlined communication with the other platforms, and the use of a module for a multi-band communication capabilities with 4G ensured consistent uptime. Additionally, the measurement certified on blockchain in the Blockchain Access Layer component were successfully maintained without increasing block creation frequency, even with higher data volume. The DSOTP enhanced power flow calculations and flexibility management for both medium and low voltage grids and introduced a real-time intraday market. Despite an expansive and adaptable data structure, challenges arose from the distributed cloud infrastructure, causing communication lapses. However, pre-existing retry mechanisms were adjusted based on integration experiences to address this issue.

Furthermore, the Italian Demo emphasized the significance of coordination activities and pinpointed key areas for future focus. The introduction of the Local Flexibility Market revealed specific local challenges, emphasizing the importance of the location of DERs for efficient local market operation. The need for improved coordination among distribution and transmission system operators also became evident to maximize the effectiveness of flexibility products. Areti, during customer-engagement, identified challenges in equipment installation on the user's side, noting that customers are dispersed, installation in private areas demands user availability, and maintenance is challenging due to the same reason. However, Areti's involvement in the project enriched their understanding of market needs, prompting them to apply the Platone solution to various environments, with several projects lined up to utilize the knowledge gained from the Italian Demo.

3 Greek Demo

The following subchapters report the lessons learned by HEDNO and NTUA partners of the Greek Demo. Subchapters 3.1 and 3.2 elaborate respectively about the general and standard-related lessons learned during the fourth year of the project. Subchapter 3.3 summarizes the lessons learned during the previous three years.

3.1 General lessons-learned

As Platone reached its fourth and final year, the Greek Demo focused mainly on the completion of the PMUs installation, as well as the collection and visualisation of the data to be integrated in the DSOTP and used by the tools developed by the NTUA, aka the State Estimation Tool and the variable Distribution Use of System (DUoS) tariffs design tool. These tools were further developed and eventually finalised in a version that provided an end-to-end validation set up on a portion of the pilot's site network. Furthermore, the final version of the Platone Open Framework was deployed at HEDNO premises, which encompassed a substantial effort from all WP4 partners, so that any issues due to systems' compatibility, connectivity and algorithms' integration were resolved. Finally, the Greek Demo partners elaborated on the dissemination of the Platone architecture and the outcomes of this four-year project regarding the innovative solutions developed from the cooperation of HEDNO and NTUA. Several lessons learned that came up during this last phase of the pilot project in Mesogeia.

3.1.1 PMUs

In the last quarter of 2022, HEDNO purchased the appropriate equipment to facilitate the installation of the PMUs. The equipment included:

1. The voltage and current sensors required to enable the acquisition of the voltage and current signals from the field, these being the necessary input for the PMUs.
2. The required cables to perform a safe and reliable connection between the LV pillar and the PMU inputs and outputs.
3. The boxes that house the PMUs, along with the voltage sensors (transformers) and provide structural support for all components inside the pillar of the MV/LV substation.

HEDNO faced many difficulties and had to overcome several obstacles before successfully completing the PMU installation in the LV grid. The main barriers have been the limited availability of compatible equipment in the market which would allow the connection of the PMUs to the LV grid, as well as the considerable time needed on testing the PMUs offline to ensure all necessary specifications and standards for their reliable operation were met (e.g. EMC requirements, type tests, environmental tests for power, analog and digital outlets). The components' selection was concluded after exhaustive research. However, all five PMUs were successfully installed, and their safe and reliable operation is secured thanks to the extensive cooperation of HEDNO with the NTUA researchers, as well as the RWTH Aachen.

Lessons learned from the installation of the PMUs mostly concern their connection to the LV grid and the complexity that this entailed. The voltage and current levels in any network node that a PMU was to be plugged in had to be degraded by the use of transformers so that the appropriate signals could be obtained, and consequently the signals' phasors could be actually measured. On-site investigation with the use of an oscilloscope showed that this signal degradation, or in other words this additional signal transformation, magnifies the measurements' errors by adding phase angle errors and harmonics. Instead, if isolated direct sensing from live line was used for both voltage and current, such errors would be minimised. This cannot be supported by this specific PMU given that its required voltage/current input signal is +/-10V max, but it could be considered for any future upgrade of it.

What became apparent from the PMUs installation process was that this specific device is not a plug-n-play solution, and if it was to be installed at a bigger scale throughout the distribution network in Greece, further design work should be carried out. At the moment, it does not come as a standalone device that can be connected directly to the network which prolongs its actual commissioning. Also, getting from the original PMU to the final box to be installed (which includes the necessary sensors and the required wiring) needs a per unit time-consuming effort that undermines the scalability of the solution. Finally, the additional components that are necessary to enable the PMUs installation are reliant on procurement processes and stock availability which could further challenge their network wide use.

On another note, the installation of the five novel micro-PMUs during this final phase of the project marks the first installation of PMUs in the distribution network in Greece and remains a noteworthy starting point for the use of advanced metering equipment in the distribution network. HEDNO acquired significant knowledge on such devices, and in the future, they could further investigate how to use them for various DSO applications and needs. Lastly, it was shown that the PMU data, especially when combined with the State Estimation Tool developed by the NTUA within Platone, could significantly contribute towards enhanced grid observability.

3.1.2 Systems' integration / End-to-end testing of the set-up

During the last year of the Platone project, the focus was shifted on the DSOTP integration on HEDNO premises. This required fine tuning of the State Estimation Tool's (SET's) code and deciding on the exchange of aggregated metering data originating from various sources, including PMU data, as well as SCADA and AMR data. The Greek demo chose to wait for the installation of at least one PMU on the field before they complete the integration process so that all data are available. However, for future projects following a similar approach, it is recommended that any platform software is deployed even before other hardware installation is complete, so that the IT environment set up is ready the soonest possible. In that way, the potential initial problems are encountered before any integration of further software upgrades and tools/data is carried out.

To facilitate the final software deployment, a Virtual Machine (VM) was set up at HEDNO and docker images containing all the required tools were built. However, various challenges were encountered regarding software licensing, as the SET was originally developed in Matlab, which is not open-source and had to run into Octave. Because of that, further validations and modifications in the code were needed. This translation also caused delays due to the debugging needed for the code to run properly.

Regarding data transfer, RWTH initially received PMU data through a successful Virtual Private Network connection, but the goal was to transfer the data directly to HEDNO in the DSOTP. To achieve this, different options were investigated with the final solution to be chosen and implemented at the final stage of the pilot project. What became apparent during this process was that for any future upgrades/extensions of the DSOTP, the potential IT solutions should be elaborated at various stages so that any potential issues of connectivity and interoperability can be predicted early on.

Another significant aspect that should not be overseen, was the combination of different types of data required for the SET to function correctly. The Greek Demo's electricity distribution network topology and real-time measurements were stored in XML format according to the Common Interface Model (CIM) standard, while the SET required input files in another format (PTI format). Hence, the need for data converters was raised so that data from the DSOTP could be used as input to the SET. For this purpose two intermediate converters were developed in Python by HEDNO in collaboration with NTUA to act as an interface with the SET code so that the issue is addressed. The collaboration of HEDNO and NTUA with RWTH was crucial for the successful implementation of these converters. The main lesson learned was the importance of data harmonization, as significant effort was required by the Greek Demo to ensure data compatibility among different parts of the Platone Open Framework in the final version. At the end, the end-to-end setup was completed, along the lines of the proposed Platone Framework, with the smooth collaboration of all involved partners and with the help of lessons learned amassed up to this point.

3.1.3 Customer Engagement

A key lesson learned from the Platone was that customer engagement activities can become a really challenging task when regulatory restrictions are strongly related with the solutions proposed by the project. Such a challenge should be reported from early on, and the engagement strategies should be revisited periodically during the project's lifetime to define actions that can compensate for any inevitable gaps in customer engagement.

Since the methodology for DUoS tariffs definition as well as the DUoS tariffs themselves are eventually determined by the NRA, there was no possibility that the variable DUoS tariffs design tool developed within the Greek Demo could be tested in a real-life environment with real customers. In theory, if regulatory sandboxes in Greece for such energy flexibility provision tests were established during the course of the project –which unfortunately was not the case- multiple actual scenarios could have been assessed. However, the Greek Demo still put a great deal of effort to achieve some customer engagement. The decision was made to focus on workshops and activities that would raise awareness of the novel methodology that the variable DUoS tariffs design tool proposed. Furthermore, an online questionnaire was designed and shared as a first step of approaching potential future customers. Details of both customer engagement activities streams are presented below.

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On 21 December 2022, the Greek Demo of the Platone project was invited to participate in the 1st Research Projects Dissemination Event organized by the Research and Innovation Department of HEDNO (Hellenic Electricity Distribution Network Operator). The event was attended by 80 people across the company. The topic of this online workshop was flexibility, and the main focus was to present and investigate the benefits and the added value that relevant research projects and the solutions they suggest hold for HEDNO. Also, with the completion of the installation of the five PMUs, on 30 June 2023, a study tour took place in the Mesogeia pilot area with the main scope of informing the visitors and stakeholders on the work that was done in the Demo site, the outcomes of the project as well as the insights gained by the development of the Platone architecture.

In the end of the second quarter of the final year of Platone, a questionnaire was shared with stakeholders from academia, the energy sector, the Greek DSO, the Greek TSO as well as the general public to gauge their willingness to participate in a potential future flexibility provision scheme triggered by a variable DUoS tariffs' policy. This idea came up as another way -other than the simulations that took place within Platone- to understand how a future variable DUoS tariffs' policy would be viewed by the network users. The feedback received showed that most of the respondents would be highly responsive to such DUoS tariffs' 'signals' and they would shift their energy consumption if they would benefit from potential cost reductions. Also, environmental benefits and increased grid reliability would motivate their active participation in load shifting. A key lesson learned was that the Platone solution adopted in the Greek Demonstration, founded on the DUoS tariffs design tool developed by the NTUA could become the basis to build on for any future regulatory change regarding the DuoS tariffs

3.2 Lessons learned on standards

In this chapter, there will be a short description of the new regulatory framework enacted by the NRA, regarding network usage tariffs and the lessons HEDNO and NTUA obtained as the new framework touches the same topic that the Greek demo focuses on, the DUoS tariffs.

The primary purpose for determining the regulated revenue of any activity of the DSO is to ensure that the operator recovers the cost of the activity that the regulator deems reasonable for the development, operation and maintenance of the network in order to meet the demand for distribution services. An operator has incentives to reduce the above mentioned cost by improving its efficiency without compromising the level of security, network performance or quality of services provided. The reasonable cost incurred by the operator is recovered through the usage tariffs incurred by the users of the network. The methodology for determining the usage charges of the network aims at the distribution of costs among the users of the network in a fair way, i.e. based on the costs they cause to the network, as well as to provide financial signals to users, to shape their usage behaviour in a way which helps to reduce the distribution costs.

The methodology for the determination of the network usage tariffs is set out in the Network Usage Tariffs Manual. In this document, the following topics are elaborated: the recovery of the required network revenue, its fair distribution among the network users, the structure of the tariffs to reflect the different network costs (i.e. fixed costs and those costs dependent on the electricity demand), the objectivity, the transparency, the clear formulation of the methodology and the way of determination of the tariffs. A uniform tariff per consumer category is foreseen. Each consumer category includes consumers based on the consumption characteristics of their facilities so that the costs of the network are reasonably incurred by them. Especially for the producers connected to the network, individual tariffs are provisioned based on the network used exclusively by them, but this part of the framework is not yet applied.

With the current regulatory framework, network usage tariffs are paid by the consumers based on a fixed price, which is related to their installed capacity, and a variable price, which is related to their energy consumption levels (per kWh) during each billing period. The main source of revenue for the DSO (90%) in the past was provided by the variable part of the network usage charge, while the 10% of DSO's revenue was provided by the fixed part of the network usage charge. With the new regulatory framework, the percentage of the DSO revenue provided by the fixed part of the network usage charge changed to 60%, and in the future, it is provisioned that it will increase to 90%.

In practice, the enacted law regarding network usage tariffs aims to shift the focus of the network usage charges, with the fixed price of the bill being the main source of revenue for the DSO. In particular, most of the required revenue concerns the capacity charge and it is distributed to the network users based on the capacity absorbed by consumers of each category during the peak load hours of the network. The peak load hours are determined before the start of the regulatory period considering the load variations of the previous two years and remain fixed throughout this period. For consumer categories with remote electricity meters with hourly metering, the capacity charge of each consumer is calculated based on the electricity demand during peak hours. For the other categories, the charge is based on the installed capacity of each consumer. The capacity charges for each consumer category are calculated by the network operator on an annual basis, immediately after the determination of the required revenue for each year, and are approved by NRA.

All things considered, it has become evident that the NRA, along with the DSO and TSO representatives, aim to boost remote electricity meters usage, and to approach a different tariff policy regarding network usage charges. All of these actions envisage the operation of a grid with increased observability where consumers will be able to provide flexibility to the grid. Therefore, one can easily realise the potential future applicability of the innovative solution of the Greek Demo tested through Platone, since a potential variable DUoS tariff scheme and the penetration of PMUs that would establish a grid with increased observability and flexibility provision capability.

3.3 Summary from previous years

3.3.1 Year 1 – Greek Demo

During the initial year of the project, the Greek Demo examined the prospects of the Platone architecture and strategized its alignment with the unique requirements of the Greek DSO. In collaboration with NTUA, HEDNO outlined the use cases for the Greek trial and set KPIs for evaluating the developed methods which subsequently determined the actors, components, and related standards. A detailed examination of standards via D6.1 enhanced the Greek Demo's comprehension of the broad range of smart grid technology standards leading to contributions to D6.2. This reflection considered not only established standards but potential ones for use cases, with Blockchain standards being of particular interest due to their innovative nature. The standards investigation fortified the groundwork for subsequent phases, with HEDNO acknowledging the significance of adhering to these standards to ensure a resilient Demo framework, anticipating further refinements and insights in the coming stages.

Moreover, the Greek Demo, informed by D6.8, extensively studied the distribution grids' characteristics in Europe and the related national and European legislative framework pertinent to Platone's innovative solutions. Based on this, HEDNO discerned applicable laws for their Demo, identifying regulatory voids tied to their use cases. As elaborated in D6.9, two significant takeaways were the need for a comprehensive national regulatory framework detailing the "Aggregator's" role and the apparent legislative gap regarding Blockchain application in the energy sector at both national and European levels. Furthermore, through the use case definition process, the Greek Demo acknowledged the project-wide consensus to employ the IEC 62559's Use Case Methodology, ensuring standardized use case formatting and fostering a profound understanding of the standard and the SGAM.

3.3.2 Year 2 – Greek Demo

During the second year of the project, the Greek Demo intensively examined the installation possibilities of Low-Cost Phasor Metering Units in the Mesogeia area's test grid, a semi-urban locale demanding constant power supply. The challenge was ensuring uninterrupted power in this densely populated area. The Platone team at HEDNO liaised across their organization to collect crucial details, aiming to install the PMUs safely and effectively. HEDNO's Network Division provided exhaustive list of standards that metering equipment must adhere to for the optimal and secure installation of the PMUs. These standards cover different areas like EMC, type tests, environmental tests, voltage and current transformer standards, and specific guidelines for phasor measurements in power systems.

During the same year, the Greek Demo expanded its expertise in regulatory areas. To complete the ‘Questionnaire on regulations concerning DSOs’, the team delved deep into Greece's national laws, examining the national legal framework for flexibility, the dynamics between TSO-DSO, and upcoming adjustments in line with EU directives and the target model proposed by European Union Agency for the Cooperation of Energy Regulators to unify European markets. Research also covered areas like energy storage, EVs, Energy communities, and the relatively new concept of the ‘Aggregator’ in Greece. Furthermore, the team investigated DSO and energy provider data management, pinpointing regulatory gaps around Blockchain and smart contracts. The finished D1.3 document provided insights into regulatory aspects in other European countries, enhancing the Greek Demo team’s comparative perspective.

3.3.3 Year 3 – Greek Demo

In the third year, the Greek Demo built upon prior research, conducting a comprehensive study on standards related to EMC requirements, type tests, environmental tests for power, and both analog and digital outlets. The study also delved into standards for voltage and current transformers as well as the accuracy of PMUs.

Beyond the standards ecosystem, the emphasis was on the practical deployment of the Platone concept, from PMU installations to hosting the Platone Open Day in November 2021, where the discussions underscored regulatory shifts needed in Greece for variable tariffs, emphasizing social justice in flexibility services and the paramount importance of data protection and anonymization. The challenge of data anonymization also became evident when uploading datasets to the Zenodo platform, compliant with GDPR. Extensive groundwork was laid for the PMU installations, navigating through HEDNO regulations and discerning suitable hardware. Furthermore, the project utilized open-source software like Octave, Docker, and Kubernetes for various tools. The submissions of D4.3 and D4.4 highlighted the regulatory gaps concerning variable tariffs such as the lack of provision for spatial and temporal granularity, the scarcity of comprehensive literature on human-response to pricing signals, and the limitations posed by the unavailability of ample field data, especially for machine learning applications.

4 German Demo

The following subchapters present the lessons learned from the German Demo in the fourth and previous years of the project.

4.1 General lessons-learned

Activities of the German Demonstrator in the fourth year of the project focused on improving the algorithms for Use Case 1 “Virtual Islanding”, their application in the field and evaluation and performance evaluation based on KPI. Furthermore, Use Case 3 and 4 “Bulk-based energy supply” were tested for the first time in the field and evaluated. Power demand characteristics of the community Abbenhausen (Twistringen) have been further analysed.

Power Exchange Characteristics of the Community Abbenhausen

The community of Abbenhausen (Twistringen) is located in a rural grid section. The community accommodates approx. 60 single-family homes that display a high share of roof top photovoltaic (PV) systems with 445 kWp installed generation capacity. More information are provided in D5.7 [1]. The community is located in the low voltage (LV) grid and supplied with energy from the medium voltage (MV) at a single point of common coupling (PCC). At the PPC, a measurement device, e.g., PMU, has been installed in 2020, to measure the power and energy exchange with MV grid, which indicates the residual load demand after generation. After 3 years of data collection it has been observed that on sunny summer days the community displays high power and energy export. The daily maximum power export measured was 384 kW. The daily exported energy reaches up to 2.33 MWh. At night-time. On same day at night-time, with no PV generation, the community displays a maximum power import peak of 38 kW. The daily imported energy at night quals 170 kW. Comparing power and energy exchange shows that on clear summer days power export peaks are 10 times higher than import peak and exported energy is 13 times higher than imported energy. On unsteady overcast days the community displays volatile power exchange with power drops from 360 kW to 0 kW within 5 minutes. Volatile power exchange is the result of changing cloud coverage. In the winter season on clear days surplus of generation can be observed either with export peaks up to 120 kW. The average exported energy is 90 kWh. The import peak on an average day reaches up to 68 kW. The highest import peak was achieved on Christmas Eve 2020 with 115 kW. The imported energy on an average winter day is 680 kWh. Further analysis and lessons learned are provided in D5.7.

The collected measured data and results of analysis gave value able insights into the power and energy exchange characteristic of PV driven communities in the LV grid with the MV grid. The results indicate that power demand characteristics of PV driven community in rural areas are almost generation driven and demand in recent years are not a decisive factor for power peaks and energy exchanges at PCC

Lessons Learned from UC 1.0 and UC 1.1

In the fourth year for UC 1 "Virtual Islanding" a second UC performance analysis has been applied based on KPI. The UC aims at reducing power and energy exchange at PCC by battery control, i.e., CBES, in respect to PV feeding in the community (Abbenhausen). A first analysis has been performed and reported in D5.4 for UC 1.0 with a near real-time operation (RTO) mode that applies rule-based logic to measurement data with a 15-minutes control cycle. The evaluation of the KPI in this first analysis is based on a relatively small data set with a limited number of UC 1.0 testing days, from July 1st 2021 to July 4th 2021. To have a better understanding of the UC 1.0 performance for this KPI additional tests have been applied on different days in 2022 that include a mixed type of days (sunny, overcast and mixed days). Additionally, UC 1.1 has been implemented with a schedule-based operation (SBO) mode, that applies optimization to a day ahead forecast of the residual power exchange at PCC. The results of both UCs have been evaluated and compared.

The results showed that both, UC 1.0 and UC 1.1, achieve a significant reduction of energy exchange at PCC on almost all testing days when control CBES in the community, which is an excellent result. Also, the import and export energy exchanges at PCC were reduced significantly, which indicates an increase of PV-self-consumption within the community in the LV grid level. Both KPI confirm the great grid beneficial effect for the DSO and community. Just on a few days UC 1.0 and UC 1.1 displays some increase of power peaks and energy exchanges for import and export. There are some reasons identified:

UC 1.0 on clear summer days - The storage capacity of CBES is limited. When UC 1.0 is applied on clear sunny summer days the storages reaches maximum state of charge before very high generation peak from PV occur. Instead of aiming zero power exchange at PCC, UC 1.0 could be configured to achieve a higher threshold at PCC. Then, charging of CBES is triggered only once this new threshold is exceeded and not before that. Thus, CBES control would only be active during phases of large PV generation, requiring less storage capacity of the CBES. Additionally, for some days UC 1.0 can be improved by a proactively discharging CBES before high PV generation occurs.

UC 1.0 on unsteady, overcast days – on some days causes high import peaks, when right after adaptation of CBES charging power, bypassing clouds cover the community, reducing solar radiation. The sharp drop in PV generation resulted in the CBES charging from the MV grid instead, increasing the import power peak. In order to react to volatile PV feed-in, the measurement-and-control cycle associated with UC 1.0 could have higher frequencies for CBES charging power adaptation. However, increasing the frequency from 15 minutes to higher requires an investigation considering the performance of hardware components, communication infrastructure and latency of the Energy Management System (EMS), i.e., ALF-C in the Platone Open Framework.

UC 1.1 in general – For most days, UC 1.1 shows great achievement at peak and energy reduction and potential to outperform UC 1.0. As the SBO mode uses day ahead forecasts as input the performance of the use case mainly depends on forecast errors of the prediction. A more accurate forecast would improve UC 1.1. A non-accurate forecasts of PV generation lead to over- or underprediction of PV feed-in. Thus, the CBES, e.g., will be charged to compensate PV generation that never materialized, which can cause high import peaks from the MV grid. A possible improvement has been identified by applying a second level algorithm intraday that uses intraday weather forecast updates to re-schedule CBES control. However, improving forecast of PV generation that include volatile power drops still is difficult, as the weather forecast used in the German demonstrator lack of accurate predictions of small cloud trains shading PV panels of narrow locations, e.g., of shading of PV panel located in the community Abbenhausen.

Alternatively, UC 1.0 and UC 1.1 can be improved by implementing a short-term forecast of PV power that uses inputs from a cloud camera that is implemented in the community of Abbenhausen [2].

Lessons Learned from UC 3 and 4

The fourth year was also dedicated to UC testing and evaluation. UC performance analysis based on KPI have been performed for UC 3 and 4 “Bulk Energy Supply”. The UC was implemented with a near real time operation (RTO) mode and a day ahead forecast for the prediction of residual energy export or import for a 24h interval. Evaluation of the UCs have shown the ALF-C was able to reduce the power peak on the medium-voltage line by up to 200 kW. Except for one instance, where the peak power was increased slightly, on every other day there was either a reduction in cable load or no change at all. The load reduction on the medium-voltage cable is larger when UC DE 4 was applied compared to UC DE 4. This is the result of the combination of the impact the significant rooftop PV generation of Abbenhausen has on this medium-voltage line and the application of UC DE 4 on sunny days, with a bulk export. Hence, the impact potential in load reduction is larger for UC DE 4.

The results have shown that using storages in LV community have significant grid beneficial effects. However, current German legislation and regulation is limiting the DSO to own, operate or event control batteries at all, no matter if a storage is a type of CBES or operated by residents as household battery energy storage systems (HBES) in combination with PV system. Active power measurement analysis on MV line feeding the community Abbenhausen showed that best time for bulk-based energy delivery (UC 3) to achieve a reduction of active power peaks for a generation driven days (UC 4) is the period from 8 p.m. to 0 a.m.. In case of demand driven scenario (UC 3) the most beneficial period for bulk exchange (import) is in the period from 0.00 a.m. to 4 p.m. on sunny days. However, in case of days with unsteady weather and overcast days with less PV generation, the period from 0.00 a.m. to 9 a.m. is most beneficial for power peak reductions the MV grid (feeder and line) for bulk energy import.

Power and Energy Demand Forecast for LV grids (UC 3 and 4)

The evaluation of the developed and implemented power and energy forecaster for LV communities pointed out that the residual load demand forecast can be very accurate on sunny days. On overcast days the forecast still is accurate at night-time (no PV generation). However, on daytime of days with unsteady weather, overcast days, the forecast can be very imprecise from morning to noon. In many cases, the forecaster is too optimistic in terms of PV feed-in compared to the actual occurred PV feed-in, which results in an imprecise generation forecast on overcast unsteady days.

4.2 Lessons learned on standards

Since all technical implementations were already completed in year 3 with no additional implementations of hardware components or new IT services in year 4, no additional experiences with standards were gained that can be reported on in this deliverable. A summary of past years lessons-learned is presented below.

4.3 Summary from previous years

4.3.1 Year 1 – German Demo

During the first year of the project, the German Demo concentrated on devising the architectural concept of the field test, primarily around the EMS, AVACON Local Flex Controller (ALF-C). This involved ensuring its compatibility with the Platone framework and linking it to physical assets within the grid. Subsequently, specific use cases were detailed emphasizing the integration of future energy communities into DSO grid operations. However, a challenge emerged when connecting physical assets: vendors for battery storage systems lacked unified standards, often utilizing proprietary or lesser-known protocols. Accessing these systems required navigating complex processes, sometimes requiring non-disclosure agreements. The obscurity around backend solutions might stem from competitive advantages or revenue models tied to proprietary services. AVACON's investigations shed light on the need for standardized connections to household storages. The broader implication suggests an industry-wide opportunity to establish uniform standards for monitoring and controlling batteries. Lastly, the project identified challenges in metering and monitoring network behaviour, underscoring a need for more standardized, cost-effective solutions in monitoring equipment.

Apart from focusing on IT architecture development and standard identification, AVACON prioritized aligning solutions with regulatory and legislative guidelines, especially concerning customer data in the context of a field test trial. To comply with both national and international data privacy standards, notably General Data Protection Regulation (GDPR) [15], AVACON instituted a thorough data management process. This process ensured the collection of only necessary personal data from participating customers, emphasized "data minimization", and detailed secure methods of data transmission, storage, and eventual disposal. All customer data management actions, from encryption to paper consent storage were constructed to align with both legal requirements and AVACON's internal policies.

4.3.2 Year 2 – German Demo

During the second year of the project, AVACON concentrated its efforts on the German Demo, emphasizing the AVACON Local Flex Controller (ALF-C) Energy Management System. The system was smoothly integrated into the Platone framework and successfully connected to physical assets, most notably the large-scale CBES. This integration wasn't without challenges. For instance, there's no standard protocol for setting up such extensive storage systems, necessitating intense communication with manufacturers and Fire Authorities and Departments. AVACON ensured the system complied with numerous industry norms, enhancing reliability and safety. Real-time data monitoring became possible with the introduction of an IoT dashboard, providing instantaneous insights into the system’s operation. Meanwhile, the community of Abbenhausen emerged as a pivotal case study for Local Energy Communities. Its consistent energy surplus showcased the necessity of smart EMSs including predictive algorithms with more localized weather data that can help to predict variable solar energy outputs and ultimately mange the flexibility more efficiently.

Moreover, in the same year, AVACON expanded its focus from just technical aspects to also involve customers and the local municipality. The goal was to execute a field trial in a village.However, selecting an ideal community, based on a set of conditions defined in grid connection guidelines, e.g. close proximity to secondary substation, conditions set for CBES in building permission from local authorities as well as the condition of having a community with a high share of households with PV systems proved intricate.. With the mayor's support, potential sites were identified, but engaging with landowners directly was a challenge. Abbenhausen was eventually chosen, revealing that its PV systems often generated excess energy, necessitating grid reinforcements for a new 300 kW CBES. Building approvals by local authorities posed issues, but early collaboration with authorities streamlined the process. Hosting a ‘Open Day’ in the community of Abbenhausen helped to motivate inhabitants to get informed about the project, gain trust and recruit participants, which accelerated the customer engagement process. As the project progressed, AVACON identified gaps in translating EU guidelines into national laws, emphasizing their commitment to monitor legislative shifts and act accordingly.

4.3.3 Year 3 – German Demo

In the third year of the Platone project, AVACON focused on standards for household battery energy storage systems (HBES) and associated technologies. They equipped five households with smart inverters, HBES, and IoT communication devices and also set up a prototype at their education department near Hannover. Key learnings from this endeavor include the prevalent combination of HBES systems with rooftop photovoltaic systems, vendors often offering integrated solutions including PV panels and smart inverters, and the presence of standardized protocols in inverters from different vendors. However, challenges arose due to the lack of standardization concerning readable and writeable data fields in vendor APIs and inconsistent datapoint allocations across vendors, complicating router implementation. Moreover, comprehensive instructions for interface parameterization were not always publicly available from vendors.

Furthermore, the third year, key lessons were drawn from two primary UCs. From the UC 2 "Coordination of Flexibility Requests," the results show that the field-test setup, consisting of a CBES, sensors, controllers, and an ALF-C balancing scheme, was highly efficient, achieving 99% flexibility availability. The responsiveness met the target of a 5-minute response time, with the flexibility request dispatching achieved in under 2 minutes. Despite an 8% deviation between requested and achieved setpoint due to unpredictable community load demands and PV generation, the 15-minute control cycle of the balancing scheme proved adequate. Automation of UC2 tests through a runbook simplified the process, and the importance of adequate flexibility storage capacity was highlighted. In contrast, UC 1.2, focused on "Virtual Islanding," adopted a forecast-based approach for battery control based on solar radiation and community consumption. Key takeaways include the high sensitivity of net load demand to solar radiation and the reliability of solar forecasts on sunny days. However, on cloudy days, forecasts occasionally exacerbated peak loads. Shifting to a 15-minute interval for forecasts and refining model parameters could further improve accuracy, and the overall UC 1.2 approach significantly reduced peak load at substations.

5 Beyond Demo activities

In this Chapter lessons-learned from other activities are reported.

5.1 ACEA

Throughout the project, Acea Energia performed the role of the aggregator in the Platone Italian Demo and was also responsible in setting up the activities for the customer engagement strategies. The Aggregator is a prominent actor in the development of local flexibility energy market with the ability to bundle different type of DERs, i.e. generation, consumption, and storage, to provide flexibility services to interested stakeholders, and to enable DER's access to the established power markets. During the engagement of the users in the project, two main difficulties have emerged:

- **The actual involvement of users in the experimentation:** The process of user's involvement in the experimentation highlighted some barriers and resistance from users, mainly derived from the experimentation requirements of installing devices in the users households and the initial scepticism in taking part in the project. In this regard, the involvement of ENEA (an important national agency for new technologies operating in Rome) was crucial to target a niche of people already interested in energy and environmental issues in order to increase the involvement rate of customers.

- **The management of data exchange between residential users and areti/Acea Energia:** The need to trace a clear path regarding the communication of users' consumption data between project partners was highlighted, 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). This imposed a risk concerning the exchange between DSO and Aggregator and the potential exchange of information that could have been considered as commercially sensitive, with an involuntary undue advantage in favour to the Aggregator. In order to prevent this potential risk and the misunderstanding of effective aims within the project, dedicated discussion tables and focus boards were established involving the Legal & Compliance and Regulatory Functions of Acea Energia and areti, together with the Privacy Responsible of Acea S.p.A.. This 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 in line with the Platone data management plan.

5.2 E.DSO

In the project's initial stage, E.DSO was instrumental in WP1, dedicated to establishing DSO operation specifications for the aggregator/customer flexibility market system. Their work sought to ensure that there was consistency across the Demonstration sites and that a uniform methodology was applied in analysing the outcomes. Central to their endeavours was the creation of Deliverable 1.3 - a comprehensive report outlining the regulatory challenges that might affect the solutions being tested in the Demonstrations across European nations. To gather the necessary information for this report, a detailed questionnaire was designed and distributed, focusing on eight thematic topics including flexibility, energy storage, aggregation, blockchain, and more. One of the critical findings of this effort was the identification of a significant legislative disconnection: while the EU was setting progressive directives, their actual implementation at the member state level was inconsistent and often lagging. This gap poses challenges, especially as the Clean Energy Package goals necessitate the integration of new technologies, EV infrastructure, enhanced grid observability, and robust cybersecurity measures. Furthermore, E.DSO emphasized the importance of coordination, demonstrated by their April 2021 workshop. This event convened various projects under the H2020 banner, encouraging a cross-pollination of ideas and best practices. This initiative highlighted the regulatory barriers to innovation across European countries and Canada, and also addressed the potential influence of legislation on the scalability of solutions developed by Demos. To ensure seamless communication among Platone project partners and to drive continuous alignment, E.DSO initiated monthly calls, proving invaluable for knowledge sharing, collaboration, and the overall success of the project.

During the latter stages of the Platone project, E.DSO spearheaded WP1 "DSO Operation Strategies and Harmonization", striving for a harmonious approach between Demonstration sites, a unified analytical methodology, and integration with the broader European regulatory framework. Central to WP1 was Task 1.3, which focused on defining and assessing KPIS to gauge Platone's effectiveness in meeting its technical goals. Initially, 5 overarching KPIs and 26 Demo-specific ones were identified. However, as the project matured, it became evident that these KPIs needed re-evaluation in light of new developments and insights. A thorough assessment method was instituted, which included criteria to appraise the KPIs against the specific Use Cases, the broader project objectives, and its scalability and replicability aims. This evaluation process, intimately connected with the insights of the Demo leaders, led to the modification, addition, or dismissal of certain KPIs, underscoring the significance of frequently revisiting these metrics to ensure their continued relevance. This rigorous KPI assessment not only fortified the connection between the KPIs and the overarching project goals but also highlighted the interplay between these KPIs and WP7's activities, particularly the Scalability, Replicability Analysis (SRA), and Cost Benefit Analysis (CBA). The synergy with the CBA and SRA augmented the perspective on the KPIs, emphasizing their broader implications and roles in the project's success.

5.3 BAUM

Throughout the initial two years of the project, BAUM took the lead in the Dissemination & Exploitation aspect, as well as playing a central role in Task 1.5 which emphasized harmonizing with stakeholders' and partners' requirements and expectations. This entailed initiating a customer engagement strategy, which began with a foundational workshop involving all project collaborators. The workshop's focus was on promoting user-centric methodologies, such as design thinking, and creating innovative customer-centric solutions. Subsequent workshops and activities were set up to foster user participation and to ensure that developed solutions resonated with their needs and desires. The project planned for two main workshop series: the first aimed at engaging with consumer representatives to understand their perspectives and cultivate them as communication partners; the second intended to anticipate user requirements ahead of the Platone Field Trials. A significant realization during this phase was that the initial plan for these workshops was overly optimistic. Challenges arose internally, as prototypes weren't ready for early testing. Additionally, pivotal feedback from key parties was crucial before defining the extent and nature of engagement. This led to the first set of workshops targeting system-critical stakeholders such as DSOs, aggregators, and commercial prosumers. Subsequent workshops shifted their attention to potential end-users, both private and commercial. The German trial, steered by AVACON, started their engagement by informing households about the project. However, the unforeseen COVID-19 pandemic posed challenges, particularly for in-person engagements. Initially, the plan involved hosting events where stakeholders could experience and review the project's outcomes. But, with the pandemic restrictions, especially in Italy and Greece, in-person events became infeasible post-March 2020. Consortium discussions further highlighted that virtual events couldn't match the engagement levels of physical ones. Finally, in the project's initial two years, BAUM led the Dissemination & Exploitation and Task 1.5, focusing on aligning with stakeholders' needs through a series of workshops. However, challenges like unprepared prototypes and the COVID-19 pandemic disrupted plans, leading to a shift in engagement strategy and the realization that virtual events couldn't replicate the engagement quality of in-person interactions.

5.4 RWTH

During the project, RWTH Aachen was actively engaged across all WPs of Platone acting as the central administrative contact point in addition to providing technical support to Demos for developing hardware and software solutions and for developing Platone framework components. The following subchapters describe the main lessons learned from the involvement in different WP activities.

WP1- Lessons Learned

In WP1 and during the early phases of the project, efforts have been put towards the consolidation of the different Demonstration architectures along with their corresponding use cases. The goal was to articulate and categorize these use cases based on specific criteria, encompassing scope, adopted solutions, level of detailing, solution topology, and standardized actors or systems involved. A major lesson learned in this regard concerns the use of the Software package for Use Case Description Generation which enables the conversion of existing Use Case descriptions from proprietary commercial tools into a practical open format [2]. Additionally, the tool establishes an accessible repository for Use

Cases, promoting an open approach to sharing and reusing these descriptions. As one of the main objectives in WP1 was to establish operational strategies for DSOs and ensure a seamless alignment between the Demonstration sites and the methodology employed to evaluate their outcomes, consistent and coordinated communication was established between the leaders of the Demonstrators and other relevant parties including RWTH. As a crucial lesson learned in this regard, it became soon clear how important it is to define KPIs shared across different Demonstrations to ensure uniformity; to have also Demo-specific KPIs to enable a quantitative analysis of Demo specific solutions; and last but not least, to provide the opportunity for partners to revise and update the already defined KPIs as the project activities moved on and the first iterations of implementations took place.

WP2- Lessons Learned

In WP2 and from RWTH's side, a primary focus was directed towards the open-source developments of the DSOTP as one of the main components of the proposed Platone framework. When engaging with an open-source platform, a valuable lesson learned is the necessity to effectively demonstrate the platform's robustness and user-friendliness through showcasing success stories, highlighting cost savings, and showing the benefits of having an organized community that can help in maintenance aspects. Additionally, defining platform services with intuitive names, streamlining service deployment using Docker and Kubernetes, and providing clear resource definitions contribute to a smoother adoption process. Providing tutorials plays a fundamental role in fostering confidence and facilitating the successful integration of the open-source solution for developers and stakeholders.

During the integration process, it also became clear that an always "online version" of the software in its current state of development is very useful. This allows partners to test their work on a practical level and detect problems like runtime concerns, diverging versions of a standard or problems arising from unstable communication channels. It especially allows detection of misunderstandings or diverging expectations very quickly and thus reduces the need for synchronous coordination. This "online version" can also act as a "source of truth" as it clearly shows what functionality exists reliably as opposed to what is planned for the future. Especially for the German Demonstrator, the positive effect of this approach was observed.

Furthermore, it became clear how important it is to maintain a singular code base for a software component and to use proper version management for it. This is especially true when practical problems arise. To prevent ad hoc solution that only work in that specific use case, it is necessary that the changes made do not negatively impact other use cases and other versions of the base code. Consolidating such diverging versions if not managed properly and postponed to future can be very time consuming. In addition, this eases the on-boarding process for new developers and collaboration with people not familiar with the code base.

With respect to intra-platform communications, the use of standards can help to improve the development of information exchange mechanisms and provide a solid and consistent communication between components avoiding delays in the development and implementation of solutions. A good plan established from the beginning in terms of defining the unification of standards to be used by two or more components that will need to communicate, can help to speed up setting up of intra-platform communications. In cases where this adoption of unified standardized data models for the actors and interfaces involved in the data exchange is not achieved from the beginning, the need to use additional mechanisms like converters will be necessary and will lead to an extra effort possibly in the mid or final phases of the project.

WP4- Lessons Learned

During the course of Platone, RWTH provided support to the Greek (WP4) and German (WP5) Demonstrations for the PMU installations, deployment, and the overall development aspects related to the low-cost PMUs. The installation of these devices within the field trials (especially when combined with the SE tool of the Greek Demo) proved to increase the grid observability significantly by providing accurate measurements with high resolution thanks to their high reporting frequency. As the major lesson learned, it turned out that the modular and open-source design of the hardware and software of the low-cost PMU allows for a relative easy integration of needed features in order to match the respective applications of DSOs and other relevant interested parties. On the other hand, this modularity and flexibility of the low-cost PMUs requires an appropriate installation time planning, starting the commissioning process as early as possible, to help with solving possible implementation or software problems that might arise afterwards. Obviously, the established meetings and communications with the Demonstrators helped RWTH identify the direction to follow for providing a more integrated concept of low-cost PMUs during the project period and beyond its period.

WP5- Lessons Learned

In order to achieve the local balancing between generation and consumption for the Renewable Energy Community (REC) under study in WP5, RWTH developed algorithms and tools that helped the REC to virtually experience islanding. These algorithms were used for the different Use Cases of the German Demonstration and enabled ALF-C to make the most out of flexibility resources within the REC. Such resources were steered according to the set-points defined based on (near) real time measurements of the net active power consumption of the REC and the RBC logic applied on them or based on the forecast values and the optimisation-based SBC logic applied on them. It is noteworthy that the development of ALF-C and the above-mentioned logics was done from the ground up and considering the scarcity of data. Despite this scarcity, RWTH learned that it is possible to develop algorithms that can fulfil the flexibility management within RECs. Both of the above-mentioned logics proved to achieve fully their objectives in minimizing the power exchange of the REC with the main grid, reducing peak exports and imports of power, delivering (receiving) energy packets in form of bulk export (import), and satisfying the requested power request at PCC. However, and for the performance of SBC, the importance of the forecast inputs was quite significant as approved by the conducted sensitivity analysis [16]. In fact, the performance of SBC in comparison to RBC is quite superior once they are compared against each other with the same set of input data (neglecting forecast errors). However, when it comes to the forecast of consumption and generation, especially considering the intermittent behavior of renewable generation from PVs, their impact on the respective objective of the UCs in which SBC is applied is not negligible. This implies that sufficient effort has to be made to achieve a better forecast of the consumption and generation patterns assets. In addition, future development of ALF-C should take into consideration the forecast error which is mainly due to the high level of intermittent PV generation and try to minimize its impact.

WP7- Lessons Learned

In the context of the WP7 activities, RWTH played a crucial role in supporting the SRA as well as CBA, both in the methodological part and in the simulation activities.

- Regarding the SRA, an algorithm for sampling random scenarios of demand and generation profiles has been elaborated, which served as input for the SRA software adopted for performing SRA simulations. In this regard, it emerged how crucial is to precisely define a variety of input data, e.g., the network topology (of the real Demo as well as of representative grids to be used for emulating specific boundary conditions), and the original and target (i.e., expected in the future) profiles of load and generation, which altogether required a close collaboration and continuous exchange with the Demos for an as much accurate as possible definition of them.
- In the SRA study, the included Optimal Power Flow (OPF) algorithm does not converge in several scenarios of integration of flexible units in the different Demo systems. This means that not all possible scenarios of the size and the location of these units respect the power flows and power balance constraints in the system. This is an indication of the necessity to include the OPF problem in the flexibility studies for providing feasible solutions for the planning of the system, especially in scenarios of power congestion in the lines of the system.
- Regarding the OPF problem in real systems, the combination of the values of certain parameters of the power units is critical for the convergence of the OPF algorithm. In particular, the cost factors of the flexible units, which are used as priority/penalty factors, or even as normalisation factors, in the objective function of the optimisation problem, should be selected by considering the cost factors of other units in the system, as well as physical characteristics of the integrated flexible units, such as their size (min/max parameters) and location. This combination of parameters in the optimisation problem becomes even more critical in scenarios of certain desired system operation, where some of these should present specific values. Further studies are needed to systematise the selection of these parameters for the newly integrated flexible units in the system. More precisely, genetic algorithms can be used to

generate these parameters for the formulation of the OPF problem and before the execution of the OPF algorithm.

- Regarding the CBA, the need to combine the traditional CBA with a Multi-Criteria (MC) feature (i.e., taking into account also non-monetary costs and benefits) led to the adoption of the Smart Grid Evaluation toolkit developed by ISGAN [17]. The toolkit works with a set of pre-defined KPIs (i.e., those defined by the JRC in [18]. However, studying the toolkit allowed learning how to customize some settings to integrate customized KPIs and analyze them under a MC-CBA perspective. By doing this, the “uniformity” is obviously lost: Demo- and project-specific KPIs were used, instead of those defined by the JRC, so no cross comparison was possible across Demos. However, as the toolkit was still able to work with user-defined KPIs, it was still possible to employ the mathematical algorithm therein implemented (based on Analytical Hierarchy Process for performing multi-criteria decision-making) to conduct the intended MC-CBA in a straightforward and “standardized” manner.

WP8- Lessons Learned

With respect to the dissemination and exploitation activities conducted in WP8, RWTH played a crucial role in different physical and remote meetings to disseminate the developed solutions of Platone (including its proposed framework) and to find possible paths for the exploitation of Platone results. Some of the RWTH activities in WP8 can be listed as:

- The participation and collaboration with Linux Foundation Energy and the corresponding dissemination and exploitation of the open-source developments of Platone
- Collaboration with Canada and the investigation of extending Platone use case and its solutions to microgrid applications in Canada;
- Contribution to European Joint Research, development, and Innovation efforts by cooperating and collaborating with different Bridge working Groups;
- Having an active role in the FlexCommunity to facilitate the exploitation of flexibilities in the energy sector and to contribute to a more sustainable power supply based on renewable energy sources.

The importance of dissemination and exploitation activities within different workshops, panel discussions, forums, initiatives, inter-country associations, and communities within and outside the European context was once again highlighted. Such activities helped and will help to outreach wider audience, broadcast the lessons learned within Platone towards different stakeholders and researchers within the energy domain, and ultimately pave the path for future exploitation of the proposed solutions and platforms of Paltone. In short, RWTH learned how beneficial it is to have a proper strategy for the dissemination and exploitation of Platone solutions as they bring about the following benefits:

- Scientific Progress and Reuse: Scientific outcomes encompassing models, methods, prototypes, and any relevant data produced during the project can be harnessed by other scientific communities for future research endeavors.
- Informing Policy-Making: The outcomes of the project have the potential to supply policy-makers and regulators with substantiated data, aiding them in crafting new policies or revising existing ones.
- Educational Value: Certain project outcomes can serve as the foundation for the creation of educational and training initiatives targeted at students, professionals, or the wider public as this was already proven by the production of the Platone educational video series [19].

WP9- Lessons Learned

To facilitate an effective project implementation on administrative and financial fronts, RWTH worked alongside the consortium partners in WP9 to manage the project technically and financially. The activities in this regard encompassed advising consortium members on financial and administrative matters pertaining to the project. Furthermore, RWTH oversaw the project's management and reporting, ensuring compliance with European Commission (EC) regulations. Acting as the intermediary between the EC and the consortium, RWTH served as the central administrative contact point. As the main learned lesson, sharing the data and project management plans with the consortium partners, in due time and periodically turned out to be very crucial to ensure the delivery of different reports, achievement of the milestones, and the overall meeting of the project objectives while respecting the necessary quality levels. Additionally, and with respect to the pandemic situation, the increased dependence on remote work has impeded the typically collaborative dynamics that thrive within a traditional team setting. Lockdowns have introduced significant disruptions to supply chains, leading to a notable escalation in the risks associated with project management. However, and on the bright side, the project management team within Platone managed to relatively and smoothly adapt to the pandemic and post-pandemic situations. In light of this and just as an example, with employees dedicating increased hours to their computer desks, their accessibility and responsiveness have improved. This shift prompted partners such as RWTH to embrace project management and team communication platforms such as Slack and Microsoft Teams, tools that were previously considered as “not necessary” or in the best case as “nice to have”. This altered perspective is primarily due to the heightened likelihood of employees actively monitoring their messages and project updates. A similar pattern was also observed by moving from physical to remote meetings (partially or fully) with more frequent occurrences and with much less organization burden.

6 Conclusion

The Platone project, which has seen implementations in Italy, Greece and Germany, has amassed a wealth of experience during its course, especially regarding innovative demos that span a wide array of applications. Central to its agenda, Platone seeks to chronicle these lessons, thereby offering invaluable insights to subsequent projects venturing into similar domains. This document specifically chronicles the insights gleaned during the project's 4th and concluding year, with a dual focus: one on general themes and another dedicated to applicable standards. Moreover, a summary of previous years highlights on lessons learned is included for each demo.

During the fourth year of the Platone project, the Italian Demo was in its concluding stages, with most technical tasks nearing completion. Despite this, new insights continued to emerge, especially from debugging activities and efforts in communication, dissemination, and exploitation. A significant focus was on refining existing functionalities and implementing final technology updates. Key efforts included analyzing the scalability of the proposed solution and assessing its real-life replicability, with an emphasis on broader applications such as the RomeFlex Italian project. Notably, the Italian Demo showcased noteworthy results, leading to proposals for Horizon Europe projects and collaboration with the Italian National Regulator, ARERA. However, challenges persisted, such as delays in PV generator installations due to administrative hurdles. Regarding standards, since most technical implementations concluded by the third year, no fresh experiences with standards emerged during this period.

The Greek Demo prioritized the completion of PMUs installation, focusing on data collection and visualization. This data was integrated into the DSOTP and utilized by tools developed by the NTUA, notably the State Estimation Tool and the variable DUoS tariffs design tool. These tools underwent further development, culminating in a version that facilitated end-to-end validation on a segment of the pilot's site network. The definitive version of the Platone Open Framework was rolled out at HEDNO's premises, with concerted efforts from all WP4 partners ensuring resolution of issues related to system compatibility, connectivity, and algorithm integration. The Greek Demo's partners also undertook the dissemination of the Platone architecture, emphasizing the project's innovative solutions stemming from the collaborative endeavours of HEDNO and NTUA.

During the fourth year, the German Demo concentrated on refining the algorithms for the "Virtual Islanding" Use Case and evaluating their real-world application. Additionally, Use Cases 3 and 4 were field-tested for the first time, exploring various balancing methodologies. Two primary balancing strategies, the rule-based, and the schedule-based control approaches, were implemented and assessed. The rule-based method concentrated on balancing power exchange in the LV community, relying on measurements from the point of common coupling and the community battery energy storage. An intriguing observation was the high surplus generation across ten communities, leading to significant power exports. This phenomenon wasn't isolated to the field test community but was also evident in other regional communities. Comparisons between the two control methods showcased varying degrees of energy export reduction, emphasizing the influence of seasonal variations on their performances.

Beyond the purely demo-related activities, more partners reported on their lessons-learned throughout the project in this report. ACEA, as the aggregator in the Platone Italian Demo, confronted hurdles in user engagement, particularly surrounding device installations in households and the intricacies of data privacy. Their collaboration with ENEA and the establishment of clear governance protocols proved instrumental. E.DSO took the helm in the project's early phases, formulating DSO operation specifications and unearthing a disparity between EU directives and their state-level execution. Their emphasis on coordination, showcased through workshops and regular partner communications, was another highlight. Meanwhile, BAUM, entrusted with Dissemination & Exploitation, adopted a user-focused approach which proved effective. They navigated challenges such as prototype readiness and the COVID-19 pandemic's impact, necessitating strategic shifts while ensuring stakeholder alignment.

Finally, RWTH was a pivotal contributor across all WPs of the Platone project. In WP1, they focused on solidifying Demonstration architectures, employing innovative tools to promote open sharing and reuse of Use Case descriptions. In WP2, RWTH emphasized on open-source developments and version management while highlighting the importance of providing online working versions for testing, troubleshooting, and alignment with standards. In demo-related WP4 and WP5, RWTH's support for the Greek Demo involved the design of low-cost PMUs (WP4) for significantly enhancing grid observability and crafting algorithms for local energy balancing (WP5). For the former, the modularity of the PMUs provided a good chance for incremental adaptations and updates while the pathways to follow for increasing the technology readiness of the PMUs were identified in close collaboration with Demos. For the latter, the importance of the forecast inputs for the performance of the local balancing mechanisms were highlighted via a thorough sensitivity analysis. In WP7, RWTH significantly supported the SRA and CBA, emphasizing the importance of precise input data for SRA simulations and addressing challenges with the OPF algorithm in integrating flexible units. Additionally, they made adaptations to be able to use the Smart Grid Evaluation toolkit for a Multi-Criteria Cost-Benefit Analysis, highlighting the flexibility of the toolkit to work with custom KPIs, i.e., those defined by the demos themselves. In WP8, RWTH spearheaded dissemination and exploitation activities for Platone's solutions, collaborating with global entities, and emphasizing the significance of outreach strategies for scientific progress, policy-making, and educational endeavours. Lastly, in WP9, RWTH adeptly managed the project's administrative and financial aspects, emphasizing timely data sharing and adapting to pandemic-induced challenges by leveraging digital communication tools and remote work strategies.

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8 List of Abbreviations

Abbreviation	Term
ALF-C	Avacon Local Flex Controller
AMI	Advance Metering Infrastructure
API	Application Program Interface
BAL	Blockchain Access Layer
CBA	Cost Benefit Analysis
CBES	Community Battery Energy Storage System
DEMI	Canadian Distributed Energy Management Initiative
DER	Distributed Energy Resources
DSO	Distribution System Operator
DSOTP	DSO Technical Platform
DUoS	Distribution Use-of-System
EC	European Commission
EMC	Electromagnetic Compatibility
EMS	Energy Management System
ENEA	National Agency for New Technologies, Energy and Sustainable Economic Development (Italy)
GDPR	General Data Protection Regulation
HBES	Household Battery Energy Storage
IEC	International Electrotechnical Commission
IoT	Internet of Things
ISGAN	International Smart Grid Action Network (ISGAN)
KPI	Key Performance Indicator
LFM	Local Flexibility Market
LV	Low Voltage
MCA	Multi-Criteria Analyses
MQTT	Message Queue Telemetry Transport
MV	Medium Voltage
NRA	National Regulatory Authority
OPF	Optimal Power Flow
PCC	Point of Common Coupling
PMU	Phasor Measurement Unit
PNRR	Piano Nazionale di Ripresa e Resilienza
PV	Photovoltaic
REC	Renewable Energy Community
RBC	Rule-based Control

SBC	Scheduled-based control
SE	State Estimation
SET	State Estimation Tool
SGAM	Smart Grid Architecture Model
SCADA	Supervisory Control and Data Acquisition
SRA	Scalability and Replicability Analysis
TCP	Transmission Control Protocol
TSO	Transmission System Operator
UC	Use Case
VM	Virtual Machine
WP	Work Package
XML	Extensible Markup Language