Interoperable solutions for implementing holistic **FLEXI**bility services in the distribution **GRID**

Obstacles to innovation report

Deliverable 7.2

WP7

Grant agreement: 864579

From 1st October 2019 to 30th September 2023

Prepared by: CAP

Date: 31/08/2023

This project has received funding from the European Union 's Horizon 2020 research and innovation programme under service agreement No 864579

DELIVERABLE FACTSHEET

Deliverable no.	**D 7.2**
Responsible Partner	Capenergies
WP no. and title	WP7 Guarantees of replication
Version	V7
Version Date	31/08/2023

Dissemination level	
X	**PU**→ Public
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Approvals

	Company
Author/s	CAP
Task Leader	CAP
WP Leader	CIRCE

Documents History

Revision	Date	Main Modification	Author
1	15/02/2023	ToC template	HYPER
2	01/03/2023	Adoption	CAP
3	16/06/2023	Draft	CAP
4	21/06/2023	First Internal draft review	CAP, MOH, CIRCE
5	20/07/2023	Second internal draft review	CAP
6	26/07/2023	Third internal draft review	CAP, MOH, CIRCE, UNIZG-FER, EDYNA, HYPERTECH
7	28/08/2023	Final review	CIRCE

ABBREVIATONS

AC:	Alternating Current
AI:	Artificial Intelligence
API:	Application Programming Interface
CA:	Consortium Agreement
Capex:	Capital Expenditure
CC:	Communication Committee
D:	Deliverable
DC:	Direct Current
DG:	Distributed Generation
DG:	Decentralised Generation
DMP:	Data Management Plan
DoA:	Description of Action
EC:	European Commission
ESCO:	Energy Service Companies
FTP:	File Transfer Protocol
FUSE:	Framework for Utilities and Services
GA:	General Assembly
GDPR:	General Data Protection Regulation
H2020:	Horizon 2020
IPR:	Intellectual Property Right
IT:	Information Technologies
KPI:	Key Performance Indicator
LV:	Low Voltage
M:	Month
MV:	Medium Voltage
Opex:	Operational Expenditure
PH:	Project Handbook
R&D:	Research and Development
RES:	Renewable Energy Sources
SC:	Steering Committee
SME:	Small and Medium Enterprise
T:	Task
TP:	Technical Partner
UC:	Use Case
Vars:	Volt-Amps Reactive
VPN:	Virtual Private Network
WP:	Work Package

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EXECUTIVE SUMMARY

This deliverable contains the work developed in WP7 for 12 months, from M37 to M48, that comprises the analysis conducted in D7.2, which analyses obstacles to innovation under the current and future market design contexts. D7.2 aims at identifying and understanding the obstacles to innovation in the European distribution grid network within the context of the FLEXIGRID project. This analysis addresses these obstacles and provides valuable insights, lessons learned, and recommendations to all stakeholders in improving distribution grid flexibility. This summary outlines key challenges to innovation identified in the four demo sites and lesson learnt on how to navigate some of them effectively.

Technical obstacles: The obstacles faced during the demo deployment were not limited to functional challenges but also included essential factors for ensuring success. These common obstacles were identified across all four demo sites and encompassed technological immaturity, unreliability, and incompatibility. Other technical barriers included the need for more capacity in the existing infrastructure to support innovative solutions for end-users and further operational excellence advancement to achieve high returns. From the lesson learned, it was noted that overcoming these obstacles required addressing technology maturity, compatibility, infrastructure enhancement, and operational efficiency to ensure a smooth and successful demo deployment at all sites.

Financial obstacles: From the demo sites, it was observed that limited financial availability, high cost of investment, low financial allocation or few sponsors, unclear innovative solutions, as well as unclear financial benefits and limited awareness for potential gains from adopting innovations impedes innovations efforts, limiting the ability to invest in research development and experimentation. The lesson learned section of this deliverable shows that, addressing financial obstacles requires a multi-faceted approach, including diversifying funding sources, transparent communication of benefits, raising awareness, showing clear financial benefits, and cultivating an innovation-supportive culture. By implementing these strategies, organizations can create an environment conducive to innovation and overcome financial barriers.

Societal obstacles: These were the most and common barriers identified on the four demo sites. An instance of these obstacles could be seen as the challenges posed by non-consideration or recognition of new innovative solutions due to current market structure, low level of technology readiness level, lack of sufficient AI based workforce, sometimes developers and innovators have different interests, e.g., in case where technology and business goals were not completely aligned and lack of local service support for innovative products in some regions. Moreover, other unforeseen obstacles included COVID-19 pandemics affecting the overall supply chain of demo site deployment causing mobility limitations and facilities inaccessibility. To tackle these issues, diverse strategies were implemented, encompassing proper planning, scheduling, collaboration, and coordination among affected projects. Engaging stakeholders through strategic communication played a pivotal role in actively overcoming some of these challenges.

Market obstacles: The implementation of innovative energy services primarily stem from external forces, including inadequate commercialization costs (CapEx and Opex). Globalization issues, such as the high cost of energy and insufficient ancillary energy market support, further compound these challenges. Moreover, the growing demand for energy supply due to electrification poses considerable pressure on the market. Looking to the future, there are foreseen challenges, including the potential for AI technology to cause market dominance and

price manipulation in the electricity market. Drawing from the insights gained during the pilot demos, to effectively address these market obstacles it is required careful consideration of pricing structures, robust regulatory frameworks, and proactive measures to promote fair competition and foster innovation in the energy sector. Moreover, some of the operators (aggregators, retailers, ESCOs) have started implementing more direct marketing approaches to achieve a wider reach to their customer base and persuade them to invest in new technologies.

Security obstacles: These encompass a range of challenges that demo sites encountered in safeguarding their systems and data. These obstacles include limited data accessibility, outdated technology protection requirements, inaccurate data input, unauthorized access, and potential interference. Ensuring data security and mitigating these risks requires a proactive approach, such as implementing robust access controls, regular technology updates, data validation measures, and continuous monitoring for any unauthorized activities. Therefore, it was learnt that addressing security obstacles is vital in maintaining the confidentiality, integrity, and availability of sensitive information and protecting against potential cyber threats and breaches.

Knowledge-related obstacles: Among the common obstacles in this category are issues related to patent rights, including concerns over infringement and licensing. Additionally, a shortage of experts and entities with specialized knowledge can hinder progress and limit collaborative opportunities. Lack of access to essential technological information further complicates the innovation process, impeding the development of novel solutions.

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1. INTRODUCTION

Deliverable D7.2, "Obstacles to innovation report," is part of Task 7.2, "Analysis of obstacles to innovation under the current context and future market design context" of the FLEXIGRID project. This task aims to analyse the barriers to innovation for decarbonizing the European distribution grid network under the existing framework and in light of potential market developments. Current studies regarding the barriers to the development of smart grid technologies are mainly focused on *"costs, consumer engagement, data protection, privacy and physical security, cybersecurity, compatibility problems with intelligent devices, financial issues, and technical standards"*[1]. Nevertheless, other studies identified barriers linked to knowledge and institutional mechanisms.[2]

The analysis conducted in this D7.2 involved collaboration between the task leader and deliverable author CAP, and various partners, including CIRCE, VIESGO, MOH, HEP-ODS, EDYNA, OPA, ZIV, DP, ATOS, IOSA, UNICAN, UNIZG-FER, and LINKS. It encompasses a comprehensive examination of technical, financial, societal, security, market, and knowledge-related issues that hinder EU distribution grid network innovation.

Therefore, this deliverable aims to analyse the barriers mentioned in each classification into the following categories: technical, societal, financial, security, market, and knowledge-related. These barriers impede the decarbonization of the European distribution grid network, not only for FLEXIGRID project but also for other pertinent European initiatives aiming at the same goal. Various researchers have independently highlighted comparable obstacles to innovation in the decarbonization of the EU distribution grid akin to those identified in FLEXIGRID: system integration difficulties, long-term financing, and policies, as well as the need for investments and mitigation strategies.[3] In addition, according to the report Global Energy Transformation: The Remap Transition Pathway by the International Renewable Energy Agency (IRENA) emphasizes that integration costs and investments must be held in a cost-effective approach. [4]

For a comprehensive analysis of the obstacles, six different categories have been identified in this deliverable:

1) **Technical barriers**, caused by either the technological limitations presented by the difficulty in achieving the integration/compatibility between the power systems since these are developed independently by different developers, as well as the need for more skilled technicians or shortage of equipment.

Technology incompatibility, unreliability, and malfunctioning were identified as the main challenges in all four demo sites, primarily attributed to a different partner developing the solution deployed. Great efforts had to be made to achieve seamless technical compatibility, reliability, and proper functioning of the system installed on the FLEXIGRID project. After

[1] https://www.sciencedirect.com/science/article/abs/pii/S1364032116000393?via%3Dihub
[2] https://www.sciencedirect.com/science/article/abs/pii/S0301421514003668?via%3Dihub
[3] https://www.sciencedirect.com/science/article/pii/S0360544220311324?via%3Dihub
[4] https://www.irena.org//media/Files/IRENA/Agency/Publication/2019/Apr/IRENA_GET_REmap_pathway_2019.pdf?

interoperability and compatibility were completed, the four pilots operated as expected, with minimal constraints.

2) **Societal barriers,** which can have multiple forms: social acceptance, social involvement of the community in projects, or specific social issues within the pilot. The common barriers identified in this category include a lack of information, unclarity, uncertainty, incentives to change, difficulties with external entities, lack of proper planning, unpreparedness, COVID-19 pandemic, amongst others.

Regarding smart electricity grids, social acceptance issues are identified by value conflicts[5], which are specified in some pilots of the FLEXIGRID project. The value conflicts are not to be mistaken as "solely indicators of human or moral concerns of citizens or users" [6], but seen from a technical and economic standpoint as well. This may include topics such as environmental sustainability and profitability from entities involved. [7]

According to Wüstenhagen et al., there are three dimensions of social acceptance: *socio-political*[8]*, community*[9]*, and market acceptance*[10]*.* The following triangle of social acceptance describes the three categories of entities that compose societal barriers:

Figure 1. Triangle of social acceptance at different levels of society by Wolsink M.[11]

3) **Financial barriers,** whether this considers investment or specific economic situations. Investment difficulties derive from an absence of a clear cost-benefit mechanism, as determined by the survey on the development of status and challenges of smart grids in main driver countries.[12]

[5]https://www.sciencedirect.com/science/article/pii/S1364032119303119 pg.184
[6]https://www.sciencedirect.com/science/article/pii/S1364032119303119 pg.185
[7]https://www.sciencedirect.com/science/article/pii/S1364032119303119 pg.185
[8]*Socio-political acceptance relates to the national, political, and policy level. At this level, a technology is typically considered as accepted when it is encouraged by policies, enabled by law, and supported within political debates."* https://www.sciencedirect.com/science/article/pii/S1364032119303119 pg.185
[9]*Community acceptance refers to the response at local level, by residents and local authorities."* https://www.sciencedirect.com/science/article/pii/S1364032119303119 pg.185
[10]*"Market acceptance is an indicator of the adoption of technologies (i.e. whether they are commercially successful) and of the willingness for investors to invest.* https://www.sciencedirect.com/science/article/pii/S1364032119303119 pg.185
[11]Wolsink M. The research agenda on social acceptance of distributed generation in smart grids: Renewable as common pool resources. Renew Sustain Energy Rev 2012;16(1):822–35. http://dx.doi.org/10.1016/j.rser.2011.09.006.
[12]https://www.sciencedirect.com/science/article/abs/pii/S1364032117306755?via%3Dihub

4) **Security barriers,** due to the risks regarding smart meters and data systems, the possibility of cyberattacks, viruses, malware, and phishing arises. Thus, cybersecurity, data access, malfunctioning, outdated technology, and GDPR are the primary factors that may affect similar projects.
5) **Market barriers,** depend highly on whether there was an existing infrastructure or not, and may be affected due to rapidly changing conditions, external factors, inflation, and the market development.
6) **Knowledge-related barriers,** whether this be due to limited previous knowledge within the projects of the same nature, little information of current/future developments, or insufficient entities and experts linked to a lack of knowledge sharing, transfer, and management dynamics.

The insights gained from the FLEXIGRID project and other relevant initiatives, including the successful demonstration sites in Spain, Croatia, Greece, and Italy, have contributed to synthesizing a deliverable containing best practices for various stakeholders. It offers practical lessons learned and actionable recommendations to overcome the identified obstacles. By following the guidelines provided, all stakeholders can navigate the complexities of the current and future market design context, ensuring flexibility, cost-effectiveness, and competitiveness. These stakeholders include but are not limited to; technology providers, energy utilities, Distribution System Operators (DSOs), Transmission System Operators (TSOs), policymakers, and engineering companies.

The deliverable is structured into four major chapters, each providing valuable and insightful information:

- Chapter One: This chapter presents a classification and discussion of six broad categories of obstacles commonly encountered FLEXIGRID and other projects of similar nature. These categories encompass technical, financial, societal, security, market, and knowledge-related obstacles, shedding light on their impact on innovative projects.
- Chapter Two: Here, a comprehensive analysis is conducted on the specific obstacles faced at each of the four demo sites (Spain, Croatia, Greece, and Italy) throughout the entire phase of the FLEXIGRID project. This includes project development, design, equipment outsourcing, installation, commissioning, testing, and all other processes involved along the FLEXIGRID value chain.
- Chapter Three: Practical lessons learned by the FLEXIGRID demo partners, along with actionable recommendations and best practices, are discussed in this chapter. These insights aim to assist all stakeholders in overcoming obstacles and promoting grid flexibility innovations within the EU. Moreover, this chapter contains best practices and suggestions for various stakeholders, including technology providers, energy utilities, DSOs, TSOs, engineering firms, etc. By presenting this information, the report guides any stakeholder interested in enhancing the European distribution grid flexibility.
- Chapter Four: Finally, this chapter provides a comprehensive conclusion to the deliverable. It offers both a general conclusion summarizing the key findings and a specific conclusion tailored to the FLEXIGRID project.

2. ANALYSIS OF OBSTACLES TO INNOVATION

Decarbonizing the energy sector is crucial for the European Union to become the first climate-neutral continent by 2050; the FLEXIGRID project aims to aid in this goal. While FLEXIGRID allows a profound transformation regarding the EU distribution grid operation, there are obstacles observed throughout the pilots that are to be taken into account; these were the following barriers identified by the pilot country.

Table 1: Nature of Obstacles identified per pilot

Obstacles identified	Spain	Greece	Croatia	Italy
Technical Obstacles	✔	✔	✔	✔
Societal Obstacles	✔	✔	✔	✔
Financial Obstacles	✔	✔	✔	✔
Security Obstacles	✔	✔	✔	✔
Market Obstacles	Unspecified[13]	✔	✔ [14]	✔
Knowledge-related Obstacles	✔	✔	✔	✔

As a disclaimer, the table above shall help the reader identify the categories of obstacles. Nonetheless, a demo site with fewer barriers within these classified categories does not imply that the project has fewer challenges; instead, the demo-site partner identified fewer obstacles.

The demo-site obstacles to innovation should be seen with a holistic approach. This was suggested during the 2021 International Energy Agency and the Electric Power Research Institute workshop series on challenges in Energy Decarbonisation: Building a Resilient Net-Zero Future.[15] The identified barriers, categorized individually, are intricately interconnected, leading to mutual influence and simultaneous implications on the development of the demo sites. For instance, the COVID-19 pandemic in 2020-2021 and the crisis in Ukraine in 2022 were frequently cited by pilots as societal and market obstacles. These events exemplify how various barriers can overlap and directly impact the progress of an innovative project.

[13]The term "unspecified" indicates that specific details or information were not identified or provided during that particular time or context. It does not imply that nothing existed but rather that the information was not disclosed or known at the time.
[14]The obstacles faced by innovation in the energy market extend beyond this specific pilot project and impact all the pilots and the entire power industry.
[15]https://www.iea.org/events/8th-annual-epri-iea-workshop-challenges-in-energy-decarbonisation-building-a-resilient-net-zero-future-3.

2.1 Spain

Technical Obstacles	**Technology immaturity and unreliability:** new technologies introduced within the power distribution network can be problematic for the existing system since it is common for failures to occur in the early stages of implementing these technologies due to various specific issues deriving from unforeseen challenges that arise during their development. Thus, introducing new technologies in the real network carries inherent risks to its reliability. For this reason, carrying out a pilot study is essential to mitigate these risks and allow opportunities to evaluate new technologies properly. It, therefore, allows thorough assessment and refinement before the deployment at full-scale. During the deployment of the Spanish demo site, two new passage indicators installed at the secondary substation initially encountered functionality issues, highlighting the potential for unreliability in new technologies. Unfortunately, these indicators did not function as intended upon installation. However, swift action was taken, and the malfunctioning gadgets were promptly replaced with functional ones. This incident exemplifies the inherent risks of introducing unmatured technologies into operational systems. <u>Impact</u>: There is a delay in introducing new technologies in the distribution network. For instance, during the deployment of the Spanish demo, there was a delay in the development of (*Ekor.rsa*-advanced low-voltage remote monitoring units) smart hardware, which delayed the real-time communication on the system with the Supervisory Control and Data Acquisition (SCADA). **Smart integration:** Integrating artificial intelligence (AI) with existing systems poses significant challenges in deploying innovative power technology. Synchronizing current equipment with new equipment creates some innovative production technology deployment challenges. At this time of artificial intelligence, the old protocol is difficult to support the communication of the new devices; it needs a new protocol to replace old protocols to support new machines in the distribution system. To address this issue, developing a new protocol becomes essential to replace outdated ones and facilitate seamless communication between current and new equipment, ultimately contributing to the economic operation of the entire system [8]. <u>Impact</u>: Without proper systems synchronization use of AI may cause issues to the current distribution power systems hindering its linear development.
Financial Obstacles	**Lack of funding colocation:** Certain national R&D aid programs do not contemplate piloting new technologies primarily due to the high cost associated with such activities. Piloting a technology requires specialized infrastructure, equipment, operational expenses, and skilled personnel, which attracts high costs. Unfortunately, most of the national R&D aid programs lack sufficient financial support to cover such costs, hindering a meaningful and comprehensive evaluation of new technologies performance, scalability, and feasibility in real-world operational conditions. Consequently, there is a need to consolidate aid programs, which often require challenging coordination and consume significant time, effort, and

	resources. These circumstances frequently result in delays when introducing new technologies to the market. <u>Impact</u>: The delay in introducing new technologies within the distribution network impacts the recovery of investment in the R&D of equipment manufacturers.
Societal Obstacles	**Lack of recognition of new technologies**: One primary obstacle to innovation in the power sector comes from the need for recognition and non-consideration of new assets or technologies installed within the distribution network concerning the remuneration for utility companies. These issues arise when the regulatory frameworks and the present market structure need to adequately account for the benefits and values that come with these innovative technologies. Carrying out pilots or trials with equipment that introduces new functionalities entails a much higher cost (due to research, testing, development, and implementation) than the presently approved or recognized Regulator budget. Hence, the regulatory framework may need to compensate for or quickly identify these new innovations adequately. Otherwise, it makes it difficult for utility companies to carry out tests and dissemination quickly, hindering the adoption of new advanced technologies in the energy industry. <u>Impact</u>: Normally, the regulatory framework provides project remuneration and incentives based on existing and ready-proven technologies. Consequently, utility companies are only forced to use new technologies once the Regulator recognizes them. **Low technology Readiness Levels (TRL):** The development and deployment of technology are achievable with a robust, reliable, and responsive system. Low TRLs can easily cause technical debts, misaligned objectives, scope creep, model failures, and expensive consequences. Overall, the TRL can significantly impact the development and deployment of the technologies by informing funding decisions, facilitating collaboration, managing risk, and driving innovations. In the Spanish demo deployment case, the Time Domain Reflectometer (TDR) deployment experienced delay due to the complexity and computational cost of the simulations. Equally, the low-voltage remote data visualisation also encountered a deployment delay. Such challenges are largely attributed to low technology readiness levels within the system. <u>Impact</u>: Delays in the installation of certain equipment were encountered, primarily attributed to VIESGO's grid functionality requirements to be integrated with newly installed components which could have led to additional modifications, or adjustments, causing further delays in the installation process. **Workforce capacitation in AI skills evolving:** The successful integration of AI technology into the energy system requires a substantial number of AI professionals with proficient technological skills to drive this transformative

	process. Unfortunately, such talent is scarce to support the growth of the AI-enabled energy market. Moreover, the technical deployment of AI in the distribution network involves tasks like software production, data space, grid management module, and others, all of which demand extensive technological skills development. As a result, the need for experienced individuals with sufficient expertise and specialized skills becomes a critical obstacle in the development of highly intelligent distribution systems. Impact: This challenge necessitates a concerted effort to bridge the skills gap and cultivate a workforce that can effectively leverage AI to enhance the power distribution grid's efficiency and performance.
Security Obstacles	**Lack of access to data and sharing:** Due to internal security regulations from data providers, it is not possible (in some cases) to directly access data from some equipment (for instance, in the Spanish case, there was limitation in accessing and sharing of data was made through the Thin Linc servers, the platform which supposed to centralize computing data resources rather than distributing them amongst end users) provided by the local utility company. In most cases, the internal IT departments who are the custodian of these data are usually not aligned with the R&D projects requirements, so their policies don't allow sharing, direct accessing, or connections of other partners to the data sources (sFTP, VPN, …). In the Spanish demo, data access experienced a hiccup due to VIESGO's security policy regarding data access. To ensure compliance and maintain data integrity, an agreement needed to be reached on the best method for sharing the collected data with the FUSE platform. This agreement aimed to establish a secure and efficient data-sharing process that would satisfy both VIESGO's security requirements and the operational needs of the FUSE platform. Impact: The delays in the data gathering and manual data processing (through e-mail reception and posterior analysis) hinder the direct automation of data feeding to the FUSE platform, the KPI calculations, and performance, which resulted in further delay.
Knowledge-related Obstacles	**Abuse of patent rights:** Sometimes patents pose a considerable challenge in developing and adopting innovative technologies in the energy industry. For instance, when electric companies request multiple offers for equipment supplies. Sometimes technology developed and patented by one manufacturer may prevent other manufacturers from participating in the bidding. Such a situation often leads to technology delay or shelving once the competitors develop alternative solutions. While patents are intended to protect intellectual property and incentivize innovation, sometimes they can be abused to create limitations in market competition causing monopoly. In addition, patents have created other negative implications, such as slower innovation, higher costs, and limited choices for electric companies. Therefore, there is a need to balance

	intellectual property protections while promoting technological advancement and healthy market competitiveness [10]. Additionally, patent protection may also hamper further innovation, especially when it limits access to essential knowledge. This may be the case in emerging technological areas when innovation has a marked cumulative character and patents protect foundational inventions. In this context, a too broad protection on basic inventions can discourage follow-on inventors if a patent holder for an essential technology refuses access to others under reasonable conditions. This concern has often been raised for new technologies, most recently for genetic inventions. Impact: When the patent is abused, it potentially delays the market adoption and advancement of technologies.

2.2 Croatia

Technical Obstacles	**Equipment malfunctions:** During the trial of the solutions implemented and the use cases on the Croatian demo, different barriers were presented, among which was malfunctioning equipment or breakdown, e.g., some of the shelly devices, such as smart metering equipment and WIFI appliances installed, were not functioning. These obstacles pose a considerable challenge to the smooth monitoring and operation of controllable loads, hindering the project from working as expected. Often the malfunctioning of equipment disrupts the intended functionality of the distribution network system. Subsequently, breakdown hinders the ability of the distribution network to function effectively. Furthermore, equipment malfunctions disrupt the networks' operations and create a discrepancy between the expected and actual outcomes, slowing down the process of adopting and integrating new technology into the existing systems [11]. Impact: Equipment malfunction can delay the developing and deploying new technologies and increase associated costs. In this case, the malfunctioning devices were replaced, facilitating smooth utility metering and strengthening the internet connections. **Technology mismatch**: Also known as incompatibility, the technology mismatch can significantly impact innovation projects. In an innovation project such as FLEXIGRID, new and emerging technologies are often used, and there may be a need for more commercially available equipment or tools to support these technologies development. This can lead to a technology mismatch where the available equipment cannot support the new project's requirements if the existing equipment's fails to meet the current needs. In this case, it can have a detrimental effect on the final project or technology performance. Consequently, it compromises innovative projects, reducing market adoption and potentially losing revenue.

	Therefore, it is essential to consider equipment availability, compatibility, and suitability before starting an innovation project to avoid unnecessary technology mismatch and its negative effects. This can involve conducting a thorough evaluation of the available equipment, identifying any gaps or limitations, and exploring potential solutions such as custom equipment design or partnering with equipment suppliers to develop new tools that meet project requirements. Impact: Technology mismatch can lead to delays in innovation development, increased costs, and decreased performance, lowering innovation market uptake.
Financial Obstacles	**High cost of financing:** The high upfront cost of installing new infrastructure and equipment is one of the main financial obstacles that hinder DSOs from adopting smart grid project innovation or other similar projects. These costs can be exceptionally high in regions where the grid infrastructure is outdated and needs significant upgrades, as exemplified by HEP-ODS, a Croatian DSO, on deploying the FLEXIGRID pilot project on the distribution network. When integrating smart grid technologies into the distribution network, DSOs must invest in various components, including software and hardware systems, communication networks, and advanced metering systems. Even though these technologies enable the network to correct real-time information, integrate renewable energy systems into the distribution network, and manage the grid effectively, the cost associated with these innovations are markable high, making it difficult for grid operators to embark on a large-scale infrastructure upgrade. Impact: Croatian demo site involved: modelling, developing, and testing new control algorithms, networks, and equipment outsourced from third-party flexibility providers, which was capital-intensive. **Limited funding available**: Another common challenge to similar projects is the limited option for securing sufficient funding for smart grid innovation projects. Smart grid innovation projects require a significant capital cost, and obtaining financing can be difficult. The lack of available funding sources and financial instruments tailored to the needs of the grid projects may hinder the implementation of such innovative projects. Some common reasons that make it hard to access or secure funding from financial institutions for these types of projects include being capital intensive, having a long payback period, and having a high-risk perception. Impact: The grid operator's ability to integrate and adopt innovative solutions is constrained without adequate funding options like FLEXIGRID, supported by the European Commission supports. **Unclear financial benefits:** Refer to a situation where a project or investment's potential economic advantages or returns are uncertain or unclear. The benefits of smart grid projects on distribution networks are often spread across

	stakeholders, such as utility regulators, operators, and consumers. This can make identifying clear financial benefits and incentives challenging for each party. As a result, there is hesitance in the willingness to invest in smart grid innovations due to uncertainties about financial returns. In many cases, as the benefits, such as efficiency increase and reduced energy costs, come with this innovation investment as they are spread across different stakeholders, it becomes challenging to quantify and monetize individually. This may lead to a conservative approach that limits the potential for breakthrough innovations. Impact: If stakeholders are hesitant to invest in an innovation project due to unclear financial benefits, it may result in missed opportunities for growth and development. Subsequently, it limits the potential for the project to generate economic benefits or create new markets.
Societal Obstacles	**Issues between entities and stakeholders in the pilot:** A major social obstacle that was witnessed during the testing phase of the FLEXIGRID project was issues of involvement of other entities or stakeholders in a pilot project. Although problems may arise for various reasons, they potentially prevent the installation and commissioning of various equipment finalization. Even though a solution could be found, similar issues may reoccur due to the innovative nature of the project or those involved in the execution. Similarly, to technical obstacles, societal issues present significant challenges to the full realization of the solutions deployed on the FLEXIGRID demo site, especially the Croatian pilot. For instance, in the case of equipment failure, responsible entities may fail to address the issues efficiently and promptly, leading to a broader disruption of project operations. Impact: There can be delays in the pilot, specifically during the final installation and equipment commissioning. **Lack of relevant measurements and necessary technical information:** Certainly, measurements are crucial for assessing and gathering accurate data from various components of the smart grid system. However, when a project or the installation of its components still needs to be completed, it becomes challenging to obtain the necessary measurements and other critical information essential in guiding the entire or similar projects. Impact: lack of relevant information and necessary measurement negatively impacts system integration, performance monitoring, and performance validation, which hinders technology advancement. **Impact of COVID-19 on Smart Grid project supply chain:** Same as other demos, Croatian smart grid demo was significantly affected by the COVID-19 pandemic. The measures and restrictions imposed to control the spread of the virus disrupted the linear flow of delivery of equipment across the borders (customs) points. Subsequently, the project experienced delays in deploying the smart grid technologies against the planned schedule.

	Some of the challenges experienced include customs' clearance delays, transportation disruptions, supply chain disruptions, and other logistic challenges that collectively resulted in the delay of the project implementation. These delays did not only impact the integration and installation of smart grid components but also had a ripple effect on other crucial project activities, including project testing, deployment, and commissioning. <u>Impact</u>: There were significant delays in the project implementation against the time planning schedule due to the impact of the COVID-19 pandemic. **Mobility limitation and facility inaccessibility:** The impact of mobility limitation and facility inaccessibility on the COVID-19 pandemic in Croatia's UC6 (residential facility demo site) has been significant. The COVID-19 situation worsens the difficulties the developing partners face and hinders their ability to manage the situation effectively. The mobility limitations have made it difficult for the developing partners to regularly monitor and provide the necessary support to the residents of the UC6 residential facility. It resulted in less oversight by the managing partner and increased vulnerability of the residents to the pandemic. Moreover, it resulted in the disruption of the entire supply chain. It made it challenging for the project developers to provide the equipment and services needed to implement the project. <u>Impact:</u> Project implementation and schedule have been significantly hampered by restricted mobility and limited access to critical facilities sites.
Security Obstacles	**Lack of access to data:** One of the main obstacles found in the Croatian pilot relates to access to data, primarily due to delays in the data gathering and lack of real-time data to carry out the KPIs calculations. These challenges arose from difficulties in managing the equipment installed in the designated facilities where the demo was conducted. A special authorization was needed to access some of these buildings, so when the permission was denied, equipment could not be accessed when the approvals could not be obtained. The process of addressing and resolving these issues effectively results in delays and setbacks in the project of concerns. In this case, the connectivity and configuration problems took a long time to be solved, so the delay in the data gathering further contributed to the pilot delay. <u>Impact</u>: Delays in the data gathering and lack of actual data hindered the calculation of KPIs and, subsequently, delayed visualizing of project results. **Dependence on end-users' site:** A lot of installed equipment was done on the end user's location, and there were a lot of issues related to unallowed data access, unwanted revealing of GDPR information, and cybersecurity-related issues, such as hacker attacks or computer viruses. These issues pose a significant risk and need to be addressed to ensure the privacy, security, and integrity of the data collected. These issues create a genuine concern for the end-users, creating restrictions and limitations on the accessibility and utilization of the data generated by the equipment. Subsequently, these

challenges hindered the project's ability to collect and analyse relevant information.

Therefore, a collaboration between the project partners, stakeholders, cybersecurity experts, and end-users is crucial to ensure adequate measures are in place to protect data, comply with relevant regulations, and maintain the security and integrity of such a project to create trust and confidence in the end-users.

Impact: Installing equipment on end-user's sites means there may be limitations or restrictions on accessing the data generated by the equipment since end-users may have concerns about data privacy or internal policies that restrict third-party access to their data.

Outdated technology on updates requirement: With advanced protection and metering equipment installed, the technology may get outdated and must be replaced well before life expectancy. The impact of outdated technology can directly be seen in unexpected financial expenditures caused by premature investment in newer equipment that was not initially planned, leading to unforeseen costs straining project budgets.

Additionally, outdated technology may cause compatibility and integration issues with newer components and systems. As technology keeps evolving, ensuring seamless integration and interoperability between different equipment and technologies is essential. The older technology may need more interfaces or protocols to effectively integrate or communicate with newer systems, adversely affecting the solution's overall performance and efficiency.

Impact: Updating outdated technology can have several implications: unexpected financial expenditures, compatibility and integration challenges, and security and reliability of the implementation solution.

Inaccuracy data inputs: Data processing issues can arise in various situations, such as when there are errors or inconsistencies in the data input, output, or processing. More often, when data is not well formatted, too large for processing effectively, and when the processing algorithms need to be appropriately designed or implemented can affect the reliability and accuracy of the results.

During the Croatian demo trial case, it became evident that the algorithm used to collect measurements for demand forecasting had traces of ambiguous values (negative and zeros), making the analysis to fail in meeting the success criteria. Therefore, addressing such issues through data integration processes such as standardization, cleaning, and transformation becomes crucial.

Impact: Any data misinformation can adversely impact the accuracy and reliability of the data, which result in incorrect conclusions or decision.

Market Obstacles	**Global issues:** The latest global challenges have led to the surge in prices of energy. This increase changed the matrix of the electricity markets, in which the peak and average electricity prices increased multiple times. An additional obstacle is increasing inflation and the lower living standard of end-users. At the same time, one of the project's goals and the implementation of developed solutions is to increase the flexibility potential and encourage end-users and other entities to participate in providing flexibility services. However, under the current electricity market, it needs to be sufficiently designed to offer flexible services. Market inflation and increased electricity prices decrease consumers' living standards, negatively impacting their capability and affordability to invest in new equipment. On the other hand, it also allows end-users to turn to solutions that will help them reduce electricity bills, such as energy-efficiency appliances and pro-consuming energy solutions. The lack of development of local electricity markets could prevent entities from providing flexible services [12]. However, the electricity providers, investors, and system operators can develop innovations to ensure the suppliers and consumers mutually benefit. Impact: Market inflation and the rising price of electricity increase the cost of producing electrical products and equipment. Ultimate, delay or reduce financing options currently available and their profitability. **Artificial price manipulation on the electricity market:** One significant challenge is the potential for market price manipulation due to the complex nature of AI algorithms and the various actors involved. The opacity of AI programs makes it difficult for system operators (SOs) to monitor the data used by these programs to make decisions in the electricity market. As a result, conflicting AI programs may emerge; for example, some may be programmed to prioritize buying at the lowest price for electricity buyers, and others are programmed to sell at the highest price for electricity sellers. This inconsistent behaviour can lead to delays in meeting electricity demand and potentially inflate market prices. Another concern is the emergence of automated trading systems that may give rise to resellers who add little value to the system, contributing to market instability. The volatility of demand and supply in such "flash markets" further exacerbates the potential for unintended or intentional price inflation. Impact: The impact of artificial price manipulation on the electricity market includes potential market instability, delays in meeting electricity demand, and the risk of unintended or intentional price inflation due to conflicting AI programs and automated trading systems. **AI technology entry causes Market dominance:** The integration of AI technology in the electricity market can lead to market dominance by a limited number of actors, which can hinder power growth and create challenges for distribution system operators (DSOs).

	Platformization, where larger platforms offer superior services at lower prices due to economies of scale, can follow a winner-takes-all principle. This principle has been observed in various sectors, such as Google's dominance as the major search engine [8]. Smaller platforms may need help to compete effectively in the electricity market if a few large energy platforms establish dominance. This concentration of power distorts the market and creates barriers for smaller players to enter and thrive. Impact: AI creates market dominance causing the system operators to face the complex task of promoting fair competition and ensuring a level playing field in such an environment.
Knowledge-related Obstacles	**Limited for experts and entities:** None of the solutions and proposed improvements to the power system operation can be achieved without a significant number of experts or innovative entities in the field. Relying on their knowledge is a prerequisite in the energy transition. Without them, it is impossible to make the power system more advanced and easier to operate. Lack of sufficient entities, including partners from the industry, system operators, end-users, etc., that are aware of their potential can prevent the power industry from transitioning toward advanced and more efficient systems. Therefore, there is a need for more awareness and more engagement of professional entities and stakeholders to ensure the progress of power systems towards more advanced and efficient operations. Impact: Expert's and entities' lack of involvement hinders archiving effective solutions and improvements in power innovations, particularly during the energy transition. **Failure for knowledge adoption, transfers, and management:** Effective knowledge adoption, transfer, and management are critical to driving innovation. When knowledge is not effectively adopted, transferred, or managed, it can create barriers to innovation by limiting access to critical information, skills, and expertise. One of the main ways that knowledge adoption, transfer, and management can impact innovation is by influencing the speed and effectiveness with which new ideas are developed and implemented. Effective knowledge management can enable organizations to leverage their personal and stakeholders' knowledge and expertise better, which can drive innovation by fostering collaboration and cross-functional learning [13]. Impact: Effective knowledge adoption, transfer, and management can significantly impact an organization's ability to innovate by helping to ensure that critical knowledge is shared and leveraged effectively and that innovation efforts are optimized for success.

2.3 Greece

Technical Obstacles	**Lack of compatibility of multi-source data:** Within the FLEXIGRID project, different systems needed to be integrated to control the devices on site. It was therefore necessary to integrate various systems which were developed by multiple entities, including software modules developed by VERD/LINKS, the gateway (Energy Box) developed by CIRCE, and the overarching platform for storing data and performing calculations (FUSE) developed by ATOS. The successful functioning of the Greek FLEXIGRID pilot project relied heavily on the compatibility of these data sources. Each system had its own data format, structure, and protocols, making it difficult to exchange information seamlessly. This lack of compatibility presented obstacles to achieving a cohesive and integrated control system. Therefore, data from these sources must be compatible for the pilot to function. Impact: Leveraging the full potential of the multi-source data of the devices wasn't possible. **Technological immaturity:** Different technologies that make up a Smart Energy System can widely range in terms of the level of technological advancement. Smaller-scale low-carbon and smarter technologies are typically more immature than well-established ones like on-grid on-shore wind energy or domestic gas-fired boilers. The rate of development of technologies for small-scale distributed energy generation has been very diverse. Every time, a combination of technology readiness levels, market and system needs, and economics determine this pace. As a result, some technologies, like photovoltaics, are more advanced and well-developed than others, such as battery storage systems, despite only being commercialized recently. This variety of maturity affects the rate at which innovation projects develop. Impact: Some technologies are more advanced than others, creating an imbalance between their compatibility to the newer, less commercialized technologies. **Existing Infrastructure Limiting Innovative Energy Management Applications for Residential/Commercial Customers:** In the realm of energy management for residential and commercial customers, one notable challenge is the limitation posed by existing infrastructure in supporting innovative applications. One specific example is the inability of already installed energy management systems to adequately support innovative energy services, such as peak shaving support from battery inverters. For instance, in the Greek demo case, there were many gaps in the SunSpec protocol regarding the provision of straightforward control signals to the HV DC-coupled residential batteries, thus making peak shaving/cost reduction initiatives at the domestic level rather challenging and requiring workarounds. To schedule a peak shaving functionality at the inverters, a workaround needed to be performed where the daily peak loads were prioritized, and the

	battery was set to discharge when priority was high. A better operation is the option to discharge the battery when the load exceeds a specific limit, but this functionality wasn't available. Impact: The limited availability of straightforward functionalities to control the inverters and batteries increases the effort needed to schedule these assets and reduces the flexibility in which those assets operate.
Financial Obstacles	**Insufficient Financial Support and Business Sponsorship Hindering Capital Expenditure (CapEx) Solutions:** Lack of financial support or business sponsorship challenges adopting innovative systems, especially among small commercial and domestic energy users. Often, energy innovations come at a high cost compared to traditional counterparts, making their business cases less attractive when assessed from a financial perspective, especially by domestic and small commercial energy users who need the strong financial capability. Without considerable financial incentives or support, these users are reluctant or unable to adopt those innovative solutions despite their benefits of return. Therefore, limited financial resources hinder the implementation of technologies due to the higher upfront cost associated with infrastructure upgrades and the purchase and installation of equipment. Impact: Reduced adoption of innovative systems doesn't allow consumers to maximize profits. **Limited Awareness of Potential Financial Benefits versus risk Hindering Adoption of Innovative Energy Services over Business-as-Usual Practices:** Energy customers often need to understand the full financial potential of innovative energy solutions and may perceive the risks as much higher than the benefits of the new solutions. As a result, energy consumers may be reluctant to adopt new business models. Energy users need a proper understanding of the benefits that come with innovative technologies and their financial implications. Conventional technology and its business model have been in the market for a long time, and therefore, the energy users are accustomed to the current norms and practices in the market; hence it's difficult for the users to change and adopt emerging technologies immediately. Impact: Reduced adoption of innovative systems limits consumers from enjoying maximizing benefits, hindering market penetration.
Societal Obstacles	**Lack of local support services and infrastructure availability:** Most of the manufacturers offer local support services. Most technology providers often need more support infrastructure and physical presence in various countries or regions, especially where their products are used. This poses challenges to product users who require local support services such as technical assistance, including installation, repair, and troubleshooting but fail to get or reach local support services or infrastructure available to address their challenges.

	Due to the wide distribution of energy users and the global nature of the energy market, technology providers may focus on specific markets and regions and leave the other region with less or no local support, especially in regions or markets with less market power drive or underdeveloped regions. Technical expertise is scarce in those underserviced regions, making it difficult to adopt new technology since, in case of any issue, it may lead to project delay, increase cost and ultimately affect the project performance. An example can be drawn from the Greek demo case where maintenance needed for the inverters onsite took longer than expected due to the unavailability of local support or a technical specialist for that specific product in Greece. <u>Impact:</u> Lack of local technical expertise caused delay in maintenance for the inverters onsite, causing project delays. **Lack of transparency:** Although AI technology can revolutionize the power sector and drive its development forward, if not implemented and managed carefully, AI can pose risks and create challenges in the power innovation sector. One primary concern is the lack of transparency, which can lead to accountability issues. When AI models are used to make decisions about balancing or investments in the power sector, there is a risk that stakeholders, such as distribution system operators (DSOs), may need to understand or have control over the underlying models fully. This lack of transparency can raise questions about accountability for public spending and issues such as high electricity prices or network downtime. Therefore, it is crucial to ensure transparency in decision-making by clearly defining the basis of data and data-analyses decisions. <u>Impact</u>: AI models that they do not understand power market or control, leading to questions regarding accountability for public spending, high electricity prices or network downtime.
Security Obstacles	**Concerns about Cybersecurity and Data Security Impacting Perception of the Energy System's Vulnerability:** Most of the time, access to local systems is required to obtain data from on-site devices (access through a local router). This occasionally prompts worries about the security of the local network and data and prevents energy consumers from implementing new technologies. The recent increase in cyber threats and data breaches on critical infrastructure such as energy systems has heightened the fear of cyber attach on users with sensitive services (industrial facilities and utilities). Therefore, it creates a valid point of concern, especially when dealing with external partners. <u>Impact</u>: Increasing frequency and sophistication of cyber threats in today's interconnected world discourage energy users from implementing new technologies due to fear of possible attack. **Smart manufacturing security issues:** Smart devices for real-time monitoring of the electricity infrastructure can also be used to increase cybersecurity. The increase in renewable energy and electrification leads to more devices

	connected to the grid and connected to the internet via their smart systems. These devices and programs require two-way communication: the program gathers data (such as electricity consumption) and sends commands (for example, a signal to an electric vehicle to charge). These open networks are more vulnerable to non-authorized access or other types of disruption (such as false data injection) than one-way communication systems. The potential consequences of cyberattacks on smart devices are particularly concerning as they can lead to faulty autonomous decisions that directly impact the electricity grid. Despite recognizing the need to prevent such attacks, a recent successful breach on the European Network of Transmission System Operators for Electricity is a stark reminder that ensuring fool-proof cybersecurity measures is not always feasible. Impact: By using smart devices for real-time monitoring of the electricity infrastructure, it can also be used to increase cybersecurity. **Trust deficit:** The unpredictable and uncertain nature of the algorithm's forecast performance is a significant concern, particularly in the context of the electrical energy system. This concern arises from many uncertainties in the entire energy system, including factors related to energy sources, grid operations, energy consumption, and energy storage. The generation, transmission, distribution, and consumption of power all involve random elements that can significantly impact the accuracy of algorithms predictions. Furthermore, unforeseen emergencies such as extreme natural disasters, significant epidemics, or other unexpected events pose even greater challenges to algorithms prediction software. These situations introduce additional complexities and variables that make it difficult for algorithms systems to accurately forecast and respond to sudden energy demand and supply changes. Impact: How the algorithms software operates creates a lot of uncertainty in the power sector, causing trust issues with its performance and how it executes its functions, hindering its large-scale adoption in power technology.
Market Obstacles	**Lack of commercialization costs (CapEx, OpEx) in the implementation of innovative energy services:** Innovative energy management systems, such as smart meters, smart appliances, etc., typically cost more than conventional ones. Commercial and domestic energy users are not well-informed of the long-term benefits of those solutions and are not likely to invest without significant incentives. Solution providers (aggregators, retailers, ESCOs) have started implementing more direct marketing approaches to achieve a wider reach to their customer base and persuade them to invest in new technologies. However, this process has not yet been rolled out to the extent that would be needed, nor has the technology been established as much to achieve significant commercial results [14]. Consequently, this market is premature and would need more development time.

	Impact: The lack of commercialization of new technologies, creates a barrier for the implementation of innovative energy services.
Knowledge-related Obstacles	**Low level of knowledge regarding technological solutions:** The low level of knowledge regarding technological solutions poses a barrier to adopting advanced energy technology systems and practices. Many individuals, both residential and commercial customers, may need to be aware of the technological options available to optimize energy consumption, reduce costs, and improve overall efficiency. For instance, in Greece, there was no significant variety of commercially available technological solutions (inverters/batteries). Therefore, a weak knowledge base exists relevant to exploiting such systems toward more advanced use cases such as demand response, peak shaving, etc. Another concerning issue is the fact that only a small portion of the already small number of available solutions are accompanied by local customer support and maintenance, thus making it even more difficult to address more complex issues. Impact: Complex issues are difficult to face without the proper knowledge to challenges, such as peak shaving and demand.

2.4 Italy

Technical Obstacles	**Emphasis on Profitability Outweighing Focus on Operational Excellence in power sector:** During the development and execution of the Italian demo, one of the technical challenges identified was the adequacy level of the existing hydropower plants, which needed to be prepared or equipped with the necessary hardware to handle island mode operation. Island mode operation refers to the ability of the power plant to operate independently, disconnected from the main grid, and supply power to a localized area [15]. It is important in case of grid outages or emergencies and when the main grid is unavailable. The main reason behind the existing hydropower plant's inability to handle island mode operation can be attributed to the primary focus of private power plants developer on profitability rather than their contribution to the overall operation of the distribution network. In most cases, private plants pay more attention in optimizing power generation for maximum electricity revenues. Therefore, the plant design and technology are primarily tailored toward high returns, compromising other essential operational aspects supporting the grid's resilience and stability. This focus on profit-driven objectives is not unique to the Italian pilot but can be a common occurrence in the development of most private power plants. Therefore, integrating some technology into these existing power

plants becomes difficult since they must be better equipped to handle such operational upgrades, delaying innovation.

Impact: Time delay for advanced research to find a technique of how these power plants can adapt to hardware with island mode operation and ensure they can operate on island mode when needed while maximizing their returns.

Compatibility issues: Integrating various new functions in the island mode on the existing SCADA system confronted the co-workers with various difficulties. The difficulties primarily revolved around adapting the communication systems, visualizing new measures arriving from the field, and ensuring the full performance of the existing functions. These difficulties were caused by differences in the technologies involved, which needed more time and effort to identify appropriate solutions.

When adopting new functions and equipment, it is crucial to establish seamless communication between various components and systems within the power system. It includes integrating new functions into the existing SCADA system, a central control and monitoring platform for the plant's operations. However, ensuring the full performance of existing functions while incorporating new features is a complex task. The existing functions may have been designed with different technology or assumptions in mind, and their compatibility with the new system needs to be carefully assessed. It may require adjustments, upgrades, or optimization to ensure that all functions work seamlessly together, which needs time.

Impact: Time delay due to work on adapting existing hardware and configuring the software to receive and visualize the new information correctly.

Technology Functionality Issues: In the Italian pilot, the installation of communications radio receivers (PCRs) was updated by the FLEXIGRID project on the power plant. These PCRs encountered various functional issues in terms of communicating information during testing.

This situation exemplifies a challenge in technology development. The challenge lies in ensuring the smooth and reliable functioning of newly developed technologies or updates when deployed in real-world scenarios. Technology development often involves creating innovative solutions or incorporating advancements to improve existing systems' performance, efficiency, or capabilities.

However, transitioning from the development stage to practical implementation can reveal unforeseen issues or limitations not evident during testing in controlled environments. In the case mentioned, the PCRs, intended to enhance communication and information exchange, faced challenges when transmitting information during testing.

	Such challenges can arise due to various reasons. It could be related to compatibility issues between different components or systems, interoperability problems with existing infrastructure, software or hardware bugs, inadequate testing, or a lack of comprehensive understanding of the operational environment. Impact: The PCRs encountered functional issues communicating information during testing. However, faulty PCRs were replaced, which started to send measures and receive commands. **Communication difficulties with local service providers**: During the Italian FLEXIGRID deployment, there were communication difficulties experienced by local telephone/internet service providers in Italy, particularly during the transition from 2G to 3/4G protocols. Such communication challenges can affect the development of technology in several ways. Firstly, the delays and difficulties in communication with service providers can hinder the timely access to and availability of necessary infrastructure for technology development. The upgrade from 2G to 3/4G involves changes in communication protocols and technologies, and the need for smooth coordination and communication with service providers can result in limited access to the infrastructure required for testing and implementing new technologies. This can significantly impede the progress of technology development projects that rely on reliable and high-speed communication networks. Secondly, the lengthened delivery times for components required for the communication protocol upgrade can cause delays in deploying and testing new technologies. Technology developers may need help obtaining the necessary components within their planned timelines, leading to setbacks in implementing and evaluating their innovations. These delays can slow the overall development process, affecting the speed at which new technologies can be introduced to the market. Furthermore, communication difficulties and extended delivery times can introduce uncertainties and planning challenges for technology developers. The need for clarity regarding the availability and timing of communication infrastructure upgrades makes it difficult to plan and allocate resources effectively. This uncertainty can impact decision-making, investments, and project timelines, potentially leading to a cautious approach or a slowdown in technology development efforts. Impact: Telecommunication upgrades in Italy resulted in communication delays or breakdowns, which impeded the progress of technology development projects that rely on reliable and high-speed communication networks.
Financial Obstacles	**Limited interest for investment:** It was noted that the power operators were unwilling to invest in various power adaptation measures, such as

	making power plants compatible with new technology since they attract high capital. As described in the section on technical obstacles, the power plant operator's focus is to make their profitable investment vis a vis other operational factor. Any investment is perceived as unnecessary additional expenses, and the power operators may be reluctant to incur these costs as they might not directly contribute to their profitability. Focusing on short-term financial gains can overshadow the long-term benefits of grid compatibility and emergency support. This reluctance to invest more than necessary for basic operations becomes a financial obstacle. Moreover, the lack of incentives or regulatory frameworks that reward power plant owners for investing in grid compatibility and emergency support can further discourage such investments. They are less likely to prioritize these adaptations without mechanisms to compensate power plant owners for their role in grid stability or emergencies. Impact: Most power producers were unwilling to invest in systems that improve grid operation without direct financial gains.
Societal Obstacles	**The misalignment of interests and needs between distributors and manufacturers can impact energy sector innovation:** When the goals and priorities of distributors and manufacturers do not align, it can have an adverse impact on innovation in the energy sector. When manufacturers or distributors primarily focus on maximizing their profits, they may prioritize short-term gains over long-term investments such and research and development [16]. This can result in a reduced emphasis on innovation and the development of new technologies or solutions that could address the specific needs of the energy system. The misalignment between distributors needs and manufacturers interests can create a lack of incentives for collaboration and cooperation. Manufacturers may need more motivation to engage with distributors in developing innovative solutions or adapting their production processes to match the demand better. This lack of collaboration can hinder the exploration of new ideas and the implementation of innovative practices. If distributors' needs are not effectively communicated or reflected in market signals, manufacturers may have limited visibility and understanding of the specific requirements or challenges they must address. This lack of information can hinder the development of targeted innovations that could better align with the needs of the distribution network.Impact: The imbalance between distributor needs and manufacturers' interests hinders an efficient and innovative energy system. **COVID-19 impact on time planning:** COVID-19 pandemic significantly affected time planning and subsequent technology development, especially in the power industry. The disruptions caused by the crises, such as delivery bottlenecks for various components and the absence of

employee dues to restriction, strongly impacted the time planning. The same bottlenecks and failures have also affected the third-party companies working with us, leading to delays.

Delivery bottlenecks for components and materials have disrupted supply chains globally. Manufacturers and technology developers rely on a steady and timely supply of components to continue their development processes. When supply chains are disrupted, it can lead to delays in receiving essential parts, thereby hindering the progress of technology development.

The absence of employees due to COVID-19 cases, quarantine requirements, or remote work arrangements has impacted technology development. Research and development teams, engineers, and technicians may need help to work on-site, leading to reduced efficiency and productivity. The need to adhere to health and safety protocols may also affect the capacity and speed of technology development activities.

<u>Impact</u>: Delays within the pilot execution subsequently led to slow implementation of FLEXIGRID innovative solutions.

Stiffness in time constraints: Lack of time can also be a major barrier to innovation. When circumstances force to focus on short-term goals and deadlines, organizations may not have the opportunity to dedicate sufficient time and resources to exploring new ideas and approaches. This can lead to a lack of innovation and stagnation.

Furthermore, if time pressures lead to a culture of rushing and cutting corners, it can also lead to errors and setbacks in the innovation process. To maximize the potential positive effects of time constraints on innovation, it is important to balance short-term goals and long-term innovation strategies and ensure adequate time and resources are allocated to innovation initiatives. Due to the Italian pilot's delay, the stipulated testing period for the second trial (#9) of the Italian demo, initially set for six months, was shortened. Nevertheless, the preceding test conducted during trial #2 demonstrated the correct actuation of PCR for trial #9. Therefore, it inferred that trial #9 was similar to trial #2, making the observations from trial #2 applicable to visualize the expected results for trial #9.

<u>Impact</u>: Time constraints can hinder the opportunity to thoroughly explore different ideas and approaches during the trial period. It may limit the ability to test alternative methods that could lead to even better results or outcomes.

The decline of human autonomy: The widespread application of AI in various sectors, including the power sector, raises concerns about the potential decline of human autonomy in decision-making processes. One significant risk is that using AI for automated flexibility asset management could limit the autonomy of distribution system operators. Instead of

	allowing DSOs to exercise their judgment and manage flexibility manually, reliance on AI systems may leave them with limited or no options regarding flexibility management. This can hinder their ability to deviate from pre-programmed paths and respond effectively to changing circumstances. Human intervention may still be necessary to override the AI program in various aspects [8]. Impact: The application of AI might limit human autonomy, leaving distribution system operators with limited or no options regarding flexibility management which is harmful increase of cyber-attack or bias.
Security Obstacles	**Vulnerability in system interconnections**: The interconnection points of a communication system between the SCADA system and the power plants represent a vulnerable point for ill-intentioned entities/persons who may want to interfere with the correct functionality of the power plant or the electric grid. The need for a high level of informatics security to prevent unauthorized access and interference with the power plant or electric grid functionality introduces several challenges and limitations that impact technology development. Firstly, the emphasis on stringent security measures adds complexity and additional requirements to the design and development of devices and systems used in system interconnections. Developing secure communication protocols, implementing encryption mechanisms, access controls, and authentication protocols, and ensuring the integrity of the data exchange all demand significant expertise and resources. This can lead to longer development timelines, increased costs, and a more intricate development process. Secondly, the need for advanced security measures can limit the flexibility and agility of technology development. Impact: This causes time delay due to work on adapting the hardware and configuring the software to secure data exchange while complying with IT security regulations. **Lack of access to data due to security restrictions:** Maintaining secure systems in today's interconnected digital landscape is crucial to safeguard sensitive information against external threats. However, one unintended consequence of stringent security measures is limiting data access for authorized users, which impede the ability to access and utilize information, and slow down the collaborative processes necessary for innovation can be hindered. Innovation thrives on the free flow of ideas, insights, and data-driven experimentation. For instance, in Italian demo, several conversations were maintained among involved partners to have an adapter to connect the data sources directly to FUSE. However, data security restrictions resulted in the

	inability to develop and use a universal adapter to connect data sources directly to FUSE. Although an alternative repository was put in place to allow the demo to upload the data through FTP protocol, it's essential to recognize its potential drawbacks and limitations on the innovation process to ensure the future innovations are robust, scalable, and efficient. By not having an adapter in place, the innovation process may have to rely on outdated or delayed data, compromising the effectiveness and relevance of the developed solutions. Therefore, lack of direct access to data due to security restrictions may limit the scope and depth of the solutions being developed. Innovations often thrive on comprehensive, diverse datasets that provide valuable insights and support informed decision-making. Impact: For data to be accessed, more steps had to be engaged, and more teams were involved to upload the data to FUSE; hence the process follows a different approach than originally planned.
Market Obstacles	**Burden of high energy costs:** When the energy prices are exorbitant, it creates barriers and challenges that impede the development and adoption of innovative technologies in the power industry. Companies and investors are forced to implement cost-cutting measures and operational efficiency to cope with these high energy costs over investing in ground-breaking solutions. Therefore, the high energy cost reduces incentives for R&I to minimize expenses while managing operational costs. Additionally, the high energy cost hurts new market players and start-ups that create disruptive solutions in the energy market. High energy costs limit the market demands, making it challenging for new technologies to gain traction and achieve economies of scale. As a result, scaling up innovative energy technologies becomes more challenging, limiting competition and the entry of disruptive solutions. By addressing the high energy cost and fostering a supportive ecosystem, the power sector can unlock the potential for innovation and drive the development and adoption of transformative technologies that enhance affordability, efficiency, and sustainability in energy production and consumption. Impact: High energy cost causes a reduction in R&D activities and stifles the potential for breakthrough advancements in the power sector. **Lack of adequate ancillary services market:** Ancillary services are crucial for maintaining the power grid's reliability, stability, and efficiency. The lack of well-functioning ancillary services markets available to the power providers is an obstacle to the development of the power industry. A well-established ancillary service market offers clear incentives and signals for technology developers and power providers to invest in R&I, development, and deployment of various power technologies. However,

	inadequate ancillary service markets often discourage such investments and efforts. With little or no market to reward and value these contributions, the motivation for developing and implementing new technologies decreases, slowing innovation. The lack of a market for the necessary devices and equipment to implement ancillary services can limit the availability and accessibility of these technologies. The absence of such a market may result in a limited supply of these devices, increased costs, and decreased competition, hindering the advancement and widespread adoption of technology solutions. Impact: The absence of an ancillary services market can create uncertainty and inefficiencies in deploying and utilizing innovative technologies.
Knowledge-related Obstacles	**Lack of sufficient information:** Without access to sufficient and reliable information, conducting thorough analyses, identifying patterns, and making informed decisions becomes challenging for development in the power sector. In the context of the Italian pilot, the difficulties in collecting and processing data delayed the development of visualization templates, as the data needed to be transformed into a usable format for ingestion into the platform and be used to determine actual KPIs. This delay directly impacted the overall progress of technology development. The final agreement was that the calculation of the KPIs in the demo environment is sent to FUSE for storage and visualization of those results. Nevertheless, calculated data was used instead of real-time data. The absence of real-time data and the reliance on estimated data can undermine the accuracy and effectiveness of technology solutions. Lack of data availability hinders the ability to validate and refine technology solutions. Access to a comprehensive dataset is necessary to validate the performance and functionality of the developed technology. Impact: Using calculated data creates the risk of inaccuracies and limited responsiveness to changing conditions, which can hamper the effectiveness and reliability of technology solutions. In this case, it impacted delays in data visualization and the use of calculated data instead of actual parameters.

3. LESSONS LEARNT

For several reasons, it is essential to note lessons learned after completing an innovative project such as the FLEXIGRID. Lessons learned provide an opportunity to reflect on and identify areas where improvements can be made on similar and future innovation projects. It helps the partners avoid making the same mistakes and enhance the success of future innovation projects of similar clusters.

Furthermore, highlighting the lessons learned from innovation projects can offer valuable insights and knowledge that can be shared with others within the industry. It enables improvement procedures, approaches, and processes in the border context of innovation.

Moreover, the lessons learned can serve as a record of the projects and their outcomes, which can be used as a reference for future projects. It helps to build project memories and ensure that knowledge gained from the project is not lost over time.

In a nutshell, the lessons learned can enhance project evaluation by clearly understanding what worked well and what did not. This can help inform future innovation project planning and decision-making, ultimately leading to tremendous success in future innovation projects.

This section highlights lessons from the FLEXIGRID project demo sites and provides best practices and recommendations per pilot country. It is essential to note that these recommendations are addressed to different stakeholders, e.g., technology providers, energy utilities, DSOs, TSOs, engineering companies, decision makers etc.

Within the context of the FLEXIGRID project, valuable insights have emerged from the diverse experiences of project partners. These lessons encompass various aspects, including technical considerations, regulatory frameworks, societal implications, security concerns, market dynamics, and knowledge acquisition. The recommendations derived from these lessons are structured on specific categories while others are presented as a general list in conclusion section. While many lessons have broader applicability, some are more specific to FLEXIGRID contexts. This comprehensive approach ensures that the FLEXIGRID project's outcomes encompass a broad spectrum of expertise, offering knowledge and guidance for stakeholders involved in similar initiatives. By sharing these lessons, the FLEXIGRID project aims to advance innovative solutions in the power sector and facilitate informed decision-making across various domains. Subsequently, the report will contribute to the industry's collective knowledge, enabling future projects to anticipate and tackle challenges effectively, thus accelerating the progress of smart grid and energy transition initiatives.

3.1 Spain

3.1.1 Technical

Definition and integration of new solutions: Although there is a need to study, identify and adopt innovative approaches, solutions, or technologies into the current energy system across the value chain, it is essential to understand how these innovations can be effectively integrated into the existing processes, operations, and infrastructure to ensure there is compatibility and interoperability for seamless interaction and function. The success of the Spanish FLEXIGRID project hinged upon the recognition and implementation of a comprehensive approach to integrating innovative technologies.

There is a need to study both the integration into the DSO systems and their potential impact on cybersecurity to see the viability of the pilots. Integration of DSO systems involves various aspects, such as interoperability with the existing hardware and software, data exchange protocol, and adherence to regulatory standards. It helps to identify potential shortcomings such as operational limitations, communication challenges, and incapability issues. Subsequently, future projects can benefit by evaluating the level of effort, potential benefits, and resources needed when executing these innovative projects on a large scale.

On the other hand, data and information necessary for analysis are always limited to the available and permitted communications, which are sometimes not accessible to partners, as they are DSO communication systems. Addressing such challenges from the future occurrence, it is essential for both the external partners and the DSOs to establish clear collaboration, relations, and communication channels, including formulating data-sharing agreements to enhance the projects' effectiveness, enabling analysis, and deriving valuable insights.

3.1.2 Financial

Financial risk analysis: Obtaining costs and market prices for the products to be developed can encounter numerous drawbacks, particularly when factors such as import and investments are considered when the development of a new project which involves the importation of basic materials, components, or its entire product, the final cost of such a product is highly influenced by external factors such as shipping fees, transportation costs, and customs levies. These factors are highly volatile and keep changing due to geopolitical factors, trade agreements, fuel prices, and other economic variables. Therefore, it is challenging to get the actual market cost information due to their dynamic nature, which can ultimately impact or adjust the overall cost of the price.

Moreover, currency exchange rates largely influence the product's final cost for the international trade market. Therefore, monitoring the market exchange requires access to real-time market information and indicators that are not easily accessible. To have actual market prices of a product, the project developers undertake comprehensive market research and demand analysis by analysing market trends, competitor pricing strategies, and customer demand. It is costly and time-consuming to undertake such an in-depth aspect of the market analysis. There is a need to undertake financial risk analysis, engage market experts and consultants, and partner with local suppliers to avoid such hustle.

3.1.3 Security

Undertake thorough testing and evaluations: Being pilots, the most innovative developments, such as new equipment, technologies, and procedures that require testing, are presented, which carries a risk of possible failures in the field. However, like any other innovation development, there is always a risk of failure in the field. It could attribute to various factors such as design flaws, technical issues, human error, or unforeseen environmental factors.

Therefore, through the project development, it was understood that it is crucial to undertake thorough testing and evaluations of these developments and innovations before deploying them to the field. This process helps to identify potential issues and allows room for improvement or adjustment at the initial stage, minimizing the risk of failure. Further, it helps to mitigate potential risks through evaluation, testing, and monitoring in a controlled environment.

3.1.4 Knowledge-related

The knowledge of the LV network and the interaction of the DG is something that is being studied. The interaction between the LV network and DG has important implications for the efficient and reliable operation of the power grid. Some of the active areas being studied on and could have significant contribution to the deployment of the FLEXIGRID in Spanish demo case include. These active areas are:

Integration challenges: Integrating the LV network and DG systems is challenging since managing the intermittency and variability of the RES is difficult. DG systems have non-continuous power generated, thus creating voltage and frequency fluctuations on the LV network. Hence, the outcome of this study will further contribute to grid network reliability, stable, and flexible.

Grid management: the DG penetration has been dramatically rising, and attention has been focusing on optimising the LV network to ensure maximum uses of the available resources while ensuring grid stability and minimising risk. To achieve this, grid operators must develop new grid management approaches, such as control of DG systems and real-time monitoring. Through modelling and simulation, the grid operator can identify optimal grid management strategies and options viable for the new system.

Controls and communication: to ensure effective control systems and communication are in place, the study focuses on adopting advanced control systems, including control algorithms and network monitoring, on a real-time basis. Subsequently, we will identify various approaches and options for efficient and reliable grid power operation.

3.2 Croatia

3.2.1 Technical

Comprehensive technical analysis: Even though the audit procedure of the Croatian pilot resulted in detailed information on the existing building infrastructure, the actual functionalities of available devices resulted in limitations in using some devices for the project. A more accurate investigation of the operation of devices can help identify such issues at the beginning of the project. Such investigation entails an intensive technical analysis (device testing, compatibility assessment, functionality review, communication protocols, and scalability analysis, among others) of the devices and their capabilities and capacity to identify possible limitations and issues that can arise during such projects' deployment.

Project deployment delays: Several issues with installed devices were encountered, rendering the deployment process more difficult and time-consuming. For instance, during the trials that could be conducted following the installation of the relays, the testing phase took longer than expected since relays initially did not perform in a way that satisfied commissioners. To address such challenges testing should involve simulating various conditions and scenarios to ensure the deployed relays can respond positively and withstand different operations conditions.

Therefore, this project phase can serve as a warning for DSOs that want to use the same relays in a similar environment. This can be anticipated in future projects by extending the deployment phase and/or considering alternative options where applicable. This proactive approach minimizes disruptions and ultimately leads to smoother and more successful project implementations.

Provision of flexibility services: In addition to the technical aspects of the project, we learned the importance of the provision of flexibility services, such as the HVAC systems in the apartment where the trial took place. During the trials, several problems arose related to the activation of flexibility assets, particularly when the communication issues hindered the monitoring of the energy consumption and the transmission of the commands to the controllable devices. This kind of experience emphasizes the importance of improving solutions related to communication infrastructure, command and feedback verification, remote diagnosis, and troubleshooting in the area.

Overall, better planning of site visits should be considered in advance (anticipation of works to be carried out, carrying extra equipment), making the visits more efficient, presenting less annoyance to the occupants, and enhancing overall project outcomes.

3.2.2 Market

Inflexibility in flexible services: In the context of market aspects, the FLEXIGRID project has highlighted a crucial lesson: the existing market is ill-prepared to accommodate flexible services. This poses a significant challenge as end-users may not be adequately rewarded or incentivized to modify their consumption patterns when necessary for the secure and reliable operation of the distribution network. The following points were the main issues in the current market challenge: inadequate market structure, limited financial incentives, lack of public awareness, regulatory framework barriers, and market design and price signals. Therefore, this calls for the need to design an appropriate market structure, foster a supportive regulatory environment, enhance stakeholder engagement and collaboration, and provide adequate financial incentives. Addressing these market challenges will help to fully unlock the potential of demand-side resources, promote market readiness for flexibility services, and ensure the operation of the distribution networks is more reliable and safer.

The COVID-19 pandemic also disrupted the market supply chain shortage, resulting in the limited availability of specific devices (e.g., raspberry devices) or extended delivery time. Even though the COVID-19 repercussions are now less significant, the purchase procedure should be planned and started as soon as possible to avoid delays in acquiring the necessary equipment.

Staying ahead of time allows for flexibility in case of unforeseen circumstances, and it can help mitigate the effect of potential disruptions in the market supply chain, ensure the timely availability of procured pieces of equipment, and maintain project momentum for the successful deployment of innovative developed solutions.

3.2.3 Societal

During the Croatian project, several lessons were learnt regarding the cooperation and availability of the occupants of the premises in which the FLEXIGRID solution was being deployed and tested. The coordination between different parties participating in the conduction of trials, including occupants living in an apartment that was part of the Croatian demo, was a major issue. Due to different private issues of the occupants, it was hard to coordinate the installation and testing of necessary devices. Due to that, the trials could not have been started on time which also prolonged the calculation of KPIs. Therefore, to ensure better cooperation, the project's objectives can be explained and reminded, along with information on specific and well-defined timelines, progress, and project results.

In addition, offering specific incentives can motivate occupants to participate and cooperate in the project. Some of the specific incentives which can be considered at the beginning of the project include but are not limited to:

Lower Energy Tariff: Occupants can receive a reduced energy tariff to incentivize their involvement in innovative solutions such as FLEXIGRID Project. This can be implemented by working with energy providers to offer discounted rates for participants in the project.

App for Monitoring and Device Control: A dedicated mobile or web application can be developed to allow occupants to monitor and control their devices connected to the FLEXIGRID solution. The app can provide real-time energy consumption information, allow users to adjust settings, and offer tips for optimizing energy usage. This empowers occupants and gives them a sense of control over their energy consumption.

Enhanced Comfort and Convenience: The FLEXIGRID solution can be designed to enhance occupants' comfort and convenience. For example, it can include features like automated scheduling of appliances, adaptive lighting controls, or personalized temperature settings. These enhancements improve the overall living experience and can incentivize occupants to actively engage in the project.

3.2.4 Security

Data security: this was an essential aspect of this project. Authorization and authentication API services ensured secure and seamless data transmission between involved partners and the Infrastructure Management Layer (IML) cloud. In addition, new hardwired devices in the circuit board have been used for secure and non-intrusive data transmission. These two services are essential in verifying the identity of the entities responsible and giving permissions for the data transmission process. Optimizing these services helps ensure that only the IML cloud and the authorized partners can access the transmitted data.

Therefore, combining the authorization and authentication API services with the new hardwired devices, the project ensures high data security throughout the entire data transmission process. This approach helps mitigate the risks associated with unauthorized access, data breaches, and other security threats, providing a robust and reliable foundation for the project's data transmission requirements.

Data anonymization: Another crucial point noted was the need for anonymization of data used in the project. This requirement arises from the need for data protection due to potential cyber risk since discovering information could cause a violation of GDPR compliance. Thus, the need to implement effective and robust data anonymization procedures, ensuring regulatory compliance and protection of privacy.

3.2.5 Knowledge-Related

Innovation awareness: It has been observed that certain entities were unaware of their potential and role in the energy transition, leading to delays in introducing modernized processes, procedures, and systems. Even as the situation evolves, the persistent lack of awareness among different entities can hinder the success of developing this project and other similar initiatives. To address this, there is a need for comprehensive education campaigns, creating awareness, stakeholder engagement, building long-term engagement, information sharing, and best practices which will enable to bridge the knowledge gap among various entities.

3.3 Greece

3.3.1 Technical

In Greek demo, the primary lesson learnt revolved around specific technical aspects. Several critical insights emerged from this context, shedding light on key considerations that deserve attention which include the below:

Battery control: Several important findings reviewed on impact of various battery control approaches during the Greek demo site's testing phase. Initially, using a specific Modbus register linked to the minimum SOC (original strategy), it was noted that this technique doesn't force the inverter to draw power from the grid to feed the battery. Ultimately, there is no way to directly control the power rate at which the battery was being charged or discharged. To elaborate further, setting the battery SOC at a low level ensures that there was a discharge with a stable rate of the maximum charging/discharging power rate the battery supports. However, it was noted that this occurs only when there was enough load in the associated bungalow to draw this power.

On the other hand, when the setting of SOC was at a high level, e.g., 100%, it ensures that the battery was charged with a stable rate of the maximum power, but only when there was sufficient solar production serving the associated bungalow's load and leaving a remaining power equal to this maximum rate to charge the battery.

Based on the testing activities at the Greek demo site, it was concluded that directly controlling the power rate at which the battery was charged or discharged was not feasible. Instead, manipulating the battery SOC levels allows for a stable rate of charging or discharging within the battery's supported power limits, depending on load availability or solar production.

Reactive power control: On the reactive power control mode front, activities in the Greek demo site led to the conclusion that the power factor setting has limits between 0.8-1 (leading or lagging), while the PF register can get negative values between -0.8 (scaled -800) and -1 (scaled -1000) and positive values between 0.8 (scaled 800) and 1 (scaled 1000). On top of that, the PF setpoint is relative to the active power output of the inverter. When sending a setpoint of -0.8 (scaled -800), if the active inverter power is negative (overall export to the metering point adding PV, load, and battery), it seems to "produce/export VArs". Conversely, if the inverter's active power is positive (overall import from the metering point adding PV, load, and battery), the inverter would "consume/import VArs".

Therefore, it was noted that the above is rather more complicated to implement in logic, requires more real-time feedback (potentially a local control loop), and may lead to more "expensive processing" for a commercial system in the future.

On the other hand, using the same registers in the non-hybrid inverters, it is possible to control the reactive power flows of the non-hybrid inverters without needing a reading/control loop. By sending a value between -0.8 and -1 to the non-hybrid inverters, we always achieve reactive power export from the inverters to contribute to reactive power minimization at the substation level and hence peak shaving. A workaround using different registers has been developed and is thoroughly described in D6.7 with further details also given in D6.11.

3.3.2 Market

Inverter parallel operation (cascading): A rather important feature learned when selecting a residential hybrid inverter is the ability to operate in cascading mode when more than one inverter is apparent in an installation. This feature allows the inverters to function simultaneously during an emergency operation (black-out support), thus harvesting the available capacity and services from all of them.

In cascading mode, one of the inverters needs to operate as a “master” or “leading” device while the other(s) as a “slave” or “following” device. The “master” device regulates voltage/frequency levels for the islanded grid, while the slave devices need to follow the master’s pace.

On the contrary, non-cascading inverters, such as the Fronius inverters installed in the Greek demo site, restrain the black-out support capabilities, leaving only one hybrid inverter able to operate during a black-out. As it turns out, this matter needs to be considered when choosing an inverter because cascading may be a hard requirement depending on the use cases and operational parameters that need to be satisfied; thus, turning towards specific brands in the markets would be advisable.

By carefully considering the black-out support capabilities and evaluating whether the cascading mode is required, users can ensure that their chosen inverter meets their specific needs and provides the desired level of functionality during emergencies.

3.3.3 Security

Real-time data loss: it was learnt that there is importance of thoroughly assessing the power supply sources for the equipment involved in trials or experiments. In this case, the omission occurred concerning the ancillary network equipment, specifically a switch, which resulted in the inability to acquire high-granularity data through the locally installed gateway.

To prevent such omissions in the future, a more thorough assessment may have prevented this omission by applying an alternative power source to the switch, which was the mitigation plan conducted for the Greek pilot. As a learning point from this incident, it is always a good practice to have the network equipment (which, in the case of a simple residence, most probably is only a low-consumption router unit) connected either directly to an Uninterruptible Power Supply (UPS) device, which will ensure its uninterrupted operation, or at least on a circuit that will be served by the hybrid inverter while in emergency operation.

Therefore, it is crucial to consider all equipment involved in a trial or experiment and assess their power supply requirements. Uninterrupted operation can be ensured by implementing backup power solutions or connecting critical equipment to circuits powered by alternative sources, minimizing the risk of data loss or operational disruptions. Further details are also reported in D6.7.

3.4 Italy

3.4.1 Technical

During the implementation of the Italian pilot demo, a key lesson was the importance of considering and evaluating various characteristics and elements of each project within the technical aspects. It became evident that when attempting to undertake a specific function or service, several project characteristics and aspects, which might be overlooked, play a significant role in determining the success of the desired task.

Island mode Operation: For example, during the execution of the Italian pilot project, it was learned that the oldest power plant could not self-regulate nor feed a grid in island mode. It means that the power plant could not be able to function independently. Therefore, when disconnected from the main grid network, the plant could not be able to supply electrical power to the localized grid. Despite initially overlooking or underestimating the importance of this particular characteristic of the power plant, project partners took decisive action to address and overcome this challenge, resulting in commendable progress and successful outcomes for the project. By proactively finding a solution, it was possible to effectively navigate around potential obstacles and achieved positive results.

Plant's power capacity: Another notable lesson learned concerns generator's minimum and maximum power capacity in relation to grid's load. At the commencement of the project, the Italian pilot needed to test an island mode with a high voltage (HV) hydroelectric plant. However, it was learned that this specific power plant had a minimum power production level that exceeded the minimum load requirement of the medium voltage (MV) grid. Consequently, it was not feasible for the hydroelectric power plant to achieve stable island mode when it needed to supply the grid with power solely.

These two examples highlight the need to carefully assess a plant's power capacity, characteristics, and other technical aspects with specific constraints and requirements of the intended application.

3.4.2 Market

A positive lesson learned from the Italian pilot was the increased interest the power plant owners showed in offering new ancillary services for the grid. Such a shift in perspectives shows the recognition of the possibility of various benefits these services can avail to the plant owner and the community it serves.

Power ancillary services and functions: Conventionally, the power plant owner focuses more on electricity production and supply to the grid. Thanks to the FLEXIGRID project, the plant owners learned the various ancillary services and functions, including (load balancing, frequency regulation, and grid stabilization, among others) to contribute to the reliability and stability of the grid significantly. In addition, these ancillary services improve the performance of the power plant. Ultimately, will improve the overall sustainability of their power plant operations, efficiency, and resilience of the grid system in supporting the community's energy needs. Overall, this lesson shows power operators' importance in considering ancillary services, collaboration, and mutual benefits while supporting the performance and stability of the energy systems.

Subsequently, power plant owners will benefit from the diversification of revenue streams by offering such ancillary services, ultimately increasing their business opportunities.

3.4.3 Societal

The Italian pilot experienced various issues that required adaptability and flexibility to overcome unforeseen obstacles in the future. One of the significant global issues that adversely impacted the pilot was the COVID-19 pandemic. This crisis created a domino effect that resulted in multiple challenges among the bottlenecks within the delivery process of the technology and the technical communication difficulties. All these and many other experiences taught essential lessons about project development in the face of unexpected circumstances including:

Importance of agility: The COVID-19 pandemic has shown the critical need for agility in project development. In such a situation, it becomes vital to quickly learn and adapt plans, processes, and resources to circumnavigate the changing landscape. Therefore, a rigid project framework may not be suitable for such a crisis time, and it is essential to adopt a flexible approach when dealing with such crises to overcome obstacles and mitigate risks.

Flexibility in technology implementation: technology delivery processes encounter bottlenecks due to the crisis. This created the need to adopt flexibility in technology implementation. To ensure continued progress amidst the COVID-19 pandemic and overcome supply chain disruptions, the Italian pilot learned the importance of being open to alternative technologies, adjusting timelines, and considering adaptable solutions.

Collaboration and communication: the challenges faced during the pilot deployment underscored the importance of having robust communication and cooperation between the leading players and the external stakeholders. Clear, frequent, and well-defined communication and collaboration ensure that every player is aligned with the project objective, scope, and expected outcomes despite other limitations. Moreover, for a project that involves different players to succeed, good coordination between all entities is required to effectively adapt collaboration strategies and virtual communications tools to ensure that all teams involved are well-informed and engaged for optimum productivity.

By incorporating these lessons into future projects, the team can be better prepared to tackle unexpected obstacles and ensure successful outcomes.

Public policy makers: Additionally, it was noted that public policy makers, including national and local government, significantly contribute towards the uptake of innovative solutions in power sectors. To promote innovation in the power sector, public policymakers must embrace a framework that focuses on capacity building and recognizes the limitations of traditional approaches. They must acknowledge that the complex challenges faced by the power sector today require new and different perspectives. This entails developing innovative organizational forms, governance structures, funding mechanisms, policy approaches, partnerships, and accountability structures that transcend traditional boundaries between the public and private sectors. By seeking novel solutions to address the world's most challenging problems, such as climate change, policymakers can harness the potential of technological progress, which is advancing at an unprecedented pace. However, this also places immense pressure on them to stay abreast of the latest tools and approaches. Therefore, policymakers must continuously adapt and evolve their strategies to effectively incorporate new technologies and drive innovation in the power sector.

4. CONCLUSIONS

The implementation of the FLEXIGRID solutions represents a transformative approach to modernizing the European medium voltage (MV) and low voltage (LV) distribution grid network. The innovative FLEXIGRID solutions ensure that the present distribution grid system has achieved high reliability and flexibility, improved integration of renewable energy sources and efficiency, and will be more resilient in the future. While fully exploring the benefit of FLEXIGRID solutions, the project identifies numerous challenges and obstacles which can hinder innovation in this field of smart grids or similar areas of innovation in the power sector. The identified barriers must be addressed to foster development in this sector. Therefore, this section provides comprehensive conclusions of an analysis of the obstacles encountered in innovative projects. These obstacles arise from various sources, including technological limitations, societal barriers, financial and market constraints, security, and knowledge-related issues.

Further, the report's conclusion summarizes significant insights and lessons derived from the FLEXIGRID project, which are valuable for the future development of similar innovative projects. It systematically addresses obstacles anticipated in smart grid projects, presenting the lessons learned from effectively addressing these challenges. Moreover, the report provides a glimpse into specific examples encountered while deploying FLEXIGRID solutions within the four identified demo-case studies, outlining the solutions devised to overcome these hurdles.

4.1 General Conclusion and Recommendations

4.1.1 Common technical obstacles: maturity, compatibility and reliability

The deployment of new technologies in the energy sector comes with its fair share of technical challenges and impacts across different countries, as observed in the case studies of Spain, Croatia, Greece, and Italy. These challenges range from technology immaturity and unreliability to equipment malfunctions, compatibility issues, and limitations of existing infrastructure. These factors significantly affect the successful implementation of innovative solutions, particularly smart grid projects, and the overall advancement of the energy sector.

However, the four demo cases highlight several important lessons learned in implementing similar innovative energy projects. The importance of comprehensive integration of new technologies into existing processes and infrastructure was highly emphasized. This requires studying compatibility, interoperability, and infrastructure limitations to ensure successful integration. Throughout the project implementation, evaluations, pilot studies, comprehensive testing, and collaborative efforts between stakeholders (grid operators and external partners) are critical to ensure seamless integration and reliable performance. Moreover, testing should involve simulating various conditions and scenarios to ensure devices can perform satisfactorily.

In addition, there is a need for flexible services, and improvements in communication infrastructure and troubleshooting processes are essential for smooth project implementation. By overcoming these obstacles, the MV/LV distribution grid network can advance toward a more efficient, sustainable, and resilient future.

4.1.2 Financial obstacles: high capital costs, low financial knowledge

FLEXIGRID project shed light on various financial obstacles in adopting innovative energy solutions. The lack of funding for R&D programs hinders the comprehensive evaluation of new technologies, resulting in delays in their market introduction and investment recovery by equipment manufacturers. In this case, the entire FLEXIGRID solutions were fully financed by European Commission to the tune of about €8.6 million. The scale and complexity of similar project upgrades often posed financial burdens that few projects could afford to bear, making it challenging for private developers to secure adequate funding to support such a high-cost project.

Additionally, unclear financial benefits and a conservative investment approach hinder the adoption of smart grid innovations. The lack of financial support and business sponsorship, particularly for small consumers, restricts the ability to adopt innovative systems despite their benefits.

Moreover, there is a high level of insufficient understanding of the risks versus potential financial benefits and resistance to change, which impede the market penetration of innovative energy solutions. Furthermore, there is a low willingness to invest in power adaptation measures due to concerns about profitability, and the absence of incentives or regulatory frameworks compounds the financial obstacles.

The demonstration case studies show the need for similar projects to have adequate funding, tailored financial instruments, clear financial benefits, and financial regulatory frameworks that reward investments are crucial to overcoming these obstacles and driving the widespread implementation of innovative technologies. Moreover, project developers should engage in comprehensive financial risk-benefit analysis and collaborate with market experts and consultants to mitigate financial risks and access accurate market prices.

4.1.3 Societal: entities, misaligns of interests, invisibility of service providers

Societal obstacles were one of the challenges uniquely identified and differed in each locality of a pilot study. In Spain, the regulatory framework's non-recognition and inadequate compensation of new technologies hinders electric companies' quick adoption of innovative solutions.

In Croatia, a lack of proper collaboration between project developers and facility host partners where the deployment took place and other issues with various entities participating in pilot projects could prevent the successful installation and commissioning of equipment, potentially leading to delays.

Additionally, the lack of after-service and know-how in smart grid projects can impede system integration, performance monitoring, and performance validation, hampering technological advancements. For instance, in Greece, failure to get local support services and infrastructure available to service failed equipment can hinder the adoption of new technologies, leading to project delays and increased costs.

Lastly, in Italy, misalignments of interests between distributors and manufacturers, natural factors affecting power generation, and communication difficulties with local service providers can all impact energy sector innovation and slow down technology development. Overcoming these societal obstacles is crucial for the successful deployment and widespread adoption of smart grid technologies.

Other social external events and market factors that occurred during the implementation cycle of the FLEXIGRID projects, such as the COVID-19 pandemic and the crisis in Ukraine, have significantly impacted the project's trajectory and outcomes.

COVID-19 pandemics:
The outbreak of the COVID-19 pandemic in 2020 brought unprecedented challenges to the FLEXIGRID projects and smart grid projects worldwide. Lockdown measures, supply chain disruptions, and shifts in energy demand patterns adversely affected implementing of the FLEXIGRID project. Restrictions on construction activities, workforce availability, and travel limitations hindered progress in some demo sites; the Italian demo was highly affected due to heavy restrictions imposed by the Italian authority.

The pandemic also caused economic uncertainties, impacting financing and investment decisions. Lessons learned from the pandemic include building resilience and flexibility into project plans to adapt to unforeseen events. It highlighted the need for robust contingency plans, risk management strategies, and the ability to leverage digital technologies for remote monitoring and control. Moreover, the collaboration and communication among project partners and stakeholders became even more critical during such challenging times.

Crisis in Ukraine:
The crisis in Ukraine, mainly regarding energy supply disruptions and geopolitical tensions, had a cascading effect on the energy landscape in Europe during the FLEXIGRID project. There were uncertain energy market dynamics, particularly gas supply which posed a challenge for the dependence of low carbon energy on the grid and ultimately slowed the integration of renewable energy sources, affecting energy security and grid stability. The lesson learned in the Ukraine crisis was the need to enhance energy storage capacities and diverse energy sources and reinforce the regional grid interconnection by modernizing and advancing the grid network. These lessons will ensure European grid in the future is flexible and resilient against external shocks.

4.1.4 Market: global issues, commercialization costs, ancillary services

The surge in energy prices, driven by global factors, has led to increased electricity prices, impacting the affordability and living standards of end-users. The current electricity markets are not designed to be flexible, thus limiting the participation of entities in providing flexible solutions. Additionally, the lack of commercialization costs and inadequate market development poses challenges in promoting and investing in innovative energy services.

Moreover, the demand for constant energy supplies forces power providers to divert their resources from exploring and implementing innovative solutions. Furthermore, the high energy cost creates barriers for companies, investors, and new market players, reducing incentives for research and development and hindering the scaling up of innovative technologies. Insufficient incentives and inadequate ancillary services market discourage investments in research, development, and deployment of power technologies.

The current market obstacle of unpreparedness for flexibility services highlights the need for an appropriate market structure, regulatory framework, financial incentives, public awareness, and effective market design and price signals. Addressing these challenges will unlock the full potential of demand-side resources, promote market readiness for flexibility services, and ensure safer and more reliable distribution network operations.

Furthermore, offering specific incentives can motivate occupants to participate and cooperate in the project. Lower energy tariffs, dedicated monitoring and control applications, and enhanced comfort and convenience can incentivize occupants to actively engage with the solution, optimize their energy usage, and contribute to the project's success. The power plant owners should offer ancillary services for the grid, including revenue diversification, improved power plant performance, and overall grid resilience.

4.1.5 Security: data access, unauthorised data access, inaccurate data, outdated technology

In order to guarantee the stability and sureness of innovative project, mitigating possible data penetration from external sources becomes a priority. Assuring the optimality of upgraded protection and defence systems while following policies and regulations shall be one of the main guidelines of any project. As seen throughout the four pilots, there is a high concern for a security breach, which implies that the data from future similar projects must concede in both: mutual collaborations between private-public networks, as well as a strict GDPR respectful of the final consumers' privacy.

4.1.6 Knowledge-related

Although it is crucial for protecting intellectual property, patents can sometimes impede market competition, resulting in slower innovation, higher costs, and limited choices. Finding a balance between intellectual property protection and promoting technological advancement is crucial to ensure healthy market competitiveness. The involvement of experts and entities is essential for advancing power systems and driving innovation. The need for more awareness and engagement from industry partners, system operators, and end-users can impede the transition toward more advanced and efficient systems. Prioritizing knowledge adoption, transfer, and management is critical to overcoming barriers to innovation and accessing necessary information and expertise.

4.2 Specific Conclusion and Recommendations

During the deployment of the FLEXIGRID solutions, several specific and substantial obstacles were encountered, which merit acknowledgment. These specific challenges had a notable impact on the project implementation.

The Italian pilot concluded that achieving stable island mode operation is of utmost importance for power plants when they need to supply power solely to the grid. In island mode, the power plant operates independently from the primary grid, ensuring continuity of power supply to critical loads and maintaining grid stability. This capability is particularly crucial during emergencies or grid disturbances when the primary grid is unavailable or experiencing disruptions.

By seamlessly transitioning to island mode, power plants can support the reliability and resilience of the grid, preventing blackouts and minimizing the impact on end-users. Stable island mode operation enables power plants to fulfil their responsibility as essential providers of electricity and contribute to the energy system's overall stability and functionality, hence the need to carefully assess a plant's power capacity, characteristics, and other technical aspects to determine specific constraints and capabilities.

Another important note was that choosing components well-suited to your applications' requirements, as witnessed in the Greek demo, such as inverters that operate in cascading mode, is essential. When choosing an inverter, assessing the need for cascading mode based on specific use cases, such as a residential hybrid inverter, is essential. By making a well-informed market decision and considering brands that support their needs, users can ensure that their selected inverter or other components aligns with their requirements and delivers the desired functionality during critical situations.

Additionally, testing activities conducted at the Greek demo site highlighted the challenge of directly controlling the power rate of battery charging or discharging. However, an alternative approach was identified, which involved manipulating the battery's state of charge (SOC) levels. Adjusting the SOC levels could enable a stable rate of charging or discharging while staying within the supported power limits of the battery. This strategy effectively optimized the battery's performance based on load availability or solar production. This shows the importance of considering SOC manipulation as a viable method for managing battery operations and ensuring stability in power systems.

The impact of AI technology modules on the power system can be significant and multifaceted. Across different case studies, there are various societal, security, market, and technical challenges highlighted in this report. To address these challenges and harness the potential of AI technology in the power system, it is crucial to prioritize human autonomy, ensure security measures, promote transparency and accountability, foster fair market competition, and invest in technological and financial expertise. By striking a balance between the advantages of AI technology and addressing these concerns, it is possible to create a more efficient, reliable, and sustainable power system that benefits society. Overall, AI will likely play a key role in the future of the power sector across the value chain differently. In the field of power technology, AI has the potential to revolutionize the control algorithms that support the entire sector. By harnessing the power of artificial intelligence, we can significantly enhance development of future of power innovation.

To sum up, challenges faced by FLEXIGRID project pilots are shown in Table 2.

Table 2: Summary of obstacles faced by the four demo-sites of FLEXIGRID project

		Demo-Sites			
Obstacles Category	**Identified obstacles**	**Spain**	**Croatia**	**Greece**	**Italian**
Technical obstacles	Technology immaturity	✓	✓	✓	✓
	Technology unreliability	✓	✓	✓	✓
	Technological incompatibility		✓	✓	✓
	Lack of operational excellence				✓
	Incapacity for available infrastructure to support end users' innovative solutions			✓	
	Communication difficulties with local services providers				✓
Financial obstacles	Lack of funding colocation	✓			
	High cost of financing		✓		
	Limited funding available		✓	✓	
	Unclear financial knowledges and benefits		✓	✓	
Societal obstacles	Low level of willingness to investment				✓
	Lack of recognition of new technology	✓			
	Low technology readiness level	✓			
	Issues between entities and stakeholders		✓		
	Lack of relevant measurements and information's		✓		

	COVID-19 pandemic (planning, mobility, facility, supply chain) limitations	✓	✓	✓	✓
	Lack of local support services and infrastructure availability			✓	
	Misalignment of interests between distributor needs and manufacturers				✓
	Globalisation issues (high energy cost)		✓		✓
	Lack of commercialization cost (CapEx, OpEx)			✓	
	Inadequate ancillary services market				✓
	Limited access to data	✓	✓		✓
	Overdependence on end-users' site		✓		
Security obstacles	Outdated technology and updated requirement		✓		
	Inaccuracy data inputs		✓		
	Unauthorized access and interference			✓	✓
Knowledge-related obstacles	Intellectual property protections abuse	✓			
	Limited experts and entities		✓	✓	
	Inefficient knowledge adoption, transfers, and management		✓		
	Limited information				✓

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