Evaluation of OneNet demonstrators' results
D11.1

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About OneNet

The project OneNet (One Network for Europe) will provide a seamless integration of all the actors in the electricity network across Europe to create the conditions for a synergistic operation that optimizes the overall energy system while creating an open and fair market structure.

OneNet is funded through the EU's eighth Framework Programme Horizon 2020, "TSO – DSO Consumer: Large-scale demonstrations of innovative grid services through demand response, storage and small-scale (RES) generation" and responds to the call "Building a low-carbon, climate resilient future (LC)".

As the electrical grid moves from being a fully centralized to a highly decentralized system, grid operators have to adapt to this changing environment and adjust their current business model to accommodate faster reactions and adaptive flexibility. This is an unprecedented challenge requiring an unprecedented solution. The project brings together a consortium of over seventy partners, including key IT players, leading research institutions and the two most relevant associations for grid operators.

The key elements of the project are:

1. Definition of a common market design for Europe: this means standardized products and key parameters for grid services which aim at the coordination of all actors, from grid operators to customers;
2. Definition of a Common IT Architecture and Common IT Interfaces: this means not trying to create a single IT platform for all the products but enabling an open architecture of interactions among several platforms so that anybody can join any market across Europe; and
3. Large-scale demonstrators to implement and showcase the scalable solutions developed throughout the project. These demonstrators are organized in four clusters coming to include countries in every region of Europe and testing innovative use cases never validated before.

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List of Abbreviations and Acronyms

Acronym	Meaning
(a or m)FRR	(automatic or manual) Frequency Restoration Reserve
(E)HV	(Extra) High Voltage
(G)UI	(Graphical) User Interface
(I)MO	(Independent) Market Operator
(S/W/H)PP	(Solar/Wind/Hydro) Power Plant
ABCM-D	Active Balancing and Congestion Management - DSO
ABCM-T	Active Balancing and Congestion Management - TSO
AC	Alternating Current
AI	Artificial Intelligence
API	Application Programming Interface
ASM	Active System Management
AST	Abstract Syntax Trees
AWS	Amazon Web Services
BaU	Business as Usual
BESS	Battery Energy Storage System
BRP	Balance Responsible Party
BSP	Balancing Service Provider
BUC	Business Use Case
CDF	Cumulative Distribution Function
CEF	Connecting Europe Facility
CGMES	Common Grid Model Exchange Standard
CHP	Combined Heat and Power
CIM	Common Information Model
CM	Congestion Management
DDEP	DSO Data Exchange Platform
DER	Distributed Energy Resource
DG	Distributed Generation
DMZ	Demilitarized Zone
DNS	Domain Name System
DPLAN	Distribution Planning
DSO	Distribution System Operator
DSR	Demand-Side Response
EAC	Electricity Authority of Cyprus
ECC	External Communication Channel
ECCo SP	ENTSO-E Communication and Connectivity Service Platform

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ECP	Energy Communication Platform
EMS	Energy Management System
ESMP	European Style Market Profile
EU	European Union
EV	Electric Vehicle
FP	Flexibility Platform
FR	Flexibility Register
FSP(A)	Flexibility Service Provider (being Aggregator)
GDPR	General Data Protection Regulation
gRPC	Google Remote Procedure Call
HES	Head End System
HMI	Human Machine Interface
HTTP(S)	Hypertext Transfer Protocol (Secure)
HVDC	High-Voltage Direct Current
ICT	Information and Communications Technology
IEEE	Institute of Electrical and Electronics Engineers
IEGSA	Interoperable European Grid Services Architecture
IoT	Internet of Things
IP	Internet Protocol
IS	Information System
IT	Information Technology
JSON	JavaScript Object Notation
JWT	JSON Web Tokens
KPI	Key Performance Indicator
LMP	Local Market Platform
LMS	Local Management System
LT-P-C/E	Long-term Capacity/Energy Product
LV	Low Voltage
MARI	Manually Activated Reserves Initiative
MEI	Mobility Energy Innovations Kft.
MO	Market Operator
MQ	Message Queue
MQTT	Message Queuing Telemetry Transport
MS	Microsoft
MV	Medium Voltage
NAZA	New Adaptive Zonal Automaton
NEMO	Nominated Electricity Market Operator
NRT-P-C/E	Near-real-time Capacity/Energy Product

NWP	Numerical Weather Prediction
OHL	Overhead Line
OIDC	OpenID Connect
PCI	Project of Common Interest
PDC	Phasor Data Concentrator
PICASSO	Platform for the International Coordination of Automated frequency restoration and Stable System Operation
PMU	Phasor Measurement Unit
POI	Point Of Interest
PSS®E	Power System Simulator for Engineering
PTDF	Power Transfer Distribution Factors
PV	Photovoltaic
RES	Renewable Energy Sources
REST	Representational State Transfer
RR	Replacement Reserve
RTE	Réseau de Transport d'Électricité
RTS	Real Time Simulator
SCADA	Supervisory Control and Data Acquisition
SCRAM-SHA	Salted Challenge Response Authentication Mechanism - Secure Hash Algorithm
SO	System Operator
SQL	Structured Query Language
SSH	Secure Shell
SSL	Secure Sockets Layer
STAR	System of Traceability of Renewables Activations
ST-P-C/E	Short-term Capacity/Energy Product
TCP/IP	Transmission Control Protocol/Internet Protocol
TDEP	TSO Data Exchange Platform
TRL	Technology Readiness Level
TSO	Transmission System Operator
TSR	Trading and Settlement Rules
TYNDP	Ten-Year Network Development Plan
VC	Voltage Control
VPN	Virtual Private Network
WFS	Web Feature Services
WMS	Web Map Services
WP	Work Package
XBID	Cross-Border Intraday
XML	Extensible Markup Language

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Executive Summary

This report presents and evaluates the results of the OneNet demonstration activities in a comprehensive manner, based on the frameworks set in previous OneNet work packages, and presents the main conclusions stemming out of them.

OneNet demonstrations were carried out in geographically dispersed pilot sites, each one with different business objectives, which led to a variety of flexibility services and market designs being demonstrated. In addition, their grid characteristics and resources set up varied a lot. Table 6.1 presents an overview of the main characteristics of the OneNet demo clusters:

Table 6.1: Overview of the OneNet demo clusters

Cluster	Voltage levels	Number of TSOs/ DSOs	Number of resources	Type of resources	Products tested	Type of SOs coordination
Northern	400V – 20kV	4 TSOs / 4 DSOs	~ 130	Residential, commercial	• mFRR product • Corrective local active energy product • Predictive short-term local active energy product • Predictive short-term local active capacity product • Predictive long-term local active capacity/ energy product	Market-based TSO - DSO coordination
Southern	400kV, 220kV, 150kV, 110kV, 35kV, 20kV	2 TSOs / 2 DSOs	> 200	Residential, commercial, industrial	• Inertia product • mFRR product • RR product • Predictive short-term local active product • Predictive long-term local active product • Corrective local active product • Corrective local reactive product	Technical- and market-based TSO - DSO coordination
Western	400kV, 220kV, 60kV, 10kV-30kV	2 TSOs / 4 DSOs	~ 270	Residential, commercial, industrial	• Predictive short-term local active product • Predictive long-term local active product • Corrective local active product	Technical- and market-based TSO - DSO coordination

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Eastern	132kV, 110kV, 30kV, 22kV, 15kV	3 TSOs / 6 DSOs	~ 270	Residential, commercial, industrial	• mFRR product • aFRR product • RR product • Predictive short-term local active product • Corrective local active product • Predictive short-term local reactive product • Predictive long-term local reactive product	Market-based DSO coordination

In the majority of tests conducted during the demonstrations (roughly around 84% of the time), the target values set for the Key Performance Indicators (KPIs) were reached. For the commonly shared KPIs among the OneNet demonstrators the predefined targets were achieved in around 78% of cases. Besides these common KPIs, additional KPIs were categorized into four distinct groups of high importance to OneNet: (i) technical assessment of system service provision, (ii) market platforms and economic performance assessment, (iii) customer engagement-centric performances, and (iv) ICT and data processing performances. This categorization was based on the relevance of each KPI to the aspects each category focused on regarding the performance of the demonstrations. It's important to note that some KPIs could fit into more than one category, but for clarity and readability purposes, each KPI was assigned to a single category.

The most successful KPI target achievements were in the areas of customer engagement-centric performances, where all targets were met, and ICT and data processing performances, with approximately 94% of targets achieved. In contrast, the technical assessment of system service provision and market platforms and economic assessment areas saw lower percentages of roughly 80% and 88% target achievement, respectively. It's worth mentioning that these performance percentages are influenced by the number of KPIs within each category, which can vary significantly.

Some standout KPIs in terms of demonstration performance include those related to the percentage of avoided technical restrictions and available flexibility, for both of which the target values were reached in a high percentage of the tests. For the former, in many cases, a 100% avoidance of technical restrictions was achieved, and for the latter, the available flexibility was notably high, with some tests reaching values as high as 80%. Less promising performance was observed for KPIs related to the number of Flexibility Service Providers (FSPs) and transactions, with only two-thirds of the demonstrations meeting their targets. Similar results were seen for KPIs related to the volume of transactions-cleared bids.

The analysis of criticalities identified by the demonstrators regarding the calculation of the KPIs, revealed common difficulties, including:

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- The challenge of accurately measuring the reduction of entry barriers for flexibility provision and the engagement of FSPs.
- The complexity of defining KPIs for new market structures and flexibility products, along with the difficulty of establishing meaningful baselines and target values.
- The absence of baseline values for some data processing KPIs, making precise target estimation challenging.
- Concerns about the computation of the KPI "Error of load forecast" based on forecasting tools.

In addition to these criticalities, the demonstrators faced some cybersecurity challenges, particularly regarding the sharing of sensitive information and data confidentiality among various actors, as well as firewall- and proxy-configuration issues during the deployment of the OneNet Connectors.

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1 Introduction

1.1 Work Package 11 objectives

The overall objective of WP11 is to conduct an analysis of the results of the different cluster demonstrations and extract conclusions for EU implementation, including the corresponding supportive policies to enable TSOs, DSOs and customers to procure standardized system products in a coordinated manner through interoperable platforms. To accomplish this, the following sub-objectives are addressed through the WP11 tasks:

- Evaluation of the technical, economic and regulatory aspects for standardized products and services.
- Assessment of the feasibility of implementing various market schemes and their impact on existing markets.
- Interoperable platforms and data architectures to support TSOs-DSOs-customers coordination.
- Scalability and replicability analysis of the proposed standardized products, market schemes and IT tools and platforms for the EU-wide implementation.
- Business models analysis for OneNet solutions.
- Recommendations for customer engagement strategies.
- Identification of challenges for the implementation of standardized products, market schemes, data access and management and interoperable platforms in the EU.

In this context Task 11.1 focused in evaluating technical, economic and social aspects of the OneNet demonstration activities based on relevant KPIs.

1.2 Description of Task 11.1 and relation to other tasks and WPs

The main objective of Task 11.1 was to evaluate the OneNet demonstrators' results by gathering information on the different cluster demos and withdrawing conclusions in a comprehensive manner, based on the standardized frameworks defined in WP2 and the market designs defined in WP3. Task 11.1 was divided into two main parts. The first part comprised an initial characterization of the demonstrators, including a summary of the solutions chosen for specified products, market schemes, IT solutions and system operations (defined in WP4 and WP5), as well as information about the location, grid specifications, customers and cybersecurity issues for each of the pilot sites. In the second part, the demonstrators' results were evaluated and assessed with respect to the technical, economic and social KPIs defined in WP2 and more specifically in deliverable D2.4 [17], in relation to a predefined Business as Usual (BaU) scenario. Also, this task played a supportive role towards demos by providing coordination, insights and templates for defining KPIs for each demonstration cluster, defining a common methodology for the characterization and evaluation of the pilot sites, providing support on data gathering and conducting analyses on demonstration cluster level.

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As shown in Figure 1.1, Task 11.1 plays an important role within OneNet, since it concerns the evaluation of the solutions developed and the overall work done within the project. Task 11.1 takes inputs from all the demonstrator WPs (WP7 – WP10), as well as WP2, and its conclusions constitute inputs for all other WP11 tasks (Tasks 11.2 – 11.7). More specifically:

- WP2: The standardized frameworks and KPIs defined in WP2 were used in Task 11.1 to conduct the evaluation of the demonstrators.
- WP7 – WP10: The evaluation process conducted in Task 11.1 was based on the KPIs selected by each demonstrator and their calculated values after the implementation of the OneNet solutions.
- WP11: All WP11 tasks take as input the demonstrators' evaluation results and conclusions from Task 11.1.

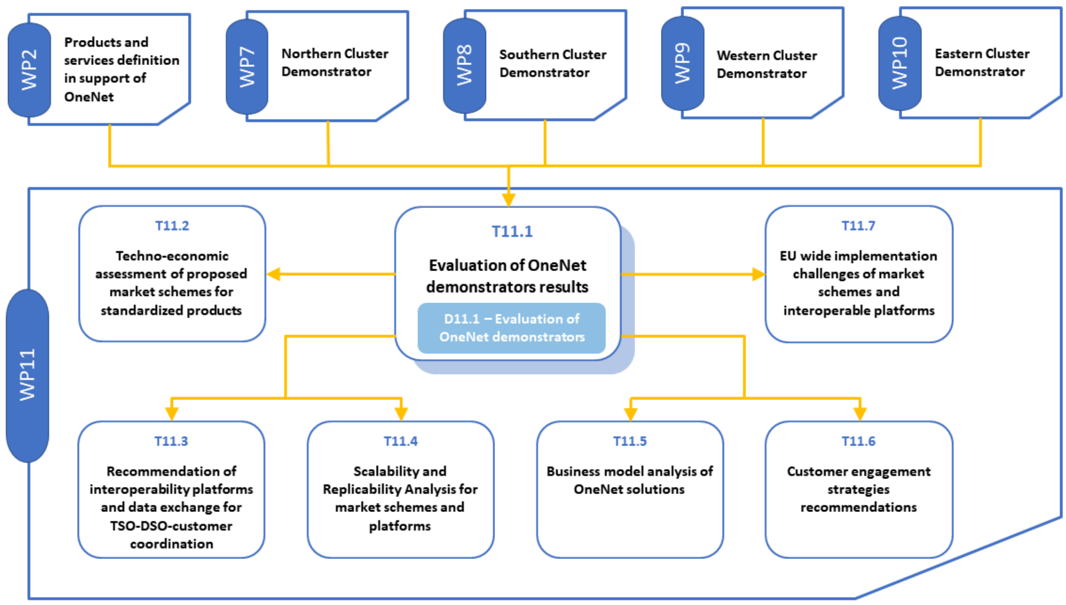

Figure 1.1: Relation between Task 11.1 and other OneNet WPs and Tasks

1.3 Structure of the deliverable

This deliverable (D11.1) aims at providing conclusions regarding the different cluster demonstrators' results in a comprehensive manner, based on the standardized frameworks defined within OneNet. The rest of the deliverable is organized as follows. Firstly, Chapter 2 provides a description of the methodology that was used for the characterization of the demos and the evaluation of the results, as well as the reasoning behind it. In Chapter 3 the information collected for the demonstrators' characterization (i.e., networks' and resources' characteristics, specified products and services, market schemes, IT solutions and system operations) is

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presented, while in Chapter 4 the evaluation of the results takes place based on the calculated KPI values. The evaluation is conducted according to three different perspectives: 1) Demo level: evaluation of the results based on a comparison between the common KPIs defined for the demos in OneNet and between the calculated KPI values in each demo and their initial target values; 2) Cluster (regional) level: evaluation of the results based on KPIs that were defined for each cluster as a whole; 3) Macro-area level: evaluation of the results based on four macro-areas that are of interest to the project. Furthermore, in Chapter 5, the foreseen possible criticalities identified regarding the definition of the KPIs and the cybersecurity challenges encountered by each demonstrator are presented, along with the mitigation measures that were taken to bypass or overcome them. Finally, Chapter 6 concludes the deliverable summarizing the key outcomes of the evaluation process.

It Is Important to note here that this is the first version of this deliverable, which will be followed by a second version that will also be the final version of this deliverable. This first version includes those demonstrators' results that were available so far, which are the majority. The results not presented and analyzed in this version, caused by a slightly prolonged validation process from the demonstrators, will be included in the second and final version of D11.1.

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2 Methodology

The core objective of this deliverable is to evaluate the results of the demonstration activities in all four OneNet clusters in a comprehensive manner, based on the standardized frameworks defined within the OneNet study, as well as to present the conclusions stemming out from them. To conduct this study our work was structured upon 3 parallel workstreams, as shown in Figure 2.1.

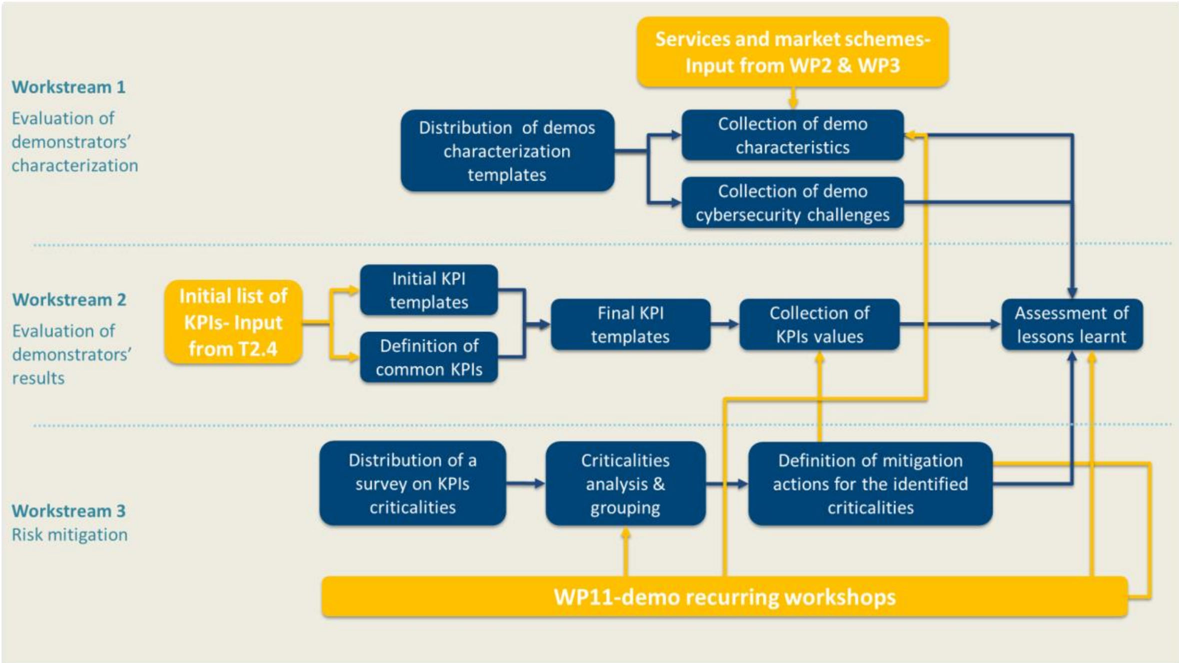

Figure 2.1: T11.1 methodology

In the first workstream, we analyzed the demonstrators' individual network and resources characteristics. The analysis focused on collecting information on the networks and resources participating in the demos and mapping the IT solutions and schemes developed in each one in relation to the specified products and market schemes as defined in WP2 and WP3. A special focus was given to analyzing the cybersecurity challenges encountered within each demonstrator and the countermeasures that were taken to overcome them.

In the second workstream, we created a list of KPIs to be adopted from all demos in order to ensure that some specific aspects that are crucial for evaluating the OneNet demos performance at a project level are covered through the individual demo evaluation process. At a later stage, when the demonstrators' activities were progressing towards completion, we collected the values of the demo KPIs. Overall, the work carried out in this workstream supported demos towards defining their evaluation methodology and data gathering at cluster level by providing them with the appropriate templates for the evaluation of their results.

The third workstream aimed to address how the foreseen risks related to the process of KPIs calculation and evaluation could be mitigated. To this end, a survey was distributed to the demonstrators collecting the foreseen

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criticalities linked to the calculation of KPIs. Then the criticalities were grouped based on their characteristics and specific mitigation actions were formed for each criticality.

Task 11.1 activities required multiple interactions with the demonstrators' representatives to ensure the consistency of the adopted evaluation method and the alignment of the individual demos with the approach adopted in a project level. These interactions were carried out through recurring workshops which WP11 organized and in which all demo clusters participated.

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3 OneNet demonstration sites characterization

For the characterization of the OneNet demonstration sites, a common template document was created and distributed to the demo representatives, who were also responsible for filling it out. The document contained different sections for information gathering regarding the demonstrations' activities and organization (i.e., type of demonstration, networks' characteristics, resources' characteristics, duration of demonstration, developed/upgraded/existing IT solutions utilized, assets and devices installed and necessary data sources) and a separate section pertaining to the cybersecurity challenges encountered by each demo, as well as the measures that were taken to address them. Additional information about the specified services, products and market schemes in each demo has been extracted from the continuous interaction of T11.1 with the demo representatives, during the writing of this deliverable. In Sections 3.1 – 3.4 the information collected for each of the demonstration sites is presented, while the cybersecurity challenges and the respective countermeasures are discussed in Chapter 5.

The complete concept of OneNet was proven in 4 cluster demos involving 15 European countries. The Northern cluster included demos in Finland, Estonia, Latvia and Lithuania, the Southern cluster included demos in Greece and Cyprus, the Western cluster included demos in Spain, Portugal and France and lastly, the Eastern cluster included demos in Slovenia, Poland, Hungary and the Czech Republic. Table 3.1 presents an overview of the four demo clusters within OneNet, including the voltage levels in which each cluster tested the developed solutions, the number of TSOs/DSOs, the number of resources (that gives a measure of each cluster's size) and the type of resources in each cluster.

Table 3.1: Overview of the OneNet demo clusters

Cluster	Voltage levels	Number of TSOs/ DSOs	Number of resources	Type of resources	Products tested	Type of SOs coordination
Northern	400V – 20kV	4 TSOs / 4 DSOs	~ 130	Residential, commercial	• mFRR product • Corrective local active energy product • Predictive short-term local active energy product • Predictive short-term local active capacity product • Predictive long-term local active capacity/ energy product	Market-based TSO – DSO coordination
Southern	400kV, 220kV, 150kV, 110kV,	2 TSOs / 2 DSOs	> 200	Residential, commercial, industrial	• Inertia product • mFRR product • RR product	Technical- and market-based TSO –

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	35kV, 20kV				• Predictive short-term local active product • Predictive long-term local active product • Corrective local active product • Corrective local reactive product	DSO coordination
Western	400kV, 220kV, 60kV, 10kV-30kV	2 TSOs / 4 DSOs	~ 270	Residential, commercial, industrial	• Predictive short-term local active product • Predictive long-term local active product • Corrective local active product	Technical- and market-based TSO – DSO coordination
Eastern	132kV, 110kV, 30kV, 22kV, 15kV	3 TSOs / 6 DSOs	~ 270	Residential, commercial, industrial	• mFRR product • aFRR product • RR product • Predictive short-term local active product • Corrective local active product • Predictive short-term local reactive product • Predictive long-term local reactive product	Market-based DSO coordination

Figure 3.1 shows the type of resources used for demonstration purposes. The type of resources in this case are presented in demonstrator level.

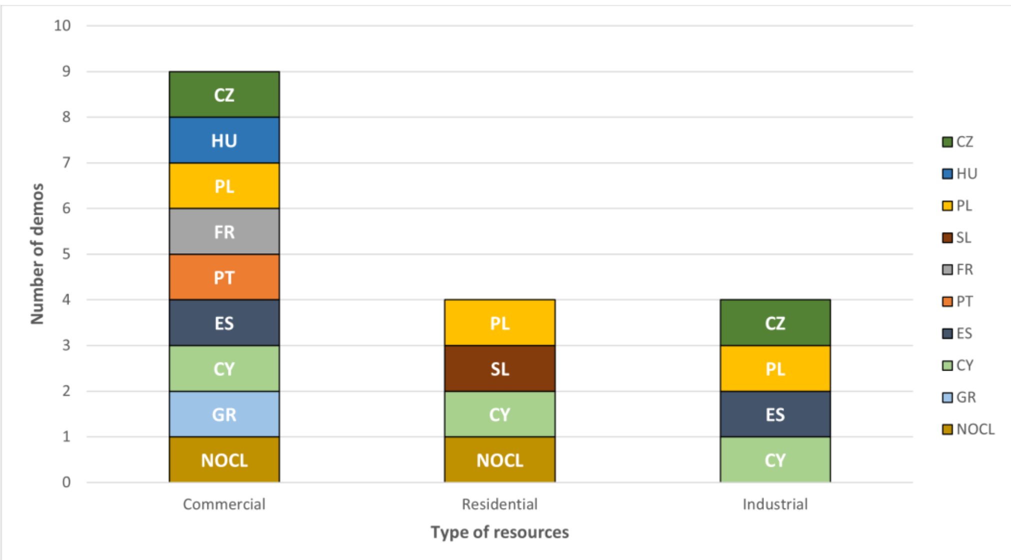

Figure 3.1: Type of resources used in each demonstrator (CZ: Czech Republic, HU: Hungary, PL: Poland, FR: France, PT: Portugal, ES: Spain, CY: Cyprus, GR: Greece, NOCL: Northern cluster, SL: Slovenia)

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3.1 Northern cluster

The Northern cluster demonstrator (OneNet WP7) is an integrated effort by multiple stakeholders including TSOs, DSOs, MOs, research centers and technology providers to enable market-driven flexibility uptake by networks in a coordinated way through multiple markets, where market liquidity can be reached due to the scope of existing trade volumes. The demonstration involves the mapping and management of network needs in multiple use cases over multiple networks and focuses on how joint and shared mechanisms can be used by multiple networks, to demonstrate scalability and contribute towards a pan-European solution. The Northern cluster demonstrator was enabled by implementing the framework developed in the INTERRFACE[1] and EU-SysFlex[2] projects and scaling up both the number of networks and the capability of the flexibility enabling solution mechanisms [1].

The objectives of the BUCs defined for the Northern cluster demonstrator, along with an overview of the specified services, products and market schemes are briefly presented in Table 3.2.

Table 3.2: Northern cluster demonstrator – Overview of specified services, products and market schemes

Overview	
BUCs' objectives	• Develop seamless end-to-end process for market-based flexibility utilization for grid services. • Lower the entry barrier for flexibility by simplifying the process for flexibility service providers. • Ensure availability of short-term flexibility from multiple sources.
Services	Agnostic (Frequency control, VC, CM)
Products	• mFRR • Corrective local active energy product • Predictive short-term local active energy product • Predictive short-term local active capacity product • Predictive long-term local active capacity/energy product
Coordination type	Market-based TSO-DSO coordination

The Northern cluster demonstration included both physical implementations and simulated scenarios. In Table 3.3 the characteristics of the networks and resources of the Northern cluster demonstrator are presented (the reader can refer to deliverable D7.6 [12] for additional information).

[1] https://www.interrface.eu/
[2] https://eu-sysflex.com/

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Table 3.3: Northern cluster demonstrator – Networks' and resources' characteristics

Networks	
Voltage levels	400V – 20kV, 3-phase 400V
Area/Location	4 TSO – DSO network pairs, with one pair each in Finland, Estonia, Latvia and Lithuania
Customers connected within the demo area	Countries of Finland, Estonia, Latvia and Lithuania (country-wide demonstrations)
№ of connection points participating in the demo	Many
Resources	
Type of usage	Residential, commercial
№ of resources	Many
Type	Buildings, end-customers, servers, virtual demand-response resources
Characteristics	Finland: • 1 small server with 12kW flexibility capacity. • 1 residential building's heat pump with 13kW flexibility capacity. • 2 simulated resources, one with 5MW downward flexibility potential and one with 2MW upward flexibility potential. • A residential cluster comprising at least 10 EVs, each with 7.2kW flexibility capacity, and 5 air heat pumps. Estonia: • 10 residential consumers (equipped with heating loads, PVs) with an aggregated flexibility capacity in the range of 10kW to 100kW. • 2-3 commercial consumers (smart office buildings, storage providers, generators). • 4-5 residential consumers located physically in France, but virtually connected to Elering Grid, Estonia. Lithuania: • 2 KTU buildings with heat pumps, the first one with 200kW consumption and the second one with 250kW consumption. • 1 KTU rooftop solar power plant – 380kWp. • KTU demand response resources connected to the DSO network. • Litgrid 1MWh battery storage with 1MW power for 1h, both directions connected to virtual line in Litgrid network. Total flexibility potential can be near 1,5MW power using the abovementioned resources. Latvia: • 85 simulated flexibility resources providing demand response (customers, prosumers (load + generation), solar PVs). • 1 simulated aggregated generation capacity – 5,9MW. • 1 simulated aggregated generation capacity – 43,6MW. • 1 simulated aggregated flexibility potential – 20,9MW.

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The developed, upgraded and existing solutions that were utilized for the demonstrations' activities are presented in Table 3.4.

Table 3.4: Northern cluster demonstrator – Developed, upgraded and existing IT solutions utilized

IT solutions	Tools and algorithms	Platforms	Data exchange architectures	Data models
Developed	• Grid prequalification algorithm • Bid optimization algorithm • Consent service • Schedular service	• Flexibility register • TSO-DSO coordination platform • Optimization-based market clearing module • Enerim aggregator and market interface • FSP UI	• MO services APIs • SO services APIs • Elering API • Piclo API • AST API • Litgrid API • Fingrid API • Nordpool API	-
Upgraded	-	• Nord Pool locationally enhanced intraday module	-	-
Existing	Smart meter management system of Kamstrup	• MARI • PICASSO • Piclo • Estfeed • ECCo SP	IEGSA	CIM

The main functionalities of the developed core platforms, the Flexibility register and the TSO-DSO coordination platform for the Northern cluster demonstrator case, are also of interest to Task 11.1 and are presented below:

Flexibility register

- Creates resource groups.
- Performs product prequalification.
- Supports grid qualification, bid validation and bid optimization.
- Determines the verification method.
- Calculates the baseline.
- Determines the actual delivered flexibility quantities.
- Determines the deviation.
- Calculates the delivered amounts per BRP.

TSO-DSO coordination platform

- Manages the SO's topology, forecasts and PTDF matrices information exchange with SOs.
- Provides endpoints to SOs for exchanging information about their flexibility needs, flexibility calls for tender, as well as purchasing offers for flexibility procurement purposes.

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- Provides endpoints to MOs for exchanging information about the available bids for optimization and activation orders after the successful clearing of bids, but also gives MOs access to flexibility needs and open calls for tender information.
- Performs bid optimization.
- Provides a scheduler service that triggers different activities for flexibility procurement and verification processes based on flexibility product defined specifics.
- Integrates OneNet's middleware ecosystem connector, that allows MOs to integrate to the platform's services without integrating directly to the platform.

Lastly, Table 3.5 contains the installed assets and devices, as well as the necessary data sources for the Northern cluster demonstrations.

Table 3.5: Northern cluster demonstrator – Assets, devices and data sources

Assets and devices	Data sources
Smart meters	• Smart meter data from FSPs • Data from MO • SCADA data from SOs

3.2 Southern cluster

The Southern cluster demonstrator (OneNet WP8) consists of the implementation of two pilot projects situated in Greece and Cyprus. These countries and their respective pilots are currently facing different challenges. The two pilot projects are addressing the specific needs of TSOs, DSOs, market actors and consumers in both countries, market and regulatory specificities, but at the same time present an innovative common approach for TSO-DSO coordination for common services and flexibility. The overall objective of the Southern cluster demonstrator was to prescribe, develop, implement and evaluate the two pilot projects, dealing with balancing and congestion management challenges that SOs are facing in the clean energy era, in compliance with the OneNet overall architecture. The TSOs and DSOs in both countries aimed at sharing flexibility resources and coordinating their efforts to meet their augmenting regional challenges through grid services stemming from prosumers, aggregators, suppliers and producers, while at the same time optimizing the use of network assets and big data processing tools for network predictability and observability [2].

3.2.1 Greek demo

In the Greek demo, an advanced forecasting platform (F-platform) evaluating the needs and flexibilities for balancing and congestion management was developed and implemented in the areas of Peloponnese and Crete. The island of Crete has been recently interconnected with mainland Greece and consequently with the pan-European interconnected electricity network. For the time being, the high voltage level is 150kV in Crete and

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Peloponnese, while in the latter area two new projects of 400kV OHLs and new substations have been planned in the national TYNDP and are currently under construction. Peloponnese is a mountainous area with high wind capacity, thus there are a lot of wind parks installed while the current network capacity is insufficient for the installation of even more wind generation. The island of Crete was isolated from mainland Greece until the end of 2020. Due to the environmental regulation, diesel generation units have to be phased out in the following years. This is why the TSO included some years ago the AC interconnection with southern Peloponnese, primarily, and with Attica through a second HVDC interconnection at a later stage (scheduled to be commissioned by the end of 2023) [2].

The objectives of the BUCs defined for the Greek demo, along with an overview of the specified services, products and market scheme are briefly presented in Table 3.6.

Table 3.6: Greek demo – Overview of specified services, products and market schemes

Overview	
BUCs' objectives	SOCL-GR-01 BUC: • Maintain frequency stability. • Demonstrate improved load flow and contingency monitoring and predictions. • Facilitate predictive congestion management for maintaining secure and stable power system operation. • Achieve cost-effective operation of the system. • Implement early warning on hazardous power system regimes. • Demonstrate better FSPs' planning and managing of flexibility resources. • Demonstrate better energy predictions and power system state predictions. • Achieve improved identification of the available flexibility resources on all power system levels. • Achieve improved prediction of the system flexibility needs. SOCL-GR-02 BUC: • Facilitate predictive maintenance and outage management. • Achieve enhanced severe weather condition management. • Demonstrate outage management optimization for increased system adequacy. • Implement early warning on a potentially hazardous power system topology and regimes. • Avoid damages caused by the severe weather conditions.
Services	SOCL-GR-01 BUC: mFRR, RR, predictive active power management for CM, predictive reactive power management for VC SOCL-GR-02 BUC: Agnostic
Products	• mFRR product • RR product • Predictive short-term local active product • Predictive long-term local active product • Corrective local reactive product
Coordination type	Technical-based TSO-DSO coordination

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The Greek demo involves only simulated implementations of the tested scenarios. In Table 3.7 characteristics of the networks and resources for the Greek demo are presented (the reader can refer to deliverable D8.4 [13] for additional information).

Table 3.7: Greek demo – Networks' and resources' characteristics

Networks	
Voltage levels	400kV, 220kV, 150kV, 110kV, 35kV and 20kV (network models)
Area/Location	1 TSO and 1 DSO network – Peloponnese, Crete (Crete AC interconnection at 150kV)
Customers connected within the demo area	Virtual customers
№ of connection points participating in the demo	50 substations (28 load + 22 RES) in Peloponnese and 1 substation in Chania, Crete (due to the Peloponnese-Crete interconnection)
Resources	
Type of usage	Commercial
№ of resources	13 SPPs, 63 WPPs, 2 battery storages
Type	Prosumers, distributed generation units (WPPs, SPPs and individual units), Micro-grid OHLs, TSO/DSO OHLs
Characteristics	WPPs: • 802,4MW total installed capacity • 5,1MW – 39MW installed power per WPP • 0,18MW – 10,24MW average generation/hour per WPP SPPs: • 77,3MW total installed capacity • 2,13MW – 11,96MW installed capacity per SPP • 0,19MW – 1,66MW average generation/hour per SPP Individual distributed generation units: • Up to 269,2MW of active power per unit • 2,043GW total active power • -55,6MVAr – 24,3MVAr reactive power per unit Substations: • 418,11MW total average consumption/hour • -5,14MW – 41,68MW average consumption/hour per substation

The developed and existing solutions that were utilized for the demonstrations' activities are presented in Table 3.8. The Greek demo did not upgrade any already available solutions or utilize any data models for the demonstration purposes.

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Table 3.8: Greek demo – Developed and existing IT solutions utilized

IT solutions	Tools and algorithms	Platforms	Data exchange architectures
Developed	• Predictive maintenance algorithms with enhanced storm and icing predictions • Increased spatial resolution NWPs and AI algorithms for improved predictions and forecasting efficiency on outage management	• F-channel digital platform with a forecasting and a coordination module • Cloud computing engine • An engine similar to the cloud computing one for grid analysis and calculation purposes • GUI made in Flash environment	• Middleware supporting WMS and WFS for the display of geographical data
Existing	• Power system simulation models • EUROPAN forecasting tool • SSH key encryption of the server access codes to the development environment • ERA5 climatic datasets along with AI algorithms, applied in combination with terrain orography data in order to obtain behavior patterns of climatic parameters through 1-hour resolution historical weather data	Geo server technology	European data exchange reference architecture

The main functionalities of the developed core platform, the F-channel platform for the Greek demo case, are also of interest to Task 11.1. This platform is a web-based client server application using AI methods for balancing and congestion management, connected with IEGSA architecture developed within the INTERRFACE project. The platform's functionalities are presented below:

<u>F-channel platform</u>

- Identifies the available flexibility resources from the DSO and the microgrid voltage levels.
- Manages the DSO, DG and microgrid POI (POI updates, technical data, historical data, forecasted data, etc.).
- Produces energy predictions and system state predictions for different aggregation levels of the DSO grid and the local microgrid: unit level (distributed generation unit, OHL tower/section), plant level (SPP, WPP, OHL, substation), local microgrid (part of the DSO grid), DSO/TSO grid level calculations.
- Produces short-term forecasts, contingency analysis and capacity calculations through the utilization of information from the DSO and/or the local microgrid operators.

Lastly, Table 3.9 contains the installed assets and devices, as well as the necessary data sources for the Greek demo.

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Table 3.9: Greek demo – Assets, devices and data sources

Assets and devices	Data sources
• Dedicated protected server to store necessary power grid and market data • MySQL/Maria database	• SCADA • EMS

3.2.2 Cypriot demo

Cyprus is a non-interconnected island in terms of its electricity system, however, there are plans for an interconnection with Crete and Israel which is known as Euroasia Interconnector Project, co-funded under CEF as PCI. In that sense, the Cypriot system will be interconnected with the pan-European electricity backbone network and the Israeli network, linking Europe with the Middle East area. Currently, the Cypriot electricity market has already been liberalized, with the possibility of multiple generations and retail supply firms operating in a competitive market. Nevertheless, the Electricity Authority of Cyprus (EAC) has held nearly 100% of retail supply and over 90% of generation. Intending to open the market to new entrants, Cyprus has been working on reorganizing the electricity market arrangements. The Cyprus Transmission System Operator (TSO) developed the Trading and Settlement Rules (TSR) to serve as the detailed market rules for this reorganized market. To face the challenges of variable renewable energy sources, energy efficiency and distributed generation, TSOs and DSOs have to coordinate their efforts to maximize the flexibility of resources and optimize system services [2].

The objectives of the BUCs defined for the Cypriot demo, along with an overview of the specified services, products and market scheme are briefly presented in Table 3.10.

Table 3.10: Cypriot demo – Overview of specified services, products and market schemes

Overview	
BUCs' objectives	SOCL-CY-01 BUC: • Maintain frequency stability. • Demonstrate congestion management for maintaining capacity limits of the grid. SOCL-CY-02 BUC: • Maintain voltage stability. • Demonstrate congestion management for maintaining capacity limits of the grid. • Achieve power quality enhancement.
Services	SOCL-CY-01 BUC: Inertia, mFRR, corrective active power management for CM SOCL-CY-02 BUC: Corrective reactive power management for VC and CM
Products	• Inertia product • mFRR product • Corrective local active product • Corrective local reactive product
Coordination type	Market-based TSO-DSO coordination

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The Cypriot demo involves only simulated implementations of the tested scenarios. However, there is one real prosumer participating in the demo as well. In Table 3.11 the characteristics of the networks and resources of the Cypriot demo are presented (the reader can refer to deliverable D8.4 [13] for additional information).

Table 3.11: Cypriot demo – Networks' and resources' characteristics

Networks	
Voltage levels	HV, MV and LV
Area/Location	1 TSO and 1 DSO network – fully controlled non-invasive environment at the laboratory premises of the UCY, demonstrating a fictitious energy market including the TSO market and a DSO local market
Customers connected within the demo area	1 prosumer (real)
№ of connection points participating in the demo	1
Resources	
Type of usage	Residential, commercial and industrial
№ of resources	3 LV rooftop PVs, 4 MV PVs, 15 HV PVs, 15 BESSs, 9 large-scale conventional generation units, 1 battery, 1 PV system
Type	Large, medium and small-scale flexible resources
Characteristics	Conventional generation units: • 967,5MW installed capacity • 464MW average generation/h HV PVs: • 224MW installed capacity • 42MW average generation/h MV PVs: • 8MW installed capacity • 1,42MW average generation/h LV rooftop PVs: • 30kW installed capacity • 6,6kW average generation/h BESS: • 145MW installed capacity Max/Min/Average load: • 554MW/476MW/520MW Prosumer: • Battery with 6kW/7,5kWh installed capacity • PV system with 5kW installed capacity

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The developed and existing solutions that were utilized for the demonstrations' activities are presented in Table 3.12. The Cypriot demo did not upgrade any already available solutions or utilize any data models for the demonstration purposes.

Table 3.12: Cypriot demo – Developed and existing IT solutions utilized

IT solutions	Tools and algorithms	Platforms	Data exchange architectures
Developed	Digital twins of the Cypriot transmission and distribution systems	• ABCM-T platform • ABCM-D platform • HMI for both platforms	Two middleware FIWARE IoT agents to allow information exchange between the digital twin and ABCM platforms
Existing	• FIWARE ORION context broker for information management • QuantumLeap for storing, querying and retrieving data from/to historical data • Landis+Gyr interoperable HES	Open-source platform (powered by FIWARE) for integration of the middleware	The following protocols were used for the communication between the different components: • PMU measurements → PDC – protocol IEEE C37.118 (ABCM-T) • SCADA measurements → middleware – TCP/IP (ABCM-T and ABCM-D) • Actual smart meters → middleware – Modbus TCP or MQTT (ABCM-D) • Virtual smart meters → middleware – Modbus TCP or TCP/IP (ABCM-D) • Middleware → Virtual flexible actuators – TCP/IP (ABCM-T and ABCM-D) • Middleware → Actual flexible actuators – Modbus TCP or MQTT (ABCM-D)

The main functionalities of the developed core platforms, the ABCM-T and ABCM-D platforms for the Cypriot demo case, are also of interest to Task 11.1. The ABCM-T platform (TSO control center) architecture includes an API that allows the retrieval of PMU measurements and an application layer on top of the two backend systems (PDC and FIWARE), where all the applications/tools were developed. The ABCM-D platform (DSO control center) architecture includes an API that allows the interaction between the backend system (FIWARE) and the application layer. The two platforms' functionalities are presented below:

<u>ABCM-T platform</u>

- Monitors in real-time the transmission level through PMU measurements.
- Prequalifies certain products and services procured from the large FSPs located at the transmission level to ensure operation within proper limits.
- Evaluates FSPs' response in case of disturbances.

<u>ABCM-D platform</u>

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- Monitors in real-time the operating conditions of the distribution grid through SCADA and smart meter measurements.
- Prequalifies all products and services provided to the market by the FSPs located at the distribution level to ensure the safe operation of the distribution grid.
- Coordinates the flexibility services provided by the FSPs in the distribution grid.
- Evaluates, online, the response of the FSPs during and after the provision of services for frequency balancing and congestion management.

Lastly, Table 3.13 contains the installed assets and devices, as well as the necessary data sources for the Greek demo.

Table 3.13: Cypriot demo – Assets, devices and data sources

Assets and devices	Data sources
• PDC (ABCM-T) • RTS (OPAL RT OP5700) • 18 PMUs on the transmission system	• Actual or virtual PMUs (ABCM-T) • Virtual SCADA (ABCM-T and ABCM-D) • Actual and virtual smart meters (ABCM-D)

3.3 Western cluster

The Western cluster demonstrator (OneNet WP9) involves three countries, namely Spain, Portugal and France. The focus was particularly on the alignment between the demonstrations and the joint report written by ENTSO-E [3] and the distribution associations on the TSO-DSO coordination in the context of balancing and congestion management. The three demos mainly focused on the procurement of local flexibility by the DSO, the TSO or both, while other aspects of TSO-DSO coordination such as information exchange were also at the center of the demonstrations [4].

3.3.1 Spanish demo

The Spanish demo aimed at unlocking the flexibility of the resources connected to the distribution system to contribute to congestion management at the distribution level. Local markets, in which the DSO is the only buyer of the flexibility services and the FSPs are the sellers, were tested. The Spanish demo involved two DSOs, namely i-DE[3] and UFD[4], as well as OMIE[5], the nominated electricity market operator (NEMO) for managing the Iberian Peninsula's day-ahead and intraday electricity markets. Different FSPs also participated in the provision of flexibility services. The TSO-DSO coordination (although the Spanish TSO is not a partner in the OneNet project

[3] I-DE Redes Eléctricas Inteligentes, S.A.U. (Spanish DSO).
[4] Union Fenosa DIstribución (Spanish DSO).
[5] Iberian Electricity Market Operator.

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and the amount of power involved in the pilot have almost no effect on the transmission grid) is done through OMIE who coordinates the energy market results and the responsibilities with the SOs. This function is already performed by the Spanish NEMO for the energy markets and was extended, in the context of the demonstration, to include the local markets being developed in OneNet. To enable the trading of flexibility products, a local market platform (LMP) was developed by OMIE and used by DSOs and FSPs. OMIE acted as the Independent Market Operator (IMO) for the LMP and traded several different products in different submarkets [4].

The objectives of the BUCs defined for the Spanish demo, along with an overview of the specified services, products and market scheme are briefly presented in Table 3.14.

Table 3.14: Spanish demo – Overview of specified services, products and market schemes

Overview	
BUCs' objectives	WECL-ES-01 BUC: • Apply market procedures to obtain flexibility services, while meeting DSO requirements. • Demonstrate that long-term agreements are suitable among different available DERs. • Implement flexibility provision/usage through a market platform. • User consumer's demand-response in efficient flexibility services. WECL-ES-02 BUC: • Apply market procedures to obtain flexibility services, while meeting short-term DSO requirements. • Implement flexibility provision/usage through a market platform. • User consumer's demand-response in efficient flexibility services.
Services	WECL-ES-01 BUC: Predictive active power management for CM WECL-ES-02 BUC: Corrective and predictive active power management for CM
Products	• Predictive short-term local active product • Predictive long-term local active product • Corrective local active product
Coordination type	Market-based DSO coordination

The Spanish demo involves only physical demonstrations, meaning that all of the activities are real. In Table 3.15 the characteristics of the networks and resources of the Spanish demo are presented (the reader can refer to deliverables D9.3 [5] and D9.6 [6] for additional information).

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Table 3.15: Spanish demo – Networks' and resources' characteristics

Networks	
Voltage levels	15kV and 20kV
Area/Location	2 DSO networks in Murcia (Espinardo area) and Madrid (Alcalá de Henares and Cantoblanco areas)
Customers connected within the demo area	The number of customers is proportional to the population of each area: • Espinardo, Murcia: ~12k population • Cantoblanco, Madrid: ~117k population (Alcobendas) • Alcalá de Henares, Madrid: ~197k population
№ of connection points participating in the demo	1 FSP in Espinardo, 1 FSP in Cantoblanco and 4 FSPs in Alcalá de Henares
Resources	
Type of usage	Residential, commercial and industrial
№ of resources	7
Type	Universities, municipality facilities and industries
Characteristics	Demand response (University of Murcia/Espinardo): • Heating and cooling systems / 7 buildings / 0,6MW-1MW flexibility capacity Demand response (Universidad Pontificia Comillas/Madrid): • Heating and cooling systems / 2 buildings / 0,1MW flexibility capacity Demand response (Ayto Alcalá de Henares – Ciudad Deportiva El Juncal): • Swimming pool treatment machinery / 1 building / 11,5kW flexibility capacity Demand response (Ayto Alcalá de Henares – Centro demostrador de energías renovables): • Net-consumption building (EV charging points) / 1 building / 21kW flexibility capacity Demand response (METAMSA): • Factory / 1 building / 312kW flexibility capacity Generation (HERA Holding): • Biogas generator / 1 building / 1MW flexibility capacity Demand response (Fiesta Colombina): • Factory / 1 building / 770kW flexibility capacity

The developed and upgraded solutions that were utilized for the demonstrations' activities are presented in Table 3.16. The Spanish demo did not use any pre-existing solutions without upgrading them nor did it utilize any data exchange architectures or data models for the demonstration purposes.

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Table 3.16: Spanish demo – Developed and upgraded solutions utilized

IT solutions	Tools and algorithms	Platforms
Developed	Home appliances	Local market platforms (LMP) – Long and short-term
Upgraded	-	OMIE's XBID market platform to allow and implement the short-term (day-ahead and intra-day) local negotiation

The main functionalities of the developed core platform, the LMP for the Spanish demo case, are also of interest to Task 11.1 and are presented below:

Local market platform (LMP)

- Allows the DSOs and the IMO to know how many resources and which types of technology are available, their location and other relevant information about them, acting as a flexibility resource register.
- Enables local flexibility procurement by DSOs.
- Opens market sessions at the request of the DSO.
- Collects bids from market participants.
- Clears the local flexibility markets.
- Communicates the market results to the stakeholders.

Lastly, Table 3.17 contains the installed assets and devices, as well as the necessary data sources for the Spanish demo.

Table 3.17: Spanish demo – Assets, devices and data sources

Assets and devices	Data sources
-	• Smart meters • SCADA

3.3.2 Portuguese demo

The Portuguese demo aimed at specifying the exchange of information between SOs to enable flexibility provision and to improve their operational planning. For the BUCs related to flexibility, the ASM report [15] stages were considered as the necessary steps in defining the process upon which coordination should be carried out between TSO and DSO. All stages were considered, except for the settlement process since the goal was to focus on the information exchange. For the BUC related to operational planning, the operational processes of the DSO and TSO that can be improved with the exchange of information between network operators were considered [4].

The objectives of the BUCs defined for the Portuguese demo, along with an overview of the specified services, products and market scheme are briefly presented in Table 3.18.

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Table 3.18: Portuguese demo – Overview of specified services, products and market schemes

Overview	
BUCs' objectives	WECL-PT-01 BUC and WECL-PT-02 BUC: • Design and detail each process phase of ASM report [15] so that it can serve as a basis for future developments. • Coordination of the use of flexibility for different voltage levels. • Identify which information should be shared between DSO and TSO for each of the flexibility procurement process phases for short term congestion management, namely for the technical selection and validation of the bids by the relevant system operator. • Develop information exchange mechanisms to enable market-based procurement of flexibility products. WECL-PT-03 BUC: • Identify the scheduled/forecasted information exchanged between DSO and TSO in order to improve programming of DSO operation. • Identify the scheduled/forecasted information exchanged between DSO and TSO in order to improve programming of TSO operation. • Anticipate and solve distribution grid constraints. • Anticipate and solve transmission grid constraints. • Develop information exchange mechanisms to share the identified information.
Services	WECL-PT-01 BUC and WECL-PT-02 BUC: Predictive active power management for CM WECL-PT-03 BUC: Agnostic
Products	• Predictive short-term local active product • Predictive long-term local active product
Coordination type	Technical-based TSO-DSO coordination

The Portuguese demo involves only simulated implementations of the tested scenarios. In Table 3.19 the characteristics of the networks and resources of the Portuguese demo are presented (the reader can refer to deliverables D9.2 [7] and D9.5 [14] for additional information).

Table 3.19: Portuguese demo – Networks' and resources' characteristics

Networks	
Voltage levels	EHV (400kV and 220kV), HV (60kV) and MV (10kV-30kV)
Area/Location	1 TSO and 1 DSO. All mainland Portugal, with initial focus on the areas of Trás-os-Montes (northeast) and Batalha (seaside center)
Customers connected within the demo area	~26.000 HV and MV customers connected to the distribution network and 78 EHV customers connected to the transmission network
№ of connection points participating in the demo	236 MV customers (supermarkets)
Resources	

Type of usage	Commercial
№ of resources	236
Type	Supermarkets
Characteristics	Supermarkets: • ~270GWh/year overall consumption • 250kVA-500kVA individual contracted power

The developed, upgraded and existing solutions that were utilized for the demonstrations' activities are presented in Table 3.20. The Portuguese demo did not utilize any data models for the demonstration purposes.

Table 3.20: Portuguese demo – Developed, upgraded and existing IT solutions utilized

IT solutions	Tools and algorithms	Platforms	Data exchange architectures
Developed	• TSO flexibility needs evaluation and FSP flexibility provision simulation tool • Short-circuit levels forecast tool in TSO-DSO substations • Algorithm for estimating the MV flexibility potential	• DSO data exchange platform (DDEP) • TSO data exchange platform (TDEP)	REST APIs
Upgraded	DPLAN (E-REDES network planning tool)	-	-
Existing	• MATLAB • PSS®E	-	-

The main functionalities of the developed tools and platforms in the Portuguese demo, are also of interest to Task 11.1 and are presented below:

DSO data exchange platform (DDEP)

A cloud system that serves as a gateway between the internal systems of the DSO and other possible external entities. The system is capable of fulfilling the use cases and required APIs, through modules and information exchange mechanisms within a cloud environment. It is separated into two main layers: communication (API Middleware and Developer Portal) and operational (flexibility module, operational module and data storage).

TSO data exchange platform (TDEP)

A cloud system that serves as a gateway between the internal systems of the TSO and other possible external entities. The system is capable of fulfilling the use cases and required APIs, through modules and information exchange mechanisms within a cloud environment. It is separated into two main layers: communication (API Middleware and Developer Portal) and operational (flexibility module, operational module and data storage).

TSO flexibility needs evaluation and FSP flexibility provision simulation tool

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The tool is composed of two modules: one that computes the TSO nodal flexibility needs in the TSO/DSO transformers (EHV/HV) and another that provides the FSPs' optimal dispatch that solves the TSO's flexibility needs. The tool can be used for single or multi-period studies and can run a stochastic analysis.

Short-circuit levels forecast tool in TSO-DSO substations

The tool computes day-ahead three-phase short-circuit levels for the 63kV bus bars that are the interconnection for the TSO/DSO transformers (EHV/HV). It uses the grid data and the forecasted generation/load profiles known after the wholesale market results.

Algorithm for estimating the MV flexibility potential

The methodology that was used to estimate the flexibility potential from MV clients was based on original data collected through a survey distributed to consumers. The MV consumers considered are a significant group of supermarkets from a national supermarket chain and the analysis follows three steps: (1) Clusters identification methodology and results; (2) Load modelling and constraints; (3) Flexibility estimation and uncertainty evaluation.

Lastly, Table 3.21 contains the installed assets and devices, as well as the necessary data sources for the Portuguese demo.

Table 3.21: Portuguese demo – Assets, devices and data sources

Assets and devices	Data sources
-	• SCADA • Smart meters

3.3.3 French demo

The French demo is divided into two parts: the implementation of STAR (System of Traceability of Renewables Activations) and the study on innovative ways for TSO-DSO information exchange for DER activation. The STAR system is a monitoring platform that allows sharing relevant information for the settlement but not directly undertaking it. The aim of the use case for STAR was to build a shared ledger to simplify and optimize the management of renewable production curtailments by covering the entire life cycle of a flexibility offer, from the formulation of offers to the monitoring of their activation invoicing. The French demo studied innovative ways of TSO-DSO information exchange in the context of DER activation [4].

The objectives of the BUCs defined for the French demo, along with an overview of the specified services, products and market scheme are briefly presented in Table 3.22.

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Table 3.22: French demo – Overview of specified services, products and market schemes

Overview	
BUCs' objectives	WECL-FR-01 BUC: • Simplify and optimize the management of renewable production curtailments, by covering the entire life cycle of a flexibility offer, from the formulation of offers to the control of their activations for invoicing using blockchain technology. • Build a platform enabling such objectives and test it for each participating entity on a chosen area of the French network. WECL-FR-02 BUC: • Improve the information exchange between TSO and DSO in the context of local DER flexibility activation. • Carry out studies on the management of the constraints between DSO and TSO in case of activation of a flexibility. • Develop a method that would guarantee that the activation of curtailment by one TSO or DSO will not trigger other constraints on one or another network.
Services	WECL-FR-01 BUC: Corrective active power management for CM WECL-FR-02 BUC: Agnostic
Products	Corrective local active product
Coordination type	Technical-based TSO-DSO coordination

The French demo involves both physical implementations and simulated scenarios. In Table 3.23 the characteristics of the networks and resources for the French demo are presented (the reader can refer to deliverables D9.4 [8] and D9.7 [9] for additional information).

Table 3.23: French demo – Networks and resources characteristics

Networks	
Voltage levels	Up to 400kV
Area/Location	1 TSO and 1 DSO network – Southwest part of France, in the area of Melle-Longchamp
Customers connected within the demo area	8 substations and 26 RES power plants (5 substations in the area of Melle-Longchamp that are connected to NAZA, 17 WPPs and 9 PV PPs on the DSO network)
№ of connection points participating in the demo	34
Resources	
Type of usage	Commercial
№ of resources	26
Type	Substations, WPPs, PV PPs

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Characteristics	WPPs: 2,3MW – 12MW installed capacity PV PPs: 0,5MW – 7MW installed capacity

The developed and existing solutions that were utilized for the demonstrations' activities are presented in Table 3.24. The French demo did not upgrade any already available solutions or utilize any data models for the demonstration purposes.

Table 3.24: French demo – Developed and existing IT solutions utilized

IT solutions	Tools and algorithms	Platforms	Data exchange architectures
Developed	Algorithm to reconciliate RTE activation orders to Enedis activation orders based on substation, activation start date and activation end date	• STAR platform	• REST APIs • HMI
Existing	-	• Hyperledger fabric framework	• gRPCs

The main functionalities of the developed core platform, the STAR platform for the French demo case, are also of interest to Task 11.1 and are presented below:

STAR platform

- Tracks flexibility activation/deactivation orders and makes the relevant information accessible to the participants.
- Provides traceability of metering data linked to production curtailment: estimated curtailed energy and production metering.

Lastly, Table 3.25 contains the installed assets and devices, as well as the necessary data sources for the French demo.

Table 3.25: French demo – Assets, devices and data sources

Assets and devices	Data sources
-	• Meters (metering of generation) • TSO/DSO IS (activation orders, energy not served, etc.)

3.4 Eastern cluster

The Eastern cluster demonstrator (OneNet WP10) involves four different demos in four different countries, namely Slovenia, Poland, Hungary and Czech Republic. Each of the demos implemented the scope they defined and tried to solve the main problems regarding network management. The scope of needs on the part of the

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DSOs was practically the same, but due to different technical, market and regulatory conditions, the approach followed by each demo for solving a specific issue was different [10].

3.4.1 Slovenian demo

The main problems of the Slovenian demo concerned the management of the low voltage network, which is characterized by a specific group of customers: prosumers equipped with PV installations and heat pumps used as the main source of heat. Such a combination of generation and load can cause, in specific periods, voltage problems and can lead to congestion of MV/LV transformers in the supply station of given consumers. The Slovenian demo focused on using the above-described resources of the prosumers to solve network problems, both congestion and voltage by using the market platform and flexibility services [10].

The objectives of the BUCs defined for the Slovenian demo, along with an overview of the specified services, products and market scheme are briefly presented in Table 3.26.

Table 3.26: Slovenian demo – Overview of specified services, products and market schemes

Overview	
BUCs' objectives	EACL-SL-01 BUC and EACL-SL-02 BUC: • Deferral of grid reinforcement investments (defer or avoid secondary substation replacement). • Improve security of supply. • Validate demand response mechanism to prevent congestion (voltage increase for EACL-SL-02) in the distribution grid. • Test flexibility products to prevent congestion in the distribution grid under market conditions.
Services	EACL-SL-01 BUC: Corrective active power management for CM EACL-SL-02 BUC: Corrective active power management for VC
Products	Corrective local active product
Coordination type	Market-based DSO coordination

The Slovenian demo involves both physical implementations and simulated scenarios. In Table 3.27Table the networks' and resources' characteristics for the Slovenian demo are presented (the reader can refer to deliverable D10.4 [11] for additional information).

Table 3.27: Slovenian demo – Networks' and resources' characteristics

Networks	
Voltage levels	MV and LV, with the main focus on the LV network
Area/Location	1 TSO and 3 DSO networks – 3 transformer stations: Elektro Celje/Transformer station TP Železno (municipality of Žalec), Elektro

	Ljubljana/Transformer station TP Gradišče, Elektro Gorenjska/Transformer station TP Srakovlje
Customers connected within the demo area	30 households (7 household customers connected on TP Železno and 17 (20kW) on TP Gradišče with heating pumps and 6 household customers with PVs installed on TP Srakovlje – rural cable network)
№ of connection points participating in the demo	30
Resources	
Type of usage	Residential
№ of resources	6 household PVs, 24 heat pumps, 3 household battery systems
Type	PVs, heat pumps, household battery systems
Characteristics	Household battery systems: • 3 x 12kWh = 36kWh installed capacity • 3 x 5kW = 15kW installed power Heat pumps: • 24 x 1,7kW = 41kW available power Household PVs: • 11kW average power per PV • 14MWh average annual generation per PV • 12MWh average annual consumption per PV (measuring point)

The developed, upgraded and existing solutions that were utilized for the demonstrations' activities are presented in Table 3.28. The Slovenian demo did not utilize any data exchange architectures or data models for the demonstration purposes.

Table 3.28: Slovenian demo – Developed, upgraded and existing IT solutions utilized

IT solutions	Tools and algorithms	Platforms
Developed	• Tool for the calculation of the thermal power limits of transformers, close to real-time, that is part of the flexibility management system at the DSO side • Algorithm for the selection of FSP bids in auctions, which makes a simple merit order list for selecting economically optimized bids, until the total tender power is reached • Algorithm in the virtual power plant (aggregator's side) for the selection of the most suitable consumers to deliver the requested power	• Flexibility market platform (SEDMp End customer web portal mojelektro.si) • Platform for managing the fleet of devices
Upgraded	• Central electro-energy business user portal CEEPS for sharing metering data between business objects (TSO, aggregator, etc.), upgraded with "flexibility" tab for aggregators, so that they can insert bids for consumers	SEDMp end customer web portal mojelektro.si as a flexibility market platform, upgraded with the

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	that have given them authorization to do so. CEEPS is also used for activation and monthly billing reports	functionality "registration of flexibility"
Existing	Kafka MQ server on SEDMp for the exchange of MQ messages (XML) between SOs and Aggregators	Moj elektro app for end consumers

The main functionalities of the two developed core platforms for the Slovenian demo case, are also of interest to Task 11.1 and are presented below:

<u>Flexibility market platform</u>

- Validates and registers flexibility resources (these mojelektro.si functionalities were developed in the context of OneNet, the rest were already developed).
- Publishes calls for flexibility services.
- Collects bids.
- Clears the market.
- Communicates market results to the stakeholders.
- Monetizes the flexibility services (in the settlement phase).

<u>Platform for managing the fleet of devices</u>

- Transmits requests for activation and measurements.

Lastly, Table 3.29 contains the installed assets and devices, as well as the necessary data sources for the Slovenian demo.

Table 3.29: Slovenian demo – Assets, devices and data sources

Assets and devices	Data sources
Battery systems installed in the households	• Monitoring system (a properly configured smart meter with remote data reading capabilities and an appropriate gradation of the measurements) to monitor the resources of the FSPs • Modems (aggregator side) installed into the P1 port of existing billing smart meters for monitoring measurements during activations • Reconfigured summary smart meters, so they push 1-minute measurements close to real time (P, Q, I, U)

3.4.2 Polish demo

Both the DSO and the TSO are actively involved in the implementation of the Polish demo. The activities of the DSOs focus on solving problems regarding the excess of the permissible voltage range in MV and LV networks, in connection with the rapid development of distributed renewable generation, connected mainly to the LV network. Due to the global increase in demand for electricity and the development of renewable energy

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sources, congestion occurs in various areas of the HV and MV grids during specific events (i.e., extreme weather conditions related to wind or abnormal grid operating states). The above-described situations also affect the dynamics of network operation and the balancing of the power system in Poland. The main goal of the TSO during the project is to use the resources located in the distribution network (at the MV and LV levels) to support the balancing process of the Polish power system. In addition, the Polish demo focuses on the issue of coordination of activities between DSOs and TSOs in the field of active energy management as part of the acquired services [10].

The objectives of the BUCs defined for the Polish demo, along with an overview of the specified services, products and market scheme are briefly presented in Table 3.30.

Table 3.30: Polish demo – Overview of specified services, products and market schemes

Overview	
BUCs' objectives	EACL-PL-01 BUC: • Register DER in the Flexibility Register (FR), which will enable the submission of bids on FP and participation in the flexibility market. EACL-PL-02 BUC: • Ensure that the energy system is balanced and frequency is kept within the permitted range. • Open a balancing market for resources connected to the distribution network (LV/MV). • Develop rules for coordination between TSO and DSO when using flexibility services. • Create revenue opportunities for market participants for providing balancing services in the form of balancing capacity products and balancing energy. EACL-PL-03 BUC: • Elimination of congestion in the distribution network using active power. • Elimination of voltage violations in the distribution MV and LV network, using active power. • Coordination of TSO and DSO activities in the field of congestion management and voltage control. EACL-PL-04 BUC: • Enable pre-qualified FSP and FSPA resources to provide balancing services in the balancing market via BSP.
Services	EACL-PL-01 BUC: Agnostic EACL-PL-02 BUC: aFRR, mFRR, RR EACL-PL-03 BUC: Predictive active power management for CM and VC EACL-PL-04 BUC: aFRR, mFRR, RR
Products	• mFRR product • aFRR product • RR product • Predictive short-term local active product
Coordination type	Market-based TSO-DSO coordination

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The Polish demo is based on tests performed in real network operating conditions with real activation of FSPs resources who agreed to take part in the project. In Table 3.31 the networks' and resources' characteristics for the Polish demo are presented (the reader can refer to deliverable D10.4 [11] for additional information):

Table 3.31: Polish demo – Networks' and resources' characteristics

Networks	
Voltage levels	HV (110kV), MV (15kV and 30kV) and LV
Area/Location	1 TSO and 1 DSO – Kalisz (HV network), Puck (MV network), Przywidz (MV and LV network), Mława (LV network)
Customers connected within the demo area	30 FSPs in the demo areas (28 actively participating)
№ of connection points participating in the demo	30
Resources	
Type of usage	Residential, commercial and industrial
№ of resources	18 household PVs, 1 gas power plant, 2 DSR, 9 non-household PVs (schools, local authority administration buildings, etc.)
Type	Household consumers, prosumers equipped with PVs, small and medium-size business entities, utilities facilities, gas power plants,
Characteristics	FSPs: 15,3MW total installed power FSPs' resources: 5MW installed power that is used for the provision of flexibility services Gas power plant: • 5,4MW total installed power • 2MW available active power for provision of services Household PVs: • 7,29kW – 12,5kW installed power per household

The developed and existing solutions that were utilized for the demonstrations' activities are presented in Table 3.32. The Polish demo did not upgrade any already available solutions or utilize any data exchange architectures or data models for the demonstration purposes.

Table 3.32: Polish demo – Developed and existing IT solutions utilized

IT solutions	Tools and algorithms	Platforms
Developed	DSO/TSO coordination algorithm	• Flexibility market platform • Dedicated website for market participants to access the flexibility market platform

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Existing	-	Data exchange management by the centralized IT market platform “atFlex”

The main functionalities of the developed core platform, the flexibility market platform for the Polish demo case, are also of interest to Task 11.1 and are presented below:

Flexibility market platform

- Performs grid and product prequalification and registers the prequalified FSPs and BSPs in the flexibility register.
- Collects offers for balancing capacity products from BSPs whose resources are located in the DSO network.
- Verifies the technical feasibility of submitted offers for balancing capacity products and selects the optimal ones.
- Transfers offers for balancing capacity products to the balancing market.
- Opens market sessions at the request of the DSO.
- Collects bids from market participants.
- Selects the optimal offer that meets the technical and economic expectations.
- Communicates the auctions’ results to the stakeholders.
- Sends activation signals to the FSPs.
- Performs the settlement.

Lastly, Table 3.33 contains the installed assets and devices, as well as the necessary data sources for the Polish demo.

Table 3.33: Polish demo – Assets, devices and data sources

Assets and devices	Data sources
Monitoring system	• Monitoring system (a properly configured smart meter with remote data reading capabilities and an appropriate gradation of the measurements) to monitor the resources of the FSPs • Modems (aggregator side) installed into the P1 port of existing billing smart meters for real time monitoring measurements during activations • Reconfigured summary smart meters installed on the MV/LV substation, so they push 1-minute measurements close to real time (P, Q, I, U)

3.4.3 Hungarian demo

The Hungarian demo aimed at solving problems in the distribution network that are mainly caused by renewable energy sources. The recent significant increase in renewable energy sources, connected at various points of the MV grid, causes voltage problems and problems regarding the overloading of line elements in the

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distribution grid. In the demo's selected area of the grid, PV PPs were used as service providers to eliminate voltage problems in the MV grid and congestion problems of HV/MV transformers, which are overloaded due to excessive power generation in the MV grid [10].

The objectives of the BUCs defined for the Hungarian demo, along with an overview of the specified services, products and market scheme are briefly presented in Table 3.34.

Table 3.34: Hungarian demo – Overview of specified services, products and market schemes

Overview	
BUCs' objectives	EACL-HU-01 BUC: • Keep actual voltage values of MV feeders within the standard bands. EACL-HU-02 BUC: • Avoid overloading of HV/MV transformers in all operational states of the power system.
Services	EACL-HU-01 BUC and EACL-HU-02 BUC: Predictive active and reactive power management for VC
Products	• Predictive short-term local active product • Predictive short-term local reactive product
Coordination type	Market-based DSO coordination

The Hungarian demo involves only simulated implementations of the tested scenarios. In Table 3.35 the characteristics of the networks and resources of the Hungarian demo are presented (the reader can refer to deliverable D10.4 [11] for additional information).

Table 3.35: Hungarian demo – Networks' and resources' characteristics

Networks	
Voltage levels	MV (CM for radial MV network – 22kV and 132kV/22kV transformers)
Area/Location	The two demo areas are two HV/MV substation supply areas, namely: the demo area of Siklós (E.ON EDE) in south-west Hungary and the demo area of Békés (MVM DÉMÁSZ) in south-east Hungary. The Hungarian TSO (MAVIR) is also involved.
Customers connected within the demo area	78
№ of connection points participating in the demo	78
Resources	
Type of usage	Commercial
№ of resources	78 PV PPs

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Type	PV PPs, later: energy communities, aggregators and active prosumers
Characteristics	MVM DSO demo area: • 26 PV PPs with 13MW power capacity E.ON DSO demo area: • 52 PV PPs with ~26MW power capacity

The developed, upgraded and existing solutions that were utilized for the demonstrations' activities are presented in Table 3.36. The Hungarian demo did not utilize any data models for the demonstration purposes.

Table 3.36: Hungarian demo – Developed, upgraded and existing IT solutions utilized

IT solutions	Tools and algorithms	Platforms	Data exchange architectures
Developed	• Network constraint list generator algorithm • Location-based service activation	• Mock flexibility market platform • Bid generators for Monte-Carlo bidding simulations • GUI for the evaluation of results by the users	Information exchange based on CIM standard with two main components: • Network state sharing platform for real-time and planning operational data exchange • Flexibility register (continuously updated status database regarding the availability of resources, diversely connected to the DSOs/TSO grid
Upgraded	-	-	ESMP (adapted)
Existing	-	Data storage/hosting in MS Azure cloud	• CIM, CGMES • IT system, provided by MEI technology provider, for data exchange

The main functionalities of the developed core platform, the mock flexibility market platform for the Hungarian demo case, are also of interest to Task 11.1 and are presented below:

Mock flexibility market platform

- Enables capacity auctions and scheduled energy activations by DSOs.
- Opens market sessions at the request of the DSO.
- Collects bids from market participants.
- Clears the local flexibility markets.
- Communicates the market results to all the market participants.

Lastly, Table 3.37 contains the installed assets and devices, as well as the necessary data sources for the Hungarian demo.

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Table 3.37: Hungarian demo – Assets, devices and data sources

Assets and devices	Data sources
-	• Monitoring system (a properly configured smart meter with remote data reading capabilities and an appropriate gradation of the measurements) to monitor the resources of the FSPs

3.4.4 Czech demo

The Czech demo focused on solving voltage and congestion problems in the distribution network resulting from the development of the electricity market. Large-scale connected photovoltaics, electric cars and the general increase in demand impact the operation of the electricity grid. The demo also addressed the problem related to undesirable flows of reactive power in the distribution network that can limit network capacity. In order to coordinate activities between DSO and TSO, the traffic light system was used for flexibility services [10].

The objectives of the BUCs defined for the Czech demo, along with an overview of the specified services, products and market scheme are briefly presented in Table 3.38.

Table 3.38: Czech demo – Overview of specified services, products and market schemes

BUCs' objectives	EACL-CZ-01 BUC: • Identify relevant ways of service procurement to address local congestion management in the distribution networks. The test is expected to deliver knowledge on how to specify bids/offer (data format for bid announcement, specific parameters of bid, transparent market environment, activation of flexibility). EACL-CZ-02 BUC: • Identify relevant ways of service procurement to control flow of reactive power between TSO and DSO in order to keep reactive power flows in given limits. The test is expected to deliver knowledge on how to specify bids/offer (data format for bid announcement, specific parameters of bid, transparent market environment). EACL-CZ-03 BUC: • Identify relevant ways of service procurement to address voltage issues in the distribution networks through reactive power. The test is expected to deliver knowledge on how to specify bids/offer (data format for bid announcement, specific parameters of bid, transparent market environment).
Services	EACL-CZ-01 BUC: Predictive active power management for CM EACL-CZ-02 BUC and EACL-CZ-03 BUC: Predictive reactive power management for VC
Products	• Predictive short-term local active product • Predictive long-term local reactive product
Coordination type	Market-based DSO coordination

The Czech demo involves both physical implementations and simulated scenarios. In Table 3.39 the characteristics of the networks and resources of the Czech demo are presented (the reader can refer to deliverable D10.4 [11] for additional information).

Table 3.39: Czech demo – Networks' and resources' characteristics

Networks	
Voltage levels	HV, MV and LV
Area/Location	All distribution areas of 2 DSOs (in cooperation with 1 TSO)
Customers connected within the demo area	2 Aggregators (155 FSPs)
№ of connection points participating in the demo	129 (9 EV connection points + 1 BESS + 119 DERs)
Resources	
Type of usage	Commercial and industrial
№ of resources	9 EV connection points (70 wall boxes and 4 fast charging stations), 1 BESS, 119 DERs (114 CHP and 5 HPPs)
Type	CHP units, HPPs, BESS, EV connection points
Characteristics	DERs: • 90MW total installed power output • 0,8MW installed power output/unit BESS: • 1MW installed power output • 1,7MWh installed capacity EV charging points: • 1,74MW total installed capacity (707,25kW available contracted power for consumption)

The developed, upgraded and existing solutions that were utilized for the demonstrations' activities are presented in Table 3.40. The Czech demo did not utilize any data models for the demonstration purposes.

Table 3.40: Czech demo – Developed, upgraded and existing IT solutions utilized

IT solutions	Tools and algorithms	Platforms	Data exchange architectures
Developed	• Flexibility register module • Network traffic light module • Market module	Country-wide solution (IT platform) for flexibility services	• ECP communication network using CIM standard to allow the exchange of XML messages • Traffic light system scheme for flexibility

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			services and coordination between DSO and TSO
Upgraded	-	Upgrade of the existing flexibility services platform to incorporate a market platform for non-frequency services (developed by Unicorn)	-
Existing	LMS provided by Driivz	• +4U environment based on OIDC – the 3rd generation of OpenID technology (an authentication layer on top of the Oauth 2.0 authorization framework) for end user access to the web application • Data storage/hosting in the Unicorn Plus4U uuCloud (a cloud management platform) deployed in MS Azure at Azure West Europe region	• The market uses REST HTTP API, with JSON as the data format • The traffic light system uses ECP and CIM XML messages

The main functionalities of the developed core tools and platforms, the flexibility register module, the traffic light system and the market platform for non-frequency services for the Czech demo case, are also of interest to Task 11.1 and are presented below:

Flexibility register module

- Registers generators and consumers (made mandatory, as of 2022, for all units of 0.5MW and above).
- Registers/edits users (FSPs, aggregators, DSOs, TSO).
- Registers FSPs to the aggregator's portfolio.

Traffic light system

- Enables the DSOs to post network availability information that is available to the FSPs and the aggregators (planned/unplanned outages).
- Sends snapshots of the network's condition to the TSO.
- Allows the submission of information related to contracted ancillary services from the FSPs/aggregators (at the distribution grid) to the TSO.

Market platform for non-frequency services

- Enables DSOs to create, cancel, match and confirm the auctions.
- Enables FSPs/aggregators to bid at auctions.
- Sends notifications regarding auction changes to the related users.
- Allows users to display and export the auction results.
- Manages and retrieves auction, offer and result data through a REST API.

Lastly, Table 3.41 contains the installed assets and devices, as well as the necessary data sources for the Czech demo.

Table 3.41: Czech demo – Assets, devices and data sources

Assets and devices	Data sources
EV charging poles of 1.74MW installed capacity	Monitoring system (a properly configured smart meter with remote data reading capabilities and an appropriate gradation of the measurements) to monitor the resources of the FSPs.

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4 OneNet demonstrations evaluation

In this Chapter the OneNet demonstrators are evaluated based on the methodology defined in Chapter 2. The evaluation is conducted by analyzing the demo results (calculated KPI values) from three different perspectives. The first step of the demonstrations' evaluation process is presenting and analyzing the calculated common KPI values from each demo. Afterwards, we evaluate each demonstration cluster as a whole by analyzing the results for the regional KPIs defined within OneNet. Lastly, all KPIs are grouped into different categories of high interest to the OneNet project (i.e., technical assessment of system service provision, ICT and data processing performances, etc.) and the calculated values are analyzed considering the topic of each category. For the analysis of the results the initial target values set for the KPIs and the feedback provided by the demo representatives was taken into consideration. A complete list of all the KPIs defined within OneNet is located in the Appendix.

4.1 Common KPIs among demos

For measuring the demonstrations' performance and impact, each demonstrator selected a set of KPIs based on their demonstration's structure, activities and tested solutions. This led to a big variety of defined KPIs, some of which were only adopted by a few demos. This is why the common KPIs concept was introduced, as a means of common evaluation ground between the different demonstrators. The common KPIs, presented in Table 4.1, are a set of KPIs that should be ideally adopted by all demos and measure the performance of the demonstrations in high-interest areas for OneNet like the provision of flexibility services, market performance and consumer engagement.

The selection and definition of common KPIs pertaining to all OneNet demonstrators was not an easy task, due to the big variety of tested products, services and solutions and the different approaches that were followed by each demonstrator. Because of this, some demos were not able to adopt all common KPIs. The reasoning behind the decision to discard some of the common KPIs was provided by each demo and is discussed below.

Table 4.1: Common KPIs used among the OneNet demonstrators

KPI ID / KPI Name	KPI Description	KPI Formula
KPI_H01 / Number of FSPs	The overall progress of decreasing the entry barriers for flexibility provision by simplifying the process for FSPs can be measured by the number of FSPs joining the platform. For the Portuguese demo the overall progress of the above-	N_{FSP} Where: N_{FSP} is the number of FSPs.

	mentioned aim can be measured by the number of FSPs considered and involved in the demo for testing the prequalification interactions.	
KPI_H02 / Active participation	This indicator measures the percentage of customers actively participating in the demo with respect to the total number of customers that accepted the participation. This indicator will be used to evaluate the customer engagement plan.	$$R = \frac{N_{active}}{N_{accept}} \cdot 100$$ Where: R is the active participation (%), N_{active} is the number of customers actively participating in the demo and N_{accept} is the number of customers that accepted participating in the demo.
KPI_H03 / Cost-effectiveness	Compare the cost for flexibility with the avoided traditional grid cost (Cost of the flexibility solution against traditional solution). The cost of flexibility should be less than the avoided traditional solution cost to be effective (KPI < 100). The avoided cost needs to be converted into a €/MWh Year basis and compared with the flexibility solution services for the time it will be contracted. To calculate the avoided cost, several factors need to be considered, e.g., deferred capital cost, losses, O&M costs, etc.	$$Cost_{effectiveness} = (1 - \frac{Cost_{flex}}{Cost_{Sub}}) \cdot 100$$ Where: $Cost_{effectiveness}$ is the cost effectiveness (%), $Cost_{Sub}$ is the avoided traditional solution cost (€/MWh) and $Cost_{flex}$ is the cost of flexibility (€/MWh). It is assumed that the cost of avoided traditional solutions and the cost of flexibility are fixed for the periods. The cost of avoided traditional solutions and the cost of flexibility refer to the present value of the future values according to the following formula: $$PV = C \cdot \left[\frac{1-(1+i)^{-n}}{i}\right]$$ Where: PV is the present value (€), C is the cash flow per period (€), n is the number of periods and i is the interest rate (equal to 0.05).
KPI_H06 / Ease of access	Ease of access to the flexibility market for flexibility service providers, including accessibility, non-redundant barriers to entry and user-friendliness.	Based on a post-demonstration survey (questionnaire). The answer range will be [0-10], where 0 is the worst case and 10 is the best case.
KPI_H07 / Number of transactions	This indicator measures the number of transactions (reflected in average hourly amount of available flexibility for a month in the Czech demo). This indicator will be used to measure the number of offered and cleared bids for each product. This indicator will give a measure of demo	$$N_T = \sum_T n_{Bids,t}$$ Where: $n_{Bids,t}$ is the number of offered and cleared bids at time t and T is the examined period. For the Czech demo $n_{Bids,t}$ is the amount of offered flexibility and the examined period T is 1 month.

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	magnitude by summing transactions.	
KPI_H09A / Volume of transactions – received bids (P or Q Availability) (Power)	This indicator measures the volume of transactions in kW (or kVAr). This indicator will be used to measure the volume of transactions (received bids) during the examined period T for each product. This indicator will give a measure of power magnitude demo range.	$$VT_p = \sum_T \sum_I P_{i,t}$$ or $$VT_p = \sum_T \sum_I Q_{i,t}$$ Where: VT_p is the volume of bids received considering power (kW or kVAr), $P_{i,t}$ and $Q_{i,t}$ is the volume of offered capacity/volume offered in terms of power by the i^{th} flexible resource at time t in kW or kVAr respectively, I is the set of flexible resources and T is the examined period.
KPI_H09B / Volume of transactions – cleared bids (P or Q Availability) (Power)	This indicator measures the volume of cleared bids. This indicator measures the volume of transactions concerning the availability bids during the examined period T for each product. This indicator will give a measure of power magnitude demo range.	$$VT_{CAV} = \sum_T \sum_I P_{i,t}$$ or $$VT_{CAV} = \sum_T \sum_I Q_{i,t}$$ Where: VT_{CAV} is the volume of transactions considering power (MW or MVAr), $P_{i,t}$ and $Q_{i,t}$ is the volume of cleared availability (capacity) bids by the i^{th} flexible resource at time t in kW or kVAr respectively, I is the set of flexible resources and T is the examined period. The Czech demo used the formula below for the calculation of this KPI: $$VT_{CAV\_T} = \sum_I Q_{i,T}$$ Where: VT_{CAV_T} is the volume of transactions considering reactive power (MVAr), $Q_{i,T}$ is the volume of cleared availability (capacity) bids by the i^{th} flexible resource for the examined period, I is the set of flexible resources and T is the examined period.
KPI_H09C / Volume of transactions – received bids (P or Q Activation) (Energy)	This indicator measures the volume of transactions in kWh or kVArh. This indicator will be used to measure the volume of transactions (received bids)	$$VT_P = \sum_T \sum_I E_{i,t}$$ Where: VT_p is the volume of bids received considering energy (kWh or kVArh), $E_{i,t}$ is the volume of offered

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	during the examined period T for each product.	capacity/volume offered in terms of energy by the i^{th} flexible resource at time t (kWh or kVArh), I is the set of flexible resources and T is the examined period.
KPI_H09D / Volume of transactions – cleared bids (P or Q Activation) (Energy)	This indicator measures the volume of cleared bids.	$$VT_{CAC} = \sum_{T}\sum_{I} E_{i,t}$$ Where: VT_{CAC} is the volume of transactions considering P·T or Q·T (MWh/MVAr), $E_{i,t}$ is the volume of cleared activation bids by the i^{th} flexible resource at time t (kWh/kVArh), I is the set of flexible resources and T is the examined period.
KPI_H12 / Percentage of avoided technical restrictions (congestions)	Avoided congestions thanks to the measures implemented in the demo. This KPI aims to quantitatively assess the improvement in congestion management achieved thanks to the solutions developed by the demonstration activities.	$$ATR_{\%} = \frac{N_{TR_{Flex}}}{N_{TR}} \cdot 100$$ Where: $ATR_{\%}$ is the share of avoided technical restrictions (congestions), $N_{TR_{Flex}}$ is the total number of technical restrictions solved through the activation of flexibility services and N_{TR} is the total number of expected technical restrictions.
KPI_H14 / Available flexibility	Flexible power that can be used for congestion management at a specific grid segment, i.e., the available power flexibility in a defined period (e.g., per day) that can be allocated by the DSO at a specific grid segment. It relates to the total amount of power in the specific grid segment in the same period. The term power is used to refer to the measurement of power demand in the area on the reporting time at the specific grid location. For the Czech demo the flexibility providers' (aggregator's) ability to collect and offer DSOs active power-based flexibility to control load in relevant nodal areas is tested. The flexibility is managed through charging management of EV charging poles.	$$Flexibility_{\%} = \frac{\sum P_{Available_{Flexibility}}}{\sum P_{Total_{in_{Area}}}} \cdot 100$$ Where: $Flexibility_{\%}$ is the percentage of available flexible power with respect to the total demand at a specific grid segment in the reporting period (%), $\sum P_{Available_{Flexibility}}$ is the power in kW or MW of available flexibility at a specific grid segment in the reporting period and $\sum P_{Total_{in_{Area}}}$ is the total power demand in MW at the demo's grid segment (for the Czech demo this variable represents the total charging power of the EV charging stations in kW in the demonstration areas).

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KPI_H17 / Percentage of avoided technical restrictions (voltage violations)	Avoided contingencies (voltage violations) thanks to the measures implemented in the demo. This KPI aims to quantitatively assess the improvement in congestion management achieved thanks to the solutions developed by the demonstration activities.	$$ATR_{\%} = \frac{N_{TR_{Flex}}}{N_{TR}} \cdot 100$$ Where: $ATR_{\%}$ is the share of avoided technical restrictions (voltage violations), $N_{TR_{Flex}}$ is the total number of technical restrictions solved through the activation of flexibility services and N_{TR} is the total number of expected technical restrictions.

Except for the Spanish demo, the rest of the demos were not able to adopt all of the defined common KPIs, for different reasons in each case. The demo representatives were asked to provide justifications, which are discussed below, for the common KPIs they decided not to adopt. It should be noted here that KPIs H09A-H09D are all related to the volume of transactions and are just using slightly different approaches. This is also true for KPIs H12 and H17 that measure the percentage of avoided technical restrictions, either congestions or voltage violations. The demos could choose to calculate all, some or just one of the KPIs in each of these two categories, based on their demonstration activities and approach, and this would be sufficient for the evaluation process. For example, the Spanish demo only calculated KPI_H09B "Volume of transactions – cleared bids (P or Q Availability) (Power)" and KPI_H12 "Percentage of avoided technical restrictions (congestions)" from the two categories but is considered to have adopted all common KPIs.

The Northern cluster demonstrator couldn't adopt KPI "Cost-effectiveness" due to the difficulty of measuring it properly. KPIs "Number of transactions" and "Available flexibility" were also not adopted, because the demo aimed at testing the functionalities of the system (technical solution) and not at maximizing the transactions volume per se, rendering them irrelevant. KPI "Ease of access" was discarded too, as not applicable to the cluster's demonstration activities.

The Greek demo did not adopt KPIs "Active participation", "Cost-effectiveness" and "Ease of access", because the nature of the demonstration activities render them inapplicable. All demo activities were simulated in the Greek demo, so active participation of customers or ease of access wouldn't make sense. Pertaining to KPI "Cost-effectiveness", the Greek demo didn't implement market phases of flexibility and also, since there is no flexibility market in Greece, no baseline exists to compare the results with, making the calculation of this KPI impossible. Lastly, KPI "Available flexibility" was also discarded, because it was only partly applicable to the demo as the FSPs were simulated through the received historic data and measurements and were not direct users of the developed platform. Transactions have also been simulated, based on the F-channel weather, production and grid state forecasts.

The Cypriot demo emulated the market framework and the market participants (customers, FSPs, etc.) so KPI "Active participation" was not applicable. For the same reason, and because there is no actual operational

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market in Cyprus to compare the results with, KPI "Cost-effectiveness" was also not adopted. Lastly, the Cypriot demo decided not to adopt KPIs "Percentage of avoided technical restrictions (congestions)" and "Percentage of avoided technical restrictions (voltage violations)", since the improvement in technical restrictions is measured through KPIs "Overloading" and "Improvement on voltage limits violations".

The Portuguese demo couldn't adopt KPI "Cost-effectiveness", since the prices weren't defined by a market mechanism or by bilateral contracts, rendering the estimation of the cost of flexibility impossible. KPI "Ease of access" was also discarded, since no actual FSPs participated in the demo. Finally, KPI "Number of transactions" was not adopted, because the Portuguese demo didn't focus on flexibility market mechanisms.

The French demo decided to not include KPI "Cost-effectiveness", because the method to estimate avoided network costs is not mature yet. KPI "Ease of access" was also discarded as not applicable, since all considered flexibilities were subject to potential activation orders according to their network access contract. As an equivalent to KPI "Number of transactions", the French demo calculated KPI "Tracked flexibility". Additionally, KPIs "Percentage of avoided technical restrictions (congestions)" and "Percentage of avoided technical restrictions (voltage violations)" were not adopted, because the activation of flexibilities was being decided close to real time by monitoring currents, most of the time automatically, and thus considering "expected congestions" didn't really make sense.

The Slovenian demo adopted all common KPIs except "Ease of access" which was discarded as not applicable. This is also the case for the Hungarian demo, as this KPI could not be applied to the simulated scenarios that were tested in the demonstration phase.

The Polish demo couldn't adopt KPI "Cost-effectiveness" because the market framework was emulated and the clearing prices that defined the cost of the solution couldn't be compared to an actual operational market, since no such market nor respective regulations existed in Poland during demonstration.

The Czech demo wasn't able to adopt KPI "Active participation". The demo had two aggregators as active participants (involved in the design of the whole IT platform, data model and XML/CIM based commutation) and a number of registered units participating in the demonstration activities. As these units registered themselves in order to participate actively, it wouldn't be possible to distinguish between active and inactive participation. In addition, it wouldn't be possible to differentiate between more or less active participation. KPI "Cost-effectiveness" was also discarded. The reason was that the Czech demo's goal was to build a platform for non-frequency services, which only had indirect impact on the grid operation/management. This impact could not be monetized in terms of counteraction like grid reinforcement, etc. Also, the non-frequency services (specifically reactive energy) were capacity based so the price didn't reflect the amount of energy delivered, which again made the calculation of the flexibility price vs the grid reinforcement measures impossible. The non-frequency system services that dealt with voltage problems through reactive power procurement, on which the Czech demo focused, were based on long-term contracts and were measured/priced on the availability. In this

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regard, the number of transactions/bids, etc., for availability, remained stable. What mattered the most in the demo activities was the frequency of activations, which were not done through the marketplace/platform – relevant units were controlled directly through SCADA systems. Lastly, KPI "Ease of access" was discarded as not applicable.

The calculated values of the common KPIs each demonstrator eventually adopted and measured are presented in separate sections below.

4.1.1 Northern cluster

The missing values for the Northern cluster's KPIs will be included in the second version of deliverable D11.1.

Table 4.2: Northern demo – Calculated values of common KPIs

KPI ID / KPI Name	Calculated values (Target values)			
	Finland	Estonia	Latvia	Lithuania
KPI_H01 / Number of FSPs	2	3	0	1
KPI_H02 / Active participation	100%		N/A	100%
KPI_H09B / Volume of transactions – cleared bids (P or Q Availability) (Power)			N/A	
KPI_H09D / Volume of transactions – cleared bids (P or Q Activation) (Energy)	6150kW		N/A	
KPI_H12 / Percentage of avoided technical restrictions (congestions)	100%		100%	

4.1.2 Greek demo

The result for KPI "Number of FSPs" in the Greek demo was really positive, as 83 FSPs in total participated in the demo activities, surpassing the target value by quite a lot.

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Regarding the number and volume of transactions the results are also considered really good, as in both cases the targets have been achieved.

During the demonstration simulations the Greek demo managed to avoid all technical restrictions (congestions), through the appropriate ancillary or system services offered via the platform, thus the result for this KPI is 100%. This is due to the fact that only a small region in Greece, between Peloponnese and the island of Crete, was considered, where no major congestions could be detected. What is important to mention is that the F-channel platform was in this case focusing on the local microgrid (distribution grid) issues from both the active power and the reactive power flow (voltage) points of view.

Table 4.3: Greek demo – Calculated values of common KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_H01 / Number of FSPs	4 consumers, 1 aggregator, 13 solar parks, 63 wind parks and 2 battery storages Total: 83 (>20)
KPI_H07 / Number of transactions	3 for CM and VC+, 5 for CM and VC-, 9 for mFRR+, 16 for mFRR-, 1 for aFRR+ and 1 for aFRR- Total: 35 (>0)
KPI_H09A / Volume of transactions – received bids (P or Q Availability) (Power)	4000 kW for CM and VC+, 5000 kW for CM and VC-, 2000 kW for mFRR+, 5000 kW for mFRR-, 4000 kW for aFRR+ and 5000 kW for aFRR- Total: 25000 kW (>0)
KPI_H12 / Percentage of avoided technical restrictions (congestions)	100%

4.1.3 Cypriot demo

In the Cypriot demo scenarios, the FSPs are available in three levels of the grid namely the HV, MV, and LV levels. These FSPs participate in the market providing bids for frequency support, ΔP and ΔQ coordination, and phase balancing. The number of FSPs available are 9 at the HV level, 4 at the MV level and 2 at the LV level. Thus, the total number is 15 FSPs, making this a positive result since the number is inside the originally set target range.

Regarding the ease of access KPI the result is 10/10, since from the post-demonstration survey (questionnaire) all responses were positive. It was specifically mentioned, that for the monitoring of the buildings electricity behavior the interface was very friendly.

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In the Cypriot demo three different scenarios are executed in the transmission, medium voltage and low voltage grids. In the case of the transmission grid, a frequency containment reserve product is procured by the TSO, while in the MV and LV grids congestion management services are procured. In total, the number of transactions in the demo was 36, with the initial target aiming at a number between 2 and 20. Below, the number of transactions is analyzed for each grid separately.

TSO level-FCR product:

The 9 FSPs submit their offers and the TSO submits the grid requirements for the FCR to the OneNet system. These 10 documents are obtained from the Global TSO market administrator in order to clear the market. Based on this, a total of 10 transactions were submitted for the bidding phase (9 from the FSPs and 1 from the TSO). After the market clearing process, the market operator creates 10 documents with the cleared bids: 9 for the FSPs with cleared bids and 1 for the TSO. These documents are then submitted to OneNet and each participant retrieves them. Therefore, a total of 20 transactions for one cycle of market clearing are created.

MV level-Congestion management services:

The 4 FSPs located at the MV level submit their offers and the DSO submits the grid requirements for the Near Real Time Local Market to the OneNet system. These 5 documents are obtained from the Local DSO market operator to perform the market clearing. Thus, a total of 5 transactions are created in the bidding phase. After the market clearing, the market operator creates 5 cleared bid documents: 4 for the FSPs with cleared bids and 1 for the DSO. These documents are then submitted to OneNet and each participant retrieves them to review the market clearing results. Therefore, a total of 10 transactions for one cycle of market clearing are created.

LV level-Congestion management services:

The 2 FSPs located at the LV level submit their offers and the DSO submits the grid requirements for the Near Real Time Local Market to the OneNet system. These 3 documents are obtained from the Local DSO market operator for market clearing purposes. A total of 3 transactions exist at the bidding phase. After the market clearing, the market operator produces 3 cleared bid documents: 2 for the FSPs with cleared bids and 1 for the DSO. These documents are then submitted to OneNet and each participant retrieves them. Therefore, a total of 6 transactions for one cycle of market clearing are created.

The two KPIs related to the volume of transactions measure the volume of received and cleared bids in kW (or kVAr) for a 3-hour period in the case of the scenarios examined in the HV, MV, and LV grids. The service that is provided by the FSPs in the HV level is related to the FCR, while for the MV and LV levels it is related to congestion management. In the case of the HV level, the volume of received bids and the volume of cleared bids for a 3-hour period in the Global TSO market are provided. As shown, 60 MW were submitted, but only 10 MW (in the first hour) were cleared by the Global TSO market. At this hour, a frequency event occurred in the transmission level of the Cypriot power system. In the case of the MV level, the FSPs submitted services for

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congestion management such as ΔP, ΔQ and PB coordination, again for a 3-hour period in the Near real time DSO market. In this case, the FSPs submitted availability bids for ΔP and ΔQ coordination only and thus the cleared bids are related only to those two services. In the case of the LV grid on the other hand, different operating conditions were assumed related to the direction of the flow (nominal and reverse) according to the PV generation.

KPI "Available flexibility" assessed the available flexibility that can be provided by the FSPs that are located at the DSO level for congestion management services. This indicator was calculated for both the MV and the LV levels for each of the three hours during which the Near Real Time DSO market was executed. From the values of the KPI for both levels it can be concluded that in both grids the available flexibility is adequate for the provision of ancillary services and quite above the initial target.

Table 4.4: Cypriot demo – Calculated values of common KPIs

<table>
<tr><th>KPI ID /
KPI Name</th><th colspan="3">Calculated values (Target values)</th></tr>
<tr><td>KPI_H01 /
Number of FSPs</td><td colspan="3">9 at the HV level, 4 at the MV level and 2 at the LV level
Total: 15 (2-20)</td></tr>
<tr><td>KPI_H06 /
Ease of access</td><td colspan="3">10/10 (N/A)</td></tr>
<tr><td>KPI_H07 /
Number of transactions</td><td colspan="3">TSO level – FCR product: 20 for one cycle of market clearing
MV level – Congestion management services: 10 for one cycle of market clearing
LV level – Congestion management services: 6 for one cycle of market clearing
Total: 36 (2-20)</td></tr>
<tr><td rowspan="9">KPI_H09A /
Volume of transactions – received bids (P or Q Availability) (Power)</td><td>Grid level</td><td>Product</td><td>Results</td></tr>
<tr><td>HV</td><td>FCR</td><td>60000 kW</td></tr>
<tr><td rowspan="3">MV</td><td>ΔP coordination</td><td>1500 kW</td></tr>
<tr><td>ΔQ coordination</td><td>1500 kVAr</td></tr>
<tr><td>PB</td><td>0</td></tr>
<tr><td rowspan="3">LV – Nominal power flow direction</td><td>ΔP coordination</td><td>39 kW</td></tr>
<tr><td>ΔQ coordination</td><td>39 kVAr</td></tr>
<tr><td>PB</td><td>10,8 kVAr</td></tr>
</table>

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	LV – Reverse power flow direction	ΔP coordination	39 kW
		ΔQ coordination	39 kVAr
		PB	10,8 kVAr
			Total: ~61,6 MW for FCR and ΔP coordination (500 MW – 1000 MW) and ~1,6 MVAr for ΔQ coordination and PB (1 MVAr – 3 MVAr)
KPI_H09B / Volume of transactions – cleared bids (P or Q Availability) (Power)	Grid level	Product	Results
	HV	FCR	10000 kW
	MV	ΔP coordination	535,9 kW
		ΔQ coordination	244 kW
		PB	0
	LV – Nominal power flow direction	ΔP coordination	16,6 kW
		ΔQ coordination	1,2 kW
		PB	6 kW
	LV – Reverse power flow direction	ΔP coordination	-7,88 kW
		ΔQ coordination	3,99 kW
		PB	9 kW
			Total: ~10,5 MW for FCR and ΔP coordination (300 MW – 600 MW) and ~0,26 MVAr for ΔQ coordination and PB (1 MVAr – 3 MVAr)

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KPI_H14 / Available flexibility	Grid level	Results
	MV	99,9% (10% - 30%)
	LV	58,9% (10% - 30%)

4.1.4 Spanish demo

The number of FSPs participating in the demo activities was relatively low (7), as customer engagement was one of the main barriers the Spanish demo encountered.

Of all the customers that had initially accepted to participate in the demo activities, one dropped out during the process, leaving 7 active FSPs. That resulted in an active participation value of 88%.

In general, the calculated KPI values show positive results in terms of cost-effectiveness compared to the initial target values. In economic terms, it was more efficient to use flexibility services than the traditional solution in every one of the tested scenarios. The highest cost-effectiveness is observed in the Short-term day ahead Madrid (30 min – test 2) and the Short-term day ahead Madrid (1h) scenarios, where the cost of flexibility services was just 2% of the traditional solution cost. The lowest cost-effectiveness is observed in the Long-term day ahead Alcalá de Henares I scenario, where the cost of flexibility services was 69% of the traditional solution cost. On average the cost-effectiveness for the Spanish demo's tested scenarios was 75,4%, meaning that the cost of flexibility services was on average 24,6% of the traditional solution cost. Nonetheless, these values cannot be used to draw conclusions, since in some cases the bid price was agreed bilaterally between the DSOs and the FSPs in order to ensure flexibility was procured and activated.

Regarding the ease of access KPI the result is 5/10, since from the post-demonstration survey (questionnaire) half of the responses were positive and the other half negative. Some of the comments made by the users that answered the questionnaire were that the most complex part was the installation of the certificate to access the platform, that the platform was difficult to understand and handle in general and not intuitive.

In total, the number of transactions in the Spanish demo was 10 (cleared bids), reaching 6,63MW (KPI "Volume of transactions – cleared bids (P or Q Availability) (Power)").

The percentage of avoided technical restrictions (congestions) was 100% for the Spanish demo, reaching the target value. However, the delivery power did not reach the requested amount in two cases (Long-term Murcia and Long-term day ahead Alcalá de Henares II scenarios), even though the congestion problems did not occur due to the load forecast error.

The calculated KPI values for the available flexibility range between 9% and 28% in the different tested scenarios, with an average value of 18,4%, which is relatively low due to the difficulty of engaging customers to

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participate with their flexibility in the demo activities, as previously mentioned. The lowest available flexibility is observed in the Short-term day ahead Murcia scenario (9%). The available flexibility was also really low in the Short-term intraday Murcia, Short-term day ahead Madrid (30 min – test 1 and 2) and Short-term day ahead Madrid (1h) scenarios (10%, 12%, 12% and 12% respectively), due to the fact that only one customer participated in the demo site tests with his flexibility. The highest available flexibility is observed in the Long-term day ahead Alcalá de Henares I, Short-term day ahead Alcalá de Henares I and Short-term day ahead Alcalá de Henares II scenarios (28% in all of them), where more than one FSPs participated in the tests. It should be noted that the amount of available flexibility needs to increase in order to be enough for solving congestions problems.

Table 4.5: Spanish demo – Calculated values of common KPIs

	Calculated values (Target values)							
KPI ID / KPI Name / **Scenario**	KPI_H01 / Number of FSPs	KPI_H02 / Active participation	KPI_H03 / Cost-effectiveness	KPI_H06 / Ease of access	KPI_H07 / Number of transactions	KPI_H09 B / Volume of transactions – cleared bids (P or Q Availability) (Power)	KPI_H12 / Percentage of avoided technical restrictions (congestions)	KPI_H14 / Available flexibility
Overall demo	7 (As many as possible)	88% (100%)	-	5/10 (N/A)	10 (>0)	6,63 MW (>0)	100% (100%)	-
Short-term day ahead Murcia scenario	-	-	83% (>0%)	-	-	-	-	9% (>0%)
Short-term intraday Murcia scenario	-	-	72% (>0%)	-	-	-	-	10% (>0%)
Long-term Murcia scenario	-	-	53% (>0%)	-	-	-	-	25% (>0%)

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Short-term day ahead Madrid (30 min – test 1) scenario	-	-	74% (>0%)	-	-	-	-	12% (>0%)
Short-term day ahead Madrid (30 min – test 2) scenario	-	-	98% (>0%)	-	-	-	-	12% (>0%)
Short-term day ahead Madrid (1h) scenario	-	-	98% (>0%)	-	-	-	-	12% (>0%)
Long-term day ahead Alcalá de Henares I scenario	-	-	31% (>0%)	-	-	-	-	28% (>0%)
Long-term day ahead Alcalá de Henares II scenario	-	-	78% (>0%)	-	-	-	-	20% (>0%)
Short-term day ahead Alcalá de Henares I scenario	-	-	88% (>0%)	-	-	-	-	28% (>0%)
Short-term day ahead Alcalá de Henares II scenario	-	-	78% (>0%)	-	-	-	-	28% (>0%)

4.1.5 Portuguese demo

The number of FSPs was measured for SUC-PT-01 Mainland Portugal and was around 80,6% of its target value (250/310). The total number of FSPs connected to the distribution level (230) includes all the supermarkets that were used for the flexibility potential analysis in Mainland Portugal. Additionally, there were 20 FSPs that participated in the ancillary services market (RR market) and were connected to the transmission network. It's important to note here, that the demonstration didn't actually take into account the direct participation of FSPs in the prequalification process, meaning that only the FSP related data available to the SOs were considered for

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prequalification purposes. The only interaction made with FSPs was in a previous step, through a survey submitted to several customers connected to the distribution level, regarding their agreement on the use of the data, from which the 230 participants at the MV level were acquired.

The demonstration in Mainland Portugal was focused on the interaction between the DSO and the TSO, so active participation from the FSPs' point of view was based on the data used. Since all FSPs from which data were acquired were considered in the tested SUC, the resulting value is 100% and thus the target was achieved.

The objectives of SUC-PT-02 were achieved in the demonstration as the system processes were implemented efficiently and within the expected timeframe and identified potential network constraints, all based on the DSO/TSO coordination and the sharing of information, that was performed in a secure manner. No congestions were verified for the whole demonstration period, since the grids are planned in a way that enables them to avoid congestions under different scenarios. Apart from that, it's important to highlight that the demonstration took place in August, a period during which several industrial loads are not consuming and hydro power plants are not producing – two types of resources that are predominant in the two substations that were tested. Without any congestions, there was no need for flexibility or curtailment, meaning that no flexibilities were selected to serve their purpose. This situation left several KPIs under this SUC with a null value. This is a good and expected result, because it highlights the good decisions made by the planning teams of the Portuguese system operators.

Even though there are no congestions foreseen nowadays, congestions are expected to happen increasingly within the next years due to an increased DER penetration, justifying the need for TSO/DSO coordination in the flexibility needs assessment. This is especially true with the increasing integration of non-firm connections into the network, that is expected to take place in the coming years. Regarding that, the PT demo will include an assessment of a future scenario in which possible congestions, caused by the increase of distributed generation and EVs in the grid, will be emulated.

Although no flexibility needs were identified to enable a comparison with the flexibility potential (bids), it's important to note that the size of this potential and that of the available flexible assets does not fit the market requirements for ancillary services, excluding these assets from participation in TSO markets, thus minimizing the value stacking potential. However, several significant flexible assets that were not considered in the analysis (due to a lack of data), are foreseen to play a major role in flexibility provision. These assets include EVs in the parking lots, PVs, electrolyzers and heat pumps, among others. On the other hand, only one type of consumer has been considered in this test round, who was not even a heavy industrial one. An aggregated participation of several industrial and/or commercial partners could in fact result in an acceptable level of complementary flexibility for the grid in some locations.

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Table 4.6: Portuguese demo – Calculated values of common KPIs

KPI ID / KPI Name / Test round	Calculated values (Target values)						
	KPI_H01 / Number of FSPs	KPI_H02 / Active participation	KPI_H09A / Volume of transactions – received bids (P or Q Availability) (Power)	KPI_H09B / Volume of transactions – cleared bids (P or Q Availability) (Power)	KPI_H09D / Volume of transactions – cleared bids (P or Q Activation) (Energy)	KPI_H12 / Percentage of avoided technical restrictions (congestions)	KPI_H14 / Available flexibility
SUC-PT-01 Mainland Portugal	250 (310)	100% (100%)	-	-	-	-	-
SUC-PT-02 Batalha	-	-	70,7 kW (>10kW)	0 (0)	0 (0)	0% (0%)	0,04% (>0,01%)
SUC-PT-02 Pocinho	-	-	31,8 kW (>10kW)	0 (0)	0 (0)	0% (0%)	0,27% (>0,1%)

4.1.6 French demo

Regarding the number of FSPs in the French demo, producers who have been actively involved in the STAR platform usage through participation in the different workshops were considered: on user experience, on the definition of the data model, on return of experience. The demonstration also included tracking of STAR flexibility activations from other producers not attending the workshops and not using the platform, that were not considered for the calculation of this KPI. Two FSPs were actively involved, because the geographic area chosen for the experiment (corresponding to the experimental NAZA automaton action area) remains relatively small. This result is aligned with the initial expectation (target was set to 2-3 FSPs).

For the calculation of active participation all customers who agreed to participate in the French demonstration were considered. The 2 candidate producers have actively participated in the demonstration and both have limitation orders tracked in the platform, thus the resulting value is 100% in accordance with the initial target.

During the experiment RTE was responsible for computing the energy not served for HV flexibility activations occurring on its network, whereas Enedis was to compute the ones for MV flexibility activations. This was done

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for each flexibility activation using internal tools and registered manually of the platform. Producers are financially compensated proportionally to the kWh not injected due to limitations orders. Thus, KPI "Volume of transactions – cleared bids (P or Q Activation) (Energy)" is the sum of the energy not served, computed by RTE and Enedis. The results is positive, since the target was to at least have some transactions and this was achieved.

To calculate the available flexibility, all PV and wind power plants of the geographical zone "MELLE Longchamps" connected below the seven substations selected for the demonstration were considered. In total 36,66% of the flexibilities were activated. Some belonging to DSOs not participating in the experiment or connected to substations not considered could not be activated.

Table 4.7: French demo – Calculated values of common KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_H01 / Number of FSPs	2 (2-3)
KPI_H02 / Active participation	100% (100%)
KPI_H09D / Volume of transactions – cleared bids (P or Q Activation) (Energy)	4984 kWh (>0)
KPI_H14 / Available flexibility	36,66% (>0%)

4.1.7 Slovenian demo

As part of the Slovenian demo, three pilot locations were selected to demonstrate use cases of congestion management and voltage control. The participating aggregator reached out to customers and managed to obtain 34 households, which amounted to 75kW of available flexible power. Their participation in the demo was rewarded with 50€/year per household for the duration of the project. All households were upgraded with equipment for automatic remote control of their devices (heat pumps, batteries, PVs), which enabled the demo to achieve 100% active participation across all three demo sites. A whole IT chain was demonstrated from the DSO's system to the aggregator and from the aggregator to the individual devices. A CIM was implemented, so the specifications were the same for any other DSOs or aggregators that wished to participate in such demos in the future. There were 117 CM activations in total with 78 of them being successful, amounting to a 66,7% success rate of avoided congestions. On the other hand, from the 59 VC activations in total, 30 were successful. So the success rate of avoided voltage violations was just above 50%. The calculation of the baselines and the activation success was performed by local DSOs.

From the Slovenian DSO's side the maximum cost of flexibility that would cover the avoided traditional solution cost was calculated before the first auction. In the first auction, the aggregator offered more than the

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maximum cost for flexibility. In the second auction the aggregator offered the exact value of the maximum cost of flexibility (600€/MWh). That's why the result for KPI "Cost-effectiveness" was 0%.

Table 4.8: Slovenian demo – Calculated values of common KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_H01 / Number of FSPs	1 (1)
KPI_H02 / Active participation	100% (100%)
KPI_H03 / Cost-effectiveness	0% (>0%)
KPI_H07 / Number of transactions	3 (1)
KPI_H09A / Volume of transactions – received bids (P or Q Availability) (Power)	30 kW from two CM locations 45 kW from one VC location – 15 kW BESS and 30 kW PV Total: 75 kW (N/A)
KPI_H09B / Volume of transactions – cleared bids (P or Q Availability) (Power)	30 kW from two CM locations 45 kW from one VC location – 15 kW BESS and 30 kW PV Total: 75 kW (N/A)
KPI_H09C / Volume of transactions – received bids (P or Q Activation) (Energy)	1683 kWh for CM 221 kWh for VC Total: 1904 kWh (N/A)
KPI_H09D / Volume of transactions – cleared bids (P or Q Activation) (Energy)	1474 kWh for CM 112 kWh for VC Total: 1586 kWh (N/A)
KPI_H12 / Percentage of avoided technical restrictions (congestions)	78 successful CM activations from 117 CM activations in total Result: 66,7% (>50%)
KPI_H14 / Available flexibility	11% (>10%)
KPI_H17 / Percentage of avoided technical restrictions (voltage violations)	30 successful VC activations from 59 VC activations in total Result: 50,8% (>50%)

4.1.8 Polish demo

As part of the Polish demo, a functionality was implemented on the flexibility platform that allowed for automatic calculation of KPIs in accordance with formulas defined before the demonstration took place.

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Together with the definition of KPIs, expected thresholds were defined. The expected values of the KPIs were estimated prior to the demonstration, before all customer engagement actions had finished. This is the reason why in some cases the expected goals for the KPIs weren't reached, i.e., the expected value for KPI "Volume of transactions – cleared bids (Power)" was estimated based on the primary list of customers, of which only a few decided to participate in the project. In addition, different patterns of customers were assumed for each KPI performance. Small industry customers, who initially expressed interest by signing a letter of intent to join the project, later refused to sign the final agreement for test performance. Such behavior was justified due to the challenging economic circumstances, aggravated due to the COVID-19 pandemic and the Russian Federation's attack on Ukraine. As a result, the portfolio of customers who actively participated in the project changed and that impacted, significantly, all KPIs related to customer engagement and tests.

The Polish demo tested flexibility services for both DSOs and TSOs, whose products were defined in a way that corresponded to the needs of both system operators. Differences in the way these products were defined meant that the adopted KPI calculation methods did not always consider all auctions and offers. Congestion management and voltage control products are power based products. The balancing products are power and energy-based products. As a result, the calculations of KPIs don't include all services in every case. An example is KPI "Volume of transactions – cleared bids (P or Q Activation) (Energy)", which is only calculated for the balancing energy product. If the calculation for this KPI had taken all products into account (including the power products), the KPI value would be 335,853 kWh.

For the purposes of testing balancing services in the Polish demo, it was necessary to create separate users for FSPs who participated in these tests. This resulted from the need to aggregate them as a part of schedule units in order to be able to submit offers on the Balancing Market (according to EB GL regulation[6]). Therefore, the KPI value in the report generated from the platform in terms of number of FSPs is 60. As part of the tests, two customers connected to the low voltage network did not participate in auctions and did not submit any offers during the demonstration.

The low values of KPI "Number of transactions" for balancing products, compared to the congestion management and voltage control products, are related to how transactions were defined for these products. For balancing products, the bids are offered by the BSP with use of scheduling units, that could aggregate more than one FSP. In the case of the Polish demo, there were several scheduling units to which all active customers were assigned and for which all offers were submitted and activated – in one transaction. Also, the offers are contracted separately for each timeframe defined in the balancing auction – for the Polish demo it was a 1 hour timeframe. On the other hand, for CM and VC products, each accepted offer was counted as a separate transaction and is not divided into any hourly time window. As part of 65 transactions for balancing services,

[6] EUR-Lex - 32017R2195 - EN - EUR-Lex (europa.eu)

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over 660 resources were activated and if the same approach as for CM and VC services is considered, the number of transactions in the Polish demonstration would be over 750.

Table 4.9: Polish demo – Calculated values of common KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_H01 / Number of FSPs	60 (28)
KPI_H02 / Active participation	91,67% (~100%)
KPI_H06 / Ease of access	0/10 (N/A)
KPI_H07 / Number of transactions	3 for CM and VC+, 80 for CM and VC-, 38 for EB, 9 for mFRR+, 16 for mFRR-, 1 for RR+ and 1 for RR- Total: 158 (280)
KPI_H09B / Volume of transactions – cleared bids (P or Q Availability) (Power)	6000 kW for CM and VC+, 7517,6 kW for CM and VC-, 1050,8 kW for mFRR+, 5414,45 kW for mFRR-, 4000 kW for RR+ and 8673,9 kW for RR- Total: 32656,75 kW (92000 kW)
KPI_H09D / Volume of transactions – cleared bids (P or Q Activation) (Energy)	23109,65 kWh for EB (92000 kWh)
KPI_H12 / Percentage of avoided technical restrictions (congestions)	100% (100%)
KPI_H14 / Available flexibility	42,86% for CM and VC+ and 41,49% for CM and VC- Total average: 42,01% (100%)
KPI_H17 / Percentage of avoided technical restrictions (voltage violations)	100% (100%)

4.1.9 Hungarian demo

The missing values for the Hungarian demo's KPIs will be included in the second version of deliverable D11.1.

Table 4.10: Hungarian demo – Calculated values of common KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_H01 / Number of FSPs	78

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KPI_H02 / Active participation	100%
KPI_H03 / Cost-effectiveness	
KPI_H07 / Number of transactions	
KPI_H09B / Volume of transactions – cleared bids (P or Q Availability) (Power)	Number of offers on the market: 2.364.660
KPI_H12 / Percentage of avoided technical restrictions (congestions)	
KPI_H14 / Available flexibility	
KPI_H17 / Percentage of avoided technical restrictions (voltage violations)	

4.1.10 Czech demo

For the CZ demo all results are considered sufficient and fully in line with the initial ambitions declared in the application. According to the common KPIs results access to a more accurate time schedule of planned grid outages for FSPs was achieved. This will enable flexibility sources to allocate their flexibility capacities in a more efficient way and brings more certainty for aggregators in terms of portfolio utilization. Additionally, the CZ demo increased the capacity for provision of active energy, through the installation of the EV charging points (which was one of the "core" tasks of the demonstration phase). The BUC for non-frequency reactive power-based services tested (and verified) broader availability of this capacity for the energy market through the new environment – this goes namely for the management of the "reactive power overflow" at the DSO/TSO connection points. Because of this common environment where all the bids/offers can be shared amongst all market participants, SOs can easily access the needed flexibility. The tests verified that the platform enabled both the increase of liquidity to the SOs and to unlock the potential of flexibility providers.

As can be seen from Table 4.11, the number of FSPs participating in the demo was close to the initial target value (approximately 83%) and increased considerably since the introduction of the Network Traffic Light system in early 2022. For the traffic light scheme a centralized place was established, able to accommodate new flexibility providers. For this KPI only the major units/aggregated units were considered and not all the units involved in the demo activities.

The resulting values for the number and volume of transactions and the available flexibility KPIs indicate that the non-frequency services platform serves its purpose well when it comes to established services, e.g., control

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of reactive power management. There is a significant increase both in the number of available capacities and the contracted bids during the simulations, even though not all initial target values were reached. Specifically for the number of transactions KPI, the resulting value is only 12,8% of the target, which is quite below the initial ambition. This is mainly because the usage of active power is not among the regularly used services. On the other hand, the available flexibility was very high in the demo, almost 180% of its target value. Through this result the efficiency and effectiveness of the system is reflected, which is due to the upgraded system for indication of the availability of the grid. This is considered a major achievement for the further use and implementation of this scheme. The non-frequency system services that dealt with voltage problems through reactive power procurement, on which the demo focused, were based on long-term contracts and were measured/priced on the availability. This is why what mattered the most in the demo was the frequency of the activations, which were not done through the marketplace/platform (relevant units were controlled directly through SCADA systems), and not the number of transactions/bids, etc., for availability.

The resulting value for the percentage of avoided voltage violations KPI (specifically reactive power overflow occurrences) indicates a positive outcome, as discussed above. However, the resulting value was 1716% of the target value, which was exceeded by a lot. This is because the initial definition of the target assumed an average nodal area with a standard occurrence rate of "overflow" issues, but for the simulations data samples from the actual nodal area where the new system was introduced were used. It turns out that the actual technical restrictions were many more than the ones initially expected, explaining the resulting value. This result shows how diverse the problems across the DSOs' operational area of the grid and how useful a relevant solution of reactive power control might be.

Table 4.11: Czech demo – Calculated values of common KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_H01 / Number of FSPs	125 (150)
KPI_H07 / Number of transactions	6,4 MW (50 MW) * *The Czech demo calculated the volume (MW) of transactions instead of the number (#) of transactions.
KPI_H09B / Volume of transactions – cleared bids (P or Q Availability) (Power)	1954 MVAr (2247 MVAr)
KPI_H14 / Available flexibility	35,63% (20%)
KPI_H17 / Percentage of avoided technical restrictions (voltage violations)	429% (25%) * *The voltage violations measured in the Czech demo were specifically reactive power overflow occurrences.

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4.2 KPIs of demonstrated BUCs at regional level

A central objective of the OneNet project is the development of an interoperable network of platforms with near to real time multi-country operation. As such, and to further promote cooperation between countries at a demonstration cluster level, it was decided to introduce the **regional business use case** concept (regional BUC). A regional BUC comprised multi-country cross-border scenarios in which the different clustered countries foresaw the exchange of information between themselves, through the use of the technical solutions developed throughout the course of the project. These developed use cases were refined by discussing the different country needs and how they could use a pan-European system to connect and allow for different systems to exchange valuable information to improve, amongst others, network operation.

The four clusters that compose the OneNet demonstrations – Northern, Southern, Western and Eastern – were asked to develop the regional BUCs, however, as the Northern cluster is undertaking a regional, or cross-border, approach since the beginning of the demonstration efforts, the cooperation between countries within this cluster was already explicitly described in the demo individual BUC. Thus, the Northern cluster did not develop a regional BUC since their initial BUC followed a regional approach. For the remainder three clusters, three regional BUCs were developed. A detailed description of the defined regional BUCs can be found in [18].

In this section, the regional BUCs for the three aforementioned clusters are presented and assessed based on the respective KPIs. For the Northern cluster, the individual demo BUC is assessed using an additional KPI that was adopted for a more holistic regional assessment.

4.2.1 Northern cluster regional BUC

The additional KPI defined in the Northern cluster to enhance the regional approach assessment, measured the number of products implemented in more than one country. The KPI result is really positive as there were 5 products implemented in more than one country, while the initial target for this KPI was 2.

Table 4.12: Northern cluster regional BUC – Selected KPI and calculated value

KPI ID / KPI Name	KPI Description	KPI Formula	Calculated value (Target value)
KPI_N55 / Number of products implemented in different countries	This KPI indicates the implementation of the same product in at least 2 different countries.	Number of products implemented in more than one country.	5 (2)

4.2.2 Southern cluster regional BUC

The Southern cluster regional BUC aimed at enhancing regional cooperation through the provision of early warnings regarding potentially hazardous weather conditions and cyber threats. This was achieved by

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exchanging information about cyber security and severe weather condition forecasts, between the Greek and the Cypriot demos. Predictive maintenance algorithms alongside enhanced storm predictions were developed in the context of the Greek demo to prevent the system from reaching dangerous topological or operational states. Additionally, information exchange processes and an early warning system for potentially hazardous weather conditions and cyber threats was introduced for the Cypriot TSO and DSO to avoid dangerous power system regimes, which could lead to damages to the critical infrastructure. The main objectives that the Southern cluster regional BUC tried to achieve are the following:

- Cyber security.
- Critical infrastructure protection and avoidance of damages caused by severe weather conditions and cyber-attacks.
- Predictive maintenance and outage management.
- Enhanced severe weather condition management.
- Early warning on potentially hazardous power system topologies and regimes.

For the evaluation of this regional BUC two KPIs were adopted, which are presented in Table 4.13 below.

Regarding KPI "Number of successfully predicted hazardous power system regimes and cyber threats", critical information on the system, allowing operators to predict potentially harmful regimes, has been included in the platform. This allows operators to react properly without any delay caused by the data exchange issues. The exact value of this KPI has yet to be calculated, but, since the database is filled with potential threats, the KPI can be seen as achieved.

The platform monitors wind speeds of over 12 m/s, wind speeds under 5 m/s, icing, precipitation and storms, which allows the operators to prepare for the potential problems in the system caused by severe weather. KPI "Number of successfully predicted severe weather conditions" can, hence, be treated as achieved, although it proved to be difficult to quantify the value.

Table 4.13: Southern cluster regional BUC – Selected KPIs and calculated values

KPI ID / KPI Name	KPI Description	KPI Formula	Calculated values (Target values)
KPI_N23 / Number of successfully predicted hazardous power system regimes and cyber threats	Early warning on a hazardous power system regimes rate. This indicator shows how efficient the identification of the hazardous power system state is and how much in advance, timewise, it is given.	$$CFC_{\%} = \frac{C_{fc,c}}{C_o} \cdot 100$$ Where: $CFC_{\%}$ is the successfully exchanged information on hazardous power system regimes and cyber threats (%), $C_{fc,c}$ is the number of hazardous power system regimes correctly	-

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		forecasted and C_o is the number of situations where analysis of the measurements indicates that hazardous power system regimes occurred or would have occurred if no curative actions by the DSO/TSO were taken (i.e., flexibility used).	
KPI_N24 / Number of successfully predicted severe weather conditions	It Is very Important to have, as much as possible, precise information on grid reliability and reliability of each PS element. The appearance of ice or storms can cause unplanned outages and severe damages to the grid directly influencing the power system flexibility needs and the possibility of the transmission system and/or the distribution system to service those needs.	$$CFC_{\%} = \frac{C_{fc,c}}{C_o} \cdot 100$$ Where: $CFC_{\%}$ is the successfully predicted severe weather conditions (%), $C_{fc,c}$ is the number of the severe weather conditions correctly forecasted and C_o is the number of situations where analysis of the weather data indicate that severe weather conditions occurred.	-

4.2.3 Western cluster regional BUC

The challenge of the Western regional BUC was to be able to harmonize the main elements of the prequalification processes (product and grid pre-qualification) and to define the main requirements that FSPs have for their Flexibility register for all countries in the Western Cluster, while taking into account the particular constraints of each country. Therefore, a "minimum" set of information was agreed among the SOs involved in the Western Cluster for the purpose of grid and product pre-qualification. Beyond this set of information, SOs could request additional information, if necessary, to complete the pre-qualification processes. Coordination between system and market operators participating in the cluster was needed to carry out this preparatory phase.

The development of this BUC was important since it addresses principles agreed between system operators, which are described in the ASM Report [15], such as the need to clearly define their needs, from an operational perspective, to allow the FSPs to develop sound products, to facilitate the participation of all market parties and, to lower entry barriers and to enable any service provider to sell its service in all markets. For instance, an Aggregator or an FSP who wanted to participate in two Flexibility Markets from different countries could enter using the same rules. The OneNet system was essential in this BUC, in order to foster the coordinated interaction among SOs, MOs and FSPs.

The main objectives that the Western cluster regional BUC tried to achieve are the following:

- Design the pre-qualification process phase of the ASM report [15] among the Cluster, so that it can serve as a basis for future developments.

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- Design the Flexibility Resource Register requirements within the Western Cluster countries.
- Exchange information for the grid pre-qualification through the OneNet system.
- Facilitate entry of FSPs into the various flexibility markets within the Western Cluster.

For the evaluation of this regional BUC, four KPIs were adopted, which are presented in Table 4.14 below. The calculated values and the regional analysis for the Western cluster will be included in the second version of this deliverable, due to a slight delay in the deployment of the OneNet Connector in some of the cluster's countries that also delayed the calculation and validation of the Western cluster regional BUC KPI results.

Table 4.14: Western cluster regional BUC – Selected KPIs and calculated values

KPI ID / KPI Name	KPI Description	KPI Formula	Calculated values (Target values)
KPI_N48 / FSP acceptance	This indicator calculates the percentage of FSPs that accepted their participation in the joint cross-border SO prequalification with respect to the total number of FSPs contacted and asked to participate in the BUC. This indicator will also be used to evaluate the FSP engagement plan. The main objective of this KPI Is to assess the overall acceptance of the FSPs to the idea of providing services to another SO that is not the one to which they are connected. Although this is already done in the TSO-DSO context (as the FSPs can be connected to the DSO and provide services to the TSO), this KPI aims to assess the acceptance of the possibility of providing flexibility to another DSO, possibly in another country.	$A = \frac{N_{accept}}{N_{total}} \cdot 100$ Where: A is the FSP acceptance (%), N_{accept} is the number of customers that agreed on a potential cross-SO prequalification and N_{total} is the total number of contacted customers.	
KPI_N49 / Average Processing Time	This indicator measures the execution time of the prequalification process.	$APT = \frac{\sum_i T_i^{final} - T_i^{initial}}{i}$ Where: APT is the average processing time (s), T_i^{final} is the time at the end of the process for the i^{th} prequalification request (timestamp) and $T_i^{initial}$ is the time at the beginning of running the algorithm for the	

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		i^{th} prequalification request (timestamp).	
KPI_N50 / Cross SO Prequalification Acceptance	This indicator calculates the percentage of accepted Cross SO Prequalification processes. Whenever a prequalification request is forwarded from the connecting SO to the external SO, the latter can accept or refuse the request. Therefore, this KPI aims to capture how often an FSP accepts to be prequalified by another SO, in relation to the total number of prequalification requests forwarded.	$Acc. = \frac{\sum Accepted}{\sum Forwarded} \cdot 100$ Where: $Acc.$ Is the ratio of accepted prequalification requests (%), $\sum Accepted$ is the total number of accepted cross-SO prequalification requests and $\sum Forwarded$ is the total number of cross-SO prequalification requests.	
KPI_N51 / Need for additional information for cross SO Prequalification	This indicator calculates the percentage of Cross SO Prequalification processes that need additional information beyond the harmonized requirements. It is possible that the external SO cannot conclude the prequalification process only with the harmonized information sent by the connecting SO. Therefore, additional information will need to be requested by the FSP. This case may lead to delays in the prequalification process and therefore is not desirable. This KPI aims to capture how sufficient the harmonized information is for the cross-SO prequalification process.	$AIR = \frac{\sum InfoRequest}{\sum Forwarded} \cdot 100$ Where: AIR is the ratio of cross-SO prequalification requests that required a bilateral request for more information, apart from the one established in the general BUC (%), $\sum InfoRequest$ is the total number of cross-SO prequalification requests that required a bilateral request for more information, apart from the one established in the general BUC and $\sum Forwarded$ is the total number of cross-SO prequalification requests.	

4.2.4 Eastern cluster regional BUC

The Eastern regional BUC defines how an external entity can retrieve market data from national market platforms through the OneNet system, in a standardized way and data format. It provides preliminary information to be exchanged through the OneNet system and it includes the following processes:

1) Definition of the category of information to be shared by national platforms

Creation of information indicators characterizing the national flexibility markets, that are available through national market platforms. The preliminary information and indicators may include:

- Market participants (number of prequalified FSPs, range of volumes and sources, etc.).

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- Auction results (range of prices, volumes, number of offers, etc.).
- Identified and avoided constraints in the DSO network (volumes, number of transactions, etc.).

In each information category, the results present the information and indicators that characterize the parameters of the flexibility market. Each national data and/or particular indicators (KPIs) should be prepared in a unified way and should be available to the OneNet system users. The meaning of individual indicators should be identical for individual national platforms.

All data and indicators should be made available according to the following rules:

a) Individual data should be anonymized to avoid breaking the GDPR rules or to reveal trade secrets.
b) Data representing specific information should be aggregated (in terms of range and requested time frame). In this case, uniform results are expected within the Eastern cluster.
c) KPI data should be calculated by the flexibility market platform based on already defined algorithms.

2) OneNet system user registration

Each eligible entity interested in obtaining data about national flexibility markets should be authenticated and authorized for this access (undergo the registration process) through the OneNet system, with a request to provide information regarding the nature of the activity and the objective of data use. Only users registered on the OneNet system can obtain data.

3) Data retrieval request sent by a registered OneNet system user

In order to obtain data, the user must create a data request. A data request has to define the following:

a) Addressee (Flexibility Platform of national demonstration)
b) Information category (already determined and described in process 1)
c) Time frame (from date – to date) of required information (for already available data).

The request for data submitted on the OneNet system is sent to a given national platform on which the data is collected in accordance with the request and returned. National platforms apply data access restrictions:

a) Individual data related to the FSP or another entity, subject to the GDPR, or being a trade secret can be anonymized, or
b) Data can be aggregated.

4) Collecting and processing data

The collected data are sent in an appropriate (agreed) standardized format (CIM) to the user registered on the OneNet system.

5) Data statistics

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Statistics of data downloaded from national platforms via the OneNet system are published on the OneNet system (e.g., log file). This information may concern: the number of serviced queries (including those concerning individual countries), types of users, time of data acquisition, etc.

The main objectives that the Eastern cluster regional BUC tried to achieve are the following:

- Defining and preparing key data on the results of national demonstrations (national platforms).
- Rules for sharing data through the OneNet system, by registered users of the OneNet system.

For the evaluation of this regional BUC three KPIs were adopted, which are presented in Table 4.15 below along with the corresponding values calculated during the demonstrations period.

Table 4.15: Eastern cluster regional BUC – Selected KPIs and calculated values

KPI ID / KPI Name	KPI Description	KPI Formula	Calculated values (Target values)
KPI_N52 / Data retrieval successful	When a registered OneNet user sends a request for data retrieval, this request can either be successful or unsuccessful. This KPI is used to validate system functionality. Defining and preparing key data on the results of national flexibility markets. Rules for sharing data through the OneNet system, by registered users of the OneNet system.	There is no calculation formula. The result is either pass or fail.	Pass – All data successfully retrieved (Pass)
KPI_N53 / Data retrieval delay	The time interval between sending the request and receiving the response. Defining and preparing key data on the results of national flexibility markets. For a number of trials, histogram and CDF should be provided to represent the stochastic nature of the delay.	$\bar{d} = \sum_{k=1}^{N} d_k$ Where: $\bar{d}$ is the average delay (s), d_k is the delay of the k^{th} trial (s) and N is the number of trials.	2 days (5-10 sec)
KPI_N54 / Data reliability ratio	To prove the reliability of the retrieved data.	$DRR = \sum_{T} \frac{n_{reliable}}{n_{received}} \cdot 100$ Where: DRR is the data reliability ratio (%), $n_{reliable}$ is the amount of reliable data received over the period T and $n_{received}$ is the amount of data received over the period T.	100% (95%)

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4.3 Macro-area analysis of KPIs of demonstrated BUCs

In this section, the defined OneNet KPIs are clustered into four different topic groups namely "Technical assessment of system service provision", "Market platforms and economic performance assessment", "Customer engagement (-centric) performances" and "ICT and data processing performances". These topics were selected as the most suitable and inclusive to measure the performance of the demonstrations in key aspects of the OneNet project from a macro-area point of view. In the following subsections the KPIs selected for each of the four topics are presented and subsequently, the calculated values are discussed for each demonstrator.

4.3.1 Technical assessment of system service provision

This subsection concerns the OneNet KPIs that are related to the technical assessment of system service provision in the different demonstrators. Table 4.16 includes all the KPIs selected for this topic, as well as a description and the calculation formula for each one. Later on, the calculated values for each KPI are presented per demonstration, alongside an extensive commentary on the results, the overall performance regarding the system service provision aspects and the macro-level technical prowess of each demo.

It is important to note here that not all demonstrators adopted KPIs related to the technical assessment of system service provision, other than the common KPIs that are relevant to this macro-area and were analyzed in Section 4.1. This is why some demonstrators are not mentioned at all in this section.

Table 4.16: Technical assessment of system service provision KPIs

KPI ID / KPI Name	KPI Description	KPI Formula
KPI_H05 / Reduction in RES curtailment	This indicator measures the reduction in the amount of energy from Renewable Energy Sources (RES) that is not injected into the grid (even though it is available), due to operational limits of the grid, such as voltage violations or congestions.	$$E_{RES} = \sum_{i=1}^{I}\sum_{t=1}^{T}(E_{i,t}^{prod} - E_{i,t}^{inj})$$ Where: E_{RES} is the reduction in RES curtailment (MWh), I is the set of RES facilities under consideration, T is the set of time intervals of the period under consideration excluding periods of scheduled maintenance and outages, $E_{i,t}^{prod}$ is the available energy production of the i^{th} RES facility at period t (kWh or MWh) and $E_{i,t}^{inj}$ is the injected energy of the i^{th} RES facility at the period t (kWh or MWh).
KPI_H13 / Asset load profile variation	This indicator measures the percentage decrease of load demand in the requested asset by a flexibility provider resource. As asset, the distribution electric facility	$$CR = \frac{AL_{initial} - AL_{final}}{AL_{initial}} \cdot 100$$ Where: CR is the congestion reduction (asset load profile variation (%)), $AL_{initial}$ is the asset load before the delivery of

	where the congestion problem needs to be solved is considered.	flexibility (initial asset load (kW)) and AL_{final} is the asset load during the delivery of flexibility (final asset load (kW)).
KPI_H15 / Requested flexibility	For the Portuguese demo, this indicator measures the amount of flexibility (power or energy) requested by the DSO or TSO for ancillary services from all the flexible resources of the portfolio. For the Polish demo, this indicator measures the amount of flexibility (power) requested by the DSO on the market platform for congestion management and voltage control services, to solve identified issues in the DSO network.	$P_{Flex_R} = \sum_{t=1}^{T} P_{flex_{R_t}}$ and/or $E_{Flex_R} = \sum_{t=1}^{T} E_{flex_{R_t}}$ Where: P_{Flex_R} is the requested flexibility (power in kW or MW), $P_{flex_{R_t}}$ is the amount of power requested by the DSO/TSO in order to solve their forecasted constraints at a time T (kW or MW), E_{Flex_R} is the requested flexibility (energy in kWh or MWh), $E_{flex_{R_t}}$ is the amount of energy requested by the DSO/TSO in order to solve their forecasted constraints at a time T (kWh or MWh) and T is the examined period.
KPI_H18A / Volume of balancing service offers for UP reserves	Volume of balancing service offers for UP reserves (aFRR, mFRR, RR) submitted to the flexibility platform by BSPs from the distribution network. Sum of capacity reserves products direction UP (aFRR_up, mFRR_up, RR_up) offered by BSPs on the flexibility platform. In the Cypriot demo the total UP reserves that were submitted to the local DSO market and TSO market by the DERs will be calculated.	$$VBS_{UP} = \sum_{n=1}^{N} aFRR(FP)_{U,n} + \sum_{m=1}^{M} mFRR(FP)_{U,m} + \sum_{k=1}^{K} RR(FP)_{U,k}$$ Where: VBS_{UP} is the volume of balancing service offers for UP reserves (kW), $aFRR(FP)_{U,n}$ is the automatic frequency restoration reserve (up-reserve) of unit n submitted to the flexibility platform (kW), $mFRR(FP)_{U,m}$ is the manual frequency restoration reserve (up-reserve) of unit m submitted to the flexibility platform (kW) and $RR(FP)_{U,k}$ is the replacement reserve (up-reserve) of unit$k$ submitted to the flexibility platform (kW).
KPI_H18B / Volume of balancing service offers for UP reserves transferred to BM	Volume of balancing service offers for UP reserves (aFRR, mFRR, RR) transferred by the flexibility platform to the Balancing Market. Sum of capacity reserves products direction UP (aFRR_up, mFRR_up, RR_up) transferred by the flexibility platform to the Balancing Market (BM).	$$VBS_{UP-BM} = \sum_{n=1}^{N} aFRR(FP,BM)_{U,n} + \sum_{m=1}^{M} mFRR(FP,BM)_{U,m} + \sum_{k=1}^{K} RR(FP,BM)_{U,k}$$ Where: VBS_{UP-BM} is the volume of balancing service offers for UP reserves transferred to the BM (kW), $aFRR(FP,BM)_{U,n}$ is the automatic frequency restoration reserve (up-reserve) of unit n transferred by the flexibility platform to the BM (kW), $mFRR(FP,BM)_{U,m}$ is the manual frequency restoration reserve (up-reserve) of unit m transferred by

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		the flexibility platform to the BM (kW) and $RR(FP,BM)_{U,k}$ is the replacement reserve (up-reserve) of unit k transferred by the flexibility platform to the BM (kW).
KPI_H18D / Volume of balancing service offers for DOWN reserves	Volume of balancing service offers for DOWN reserves (aFRR, mFRR, RR) submitted to the flexibility platform by BSPs from the distribution network. Sum of capacity reserves products direction DOWN (aFRR_down, mFRR_down, RR_down) offered by BSPs on the flexibility platform.	$$VBS_{DO} = \sum_{n=1}^{N} aFRR(FP)_{D,n} + \sum_{m=1}^{M} mFRR(FP)_{D,m} + \sum_{k=1}^{K} RR(FP)_{D,k}$$ Where: VBS_{DO} is the volume of balancing service offers for DOWN reserves (kW), $aFRR(FP)_{D,n}$ is the automatic frequency restoration reserve (down-reserve) of unit n submitted to the flexibility platform (kW), $mFRR(FP)_{D,m}$ is the manual frequency restoration reserve (down-reserve) of unit m submitted to the flexibility platform (kW) and $RR(FP)_{D,k}$ is the replacement reserve (down-reserve) of unit k submitted to the flexibility platform (kW).
KPI_H18E / Volume of balancing service offers for DOWN reserves transferred to BM	Volume of balancing service offers for DOWN reserves (aFRR, mFRR, RR) transferred by the flexibility platform to the Balancing Market. Sum of capacity reserves products direction DOWN (aFRR_down, mFRR_down, RR_down) transferred by the flexibility platform to the Balancing Market (BM).	$$VBS_{DO-BM} = \sum_{n=1}^{N} aFRR(FP,BM)_{D,n} + \sum_{m=1}^{M} mFRR(FP,BM)_{D,m} + \sum_{k=1}^{K} RR(FP,BM)_{D,k}$$ Where: VBS_{DO-BM} is the volume of balancing service offers for DOWN reserves transferred to the BM (kW), $aFRR(FP,BM)_{D,n}$ is the automatic frequency restoration reserve (down-reserve) of unit n transferred by the flexibility platform to the BM (kW), $mFRR(FP,BM)_{D,m}$ is the manual frequency restoration reserve (down-reserve) of unit m transferred by the flexibility platform to the BM (kW) and $RR(FP,BM)_{D,k}$ is the replacement reserve (down-reserve) of unit k transferred by the flexibility platform to the BM (kW).
KPI_H18G / Volume of balancing energy offers	Volume of balancing energy offers submitted to the flexibility platform by BSPs from the distribution network. Sum of balancing energy offered by BSPs on the flexibility platform.	$$V_{BE} = \sum_{i=1}^{I} E(FP)_i$$ Where: V_{BE} is the volume of balancing energy offers (kWh) and $E(FP)_i$ is the balancing energy offered by the i^{th} unit on the flexibility platform (kWh).

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KPI_H18H / Volume of balancing energy offers transferred to the BM	Volume of balancing energy offers transferred by the flexibility platform to the Balancing Market (BM).	$$V_{BE-BM} = \sum_{i=1}^{I} E(FP, BM)_i$$ Where: V_{BE-BM} is the volume of balancing energy offers transferred to the BM (kWh) and $E(FP, BM)_i$ is the balancing energy of the i^{th} unit transferred by the flexibility platform to the BM (kWh).
KPI_H19A / Number of DERs available for BSPs	Total number of certified DERs prequalified to provide balancing services available for BSPs.	$$N_{DER\_av}$$ Where: N_{DER_av} is the number of available DERs prequalified for balancing services.
KPI_H19B / Percentage of resources available for balancing services	This indicator presents the percentage of DERs representing resources prequalified to provide balancing services against the total number of DERs certified on the flexibility platform.	$$K_{BAL} = \frac{N_{DER\_BAL}}{N_{DER\_ALL}} \cdot 100$$ Where: K_{BAL} is the indicator showing the percentage of certified resources represented by the number of DERs prequalified to provide balancing services against the total number of DERs certified on the flexibility platform (%), N_{DER_BAL} is the number of resources represented by the number of DERs prequalified to provide balancing services and N_{DER_ALL} is the total number of resources represented by the number of DERs certified on the flexibility platform.
KPI_H19C / Total capacity of DERs available for BSPs	Total capacity of certified DERs ready to provide balancing services available for BSPs. Amount of kW of resources prequalified to provide balancing services.	$$TP_{DER-BSP} = \sum_{i=1}^{I} P_{DER_{av},i}$$ Where: $TP_{DER-BSP}$ is the total capacity of DERs available for BSPs (kW) and $P_{DER_{av},i}$ is the available amount of kW of DER, i to provide balancing services (kW).
KPI_H22A / Percentage of successfully prequalified FSPs	This indicator presents the percentage of flexibility services providers in the demo that are successfully prequalified, against the number of FSPs only registered on the flexibility platform.	$$K_{FSP} = \frac{N_{FSP_{preq}}}{N_{FSP_{reg}}} \cdot 100$$ Where: K_{FSP} is the indicator showing the percentage of FSPs that are successfully prequalified against the number of FSPs only registered on the flexibility platform, $N_{FSP_{preq}}$ is the number of FSPs that are successfully prequalified and $N_{FSP_{reg}}$ is the number of FSPs registered on the flexibility platform.
KPI_H22B / Percentage of successfully prequalified DERs	This indicator presents the percentage of DERs in the demo (prequalified either directly or by an aggregator) that are successfully prequalified, against the	$$K_{DER} = \frac{N_{DER_{preq}}}{N_{DER_{reg}}} \cdot 100$$ Where:

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	number of DERs only registered on the flexibility platform.	K_{DER} is the indicator showing the percentage of DERs that are successfully prequalified against the number of DERs only registered on the flexibility platform, $N_{DER_{preq}}$ is the number of DERs that are successfully prequalified (technically) and $N_{DER_{reg}}$ is the number of DERs registered on the flexibility platform.
KPI_H22D / Capacity of certified DERs for at least one flexibility product	Total capacity of certified DERs, ready to service, for one or more flexibility products.	$$P_{DER\_cer} = \sum_{i=1}^{I} P_{DER_{cer,i}}$$ Where: P_{DER_cer} is the capacity of certified DERs (kW) and $P_{DER_{cer,i}}$ is the certified amount of kW of the i^{th} DER.
KPI_H22E / Volume of flexibility by prequalified units	The volume of prequalified flexibility is measured with this KPI.	$$FL_{units} = SUM(list\ of\ units'\ flexibility)$$ Where: FL_{units} is the total quantity of prequalified flexibility.
KPI_H22F / Number of successfully prequalified units	With this KPI, the number of successfully prequalified units is measured.	$$N_{units} = SUM(list\ of\ units'\ names)$$ Where: N_{units} is the total number of prequalified units.
KPI_H23A / Power exchange deviation	Tracking error between a set-point requested by the SO and the measure, given an FSP and a tracking period (e.g., one single service provision). Deviation between accepted and actual activated flexibility power.	$$P_{Deviation} = \frac{\lvert P_{accepted} - P_{activated} \rvert}{P_{accepted}} \cdot 100$$ Where: $P_{Deviation}$ is the power exchange deviation (%), $P_{accepted}$ is the accepted (contracted) power (kW) and $P_{activated}$ is the activated flexibility power (kW).
KPI_H23B / Energy exchange deviation	Tracking error between the energy set-point requested by the SO and the measure, given an FSP and a tracking period (e.g., one single service provision). Deviation between accepted and actual activated flexibility energy.	$$E_{Deviation} = \frac{\lvert E_{accepted} - E_{activated} \rvert}{E_{accepted}} \cdot 100$$ Where: $E_{Deviation}$ is the energy exchange deviation (%), $E_{accepted}$ is the accepted (contracted) energy (kWh) and $E_{activated}$ is the activated flexibility energy (kWh).
KPI_H23E / Deviation of the FSP response compared to the awarded bids	This indicator assesses if the response of the FSPs corresponds to the awarded bids by the market. The indicator provides a percentage of how much each FSP response is in line with its market obligation.	$$\Delta P_{max} = \max_{k} \left(\frac{P_{FSPi}(k) - P^{*}(k)}{P^{*}(k)} \right) \cdot 100$$ and $$\Delta P_{mean} = \operatorname{mean}_{k} \left(\frac{P_{FSPi}(k) - P^{*}(k)}{P^{*}(k)} \right) \cdot 100$$ Where:

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		ΔP_{max}, ΔP_{mean} are the maximum and mean value of power deviation (ΔP) (kW or kVAr) respectively and $P^*(k)$ is the active power (kW) that an FSP should provide according to the awarded market bids. Any deviations from these values is recorded as a deviation of the FSPs' response. The same formulas will be applied for reactive power as well (Q instead of P in the formulas), to determine the ΔQ_{max} and ΔQ_{mean} indicators.
KPI_N03 / Number of FSPs participating in more than one country	This KPI is valid for the BUCs that aim to harmonize the definition and process of flexibility products among SOs in different countries. The overall BUC performance of this aim can be measured considering the enhanced possibility of FSPs' participation in the flexibility market beyond the home country.	$N_{FSP,CB}$ Where: $N_{FSP,CB}$ is the number of FSPs that participate in a market beyond their original country.
KPI_N04 / Number of conflicts resulting from flexibility product activation	In the uncoordinated way of flexibility activation in the existing market, activation of flexibility products by one SO may lead to conflicts (e.g., new congestions) in another SO's grid area. One of the aims of this BUC is to avoid any such conflicts by performing the grid qualification process in prequalification, procurement and activation phases. This indicator measures the performance of this aim.	N_C Where: N_C is the number of conflicts resulting from flexibility product activation.
KPI_N14 / Rate of Change of Frequency improvement	This indicator considers the maximum rate of frequency change (in Hz/s) after an intense disturbance on system balancing. The indicator provides the improvement on the maximum ROCOF (ROCOFI) of the Research and Innovation (R&I) scenario where FSPs provide fast frequency responses compared to the Business as Usual (BaU) scenario where	$ROCOFI = \frac{ROCOF_{R\&I} - ROCOF_{BaU}}{ROCOF_{BaU}} \cdot 100$ Where: $ROCOFI$ is the Rate of Change of Frequency improvement (%) and $ROCOF_x$ for each scenario $x \in \{R\&I, BaU\}$ is given by the equation: $ROCOF_x = \max_k \left(\frac{f(k)-f(k-1)}{\Delta t}\right)$ (Hz/s).

	FSPs do not provide frequency support.	
KPI_N15 / Improvement of Frequency Nadir	This indicator shows the improvement of the frequency nadir, which is the minimum point that the frequency reaches (in Hz) after an intense disturbance on system balancing. This KPI will show the improvement of the frequency nadir after the application of the innovative solutions in the Cypriot demo and the encouragement of large- and small-scale flexibility resources to participate in the frequency balancing. For the calculation of this indicator the frequency nadir during a disturbance for two scenarios will be considered. The first scenario will be the business-as-usual scenario (BAU) which represents the current state in the Cypriot power system, while the second scenario will be the Research and Innovation scenario (R&I) that reflects the application of innovative techniques that will be developed and demonstrated in the Cypriot demo.	$$FNadirI = \frac{FreqNadir_{R\&I} - FreqNadir_{BaU}}{FreqNadir_{BaU}} \cdot 100$$ Where: $FNadirI$ is the improvement of frequency nadir (%) and $FreqNadir_x$ for each scenario $x \in \{R\&I, BaU\}$ is given by the equation: $$FreqNadir_x = min[f_x(k)],\ x \in \{R\&I, BaU\}\ \text{(Hz)}$$
KPI_N16 / Overloading	This indicator provides information for the maximum overloading conditions that occur at the distribution grid. This KPI will show the improvement in the maximum thermal loading (TL) status of a transformer/line, after the application of the innovative solutions provided by the flexible resources. The maximum power flow of the line under consideration will be considered in two	The thermal loading improvement (TL_i) between the $R\&I$ and the BaU scenarios is given by the equation: $$TL_i = \frac{\lvert TL_{R\&I} - TL_{BaU} \rvert}{TL_{BaU}} \cdot 100\ [\%]$$ where the TL_x for each scenario $x \in \{R\&I, BaU\}$ is given by the equation: $$TL_x = \frac{\max(S(k))}{S_n},\ x \in \{R\&I, BaU\}$$ Where: TL_i is the overloading of the i^{th} element, $S(k)$ is the apparent power of the line/transformer at sample k and S_n is the rated apparent power of the line/transformer.

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	scenarios. The first scenario will be the business-as-usual scenario (BAU) which represents the current state in the Cypriot power system, while the second scenario will be the Research and Innovation scenario (R&I) that reflects the application of innovative techniques that will be developed and demonstrated in the Cypriot demo.	
KPI_N17 / Improvement on voltage limits violations	This indicator provides information for the distribution grid's maximum over-/under- voltage conditions in terms of intensity and duration. The indicator provides the improvement, of the Maximum Upper Voltage Violation Intensity $(MUVVI_i)$ and the Maximum Lower Voltage Violation Intensity $(MLVVI_i)$, between the Research and Innovation (R&I) scenario and the Business as Usual (BaU) scenario for the grid under examination.	The Maximum Upper and Lower Voltage Intensity improvements ($MUVVI_i$ and $MLVVI_i$) between the $R\&I$ and BaU scenarios are calculated according to the equations: $$MUVVI_i = \frac{MUVVI_{R\&I} - MUVVI_{BaU}}{MUVVI_{BaU}} \cdot 100\ (\%)$$ and $$MLVVI_i = \frac{MLVVI_{R\&I} - MLVVI_{BaU}}{MLVVI_{BaU}} \cdot 100\ (\%)$$ where the maximum upper/lower voltage violation intensities $MUVVI_x$ and $MLVVI_x$ for each scenario $x \in \{R\&I, BaU\}$ are given by the equations: $$MUVVI_x = \max_j \left(\sum_k UVV_j(k) \cdot \left(V_j(k) - V_{max}\right) \cdot T_s \right)$$ $$MLVVI_x = \max_j \left(\sum_k LVV_j(k) \cdot \left(V_{min} - V_j(k)\right) \cdot T_s \right)$$ where $j \in \{1, \dots, N\}$ represents all the voltage buses of the distribution grid under examination. Variables UVV_j and LVV_j represent the upper and lower voltage violations, respectively, for bus j and are defined as 0/1, as given by the equations: $$UVV_j = \begin{cases} 1, & V_j(k) > V_{max} \\ 0, & V_j(k) \leq V_{max} \end{cases}$$ and $$LVV_j = \begin{cases} 1, & V_j(k) < V_{min} \\ 0, & V_j(k) \geq V_{min} \end{cases}$$ Where: $V_j(k)$ is the voltage measurements at bus j at sample k, V_{min} and V_{max} are the maximum and minimum voltage limits according to the grid regulations and T_s is the sample time (time between 2 consecutive samplings).

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KPI_N18 / Reduction of energy losses	This indicator will provide information for the energy losses of the distribution grid for the selected operational scenarios. The indicator provides the Energy Losses reduction (Elr) between the Research and Innovation (R&I) scenario where local FSPs provide flexibility services to the distribution grid and the Business as Usual (BaU) scenario where no flexibility services are provided.	The energy losses reduction between the R&I and BaU scenarios is calculated according to the equation: $$EL_i = \frac{EL_{BaU} - EL_{R\&I}}{EL_{BaU}} \cdot 100\ (\%)$$ where the energy losses EL_x for each scenario $x \in \{R\&I, BaU\}$ are given by the equation: $$EL_x = \frac{Total\ Energy\ Losses_x}{Total\ Load\ Energy_x} \cdot 100\ (\%)$$ The variable $Total\ Energy\ Losses_x$ represents the total energy losses in the part of the grid under investigation and is calculated by the difference between the input and the output energy for scenario x $(R\&I\ or\ BaU)$. The variable $Total\ Load\ Energy_x$ corresponds to the total load served by the grid under investigation during scenario x $(R\&I\ or\ BaU)$.
KPI_N19 / Reduction of Loading asymmetries– Maximum and Average Current Phase Unbalanced Factor (MCPUFR and ACPUFR)	This indicator provides information about the loading asymmetry between the three phases (Current Phase Unbalanced Factor) at the substation level (either primary or secondary substation), before (BaU) and after (R&I) the provision of local flexibility services for power quality enhancement by the local FSPs. The average and the maximum improvement will be considered for the examined period. The reduction of loading asymmetries is measured according to the maximum and average Current Phase Unbalance Factor reduction (MCPUFR and ACPUFR, respectively) between the R&I and the BaU.	The reduction of loading asymmetries is measured according to the maximum and average Current Phase Unbalance Factor reduction ($MCPUF_r$ and $ACPUF_r$ respectively) between the $R\&I$ and the BaU scenarios and is calculated according to the equation: $$MCPUF_r = \frac{\max_k\left(CPUF_{BaU}(k)\right) - \max_k\left(CPUF_{R\&I}(k)\right)}{\max_k\left(CPUF_{BaU}(k)\right)} \cdot 100\ (\%)$$ and $$ACPUF_r = \frac{\text{average}_k\left(CPUF_{BaU}(k)\right) - \text{average}_k\left(CPUF_{R\&I}(k)\right)}{\text{average}_k\left(CPUF_{BaU}(k)\right)} \cdot 100\ (\%)$$ where the Current Phase Unbalanced Factor $CPUF_x$ for each scenario $x \in \{R\&I, BaU\}$ is given by the equation: $$CPUF_x(k) = \frac{\lvert I^0(k)\rvert + \lvert I^N(k)\rvert}{\lvert I^p(k)\rvert} \cdot 100\ (\%)$$ Where: $MCPUF_r$ is the Maximum Current Phase Unbalance Factor Reduction (%), $ACPUF_r$ is the Average Current Phase Unbalance Factor Reduction (%), $CPUF_x$ is the Current Phase Unbalance Factor for scenario x, k is the sample, I^0 is the zero-sequence component of the loading current at the substation, I^N is the negative sequence component of the loading current at the substation and I^p is the positive sequence component of the loading current at the substation.
KPI_N20 / Power factor	This indicator shows the improvement of the power	The power factor Improvement PF_i between the $R\&I$ and the BaU scenarios is given by the equation:

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(PF) improvement	factor value in different nodes of the distribution grid. It should be noted that the minimum value of the power factor over a period of time is considered in the calculation of this indicator. This KPI will show the improvement in the minimum power factor of a node, after the application of the innovative solutions provided by the flexible resources (i.e., reactive support). The minimum power factor of the node under consideration (over a specific time interval) will be considered in two scenarios. The first scenario will be the business-as-usual scenario (BAU) which represents the current state in the Cypriot power system, while the second scenario will be the Research and Innovation scenario (R&I) that reflects the application of innovative techniques that will be developed and demonstrated in the Cypriot demo for reactive power support.	$$PF_i = \frac{PF_{R\&I} - PF_{BaU}}{PF_{BaU}} \cdot 100\ (\%)$$ where the PF_x for each scenario $x \in \{R\&I, BaU\}$ is given by the equation: $$PF_x = \min\left[\frac{P(k)}{\sqrt{P(k)^2 + Q(k)^2}}\right] \quad x \in \{R\&I, BaU\}$$ Where: P is the active power, Q is the reactive power and k is the sample.
KPI_N25 / Comparison between the Isc max forecasted for the 63kV by the planning and the maximum short circuit value registered for the series under analysis	Deviation between the maximum planning estimated value of Isc (iscmax – maximum short circuit current) and the maximum value effectively forecasted (MAX(Isc)) in a D-1 timeframe.	$$e = iscmax - MAX(I_{sc})$$ Where: e is the deviation between the maximum planning estimated value of I_{sc} $(iscmax)$ and the maximum value effectively forecasted $MAX(I_{sc})$ in a D-1 timeframe (A), $iscmax$ is the maximum planning estimated value of I_{sc} (A) and $MAX(I_{sc})$ is the maximum value effectively forecasted in the D-1 (A).

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KPI_N27 / Total power of avoided congestions through flexibility activation	The difference of the total amount of power of the congestions (overloaded elements) in the grid, for all periods of observation, between the scenarios without flexibility activation (before BUC implementation) and with flexibility activation (after BUC implementation) by DSO and TSO action.	$$TPAC = \sum_{t=1}^{T} \left(\sum_{\substack{i=0 \\ before\ BUC}}^{M} (P_{i,t} - P_i^{max}) - \sum_{\substack{k=0 \\ after\ BUC}}^{N} (P_{k,t} - P_k^{max}) \right)$$ Where: $TPAC$ is the total power of avoided congestions through flexibility activation (kW), M and N are the number of overloaded elements in the scenarios without and with flexibility activations respectively and T is the number of time intervals for the entire period under consideration (e.g., for one day 24 intervals of 1 hour or 96 intervals of 15 minutes).
KPI_N30 / Comparison between the rated short circuit current of the circuit breakers for the 63kV and the maximum short circuit value registered for the series under analysis	Deviation between the breaker limit Isc 63kVlim and the maximum value effectively forecasted (MAX(Isc)) in a D-1 timeframe.	$$\sigma = I_{sc}\ 63kVlim - MAX\ (I_{sc}\ )$$ Where: σ is the deviation between the breaker limit Isc 63kVlim and the maximum value effectively forecasted $MAX\ (I_{sc}\ )$ in a D-1 timeframe (A), $I_{sc}\ 63kVlim$ is the circuit breaker short circuit limit (A) and $MAX\ (I_{sc}\ )$ is the maximum value effectively forecasted in the D-1 (A).
KPI_N31 / Nº of congestions/ violations on DSO network	Anticipated distribution grid constraints because of scheduled maintenance actions. By exchanging information of maintenance works between TSO and DSO, some congestions might be identified (forecasted) and avoided with corrective actions such as topology reconfiguration, flexibility activation or even maintenance works rescheduling. This KPI will evaluate the efficacy of this information exchange in order to avoid congestions.	$$CAD_{\%} = \frac{\#congestion\ avoided}{\#congestion\ forecasted} \cdot 100$$ Where: $CAD_{\%}$ is the Nº of congestions/violations on the DSO network (%), $\#congestion\ avoided$ is the number of congestions avoided through the implementation of predictive actions resulting from the maintenance works information exchange and $\#congestion\ forecasted$ is the number of congestions correctly forecasted, so excluding the false positive congestions forecasts.
KPI_N32 / Nº of congestions/	Anticipated transmission grid constraints because of scheduled maintenance actions. By exchanging	$$CAT_{\%} = \frac{\#congestion\ avoided}{\#congestion\ forecasted} \cdot 100$$ Where:

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violations on TSO network	information of maintenance works between TSO and DSO, some congestions might be identified (forecasted) and avoided with corrective actions such as topology reconfiguration, flexibility activation or even maintenance works rescheduling. This KPI will evaluate the efficacy of this information exchange in order to avoid congestions.	$CAT_{\%}$ is the Nº of congestions/violations on the TSO network (%), $\#congestion\ avoided$ is the number of congestions avoided through the implementation of predictive actions resulting from the maintenance works information exchange and $\#congestion\ forecasted$ is the number of congestions correctly forecasted, so excluding the false positive congestions forecasts.
KPI_N34 / Successful ending of Prequalification Process	This indicator measures the percentage of prequalification processes approved.	$$SPP_{\%} = \frac{Successful}{TPP} \cdot 100$$ Where: $SPP_{\%}$ is the percentage of successful Prequalification Processes (%), $Successful$ is the number of successful prequalification processes and TPP is the total number of Prequalification Processes.
KPI_N35 / Increase in the availability of flexibility	The implementation of the traffic light scheme will enable swift sharing of data on planned outages to aggregators – this represents added value, especially if the maintenance is finished before the scheduled date (planned deadline). As this information was not previously available, the advantage lies mainly in enhancing the provision of the aggregator's flexibility, more effective utilization of flexibility and unlocking the full potential of their flexibility portfolio.	$$IAF = \frac{FP}{\text{FPS}} \cdot 100$$ Where: IAF is the increase in the availability of flexibility (%), FP is the time of blocked Flexibility Potential – time in hours, where the availability of flexibility was blocked under recent conditions (min) and FPS is the time of blocked Flexibility Potential S – time in hours, where the availability of flexibility is blocked with traffic light scheme in place (min).
KPI_N39 / Volume of activated Flexibility services	Validate the demand response mechanism to prevent congestion in the distribution grid. The total volume of needed and provided energy will be calculated and displayed.	$$K_{succ} = \frac{Vol_{del}}{Vol_{need}} \cdot 100$$ Where: K_{succ} is the indicator showing the percentage of successfully delivered energy (%), Vol_{del} is the volume of delivered energy and Vol_{need} is the volume of needed energy.
KPI_N46 / Prequalification processes that	This indicator measures the percentage of prequalification processes	$$PPA_{\%} = \frac{NPPA}{TPP} \cdot 100$$ Where:

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need additional information	that require additional information.	$PPA_{\%}$ is the percentage of Prequalification Processes that need additional information (%), $NPPA$ is the number of Prequalification Processes that need additional information and TPP is the total number of Prequalification processes.

4.3.1.1 Northern cluster

Within the Finnish demo, procurement of flexibility only through ST-P-E product has been carried out so far. The FSPs piloted a residential building and a data center server located within the Fingrid network. Both resources were pre-qualified for the ST-P-E product before participating in the trade, and the grid qualification is conducted during the optimization-based market clearing. The market clearing results showed that grid congestions were completely removed by activating the cleared flexibility. The results of the NRT-P-E product procurement for the Finnish case will be reported in the second version of this deliverable, along with the rest of the missing KPI values.

Table 4.17: Northern cluster – Calculated values of technical assessment of system service provision KPIs

KPI ID / KPI Name	Calculated values (Target values)			
	Finland	Estonia	Latvia	Lithuania
KPI_H22A / Percentage of successfully prequalified FSPs	100% (100%)	100%	100%	100% (100%)
KPI_N03 / Number of FSPs participating in more than one country	2	0	0	0
KPI_N04 / Number of conflicts resulting from flexibility product activation			0	

4.3.1.2 Cypriot demo

KPI_H18A shows the volume of balancing service offers for UP reserves submitted to the flexibility platform by BSPs from the distribution network. In particular, the KPI indicates the volume of active power that is available by the FSPs located at the distribution network for congestion management. In the Cypriot demo the market for the congestion management reserve is the Near real time DSO market, which clears the availability of FSPs every hour. According to the market results, the offers submitted by the FSPs at the MV and LV networks for

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congestion management were around 517 kW for each hour, or 1,551 MW in total, not quite reaching the initial target of more than 2 MW.

KPI_H19A indicates the number of DERs (located at the distribution grid) that take part to the market for the provision of ancillary services to the grid. In the scenarios of the Cypriot demo, the DERs are available in two levels of the grid, namely the MV and LV levels. These DERs provide bids for ΔP and ΔQ coordination and Phase Balancing (PB). The number of DERs available for BSPs was 4 at the MV level and 2 at the LV level. Thus, the total number is 6 DERs, exceeding the initial target value which was set to 5.

KPI_H23E "Deviation of the FSP response compared to the awarded bids" assesses if the response of the FSPs corresponds to the bids awarded by the market. The indicator provides a percentage of how much each FSP response is in line with its market obligation. This KPI was calculated for the case of the FSPs located in the distribution grid that participated in the near real time DSO market for the provision of congestion management services (ΔP, ΔQ and PB coordination). Two indicators were used, the maximum deviation of all the FSPs and the mean deviation of all the FSPs. The KPI was calculated for the MV and LV levels of the distribution grid. In the case of the LV grid, both nominal and reverse power flow direction was assumed, where the FSPs provided only ΔP, ΔQ coordination or ΔP, ΔQ and PB coordination. From the resulting values in all cases it is clearly depicted that the FSPs respond accurately to the coordination signals sent by the DSO for the provision of ancillary services. It should be noted, that since the KPI was calculated in a simulation environment, such values were expected as the FSPs' control algorithms for the provision of congestion management services respond according to the coordination signal values.

KPI_N14 "Rate of Change of Frequency Improvement" considers the maximum rate of frequency change (in Hz/s) after an intense disturbance on system balancing. This scenario aimed to demonstrate how RES can contribute to the frequency support of the system during a frequency disturbance. In this sense, two different RES penetration levels were considered for this KPI, while for each RES penetration level 2 scenarios are demonstrated. In the first scenario, the RES solely offer droop support to the system, while in the second scenario the RES provide both droop and virtual inertia during an under-frequency event. The two scenarios were compared with the baseline case, where the frequency support was provided only by the conventional generators. The smaller the ROCOF is the more stable the system will be in case of a frequency event. As illustrated in all scenarios, the resulting values indicate that the RES contribution is vital for improving the ROCOF of the Cypriot system. Furthermore, in case the RES penetration level is higher, the ROCOF of the system is smaller indicating that through the provision of frequency support services by RES, such as droop and virtual inertia, the frequency stability of the system can be improved considerably. In addition, in the second scenario where the RES provide both droop and virtual inertia during the event, the ROCOF improvement is further improved by 16% and 10% for the 100MW and 150MW penetration levels respectively.

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The improvement of the frequency nadir is the minimum point that the frequency reaches (in Hz) after an intense disturbance on system balancing. This KPI is also related to the frequency support of the system by RES during the disturbance. As for KPI "Rate of Change of Frequency Improvement", the calculation considers two different RES penetration levels and for each RES penetration level 2 scenarios are demonstrated. As illustrated by the resulting values, the frequency nadir during a frequency disturbance is larger in the case of RES support in comparison to the baseline. This is evident from the calculated values that range between ~0,6% and ~0,9%. Furthermore, in case the RES penetration level is higher, the improvement in the frequency nadir is also higher, as expected. In addition, in the second scenario where the RES provide both droop and virtual inertia during the event, the frequency nadir is further improved by 9% and 5% for the 100MW and 150MW penetration levels respectively, even though in all cases the improvement is lower than initially expected.

KPI_N16 "Overloading" provides information for the maximum overloading conditions that occur at the distribution grid with a high penetration of RES in the system. Actually, the KPI shows the improvement in the maximum thermal loading (TL) status of a transformer/line after the application of the innovative services provided by the flexible resources. The innovative solution provided by the FSPs is the coordination of the active and reactive power (P and Q) injection at each FSP node (ΔP and ΔQ coordination). The coordination signals are sent to the FSPs by the DSO. The KPI has been calculated in both the MV and LV distribution grids, while in the case of the LV grid, except from the ΔP and ΔQ coordination service the FSPs can provide phase balancing (PB) services as well. Furthermore, in the case of the LV distribution grid, two sub-scenarios were investigated, (1) nominal power direction (no PV generation) and (2) reverse power direction (excess PV generation). The loading condition of the grid is improved considerably by coordinating the active and reactive power injection of the FSPs. In the case of the MV distribution grid the improvement is almost 34%, while at the LV distribution grid the maximum improvement is 52%. Furthermore, in the LV grid the provision of PB services on top of the ΔP and ΔQ coordination services achieves a ~2% higher TL improvement in the case of nominal power direction, while in the reverse power direction the two cases have an equal thermal loading improvement. This is due to the fact that the maximum loading conditions were considered here and therefore in both cases the maximum loading conditions are the same.

KPI_N17 "Improvement on voltage limits violations" provides information for the distribution grid's maximum over-/under- voltage conditions in terms of intensity and duration. All the scenarios tested in the Cypriot demo did not exhibit any over- or under- voltage conditions during the steady state operation of the grid, therefore the improvement in terms of the voltage limit violation is zero for all the cases examined.

KPI_N18 "Reduction of energy losses" provides information for the energy losses of the distribution grid in case the ΔP, ΔQ and PB services are provided. Since in the Cypriot demo 2 levels of the distribution grid are considered (MV and LV), the KPI values were calculated for both. In all examined cases, with the provision of ancillary services by the FSPs for congestion management the energy losses are reduced, even though not as

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much as initially expected. This indicates that the proposed ancillary services make the system work more efficiently as well. In the case of the MV level only ΔP and ΔQ coordination services were provided and the energy losses were reduced by 3.2%. In the case of the LV level nominal and reverse power flow direction scenarios are assumed, while in both scenarios ΔP and ΔQ coordination and ΔP, ΔQ and PB coordination are applied. As a conclusion, PB seems to further contribute to the energy losses reduction in both scenarios.

The KPI related to the reduction of loading asymmetries provides information about the loading asymmetries between the three phases (Current Phase Unbalanced Factor) at the substation level (either primary or secondary substation), before (BaU) and after (R&I) the provision of local flexibility services for power quality enhancement by the local FSPs. The reduction of loading asymmetries is measured according to the maximum and average Current Phase Unbalance Factor reduction (MCPUFR and ACPUFR respectively) between the R&I (with phase balancing services) and the BaU (no phase balancing services) scenarios. Two operating scenarios were executed in the LV distribution grid for the extraction of this KPI, (1) nominal power direction (no PV generation) and (2) reverse power direction (excess PV generation). As can be seen, the loading asymmetries in the LV grid are considerably improved through the provision of phase balancing services for both scenarios. In particular, the MCPUFR and ACPUFR for the nominal power direction are 31.78% and 49.76% respectively, while for the reverse power direction they are 49.8% and 49.25% respectively.

The improvement of the power factor depicts the improvement in different nodes of the distribution grid. Actually, this KPI shows the improvement of the minimum power factor of a node after the application of the ΔP and ΔQ coordination solutions (provided by the FSPs) that were developed in the Cypriot demo. The power factor improvement was also examined in two operating conditions of the LV system, namely (1) nominal power direction (no PV generation) and (2) reverse power direction (excess PV generation), for two types of ancillary services: ΔP/ΔQ coordination and ΔP/ΔQ coordination and phase balancing. It should be mentioned that both services target congestion management and not the power factor correction, while a good power factor value should be close to 1. As illustrated by the resulting values, with the provision of ancillary services for congestion management the PF presents a deterioration of about 2.5% (average of ΔP and ΔQ coordination and ΔP and ΔQ coordination and phase balancing) in the case of nominal power direction and about 0.5% (average of ΔP and ΔQ coordination and ΔP and ΔQ coordination and phase balancing) in the case of reverse power direction. This slight deterioration in the power factor is due to the fact that during the provision of ancillary services for the alleviation of grid congestion the active power is decreased and thus the power factor is also decreased, explaining the gap between the results and the initial expectation.

Table 4.18: Cypriot demo – Calculated values of technical assessment of system service provision KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_H18A / Volume of	517 kW per hour

balancing service offers for UP reserves	Total: 1,551 MW (>2 MW)				
KPI_H19A / Number of DERs available for BSPs	4 at the MV level and 2 at the LV level Total: 6 (5)				
KPI_H23E / Deviation of the FSP response compared to the awarded bids	Grid level	Scenario		Results	
				ΔP_{max}	ΔP_{mean}
	MV	ΔP and ΔQ coordination		0,04%	0,01% (<10%)
	LV	Nominal power direction	ΔP and ΔQ coordination	0,03%	0,01% (<10%)
			ΔP, ΔQ and PB coordination	0,02%	0,01% (<10%)
		Reverse power direction	ΔP and ΔQ coordination	0,04%	0,02% (<10%)
			ΔP, ΔQ and PB coordination	0,04%	0,02% (<10%)
KPI_N14 / Rate of Change of Frequency improvement	RES penetration level	Scenario		Results	
	100 MW	Droop support by RES		15,52% (20%)	
		Droop and virtual inertia support by RES		18,04% (20%)	
	150 MW	Droop support by RES		21,44% (20%)	
		Droop and virtual inertia support by RES		23,73% (20%)	
KPI_N15 / Improvement of Frequency Nadir	RES penetration level	Scenario		Results	
	100 MW	Droop support by RES		0,643% (5%-10%)	
		Droop and virtual inertia support by RES		0,702% (5%-10%)	
	150 MW	Droop support by RES		0,846% (5%-10%)	
		Droop and virtual inertia support by RES		0,891% (5%-10%)	

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KPI_N16 / Overloading	Grid level	Scenario		Results
	MV	ΔP and ΔQ coordination		33,67% (10%-15%)
	LV	Nominal power direction	ΔP and ΔQ coordination	44,44% (10%-15%)
			ΔP, ΔQ and PB coordination	46,39% (10%-15%)
		Reverse power direction	ΔP and ΔQ coordination	52,01% (10%-15%)
			ΔP, ΔQ and PB coordination	52,01% (10%-15%)
KPI_N17 / Improvement on voltage limits violations	0% (10%)			
KPI_N18 / Reduction of energy losses	Grid level	Scenario		Results
	MV	ΔP and ΔQ coordination		3,2% (10%)
	LV	Nominal power direction	ΔP and ΔQ coordination	2,9% (10%)
			ΔP, ΔQ and PB coordination	3,5% (10%)
		Reverse power direction	ΔP and ΔQ coordination	2,8% (10%)
			ΔP, ΔQ and PB coordination	3% (10%)
KPI_N19 / Reduction of Loading asymmetries– Maximum and Average Current Phase Unbalanced Factor (MCPUFR and ACPUFR)	Scenario	MCPUFR results		ACPUFR results
	Nominal power direction	31,78% (30%)		49,76% (30%)
	Reverse power direction	49,8% (30%)		49,25% (30%)
KPI_N20 / Power factor (PF) improvement	Scenario			Results
	Nominal power direction	ΔP and ΔQ coordination		-2,74% (5%-10%)
		ΔP, ΔQ and PB coordination		-2,35% (5%-10%)
	Reverse power direction	ΔP and ΔQ coordination		-0,37% (5%-10%)
		ΔP, ΔQ and PB coordination		-0,62% (5%-10%)

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4.3.1.3 Spanish demo

In general, the calculated KPI values show positive results in terms of asset load profile variation compared to the initial target values. The highest asset load profile variation is observed in the Short-term intraday Murcia scenario, where the asset was impacted by the flexibility activation decreasing its load by 20%. The lowest asset load profile variation is observed in the Short-term day ahead Madrid (30 min – test 1) scenario, where the asset was impacted by the flexibility activation decreasing its load by 9%. On average the asset load profile variation was approximately 14,1% among the different tested scenarios.

The resulting KPI values for the power exchange deviation show both positive and negative results. For this KPI the values marked as "above" indicate an over-provision of flexibility, while the values marked as "below" indicate that the activated flexibility power did not reach the initial commitment. The only two scenarios where the delivered flexibility power didn't reach the requested amount were the Long-term Murcia and the Long-term day ahead Alcalá de Henares II scenarios. Nevertheless, in both cases the forecasted problem didn't occur because of the load forecast error. On average, the power exchange deviation was 15,8% above, meaning the volume of activated flexibility power was on average 15,8% higher than the contracted amount.

Table 4.19: Spanish demo – Calculated values of technical assessment of system service provision KPIs

Calculated values (Target values)		
KPI ID / KPI Name / **Scenario**	KPI_H13 / Asset load profile variation	KPI_H23A / Power exchange deviation
Short-term day ahead Murcia scenario	11% (<100%)	15% above (<35%)
Short-term intraday Murcia scenario	20% (<100%)	24% above (<35%)
Long-term Murcia scenario	15% (<100%)	48% below (<35%)
Short-term day ahead Madrid (30 min – test 1) scenario	9% (<100%)	63% above (<35%)
Short-term day ahead Madrid (30 min – test 2) scenario	19% (<100%)	61% above (<35%)
Short-term day ahead Madrid (1h) scenario	13% (<100%)	52% above (<35%)
Long-term day ahead Alcalá de Henares I scenario	19% (<100%)	0% (<35%)

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Long-term day ahead Alcalá de Henares II scenario	12% (<100%)	9% below (<35%)
Short-term day ahead Alcalá de Henares I scenario	12% (<100%)	0% (<35%)
Short-term day ahead Alcalá de Henares II scenario	11% (<100%)	0% (<35%)

4.3.1.4 Portuguese demo

As mentioned in Section 4.1, no congestions were verified in the tests conducted for SUC-PT-02, so there was no need for flexibility or curtailment. Thus, KPIs "Reduction in RES curtailment", "Requested flexibility" and "Total power of avoided congestions through flexibility activation" have a null value.

For the calculation of KPI "Successful ending of Prequalification Process", only the product and grid prequalification processes, which were the two prequalification steps considered in the PT demo, were considered. Considering the prequalification steps covered within the demonstration, all FSPs were able to get prequalified. However, it's important to highlight that issues related to the actual ICT capabilities from the FSPs' point of view were not taken into account, something that should be considered in a prior step of the prequalification process, which is the FSP prequalification. In fact, looking into the actual FSPs that participated in the ancillary services market, there was one that wasn't able to enter the market due to ICT issues – thus, if that prior step of the prequalification process was considered, the real value for this KPI would be 99,6%. Considering that step to assess the ICT capabilities of the FSPs, is possible in a scenario with real FSPs participating in the activities and should be noted as a point for improvement.

For the calculation of prequalification processes that need additional information, both required and optional fields were considered, since the information required to be exchanged in the prequalification process is a requirement on its own for the process to successfully finish. The exchanged information were the ones that could be extracted from the FSPs' data, and so the missing fields are the same for all FSPs. In this case, only the information of FAT could not be determined. This led to at least one optional field per FSP/process missing, leading to a value of 100% for this KPI.

Moving on to SUC-PT-06, the yearly maintenance plans were successfully exchanged through both DEPs and the annual maintenance plan was retrieved, including the 2023 works that are relevant for both SOs. For instance, local maintenance works with no repercussion to the connected SO were not communicated. Changes and additions to the existing annual plan were also possible to introduce, directly through the DEPs. There were no technical restrictions (congestions/voltage violations) identified from the works carried out, and thus the two corresponding KPIs have a value of 0. For example, from the distribution network's point of view and due to the

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high redundancy of the network, the maintenance works implemented there didn't cause any restriction. The same is true for the maintenance works implemented at the transmission level.

Regarding KPI "Comparison between the rated short circuit current of the circuit breakers for the 63kV and the maximum short circuit value registered for the series under analysis", in both test rounds for SUC-PT-08 the forecasted short circuit value was lower than the short circuit breaker limit from the TSO's side, for all observed time horizons. This means that the system was secure during the whole period under analysis.

Regarding KPI "Comparison between the Isc max forecasted for the 63kV by the planning and the maximum short circuit value registered for the series under analysis" in the Batalha test round for SUC-PT-08, the forecasted short circuit value for 2022 exceeded the corresponding planning value estimated by the TSO for the 63kV TSO/DSO interface, in 139 time-horizons out of the 720 observed in total (19,3%), with a maximum deviation of 576A. All these excesses are characterized by the presence of active DSO HV network contribution. On the other hand, in the Pocinho test round, the forecasted short circuit value was lower than the 2022 planning value estimated by the TSO for the 63kV TSO/DSO interface.

Table 4.20: Portuguese demo – Calculated values of technical assessment of system service provision KPIs

	Calculated values (Target values)						
Test round / **KPI ID / KPI Name**	SUC-PT-01 Mainland Portugal	SUC-PT-02 Batalha	SUC-PT-02 Pocinho	SUC-PT-06 Batalha	SUC-PT-06 Pocinho	SUC-PT-08 Batalha	SUC-PT-08 Pocinho
KPI_H05 / Reduction in RES curtailment	-	0 (0)	0 (0)	-	-	-	-
KPI_H15 / Requested flexibility	-	0 (0)	0 (0)	-	-	-	-
KPI_N25 / Comparison between the Isc max forecasted for the 63kV by the planning and the maximum short circuit value registered for the series under analysis	-	-	-	-	-	-576 A (>0)	853 A (>0)

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KPI_N27 / Total power of avoided congestions through flexibility activation	-	0 (0)	0 (0)	-	-	-	-
KPI_N30 / Comparison between the rated short circuit current of the circuit breakers for the 63kV and the maximum short circuit value registered for the series under analysis	-	-	-	-	-	3424 A (>0)	12153 A (>0)
KPI_N31 / Nº of congestions/ violations on DSO network	-	-	-	0 (0)	0 (0)	-	-
KPI_N32 / Nº of congestions/ violations on TSO network	-	-	-	0 (0)	0 (0)	-	-
KPI_N34 / Successful ending of Prequalification Process	100% (100%)	-	-	-	-	-	-
KPI_N46 / Prequalification processes that need additional information	100% (100%)	-	-	-	-	-	-

4.3.1.5 Slovenian demo

Table 4.21: Slovenian demo – Calculated values of technical assessment of system service provision KPIs

KPI ID / KPI Name	Calculated values (Target values)

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KPI_H22E / Volume of flexibility by prequalified units	CM: 35 kW from 24 HPs of 1,5 kW each VC: 45 kW – 15 kW from BESS and 30 kW from PV Total: 80 kW (10 kW)
KPI_H22F / Number of successfully prequalified units	3 BESS, 6 PVs and 24 HPs Total: 33 (>5)
KPI_N39 / Volume of activated Flexibility services	87,6% for CM (>75%)

4.3.1.6 Polish demo

The difference in the expected and actual value for KPI "Total capacity of DERs available for BSPs" is related to the adoption of a safe approach. At the time of determining the target value, only one agreement was signed with an entity that could provide balancing services, so the expectations (target value) were pretty low. As time progressed, though, more DERs able to provide balancing services became part of the demonstrations and the result is much higher than the initial target.

Table 4.22: Polish demo – Calculated values of technical assessment of system service provision KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_H15 / Requested flexibility	8000 kW for CM and VC+ and 6997,5 kW for CM and VC- Total: 14997,5 kW (>0)
KPI_H18A / Volume of balancing service offers for UP reserves	1052,6 kW for mFRR+ and 4000 kW for RR+ Total: 5052,6 kW (>0)
KPI_H18B / Volume of balancing service offers for UP reserves transferred to BM	1050,8 kW for mFRR+ and 4000 kW for RR+ Total: 5050,8 kW (>0)
KPI_H18D / Volume of balancing service offers for DOWN reserves	5417 kW for mFRR- and 8821,7 kW for RR- Total: 14238,7 kW (>0)
KPI_H18E / Volume of balancing service offers for DOWN reserves transferred to BM	5414,45 kW for mFRR+ and 8673,9 kW for RR+ Total: 14088,35 kW (>0)
KPI_H18G / Volume of balancing energy offers	23260,8 kWh (>0)
KPI_H18H / Volume of balancing energy offers transferred to the BM	23109,65 kWh (>0)

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KPI_H19A / Number of DERs available for BSPs	60 (15)
KPI_H19B / Percentage of resources available for balancing services	100% (30%)
KPI_H19C / Total capacity of DERs available for BSPs	78343,2 kW (2000 kW)
KPI_H22B / Percentage of successfully prequalified DERs	100% (100%)
KPI_H22D / Capacity of certified DERs for at least one flexibility product	10604,8 kW for CM and VC+ and 15129,8 kW for CM and VC- Total: 25734,6 kW (5000 kW)
KPI_H23A / Power exchange deviation	51,8% for CM and VC+, 13,8% for CM and VC-, 0% for mFRR+, 0,1% for mFRR-, 9,8% for RR+ and 13,7% for RR- Total average: 8,8% (0%)
KPI_H23B / Energy exchange deviation	2,5% for EB (0%)

4.3.1.7 Czech demo

The resulting KPI value for the increase in the availability of flexibility is really positive. A 41% increase in the availability of flexibility was achieved compared to the 10% that was the initial target. Additional comments regarding the availability of flexibility in the demo in general can be found in Section 4.1.

Table 4.23: Czech demo – Calculated values of technical assessment of system service provision KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_N35 / Increase in the availability of flexibility	41% (10%)

4.3.2 Market platforms and economic performance assessment

This subsection concerns the OneNet KPIs that are related to the market platforms and economic performance assessment in the different demonstrators. Table 4.24 includes all the KPIs selected for this topic, as well as a description and the calculation formula for each one. Later on, the calculated values for each KPI are presented per demonstration, alongside an extensive commentary on the results and the overall performance of each demonstrator regarding the market platforms and economic aspects viability and impact.

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It is important to note here that not all demonstrators adopted KPIs related to the market platforms and economic performance assessment, other than the common KPIs that are relevant to this macro-area and were analyzed in Section 4.1. This is why some demonstrators are not mentioned at all in this section.

Table 4.24: Market platforms and economic performance assessment KPIs

KPI ID / KPI Name	KPI Description	KPI Formula
KPI_H04 / ICT costs	For the Spanish demo, the term ICT costs comprises the information and communication technologies that are necessary for DSO-MO-FSP coordination through platforms to develop new local markets. Summation of ICT costs that are directly related to the implementation of new local markets. The term implementation is used to refer to the work in designing, specifying, coding, testing, validating and documenting software. It will be one for the Spanish demo, including the costs from OMIE, UFD and i-DE ICT. For the Portuguese demo, the term ICT costs comprises the information and communication technologies directly related to the implementation of the communication infrastructures between DSO and TSO.	$$ICT_{cost} = \sum_{i=1}^{N_c} c_i$$ Where: ICT_{cost} is the cost of ICT (€), c_i is the generic i^{th} cost directly related to the new local market implementation / to information exchange (€) for the Spanish and Portuguese demos respectively and N_c is the overall number of cost items.
KPI_H08 / Bid statistics (Bid Min Max Average values)	This KPI aims to collect information regarding the minimum, maximum and average value of the bids submitted and cleared to the market to assess the market's liquidity.	$$B_m = min\{bid\ set\}$$ $$B_M = max\{bid\ set\}$$ $$B_A = average\{bid\ set\}$$ Where: B_m , B_M and B_A are the minimal, maximal and average prices of the auctions given a certain period T of observation. The calculation concerns active power capacity auctions and active power activation (energy) auctions.

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KPI_H10 / Flex volume offered by FSP vs Flex request by DSO	Average ratio of offered flexibility by FSPs and flexibility requested by DSO at a given period.	$$ARF_{\%} = \frac{\sum_i \frac{F_{FSP\_bid_i}}{F_{FSP\_req_i}}}{N_{req}} \cdot 100$$ Where: $ARF_{\%}$ is the flex volume offered by the FSP vs the flex request by the DSO (%), $F_{FSP\_bid_i}$ is the amount of flexibility (kW) offered by the FSPs for a particular (i) auction, $F_{DSO\_req_i}$ is the amount of flexibility (kW) requested by the DSO for a particular (i) auction and N_{req} is the total number of auctions called by the DSO at given period.
KPI_H11 / Number of products per demo	This indicator measures the percentage of products tested in the demos with respect to the number of products initially targeted by the demos.	$$NPD = \frac{nP_{tested}}{nP_{targeted}} \cdot 100$$ Where: NPD is the number of products per demo (%), nP_{tested} is the number of products tested in the BUC and $nP_{targeted}$ is the number of products initially targeted for the BUC.
KPI_N01 / Number of implemented cross border products	This KPI is valid for the BUCs that aim to harmonize the definition and process of flexibility products among SOs in different countries. The overall BUC performance of this aim can be measured considering the number of implemented products that can be traded in more than one country (cross border products).	$$N_{P,CB}$$ Where: $N_{P,CB}$ is the number of implemented cross border products.
KPI_N02 / Number of implemented joint products	This KPI is valid for the BUCs that aim to harmonize the definition and process of flexibility products among SOs in different countries. The overall BUC performance of this aim can be measured considering the number of implemented products that can be traded between more than one SO (joint products).	$$N_{P,J}$$ Where: $N_{P,J}$ is the number of implemented joint products.
KPI_N05 / Ratio of successful bid	This indicator measures the performance of the FSP bid preparation process and price estimation. The number of times that FSP bids are selected (call-off bid) compared to the total number of bids that the FSP offered.	$$NSB_{\%} = \frac{n_{co}}{n_T} \cdot 100$$ Where: $NSB_{\%}$ is the ratio of successful bid (%), n_{co} is the number of call-off (successful) bid and n_T is the total number of bids.

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KPI_N10 / Minimizing the number of new products	The goal is to avoid defining the new product while the existing one can be used to satisfy the SO's needs. Therefore, a lower number of products that cover all of the SOs' needs is an indicator for a less complex market.	$$n_p$$ Where: n_p is the number of flexibility products traded in the market.
KPI_N11 / Rate of the secondary contract to the requested one	The aim is to find a replacement for flexibility contracts when the provider cannot keep the commitment. The ideal situation is to find a replacement instead of all the FSPs that failed to provide.	$$RC = \frac{n_C}{n_{FC}}$$ Where: RC is the rate of the secondary contract to the requested one, n_{SC} is the number of contracts in the secondary market and n_{FC} is the number of contracts that failed to keep the commitment.
KPI_N40 / Volume of total monetized flexibility	This KPI calculates the sum of all payments made to the aggregators for delivering flexibility. It can be calculated for an arbitrary period (week, month, demonstration).	$$CostSUM = \sum Pay_{aggr}$$ Where: $CostSUM$ is the sum of all payments for delivered flexibility to aggregators (€) and Pay_{aggr} is the individual payment for flexibility to the aggregator (€).
KPI_N43 / Success of local flexibility market platform test	Validate the demand response mechanism to prevent congestion in the distribution grid. Test flexibility products to prevent congestion in the distribution grid under market conditions.	$$Platform\_test = \begin{cases} Success\ (if\ all\ test\ are\ OK) \\ Fail\ (if\ all\ tests\ are\ not\ OK) \end{cases}$$

4.3.2.1 Northern cluster

The KPIs computed for the Finnish case refer only to the ST-P-E product demonstrations in which two real FSPs participated. A total of 6150kW of flexibility bid volume was cleared to resolve the network congestions. The flexibility procured through the ST-P-E product was coordinated and utilized by both the TSO and the DSO networks. Among other virtual/simulated bids, the coordination platform cleared half of the bids from one FSP and all the bids from the other one, in separate market runs.

The missing values for the Northern cluster's KPIs will be included in the second version of deliverable D11.1.

Table 4.25: Northern cluster – Calculated values of market platforms and economic performance assessment KPIs

KPI ID / KPI Name	Calculated values (Target values)			
	Finland	Estonia	Latvia	Lithuania

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KPI_N01 / Number of implemented cross border products	1 (1)	3	2	0
KPI_N02 / Number of implemented joint products	2 (2)	2	1	1
KPI_N05 / Ratio of successful bid	0.5, 1* * The two values correspond to the two FSPs that participated in the demo activities		N/A	
KPI_N10 / Minimizing the number of new products	2 (2)	2	3	2
KPI_N11 / Rate of the secondary contract to the requested one			N/A	N/A

4.3.2.2 Spanish demo

The ICT costs include developments that need to be done from the market operators' and DSOs' point of view, probably on a scale of tens of millions €, to adequately adapt their control systems and planning and operation tools.

Regarding the number of products per demo KPI, all initially targeted products were tested during the demo activities, thus the resulting value is 100%. One test was conducted for the corrective local active product, 6 tests for predictive short-term local active products and 3 tests for predictive long-term local active products.

Table 4.26: Spanish demo – Calculated values of market platforms and economic performance assessment KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_H04 / ICT costs	10 M€ (>0)
KPI_H11 / Number of products per demo	100% (100%)

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4.3.2.3 Portuguese demo

The ICT costs represent the system development and management costs required to allow the DEPs to be up and running. The calculated value for this KPI is 184k€ and corresponds to the expenses related to all the tests conducted. Since there were no such systems deployed in real operations, the value was calculated considering a baseline of zero and the result is within the initial expectation. It needs to be noted here, that the assumption that the costs for the Azure (from the DSO side) and AWS (from the TSO side) systems are only foreseen by the end of the year was made for the demonstration purposes, so, in the event of a roll-out of the solution, these costs would increase.

Table 4.27: Portuguese demo – Calculated values of market platforms and economic performance assessment KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_H04 / ICT costs	184k€ (100k€-200k€)

4.3.2.4 Slovenian demo

Table 4.28: Slovenian demo – Calculated values of market platforms and economic performance assessment KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_N40 / Volume of total monetized flexibility	1474 kWh (<10.000€)
KPI_N43 / Success of local flexibility market platform test	The platform's activation module is now fully automated and successfully running. Result: Success (Success)

4.3.2.5 Polish demo

The resulting value for KPI "Flex volume offered by FSP vs Flex request by DSO" in the Polish demo is considered really positive, as the volume of flexibility offered by the FSPs was more than enough to cover the DSO's request.

Table 4.29: Polish demo – Calculated values of market platforms and economic performance assessment KPIs

KPI ID / KPI Name	Calculated values (Target values)

KPI_H10 / Flex volume offered by FSP vs Flex request by DSO	107,1% (100%)

4.3.2.6 Hungarian demo

The average bid value for the Hungarian demo will be provided in the second and final version of deliverable D11.1.

Table 4.30: Hungarian demo – Calculated values of market platforms and economic performance assessment KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_H08 / Bid statistics (Bid Min Max Average values)	Min bid value: 0 €/kWh Max bid value: 0,651 €/kWh Average bid value:

4.3.3 Customer engagement (-centric) performances

This subsection concerns the OneNet KPIs that are related to the customer engagement (-centric) performances in the different demonstrators. Table 4.31 includes the two KPIs selected for this topic, as well as a description and the calculation formula for each one. Below, in Table 4.32 the calculated values for each KPI are presented, alongside a commentary on the results and the overall performance of each demonstrator regarding its ability to connect and resonate with its clientele.

It is important to note here that most of the demonstrators did not adopt KPIs related to the customer engagement (-centric) performances, other than the common KPIs that are relevant to this macro-area and were analyzed in Section 4.1. This is why most demonstrators are not mentioned at all in this section.

Table 4.31: Customer engagement (-centric) performances KPIs

KPI ID / KPI Name	KPI Description	KPI Formula
KPI_H22C / Number of certified DERs for at least one flexibility product	Total number of DERs representing certified resources on the flexibility platform, ready to service, for one or more flexibility products.	$N_{DER,cer}$ Where: $N_{DER,cer}$ is the number of certified DERs.
KPI_N47 / Increase in flexibility providers (units)	The implementation of the IT market platform will enable an increased number of participants (units) in providing flexibility. Recently, only major	$INFFP = \frac{N_{FSP}(platform)}{N_{FSP}} \cdot 100$

	resources are involved in case flexibility is needed, as DSOs are not aware of the potential of smaller aggregated resources and thus, this potential is not known and used. The IT platform will make this potential available and enable the participation of new resources in the market.	Where: $INFFP$ is the increase in flexibility providers (units) (%), N_{FSP} is the number of flexibility providers that are eligible according to recent conditions and $N_{FSP}(platform)$ is the number of providers for aggregated flexibility after the implementation of the market platform.

The KPI "Number of certified DERs for at least one flexibility product" was calculated by the Polish demo , while the KPI "Increase in flexibility providers (units)" was calculated in the context of the Czech demo. For both cases the results are very positive, as the target values have been surpassed significantly. For the KPI "Increase in flexibility providers (units)" only the increase of major units/aggregated units was considered and not all the units involved.

Table 4.32: Polish and Czech demos – Calculated values of consumer engagement (-centric) performances KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_H22C / Number of certified DERs for at least one flexibility product	60 (28)
KPI_N47 / Increase in flexibility providers (units)	521% (25%)

4.3.4 ICT and data processing performances

This subsection concerns the OneNet KPIs that are related to the ICT and data processing performances in the different demonstrators. Table 4.33 includes all the KPIs selected for this topic, as well as a description and the calculation formula for each one. Later on, the calculated values for each KPI are presented per demonstration, alongside an extensive commentary on the results and the overall performance of each demonstrator regarding its prowess in harnessing information technology and data to meet its objectives.

It needs to be noted here that the Czech demo did not adopt any KPIs related to ICT and data processing performances. This is why it is not mentioned at all in this section.

Table 4.33: ICT and data processing performances KPIs

KPI ID / KPI Name	KPI Description	KPI Formula
KPI_H20A / Error of the RES production	The accuracy of power production prediction largely affects the performance of the	$RES_{FA_{24h}} = \frac{1}{N}\left(\sum_{t=1}^{N}\left\lvert\frac{FC_{RES_{prod,t}} - RL_{RES_{prod,t}}}{RL_{RES_{prod,t}}}\right\rvert\right) \cdot 100$

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forecast calculated 24 hours in advance	DSO and the TSO in using flexibility services. The KPI reflects on the accuracy of DSO and TSO flexibility providers production predictions by calculating the ratio and volume of expected and actual power production.	Where: $RES_{FA_{24h}}$ is the accuracy of the RES production forecast calculated 24 hours in advance (%), $FC_{RES_{prod}}$ is the RES production estimated 24 hours in advance (MW), $RL_{RES_{prod}}$ is the real RES production (MW) and N is the number of available data points.
KPI_H20B / Error of load forecast	The accuracy of demand prediction largely affects the performance of the DSO and the TSO in using flexibility services. The KPI reflects on the accuracy of DSO and TSO flexibility demand predictions by calculating the ratio and volume of expected and actual flexibility service needs.	$$Load_{FA_{24h}} = \frac{1}{N}\left(\sum_{t=1}^{N}\left\|\frac{FC_{load,t} - RL_{load,t}}{RL_{load,t}}\right\|\right) \cdot 100$$ Where: $Load_{FA_{24h}}$ is the error of the load forecast calculated 24 hours in advance (%), FC_{load} is the load estimated 24 hours in advance (MW), RL_{load} is the real load (MW) and N is the number of available data points.
KPI_H21B / Share of false positive and negative congestion forecasts	The ratio between incorrectly forecasted congestions and the total number of forecasted congestions.	$$FFC_{\%} = \frac{C_{fc,c}}{C_{fc}} \cdot 100$$ Where: $FFC_{\%}$ is the share of false positive and negative congestion forecasts (%), $C_{fc,c}$ is the number of false positive and negative congestion forecasts, so congestions forecasted where analysis of the measurements indicates that no congestions would have occurred, even if no curative actions were taken by the DSO and the TSO (i.e., flexibility used) and C_{fc} is the total number of forecasted congestions.
KPI_N06 / Accuracy of flexibility activation	This indicator illustrates the accuracy of the FSP process in predicting the available flexibility. For this purpose, it measures the average deviation of activated flexibility resources compared to the bid.	$$AFP_{\%} = \sum_{k=1}^{n}\frac{P_{ac,k} - P_{bid,k}}{P_{bid,k}} \cdot 100$$ Where: $AFP_{\%}$ is the accuracy of the flexibility prediction (%), $P_{ac,k}$ is the power of the activated flexibility in the k^{th} trade (kW), $P_{bid,k}$ is the power of the bided flexibility for the k^{th} trade (kW) and n is the number of trades.
KPI_N07 / Activation delay	The activation speed of the flexibility resource is one of the essential aspects defined in the product specification. The activation time depends on the nature of the resource, the performance of all platforms, the connection of the FSP and the control methodology.	$$AD = Mean(\,T_{ac} - \,t_{re})$$ Where: AD is the activation delay (min), T_{ac} is the time when the requested change is adopted by the flexibility resource (min) and t_{re} is the time that the SO requested activation of a flexibility product (min).
KPI_N08 / Level of	The flexibility register facilitates the preparation of	$$LA_{\%} = \frac{N_{p,a}}{N_p} \cdot 100$$

automation of SUC process steps	FSPs and their resources before the market phase can start. This process has many steps, many of which might require manual tasks from different parties. The aim of the process definitions has been to automatize these processes.	Where: $LA_{\%}$ is the level of automation, $N_{p,a}$ is the number of automatized process steps (use case steps) and N_p is the number of process steps.
KPI_N09 / Verification method accuracy	The aim is to assess the accuracy of the reference value (e.g., computed baseline) compared to the energy/power injected into the grid, when no flexibility activation was conducted.	The mean absolute error (MAE) and the root mean square error $(RMSE)$ of the verification method are calculated by the equations: $$MAE = \frac{1}{n}\sum\lvert e_t\rvert$$ and $$RMSE = \sqrt{\frac{1}{n}\sum e_t^2}$$ Where: t is the settlement period, n is the number of settlement periods considered and e is the error, namely the difference between the baseline value and the energy/power measurement (with no dispatch).
KPI_N12 / Speed of grid qualification algorithm	Grid qualification algorithm should deliver the results as soon as required.	$$SGQ = \frac{t_p}{t_a}$$ Where: SGQ is the speed of the grid qualification algorithm, t_p is the planned time for the results' delivery (s) and t_a is the actual time of the results' delivery (s).
KPI_N13 / Speed of Bid optimization algorithm	Bid optimization algorithm should deliver the results as soon as required.	$$SBO = average\left(\frac{t_a}{t_p}\right)$$ Where: SBO is the speed of the bid optimization algorithm, t_p is the planned time for the results' delivery (s) and t_a is the actual time of the results' delivery (s).
KPI_N21 / Voltage magnitude and angle error	This indicator provides information about the estimation accuracy of the real-time monitoring scheme. It is calculated as the difference between the actual and the estimated voltage and angle (provided by the monitoring scheme). This KPI will assess the accuracy of the monitoring scheme by comparing the estimated voltage magnitude and angle with the actual ones. It should be noted that the actual	$$V_{error} = \sum_{i=1}^{N}\lvert V_{act}^i - V_{est}^i\rvert$$ and $$\theta_{error} = \sum_{i=1}^{N}\lvert \theta_{act}^i - \theta_{est}^i\rvert$$ Where: $V_{error}, \theta_{error}$ are the estimation error of the voltage magnitude (p.u.) and angle (°) respectively, N is the number of buses in the system, $V_{act}^i, \theta_{act}^i$ are the actual voltage magnitude (p.u.) and voltage angle (°) respectively of the i^{th} bus and $V_{est}^i, \theta_{est}^i$ are the estimated voltage magnitude (p.u.) and voltage angle (°) respectively of the i^{th} bus.

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	voltage magnitude and angles of the buses are known since the Cypriot demo is based on dry run simulations using the real time simulator.	
KPI_N22 / Calculated limits deviation	This indicator provides information about the calculation accuracy of the limits extracted from the SUC. As an indicator for the accuracy, the deviation (in percentage) that the calculated limits have from the actual limits in the HV/MV and MV/LV interface will be extracted. This KPI is related to the SUC that calculates the operational limits of the HV/MV and MV/LV interface in order to ensure the safe operation of the Cyprus transmission and distribution grid. These limits will be calculated for a specific time interval ahead in order to be respected by the energy markets when they are cleared. This KPI will show the maximum deviation of the calculated limits from the real ones by comparing them with the limits that the power system actually has at the corresponding operation time that the limits were calculated.	$$LD = max\left[\frac{\lvert L_{act}(k) - L_{cal}(k)\rvert}{L_{act}(k)}.100\right]$$ Where: LD is the maximum deviation of the calculated operational limits from the actual ones for a specific time interval (%), $L_{act}(k)$ is the actual operational limits of the HV/MV or MV/LV interface that the system has at the k^{th} sample (kV or kA) and $L_{cal}(k)$ is the calculated operational limits of the HV/MV or MV/LV interface extracted by the SUC for the k^{th} sample (kV or kA). These operational limits are calculated a certain time interval before the k^{th} sample.
KPI_N23 / Number of successfully predicted hazardous power system regimes and cyber threats	Early warning on a hazardous power system regimes rate. This indicator shows how efficient the identification of the hazardous power system state is and how much in advance, time wise, it is given.	$$CFC_{\%} = \frac{C_{fc,c}}{C_o} \cdot 100$$ Where: $CFC_{\%}$ is the share of successfully predicted hazardous power system regimes and cyber threats (%), $C_{fc,c}$ is the number of hazardous power system regimes correctly forecasted and C_o is the number of situations where analysis of the measurements indicates that hazardous power system regimes occurred or would have occurred if no curative actions were taken by the DSO/TSO (i.e., flexibility used).
KPI_N24 / Number of successfully predicted	It is very important to have, as much as possible, precise information on grid reliability and reliability of each PS	$$CFC_{\%} = \frac{C_{fc,c}}{C_o} \cdot 100$$ Where:

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severe weather conditions	element. The appearance of ice or storms can cause unplanned outages and severe damages to the grid directly influencing the power system flexibility needs and the possibility of the transmission system and/or the distribution system to service those needs.	$CFC_{\%}$ is the share of successfully predicted severe weather conditions (%), $C_{fc,c}$ is the number of severe weather conditions correctly forecasted and C_o is the number of situations where weather data analysis indicates that severe weather conditions occurred.
KPI_N26 / Tracked flexibility	Number of tracked flexibility activations automatically or manually triggered.	$$NAa_{Flex}$$ Where: NAa_{Flex} is the number of tracked flexibility activations.
KPI_N28 / Maximum ratio of false positive and negative congestion forecasts	The maximum ratio of the incorrectly forecasted power congestions versus the total power of congestions forecasted.	$$FFCmax_{\%} = Max\left(\frac{P_{fc,c}}{P_{fc}} \cdot 100\right)$$ Where: $FFCmax_{\%}$ is the maximum ratio of false positive and negative congestion forecasts (%) $P_{fc,c}$ is the amount of power of false positive and negative congestion forecasts, so congestions forecasted where analysis of the measurements indicates that no congestion would have occurred, even if no curative actions were taken by the DSO and the TSO (i.e., flexibility used) and P_{fc} is the total amount of power of forecasted congestions.
KPI_N33 / Improvement of the Forecast	This indicator measures the improvement of forecast value after the information exchange. The TSO currently has generation and load forecasts, short circuit levels which include embedded generation for which it does not have visibility. With information exchange the TSO has a better dataset as it is complemented with data from the DSO regarding the distribution grid outside of the TSO/DSO observability area. It is expected that these extra data will contribute to a better forecast.	$$IF_{\%} = \frac{value_{after\ information\ exchange}}{value_{before\ information\ exchange}} \cdot 100$$ Where: IF is the Improvement of the Forecast (%), $value_{after\ information\ exchange}$ is the forecast's accuracy when extra data from the information exchange between the TSO and the DSO is used in the forecast (W, Var, A) and $value_{before\ information\ exchange}$ is the forecast's accuracy when no data is exchanged between the TSO and the DSO (W, Var, A).
KPI_N36 / Average runtime of aggregated network offer algorithm	This KPI evaluates how long it takes to create an Aggregated Network Offer.	$$AR_{OA} = \frac{\sum_i runtime}{number\_of\_calls}$$ Where: AR_{OA} is the average runtime of the aggregated network offer algorithm (s) and $runtime$ is measured in seconds.

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KPI_N41 / Average time needed for prequalification of a unit	Unit prequalification has to be fast. This is why the averaged time for prequalification is calculated with this KPI.	$$ATime = \frac{\sum_{1}^{N_{units}} T_i}{N_{units}}$$ Where: $ATime$ is the average time needed to prequalify a unit (days), N_{units} is the total number of prequalified units and T_i is the number of days needed to prequalify an individual unit.
KPI_N42 / Percentage of successful automatic alignment processes	This KPI estimates the percentage of successful automatic alignment processes, based on the manual alignments needed after activation and the total number of activations.	$$AUT\_AL_{succ} = \left(1 - \frac{M_{AL_{num}}}{ACT_{num}}\right) \cdot 100$$ Where: AUT_AL_{succ} is the indicator showing the percentage of successful automatic alignment processes (%), $M_{AL_{num}}$ is the number of manual alignments needed after activation and ACT_{num} is the total number of activations.
KPI_N45 / Total Computational Runtime	This indicator measures the execution time of market clearance under different coordination schemes.	$$RT = T_{final} - T_{initial}$$ Where: RT is the total computational runtime (s), $T_{initial}$ is the time at the end of running the algorithm (s) and T_{final} is the time at the beginning of running the algorithm (s).

4.3.4.1 Northern cluster

The KPI values listed under the Finnish case correspond to the ST-P-E product demonstration only. Activation delay is not applicable for the ST-P-E product attributes. The speed of the market clearing algorithm is expressed by t_a (in deliverable D2.4) which refers to the actual time of results delivery to the concerned MO. The total market clearing time was 0,0468s, including grid qualification as well. The time t_a is not benchmarked yet (t_p) at this time of the demonstration. Lastly, the automation for FSP preparation before the start of the market trading phase will be sought in the NRT-P-E product demonstrations.

The missing values for the Northern cluster's KPIs will be included in the second version of deliverable D11.1.

Table 4.34: Northern cluster – Calculated values of ICT and data processing performances KPIs

KPI ID / KPI Name	Calculated values (Target values)			
	Finland	Estonia	Latvia	Lithuania
KPI_N06 / Accuracy of flexibility activation			N/A	

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KPI_N07 / Activation delay	N/A		N/A	
KPI_N08 / Level of automation of SUC process steps	0	>90%		
KPI_N09 / Verification method accuracy			RMSE<0,2	
KPI_N12 / Speed of grid qualification algorithm	t_a=0,0468s			
KPI_N13 / Speed of Bid optimization algorithm	t_a=0,0468s		SBO<1,0s	

4.3.4.2 Greek demo

Since the two KPIs related to the number of successfully predicted severe weather conditions, hazardous power system regimes and cyberthreats are also part of the Southern cluster regional BUC, comments regarding the results were made in Section 4.4.2.

Regarding KPI_H20A "Error of the RES production forecast calculated 24 hours in advance", the results in the Greek demo have been obtained by using the developed ANN method for the forecast of the renewable energy sources production, considering a time horizon of 168 hours into the future. This kind of generation power forecast has been done for the period from the 7th of January 2023 to the 14th of January 2023, allowing its further comparison with the actual measured values of the same parameter. During this analysis, four separate renewable energy sources have been taken into consideration, as listed below:

- SPP Arcadia (installed capacity of 4,403 MW)
- SPP Messhnia (installed capacity of 11,963 MW)
- WPP Elliniki (installed capacity of 5,95 MW)
- WPP Enel (installed capacity of 7,2 MW)

The obtained findings are crucial for the rest of the demonstration outcomes as they gave an unprecedently accurate base for further investigations of application in congestion management, mFRR and aFRR dimensioning and activations, as well as within the other weather-forecasting-related improved transmission and distribution system planning and operation processes. The error (MAPE) could be calculated for these 168 hours for each of the WPPs and SPPs. By that, it was calculated that the average error for WPP Elliniki was equal to 3%, for WPP

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Enel equal to 1%, for SPP Arcadia equal to 1% and for SPP Messhnia it was around 4%. As a benchmark, the MAPE of the WPP forecast (market schedules) is typically around 9% and for the SPP forecast, it is typically between 5% and 10%, highlighting the improvement made by the usage of ANN methods. Also, if these 7 days are observed accumulatively from the point of view of the failures in the production planning, it can be seen that the cumulative error for the ANN amounted to 0,488 MW for WPP Elliniki, -0,534 MW for WPP Enel, -0,2025 MW for SPP Arcadia and -4,107 MW for SPP Messhnia.

From the aspect of energy balancing and long-term plans, the ANN provided very good results. The observation that can be made from the results is that the ANN forecasting method can be used efficiently and reliably for both of the main types of renewable sources by monitoring the changes in the production more accurately and therefore generate a more realistic production plan than any classic planning technique.

Table 4.35: Greek demo – Calculated values of ICT and data processing performances KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_H20A / Error of the RES production forecast calculated 24 hours in advance	3% for WPP Elliniki, 1% for WPP Enel, 1% for SPP Arcadia and 4% for SPP Messhnia Total average: 2,25% (<6%-8,5%).
KPI_N23 / Number of successfully predicted hazardous power system regimes and cyber threats	-
KPI_N24 / Number of successfully predicted severe weather conditions	-

4.3.4.3 Cypriot demo

KPI "Voltage magnitude and angle error" provides information about the estimation accuracy of the real-time monitoring scheme. It is calculated as the difference between the actual and the estimated voltage and angle (provided by the monitoring scheme). In the Cypriot demo the monitoring scheme was applied to both the transmission and distribution grids and was intended to provide the operating conditions of the grid through the processing of measurements. In the case of the transmission grid both voltage magnitudes and voltage angles for all 58 buses were provided, while in the case of the distribution grid only the voltage magnitude was estimated for all 20 buses, since the angles do not deviate a lot from the reference bus. The accuracy for both the transmission and the distribution grid monitoring schemes is very high, since the voltage magnitude errors are in the range of 10^{-4} and 10^{-3} respectively, while the angle error is less than 0,1° (for the transmission grid). It should be noted that the results were obtained by running the estimator in both grids for 1 day. In the case of the distribution grid the small deviation from the target value, which was in the range of 10^{-4}, is due to the fact that the smart meters have lower accuracy in comparison to the PMU measurements (transmission grid). Thus,

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the lower quality (in terms of accuracy) in the smart meter measurements is reflected to the accuracy of the state estimation.

KPI "Calculated limits deviation" provides information about the calculation accuracy of the limits extracted from the prequalification tool. This tool provides the limits of the HV/MV interface in order to ensure that the transformer limits will not be violated in case frequency support is provided by the DERs in the distribution grid. The prequalification tool provides the operational limits to the FCR market one hour before the clearing of the market. This KPI shows the accuracy of the prequalified limits in each hour by comparing the prequalified limits (that were provided one hour ago) with the actual limits of the transformer at each hour. The KPI was calculated in the case of an under-frequency event scenario and the maximum LD, considering a three-hour period, was around 1,87%. This shows that the limits provided by the prequalification tool are quite accurate, although they are calculated one hour before the market clearing.

Table 4.36: Cypriot demo – Calculated values of ICT and data processing performances KPIs

KPI ID / KPI Name	Calculated values (Target values)		
KPI_N21 / Voltage magnitude and angle error	Scenario	Voltage magnitude error results	Voltage angle error results
	Transmission grid	3,32 x 10^{-4} p.u. (in the order of 10^{-4} p.u.)	0,02° (in the order of 0,1°)
	Distribution grid (MV)	4,8 x 10^{-3} p.u. (in the order of 10^{-4} p.u.)	-
KPI_N22 / Calculated limits deviation	1,87% (10%)		

4.3.4.4 Spanish demo

In general the calculated KPI values show very positive results in terms of the error of the load forecast compared to the initial target values, meaning that in most cases the forecast was very accurate. The highest error of the load forecast is observed in the Long-term Murcia scenario, where the forecasted load was 36% above the real one. The error in this scenario was much higher compared to all other tested scenarios, due to the fact that loads from university buildings have higher variability and uncertainty than industrial loads that have a more stable energy consumption. The lowest error of the load forecast is observed in the Short-term day ahead Murcia scenario (1,2%). On average the error of the load forecast was approximately 9,6% among the different tested scenarios.

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Table 4.37: Spanish demo – Calculated values of ICT and data processing performances KPIs

	Calculated values (Target values)
KPI ID / KPI Name **Scenario**	KPI_H20B / Error of load forecast
Short-term day ahead Murcia scenario	1,2% (as close to 0 as possible)
Short-term intraday Murcia scenario	2,4% (as close to 0 as possible)
Long-term Murcia scenario	36% (as close to 0 as possible)
Short-term day ahead Madrid (30 min – test 1) scenario	14% (as close to 0 as possible)
Short-term day ahead Madrid (30 min – test 2) scenario	11% (as close to 0 as possible)
Short-term day ahead Madrid (1h) scenario	9% (as close to 0 as possible)
Long-term day ahead Alcalá de Henares I scenario	4,6% (as close to 0 as possible)
Long-term day ahead Alcalá de Henares II scenario	4,7% (as close to 0 as possible)
Short-term day ahead Alcalá de Henares I scenario	3,2% (as close to 0 as possible)
Short-term day ahead Alcalá de Henares II scenario	9,6% (as close to 0 as possible)

4.3.4.5 Portuguese demo

For both SUC-PT-07 test rounds the data on consumption and generation forecasts were successfully exchanged from the DDEP to the TDEP. Considering that no congestions were forecasted, both KPIs related to the false-positive and negative congestion forecasts have a value of 0. For the rest of the KPIs that have a non-zero value the results are really promising as all target values have been reached.

In the Batalha test round, exchanging information allowed for an improvement in the error of the RES production forecasts for solar, wind and thermal generation in the substation, with the average errors being 1,9%, 7,46% and 4,49%, respectively. The respective average errors of the two system operators before the exchange of information were 7,82%, 15,34% and 15,35%. The error of the load forecast (calculated 24h in advance) for the Batalha substation, after the information was exchanged, had a maximum value of 6,6%, a minimum value of 2,9% and an average value of 4,8% between all the scenarios tested. Before the information exchange the maximum error was 11%. The solar and thermal generation forecasts improved the most (74,19% and 80,69%, respectively), while the wind and load forecasts were only improved on average by 3% and 7,2%, respectively. In the best scenario, the load forecast for the Batalha substation was improved by 50% due to the information exchange implemented in the SUC.

In the Pocinho test round, exchanging information allowed for an improvement in the error of the RES production forecasts for solar and wind generation, with the average errors being 4,37% and 5,73%, respectively.

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The respective average errors of the two system operators before the exchange of information were 8,2% and 10,33%. Thermal and hydro analysis were not included, due to data quality problems during the period of the demonstration. The error of the load forecast (calculated 24h in advance) for the Pocinho substation, after the information was exchanged, had a maximum value of 56,8%, a minimum value of 2,5% and an average value of 20,2% between all the scenarios tested. Before the information exchange the maximum error was 182%. This result is atypical, because during the demo phase there were maintenance works in this substation that created outliers in the forecast and consequently in the real data. For this reason, these KPIs were really affected because the prediction algorithms had not accounted for a change like this in the consumption profile of the substation caused by load transfer.

Table 4.38: Portuguese demo – Calculated values of ICT and data processing performances KPIs

	Calculated values (Target values)				
KPI ID / KPI Name / **Test round**	KPI_H20A / Error of the RES production forecast calculated 24 hours in advance	KPI_H20B / Error of load forecast	KPI_H21B / Share of false positive and negative congestion forecasts	KPI_N28 / Maximum ratio of false positive and negative congestion forecasts	KPI_N33 / Improvement of the Forecast
SUC-PT-07 Batalha	• Solar: 1,9% (<7,87%) • Wind: 7,46% (<7,58%) • Thermal: 4,49% (<24%)	4,8% (<5,55%)	0% (0%)	0% (0%)	• Solar: 74,19% (>0%) • Wind: 3% (>0%) • Thermal: 80,69% (>0%) • Load: 7,2% (>0%)
SUC-PT-07 Pocinho	• Solar: 4,37% (<11,64%) • Wind: 5,73% (<7,24%)	20,2% (<54,84%)	0% (0%)	0% (0%)	• Solar: 66,42% (>0%) • Wind: 20,42% (>0%) • Load: 36,6% (>0%)

4.3.4.6 French demo

Inside the concerned region in the French demo automated orders are the main source of activations since each NAZA algorithm's decision induces several orders to resources (usually connected to the DSO network). Regarding the tracked flexibility, the final number of activations (216) is much higher than the target value, because it was originally not planned to consider sub-orders to the DSO sites in the computation. These were eventually taken into account to give more detail on the results. The total number of activations is aligned with what was envisioned in the experiment, after the decision to include sub-orders was made.

Table 4.39: French demo – Calculated values of ICT and data processing performances KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_N26 / Tracked flexibility	213 orders automatically triggered – 3 to RTE's producers and 210 to Enedis' producers 3 orders manually triggered from Enedis Total: 216 (7-15)

4.3.4.7 Slovenian demo

Table 4.40: Slovenian demo – Calculated values of ICT and data processing performances KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_N41 / Average time needed for prequalification of a unit	7 days (<30 days)
KPI_N42 / Percentage of successful automatic alignment processes	100% (>90%)

4.3.4.8 Polish demo

The aggregated network offer algorithm (AGNO) was the main tool used in the Polish Demo to verify the impact of offers on network operation and to select the optimal set of offers for balancing services. The algorithm used network calculations based on network models provided by the DSO to verify network security. The AGNO is a highly complicated Python-written algorithm. Due to the characteristics of Python, there was a need to provide sufficient hardware, specifically in terms of CPU cores. When performing tests before the demonstration, a CPU with 4 cores had been used and calculations of AGNO were performing for even dozens of hours. Equipped with more knowledge, production hardware has been set up with 16-core CPU, which made it possible to reach the levels of runtime described above. For the partners of the Polish demonstrations these runtimes were sufficient, and it was confirmed that the speed of calculations is dependent from the hardware used – mainly from the number of CPU cores.

Table 4.41: Polish demo – Calculated values of ICT and data processing performances KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_N36 / Average runtime of aggregated network offer algorithm	335 sec for the AGNO for DGIA algorithm and 53 sec for the AGNO for reserves algorithm Total average: 194 sec (short enough to be able to submit bids to BM before gate closure time)

4.3.4.9 Hungarian demo

The assessment for KPI_N45 Total Computational Runtime will be provided in the second and final version of deliverable D11.1.

Table 4.42: Hungarian demo – Calculated values of ICT and data processing performances KPIs

KPI ID / KPI Name	Calculated values (Target values)
KPI_N45 / Total Computational Runtime	27,611 sec

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5 KPIs calculation criticalities, cybersecurity challenges and countermeasures

In the context of Task 2.4 [19], the definition of the KPIs to be used in OneNet took place, where both demo-specific and regional (cluster) KPIs were defined to assess, respectively, the impact of each demonstrator separately and the impact of the project's clusters on a European scale. After the selection of KPIs to be calculated by each pilot, a survey was conducted, in which the demo representatives were asked to identify possible foreseen criticalities regarding the calculation of each KPI and to propose mitigation measures in order to avoid them. Additionally, the common template document that was distributed for the characterization of each demonstrator, included a section addressing the cybersecurity challenges that were encountered by each demo and the countermeasures that were taken to overcome them.

In order to be able to make comparisons more accurately between the demos and to have a better understanding of the challenges encountered by the OneNet project as a whole, in regard to the KPIs calculation, a mapping of the identified criticalities took place so as to group those that were common or similar between the demos. In the end, 20 different criticalities were identified and are presented in Table 5.1 below:

Table 5.1: Identified criticalities in OneNet regarding the calculation of KPIs

Criticality ID	Description	Demonstrators
C#1	**Reducing the entry barriers for flexibility provision and simplifying the process for flexibility service providers is not easy to measure.** Thus in practice the calculated number of FSPs within the demos will just be an indicator. In this context, the estimation of FSPs' engagement can deviate from the ultimately achieved number. A more detailed analysis of the barriers to engage FSPs can be found in D11.6 [16].	Northern cluster, Portuguese, French, Czech
C#2	These demos will demonstrate a new market structure and new flexibility products. Thus, **it is challenging to define KPIs evaluating the successfulness of this new market structure** (e.g., volume of transactions, number of conflicts due to activation, cross-border products, etc.), that can be measured and have meaningful baselines and target values. This is due to the absence of benchmarks that can be used to assess the progress of these new structures. Moreover, the definition of the examined period can be challenging.	Northern cluster, Spanish, Hungarian, Czech
C#3	These demos develop new platforms, which aim to coordinate several players and remove the barriers for FSPs to participate in the flexibility provision, utilizing the OneNet reference platform. In this context, **the baseline values of some data processing KPIs** (e.g., ratio of successful bids, activation delay, flexibility prediction, tracked flexibility) **do not exist and the target values for others cannot be precisely estimated.** This is due to the absence of historical data that can be used as benchmarks.	Northern cluster, French, Czech

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C#4	There are quite a few harmonized products that need to cover all SO needs. **Gathering all SOs' needs and analyzing them, in order to calculate the number of products demonstrated in the demos, is not a straightforward task.**	Northern cluster
C#5	**The calculation of KPIs evaluating the accuracy of the forecasts** (e.g., load forecasts, production forecasts, severe weather event predictions) **is based on the availability of data from DSOs and TSOs**, which poses a risk since to limited data availability due to data privacy concerns.	Greek, Cypriot
C#6	**The definition of the baseline for the calculation of KPIs related to ICT costs can be challenging**, since the costs of the existing equipment for data exchange between the DSO and the TSO cannot be easily calculated, due to privacy issues that the ICT teams of the DSOs and TSOs are subject to.	Portuguese, Czech
C#7	**The calculation of ICT costs requires the definition of a specific area to be considered**, which can be challenging (to identify only necessary market developments).	Spanish, Portuguese
C#8	**The calculation of some KPIs**, such as the number of congestions/violations on the DSO/TSO network, the accuracy of forecasts, etc., **can be hindered by cybersecurity issues related to the exchange of information**, which comes from the most critical systems for network operation, between DSO and TSO companies.	Portuguese
C#9	**The challenges for the calculation of the KPI "Cost-effectiveness" are the selection of the factors to be considered** for the calculation of the avoided traditional cost at each location and the definition of the methodology.	Spanish, Czech
C#10	The calculation of the KPI "Error of load forecast" is based on the forecasting tools. **The foreseen criticality is on the computation of such forecasts.**	Greek, Spanish, Portuguese
C#11	The calculation of the KPI "Available flexibility" poses the challenge of defining a specific affected area.	Greek, Spanish
C#12	**The calculation of the KPI "Power exchange deviation" poses the challenge of defining the established level of DER base load,** from which a delta is measured to calculate the level of delivered service (activated power). The baseline methodology is critical because payments for FSPs are directly based on the difference between the baseline and the actual metered demand. Therefore, an optimal baseline methodology is necessary to measure the effective performance of resources and to compensate the FSP adequately.	Spanish
C#13	**The calculation of the KPI "Congestion reduction (magnitude)" poses the challenge of securing enough data points** for measurement during the flexibility delivery period.	Spanish
C#14	**It is difficult to make an accurate estimation regarding the customer engagement** that is going to be achieved.	Spanish, Czech
C#15	**The calculation of KPIs related to congestion management performance**, such as the number of successfully avoided congestions during the demonstration period and the volume of activated flexibility, **is based on the accuracy of the forecasts** in regard to when the expected congestions will occur.	Greek, Slovenian

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C#16	**The calculation of the KPI "Number of avoided voltage violations" is based on the existing DSO methodology** for determining voltage increases within the demo.	Slovenian
C#17	If the operation of the national flexibility platform is delayed, quantification of the KPIs may also be delayed.	Hungarian
C#18	**For the calculation of data retrieval delay and data reliability ratio, the main challenge is in the definition of the data to be aggregated and the efficiency of the aggregation algorithm**. Also, delayed communication between the national demo and the OneNet system can be a potential risk.	Slovenian, Polish, Hungarian, Czech
C#19	**The calculation of the FSP acceptance relies on the proper surveying of participants in the cluster.** A key challenge is on how to communicate the cross-SO prequalification process in a simple, yet precise manner, so that FSPs can provide their honest opinion on how willing to be cross-SO prequalified they would be. Another challenge is on the operationalization of this survey. The involved WECL demo countries would have to implement this survey in their prequalification systems/processes.	Spanish, Portuguese, French
C#20	The demonstration focuses on new flexibility services aimed at solving congestions emerging in the near future. Real congestions are not likely addressed during the project. Thus, **measuring avoided technical constraints is not correctly focused to measure the results.**	Northern cluster

Figure 5.1 below shows how many demonstrators identified each of the 20 KPI criticalities. As can be seen, criticalities C#1 and C#2 were the ones that were reported by the biggest number of demonstrators (4), followed by criticalities C#3 and C#10, each of which was reported by 3 demonstrators.

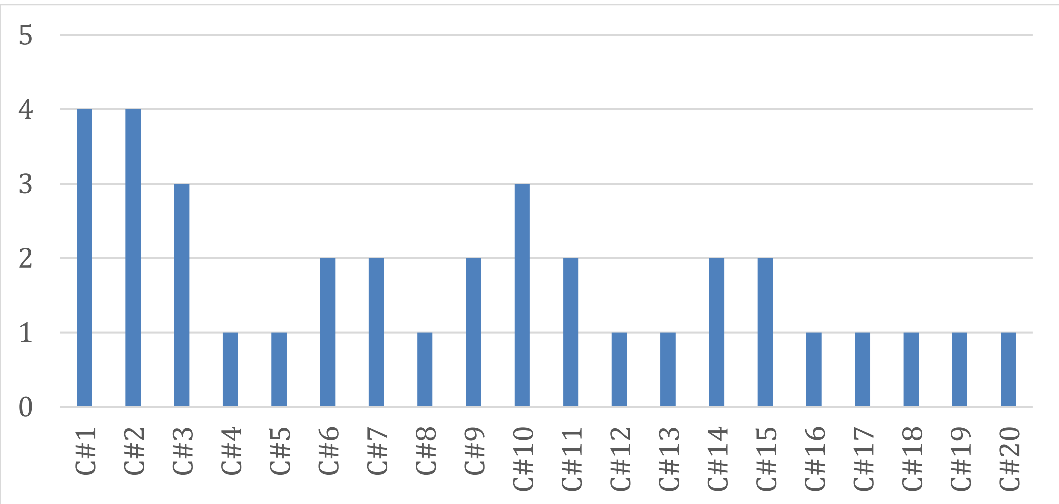

Figure 5.1: Number of demonstrators that reported each KPI criticality

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In the following sections (5.1 – 5.4), the information obtained from each demonstrator regarding these matters is presented.

5.1 Northern cluster

The proposed mitigation measures for the KPI criticalities foreseen in the Northern cluster demonstrator are presented in Table 5.2:

Table 5.2: Northern cluster demonstrator – KPI criticalities and mitigation measures

Criticality ID	Proposed mitigation measures
C#1	Defined some KPIs to measure the entry barriers for flexibility provision and the process simplification. Such as KPI "Number of FSPs".
C#2	Studied in detail the factors of influence on the KPI and investigated the results.
C#3	Studied in detail the factors of influence on the KPI and investigated the results.
C#4	Studied in detail the factors of influence on the KPI and investigated the results.
C#20	Adjusted KPI "Percentage of avoided technical restrictions (congestions)" and KPI "Percentage of avoided technical restrictions (voltage violations)" to reflect the TRL level of the demo.

The countermeasures taken preemptively by the Northern cluster demonstrator in order to address possible cybersecurity challenges during the demonstration period are presented below:

- Network segmentation: the API is running in DMZ.
- A firewall protects access to the servers and inspects packet contents (SSL termination on firewall).
- The servers regularly get security patch updates.
- There is monitoring and alerting.
- Reverse proxy on the API server only exposes HTTP port 80 for certain domain names to the outside.
- The API has an input validation layer before accepting incoming requests.

5.2 Southern cluster

5.2.1 Greek demo

The proposed mitigation measures for the KPI criticalities foreseen in the Greek demo are presented in Table 5.3:

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Table 5.3: Greek demo – KPI criticalities and mitigation measures

Criticality ID	Proposed mitigation measures
C#5	Fully defined the necessity for forecasting data. Close collaboration between the TSO and the DSO was achieved to collect and provide the requested data.
C#10	Adopted high performance forecasting algorithms.
C#11	Defined each grid segment as the area around each existing substation.
C#15	Adopted high performance forecasting algorithms. Collection of numerous data with adequately high resolution that enhance the forecasting algorithms performance.

The cybersecurity challenges encountered in the Greek demo, along with the countermeasures that were taken in order to avoid them are discussed below.

The main cybersecurity issues emerge within the data exchange processes between the TSO and the DSO. Several data, such as time series of productions and consumptions, grid models, technical parameters of assets, locational information, exchanged bids. etc., are sensitive. Towards protecting the used data, F-channel adopts a strict login identification procedure when a user accesses the data, while providing partial availability of the data based on the logged in user's ID (different data are available when someone accesses the platform as a TSO than as an FSP, an MO, etc.). In any case, the sensitive data are only available for processing purposes within the platform.

Login to the Linux server for administration purposes is only performed with public/private key encryption. Login via user/pass is disabled. Since the server is online 24/7, the main challenge identified so far is a large number of unsuccessful logins coming from suspicious IP addresses, even with disabled user/pass logins. Security settings are adjusted to block every IP address with 3 unsuccessful logins. Furthermore, the server can be set up to only be accessed from a unique IP address if needed (Server root access only via VPN).

All web admin interfaces for setting various services (Geoserver, Apache Airflow, pgadmin, etc.) are enabled only when admin settings are performed. This is due to the vulnerability of these services on user/pass logins.

User logins to the F-channel platform are foreseen through user/pass authentication, where users create their own accounts with their unique strongly encrypted password (password is known only by the end user). After all stakeholders created an account, the creation of additional accounts was disabled due to security reasons. Connecting to and exchanging data via the OneNet Connector and the F-Channel was also tested.

5.2.2 Cypriot demo

The Cypriot demo identified a single KPI criticality, for which the proposed mitigation measure is presented in Table 5.4.

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Table 5.4: Cypriot demo – KPI criticalities and mitigation measures

Criticality ID	Proposed mitigation measures
C#5	Fully defined the necessity for forecasting data. Close collaboration between the TSO and the DSO was achieved to collect and provide the requested data.

Since the Cypriot demonstration is performed in a controlled environment, no cybersecurity measures are taken for the exchange of information and co-ordination of signals between the digital twin and the ABCM-T and ABCM-D platforms. Regarding the actual prosumer who was integrated in the demo activities, HTTPS is used for communication and coordination purposes, which is an encrypted protocol.

5.3 Western cluster

5.3.1 Spanish demo

The proposed mitigation measures for the KPI criticalities foreseen in the Spanish demo are presented in Table 5.5:

Table 5.5: Spanish demo – KPI criticalities and mitigation measures

Criticality ID	Proposed mitigation measures
C#2	Clarified the KPIs definition. In those cases where the results are linked to the number of developed tests, the KPIs are representative of the demo magnitude and results.
C#7	Studied calculations done in previous projects, such as CoordiNet, in order to identify ICT developments regarding the implementation of new local markets for each of the participants and summarized them.
C#9	Used the results and calculations from previous projects, such as CoordiNet, in order to consider appropriate factors and values that change according to whether someone uses flexibility or a traditional solution.
C#10	Used historical data for forecasting.
C#11	Defined the affected area by grid modelling.
C#12	Identified and collected powered data from monitored points before, during and after the flexibility activation.
C#13	Identified and collected asset loads from monitored points before, during and after the flexibility activation.
C#14	N/A
C#19	Distributed the survey and provided instructions to the flexibility service providers which participated in the Spanish demo.

The countermeasures taken preemptively by the Spanish demo in order to address possible cybersecurity challenges during the demonstration period are discussed below.

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The platforms have been designed following OMIE's cybersecurity protocols in order to guarantee the security of shared sensitive information. To access the platforms a digital certificate or user/password credentials are required to block access of external elements to the market and keep the confidentiality of the market agent's information, according to the current regulations.

Due to the firewalls and those protocols used for security purposes, the demo experienced some issues regarding the connection through the OneNet system interfaces.

5.3.2 Portuguese demo

The proposed mitigation measures for the KPI criticalities foreseen in the Portuguese demo are presented in Table 5.6:

Table 5.6: Portuguese demo – KPI criticalities and mitigation measures

Criticality ID	Proposed mitigation measures
C#1	This criticality was addressed through the implementation of a workshop, that promoted awareness raising on FSPs.
C#6	This criticality was mitigated by considering a baseline of zero and taking into account both the costs of cloud-based infrastructure and on-premises infrastructure.
C#7	To mitigate the criticality of establishing a baseline for the ICT costs, the baseline was set to 0 and the surplus in ICT costs was calculated instead.
C#8	ICT cybersecurity best practices were taken into account, by using adequate authentication and authorization procedures.
C#10	The computation of the forecast was conducted with a specific network planning forecasting tool.
C#19	This criticality was addressed through the implementation of a workshop.

The cybersecurity challenges encountered in the Portuguese demo, along with the countermeasures that were taken in order to avoid them are discussed below.

Challenges related to firewall and proxy configurations were encountered during the deployment of the OneNet Connector. Given that the Data App and ECC ports need to be exposed to the internet, SOs' IT infrastructure administrators might consider it as a critical cybersecurity concern. Therefore, the usage of Reverse Proxy Server (NGINX), DNS and SSL was considered. In addition, HTTPS was required according to the OneNet Connector Settings page.

The IT infrastructures that AWS and Azure provide are designed and managed in alignment with the best security practices and a variety of IT security standards. In that sense, it is ensured that all TSOs' and DSOs', respectively, cybersecurity concerns and policies are taken into account.

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In both TDEP and DDEP a Token-based authentication method that generates encrypted security tokens has been implemented. This method requires users to verify their identity in order to access the APIs, which then generate a unique encrypted authentication token. That token provides users with access to protected pages and resources for a limited period of time.

Additionally, to comply with the system security policy and deploy the projects' component in a practical and flexible way, the DSO Azure cloud infrastructure was setup in a segregated corporate network and the necessary interfaces with legacy systems were created, mostly by pushing data to the systems on this network. To expose the APIs and the OneNet Connector interfaces, the DSO uses a corporate API gateway which tracks all the outbound and inbound messages. As an additional measure of security, the firewall is configured just to enable communication with the TSO resources.

All remaining cybersecurity challenges that appeared were addressed following the internal cybersecurity policies of the companies involved.

5.3.3 French demo

The proposed mitigation measures for the KPI criticalities foreseen in the French demo are presented in Table 5.7.

Table 5.7: French demo – KPI criticalities and mitigation measures

Criticality ID	Proposed mitigation measures
C#1	RTE and Enedis have organized workshops with producers to increase their engagement. Also, the STAR platform is an incentive since it eases the producers' actions and enhances their visibility.
C#3	For values such as the number of foreseen activations, which are dependent on contingencies during the monitoring period, the estimations were based on the network area's history.
C#19	N/A

The main cybersecurity challenge encountered within the French demo was related to the management of data confidentiality between actors (TSO, DSO, producer). This confidentiality issue has been managed through "Private data collection" which is a native Hyperledger fabric functionality.

5.4 Eastern cluster

5.4.1 Slovenian demo

The proposed mitigation measures for the KPI criticalities foreseen in the French demo are presented in Table 5.8:

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Table 5.8: Slovenian demo – KPI criticalities and mitigation measures

Criticality ID	Proposed mitigation measures
C#15	Accuracy of forecasts was periodically compared to actual demand, so that it could be improved.
C#16	Additional methodologies could be tested if needed.
C#18	Since the Slovenian demo reported yearly aggregated numbers, the efficiency of the aggregation algorithm and the speed of communication between the demo and the OneNet system are not of great importance.

The countermeasures taken preemptively by the Slovenian demo in order to address possible cybersecurity challenges during the demonstration period are presented below:

- The channel between the DSO (kafka) and the client (aggregator) is protected through TLS encryption. Also, SCRAM-SHA 512 is used for user authentication.
- When an aggregator bids (price for activated energy) in the CEEPS portal, he has to log in with two-factor authentication.
- Consumers can check 15 min measurements from the main meter on Moj elektro portal. For the login they use two-factor authentication.

5.4.2 Polish demo

The cybersecurity challenges encountered in the Polish demo, along with the countermeasures that were taken in order to avoid them are discussed below.

Two main cybersecurity challenges have been identified in the Polish demo. The first one regards attempts to impersonate an FSP/FSPA or a BSP during the registration process. A strict process of registration has been created in order to address this issue. The registration steps are the following:

- Firstly, the user must accept the platform and the GDPR regulations. Next, after filling in and sending the registration form, a message is sent to the email address indicated in the form.
- The user must confirm, through email, the desire to continue with the registration process.
- Then, a new registration object is created on the platform and the MO is obliged to verify the data provided by the user. If the MO does not detect any inaccuracies, the first registration form is accepted and the personal data form is sent to the user.
- The user fills in the personal data form and gains restricted access to the platform.
- The only functionality provided to the user at this stage is a chat window with the MO.
- The MO requests from the user needed documents to verify personal data and actual legal data about the user.

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- If the MO detects no inaccuracies, the user is allowed to access the platform.

The second cybersecurity challenge concerns attempts to impersonate any user on the platform, through the login process. This issue was addressed through the technology used, which is JSON Web Tokens. JWTs are used for:

- Authentication – when a user successfully logs in using their credentials, the token is returned. Every token has its own expiration date.
- Authorization – every action performed by the user on the platform (accessing views, routes, resources, etc.) can only be achieved by providing this specific JWT.
- Information exchange – every data exchange performed by a user on the platform is secured by JWT, so the identity of every user sending any streams of data is verified.

Additionally to the above-mentioned countermeasures, all production environments are restricted to HTTPS only with expirable certificates.

5.4.3 Hungarian demo

The proposed mitigation measures for the KPI criticalities foreseen in the Hungarian demo are presented in Table 5.9:

Table 5.9: Hungarian demo – KPI criticalities and mitigation measures

Criticality ID	Proposed mitigation measures
C#2	During earlier phases of the project (in WP10) the Hungarian partners have identified potential users of the flexibility platform and opted to quantify the KPIs at the start of the national flexibility platform. The KPIs were determined based on collective and realistic assessment of the market, taking into consideration the progress and feedback from the national regulatory conditions as well.
C#17	The Hungarian demonstration opted to perform the calculation of KPIs once, at the end of the demonstration period, when the national flexibility platform was operational.
C#18	The Eastern Cluster opted to use dominantly aggregated generic data on market performance, which did not necessitate taking extra measures on data sensitivity. Also, the aggregative nature of the data (e.g., total volume of trades) supported easy definition.

Since the development of the flexibility platform is not in the scope of the Hungarian demo, but only the market extensions, cybersecurity is not an issue. All communication between the DSO and the TSO goes through the OneNet platform.

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5.4.4 Czech demo

The proposed mitigation measures for the KPI criticalities foreseen in the Hungarian demo are presented in Table 5.10:

Table 5.10: Czech demo – KPI criticalities and mitigation measures

Criticality ID	Proposed mitigation measures
C#1	This was a concern at the beginning of the demo implementation. Recent data indicates that there is a positive impact of the new platform in terms of customer increase.
C#2	This is only partly relevant as there were no new products tested in the Czech demo. The positive effect of the new IT environment (platform) was measured through KPIs on customer engagement/reduced outage time.
C#3	This is correct as there is no baseline for measuring the IT platform's performance. This is why the platform's effectivity is measured through the amount of delivered active/reactive energy for example.
C#6	The ICT related costs are less relevant in this regard since the benefits of the platform are measured as discussed for C#3.
C#9	As discussed for both C#3 and C#6, benefits provided by the IT solution can be perceived through the development of the market with non-frequency services. For a number of reasons, in this case, no relevant methodologies for calculating grid-related deferred cost are available.
C#14	N/A
C#18	N/A

No cybersecurity challenges were encountered in the Czech demo.

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6 Conclusions

This report presents the evaluation of the OneNet demonstrators' results, which was based on the collection of information from the different cluster demos, and the respective conclusions that could be drawn. This is the first version of deliverable D11.1, which will be followed by a second and final one. This first version includes those demonstrators' results that were available before the official submission date of D11.1.

The OneNet demonstrations were carried out in geographically dispersed pilot sites, each one with different business objectives, which led to a variety of flexibility services and market designs being demonstrated. In addition, their grid characteristics and resources set up varied a lot. In total, 11 TSOs and 14 DSOs were involved in the OneNet demonstrations with more than 870 resources including residential, commercial and industrial resources.

Regarding the demo KPI results, which were the main focus of this deliverable, the target values set for the KPIs prior to the demonstration period were reached in the majority of the cases (approximately in 84% of the cases). For the common KPIs used among the OneNet demonstrators, the predefined target values were reached in around 78% of the cases.

Besides the common ones, the rest of the KPIs were grouped into 4 distinct categories of high interest to OneNet, namely (i) technical assessment of system service provision, (ii) market platforms and economic performance assessment, (iii) customer engagement (-centric) performances and (iv) ICT and data processing performances, in order to evaluate the demonstrations' results from a macro-area point of view. This grouping of KPIs was based on clustering the KPIs that assess relevant aspects of the performance of the demonstration activities. Nonetheless, it should be noted that this approach does not follow strict rules, meaning that some of the KPIs could pertain to more than one category. For readability purposes, however, the analysis is conducted by assigning each KPI to a single category.

The technical assessment of system service provision category includes KPIs related to the tested systems' performance in terms of reliability, stability and availability, as well as KPIs for the evaluation of the interoperability between the different solutions. The market platforms and economic performance assessment category focuses on the aspects of market participation and standardization, while also considering the economic viability and efficiency of the tested solutions. The customer engagement (-centric) performances category aims at assessing the customer engagement and involvement in the demonstration activities. Lastly, the ICT and data processing performances category delves into the accuracy, automation and promptitude of the developed ICT solutions.

The demos were most successful in terms of KPI targets achieved in the customer engagement (-centric) performances area with all the targets being reached and the ICT and data processing performances area with around 94% of targets being reached. The demos were less successful in the technical assessment of system

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service provision and the market platforms and economic assessment areas with respective percentages of roughly 80% and 88%, respectively. It should be mentioned here, though, that these performance percentages depend significantly on the number of KPIs selected for each category, which varies greatly.

Specific KPIs that stand out, in terms of demo results performance, are the ones related to the percentage of avoided technical restrictions for which all demos achieved the initially defined targets. This is also the case for the KPI measuring the available flexibility, for which the target values were reached in almost 86% of the tests. In many cases, a 100% avoidance of technical restrictions (either congestions or voltage violations) was accomplished, while for the cases in which the targets were met, the available flexibility was quite high. Some of the tests reached values as high as 80%. A less promising performance can be observed for the KPIs related to the numbers of FSPs and transactions, as only two-thirds of the demos achieved their targets. The same can be said for the two KPIs measuring the volume of transactions-cleared bids.

The analysis of the criticalities faced by the demos showed that several of them were commonly encountered, namely:

- Reducing the entry barriers for flexibility provision and simplifying the process for flexibility service providers is not easy to measure. In practice the calculated number of FSPs within the different clusters/demos will only serve as an indicator. Therefore, in this context, the estimation of producer's engagement can deviate from the ultimately achieved number.
- A new market structure and new flexibility products were demonstrated in some demos. Thus, it is challenging to define KPIs for evaluating the successfulness of this new market structures (e.g., volume of transactions, number of conflicts due to activation, cross-border products, etc.), that can be measured and have meaningful baselines and target values. Moreover, the definition of the examined period can be challenging.
- A new platform, which aims to coordinate several players while removing the barriers for FSPs to participate in the flexibility provision, was developed within some of the demos. In this context, the baseline values of some data processing KPIs (e.g., ratio of successful bids, activation delay, flexibility prediction, tracked flexibility) do not exist and the target values for others could not be precisely estimated.
- The calculation of the KPI "Error of load forecast" is based on the forecasting tools. The foreseen criticality is in the computation of such forecasts.

Finally, the most prominent cybersecurity challenges faced by the demonstrators were the sharing of sensitive information (time series of production/consumption, grid models, technical parameters of assets, locational information, exchanged bids, etc.) and data confidentiality between the different actors (TSO, DSO, FSP, BSP, etc.), as well as firewall and proxy configuration related challenges during the deployment of the OneNet Connectors.

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Annex A Complete list of OneNet KPIs

Table A. 1: Complete list of OneNet KPIs

KPI ID / KPI Name	Related BUCs and SUCs IDs	KPI Description
KPI_H01 / Number of FSPs	NOCL-BUC-01; SOCL-GR-BUC-01; SOCL-CY-BUC-01; SOCL-CY-BUC-02; WECL-ES-BUC-01; WECL-ES-BUC-02; WECL-PT-SUC-01; WECL-FR-BUC-01; EACL-SL-SUC-01; EACL-SL-SUC-02; EACL-PL-BUC-01; EACL-HU-BUC-01; EACL-HU-BUC-02; EACL-CZ-SUC-01; EACL-CZ-SUC-02	The overall progress of decreasing the entry barriers for flexibility provision by simplifying the process for FSPs can be measured by the number of FSPs joining the platform. For the Portuguese demo the overall progress of the above-mentioned aim can be measured by the number of FSPs considered and involved in the demo for testing the prequalification interactions.
KPI_H02 / Active participation	NOCL-BUC-01; WECL-ES-BUC-01; WECL-ES-BUC-02; WECL-PT-SUC-01; WECL-PT-SUC-02; WECL-FR-BUC-01; EACL-SL-SUC-01; EACL-SL-SUC-02; EACL-PL-BUC-01; EACL-HU-BUC-01; EACL-HU-BUC-02	This indicator measures the percentage of customers actively participating in the demo with respect to the total number of customers that accepted the participation. This indicator will be used to evaluate the customer engagement plan.
KPI_H03 / Cost-effectiveness	WECL-ES-BUC-01; WECL-ES-BUC-02; WECL-ES-SUC-01; EACL-SL-SUC-01; EACL-SL-SUC-02; EACL-HU-BUC-01; EACL-HU-BUC-02	Compare the cost for flexibility with the avoided traditional grid cost (Cost of the flexibility solution against traditional solution). The cost of flexibility should be less than the avoided traditional solution cost to be effective (KPI < 100). The avoided cost needs to be converted into a €/MWh·year basis and compared with the flexibility solution services for the time it will be contracted. To calculate the avoided cost, several factors need to be considered, e.g., deferred capital cost, losses, O&M costs, etc.
KPI_H04 / ICT costs	WECL-ES-BUC-01; WECL-ES-BUC-02; WECL-ES-SUC-01; WECL-PT-BUC-01; WECL-PT-BUC-02; WECL-PT-BUC-03	For the Spanish demo, the term ICT costs comprises the information and communication technologies that are necessary for DSO-MO-FSP coordination through platforms to develop new local markets. Summation of ICT costs that are directly related to the implementation of new local markets. The term implementation is used to refer to the work in designing, specifying, coding, testing, validating and

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		documenting software. It will be one for the Spanish demo, including the costs from OMIE, UFD and i-DE ICT. For the Portuguese demo, the term ICT costs comprises the information and communication technologies directly related to the implementation of the communication infrastructures between DSO and TSO.
KPI_H05 / Reduction in RES curtailment	WECL-PT-BUC-01; WECL-PT-BUC-02; WECL-PT-BUC-03; WECL-PT-SUC-02;	This indicator measures the reduction in the amount of energy from Renewable Energy Sources (RES) that is not injected into the grid (even though it is available), due to operational limits of the grid, such as voltage violations or congestions.
KPI_H06 / Ease of access	SOCL-CY-BUC-01; SOCL-CY-BUC-02; WECL-ES-BUC-01; WECL-ES-BUC-02; EACL-PL-BUC-01;	Ease of access to the flexibility market for flexibility service providers, including accessibility, non-redundant barriers to entry and user-friendliness.
KPI_H07 / Number of transactions	SOCL-GR-BUC-01; SOCL-CY-BUC-01; SOCL-CY-BUC-02; WECL-ES-BUC-01; WECL-ES-BUC-02; WECL-ES-SUC-01; EACL-SL-SUC-01; EACL-SL-SUC-02; EACL-PL-BUC-02; EACL-PL-BUC-03; EACL-HU-BUC-01; EACL-HU-BUC-02; EACL-CZ-SUC-02	This indicator measures the number of transactions (reflected in average hourly amount of available flexibility for a month in the Czech demo). This indicator will be used to measure the number of offered and cleared bids for each product. This indicator will give a measure of demo magnitude by summing transactions.
KPI_H08 / Bid statistics (Bid Min Max Average values)	EACL-HU-BUC-01; EACL-HU-BUC-02	This KPI aims to collect information regarding the minimum, maximum and average value of the bids submitted and cleared to the market, to assess the market's liquidity.
KPI_H09A / Volume of transactions – received bids (P or Q Availability) (Power)	SOCL-GR-BUC-01; SOCL-CY-BUC-01; SOCL-CY-BUC-02; WECL-PT-SUC-02; EACL-SL-SUC-01; EACL-SL-SUC-02	This indicator measures the volume of transactions in kW or kVAr. This indicator will be used to measure the volume of transactions (received bids) during the examined period T for each product. This indicator will give a measure of power magnitude demo range.
KPI_H09B / Volume of transactions – cleared bids (P or Q Availability) (Power)	NOCL-BUC-01; NOCL-SUC-05; SOCL-CY-BUC-01; SOCL-CY-BUC-02; WECL-ES-BUC-01; WECL-ES-BUC-02; WECL-ES-SUC-01; WECL-PT-SUC-02; EACL-SL-SUC-01; EACL-SL-SUC-02; EACL-PL-BUC-02;	This indicator measures the volume of cleared bids. This indicator measures the volume of transactions concerning the availability bids during the examined period T for each product. This indicator will give a measure of power magnitude demo range.

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	EACL-PL-BUC-03; EACL-HU-BUC-01; EACL-HU-BUC-02; EACL-CZ-BUC-02; EACL-CZ-SUC-01	
KPI_H09C / Volume of transactions – received bids (P or Q Activation) (Energy)	EACL-SL-SUC-01; EACL-SL-SUC-02	This indicator measures the volume of transactions in kWh or kVArh. This indicator will be used to measure the volume of transactions (received bids) during the examined period T for each product.
KPI_H09D / Volume of transactions – cleared bids (P or Q Activation) (Energy)	NOCL-BUC-01; NOCL-SUC-05; WECL-PT-SUC-02; WECL-FR-BUC-01; EACL-SL-SUC-01; EACL-SL-SUC-02; EACL-PL-BUC-02; EACL-PL-BUC-03;	This indicator measures the volume of cleared bids.
KPI_H10 / Flex volume offered by FSP vs Flex request by DSO	EACL-PL-BUC-03	Average ratio of offered flexibility by FSPs and flexibility requested by DSO at a given period.
KPI_H11 / Number of products per demo	WECL-ES-BUC-01; WECL-ES-BUC-02	This indicator measures the percentage of products tested in the demos with respect to the number of products initially targeted by the demos.
KPI_H12 / Percentage of avoided technical restrictions (congestions)	NOCL-BUC-01; SOCL-GR-BUC-01; WECL-ES-BUC-01; WECL-ES-BUC-02; WECL-PT-BUC-01; WECL-PT-BUC-02; EACL-SL-BUC-01; EACL-SL-SUC-01; EACL-SL-SUC-02; EACL-PL-BUC-03; EACL-HU-BUC-02;	Avoided congestions thanks to the measures implemented in the demo. This KPI aims to quantitatively assess the improvement in congestion management achieved thanks to the solutions developed by the demonstration activities.
KPI_H13 / Asset load profile variation	WECL-ES-BUC-01; WECL-ES-BUC-02	This indicator measures the percentage of decrease of load demand in the requested asset by a flexibility provider resource. As asset, the distribution electric facility where the congestion problem needs to be solved is considered.
KPI_H14 / Available flexibility	SOCL-CY-BUC-01; WECL-ES-BUC-01; WECL-ES-BUC-02; WECL-ES-SUC-01; WECL-PT-SUC-02; WECL-PT-SUC-07; WECL-FR-BUC-01; EACL-SL-SUC-01; EACL-SL-SUC-02; EACL-PL-BUC-03;	Flexible power that can be used for congestion management at a specific grid segment, i.e., the available power flexibility in a defined period (e.g., per day) that can be allocated by the DSO at a specific grid segment. It relates to the total amount of power in the specific grid segment in the same period. The term power is used to refer to the measurement of power demand in the area on the reporting time at the specific grid location.

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	EACL-HU-BUC-02; EACL-CZ-BUC-01	For the Czech demo the flexibility providers' (aggregator's) ability to collect and offer DSOs active power-based flexibility to control load in relevant nodal areas is tested. The flexibility is managed through charging management of EV charging poles.
KPI_H15 / Requested flexibility	WECL-PT-BUC-01; WECL-PT-BUC-02; WECL-PT-SUC-02; EACL-PL-BUC-03	For the Portuguese demo, this indicator measures the amount of flexibility (power or energy) requested by the DSO or TSO for ancillary services from all the flexible resources of the portfolio. For the Polish demo, this indicator measures the amount of flexibility (power) requested by the DSO on the market platform for congestion management and voltage control services, to solve identified issues in the DSO network.
KPI_H17 / Percentage of avoided technical restrictions (voltage violations)	EACL-SL-BUC-02; EACL-SL-SUC-01; EACL-SL-SUC-02; EACL-PL-BUC-03; EACL-HU-BUC-01; EACL-CZ-BUC-02; EACL-CZ-SUC-01	Avoided contingencies (voltage violations) thanks to the measures implemented in the demo. This KPI aims to quantitatively assess the improvement in congestion management achieved thanks to the solutions developed by the demonstration activities.
KPI_H18A / Volume of balancing service offers for UP reserves	SOCL-CY-BUC-01; EACL-PL-BUC-02	Volume of balancing service offers for UP reserves (aFRR, mFRR, RR) submitted to the flexibility platform by BSPs from the distribution network. Sum of capacity reserves products direction UP (aFRR_up, mFRR_up, RR_up) offered by BSPs on the flexibility platform. In the Cypriot demo the total UP reserves that were submitted to the local DSO market and TSO market by the DERs will be calculated.
KPI_H18B / Volume of balancing service offers for UP reserves transferred to BM	EACL-PL-BUC-02	Volume of balancing service offers for UP reserves (aFRR, mFRR, RR) transferred by the flexibility platform to the Balancing Market. Sum of capacity reserves products direction UP (aFRR_up, mFRR_up, RR_up) transferred by the flexibility platform to the Balancing Market.
KPI_H18D / Volume of balancing service offers for DOWN reserves	EACL-PL-BUC-02	Volume of balancing service offers for DOWN reserves (aFRR, mFRR, RR) submitted to the flexibility platform by BSPs from the distribution network. Sum of capacity reserves products direction DOWN (aFRR_down, mFRR_down, RR_down) offered by BSPs on the flexibility platform.
KPI_H18E / Volume of balancing service offers for DOWN reserves transferred to BM	EACL-PL-BUC-02	Volume of balancing service offers for DOWN reserves (aFRR, mFRR, RR) transferred by the flexibility platform to the Balancing Market. Sum of capacity reserves products direction DOWN (aFRR_down, mFRR_down, RR_down) transferred by the flexibility platform to the Balancing Market.
KPI_H18G / Volume of balancing energy offers	EACL-PL-BUC-02	Volume of balancing energy offers submitted to the flexibility platform by BSPs from the distribution network. Sum of balancing energy offered by BSPs on the flexibility platform.

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KPI_H18H / Volume of balancing energy offers transferred to the BM	EACL-PL-BUC-02	Volume of balancing energy offers transferred by the flexibility platform to the Balancing Market.
KPI_H19A / Number of DERs available for BSPs	SOCL-CY-BUC-01; EACL-PL-BUC-04	Total number of certified DERs prequalified to provide balancing services available for BSPs.
KPI_H19B / Percentage of resources available for balancing services	EACL-PL-BUC-04	This indicator presents the percentage of DERs representing resources prequalified to provide balancing services, against the total number of DERs certified on the flexibility platform.
KPI_H19C / Total capacity of DERs available for BSPs	EACL-PL-BUC-04	Total capacity of certified DERs ready to provide balancing services available for BSPs. Amount of kW of resources prequalified to provide balancing services.
KPI_H20A / Error of the RES production forecast calculated 24 hours in advance	SOCL-GR-BUC-01; SOCL-GR-SUC-01; WECL-PT-BUC-03	The accuracy of power production prediction largely affects the performance of the DSO and the TSO in using flexibility services. The KPI reflects on the accuracy of DSO and TSO flexibility providers production predictions by calculating the ratio and volume of expected and actual power production.
KPI_H20B / Error of load forecast	WECL-ES-BUC-01; WECL-ES-BUC-02; WECL-PT-BUC-03	The accuracy of demand prediction largely affects the performance of the DSO and the TSO in using flexibility services. The KPI reflects on the accuracy of DSO and TSO flexibility demand predictions by calculating the ratio and volume of expected and actual flexibility service needs.
KPI_H21B / Share of false positive and negative congestion forecasts	WECL-PT-BUC-01; WECL-PT-BUC-02; WECL-PT-SUC-07	The ratio between incorrectly forecasted congestions and the total number of forecasted congestions.
KPI_H22A / Percentage of successfully prequalified FSPs	NOCL-BUC-01;	This indicator presents the percentage of FSPs in the demo that are successfully prequalified, against the number of FSPs only registered on the flexibility platform.
KPI_H22B / Percentage of successfully prequalified DERs	EACL-PL-BUC-01;	This indicator presents the percentage of DERs in the demo (prequalified either directly or by an aggregator) that are successfully prequalified, against the number of DERs only registered on the flexibility platform.
KPI_H22C / Number of certified DERs for at least one flexibility product	EACL-PL-BUC-01;	Total number of DERs representing certified resources on the flexibility platform, ready for service, for one or more flexibility products.
KPI_H22D / Capacity of certified DERs for at least one flexibility product	EACL-PL-BUC-01;	Total capacity of certified DERs, ready for service, for one or more flexibility products.

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KPI_H22E / Volume of flexibility by prequalified units	EACL-SL-SUC-01; EACL-SL-SUC-02	The volume of prequalified flexibility is measured with this KPI.
KPI_H22F / Number of successfully prequalified units	EACL-SL-SUC-01; EACL-SL-SUC-02	With this KPI, the number of successfully prequalified units is measured.
KPI_H23A / Power exchange deviation	WECL-ES-BUC-01; WECL-ES-BUC-02; WECL-ES-SUC-01; EACL-PL-BUC-03	Tracking error between a set-point requested by the SO and the measure, given an FSP and a tracking period (e.g., one single service provision). Deviation between accepted and actual activated flexibility power.
KPI_H23B / Energy exchange deviation	EACL-PL-BUC-03	Tracking error between the energy set-point requested by the SO and the measure, given an FSP and a tracking period (e.g., one single service provision). Deviation between accepted and actual activated flexibility energy.
KPI_H23E / Deviation of the FSP response compared to the awarded bids	SOCL-CY-SUC-03	This indicator assesses if the response of the FSPs corresponds to the awarded bids by the market. The indicator provides a percentage of how much each FSP response is in line with its market obligation.
KPI_N01 / Number of implemented cross border products	NOCL-BUC-01	This KPI is valid for the BUCs that aim to harmonize the definition and process of flexibility products among SOs in different countries. The overall BUC performance of this aim can be measured considering the number of implemented products that can be traded in more than one country (cross border products).
KPI_N02 / Number of implemented joint products	NOCL-BUC-01	This KPI is valid for the BUCs that aim to harmonize the definition and process of flexibility products among SOs in different countries. The overall BUC performance of this aim can be measured considering the number of implemented products that can be traded between more than one SO (joint products).
KPI_N03 / Number of FSPs participating in more than one country	NOCL-BUC-01	This KPI is valid for the BUCs that aim to harmonize the definition and process of flexibility products among SOs in different countries. The overall BUC performance of this aim can be measured considering the enhanced possibility of FSPs' participation in the flexibility market beyond the home country.
KPI_N04 / Number of conflicts resulting from flexibility product activation	NOCL-BUC-01	In the uncoordinated way of flexibility activation in the existing market, activation of flexibility products by one SO may lead to conflicts (e.g., new congestions) in another SO's grid area. One of the aims of this BUC is to avoid any such conflicts by performing the grid qualification process in prequalification, procurement and activation phases. This indicator measures the performance of this aim.
KPI_N05 / Ratio of successful bid	NOCL-SUC-01	This indicator measures the performance of the FSP bid preparation process and price estimation. The number of times that FSP bids are selected (call-off bid) compared to the total number of bids that the FSP offered.

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KPI_N06 / Accuracy of flexibility activation	NOCL-SUC-01	This indicator illustrates the accuracy of the FSP process in predicting the available flexibility. For this purpose, it measures the average deviation of activated flexibility resources compared to the bid.
KPI_N07 / Activation delay	NOCL-SUC-02; NOCL-SUC-09	The activation speed of the flexibility resource is one of the essential aspects defined in the product specification. The activation time depends on the nature of the resource, the performance of all platforms, the connection of the FSP and the control methodology. This indicator measures the total activation time for the aggregated resource, i.e., how long it takes after SO requests activation until the resource updates its behavior.
KPI_N08 / Level of automation of SUC process steps	NOCL-SUC-05	The flexibility register facilitates the preparation of FSPs and their resources before the market phase can start. This process has many steps, many of which might require manual tasks from different parties. The aim of the process definition has been to automatize these processes.
KPI_N09 / Verification method accuracy	NOCL-SUC-03	The aim is to assess the accuracy of the reference value (e.g., computed baseline) compared to the energy/power injected into the grid, when no flexibility activation was conducted.
KPI_N10 / Minimizing the number of new products	NOCL-SUC-04	The goal is to avoid defining the new product while the existing one can be used to satisfy the SO's needs. Therefore, a lower number of products that cover all of the SOs' needs is an indicator for a less complex market.
KPI_N11 / Rate of the secondary contract to the requested one	NOCL-SUC-06	The aim is to find a replacement for flexibility contracts when the provider cannot keep the commitment. The ideal situation is to find a replacement instead of all the FSPs that failed to provide.
KPI_N12 / Speed of grid qualification algorithm	NOCL-SUC-07	Grid qualification algorithm should deliver the results as soon as required.
KPI_N13 / Speed of Bid optimization algorithm	NOCL-SUC-07	Bid optimization algorithm should deliver the results as soon as required.
KPI_N14 / Rate of Change of Frequency improvement	SOCL-CY-BUC-01	This indicator considers the maximum rate of frequency change (in Hz/s) after an intense disturbance on system balancing. The indicator provides the improvement on the maximum ROCOF (ROCOFI) of the Research and Innovation (R&I) scenario where FSPs provide fast frequency responses compared to the Business as Usual (BaU) scenario where FSPs do not provide frequency support.
KPI_N15 / Improvement of Frequency Nadir	SOCL-CY-BUC-01	This indicator shows the improvement of the frequency nadir, which is the minimum point that the frequency reaches (in Hz) after an intense disturbance on system balancing. This KPI will show the improvement of the frequency nadir after the application of the innovative solutions in the Cypriot demo and the encouragement of large- and small-scale flexibility resources to participate in the frequency balancing. For the

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		calculation of this indicator the frequency nadir during a disturbance for two scenarios will be considered. The first scenario will be the Business-as-Usual scenario (BaU) which represents the current state in the Cypriot power system, while the second scenario will be the Research and Innovation scenario (R&I) that reflects the application of innovative techniques that will be developed and demonstrated in the Cypriot demo.
KPI_N16 / Overloading	SOCL-CY-BUC-01; SOCL-CY-BUC-02; SOCL-CY-SUC-04	This indicator provides information for the maximum overloading conditions that occur at the distribution grid. This KPI will show the improvement in the maximum thermal loading (TL) status of a transformer/line, after the application of the innovative solutions provided by the flexible resources. The maximum power flow of the line under consideration will be considered in two scenarios. The first scenario will be the Business-as-Usual scenario (BaU) which represents the current state in the Cypriot power system, while the second scenario will be the Research and Innovation scenario (R&I) that reflects the application of innovative techniques that will be developed and demonstrated in the Cypriot demo.
KPI_N17 / Improvement on voltage limits violations	SOCL-CY-BUC-02; SOCL-CY-SUC-04	This indicator provides information for the distribution grid's maximum over-/under- voltage conditions in terms of intensity and duration. The indicator provides the improvement, of the Maximum Upper Voltage Violation Intensity (MUVVIi) and the Maximum Lower Voltage Violation Intensity (MLVVIi), between the Research and Innovation (R&I) scenario and the Business-as-Usual (BaU) scenario for the grid under examination.
KPI_N18 / Reduction of energy losses	SOCL-CY-BUC-02; SOCL-CY-SUC-04	This indicator will provide information for the energy losses of the distribution grid for the selected operational scenarios. The indicator provides the Energy Losses reduction (ELr) between the Research and Innovation (R&I) scenario where local FSPs provide flexibility services to the distribution grid and the Business-as-Usual (BaU) scenario where no flexibility services are provided.
KPI_N19 / Reduction of Loading asymmetries– Maximum and Average Current Phase Unbalanced Factor (MCPUFR and ACPUFR)	SOCL-CY-BUC-02; SOCL-CY-SUC-04	This indicator provides information about the loading asymmetry between the three phases (Current Phase Unbalanced Factor) at the substation level (either primary or secondary substation), before (BaU) and after (R&I) the provision of local flexibility services for power quality enhancement by the local FSPs. The average and the maximum improvement will be considered for the examined period. The reduction of loading asymmetries is measured according to the maximum and average Current Phase Unbalance Factor reduction (MCPUFR and ACPUFR, respectively) between the R&I and the BaU.
KPI_N20 / Power factor (PF) improvement	SOCL-CY-BUC-02	This indicator shows the improvement of the power factor value in different nodes of the distribution grid. It should be noted that the minimum value of the power factor over a period of time is considered in the calculation of this

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		indicator. This KPI will show the improvement in the minimum power factor of a node, after the application of the innovative solutions provided by the flexible resources (i.e., reactive support). The minimum power factor of the node under consideration (over a specific time interval) will be considered in two scenarios. The first scenario will be the Business-as-Usual scenario (BaU) which represents the current state in the Cypriot power system, while the second scenario will be the Research and Innovation scenario (R&I) that reflects the application of innovative techniques that will be developed and demonstrated in the Cypriot demo for reactive power support.
KPI_N21 / Voltage magnitude and angle error	SOCL-CY-BUC-01; SOCL-CY-SUC-01	This indicator provides information about the estimation accuracy of the real-time monitoring scheme. It is calculated as the difference between the actual and the estimated voltage and angle (provided by the monitoring scheme). This KPI will assess the accuracy of the monitoring scheme by comparing the estimated voltage magnitude and angle with the actual ones. It should be noted that the actual voltage magnitude and angles of the buses are known since the Cypriot demo is based on dry run simulations using the real time simulator.
KPI_N22 / Calculated limits deviation	SOCL-CY-SUC-02	This indicator provides information about the calculation accuracy of the limits extracted from the SUC. As an indicator for the accuracy, the deviation (in percentage) that the calculated limits have from the actual limits in the HV/MV and MV/LV interface will be extracted. This KPI is related to the SUC that calculates the operational limits of the HV/MV and MV/LV interface in order to ensure the safe operation of the Cyprus transmission and distribution grid. These limits will be calculated for a specific time interval ahead in order to be respected by the energy markets when they are cleared. This KPI will show the maximum deviation of the calculated limits from the real ones by comparing them with the limits that the power system actually has at the corresponding operation time that the limits were calculated.
KPI_N23 / Number of successfully predicted hazardous power system regimes and cyber threats	SOCL-GR-BUC-01; SOCL-GR-BUC-02; SOCL-GR-SUC-04; SOCL-GR-SUC-05; SOCL-GR-SUC-06; SOCL-GR-SUC-08; SOCL-BUC-01	Early warning on a hazardous power system regimes rate. This indicator shows how efficient the identification of the hazardous power system state is and how much in advance, timewise, it is given.
KPI_N24 / Number of successfully predicted severe weather conditions	SOCL-GR-BUC-01; SOCL-GR-BUC-02; SOCL-GR-SUC-05; SOCL-GR-SUC-06; SOCL-BUC-01	It is very important to have, as much as possible, precise information on grid reliability and reliability of each PS element. The appearance of ice or storms can cause unplanned outages and severe damages to the grid directly influencing the power system flexibility needs and the possibility of the transmission system and/or the distribution system to service those needs.

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KPI_N25 / Comparison between the Isc max forecasted for the 63kV by the planning and the maximum short circuit value registered for the series under analysis	WECL-PT-SUC-08	Deviation between the maximum planning estimated value of Isc (iscmax) and the maximum value effectively forecasted (MAX(Isc)) in a D-1 timeframe.
KPI_N26 / Tracked flexibility	WECL-FR-BUC-01; WECL-FR-SUC-01	Number of tracked flexibility activations automatically or manually triggered.
KPI_N27 / Total power of avoided congestions through flexibility activation	WECL-PT-BUC-01; WECL-PT-BUC-02; WECL-PT-SUC-02	The difference of the total amount of power of the congestions (overloaded elements) in the grid, for all periods of observation, between the scenarios without flexibility activation (before BUC implementation) and with flexibility activation (after BUC implementation) by DSO and TSO action.
KPI_N28 / Maximum ratio of false positive and negative congestion forecasts	WECL-PT-BUC-01; WECL-PT-BUC-02; WECL-PT-SUC-02	The maximum ratio of the incorrectly forecasted power congestions versus the total power of congestions forecasted.
KPI_N30 / Comparison between the rated short circuit current of the circuit breakers for the 63kV and the maximum short circuit value registered for the series under analysis	WECL-PT-SUC-08	Deviation between the breaker limit Isc 63kVlim and the maximum value effectively forecasted (MAX(Isc)) in a D-1 timeframe.
KPI_N31 / Nº of congestions/violations on DSO network	WECL-PT-SUC-06	Anticipated distribution grid constraints because of scheduled maintenance actions. By exchanging information of maintenance works between TSO and DSO, some congestions might be identified (forecasted) and avoided with corrective actions such as topology reconfiguration, flexibility activation or even maintenance works rescheduling. This KPI will evaluate the efficacy of this information exchange in order to avoid congestions.
KPI_N32 / Nº of congestions/violations on TSO network	WECL-PT-SUC-06	Anticipated transmission grid constraints because of scheduled maintenance actions. By exchanging information of maintenance works between TSO and DSO, some congestions might be identified (forecasted) and avoided with corrective actions such as topology reconfiguration, flexibility activation or even maintenance works rescheduling. This KPI will evaluate the efficacy of this information exchange in order to avoid congestions.
KPI_N33 / Improvement of the Forecast	WECL-PT-SUC-07; WECL-PT-SUC-08	This indicator measures the improvement of forecast value after the information exchange. The TSO currently has generation and load forecasts, short circuit levels which include embedded generation for which it does not have

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		visibility. With information exchange the TSO has a better dataset as it is complemented with data from the DSO regarding the distribution grid outside of the TSO/DSO observability area. It is expected that these extra data will contribute to a better forecast.
KPI_N34 / Successful ending of Prequalification Process	WECL-PT-SUC-01	This indicator measures the percentage of prequalification processes approved.
KPI_N35 / Increase in the availability of flexibility	EACL-CZ-SUC-02	The implementation of the traffic light scheme will enable swift sharing of data on planned outages to aggregators – this represents added value, especially if the maintenance is finished before the scheduled date (planned deadline). As this information was not previously available, the advantage lies mainly in enhancing the provision of the aggregator's flexibility, more effective utilization of flexibility and unlocking the full potential of their flexibility portfolio.
KPI_N36 / Average runtime of aggregated network offer algorithm	EACL-PL-SUC-02	This KPI evaluates how long it takes to create an Aggregated Network Offer.
KPI_N39 / Volume of activated Flexibility services	EACL-SL-BUC-01; EACL-SL-BUC-02	Validate the demand response mechanism to prevent congestion in the distribution grid. The total volume of needed and provided energy will be calculated and displayed.
KPI_N40 / Volume of total monetized flexibility	EACL-SL-BUC-01; EACL-SL-BUC-02	This KPI calculates the sum of all payments made to the aggregators for delivering flexibility. It can be calculated for an arbitrary period (week, month, demonstration).
KPI_N41 / Average time needed for prequalification of a unit	EACL-SL-SUC-01; EACL-SL-SUC-02	Unit prequalification has to be fast. This is why the averaged time for prequalification is calculated with this KPI.
KPI_N42 / Percentage of successful automatic alignment processes	EACL-SL-SUC-05	This KPI estimates the percentage of successful automatic alignment processes, based on the manual alignments needed after activation and the total number of activations.
KPI_N43 / Success of local flexibility market platform test	EACL-SL-SUC-01; EACL-SL-SUC-02	Validate the demand response mechanism to prevent congestion in the distribution grid. Test flexibility products to prevent congestion in the distribution grid under market conditions.
KPI_N45 / Total Computational Runtime	EACL-HU-SUC-01	This indicator measures the execution time of market clearance under different coordination schemes.
KPI_N46 / Prequalification processes that need additional information	WECL-PT-SUC-01	This indicator measures the percentage of prequalification processes that require additional information.

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KPI_N47 / Increase in flexibility providers (units)	EACL-CZ-SUC-01	The implementation of the IT market platform will enable an increased number of participants (units) in providing flexibility. Recently, only major resources are involved in case flexibility is needed, as DSOs are not aware of the potential of smaller aggregated resources and thus, this potential is not known and used. The IT platform will make this potential available and enable the participation of new resources in the market.
KPI_N48 / FSP acceptance	WECL-BUC-01	This indicator calculates the percentage of FSPs that accepted their participation in the joint cross-border SO prequalification with respect to the total number of FSPs contacted and asked to participate in the BUC. This indicator will also be used to evaluate the FSP engagement plan. The main objective of this KPI is to assess the overall acceptance of the FSPs to the idea of providing services to another SO that is not the one to which they are connected. Although this is already done in the TSO-DSO context (as the FSPs can be connected to the DSO and provide services to the TSO), this KPI aims to assess the acceptance of the possibility of providing flexibility to another DSO, possibly in another country.
KPI_N49 / Average Processing Time	WECL-BUC-01	This indicator measures the execution time of the prequalification process.
KPI_N50 / Cross SO Prequalification Acceptance	WECL-BUC-01	This indicator calculates the percentage of accepted Cross SO Prequalification processes. Whenever a prequalification request is forwarded from the connecting SO to the external SO, the latter can accept or refuse the request. Therefore, this KPI aims to capture how often an FSP accepts to be prequalified by another SO, in relation to the total number of prequalification requests forwarded.
KPI_N51 / Need for additional information for cross SO Prequalification	WECL-BUC-01	This indicator calculates the percentage of Cross SO Prequalification processes that need additional information beyond the harmonized requirements. It is possible that the external SO cannot conclude the prequalification process only with the harmonized information sent by the connecting SO. Therefore, additional information will need to be requested by the FSP. This case may lead to delays in the prequalification process and therefore is not desirable. This KPI aims to capture how sufficient the harmonized information is for the cross-SO prequalification process.
KPI_N52 / Data retrieval successful	EACL-BUC-01	When a registered OneNet user sends a request for data retrieval, this request can either be successful or unsuccessful. This KPI is used to validate system functionality. Defining and preparing key data on the results of national flexibility markets. Rules for sharing data through the OneNet system, by registered users of the OneNet system.

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KPI_N53 / Data retrieval delay	EACL-BUC-01	The time interval between sending the request and receiving the response. Defining and preparing key data on the results of national flexibility markets. For a number of trials, histogram and CDF should be provided to represent the stochastic nature of the delay.
KPI_N54 / Data reliability ratio	EACL-BUC-01	To prove the reliability of the retrieved data.
KPI_N55 / Number of products implemented in different countries	NOCL-BUC-01	This KPI indicates the implementation of the same product in at least 2 different countries.

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