Demo cluster lessons learned and input CBA and scalability

D10.5

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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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Table of Contents

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List of Figures

List of Tables

List of Abbreviations and Acronyms

Acronym	Meaning
aFRR	automatic Frequency Restoration Reserve
AGNO	Aggregated Network Offer Algorithm
BSP	Balancing Service Provider
BUC	Business Use Case
CBA	Cost-Benefit Analysis
CIM	Common Information Model
CM	Congestion Management
DA	Day Ahead
DSO	Distribution System Operator
FSP	Flexibility Service Provider
HU	Hungary
HV	High Voltage
KPI	Key Performance Indicator
LT	Long-Term
LV	Low Voltage
mFRR	manual Frequency Restoration Reserve
MO	Market Operator
MV	Medium Voltage
PCI	Projects of Common Interest
PL	Poland
SI	Slovenia
SO	System Operator
SRQ	Scalability & Replicability Questionnaire
TSO	Transmission System Operator
VC	Voltage Control
WP	Work Package

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Executive Summary

This deliverable aims to organize and evaluate the experiences gathered during the demonstrations of the Eastern Cluster. To provide a comprehensive view on the very different and often country-specific solutions, qualitative and quantitative analysis was carried out. The latter approach was supported by the calculation of Key Performance Indicators. Results of the four (4) demos are gathered and analyzed. Special focus is put on the comparison of results of the same services in different environments.

The demonstrations were not in an easy position to set target Key Performance Indicators due to the maturity of the flexibility markets, but the overall picture was positive, and the majority of the targets were met. The quantitative tool was the data collection for a detailed cost benefit analysis. Due to the variety of services provided by the demonstrators, the Eastern Cluster used the ENTSO-E CBA template as a common starting point to assess potential costs and benefits of the demonstrators. It must be noted in relation to the quantitative analysis that during the demonstration period, certain BUCs occurred only a few times, and therefore the KPIs and CBA inputs may change in case of an actual roll-out. Also, for BUCs focusing on local network problems, it is important to see that the results cannot be extrapolated to a one-to-one country level, but still a very good representation of the problems in each country can be seen.

While starting from notably different ground in terms of technical challenges and market maturity, the countries of the Eastern Cluster reached similar results. An important and common achievement was the definition of the frameworks coordinating the activities of the TSO and the DSOs to maximize the effective utilization of available flexibility. Notable progress was seen in the countries in relation to the design of flexibility markets, services and products. The importance of data provision (granularity, frequency, quality of the data) to ensure reliable operation of flexibility markets was highlighted.

Qualitative analysis of the demonstrations was carried out by a self-assessment where the demos completed a scalability and replicability questionnaire, which focused on five major aspects: technical, economic, regulation, environmental and acceptance. All demonstrators achieved high scores in terms of the scalability and the replicability of their solutions (74 and 72%, respectively), but they also reported that regulatory, technical and organizational constraints still exist on part of the system operators. These findings are valuable for regulators and international organizations. Finally, it was also shown that business models of flexibility markets are to be improved to achieve liquidity of these markets.

This report encapsulates the comprehensive analysis of the OneNet project's Eastern demonstrator cluster, emphasizing its contribution to a harmonized and efficient European electricity network. The self-assessments of the demonstrators led to very similar results, highlighting that while the countries were able to provide valuable answers to the technical challenges, there is still room for improvement in terms of regulatory activities.

The demonstrations have shown that regulation in most countries is not yet at a level where the results of the demonstrations can be directly implemented, which is one of the most important things to do for the future.

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1 Introduction

This deliverable analyzes the results and lessons learned from the OneNet Eastern Cluster demonstrator and benchmarks the results of the Eastern Cluster, with the active participation of multiple TSOs, DSOs, research institutes, and aggregators. The Eastern demonstrator cluster comprises the Czech Republic, Poland, Slovenia, and Hungary, all of which are integral parts of the highly interconnected region of Continental Europe's Core regional synchronous zone. While these countries share certain similarities, particularly in the evolution and maturity of their electric power systems, they each grapple with unique challenges stemming from the ongoing energy transformation. This has led to varying motivations for the initiation of flexibility markets.

The deliverable also includes the lessons learned from the demo test execution and analyses, and the comparison with other demos are the main parts of this deliverable. Results of the four (4) demos are gathered and analyzed. Special focus is on the comparison of results of the same services in different environments. Inputs for CBA and scalability and replicability analyses have been prepared.

1.1 Task 10.5

Results of all demos were gathered and analyzed in task T10.5 "Demo Cluster Lessons learned and input CBA and Scalability". Special focus was given on comparison of results of same services in different environments. Inputs for CBA and scalability analysis were prepared. To provide a comprehensive view on a different and often country-specific solutions, qualitative and quantitative analysis was carried out in this task. Eastern Cluster used the ENTSO-E CBA template as a common starting point to assess potential costs and benefits of the demonstrators.

1.2 Objectives of the Work Reported in this Deliverable

The deliverable aims to develop an interoperable network of flexibility platforms to support the utilization of various flexibility services, service integration and interaction, as well as the related data exchange. This development strongly relying on field test that performed on various locations and supported by various groups of Eastern Cluster Demos. Partners of Eastern Cluster Demos develop and extend capabilities of existing flexibility market platforms for TSO and DSO grid services, which standardized to an appropriate European format. The development focuses on four areas: definition of new standardized flexibility services, elaboration of related market-based product and grid prequalification processes, the conceptualization of location-based service activation and the coordination of access to local and system-level services. It also includes the definition of technical requirements for flexibility providers and aggregators offering flexibility services. Demo coordinators perform pilot testing of flexibility services for DSOs and the TSO utilizing a varied mix of providers and resources. The Eastern Cluster Demos is focusing on the coordinated activation of flexibility services for

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congestion management and balancing (TSO, DSO) as well as for new market based non-frequency flexibility services addressing local issues. The cluster addresses these services as standardized market products provided in market-based environment. Various middleware solutions covering power system and related domains (e.g. smart city) have been developed in recent years and will serve as a basis for the abovementioned development.

1.3 Outline of the Deliverable

The D10.5 document offers an in-depth exploration of the demonstrations conducted in the eastern cluster countries for the OneNet project, covering the Czech Republic, Poland, Slovenia, and Hungary.

Chapter 1 sets the foundation, providing readers with a clear understanding of the OneNet project, its overarching objectives, and the significance of the demonstrations in the eastern cluster countries.

Chapter 2 introduces KPIs from Eastern Cluster Demos, providing detailed evaluations for each country's demo.

Inputs for CBA focuses on the Key Performance Indicators (KPIs) to quantify and evaluate the different technologies demonstrated in the Eastern Cluster Demos, providing detailed evaluations for each country's demo, that will later contribute to the CBA input. Chapter 3 examines the way that the KPIs will be used as an input in Cost-Benefit Analysis (CBA) from each country, contributing to the economic assessment of the project.

Chapter 4 identifies the scalability dimensions and their intrinsic factors through a comprehensive questionnaire, focusing on Hungary, Poland, Slovenia, and the Czech Republic, that have been defined in the SRQ (Scalability & Replicability Questionnaire.

Chapter 5 presents insights gained from the demo test execution and analysis in each country, highlighting regulatory and legislative changes. The results will show the direction in which the regulatory/legislative environment seen at the beginning of the project has changed and whether this has influenced the evaluation of the project results.

Chapter 6 – Conclusions.

1.4 How to Read this Document

This deliverable provides an overview of the work conducted in the eastern countries for the OneNet project, specifically focusing on the Czech Republic, Poland, Slovenia, and Hungary. We've structured the content to be both informative and straightforward.

The introduction gives a clear picture of the OneNet project and its main goals. As you progress, you'll find sections dedicated to KPIs, CBA inputs and lessons learned from each country in the eastern cluster.

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It's important to note that D10.5 builds upon the foundation laid by WP10, WP11, and other WP deliverables preceding this document. These earlier documents set the technical tasks that D10.5 addresses. The D10.2 “Report on selection of services” [1] and D10.3 “Report on development of integral market platform” [4], played a pivotal role in defining the objectives and setting the stage for the demonstrations and findings presented in this report. Therefore, for readers seeking a holistic understanding of the project's evolution and the context in which D10.5 operates, it would be beneficial to familiarize themselves with other WP10 and WP11 documents.

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2 Key Performance Indicators

The purpose of this chapter is to introduce the Key Performance Indicators (KPIs) developed in the context of the Eastern Cluster Demos. At the first stage, these KPIs are used to quantify and evaluate the different technologies demonstrated in the Eastern Countries and later they contribute to the CBA input. The way that the KPIs will be used as an input in the CBA process is described in the 2 Inputs for CBA chapter.

2.1 Introduction of KPIs from the Eastern Cluster Demos

The following indicators were used in the Eastern Cluster Demos by countries.

Polish KPIs:

- Number of FSPs
- Active participation
- Number of transactions
- Volume of transactions – cleared bids (P or Q Availability) (Power)
- Volume of transactions – cleared bids (P or Q Activation) (Energy)
- Percentage of avoided technical restrictions (congestions)
- Available flexibility
- Percentage of avoided technical restrictions (voltage violations)
- Requested flexibility
- Volume of balancing service offers for UP reserves
- Volume of balancing service offers for UP reserves transferred to BM
- Volume of balancing service offers for DOWN reserves
- Volume of balancing service offers for DOWN reserves transferred to BM
- Volume of balancing energy offers
- Volume of balancing energy offers transferred to BM
- Number of DERs available for BSPs
- Percentage of resources available for balancing services
- Total capacity of DERs available for BSPs
- Percentage of successfully prequalified DERs
- Capacity of certified DERs for at least one flexibility product
- Power exchange deviation
- Energy exchange deviation
- Flex volume offered by FSP vs Flex request by DSO

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Hungarian KPIs:

- Number of FSPs
- Active participation
- Active participation
- Volume of transactions – cleared bids (P or Q Availability)
- Volume of transactions – cleared bids (P or Q Activation) (Energy)
- Contingencies reduction (Nº of reduced congestions)
- Available Flexibility
- Ratio of activated reserved flexibility
- Contingencies reduction (Nº of reduced voltage constraints violation)
- Bid statistics (Bid Min Max Average values)
- Share of correctly forecasted contingencies
- Ease of access
- Cost-effectiveness
- Total Computational Runtime

Slovenian KPIs:

- Number of FSPs
- Active participation
- Cost-effectiveness
- Number of transactions
- Volume of transactions – received bids (P or Q Availability) (Power)
- Volume of transactions – cleared bids (P or Q Availability) (Power)
- Volume of transactions – received bids (P or Q Activation) (Energy)
- Volume of transactions – cleared bids (P or Q Activation) (Energy)
- Percentage of avoided technical restrictions (congestions)
- Available flexibility
- Percentage of avoided technical restrictions (voltage violations)

Czech KPIs:

- Number of FSPs
- Number of transactions
- Volume of transactions – cleared bids (Q Availability)

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- Number of avoided technical restrictions (reactive power overflow occurrence)
- Increase in availability of flexibility
- Increase of active power-based flexibility

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2.1.1 KPIs - Polish demo

This following table contains the full KPIs list defined in the Polish demo.

Table 2-1 - Polish KPIs list

KPI ID	Impact category	KPI Name	KPI Description	Formula	Unit of measurement
KPI_H01	General	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.	N_{FSP} Where: N_{FSP} is the number of FSPs.	Integer
KPI_H02	Customer engagement	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 **is** 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_H07	Market	Number of transactions	This indicator measures the number of transactions. This indicator is 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.	Integer

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			magnitude by summing transactions.		
KPI_H09B	Market	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 gives 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.	**kW (kVAr)**
KPI_H09D	Market	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.	kWh
KPI_H12	Technical	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	$$ATR_{\%} = \frac{N_{TR_{Flex}}}{N_{TR}} \cdot 100$$ 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	%

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			developed by the demonstration activities.	services and N_{TR} is the total number of expected technical restrictions.	
KPI_H14	Technical	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.	$$Flexibility_{\%} = \frac{\sum P_{Available_{Flexibility}}}{\sum P_{Total_{in_{Area}}}} \cdot 100$$ 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.	%
KPI_H17	Technical	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.	%
KPI_H15		Requested flexibility	This indicator measures the amount of flexibility (power) requested by the	$P_{Flex_R} = \sum_{t=1}^{T} P_{flex_{R_t}}$ and/or $E_{Flex_R} = \sum_{t=1}^{T} E_{flex_{R_t}}$	kW

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			DSO on the market platform for congestion management and voltage control services, to solve identified issues in the DSO network.	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	$VBS_{UP} = \sum_{n=1}^{N} \mathrm{aFRR(FP)_{U,n}} + \sum_{m=1}^{M} \mathrm{mFRR(FP)_{U,m}} + \sum_{k=1}^{K} \mathrm{RR(FP)_{U,k}}$ Where: VBS_{UP}: Volume of balancing service offers for UP reserves (aFRR, mFRR, RR) (kW) $\mathrm{aFRR(FP)_{U,n}}$: Automatic Frequency restoration reserve (up-reserve) of unit n submitted to the flexibility platform (kW) $\mathrm{mFRR(FP)_{U,m}}$: Manual Frequency restoration reserve (up-reserve) of unit m submitted to the flexibility platform (kW)	kW

				$\mathrm{RR(FP)}_{\mathrm{U,k}}$: 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	$VBS_{UP-BM} = \sum_{n=1}^{N} \mathrm{aFRR(FP,BM)}_{U,\mathrm{n}} + \sum_{m=1}^{M} \mathrm{mFRR(FP,BM)}_{U,\mathrm{m}} + \sum_{k=1}^{K} \mathrm{RR(FP,BM)}_{U,\mathrm{k}}$ Where: VBS_{UP-BM}: Volume of balancing service offers for UP reserves transferred to BM (kW) $\mathrm{aFRR(FP,BM)}_{U,\mathrm{n}}$: Automatic Frequency restoration reserve (up-reserve) of unit n transferred by the flexibility platform to the Balancing Market (kW) $\mathrm{mFRR(FP,BM)}_{U,\mathrm{m}}$: Manual Frequency restoration reserve (up-reserve) of unit m transferred by the flexibility platform to the Balancing Market (kW) $\mathrm{RR(FP,BM)}_{U,\mathrm{k}}$: Replacement Reserve (up-reserve) of unit k transferred by the flexibility platform to the Balancing Market (kW)	kW

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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.	$$VBS_{DO} = \sum_{n=1}^{N} \mathrm{aFRR(FP)}_{D,\mathrm{n}} + \sum_{m=1}^{M} \mathrm{mFRR(FP)}_{D,\mathrm{m}} + \sum_{k=1}^{K} \mathrm{RR(FP)}_{D,\mathrm{k}}$$ Where: VBS_{DO}: Volume of balancing service offers for DOWN reserves (kW) $\mathrm{aFRR(FP)}_{D,\mathrm{n}}$: Automatic Frequency restoration reserve (down-reserve) of unit n submitted to the flexibility platform (kW) $\mathrm{mFRR(FP)}_{D,\mathrm{m}}$: Manual Frequency restoration reserve (down-reserve) of unit m submitted to the flexibility platform (kW) $\mathrm{RR(FP)}_{D,\mathrm{k}}$: Replacement Reserve (down-reserve) of unit k submitted to the flexibility platform (kW)	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	$$VBS_{DO-BM} = \sum_{n=1}^{N} \mathrm{aFRR(FP,BM)}_{D,\mathrm{n}} + \sum_{m=1}^{M} \mathrm{mFRR(FP,BM)}_{D,\mathrm{m}} + \sum_{k=1}^{K} \mathrm{RR(FP,BM)}_{\mathrm{D,k}}$$ Where:	kW

			the flexibility platform to the Balancing Market.	VBS_{DO-BM}: Volume of balancing service offers for DOWN reserves transferred to BM (kW) $\mathrm{aFRR(FP,BM)}_{D,\mathrm{n}}$: Automatic Frequency restoration reserve (down-reserve) of unit n transferred by the flexibility platform to the Balancing Market (kW) $\mathrm{mFRR(FP,BM)}_{D,\mathrm{m}}$: Manual Frequency restoration reserve (down-reserve) of unit m transferred by the flexibility platform to the Balancing Market (kW) $\mathrm{RR(FP,BM)}_{D,\mathrm{k}}$: Replacement Reserve (down-reserve) of unit k transferred by the flexibility platform to the Balancing Market (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).	kWh
KPI_H18H		Volume of balancing energy offers transferred to 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).	kWh

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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.	Integer
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).	kW
KPI_H22B		Percentage of successfully prequalified DERs	This indicator presents the percentage of flexibility services providers being aggregators in the demo that are successfully prequalified against the	$K_{FSPA} = \frac{N_{FSPA\ preq}}{N_{FSPA\ req}}.100$ Where: K_{FSPA} : indicator showing the percentage of flexibility services providers being aggregator that are successfully	%

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			number of FSPAs only registered on the flexibility platform	prequalified against number of flexibility service providers being aggregator only registered on the flexibility platform (%) $N_{FSPA\,preq}$ – number of flexibility services providers being aggregator that are successfully prequalified $N_{FSPA\,req}$ – number of of flexibility services providers being aggregator, registered on the flexibility platform.	
KPI_H22D		Capacity of certified DERs for at least one flexibility product	Total capacity of certified DERs	$$P_{DER\_cer} = \sum_{i=1}^{I} P_{DER\_cer,i}$$ Where: $P_{DER_{cer}}$: Capacity of certified DERs (kW) $P_{DER,i}$: certified amount of kW of $DER, i-th$ (kW)	kW
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)	$$P_{Deviation} = \frac{\lvert P_{accepted} - P_{activacted} \rvert}{P_{accepted}} \cdot 100$$ Where: $P_{Deviation}$: Power exchange deviation (%) $P_{accepted}$: accepted (contracted) power (kW) $P_{activacted}$: 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)	$$E_{Deviation} = \frac{\lvert E_{accepted} - E_{activacted} \rvert}{E_{accepted}} \cdot 100$$ Where: $E_{Deviation}$: Energy exchange deviation (%) $E_{accepted}$: accepted (contracted) energy (kWh)	%

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				$E_{activacted}$: activated flexibility energy (kWh)	
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.	%

2.1.2 KPIs - Hungarian demo

This following table contains the full KPIs list defined in the Hungarian demo.

Table 2-2 - Hungarian KPIs list

KPI ID	Impact category	KPI Name	KPI Description	Formula	Unit of measurement
KPI_H01	General	Number of FSPs	This BUC aims to decrease the entry barriers for flexibility provision by simplifying the process for flexibility service providers. Overall progress of this aim can be measured by the number of FSP joining the platform.	N_{FSP} Where: N_{FSP} : Number of FSPs	Integer
KPI_H02	General	Active participation	This indicator measures the percentage of customers actively participating in the demo with respect to the number of service providers enrolled in the demonstration exercise.	$R = \frac{N_{active}}{N_{accept}} \cdot 100$ Where: R: Active participation (%) N_{active}: Customers actively participating in the demo exercise N_{accept}: Number of service providers enrolled in the demonstration exercise (KPI_H01)	%
KPI_H07	Market	Active participation	This indicator measures the number of transactions. This indicator will be used to measure the number of offered and cleared bids for each product.	$N_T = \sum_T n_{Bids,t}$ Where: $n_{Bids,t}$: Number of offered or cleared bids at time t T: Examined period	Integer

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KPI_H09B	Market	Volume of transactions – cleared bids (P or Q Availability)	This indicator measures the volume of cleared bids. This indicator measures the volume of transactions concerning the availability bids.	$$VT_{CAV} = \sum_{T}\sum_{I} P_{i,t}$$ Where: VT_{CAV}: Volume of transaction considering active power (MW). $P_{i,t}$: Volume cleared availability (capacity) bids by the i-th flexible resource at time t (kW or kVA). I: Set of flexible resources. T: Examined period.	MW
KPI_H09D	Market	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: V_{CAC}: Volume of transaction considering P·T or Q·T (MWh). $E_{i,t}$: Volume cleared activation bids by the ith flexible resource at time t (kWh). I: Set of flexible resources. T: Examined period.	MWh
KPI_H12	Congestion management	Contingencies reduction (Nº of reduced 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	$$ATR_{\%} = \frac{N_{TR_{Flex}}}{N_{TR}} \cdot 100$$ Where:	%

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			solutions developed by the demonstration activities.	$ATR_{\%}$: Contingencies reduction (Nº of reduced congestions) (%) N_{TR}: Total number of expected technical restrictions $N_{TR_{Flex}}$: Total number of technical restrictions solved through activation of flexibility services	
KPI_H14A	Congestion management	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. It is measured in MW.	$Flexibility_{\%} = \frac{\sum P_{Available_{Flexibility}}}{\sum P_{Total_{in_{Area}}}} \cdot 100$ Where: $Flexibility_{\%}$: Percentage of available flexible power with respect to the total demand at a specific grid segment in reporting period (%) $\sum P_{Available_{Flexibility}}$: Power in MW of available flexibility at a specific grid segment in reporting period (MW). $\sum P_{Total_{in_{Area}}}$: Total power demand in MW at DEMO grid segment (MW)	%

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KPI_H16	Congestion management	Ratio of activated reserved flexibility	Percentage of the total flexibility reserved that is activated used to manage the operation for both active and reactive power. The Flexibility Activated Reserved Ratio (FARR) KPI is defined as the percentage of the total flexibility reserved from FSPs activated to manage the grid operation without technical constraints.	$FARR_{P\%} = \frac{\sum_{t=0}^{T} P_{flex,Activated_t}}{\sum_{t=o}^{T} P_{reserved_t}} \cdot 100$ $FARR_{Q\%} = \frac{\sum_{t=0}^{T} Q_{flex,Activated_t}}{\sum_{t=o}^{T} Q_{reserved_t}} \cdot 100$ Where: $FARR_{P\%}$: Percentage of the total flexibility (Active power) from FSP reserved in the network that was activated for grid management purposes, for the period T (%); $FARR_{Q\%}$: Percentage of the total flexibility (Reactive power) from FSP reserved in the network that was activated for grid management purposes, for the period T (%); $P_{flex,Activated_t}$: Total flexibility from FSPs reserved that is activated in the network at each time instant t used for grid management purposes (Active power) (kW);	%

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				${P_{reserved}}_t$: Total flexibility from FSP reserved in the network at each time instant t (Active power) (kW). The same applied to reactive power Q (kVAr).	
KPI_H17	Voltage control	Contingencies reduction (Nº of reduced voltage constraints violation)	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: $ATR_{\%}$: Contingencies reduction (Nº of reduced voltage constraints violation) (%) N_{TR}: Total number of expected technical restrictions $N_{TR_{Flex}}$: Total number of technical restrictions solved through activation of flexibility services	%
KPI_H08	Market	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: Minimal (B_m), maximal (B_M) and average (B_A) prices of the auctions given a certain period T of observation. The calculation concerns active power (P) capacity auctions, active power (P)	€/kW or €/kWh, €/kVAr, or €/kVArh

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				activations (energy) auctions, reactive power (Q) capacity auctions, and reactive power (Q) activations.	
KPI_H21A	Data processing	Share of correctly forecasted contingencies	The "Effectiveness of the event forecasting" KPI aims to assess the forecasting tools' performance in predicting specific circumstances.	$CFC_{\%} = \frac{C_{fc,c}}{C_o} \cdot 100$ Where: $CFC_{\%}$: Share of correctly forecasted contingencies (%) $C_{fc,c}$**:** Number of contingencies correctly forecasted, so excluding the false-positive contingencies forecasts. C_o**:** Number of situations where analysis of the measurements indicate that contingencies occurred or would have occurred if no curative actions by the SO were taken (i.e., flexibility used).	%
KPI_H06	Environmental and societal	Ease of access	Ease of access to the flexibility market for flexibility service providers, including accessibility, no redundant barriers to entry, user-friendliness.	Based on a post-demonstration survey	N/A

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KPI_H03	Economic	Cost-effectiveness	Compare the cost for flexibility with 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 <1) The avoided cost needs to be converted into a €/MWh Year basis and compare with the flexibility solution services for the time it will be contracted. To calculate the avoided cost, several factors need to be considered as deferred capital cost, losses, O&M costs...	$Cost_{effectiveness} = (1 - \frac{Cost_{flex}}{Cost_{Sub}}) \cdot 100$ Where: $Cost_{effectiveness}$: Cost effectiveness (%) $Cost_{Sub}$: Avoided traditional solution cost (€/MWh) $Cost_{flex}$: Cost of flexibility (€/MWh) It is assumed that the cost of avoided traditional solutions and the cost of flexibility are fixed for the periods. 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: Present value [€] C: Cash flow per period [€] n: number of periods i: interest rate, equals to 0.05	%
KPI_N45	Data processing	Total Computational Runtime	This indicator measures the execution time of market clearance under different coordination schemes.	$RT = T_{final} - T_{initial}$ Where: RT: Total Computational Runtime (s)	s

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				$T_{initial}$: Time at the end of running the algorithm (s). T_{final} : Time at the beginning of running the algorithm (s).	

2.1.3 KPIs - Slovenian demo

This following table contains the full KPIs list defined in the Slovenian demo.

Table 2-3 - Slovenian KPIs list

KPI ID	Impact category	KPI Name	KPI Description	Formula	Unit of measurement
KPI_H01	General	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.	N_{FSP} Where: N_{FSP} is the number of FSPs.	Integer
KPI_H02	Customer engagement	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 **is** 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	Technical	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	$Cost_{effectiveness} = (1 - \frac{Cost_{flex}}{Cost_{Sub}}) \cdot 100$ 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).	%

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			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.	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_H07	Market	Number of transactions	This indicator measures the number of transactions. This indicator is 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.	$$N_T = \sum_T n_{Bids,t}$$ Where: $n_{Bids,t}$ is the number of offered and cleared bids at time t and T is the examined period.	**Integer**
KPI_H09A	Market	Volume of transactions – received bids (P or Q Availability) (Power)	This indicator measures the volume of transactions in kW (or kVAr). This indicator is used to measure the volume of transactions (received bids) during the examined period T for each product. This indicator gives 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:	**kW (kVAr)**

				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	Market	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 gives 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.	**kW (kVAr)**
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 is used to measure the volume of transactions (received bids) during the examined period T for each product.	$$VT_P = \sum_T \sum_I E_{i,t}$$ Where: VT_p is the volume of bids received considering energy (kWh or kVArh), $E_{i,t}$ is the volume of offered capacity/volume offered in terms of energy by the i^{th} flexible	**kWh**

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				resource at time t (kWh or kVArh), I is the set of flexible resources and T is the examined period.	
KPI_H09D	Market	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.	kWh
KPI_H12	Technical	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	Technical	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	$$Flexibility_{\%} = \frac{\sum P_{Available_{Flexibility}}}{\sum P_{Total_{in_{Area}}}} \cdot 100$$ Where: $Flexibility_{\%}$ is the percentage of available flexible power with respect to the total demand at a	%

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			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.	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.	
KPI_H17	Technical	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.	%

2.1.4 KPIs - Czech demo

This following table contains the full KPIs list defined in the Czech demo.

Table 2-4 - Czech KPIs list

KPI ID	Impact category	KPI Name	KPI Description	Formula	Unit of measurement
KPI_H01	General descriptive	Number of FSPs	This KPI aims to decrease the entry barriers for flexibility provision by simplifying the process for	N/A	Number of new FSP

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			flexibility service providers. Overall progress of this aim can be measured by the number of FSP joining the platform.		
KPI_H07	Market performance	Number of transactions	Number of transactions reflected in average hourly amount of available flexibility for a month	$N_T = \sum_T n_{Bids,t}$ Where: $n_{Bids,t}$: Number of offered or cleared bids at time t. T: Examined period.	MW
KPI_H09 B	Market performance	Volume of transactions – cleared bids (Q Availability)	Sum of available generators providing reactive power/sum of available extent of reactive power	$VT_{CAV\_T} = \sum_I Q_{i,T}$ Where: $VTCAV\_T$: Volume of availability of reactive power in examined period (kVAr) Qi,T: Volume cleared availability (capacity) bids by the i-th flexible resource in examined period (kVAr) I: Set of flexible resources T: Examined period	kVAr
KPI_H17		Number of avoided technical restrictions (reactive power overflow occurrence)	There is a given limit between DSO and TSO concerning reactive power energy overflow from DSO to TSO. To keep the reactive power occurrence within given limits, DSOs contract the service from FSP. It is expected that due to solution implemented, DSO can increase number of FSPs available for the service and thus decrease the occurrence of the reactive power overflow.	$ATR_{\%} = \frac{N_{TR_{Flex}}}{N_{TR}} \cdot 100$ $ATR\%$: share Number of avoided technical restrictions (%) NTR: Total number of expected technical restrictions $NTRFlex$: Total number of technical restrictions solved through activation of flexibility services	in %
KPI_N35		Increase in availability of flexibility	Implementation of the traffic light scheme will enable swift sharing information of data on planned outages to	$IAF = \frac{FP}{\text{FPS}} \cdot 100$ Where:	in %

			aggregators – this represents added value especially in case the maintenance is finished before scheduled date. As this information was not previously available, the advantage lies mainly in enhancing the provision of the aggregators´ flexibility capacity, increasing profits and unlocking the full potential of their flexibility portfolio.	IAF: Increase in availability of flexibility (%) FP: Time of blocked Flexibility potential - time in hours, where availability of flexibility was blocked under recent conditions (min) FPS : Time of blocked Flexibility potential S – time in hours, where availability of flexibility is blocked with traffic light scheme in place (min)	
KPI_H14 A		Increase of active power-based flexibility	The BUC will test the ability of flexibility provider (aggregator) to collect and offer to DSOs active power-based flexibility to control load in relevant nodal areas. The flexibility is managed through charging management of EV charging poles.	$$Flexibility_{\%} = \frac{\sum PAP}{\sum PTA} \cdot 100$$ Where: $Flexibility_{\%}$:percentage of flexible power used available in reporting period (%) PAP: power in kW of available flexibility in reporting period (kW) PTA: total charging power of EV charging stations in kW in demonstration areas (kW)	in %

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2.2 Evaluation of the KPIs

Evaluation of the KPIs is based on the expected outcomes by each demo. In this chapter each country evaluates their results and draws a conclusion.

2.2.1 Evaluation of the 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 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 [1].

Table 2-5 - Target values of the Polish demo

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	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%)

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KPI_H17 / Percentage of avoided technical restrictions (voltage violations)	100% (100%)
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)
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%)
KPI_H10 / Flex volume offered by FSP vs Flex request by DSO	107,1% (100%)
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)

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.,

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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 main change during the tests compared to the initial assumptions was that the aggregator took full responsibility for tasks related to submitting offers and activities on the platform. Therefore, the Ease of access KPI ceased to make sense and was not calculated at all.

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.

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, 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.

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.

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.

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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.

2.2.2 Evaluation of the Hungarian demo

As part of the Hungarian demo, two pilot sites were selected to demonstrate use cases. As the demonstration of the flexibility market was run in a simulation environment, active participation was set to be maximal artificially. In total, 71 FSPs participated in the bidding processes, all of which were photovoltaic plants connected to medium-voltage networks. As current Hungarian grid codes oblige almost all generators (except household scale, i.e. rooftop solar with < 50 kVA connection capacity) to be capable of providing aFRR bids, from a technical perspective, such a high rate of active participation on ex-ante DSO flexibility markets is considered fully possible, and realistic. The number of offered bids was calculated for the two demonstration areas and the two BUCs, combined. The vast majority of these bids were submitted for high-medium voltage transformer overload use cases. The number represents a typical daily average and hourly bids. We also note that every single bid consists of 6 steps due to the nature of the market products. The use-cases and demonstration only comprise of availability auctions, i.e. bids represent capacity limits in the unit of power, hence KPI_H09D cannot be applied. The congestions observed during the demonstration are solely induced by the high penetration of PV plants in the demonstration areas. The FSPs that bid on the flexibility market are the main reason of the congestion themselves, hence the market clearing can yield solution for each use-case simulation.

Table 2-6 - Target values of the Hungarian demo

KPI ID / KPI Name	Calculated values (Target values*)
KPI_H01 / Number of FSPs	71
KPI_H02 / Active participation	100%
KPI_H07 / Active participation	1707
KPI_H09B / Volume of transactions – cleared bids (P or Q Availability)	27.46 MW
KPI_H09D / Volume of transactions – cleared bids (P or Q Activation) (Energy)	N/A MWh

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KPI_H12 / Contingencies reduction (Nº of reduced congestions)	100%
KPI_H14A / Available Flexibility	132.5%
KPI_H16 / Ratio of activated reserved flexibility	N/A
KPI_H17 / Contingencies reduction (Nº of reduced voltage constraints violation)	100%
KPI_H08 / Bid statistics (Bid Min Max Average values)	Max: 42.10 EUR/kW/h, Min: 0 EUR/kW/h, Average: 13.52 EUR/kW/h
KPI_H21A / Share of correctly forecasted contingencies	N/A
KPI_H06 / Ease of access	N/A
KPI_H03 / Cost-effectiveness	32.6%
KPI_N45 / Total Computational Runtime	22.639 s

* As the actual flexibility market has not yet started in Hungary, it was not relevant to include target values.

2.2.3 Evaluation of the Slovenian demo

As part of the Slovenian demo, three pilot sites were selected to demonstrate use cases for congestion management and voltage control. The participating aggregator approached customers and was able to attract 34 households, which provided a total of 75 kW of 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 devices for automatic remote control of their appliances (heat pumps, batteries, PV systems), so that the demo achieved 100% active participation at all three demo sites. A complete IT chain was demonstrated from the DSO system to the aggregator and from the aggregator to the individual appliances. A CIM (Common Information Model) was implemented so that the specifications were the same for all other DSOs (enabling data interoperability) or aggregators wishing to participate in such demos in the future. In total, there were 117 CM activations, of which 78 were successful, representing a 66.7% success rate in avoiding congestion. On the other hand, of the total 59 VC activations, 30 were successful. The success rate of avoided stress injuries was therefore just over 50%. The calculation of the baselines and the activation success was carried out by the local DSOs.

Before the first auction, the Slovenian DSO calculated the maximum flexibility costs that would cover the costs of the avoided traditional solution. In the first auction, the aggregator bid more than the maximum flexibility costs. In the second auction, the aggregator bid exactly the value of the maximum flexibility costs (600€/MWh). Therefore, the result for the KPI “cost efficiency" was 0%.

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Table 2-7 - Target values of the Slovenian demo

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%)

2.2.4 Evaluation of the Czech demo

For the Czech DEMO we consider all project's results sufficient and fully in line with the initial ambitions we declared in the application. For the Network traffic light scheme a centralized place able to accommodate new flexibility providers has been established. We reported the increase of only major unit/aggregated units (KPI_H01), not of all the units involved (for that reason there is a moderate increase, slightly below ambition).

Target value: 150 FSP units

Result value: 125 FSP units

On the other hand, efficiency and effectiveness of the system is reflected in the unblocked amount of flexibility (due to the upgraded system for indication of the availability of the grid). It means, that some units, which cannot provide flexibility due to a planned outage in the distribution grid, now receive online information, when the outage is over and can start providing flexibility from that moment (no need to wait for officially planned end of the works). This we consider as a major achievement for the further use and implementation of this scheme as we demonstrated the potential of this solution to unlock flexibility.

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Target value: 10 %-time reduction of blocking flexibility

Result value: 41 %-time reduction of blocking flexibility

The second goal – the tests of a platform for purchase of non-frequency services also provided relevant achievements. It indicated that such a platform can work well for established services – control of reactive power management. There was a significant increase both in the amount of capacities available and contracted bids during simulations, which is reported in KPI_H05b (Volume of transactions – clear bids Q).

Target value: 1 954 MVAr

Result value: 2 392 MVAr

For the active power trades, we were below our ambition mostly because it is not a regularly used service. On the other hand, the amount of available capacities in this regard has increased as well.

Target value: 50 MW

Result value: 6 MW

The KPIs for the Czech DEMO both common and DEMO specific were reported and acknowledged by WP 11.

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3 Inputs for CBA

This chapter gives an overview of the indicators that can be applied to the CBA for the 4 demonstrations by two indicator categories. The input data for the CBA was based on the methodology of the ENTSO-E guidelines [2] applied to other projects. The information and KPI calculations were established based on independent activities at each demo site, yet the approaches were uniformly applied. The sources were as follows:

Demo Participants: It is likely that the values were provided by the participants of the demonstrations. In many projects, particularly those involving demonstrations or pilot implementations, participants contributed data based on their experiences and operational metrics. This data was particularly useful for CBAs as it reflected real-world applications and outcomes.

Reference Values for Countries: The values also served as reference values specific to the countries where the demonstrations took place. These encompassed standard cost metrics, economic indicators, energy prices, or other relevant data that typically vary by country. Utilizing country-specific reference values helped tailor the CBA to the context of each demonstration, making the analysis more relevant and accurate. The values constituted a mix of data provided by the demo participants and reference values for the countries involved. This approach offered a comprehensive perspective, combining real-world data from the demonstrations with contextual data from the respective countries.

ENTSO-E Guidelines and Other Projects: The methodology for the CBA incorporated standard practices or benchmarks established in the ENTSO-E guidelines. The reference to "other projects" suggested that historical data or precedents from similar projects were used as a reference point or to validate the current project's data.

In summary, the KPI calculations and information were derived from a combination of contributions by demo participants, country-specific reference values, and established practices from the ENTSO-E guidelines and similar projects. This integrated approach ensured the CBA was both relevant and grounded in real-world experiences and standardized benchmarks.

3.1 Polish inputs for CBA

The following table presents the indicators used in the Polish demo, which can be used for CBA, by two indicator categories (benefit indicator (B) and cost indicator (C).

Table 3-1 - Polish inputs for CBA

Indicator type	Indicator ID	Indicator name	Indicator description	Unit
Benefit indicator (B)	B1	Socioeconomic welfare (SEW)	Instead of investing in strengthening the network, we give money to flexible consumers. The amount of payout depends on the duration of network congestion and voltage problem. Average price per consumer was based on prices of energy on Polish market - 112 EUR for kWh.	6,250,000 €/year
	B2	CO_2 emissions	The main goal of the PL DEMO was to create a platform service procurement for TSO and DSO. Using flexibility to solve congestion and voltage problems in the network doesn't reduce carbon emissions because consumers just shift their consumption to time without a congested network. On the other hand, CO_2 emissions decreased due to the replacement of coal power plants generation to the PV renewable generation. Limiting PV installation in the peak hours to solve the voltage problems in the LV grid allows to connect more PV installation and generate more energy in the peak hours. Instead of making electricity from fossil fuels, new RES will decrease CO_2 emissions.	102.5 t CO_2/year
	B3	RES integration	The ability to limit generation during critical peak hours of the day allows for increased connection of additional PV sources to the grid, which will overall provide additional energy throughout the year (despite limiting production during peak hours on certain days).	248 MW
	B4	Non-CO_2 emissions	Because consumers replaced fossil fuels heating with heat pumps non-CO_2 emissions decreased. (e.g. COX, NOX, SOX, PM2,5,10).	23.7 Tons/yr
Costs indicator (C)	C1	Capital expenditure (CAPEX)	The CAPEX covering the platform with backend systems	390,000 €

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	C2	Operating expenditure (OPEX)	OPEX concerns maintenance contracts for backend systems. + OPEX for payment for services (same as social welfare)	3,000 €/year +6,250,000 €/year

This table is just for the DSO's congestion/voltage control part of the flexibility services. We couldn't provide any reliable data for the analysis of the rest of the services (especially the balancing services for the TSO). Since we do not know what approach the Regulator will adopt in Poland, we assume that purchasing services will be a cost for the DSO to bear when using the flexibility market.

3.2 Hungarian inputs for CBA

The following table presents the indicators used in the Hungarian demo, which can be used for CBA, by two indicator categories (benefit indicator (B) and cost indicator (C)).

Table 3-2 - Hungarian inputs for CBA

Indicator type	Indicator ID	Indicator name	Indicator description	Unit
Benefit indicator (B)	B1	Socioeconomic welfare (SEW)	The project enhances the selection process for network development in terms of location, timing, and necessity. Approximately 600 billion HUF is allocated for network construction under the Recovery and Resilience Facility (RRF), with 1-1.5% of this amount earmarked for the project. Considering that the RRF funds will be disbursed over a period of approximately 2-3 years, it is important to proportionately allocate the budget, resulting in an annual expenditure in EUR.	7,894,000€/yr
	B2	CO_2 emissions	The functional extension package demonstrated in the demo includes, in addition to purely market-based offers, DSO redispatch offers which are integrated into the merit order with a pseudo price, thereby enabling their activation. Activation occurs at the asset level, allowing for the individual selection of which assets to activate. The renewable energy sector in Hungary has shown significant development, particularly with a	2.74mt CO_2/year

			focus on photovoltaic power plants. By 2022, the installed capacity of solar power plants in Hungary exceeded 4,000 megawatts, with future projects potentially doubling this capacity, helping Hungary to potentially reach its target of 6,000 megawatts of total installed solar capacity well before the 2030 goal. Wind power in Hungary is relatively small, with a capacity around 330 megawatts, all of which were authorized and constructed before 2016 due to restrictive legislation that has since made the construction of new wind farms practically impossible. In terms of Hungary's overall energy policy and climate targets, the country has made a legal commitment to achieve carbon neutrality by 2050, guided by its National Energy and Climate Plan (NECP) and the National Clean Development Strategy (NCDS). These plans set out ambitious targets, including a minimum of 21% share of renewable energy sources in gross final energy consumption by 2030. The renewable energy share in gross final energy consumption had already reached 13.9% by the end of 2020, surpassing the 2020 target but still below the 2030 ambition. To calculate the amount of renewable energy production in TWh, more specific data on the total energy production and the share of renewables would be needed, which was not directly available from the sources reviewed. However, knowing the installed capacity and the target percentages for renewable energy shares can give an indication of the growing importance of renewables in Hungary's energy mix. Concerning the calculation of savings in terms of CO2 emissions by avoiding curtailments using renewable energies, specific data on the total renewable energy production in TWh is required. Without this, it's challenging to provide an accurate calculation. Typically, these calculations would involve knowing the total renewable energy output, the percentage of this that could be considered as saved or additionally utilized through efficiency measures (in this case, the 5% figure you mentioned), and then applying a typical CO2 emission factor for a gas-fired power plant to the amount of energy saved. The emission factor varies by plant and technology, but a common figure used in such	

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			calculations is around 0.4 kg CO2 per kWh for natural gas plants. This figure would then be applied to the calculated 'saved' energy amount to estimate the CO2 savings.	
	B3	RES integration	In the Flexon grant application, a key performance indicator is the engagement of 657 participants, which could be used as a basis for performance measurement. Additionally, the overall goal of the Flexon grant is to integrate 9.9 MW of producers, although this figure represents only the number of physically implemented units.	9.9 MW
	B4	Non-CO2 emissions	Same as B2	2.74m Tons/yr
	B5	Grid losses	In the use case of transformer overload, the iron losses in transformers decrease, thereby potentially avoiding the need for transformer expansion. This use case also facilitates the integration of more renewable energy sources onto the grid, which in turn affects network losses. Due to this impact on network losses, we prefer not to quantify this aspect.	N/A
	B6	Security of supply: Adequacy	Local extra production clearly enhances supply security. However, we are unable to quantify this effect.	N/A
	B7	Security of supply: Flexibility		7
	B8	Security of supply: Stability	More accurate network modeling and data enhance the precision of analyses, which is crucial as power companies integrate increasing amounts of renewable generation and distributed energy resources. This accuracy is especially important today, saving significant time in data handling and facilitating better decision-making. In the context of TSO-DSO coordination, the implementation of a "traffic light" system ensures that offers remain available even in the last moments on the balancing market. This system allows for more effective management of network constraints and integration of renewable energy sources, enhancing grid stability and efficiency.	8
	B9	Redispatch Reserves/Reduction of	The demo was not connected to the intraday market, and this aspect was not examined.	N/A

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		Necessary Reserves for Redispatch Power Plants		
Costs indicator (C)	C1	Capital expenditure (CAPEX)	For IT development, we allocated 18 person-months (PM). The platform design was allocated 52 PMs, and its development was estimated at 36 PMs. (One PM is equivalent to 4,000 EUR.)	424,000 €
				€
	C2	Operating expenditure (OPEX)		42,000 €/year

3.3 Slovenian inputs for CBA

The following table presents the indicators used in the Slovenian demo, which can be used for CBA, by two indicator categories (benefit indicator (B) and cost indicator (C)).

Table 3-3 - Slovenian inputs for CBA

Indicator type	Indicator ID	Indicator name	Indicator description	Unit
Benefit indicator (B)	B1	Socioeconomic welfare (SEW)	Instead of investing in strengthening the network, we give money to flexible consumers. The amount of payout depends on the duration of network congestion, average price per consumer was 50 EUR, multiplied by 30 consumers for SI demo.	1500 €/yr
	B2	CO_2 emissions	The main goal of the SI DEMO was to create a platform for non-frequency service procurement for DSO. Using flexibility to solve congestion in the network doesn't reduce carbon emissions because consumers just shift their consumption to time without a congested network. On the other hand, CO_2 emissions decreased due to the	60 t CO_2/year

			replacement of fossil fuels heating with heat pumps. Limiting solar power plants at high voltages on the LV grid increases new RES integration. Instead of making electricity from fossil fuels new RES will decrease CO2 emissions.	
	B3	RES integration	In a rural environment, the grid is usually overloaded in the evening hours when RES (PVs) are not working and cannot solve the overloaded grid. Overloads also occur on weekends when PVs are operating, but they cannot increase production further because production depends on the sun. Limiting PV's in time of high voltage can increase new RES integration (unlocking of renewable generation potential).	200 MW
	B4	Non-CO2 emissions	Because consumers replaced fossil fuels heating with heat pumps non-CO2 emissions decreased. (e.g. COX, NOX, SOX, PM2,5,10).	6 Tons/yr
	B5	Grid losses	There is no significant change in losses since we use flexibility to solve congestion and voltage problems at the LV network, where power is less than 10 kW per consumer. Changes of loses couldn't be observed in SI demo.	0 MVAr/year
	B6	Security of supply: Adequacy	Congestion management contributed on adequacy in SI demo which we measured to the activated flexibility energy.	2 MWh/yr
	B7	Security of supply: Flexibility	When the overload of the transformer is at its thermal limit, the failure of the entire transformer can be avoided with flexibility. With flexibility we can reduce interruption time. In the demonstration period we didn't have interruptions due to congestion.	0
	B8	Security of supply: Stability	When the overload of the transformer is at its thermal limit, the failure of the entire transformer can be avoided with flexibility. By keeping normal operation, we didn't have any distributed generation disruptions.	0
	B9	Redispatch Reserves/Reduction of Necessary Reserves for Redispatch Power Plants	As the main concern of the project is non-frequency services, the redispatch is not involved at all in the portfolio of included activities.	0 €/yr

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Costs indicator (C)	C1	Capital expenditure (CAPEX)	The CAPEX covering the platform with backend systems	350,000 €
	C2	Operating expenditure (OPEX)	OPEX concerns maintenance contracts for backend systems.	12,000 €/year

3.4 Czech inputs for CBA

The following table presents the indicators used in the Czech demo, which can be used for CBA, by two indicator categories (benefit indicator (B) and cost indicator (C)).

Table 3-4 - Czech inputs for CBA

Indicator type	Indicator ID	Indicator name	Indicator description	Unit
Benefit indicator (B)				
	B2	CO2 emissions	The main goal of the Czech DEMO was to create a platform for non-frequency service procurement, which included both renewables/intermittent resources i.e. There isn't a primary goal to identify reduction of carbon emissions. However due to a certain part of renewables incorporated into the platform there is reduction of the CO2 emissions involved.	27 t CO2/year
	B3	RES integration	It defines the ability of the power system to connect new RES generation, unlock existing and future 'renewable' generation, and minimize the curtailment of electricity produced from RES. The RES integration indicator is linked to the EU 2030 goal of increasing the share of RES to 32% of overall energy consumption.	6,725 MW
	B5	Grid losses	Grid losses in the transmission grid are the cost of compensating for thermal losses in the power system due to the project. It is an indicator of energy efficiency24 and is expressed as a cost in euros per year.	2,392 MVAr/year

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	B7	Security of supply: Flexibility	The project enables to considerably improve the environment for flexibility procurement in the Czech Republic as it provides one centralized place indicating availability of the grid for flexibility activation (traffic light scheme). This solution is now enabled for regular network operation.	9
	B8	Security of supply: Stability	The project as such has not direct emphasize on “security of supply”. However, the system (the Czech DEMO) enables the increase of registered flexibility providers which means there is a bigger portfolio of resources enabling system security and stability in case of any imbalance or network issues.	9
Costs indicator (C)	C1	Capital expenditure (CAPEX)	The CAPEX covers the creation of the traffic light scheme including flexibility register, grid availability module, data architecture/data design.	176,240 €
			The CAPEX covers the creation of the Non frequency market platform for procurement non frequency services (based on same flexibility register module as traffic light scheme).	128,435 €
	C2	Operating expenditure (OPEX)	OPEX concerns mainly hosting services from external IT service providers. This goes mainly for the first part of the DEMO (traffic light scheme).	19,992 €/year

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4 Scalability and replicability

To determine the capability that the developed solutions could be implemented at a larger scale, and to assess the potential of these solutions in other countries, a scalability and replicability questionnaire was circulated among the countries of the Eastern Cluster. The demonstration leaders were assigned to complete these questionnaires based on the experiences they gained during the project and use their whole previous experience of the organizations. The questionnaires used a simple scoring scheme, where higher scores represented better scalability and replicability potentials. The overall assessment of the solutions developed by the Eastern Cluster was done by averaging the score of each country.

The rationale for the scalability and replicability questionnaire is available in Annex A and Annex B. We indicated the scores by bolding the numbers in the last column of the questionnaires.

4.1 Cluster level

The overall average of the **scalability questionnaire** considering the answers of Hungary, Poland, Slovenia, and Czech Republic was 73.85%. That means a good scalability potential in general. In the technical dimension, the countries surveyed gave quite similar answers. In this dimension, the highest possible level of scalability (100%) was achieved in two factors: integration feasibility and external constraints. All countries involved in the survey answered that the design of the solution permits the integration of other components, and the scalability of the solution was not influenced by the specific locations. The worst results for scalability were achieved in interface design readiness (66.67%) in the factors of technical dimension, which reflects that a different approach is necessary when designing demonstration systems and systems that are ready for roll-out. It is also observed that as each country designed their products and services to reflect on the flexibility needs of their own grid, the applicability of the solutions in other countries is limited in many cases, which decreases this score. The economic viability question was only answered by Slovenia and Poland. Poland stands out in terms of economies of scale. All the surveyed countries had some regulatory barriers with respect to scalability that could have affected the solution. The contribution to the green energy transition in the environmental dimension resulted in the best average (93.75%) in scalability potential. Most countries thought that the solution will have a major direct impact in the green energy transition. Mixed feedback (50%) was given on how much the stakeholder's perceived acceptance of the developed solutions affect scalability; while in some cases a rather strong dependence on the stakeholders is seen, in other cases the developed solutions are more user-agnostic.

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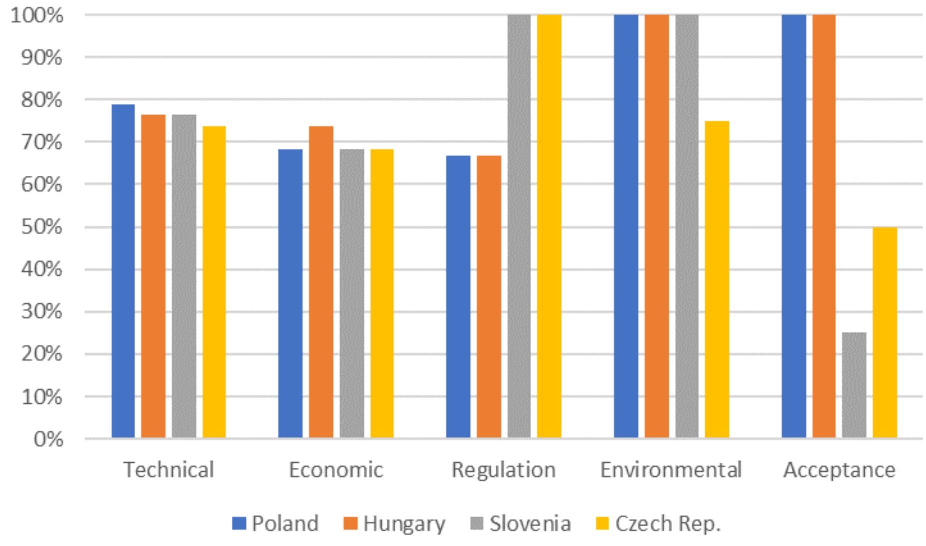

Figure 4-1 - results of the scalability questionnaire

The overall average of the **replicability questionnaire** was 72%, a bit lower compared to scalability. Considering the technical dimensions of replicability, the results of the factors of standardization and external conditions stand out (both over 90%). The economic dimensions of replicability gave the worst result overall, except for the factor of market design, which was over 90% in average. Compared to scalability, where all the questioned countries had some regulatory barriers, the situation for replicability is better, only two countries had such barriers. Also, the acceptance level is better for replicability potential in the analyzed countries. The environmental dimension gave the best result for replicability, because all the involved countries thought that the solution will have a major direct impact in the green energy transition.

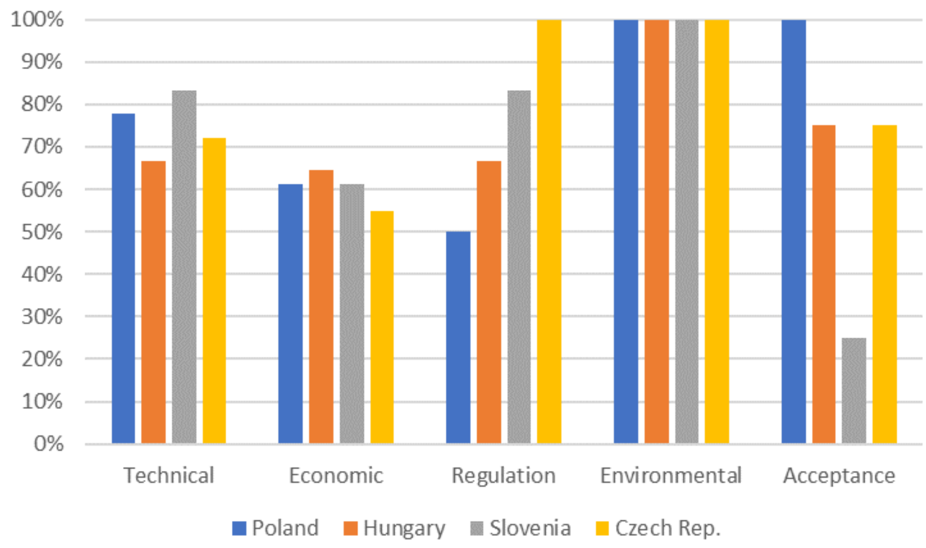

Figure 4-2 - results of the replicability questionnaire

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Table 4-1 - Scalability questionnaire of average (total average: 74%)

Dimension	Factor	Question No.	Average
Technical	Modularity (78%)	1.	83%
		2.	81%
		3.	69%
	Technology process (75%)	1.	100%
		2.	50%
	Interface design readiness (67%)	1.	75%
		2.	44%
		3.	81%
	Integration feasibility (100%)	1.	100%
	Existing infrastructure (71%)	1.	67%
		2.	75%
	External constraints (100%)	1.	100%
Economic	Viability (38%)	1.	38%
	Economy of scale (77%)	1.	81%
		2.	75%
		3.	69%
		4.	83%
Regulation	Regulatory & Legal issues (63%)	1.	63%
Environmental	Green investment (94%))	1.	94%
Acceptance	Level of acceptance (50%)	1.	50%

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Table 4-2 - Replicability questionnaire of average (total average: 72%)

Dimension	Factor	Question No.	Average
Technical	Standardization (92%)	1.	92%
	Interoperability (81%)	1.	81%
	Interface design flexibility (64%)	1.	78%
		2.	50%
	External conditions (94%)	1.	94%
Economic	Business model (47%)	1.	56%
		2.	38%
	Economy of scale (65%)	1.	78%
		2.	50%
		3.	67%
		4.	67%
		5.	63%
	Market design (94%)	1.	94%
Regulation	Regulatory (75%)	1.	75%
		2.	75%
Environmental	Green investment (100%)	1.	100%
Acceptance	Level of acceptance (69%)	1.	69%

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4.2 Poland

Table 4-3 - Scalability questionnaire - Poland

Dimension	Factor	Question	Options	Score to Scalability
Technical	(1) Modularity	1.Solution can be divided into interdependent components?	Clearly	**3**
			Partially	2
			No	1
		2. Would it be technically possible to increase the scale of the solution by easily adding components?	Yes, with minor	4
			Yes, with significant	**3**
			Yes, major	2
			No	1
		3. Does the increase in scale deteriorates the performance of the system/ algorithms/ software?	No	4
			Yes, minor	3
			Yes, certain	**2**
			Yes, major	1
	(2) Technology progress	1. Technological solutions allow increasing the solution size?	Yes	**3**
			Partially	2
			Not	1
		2. In case of not, do you foresee technological advances in the short to medium term that will mitigate performance reduction	Yes	1
			No	**0**
	(3) Interface design readiness	1. How the control of components in your solution is organized? By centralized we mean that it is a plug-and-play process to scale up.	Centralized	3
			Mixed	**2**
			Decentralized	1
		2. From a scalability point of view how is the impact of the solution described in the demonstrator?	Global	4
			European	**3**
			SE region	2
			Country-specific	1

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		3. Design of the solution so that is compatible with different utilities and other third-party systems	Fully	**4**
			Only to other utilities	3
			Only to other vendors systems	2
			No	1
	(4) Integration feasibility	1. Does the design of the solution (i.e., system, software, hardware) permit the integration of more components?	Yes	**2**
			No	1
	(5) existing infrastructure	1. Are there any physical size limitations that hinder the scale-up of the solution?	No	3
			Not of importance	**2**
			Yes	1
		2. Presence of weak elements (network configuration, specific parts of network or specific required infrastructure, size limitation)	No	3
			Not of importance	**2**
			Yes	1
	(6) external constraints	1. Is the scalability of the solution influenced by the specific location of your demo?	No	**4**
			Yes minor	3
			Yes, certain	2
			Yes, major	1
Economic	(1) Viability	1. Input from CBA process	BCR > 10	4
			2<BCR <10	3
			1< BCR < 2	2
			BCR=1	**1**
	(2) Economy of scale	1. If the solution size increases, how do you think the costs and benefits of the solution would increase	Benefit would increase significantly compared to costs	**4**
			Benefits would increase slightly compared to costs	3
			Similar increase	2
			Not yet considered	1
			Yes, major	**4**

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		2. Do you foresee evolutions in the short to medium term which will have a positive influence on the cost-benefit ratio of your solution from scalability point of view?	Yes, partial	3
			Yes, minor	2
			No	1
		3. Are there any economic barriers with respect to scalability that could affect the solution?	No	4
			Yes minor	**3**
			Yes, partial	2
			Yes, major	1
		4. The business model can be scaled up	Yes	3
			No	2
			Not yet considered	**1**
Regulation	Regulatory & Legal issues	1. Are there any regulatory barriers with respect to Scalability that could affect the solution?	No	4
			Yes minor	3
			Yes some	**2**
			Yes major	1
Environmental	Green investment	1. Does the solution contributes to the energy green transition	Yes, major direct impact	**4**
			Yes, partial direct impact	3
			Yes, indirect impact	2
			Not yet considered	1
Acceptance	Level of acceptance	Is the stakeholders' importance regarding scalability potential for your solution?	Yes, major	1
			Yes, some	2
			Yes, minor	3
			No importance	**4**

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Table 4-4 - Replicability questionnaire - Poland

Dimension	Factor	Question	Options	Score to Scalability
Technical	(1) Standardization	1. Is the solution standards compliant? If yes, with which type of standards (mandatory or voluntary)	Yes, mandatory standards	**3**
			Yes, voluntary standards	2
			No	1
	(2) Interoperability	1. Is the solution interoperable both northbound and southbound with existing systems regardless the country of installation?	Yes, both	**4**
			Yes, with minor adjustments based on location	3
			Yes, only partially	2
			No, significant adjustments needed	1
	(3) Interface design flexibility	1. The installation of your system/ components in different locations/countries requires centralized, decentralized control or both	Centralized	3
			Both	**2**
			Decentralized	1
		2. From a replicability point of view how is the impact of the solution described in the Demo Case: national/ regional/ local...?	Global	4
			National	3
			Eastern Cluster	2
			Country-specific	**1**
	(4) External conditions	1. Is the replicability of the solution influenced by the specific infrastructure of the location of your demo?	No influence	**4**
			Yes, minor	3
			Yes, some	2
			Yes, major	1
Economic	(1) Business model	1. Based on the own experience, do you think that solution could easily deployed in other environment without additional investment (time/money)? If not; why?	Yes, minor	4
			Yes, some	**3**
			Yes, major	2
			No	1
		2. Input from CBA process	BCR > 10	4
			2<BCR <10	3
			1< BCR < 2	2
			BCR=1	**1**

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	(2) Economy of scale	1. Have you evaluated different options (locations, network topology...) before the implementation?	Yes, with good results	3
			No	**2**
			Yes, with negative	1
		2. Do you foresee evolutions in the short to medium term which will have a positive influence on the cost-benefit ratio of your solution from replicability point of view?	Yes, major	4
			Yes, some	3
			Yes, minor	2
			No	**1**
		3. Have you performed some analyses to study the influence of economic factors on the replicability capacity of the adopted solution in OneNet demo countries?	Yes, with positive	3
			No	**2**
			Yes, with poor	1
		4. From replicability point of view do you think the solution would be profitable in the rest European countries?	Yes, all minor	5
			Yes, all major	**4**
			Yes, some minor	3
			Yes, some major	2
			No	1
		5. Are there any economic barriers with respect to Replicability that could affect the solution?	No	4
			Yes, minor	3
			Yes, some	**2**
			Yes, major	1
	(3) Market design	1. Does the existing European electricity markets design or any progress of it in the future directly affect the technical performance of the solution?	No	**4**
			Yes, minor	3
			Yes, some	2
			Yes, major	1
Regulation	Regulatory	1.Are there any regulatory barriers with respect to Replicability that could affect the solution?	No	4
			Yes, minor	3
			Yes, some	**2**
			Yes, major	1
		2. Does your solution depend on elements of current national or regional regulation that are necessary for your solution to be feasible and viable?	No	2
			Yes	**1**

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Environmental	Green investment	1. Does the solution contributes to the energy green transition	Yes, major direct impact	**4**
			Yes, partial direct impact	3
			Yes, indirect impact	2
			Not yet considered	1
Acceptance	Level of acceptance	Is the stakeholders' importance regarding scalability potential for your solution?	Yes, major	1
			Yes, some	2
			Yes, minor	3
			No importance	**4**

4.3 Hungary

Table 4-5 - Scalability questionnaire - Hungary

Dimension	Factor	Question	Options	Score to Scalability
Technical	(1) Modularity	1.Solution can be divided into interdependent components?	Clearly	3
			Partially	**2**
			No	1
		2. Would it be technically possible to increase the scale of the solution by easily adding components?	Yes, with minor	**4**
			Yes, with significant	3
			Yes, major	2
			No	1
		3. Does the increase in scale deteriorates the performance of the system/ algorithms/ software?	No	4
			Yes, minor	**3**
			Yes, certain	2
			Yes, major	1
	(2) Technology progress	1. Technological solutions allow increasing the solution size?	Yes	**3**
			Partially	2
			Not	1
			Yes	1

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		2. In case of not, do you foresee technological advances in the short to medium term that will mitigate performance reduction	No	0
	(3) Interface design readiness	1. How the control of components in your solution is organized? By centralized we mean that it is a plug-and-play process to scale up.	Centralized	**3**
			Mixed	2
			Decentralized	1
		2. From a scalability point of view how is the impact of the solution described in the demonstrator?	Global	4
			European	3
			SE region	2
			Country-specific	**1**
		3. Design of the solution so that is compatible with different utilities and other third-party systems	Fully	4
			Only to other utilities	**3**
			Only to other vendors systems	2
			No	1
	(4) Integration feasibility	1. Does the design of the solution (i.e., system, software, hardware) permit the integration of more components?	Yes	**2**
			No	1
	(5) existing infrastructure	1. Are there any physical size limitations that hinder the scale-up of the solution?	No	3
			Not of importance	**2**
			Yes	1
		2. Presence of weak elements (network configuration, specific parts of network or specific required infrastructure, size limitation)	No	3
			Not of importance	**2**
			Yes	1
	(6) external constraints	1. Is the scalability of the solution influenced by the specific location of your demo?	No	**4**
			Yes minor	3
			Yes, certain	2
			Yes, major	1
Economic	(1) Viability	1. Input from CBA process	BCR > 10	4
			2<BCR <10	3
			1< BCR < 2	**2**

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			BCR=1	1
	(2) Economy of scale	1. If the solution size increases, how do you think the costs and benefits of the solution would increase	Benefit would increase significantly compared to costs	**4**
			Benefits would increase slightly compared to costs	3
			Similar increase	2
			Not yet considered	1
		2. Do you foresee evolutions in the short to medium term which will have a positive influence on the cost-benefit ratio of your solution from scalability point of view?	Yes, major	4
			Yes, partial	**3**
			Yes, minor	2
			No	1
		3. Are there any economic barriers with respect to scalability that could affect the solution?	No	4
			Yes minor	3
			Yes, partial	**2**
			Yes, major	1
		4. The business model can be scaled up	Yes	**3**
			No	2
			Not yet considered	1
Regulation	Regulatory & Legal issues	1. Are there any regulatory barriers with respect to Scalability that could affect the solution?	No	4
			Yes minor	3
			Yes some	**2**
			Yes major	1
Environmental	Green investment	1. Does the solution contributes to the energy green transition	Yes, major direct impact	**4**
			Yes, partial direct impact	3
			Yes, indirect impact	2
			Not yet considered	1
Acceptance	Level of acceptance	Is the stakeholders' importance regarding scalability potential for your solution?	Yes, major	1
			Yes, some	2
			Yes, minor	3
			No importance	**4**

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Table 4-6 - Replicability questionnaire - Hungary

Dimension	Factor	Question	Options	Score to Scalability
Technical	(1) Standardization	1. Is the solution standards compliant? If yes, with which type of standards (mandatory or voluntary)	Yes, mandatory standards	**3**
			Yes, voluntary standards	2
			No	1
	(2) Interoperability	1. Is the solution interoperable both northbound and southbound with existing systems regardless the country of installation?	Yes, both	4
			Yes, with minor adjustments based on location	**3**
			Yes, only partially	2
			No, significant adjustments needed	1
	(3) Interface design flexibility	1. The installation of your system/components in different locations/countries requires centralized, decentralized control or both	Centralized	3
			Both	**2**
			Decentralized	1
		2. From a replicability point of view how is the impact of the solution described in the Demo Case: national/ regional/ local...?	Global	4
			National	3
			Eastern Cluster	2
			Country-specific	**1**
	(4) External conditions	1. Is the replicability of the solution influenced by the specific infrastructure of the location of your demo?	No influence	4
			Yes, minor	**3**
			Yes, some	2
			Yes, major	1
Economic	(1) Business model	1. Based on the own experience, do you think that solution could easily deployed in other environment without additional investment (time/money)? If not; why?	Yes, minor	4
			Yes, some	3
			Yes, major	**2**
			No	1
		2. Input from CBA process	BCR > 10	4
			2<BCR <10	3
			1< BCR < 2	**2**
			BCR=1	1

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	(2) Economy of scale	1. Have you evaluated different options (locations, network topology...) before the implementation?	Yes, with good results	**3**
			No	2
			Yes, with negative	1
		2. Do you foresee evolutions in the short to medium term which will have a positive influence on the cost-benefit ratio of your solution from replicability point of view?	Yes, major	4
			Yes, some	3
			Yes, minor	**2**
			No	1
		3. Have you performed some analyses to study the influence of economic factors on the replicability capacity of the adopted solution in OneNet demo countries?	Yes, with positive	3
			No	**2**
			Yes, with poor	1
		4. From replicability point of view do you think the solution would be profitable in the rest European countries?	Yes, all minor	5
			Yes, all major	**4**
			Yes, some minor	3
			Yes, some major	2
			No	1
		5. Are there any economic barriers with respect to Replicability that could affect the solution?	No	4
			Yes, minor	3
			Yes, some	**2**
			Yes, major	1
	(3) Market design	1. Does the existing European electricity markets design or any progress of it in the future directly affect the technical performance of the solution?	No	4
			Yes, minor	**3**
			Yes, some	2
			Yes, major	1
Regulation	Regulatory	1.Are there any regulatory barriers with respect to Replicability that could affect the solution?	No	4
			Yes, minor	3
			Yes, some	**2**
			Yes, major	1
		2. Does your solution depend on elements of current national or regional regulation that are necessary for your solution to be feasible and viable?	No	**2**
			Yes	1

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Environmental	Green investment	1. Does the solution contributes to the energy green transition	Yes, major direct impact	**4**
			Yes, partial direct impact	3
			Yes, indirect impact	2
			Not yet considered	1
Acceptance	Level of acceptance	1. Is the stakeholders' importance regarding scalability potential for your solution?	Yes, major	1
			Yes, some	2
			Yes, minor	**3**
			No importance	4

4.4 Slovenia

Table 4-7 - Scalability questionnaire - Slovenia

Dimension	Factor	Question	Options	Score to Scalability
Technical	(1) Modularity	1.Solution can be divided into interdependent components?	Clearly	**3**
			Partially	2
			No	1
		2. Would it be technically possible to increase the scale of the solution by easily adding components?	Yes, with minor	4
			Yes, with significant	**3**
			Yes, major	2
			No	1
		3. Does the increase in scale deteriorates the performance of the system/ algorithms/ software?	No	4
			Yes, minor	3
			Yes, certain	**2**
			Yes, major	1
	(2) Technology progress	1. Technological solutions allow increasing the solution size?	Yes	**3**
			Partially	2
			Not	1

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		2. In case of not, do you foresee technological advances in the short to medium term that will mitigate performance reduction	Yes	1
			No	0
	(3) Interface design readiness	1. How the control of components in your solution is organized? By centralized we mean that it is a plug-and-play process to scale up.	Centralized	3
			Mixed	**2**
			Decentralized	1
		2. From a scalability point of view how is the impact of the solution described in the demonstrator?	Global	4
			European	3
			SE region	**2**
			Country-specific	1
		3. Design of the solution so that is compatible with different utilities and other third-party systems	Fully	4
			Only to other utilities	**3**
			Only to other vendors systems	2
			No	1
	(4) Integration feasibility	1. Does the design of the solution (i.e., system, software, hardware) permit the integration of more components?	Yes	**2**
			No	1
	(5) existing infrastructure	1. Are there any physical size limitations that hinder the scale-up of the solution?	No	3
			Not of importance	**2**
			Yes	1
		2. Presence of weak elements (network configuration, specific parts of network or specific required infrastructure, size limitation)	No	**3**
			Not of importance	2
			Yes	1
	(6) external constraints	1. Is the scalability of the solution influenced by the specific location of your demo?	No	**4**
			Yes minor	3
			Yes, certain	2
			Yes, major	1
Economic	(1) Viability	1. Input from CBA process	BCR > 10	4
			2<BCR <10	3
			1< BCR < 2	**2**

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			BCR=1	1
	(2) Economy of scale	1. If the solution size increases, how do you think the costs and benefits of the solution would increase	Benefit would increase significantly compared to costs	**4**
			Benefits would increase slightly compared to costs	3
			Similar increase	2
			Not yet considered	1
		2. Do you foresee evolutions in the short to medium term which will have a positive influence on the cost-benefit ratio of your solution from scalability point of view?	Yes, major	4
			Yes, partial	3
			Yes, minor	**2**
			No	1
		3. Are there any economic barriers with respect to scalability that could affect the solution?	No	4
			Yes minor	3
			Yes, partial	**2**
			Yes, major	1
		4. The business model can be scaled up	Yes	**3**
			No	2
			Not yet considered	1
Regulation	Regulatory & Legal issues	1. Are there any regulatory barriers with respect to Scalability that could affect the solution?	No	4
			Yes minor	**3**
			Yes some	2
			Yes major	1
Environmental	Green investment	1. Does the solution contributes to the energy green transition	Yes, major direct impact	**4**
			Yes, partial direct impact	3
			Yes, indirect impact	2
			Not yet considered	1
Acceptance	Level of acceptance	Is the stakeholders' importance regarding scalability potential for your solution?	Yes, major	**1**
			Yes, some	2
			Yes, minor	3
			No importance	4

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Table 4-8 - Replicability questionnaire - Slovenia

Dimension	Factor	Question	Options	Score to Scalability
Technical	(1) Standardization	1. Is the solution standards compliant? If yes, with which type of standards (mandatory or voluntary)	Yes, mandatory standards	3
			Yes, voluntary standards	**2**
			No	1
	(2) Interoperability	1. Is the solution interoperable both northbound and southbound with existing systems regardless the country of installation?	Yes, both	4
			Yes, with minor adjustments based on location	**3**
			Yes, only partially	2
			No, significant adjustments needed	1
	(3) Interface design flexibility	1. The installation of your system/components in different locations/countries requires centralized, decentralized control or both	Centralized	**3**
			Both	2
			Decentralized	1
		2. From a replicability point of view how is the impact of the solution described in the Demo Case: national/ regional/ local...?	Global	4
			National	**3**
			Eastern Cluster	2
			Country-specific	1
	(4) External conditions	1. Is the replicability of the solution influenced by the specific infrastructure of the location of your demo?	No influence	**4**
			Yes, minor	3
			Yes, some	2
			Yes, major	1
Economic	(1) Business model	1. Based on the own experience, do you think that solution could easily deployed in other environment without additional investment (time/money)? If not; why?	Yes, minor	4
			Yes, some	3
			Yes, major	**2**
			No	1
		2. Input from CBA process	BCR > 10	4
			2<BCR <10	3
			1< BCR < 2	**2**

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			BCR=1	1
	(2) Economy of scale	1. Have you evaluated different options (locations, network topology...) before the implementation?	Yes, with good results	3
			No	**2**
			Yes, with negative	1
		2. Do you foresee evolutions in the short to medium term which will have a positive influence on the cost-benefit ratio of your solution from replicability point of view?	Yes, major	4
			Yes, some	**3**
			Yes, minor	2
			No	1
		3. Have you performed some analyses to study the influence of economic factors on the replicability capacity of the adopted solution in OneNet demo countries?	Yes, with positive	3
			No	**2**
			Yes, with poor	1
		4. From replicability point of view do you think the solution would be profitable in the rest European countries?	Yes, all minor	5
			Yes, all major	4
			Yes, some minor	3
			Yes, some major	**2**
			No	1
		5. Are there any economic barriers with respect to Replicability that could affect the solution?	No	4
			Yes, minor	3
			Yes, some	**2**
			Yes, major	1
	(3) Market design	1. Does the existing European electricity markets design or any progress of it in the future directly affect the technical performance of the solution?	No	**4**
			Yes, minor	3
			Yes, some	2
			Yes, major	1
Regulation	Regulatory	1.Are there any regulatory barriers with respect to Replicability that could affect the solution?	No	**4**
			Yes, minor	3
			Yes, some	2
			Yes, major	1
		2. Does your solution depend on elements of current national or regional regulation that are	No	2
			Yes	**1**

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		necessary for your solution to be feasible and viable?		
Environmental	Green investment	1. Does the solution contributes to the energy green transition	Yes, major direct impact	**4**
			Yes, partial direct impact	3
			Yes, indirect impact	2
			Not yet considered	1
Acceptance	Level of acceptance	1. Is the stakeholders' importance regarding scalability potential for your solution?	Yes, major	**1**
			Yes, some	2
			Yes, minor	3
			No importance	4

4.5 Czech Republic

Table 4-9 - Scalability questionnaire – Czech Republic

Dimension	Factor	Question	Options	Score to Scalability
Technical	(1) Modularity	1.Solution can be divided into interdependent components?	Clearly	3
			Partially	**2**
			No	1
		2. Would it be technically possible to increase the scale of the solution by easily adding components?	Yes, with minor	4
			Yes, with significant	**3**
			Yes, major	2
			No	1
		3. Does the increase in scale deteriorates the performance of the system/ algorithms/ software?	No	**4**
			Yes, minor	3
			Yes, certain	2
			Yes, major	1
	(2) Technology progress	1. Technological solutions allow increasing the solution size?	Yes	**3**
			Partially	2

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			Not	1
		2. In case of not, do you foresee technological advances in the short to medium term that will mitigate performance reduction	Yes	1
			No	0
	(3) Interface design readiness	1. How the control of components in your solution is organized? By centralized we mean that it is a plug-and-play process to scale up.	Centralized	3
			Mixed	**2**
			Decentralized	1
		2. From a scalability point of view how is the impact of the solution described in the demonstrator?	Global	4
			European	3
			SE region	2
			Country-specific	**1**
		3. Design of the solution so that is compatible with different utilities and other third-party systems	Fully	4
			Only to other utilities	**3**
			Only to other vendors systems	2
			No	1
	(4) Integration feasibility	1. Does the design of the solution (i.e., system, software, hardware) permit the integration of more components?	Yes	**2**
			No	1
	(5) existing infrastructure	1. Are there any physical size limitations that hinder the scale-up of the solution?	No	3
			Not of importance	**2**
			Yes	1
		2. Presence of weak elements (network configuration, specific parts of network or specific required infrastructure, size limitation)	No	3
			Not of importance	**2**
			Yes	1
	(6) external constraints	1. Is the scalability of the solution influenced by the specific location of your demo?	No	**4**
			Yes minor	3
			Yes, certain	2
			Yes, major	1
Economic	(1) Viability	1. Input from CBA process	BCR > 10	4
			2<BCR <10	3

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			1< BCR < 2	**2**
			BCR=1	1
	(2) Economy of scale	1. If the solution size increases, how do you think the costs and benefits of the solution would increase	Benefit would increase significantly compared to costs	4
			Benefits would increase slightly compared to costs	3
			Similar increase	2
			Not yet considered	**1**
		2. Do you foresee evolutions in the short to medium term which will have a positive influence on the cost-benefit ratio of your solution from scalability point of view?	Yes, major	4
			Yes, partial	**3**
			Yes, minor	2
			No	1
		3. Are there any economic barriers with respect to scalability that could affect the solution?	No	**4**
			Yes minor	3
			Yes, partial	2
			Yes, major	1
		4. The business model can be scaled up	Yes	**3**
			No	2
			Not yet considered	1
Regulation	Regulatory & Legal issues	1. Are there any regulatory barriers with respect to Scalability that could affect the solution?	No	4
			Yes minor	**3**
			Yes some	2
			Yes major	1
Environmental	Green investment	1. Does the solution contributes to the energy green transition	Yes, major direct impact	4
			Yes, partial direct impact	**3**
			Yes, indirect impact	2
			Not yet considered	1
Acceptance	Level of acceptance		Yes, major	1

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		Is the stakeholders' importance regarding scalability potential for your solution?	Yes, some	**2**
			Yes, minor	3
			No importance	4

Table 4-10 - Replicability questionnaire – Czech Republic

Dimension	Factor	Question	Options	Score to Scalability
Technical	(1) Standardization	1. Is the solution standards compliant? If yes, with which type of standards (mandatory or voluntary)	Yes, mandatory standards	**3**
			Yes, voluntary standards	2
			No	1
	(2) Interoperability	1. Is the solution interoperable both northbound and southbound with existing systems regardless the country of installation?	Yes, both	4
			Yes, with minor adjustments based on location	**3**
			Yes, only partially	2
			No, significant adjustments needed	1
	(3) Interface design flexibility	2. From a replicability point of view how is the impact of the solution described in the Demo Case: national/ regional/ local...?	Global	4
			National	**3**
			Eastern Cluster	2
			Country-specific	1
	(4) External conditions	1. Is the replicability of the solution influenced by the specific infrastructure of the location of your demo?	No influence	**4**
			Yes, minor	3
			Yes, some	2
			Yes, major	1
Economic	(1) Business model	1. Based on the own experience, do you think that solution could easily deployed in other environment without additional investment (time/money)? If not; why?	Yes, minor	4
			Yes, some	3
			Yes, major	**2**
			No	1
		2. Input from CBA process	BCR > 10	4
			2<BCR <10	3

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			1< BCR < 2	**2**
			BCR=1	1
	(2) Economy of scale	1. Have you evaluated different options (locations, network topology...) before the implementation?	Yes, with good results	3
			No	**2**
			Yes, with negative	1
		2. Do you foresee evolutions in the short to medium term which will have a positive influence on the cost-benefit ratio of your solution from replicability point of view?	Yes, major	4
			Yes, some	3
			Yes, minor	**2**
			No	1
		3. Have you performed some analyses to study the influence of economic factors on the replicability capacity of the adopted solution in OneNet demo countries?	Yes, with positive	3
			No	**2**
			Yes, with poor	1
		4. From replicability point of view do you think the solution would be profitable in the rest European countries?	Yes, all minor	5
			Yes, all major	4
			Yes, some minor	**3**
			Yes, some major	2
			No	1
		5. Are there any economic barriers with respect to Replicability that could affect the solution?	No	**4**
			Yes, minor	3
			Yes, some	2
			Yes, major	1
	(3) Market design	1. Does the existing European electricity markets design or any progress of it in the future directly affect the technical performance of the solution?	No	**4**
			Yes, minor	3
			Yes, some	2
			Yes, major	1
Regulation	Regulatory	1.Are there any regulatory barriers with respect to Replicability that could affect the solution?	No	**4**
			Yes, minor	3
			Yes, some	2
			Yes, major	1
			No	**2**

		2. Does your solution depend on elements of current national or regional regulation that are necessary for your solution to be feasible and viable?	Yes	1
Environmental	Green investment	1. Does the solution contributes to the energy green transition	Yes, major direct impact	**4**
			Yes, partial direct impact	3
			Yes, indirect impact	2
			Not yet considered	1
Acceptance	Level of acceptance	1. Is the stakeholders' importance regarding scalability potential for your solution?	Yes, major	1
			Yes, some	2
			Yes, minor	**3**
			No importance	4

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5 Lessons learned

The feedback from the demos has been collected and the stakeholder input is presented below.

5.1 Poland

The OneNet project demonstration in Poland aimed to develop and test market solutions increasing network operation's flexibility, which will increase the reliability and efficiency of the distribution network and enable coordination of activities between DSOs and TSOs in the functioning of the future flexibility services market. The lack of regulations in Poland regarding flexibility and the flexibility market itself during the project forced the creation of such market mechanisms within the project from scratch and the method of its cooperation with the Balancing Market. As part of the project work, the scope of services and products was defined, which were tested by the DSO and TSO as part of the Polish demonstration. Both business and system use cases (BUC and SUC) have been developed to reflect the processes and the relationship between individual actors operating in the energy market. Building on these foundations, a prototype flexibility platform was created. This platform was designed as an open environment that provides easy access to entities operating in the flexibility market. The platform played a key role for the stakeholders involved in the demonstration: TSO, DSO, FSPs, Aggregator and market operator. The platform is equipped with one of the pivotal elements developed as part of the project - a mechanism coordinating activities between the DSO and the TSO, which is used to ensure the security of the distribution network. An algorithm was developed and tested to optimize the use of available resources while maintaining an appropriate DSO network security level. An algorithm was developed and tested to optimize the use of available resources while maintaining an appropriate level of security of the DSO network. Details of the demonstration were reported in Deliverable D10.4 [3].

The tests and demonstrations carried out as part of the project provided a huge amount of practical knowledge about the functioning of the flexibility market and the regulatory, technical and organizational constraints that currently exist on the part of System Operators, clients and aggregators to launch the flexibility market in Poland.

As a result, the project developed several solutions described above, which may be used in the future, provided that the regulations and the flexibility market in Poland will be designed similarly to the ones established in the project. This is related to the amendment to the law and the method of implementing network codes regarding flexibility in Poland, which will take place in the coming years. If an integrated flexibility market is implemented, both the market platform and optimization algorithms can be used by Network Operators. The flexibility platform is prepared for large-scale implementation and launch in operating conditions of the energy market outside the demonstration framework. The developed coordination mechanisms between DSOs and TSOs and procedures for market processes on the platform may also be used in the future as the main products

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of the Polish demo. Before their launch and implementation, an extensive discussion is necessary with other DSOs in Poland and the adoption of the developed solutions as standard.

However, it should be remembered that when we talk about using the experience and solutions from the project in the future when shaping the flexibility market in Poland, a critical element is the implementation of national regulations and future network codes in a similar form and assumptions to those adopted when designing the market as part of the project.

5.2 Hungary

For the proper (error-free) operation of the developed functional extensions, the detection of data sources on the DSO side, as well as the pre-processing of heterogeneous data at the level of DSOs, require significant resources on the developer and company side, limiting the possibility of replication. The network calculation that is part of the market process, as well as the detail of the network modelling that supports it (both spatially and temporally), place high expectations on the DSO. However, their fulfilment can have a positive impact on other areas of expertise (e.g. the raison d'être of installing smart meters, data quality, AI applications) and promotes the synergy of the applied solutions. Nevertheless, the small-scale demonstrations have confirmed that the concept and the realization of the functional extensions, especially a single platform handling multiple products on multiple voltage levels for multiple congestion zones is adequate to define an operational, DSO-centric flexibility market, and the solution appears to be agnostic of the specificities of countries.

Stakeholders of the Hungarian demonstrator was the TSO (MAVIR), two DSOs (E.ON and MVM) providing service in 5 of 6 DSO areas of Hungary, and the national regulator (MEKH), who was involved in each step as a consulting party and who is responsible for channeling the results of the demonstration to actual regulation. The SOs has reached out frequently to potential users of flexibility services (FSPs, aggregators, etc.) to test the ideas being developed.

At the start of the project, it was a serious challenge that we are talking about a derivative market that is looking for a solution to an occasional technical problem, while its parameters (market volume, frequency of problem occurrence, location, severity, etc.) are not known. Taking all of this into account, we were looking for a comprehensive, extensible solution, but at the same time, this resulted in a complex tool that complements the current DSO toolbox. Among the advantages of the implemented system can be listed the rapid implementation, which can help DSOs in dealing with congestion, especially in the short and medium term. The same timeframe is supported by the fact that, in addition to market-based bids, we have created the management of other types of bids (e.g. DSO redispatch) in a common merit order by using pseudo prices.

The optimization task solved by the platform is highly non-linear. In the current state of the market, the DSO may need flexibility services in a small number of network locations, but their volume does not reach the amount

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that would appear at the TSO level. The perception of the magnitude of the problem affects the attitude of market participants (e.g. approach of the traffic light concept). The escalation of the technical issues is also non-linear (e.g. involved service areas), thus the scalability of the solutions is complicated to assess.

The timing determined by the participants of the demonstration was based on the existing market processes (bid submission and delivery times) with the aim of creating an independent flexibility market that can be operated by a DSO and has minimal impact on the TSO's processes. Due to the strong compromises made, bidding and market activation are relatively far apart in time, which brings a lot of uncertainty to the system from the side of the user (DSO) and supplier (FSP). However, the problem is not unique, in other cases we can also find examples of individually developed markets that do not converge in their timing (e.g. balancing and wholesale markets). However, it cannot be ignored that this timing has a negative impact on the operation of the flexibility markets, which are currently in first place in the queue; it predicts fewer expected transactions, lower expected revenues, lower liquidity, a situation which is expected to be less attractive for FSPs, thus making it more difficult for the extension of an otherwise good technical-economic solution.

During the demonstration, it was difficult to match the internal business processes of the various stakeholders (DSO, TSO, FSP) to the jointly used platform (and its operational logic), because in many cases these processes are not controlled from top level within the companies. Due to the structural heterogeneity of the companies, different effort requirements appeared. The relative immaturity of the market also contributes to the fact that the structural roles and functions responsible for flexibility are currently still missing in large companies. For this reason, in many cases it is not only difficult to find the answer to the questions that arise during the development, but also to identify the actor and competence possessing the answer. In many cases, we have experienced that people dealing with flexibility within companies have a different professional background, so they may have basic knowledge gaps related to electricity markets. In summary, the introduction of demonstration and flexibility markets represents a huge leap compared to the current DSO and TSO structures and operations. It was a common experience that the actors involved have difficulty proactively handling problems and providing solutions; such areas were, for example, market products and services.

None of the use-cases tested during the demonstration alone resulted in sufficient business benefits; this prioritizes the optimization (stacking) of services, in connection with which we also conducted research. The appearance of business benefits would be clearly supported if several entities started to work in coordination with each other in the flexibility markets. It was also a general opinion that the appearance of an independent market operator could facilitate the processes, especially if this actor is financially interested in the operation of the market.

DSO-centred flexibility appeared as part of the Winter Package as early as 2019, but its introduction was not achieved along the horizontal structure of the stakeholders. Due to the new policy plans that have come to light

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over time and the expected changes in the relevant network codes, the slower-reacting market players are playing a wait-and-see game. The initial expectation for the flexibility market was to deal with technical problems faster than traditional, CAPEX-centred solutions (e.g. network development) or with tools with a different approach (e.g. TOTEX). Based on the experience of the demonstration, however, it cannot be said that the participants were prepared for this; corporate thinking focuses on much shorter time horizons. Since the introduction of such solutions does not appear as a goal among the current tariff regulation goals, the advantages of the flexibility platform presented in the demonstration (including the related service and product structure, and the functional extensions) cannot be immediately implemented in the tariff structure. This is the most important task facing the regulatory environment for the future.

5.3 Slovenia

The Slovenian pilot is primarily focused on the flexibility services of the DSOs and the establishment of a local flexibility market. The data exchange is intended to enable interoperability using the CIM. As this pilot includes the actual activation of flexibility services, important knowledge and experience was gained in terms of technical solutions, customer engagement and increasing the success rate of flexibility service activation.

Stakeholders in Slovenian demonstrator TSO(Eles), three DSOs (ELGO, ELLJ, ELCE), aggregator GEN-I, and academia (UNLJ, EIMV) establish the demo areas where testing of the flexibility service to address congestion and voltage violations in the low-voltage distribution grid were performed.

In the Slovenian demo, we have set up a local flexibility market platform, which was implemented as an extension of the national data hub for customer access. There are five DSOs in Slovenia; three of them are partners in the OneNet project. As the flexibility market is implemented in the national data hub for customer access, the other two DSOs can easily connect to the flexibility market and all consumers in Slovenia have the same access regardless of their local DSO. This approach ensures sustainability, as this platform is now in normal operation and will continue to be used in the future. Details of the demonstration were reported in Deliverable D10.4 [3].

The ratio between the length of the LV and MV network in the Slovenian distribution network is much more favorable for the LV network compared to the other countries, with a ratio of 72% to 28% even close to the top of the EU. This means that the LV feeders are much longer and there are more voltage and congestion problems there. The flexibility market platform is used to solve the problems of the connected low-voltage grids. This means that the majority of flexible suppliers will be households and small commercial enterprises with higher consumption, such as heat pumps and battery storage systems. The developed flexibility market is intended to solve local overloads, so that larger projects (e.g. PCI) are not applicable.

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The flexibility market platform was presented several times (during design, development, and implementation) to the national regulatory authority (the Energy Agency). Regulator gave positive feedback and supported the developed platform. In fact, Slovenian regulator is on the Advisory and Dissemination Board of OneNet, and therefore monitors the project. Understands the developed platform as a sandbox.

The regulator was presented not only with positive but also negative lessons learned. One of the DSOs has already published a tender for 30 overloaded MV/LV substations supplying around 2000 consumers. Not only households and commercial consumers could offer flexibility on the tender; if they authorized an aggregator, the aggregator could also participate in the tender. After four months, no one has applied for a tender. Obviously, the value of the supply to the customer is higher than the cost of network reinforcement. Due to the low power (<4 kW per customer), the aggregators saw no business opportunity to aggregate this flexibility for frequency products for the TSOs (such as aFRR, mFRR). In addition, consumers expected automatic remote control of their loads. Although DSO has a technical solution to enable remote control via the relay at the main electricity meter, the consumer still needs to provide a two-wire connection from the load to the electricity meter or a similar solution. With a little available amount of flexibility, business cases are not viable.

Therefore, the regulatory and legislative environment is adequate and market platform was developed, further development is needed.

5.4 Czech Republic

The Czech demonstration project already incorporated part of the solution into real operation. The so-called traffic light scheme, described in more detail in Deliverable D10.4 [3], is a centralized environment reporting expected outages/outages from DSOs for each generator or flexibility unit. In addition, the TSO sends into the platform the information concerning procured/contracted services (total amount) for DSOs. The provider of a service sends into the platform information about activated services detailing all participating resources (which is important for the DSOs in terms of quality of supply in nodal areas). This scheme also contains a flexibility register detailing all relevant data for each aggregator/supplier.

The Czech demonstration project involved customers through aggregators (ČEZ ESCO and E.ON Energie) – direct participants of the demonstration projects. They provided customers to participate in the test of the platform of the non-frequency services as well as traffic light scheme. Part of the solution (EV charging points) was directly tested by ČEZ distribute, as these assets are owned and operated by the company itself.

Apart from the implementation of the part of the project results, some of the findings and achievements can be further piloted e.g. further development of the management of the EV charging infrastructure. Increasing the amount of EV charging stations will require sophisticated means for charging management but avoids massive investment into the reinforcement of the distribution grid. The project results will serve for further research concerning relevant grid tariffs methodology, charging patterns, data exchange among TSO, DSO, and aggregators etc.

Flexibility is an issue of key importance enabling further integration of renewables. Moreover, EU member states will have to implement the market design directive encouraging them to introduce regulatory flexibility framework. It is important to enable these key drivers' findings from national demo and other OneNet demonstrators. This goes mainly for DEMO findings on data exchange – i.e. data provided by aggregators and TSO to DSOs. The granularity, frequency and type of the data needed as well as a data model/architecture were a pivotal input for the debate on the design of the national solution for flexibility platform. The above-mentioned traffic light scheme as an interim solution will be also integrated into the new environment with all the modules, notably with the flexibility register.

The regulatory environment will have to reflect all the lessons learned from the projects. National guidelines for the operation of the distribution and transmission grid include definitions and methodology of non-frequency services – namely reactive power based. This should be completed at the end of 2024. There will have to be created methodology on data exchange allowing detailed knowledge about contracted capacities of flexibility for DSOs/local communities. The new Energy Law will also encompass new rules (standardization/certification) for flexibility providers. As the revision of the Energy law is more complex it will be completed in two phases – first part of the Energy law (the interim one) is to be finished in the 3Q of 2024, the full revision will be completed in the course of the 2025.

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6 Conclusions

Deliverable D10.5 aimed to organize and evaluate the experiences gathered during the demonstrations of the Eastern Cluster. To provide a comprehensive view on the very different and often country-specific solutions, qualitative and quantitative analysis was carried out.

The latter approach was supported by the calculation of key performance indicators (Chapter 2). The demonstrations were not in an easy position to set target KPIs due to the maturity of the flexible markets, but the overall picture was positive, and the majority of the targets were met. The quantitative tool was the data collection for a detailed cost benefit analysis (Chapter 3). Due to the variety of services provided by the demonstrators, the Eastern Cluster used the ENTSO-E CBA template as a common starting point to assess potential costs and benefits of the demonstrators. It has to be noted in relation to the quantitative analysis that during the demonstration period, certain BUCs occurred only a few times, and therefore the KPIs and CBA inputs may change in case of an actual roll-out. Also, for BUCs focusing on local network problems, it is important to see that the results cannot be extrapolated to a one-to-one country level, but still a very good representation of the problems in each country can be seen.

Qualitative analysis of the demonstrations was carried out by a self-assessment where the demos completed a scalability and replicability questionnaire (Chapter 4), which focused on five major aspects: technical, economic, regulation, environmental and acceptance. In summary, the self-assessments of the demonstrators led to very similar results, highlighting that while the countries were able to provide valuable answers to the technical challenges, there is still room for improvement in terms of regulatory activities. The demonstrations have shown that regulation in most countries is not yet at a level where the results of the demonstrations can be directly implemented, which is one of the most important things to do for the future.

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Annex A Scalability questionnaire description

The scalability dimensions and their intrinsic factors that have been defined in the SRA (Scalability & replicability Analysis) are:

(1) Technical

(1.1) Modularity

A precondition for scaling up. It refers to whether a solution can be divided into interdependent components. This factor examines how easy adding new components to a solution is.

(1.2) Technology Progress

Determines to what extent technological advances allow increases in the solution's size. This corresponds to technological improvements over time and the potential changes that may imply a solution.

(1.3) Interface design readiness

To what extent interactions between components are locally or centrally controlled? This factor must be considered when a solution is scaled up since the interfaces could increase in number or become more complex. It may be the case that the original approach (on a small scale) is not compliant with the new number of components (scaled-up solution) and therefore the interfaces need to be defined or adapted.

(1.4) Integration feasibility

Difficulties emerge in the system integration both from a software and hardware perspective by an increase in the size and complexity of the solution, e.g., storage capacity for the data created, and bandwidth.

(1.5) Existing infrastructure

Identifies to what extent the current infrastructure creates limits on the maximum size of the solution. Even if the original project is integrated, the current infrastructure may limit the maximum scale that can be reached.

(1.6) External constraints

Refer to elements, which are given and cannot be changed within the scope of a project (e.g., climate conditions such as temperature, wind, precipitation levels, terrain conditions, local generation mix, demographics, consumption mix and profiles, etc.)

(2) Economic

(2.1) Viability

Determines to what extent there is a return on the invested capital.

(2.2) Economy of scale

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Economies of scale are present if the percentage increase in cost is less than the percentage increase in project size. Economies of scale will have an influential role in the decision to expand a solution.

(3) Regulation

(3.1) Regulatory & Legal issues

There are potential regulations and laws that distort markets, and that can be a barrier to the scaling up of a solution.

(4) Environmental

(4.1) Green investment

Contribution to the green transition pathway.

(5) Acceptance

(5.1) Level of Acceptance

The successful implementation of a solution is important for all stakeholders to accept and support the scheme. If there is no demand for the product or service, the scale-up will not be possible.

Annex B Replicability questionnaire description

The replicability dimensions and their intrinsic factors that have been defined in the SRA are:

(1) Technical

(1.1) Standardization

Determines whether different manufacturers can implement the solution. Standardization is not sufficient to ensure replicability, but it facilitates procurement and construction.

(1.2) Interoperability

It is related to the capacity of the solution components to be adapted to or to interact with existing networks and environments without requiring tailored interfaces. The ability to exchange components (e.g., interchangeability) whilst retaining solution performance is included in this definition.

(1.3) Interface design flexibility

It reflects that a solution interacts and communicates with systems and components that already exist in an environment. Known and predictable interaction supports technology evolution.

(1.4) External conditions

Refer to elements, which are given and cannot be changed within the scope of a project (e.g., climate conditions such as temperature, wind, precipitation levels, terrain conditions, local generation mix, demographics, consumption mix and profiles, etc.)

(2) Economic

(2.1) Business model

The viability of a solution and how viable it is under different settings (for example between EU member states or between operators) is intended.

(2.2) Economy of scale

Are linked to existing conditions that set the market on which the solution is implemented. Examples of macro factors are the discount rate, inflation rate, unemployment level, GNP development, and other.

(2.3) Market design

Whether the existing European electricity markets design or any progress of it in the future directly affect the technical performance of the solution?

(3) Regulation

(3.1) Regulatory permission

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For successful replication, it is important that regulation in the area allows the project to be replicated. The factor regulation addresses to what extent the solution depends on national or local regulation to be feasible and viable. It could also be that barriers arise from regulatory factors.

(4) Environmental

(4.1) Green investment

Contribution to the green transition pathway

(5) Acceptance

(5.1) Level of Acceptance

Successful solution implementation is important for all stakeholders to accept and support the scheme. If there is no demand for the product or service, the scale-up will not be possible.

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