OneNet priorities for KPIs, Scalability and Replicability in view of harmonised EU electricity markets

D2.4

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About OneNet

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

The project OneNet (One Network for Europe) is funded through the EU's eighth Framework Programme Horizon 2020. It is titled "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)".

While the electrical grid is moving from being a fully centralised to a highly decentralised system, grid operators have to adapt to this changing environment and adjust their current business models to accommodate faster reactions and adaptive flexibility. This is an unprecedented challenge requiring an unprecedented solution. For this reason, the two major associations of grid operators in Europe, ENTSO-E and EDSO, have activated their members to put together a unique consortium.

OneNet will see the participation of a consortium of over 70 partners[1].

The key elements of the project are:

1. Definition of a common market design for Europe: this means standardised 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 organised in four clusters coming to include countries in every region of Europe and testing innovative use cases never validated before.

[1] The OneNet project partners are listed at: https://onenet-project.eu/partners/

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List of Abbreviations and Acronyms

Acronym	Meaning
ACF	Autocorrelation Function
ACPUF	Average Current Phase Factor
aFRR	Automatic Frequency Restoration Reserve
AI	Artificial Intelligence
ASM	Active System Management
ATR	Avoided Technical Restrictions
BaU	Business as Usual
BESS	Battery Energy Storage System
BM	Balancing Market
BSP	Balance Service Provider
BUC	Business Use Case
CAIDI	Customer Average Interruption Duration Index
CCGT	Combined Cycle Gas Turbines
CDF	Cumulative Distribution Function
CHP	Combined Heat and Power
cross-SO	Cross System Operator
CY	Cyprus
CZ	Czech Republic
DER	Distributed Energy Resource
DoA	Description of Actions
DSO	Distribution System Operator
DSR	Demand Side Response
EA	Eastern Cluster
EHV	Hybrid Electric Vehicles
ELr	Energy Losses Reduction
ES	Spain
EV	Electric Vehicle
FARR	Flexibility Activated Reserved Ratio
FP	Flexibility Platform
FR	France
FMO	Flexibility Market Operator
FSP	Flexible Service Provider
GHG	Greenhouse Gas
GR	Greece
HU	Hungary
HV	High Voltage
ICT	Information Communication Technology
ID	Identifier
IRPF	Increment of Reactive Power Flexibility

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KPI	Key Performance Indicator
LMP	Local Market Platform
LT-P-C/E	Long Term Active Capacity/Energy
LT-Q-C	Long Term Reactive Capacity
LV	Low Voltage
MAE	Mean Absolute Error
MCPUF	Maximum Current Phase Factor
ME	Maximum Error
mFRR	Manual Frequency Restoration Reserve
MLVVIi	Maximum Lower Voltage Violation Intensity
MO	Market Operator
MOL	Merit Order List
MUVVIi	Maximum Upper Voltage Violation Intensity
MV	Medium Voltage
NOCL	Northern Cluster
NRT-P-E	Near Real Time Active Energy
NRT-Q-E	Near Real Time Reactive Energy
P	Active Power
PF	Power Factor
PL	Poland
PMU	Phasor Measurement Unit
POI	Point of Interests
PT	Portugal
Q	Reactive Power
R&I	Research and Innovation
RES	Renewable Energy Sources
RMSE	Root Mean Squared Error
ROCOF	Rate of Change of Frequency
ROCOFI	Rate of Change of Frequency Improvement
RR	Refresh Rate
RR	Replacement Reserve
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SGAM	Smart Grids Architecture Model
SL	Slovenia
SO	System Operator
SOCL	Southern Cluster
SRA	Scalability and Replicability Analysis
STAR	System for Traceability of Renewable Activations
ST-P-C	Short Term Active Capacity
ST-P-E	Short Term Active Energy

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SUC	System Use Case
T&D CP	TSO & DSO Coordination Platform
TFP	Type of Flexibility Providers
TOW	Tunnel of Warranty
TSO	Transmission System Operator
UMEI	Universal Market Enabling Interface
VC	Voltage Control
WECL	Western Cluster
WP	Work Package

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Executive Summary

Scope and motivation

The OneNet project aims to foster the conditions for a new generation of grid services that fully exploit demand response, storage, and distributed generation, creating at the same time fair, transparent, and open conditions for the consumer. This goal is pursued by proposing new markets, products, services, and a unique IT architecture characterised by innovative mechanisms of platform federation. The OneNet project considers flexibility and digitalisation as key resources and enablers for the evolution of the electricity system by addressing flexibility market unlocking, TSO-DSO cooperation enhancement, renewable energy sources (RES) integration, network operation improvement, and stabilisation of future grid connection costs. The OneNet project involves 15 European countries pursuing regional cross-border cooperation among demonstrators to create a base of knowledge on the proposed solutions.

Within OneNet Task 2.4, Deliverable 2.4 contributes to the OneNet project by defining the Key Performance Indicators (KPIs) and the methodology for scalability and replicability analysis (SRA) to assess the impacts of the OneNet solutions. This Deliverable describes the collaborative process undertaken to identify and define the KPIs for assessing the performances of the OneNet demonstrators' activities. The harmonisation of the KPI definitions to reach project-wide KPIs and the devised methodology for scalability and replicability will allow evaluating the impacts of the OneNet solutions on a European scale. Moreover, in this Deliverable, the gaps and challenges concerning the KPI definition and the scalability and replicability analysis are identified to provide recommendations to address the following OneNet Tasks. OneNet Task 2.4 outcome represents an input for OneNet Task 11.4.

The main contributions of OneNet Task 2.4 are:

a. the definition of the KPIs for the OneNet demonstrators' BUCs, SUCs, Regional BUCs (Deliverable 2.4);
b. the identification of project-wide KPIs to appraise the impact of the OneNet solutions on a European scale (Deliverable 2.4);
c. the definition of the methodology for scalability and replicability to be used in OneNet developed based on best practices proposed by the task force on replicability in BRIDGE (Deliverable 2.4);
d. the identification of the related gaps and challenges concerning KPI identification and definition, and the SRA methodology for the OneNet project (Deliverable 2.4);
e. the analysis of all roles and actors presented on each use case of the OneNet project (Deliverable 2.5);
f. definition of recommendations for the harmonised electricity market role model (HRM) (Deliverable 2.5).

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The outcomes of Task 2.4 are a set of KPIs for OneNet, the methodology for scalability and replicability to be used as input for OneNet Task 11.4, a set of recommendations for the Harmonised electricity market Role Model (HRM). The present document is the so-called OneNet Deliverable 2.4; it covers the listed contributions from a. to d.; while Deliverable 2.5 focuses on the contributions e. and f.

Methodology for KPI identification and definition in the OneNet project

The KPIs are a meaningful tool to evaluate the performances of specific solutions implemented within a project use case. The KPIs have to be meaningful, understandable, and quantifiable. The KPIs have to give quantitative information to assess the achieved performances; the corresponding values have to be comparable to reference values.

The KPIs defined in the OneNet project cover demonstrators' Business Use Cases (BUCs), demonstrators' System Use Cases (SUCs), and OneNet Regional BUCs. These KPIs measure the impact of the innovative solutions proposed and implemented within the OneNet project. These KPIs are employed to assess the cluster demonstrations results, hence the OneNet project impact.

The methodology to identify and define the OneNet KPIs reported in the full document is illustrated in Fig. 1. It represents a step-by-step approach that allows defining harmonised KPIs through a structured, inclusive, and iterative procedure.

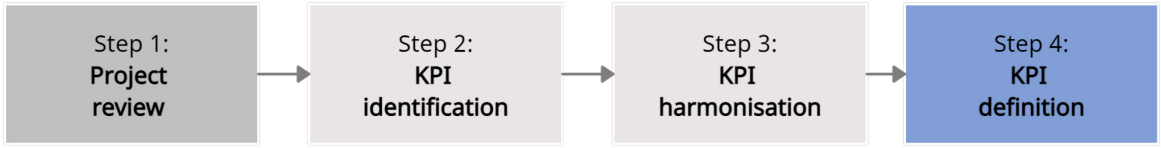

Fig. 1 - Methodology to identify and define the key performance indicators of the OneNet project

Step 1 – Project review. One of the main principles for KPIs identification and definition is to use the existing recognised references as a starting point. Several European projects were analysed, and the most relevant KPIs for OneNet were selected. In the full document, section 2.1 describes this review process; the results are presented in chapter 3.

Step 2 – KPI identification. Some of the KPIs from the project review have been directly adopted by the OneNet demonstrators. However, for some OneNet BUCs and SUCs, novel KPIs are defined to suit the corresponding demonstration objectives. The exploited KPI identification process is described in section 2.2 of the full document. The identified KPIs are listed in chapters 4 and 5 in the full document.

Step 3 – KPI harmonisation. A harmonisation process has been undertaken to achieve the highest consensus on the KPI definition and promote the adoption of common KPIs. The methodology used to harmonise the

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demonstrators' BUC KPIs is presented in the full document in section 2.3. The harmonisation process has been limited to the OneNet BUCs due to the observed higher generality of OneNet BUCs over SUCs and regional BUCs.

Step 4 – KPI definition. The complete KPI definition has been addressed through a KPI template. The KPI template gathers the key information from the demonstrators to complete the identification and definition of the adopted KPIs. The activities related to this step are described in the full document in section 2.4. Since the information collected is preliminary, the KPI templates are not published at this stage of the OneNet project.

European projects' review concerning relevant KPIs

The OneNet project leverages the experiences and best practices from previous Horizon 2020 projects with similar goals and activities. An extensive literature review has been addressed to identify the KPIs adopted by other relevant European projects. The selected projects have defined use cases related to the procurement of system services by the system operators, such as congestion management, voltage control, system restoration, balancing, etc. These are comparable to the BUCs defined in OneNet.

The project review process is illustrated Fig. 2, where the most suitable KPIs for OneNet were selected based on how these KPIs could be used and adapted to the features and objectives of the OneNet demonstrators to pave the way for monitoring their performance.

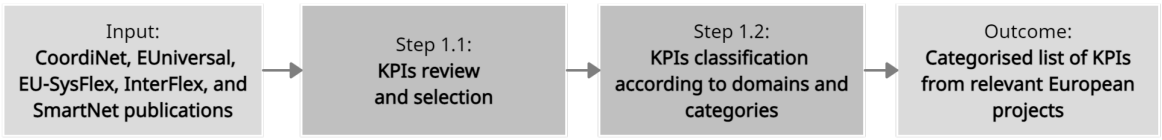

Fig. 2 – Review process of KPIs from relevant European projects

As a result of this process, a categorised list of 83 KPIs is obtained. These selected KPIs are the starting point of the identification process of the OneNet project described in Deliverable 2.4. The list of KPIs from the project review is available in chapter 3 of the full document.

OneNet BUCs, SUCs, and Regional BUCs KPIs

The list of KPIs gathered from the project review represents the main input to the iterative process that actively involved the demonstrators in identifying the KPIs of interest and reaching a common list of KPI definitions. Fig. 3 shows the identification process of the demonstrators' BUCs KPIs, regional BUCs KPIs, and demonstrators' SUCs KPIs, which consist of the following steps:

- **Step 2.** KPI identification
    - **Step 2.1.** Some KPIs definitions gathered from the project review are directly adopted by demos and clusters to assess the respective demonstration performances.

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- **Step 2.2.** Some KPI definitions from the project review are selected and adapted according to the OneNet BUCs and SUCs objectives.
- **Step 2.3.** Novel KPIs definitions are proposed by the OneNet demos and clusters to comply with the corresponding needs.
- **Step 2.4.** The preliminary list of KPIs consists of
  - KPIs directly adopted from the project review list,
  - KPIs adapted from the project review list,
  - new KPIs proposed by OneNet.

  These KPI definitions were discussed with the project partners to ensure data availability.

- **Step 3:** The harmonisation process is applied to the demonstrators' BUCs KPIs and the system's BUCs KPIs to reach a shared definition and achieve the most extensive set of common KPIs possible.

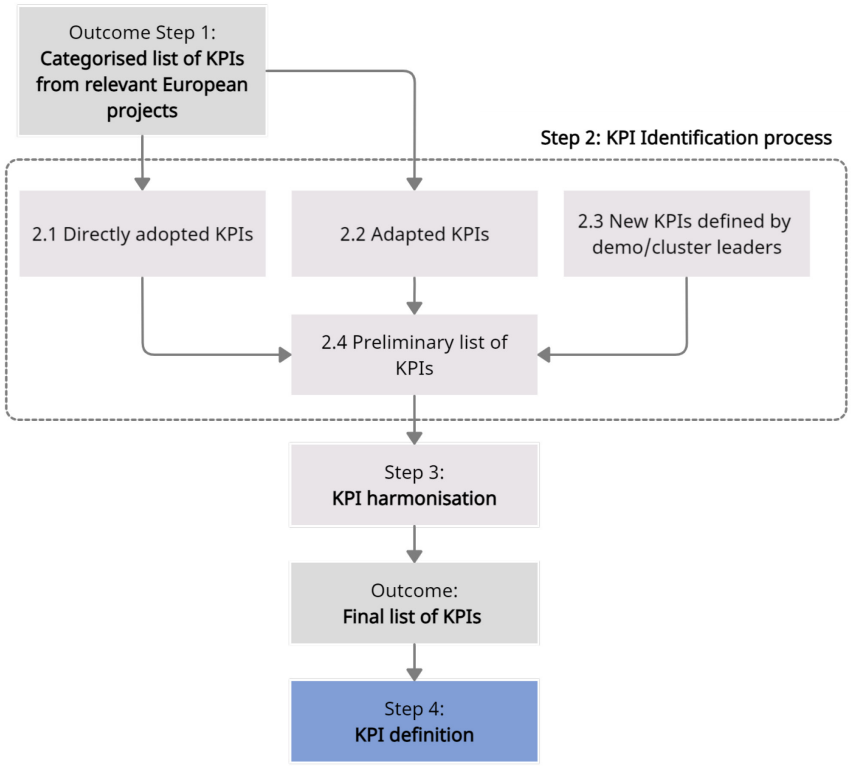

Fig. 3 – Identification process for OneNet demonstrators' BUCs, SUCs, and regional BUCs KPIs

The procedure's outcome is the final list of 99 KPIs adopted to assess the OneNet BUCs, SUCs, and regional BUCs. The definition of the KPIs adopted in the OneNet project are reported in the full document in chapter 4.

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Harmonising the OneNet KPIs

The OneNet project is characterised by a large number of demonstrators (15) situated in different countries[2]; the multiplicity of demonstrators, partners, and countries involved in the OneNet project led to a great variety of initiatives (both BUCs and SUCs) that differ in terms of objectives and activities. Consequently, the corresponding KPIs for assessing the performances of BUCs and SUCs show great diversity; however, common points can be identified among the demonstrators. Fig. 4 depicts the methodology applied to identify a harmonised set of KPIs, whose general definition applies to the whole OneNet demonstration activities. This methodology is applied to the demonstrators' BUCs, considering the comprehensiveness of the description of the demonstration initiatives embraced.

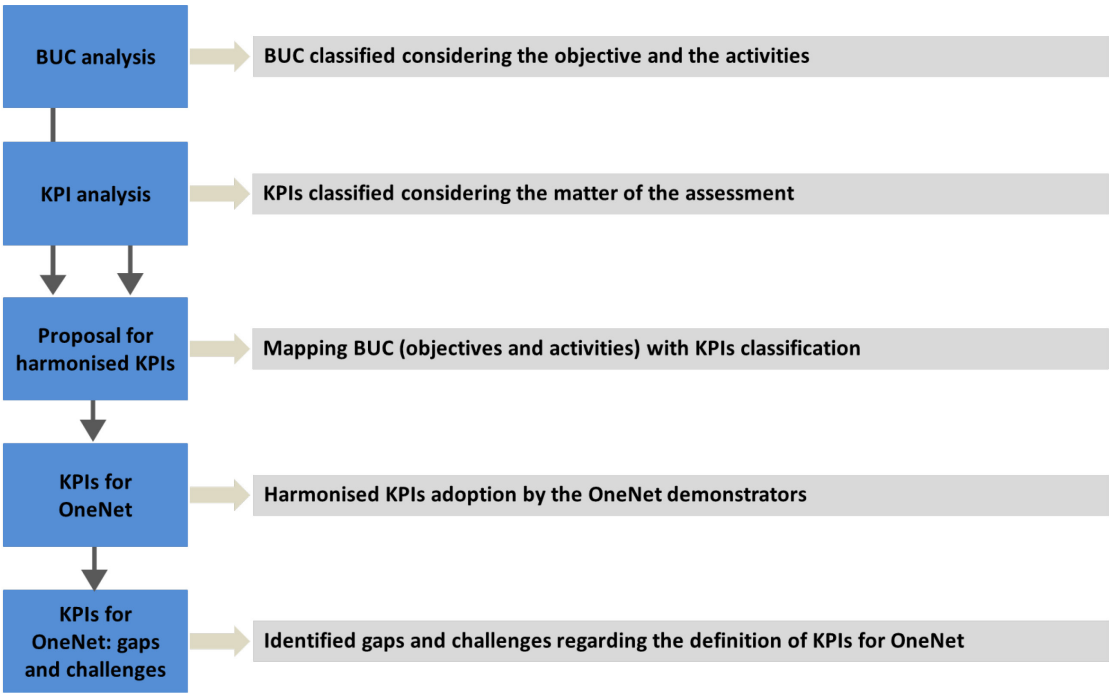

Fig. 4 – Methodology developed and applied for harmonizing the KPI definition within the OneNet project

The process of identification and definition of KPIs allowed to point out a set of challenges mainly related to the peculiarities of the OneNet project in terms of project size, diversity of the demonstration goals and activities, the actual status of development, local demonstrators' characteristics, and the innovative nature of the demonstration activities. The full document discusses in section 5.4 the identified challenges.

[2]Updated information is available at: https://cordis.europa.eu/search?q=contenttype%3D%27project%27%20AND%20programme%2Fcode%3D%27LC-SC3-ES-5-2018-2020

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Methodology for scalability and replicability analysis

The SRA aims to assess the effect of implementing the proposed solutions on a larger scale or under different contexts. This analysis will be carried out in OneNet Task 11.4. The proposed SRA methodology is depicted in Fig. 5. The proposed SRA is qualitative with two input data sources:

i. desk research to identify and analyse relevant SRA results from previous EU projects and
ii. feedback from partners and project stakeholders on SRA results and gaps.

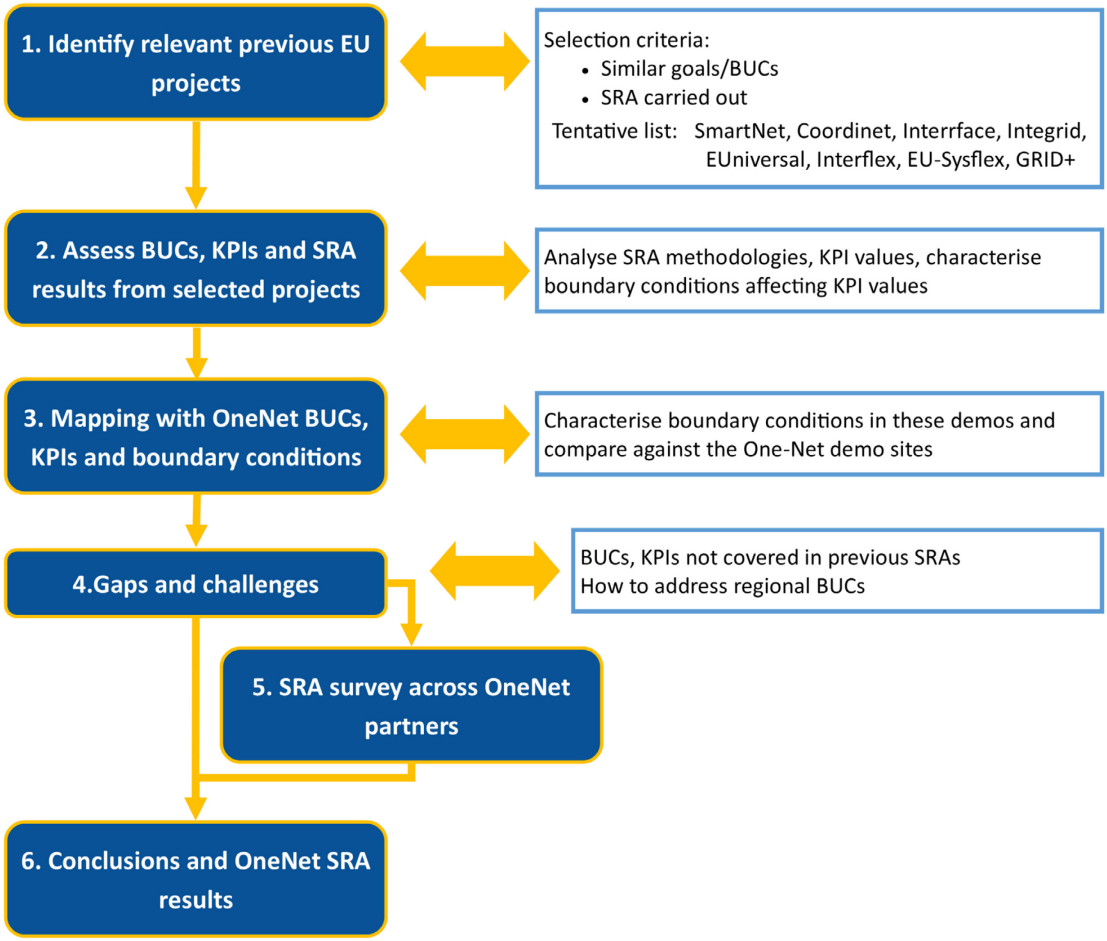

Fig. 5 - Overview of the SRA methodology

Conclusions

This Deliverable describes the methodology adopted to identify and define the KPIs for the OneNet project; Moreover, it also describes the SRA methodology devised for the OneNet project. These KPIs aim to appraise the impact of the innovative solutions proposed and implemented by the OneNet demonstrators; the SRA aims to assess the effect of implementing the proposed solutions on a larger scale or under a different context.

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The defined KPIs cover OneNet demonstrators' BUCs, SUCs, and OneNet Regional BUCs. The OneNet demonstrators adopted a broad set of KPIs (99 in total) to quantify the performances of the demonstration activities, and in turn, the OneNet project goals. The significant number of demonstrators in the OneNet projects led to a great variety of goals, actors involved, activities addressed, and local conditions. This great variety is beneficial from the research and innovation perspective; it allows to devise and test different aspects concerning the TSO-DSO-customers coordination and explore different paths for achieving the OneNet project goals. This variety is reflected in the significant number of KPIs, which allows assessing the project results from different perspectives.

The KPIs adopted by the OneNet demonstrators are classified into 10 categories, all KPIs concern performances assessment of demonstration activities concerning the TSO-DSO-Customer coordination. A detailed description of these categories and the list of the OneNet KPIs that form each category is provided in section 4.1 of the full document.

1. General descriptive aspects (KPIs to assess generic aspects of demonstration activities);
2. Economic impacts (KPIs able to capture the economic aspects of the demonstration activities);
3. Environmental and societal impacts (KPIs able to capture the externalities);
4. Market performance (KPIs that aim to assess the outcome of the market development and testing);
5. Congestion management performance (KPIs that aim to assess the performances of the use cases dealing with the development and testing of congestion management procedures);
6. Voltage control performance (KPIs that aim to assess the performances of the use cases dealing with the development and testing of voltage control procedures);
7. Balancing performance (KPIs that aim to assess the performances of the use cases dealing with the development and testing of balancing procedures);
8. Data processing performance (KPIs that aim to assess the performances of the use cases dealing with the development and testing of data processing procedures);
9. Network operation performance (KPIs that aim to assess the performances of the use cases dealing with the development and testing of solutions that affect the network operation procedures);
10. Prequalification process performance (KPIs that aim to assess the performances of the use cases dealing with the development and testing of prequalification procedures).

The result presented in Deliverable 2.4 regarding the KPIs harmonisation has been obtained through the cooperation with demonstrators who have been actively involved in identifying and harmonising the KPIs definitions.

Among the identified challenges for defining KPIs relevant to the coordinated provision of services at the system and local levels, the lack of historical information, knowledge, and experience represents one of the main concerns. The lack of a generally recognised benchmark especially relates to the definition of the KPIs for the

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markets since the demonstrated novel market structures and new flexibility products. As a result, it is challenging to define the corresponding KPIs (with the corresponding baseline and target value). Reference values can be extrapolated from similar projects; however, the influence of the local characteristics prevent a straightforward use of these value as a benchmark for any similar demonstration activities.

The variety of activities, local peculiarities, and the differences among the actors involved make clear that a single solution will not well perform for assessing the project results. Therefore, the definition of the KPIs has to consider the peculiarities and propose general definitions that can be tailored to fit local objectives and peculiarities by preserving generality. For clarity, since the differences among different contexts, a different baseline can be required for the same KPI. The same reasoning applies to target values. Hence, performance assessment has to consider the context peculiarities. On the contrary, the KPI definition and calculation methodology have to be harmonised to ensure comparability across different contexts.

Demonstration activities concerning the coordinated provision of services at the system and local levels develop and test innovative solutions that have to be embedded within the power system. The surrounding context influences the performance achieved by the demonstration activities. In turn, the effects of the developed and tested innovative solutions cross the demonstration's border and impact the power system functioning. It is challenging to capture the extent of this mutual influence by the KPIs values calculated in the context of the demonstration activities. While the effects that the surrounding power system has on the demonstration activities can be captured by analysis of the local context and quantified through baseline and target values, the quantification of the impacts generated by the developed innovative solution requires a more complex analysis (e.g. SRA, Social Cost-Benefit Analysis, Multi-Criteria Analysis). Assessing the impact of the developed and tested innovative solutions on the power system requires considering the system perspective to complement the quantification of results based on KPIs defined from the demonstrators' perspective.

The proposed SRA to be used in OneNet is based on the best practices proposed by the BRIDGE task force. The devised SRA relies on six steps: identification of previous relevant EU projects, assessment of the information from selected projects, mapping relevant projects against OneNet demonstrators, identification of the existing gaps and challenges, information gathering from the OneNet partners and stakeholders, formulation of the OneNet SRA results.

In conclusion, this Deliverable represents the first attempt of the OneNet project regarding the definition of indicators to quantify the demonstrators' performances and the definition of the methodology to address the scalability and replicability analysis. Future OneNet Tasks will rely on this preliminary proposal and deal with KPI definitions refinement, OneNet demonstrators' alignment, enrichment of the set of common KPIs, finalization of the methodologies for data gathering and KPI calculation, and will apply the proposed scalability and replicability methodology.

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1 Introduction

The ongoing energy transition triggered by the concerns related to the tremendous consequences of extreme weather events caused by climate change requires profound changes in the operation of the electric power system [1]–[4]. The decarbonisation of the electricity supply requires increasing the electrical energy generated by renewable resources and pursuing energy efficiency [2]. In a decarbonisation scenario, an increased presence of intermittent and unprogrammable energy sources in the power system, as well as the need for maximising the use of the available resources and infrastructure, make it essential to abandon the traditional load following paradigm favouring a more interactive operation of the electric power system [5]. In this context, the concept of flexibility, meant as the capability of adapting their electricity generation or demand level according to the needs of the power system operation, has been introduced for the resources connected to the power system. However, the power system transformation has to be addressed at a reasonable cost, without harming the security and quality of the electricity supply, unlocking the potential flexibility of the already available resources, and fostering the availability of new resources [6]–[8].

In this context, the OneNet project aims to create conditions for a new generation of system services able to fully exploit demand response, storage and distributed generation while creating fair, transparent and open conditions for the consumer. As a result, while creating one network for Europe, the project aims to build a customer-centric approach to grid operation. This ambitious view is achieved by proposing new markets, products and services and creating a unique IT architecture. While a single platform for Europe is not thinkable, OneNet proposes innovative mechanisms of platform federation, which are the key technical enablers for the proposed vision.

The present deliverable is part of the Work Package 2 (WP2) contribution to the OneNet project. Figure 1.1 depicts the interconnection between the OneNet Task 2.4 and other tasks and work packages in the OneNet project. OneNet WP2 in OneNet is titled “Products and services definition in support of OneNet”. The main objective of this WP is to set the basis of the work to be done in the OneNet project. It looks back to the market solutions and digital platforms presented so far in the EU pilot projects, revisits European policy frameworks, summarises their contributions and benefits and builds on this information to sketch the new products and business use cases (BUCs) proposed in the OneNet Project. These products and BUCs will strongly engage the consumers to maximise the flexibility resources that the grid operators can use to meet the clean energy challenges. The specific priorities for KPIs, Scalability and Replicability of OneNet solutions will be devised to enable the pan-EU integration of these new services and products digitally procured for system operation.

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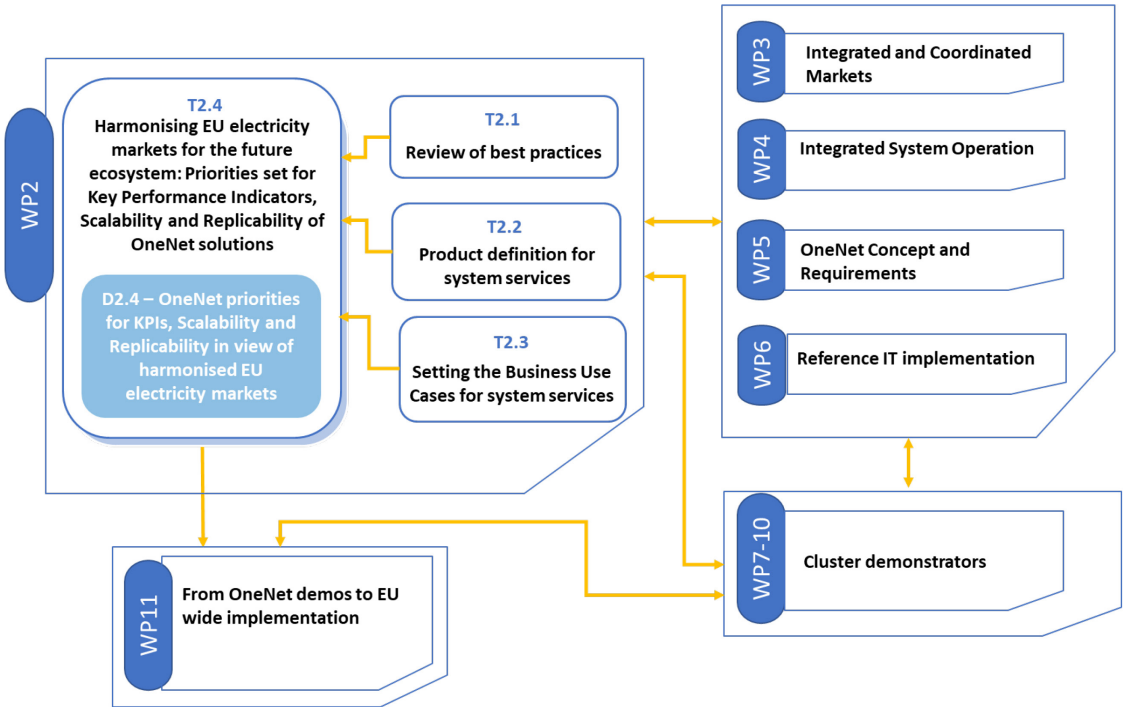

Figure 1.1 - Interconnection between the OneNet Task 2.4 with other tasks and work packages in the OneNet project

WP2 is composed of 4 tasks. The scope of Task 2.1, "Review of best practices in markets and platforms from initiatives, national and EU projects on TSO-DSO-consumer coordination", is to present a detailed review of the best practices related to TSO-DSO-consumer coordination. More specifically, recommendations related to system needs, system services, product design, market design, ICT architecture, grid operation and business models are analysed. Task 2.2 "Definition of standard products in the TSO-DSO-consumer value chain" elaborates a theoretical framework for system service products based on the different services and products being proposed in the various research and innovation activities and the models defined in the Active System Management (ASM) report [9]. Task 2.3 "Setting the business use cases for system services" has the main objective to produce a set of Business Use Cases (BUCs) for all demonstrators in the four clusters according to the standardised methodology IEC – 62559. Within the scope of Task 2.3, the BUCs were defined for all demonstrator clusters. In addition, a general BUC for the OneNet project was developed to showcase the business objectives of the OneNet project.

Within WP2, Task 2.4 entitled "Harmonising EU electricity markets for the future ecosystem: Priorities set for Key Performance Indicators, Scalability and Replicability of OneNet solutions" defines the Key Performance Indicators (KPIs) and the methodology for scalability and replicability analysis (SRA) to assess the impact of the OneNet solutions. Task 2.4 supports the OneNet demonstrators contributing to the identification and definition of the KPIs to assess the performances of the demonstrators' activities. Task 2.4 addresses the harmonisation of the KPIs among the demonstrators to reach project-wide KPIs definitions to appraise the impact of the OneNet

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solutions on a European scale. Moreover, Task 2.4 identifies the gaps and challenges related to the KPI definition and devises the methodology for scalability and replicability to be used in OneNet, based on best practices proposed by the task force on replicability in BRIDGE. The outcome of this task will be the set of KPIs and the methodology for scalability and replicability analysis to be used as input for OneNet Task 11.4.

Task 2.4 also entails an overall analysis of all the roles and actors proposed for all the use cases presented in the OneNet project. The related Deliverable 2.5 takes the work done in work package 2 regarding products, services and business use cases to devise recommendations for the Harmonised Role Model, considering contribution already provided by other OneNet Tasks and the work under development on the OneNet demonstrators. The review of all the roles presented is fundamental for harmonising the data when each actor exchanges all these data through the clusters implemented. Hence, OneNet task 2.4 is part of the OneNet project contribution to the continuous development of data and tools, proposing the experience gathered during the use cases proposals to advance the energy market.

To sum up, the main contributions of OneNet Task 2.4 are:

g. the definition of the KPIs for the OneNet demonstrators' BUCs, SUCs, Regional BUCs (Deliverable 2.4);
h. the identification of project-wide KPIs to appraise the impact of the OneNet solutions on a European scale (Deliverable 2.4);
i. the definition of the methodology for scalability and replicability analysis to be used in OneNet developed on the best practices proposed by the BRIDGE task force on replicability (Deliverable 2.4);
j. the identification of the gaps and challenges concerning KPI identification and definition, and the SRA methodology for the OneNet project (Deliverable 2.4);
k. the analysis of all roles and actors presented on each use case of the OneNet project (Deliverable 2.5);
l. definition of recommendations for the Harmonised electricity market Role Model (HRM) document (Deliverable 2.5).

The outcomes of this task are a set of KPIs for OneNet, the methodology for scalability and replicability analysis to be used as input for OneNet Task 11.4, a set of recommendations for the Harmonised electricity market Role Model (HRM). The present document is the so-called Deliverable 2.4; it covers the listed contributions from a. to d.; while Deliverable 2.5 focuses on the contributions e. and f.

The structure of the present deliverable is depicted in Figure 1.2. Chapter 1 introduces OneNet Task 2.4, describing the motivations of the activities, the interconnections between the OneNet Task 2.4 with other OneNet tasks and work packages and providing an overview of the specific activities and the methodologies adopted. Chapter 2 describes the methodology adopted for the KPI identification and definition. In chapter 3, the review of the KPIs proposed in several EU H2020 projects concerning the TSO-DSO-FSP coordination is described. Chapter 4 discusses the identification and definition of BUCs, SUCs, and OneNet regional BUCs KPIs for assessing the impact of the OneNet proposals. In chapter 5, the procedure for the harmonisation of the KPIs

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within the OneNet project is presented with the corresponding outcome. In chapter 6, the developed methodology for scalability and replicability analysis to be used in OneNet is presented. Finally, Chapter 7 provides the closing remarks.

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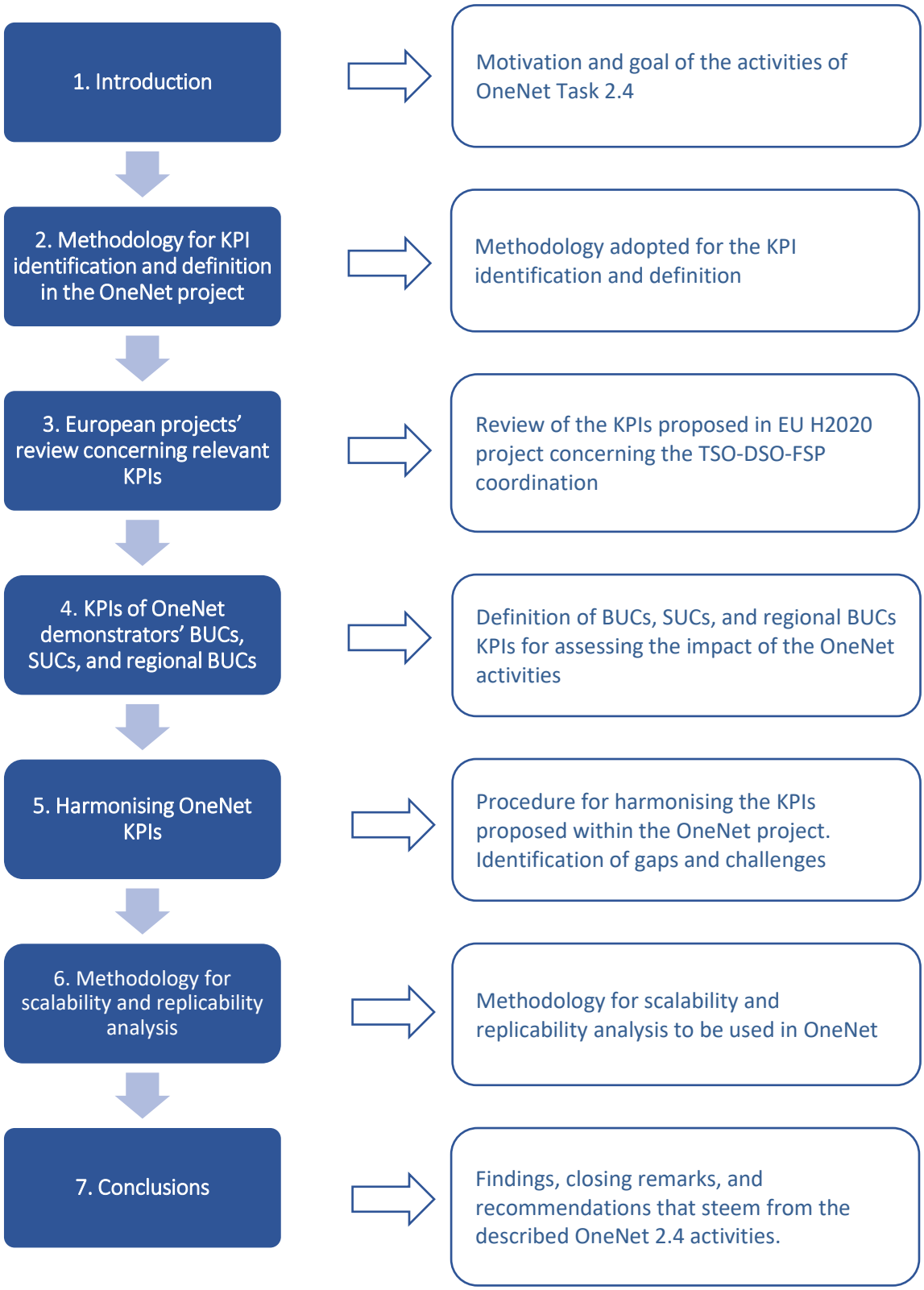

Figure 1.2 - Structure of OneNet Deliverable 2.4

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2 Methodology for KPI identification and definition in the OneNet project

This chapter describes the methodology to identify and define the key performance indicators (KPIs) for the OneNet project. KPIs identification is a meaningful tool to evaluate the development, optimisation, and potential of specific solutions implemented within a use case or achieve a project objective. According to [10], the KPIs have to be meaningful, understandable, and quantifiable. A KPI is meaningful only if it has significance as it provides evidence of a strategic objective's success or failure over a specified time. Also, it is necessary to select understandable KPIs where the KPI definition is clearly linked to the expected objectives of the use case or project. Furthermore, the KPIs have to give quantitative information calculated in a transparent and traceable manner. However, the KPI value only becomes useful when compared to a reference indicating optimal, acceptable, or unacceptable thresholds. Therefore, a comparator or baseline has to complement the definition of each KPI.

The KPIs defined in the OneNet project follow the mentioned principles and cover demonstrators' BUC, demonstrators' SUC, and OneNet Regional BUCs. These KPIs aim to measure the impact of the innovative solutions proposed and implemented within the OneNet project. For instance, the KPIs related to the OneNet demonstrators' BUCs, SUCs, and regional BUCs will play an important role in evaluating the cluster demonstrations ambitions in WP7-10 as well as for WP11, where the results of the different demos will be considered.

The methodology illustrated in Figure 2.1 is adopted to identify and define the OneNet KPIs. The goal is to follow a structured step-by-step approach that actively engages the OneNet demonstrators to achieve harmonised definitions for KPIs and a set of commonly adopted KPIs.

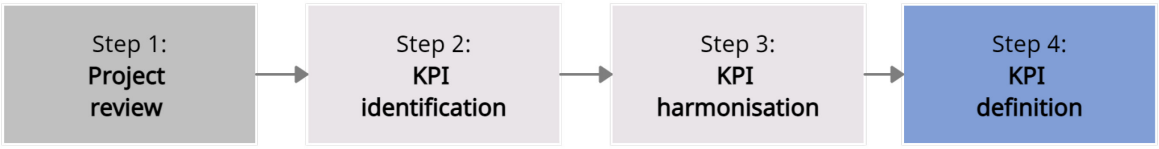

Figure 2.1 – Methodology to identify and define the key performance indicators of the OneNet project

- **Step 1: project review**. One of the main principles applied in the KPIs identification and definition is to use the existing recognised references as a starting point. Therefore, relevant European projects are analysed, and the relevant KPIs for OneNet are selected. Section 2.1 describes this review process, and the results are presented in Chapter 3.
- **Step 2: KPI identification**. The identification of the OneNet KPIs starts from the project review. The OneNet demonstrators directly adopted some KPI from the project review list; however, for some

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BUCs and SUCs, there is a need to create new KPIs or modify the original definition to tailor it to the OneNet BUCs or SUCs objectives and activities. The KPI identification process is described in Section 2.2; it applies to all OneNet KPIs. The identified KPIs are listed in Chapters 4.

- **Step 3**: **KPI harmonisation.** A KPI harmonisation process is conducted to achieve the highest consensus on the adopted KPI definitions, foster the adoption of common KPIs, and identify the gaps and challenges related to the KPI definition and calculation. The adopted harmonisation methodology is described in Section 2.3 and applies to the BUC KPIs since the generality of the corresponding definitions.
- **Step 4: KPI definition.** The KPI definition has been completed through a KPI template. The KPI template gathers the information from the demonstrators to complete the identification and definition of the adopted KPIs with baseline, target value, and calculation methodology. The activity related to this step is described in section 2.4. Since the information collected is, to some extent, preliminary, the KPI templates are not published at this stage of the OneNet project.

2.1 Step 1: KPIs review from relevant European projects

The identification and definition of the OneNet KPIs leverage the experience of previous European projects dealing with TSO-DSO-customer coordination. Therefore, the OneNet project carries out a literature review on the KPIs used in other relevant European projects. The selected projects define different use cases related to the procurement of system services by the system operators, such as congestion management, voltage control, system restoration, balancing, etc. These demonstration activities are comparable to the BUCs defined in D2.3 of the OneNet.

The review process is illustrated in Figure 2.2, where the most suitable KPIs for OneNet are selected based on how these KPIs could be used and adapted to the features and objectives of the OneNet demonstrators to pave the way for monitoring their performance.

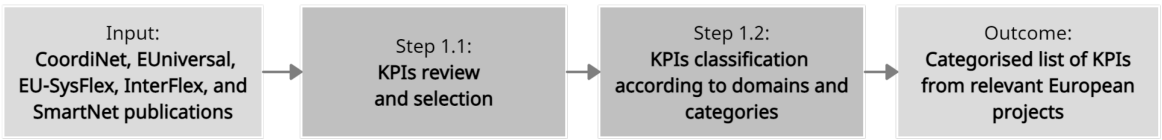

Figure 2.2 – Review process of KPIs from relevant European projects

According to the procedure depicted in Figure 2.2:

- **Step 1.1: KPIs review and selection.** A list of KPIs is compiled by reviewing the following projects and Deliverables:

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- **CoordiNet**. The CoordiNet project demonstrates how DSOs and TSOs shall coordinate to procure and activate system services [3]. It also defines a market model framework to describe the mechanisms for procuring these services. The analysed document is D1.6 "List of KPIs: KPI and process of measures" [10].
- **EUniversal.** The EUniversal project aims to develop a universal approach on the use of flexibility by DSOs and their interaction with the new flexibility markets, enabled through the development of the concept of the Universal Market Enabling Interface (UMEI), which is a unique approach to foster interoperability across Europe. The analysed document is D6.2 "Definition KPI for DEMOs" [16].
- **EU-SysFlex**. The EU-SysFlex project defines new services to support the transmission system operation by guaranteeing security and resiliency. In general, EU-SysFlex develops a roadmap to support the implementation of cost-effective solutions concerning flexibility. The analysed document is D10.1 "Report on the selection of KPIs for the demonstrations" [17].
- **InterFlex.** The InterFlex project provides insights into five areas: local flexibility markets, smart functions and grid automation, demand response and customer empowerment, cross energy carrier synergies, and multi-service storage and islanding. The analysed documents are D2.2 "Minimal set of use case KPIs and measurement methods to perform the technical and economic analysis of the resulting definitions" [18] and D2.5 "Summary of the innovative solution performances based on the measured KPIs during the demonstrations" [19].
- **SmartNet**. The SmartNet project provides optimised instruments and modalities to enhance the coordination among the system operators at the national and local levels. This coordination includes the information exchange to procure ancillary services such as congestion management, voltage control, and balancing from resources located at the distribution level. The analysed document is D4.3 "Cost-benefit analysis of the selected national cases" [20].

[3] As indicated in OneNet Deliverable 2.1 and Deliverable 3.1 [11], [12], a system service is defined in the OneNet project as the action (generally undertaken by the network operator) which is needed to mitigate a technical scarcity or scarcities that otherwise would undermine network operation and may create stability risks. Even when all network operators face similar system needs, the relevance of different system needs can vary between distribution or transmission networks since these networks serve different purposes. For example, Article 2 in the European Balancing Guideline [13] sets that TSOs are responsible for undertaking actions to "ensure, in a continuous way, the maintenance of system frequency within a predefined stability range […] and compliance with the amount reserves needed concerning the required quality". Therefore, the needs that arise as a result of the obligation to keep the balancing of the grid, will only be addressed by TSOs. The definition of system service answers the question, "what are the service required to ensure stability of the grid?". In Deliverable 2.1 of OneNet [11] different definitions that were used in previous H2020 projects of what constitute system services are reported. The review of the previous H2020 project definition together with the experience of the different members of the OneNet team lead to the definition adopted in this report. Therefore, the adopted definition of "system services" extends the definition provided in DIRECTIVE (EU) 2019/944 regarding ancillary services (balancing and non-frequency ancillary services) including also congestion management services [14]. Frequency ancillary service means a service used by a transmission system operator for the active power balancing the power system [14]. Non-frequency ancillary service means a service used by a transmission system operator or distribution system operator for steady state voltage control, fast reactive current injections, inertia for local grid stability, short-circuit current, black start capability and island operation capability [14]. Congestion management service means a service used by a transmission system operator or distribution system operator to avoid or solve grid congestions and bottlenecks that saturate the power transfer capacity of the network [15].

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- **Step 1.2:** The selected KPIs are classified into four domains to support the KPI identification:
  - **Economic** KPIs to assess the economic impacts of the projects' solutions.
  - **Technical** KPIs to evaluate the technical feasibility of the projects' solutions.
  - **Environmental** KPIs to measure the environmental performance of projects' solutions.
  - **Societal** KPIs which concern network customer engagement.

This classification is also beneficial for filtering and finding the KPIs of particular interest for the OneNet project.

Outcome: As a result of the project review process, a categorised list of KPIs is reported in Chapter 3. These selected KPIs will be the starting point of the identification process illustrated in section 2.2.

2.2 Step 2: KPI Identification

The process that leads to the identification of the OneNet KPIs is described in this section. Figure 2.3 shows the identification process for the demonstrators' BUCs KPIs, demonstrators' SUCs KPIs, and regional BUCs KPIs, which consist of the following steps:

- **Step 2.1.** Some of the KPI definitions from the project review are adopted "as is" by demonstrators and clusters.
- **Step 2.2.** Some of the KPI definitions from the project review are adopted by the demonstrators tailoring the original definition to the OneNet BUCs and SUCs objectives.
- **Step 2.3.** The OneNet demonstrators and cluster define novel KPIs to fit with the OneNet BUCs and SUCs objectives.
- **Step 2.4.** The preliminary list of KPIs consists of KPIs adopted "as is" from project review, KPIs from project review which definition is adapted to the OneNet needs, and new proposed KPIs, as illustrated in Figure 2.4. These KPIs have been discussed with the project partners to ensure data availability.
- **Step 3:** A harmonisation process is applied to demonstrators' BUCs KPIs to reach the highest consensus on the KPI definitions and promote the adoption of common KPIs. Details on this step are presented in Section 2.3.

Outcome: Final lists of KPIs, as reported in Chapter 4.

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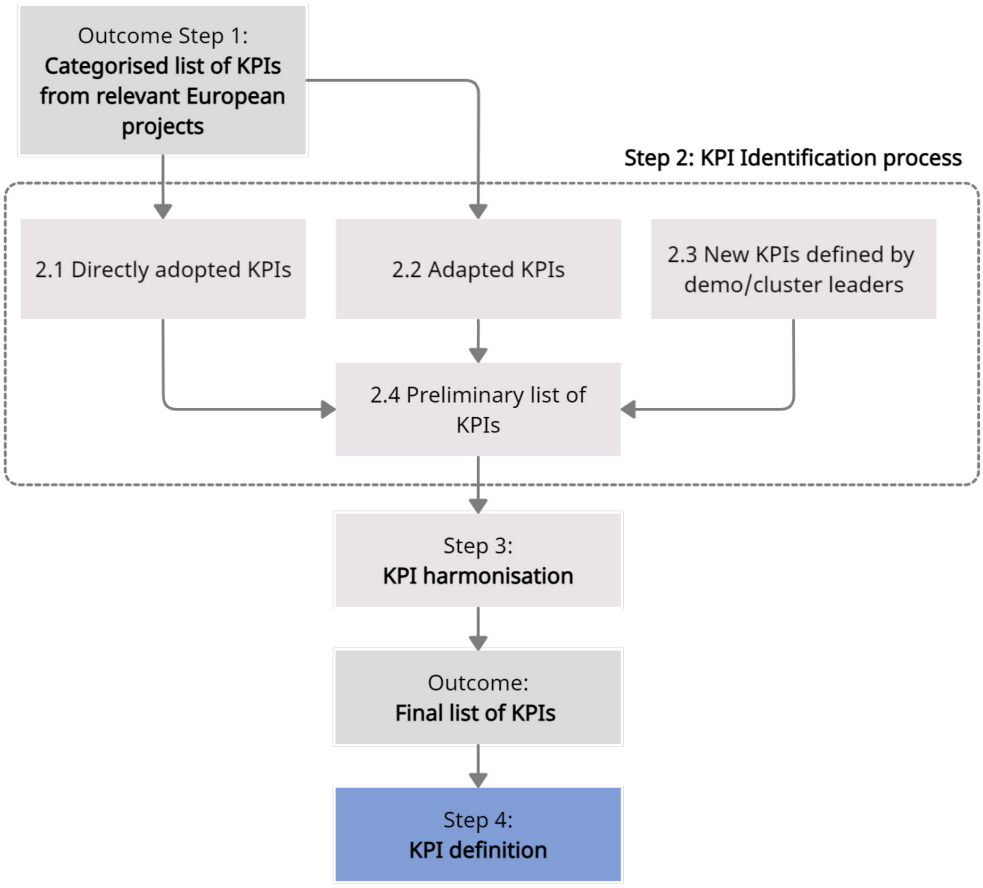

Figure 2.3 – Identification process for OneNet demonstrators' BUCs, regional BUCs, and demonstrators' SUCs KPIs

Figure 2.4 illustrates the identification process for the OneNet project-wide KPIs, where the final list of these KPIs is composed of the common KPIs among the demonstrators' BUCs KPIs, regional BUCs KPIs, and demonstrators' SUCs KPIs.

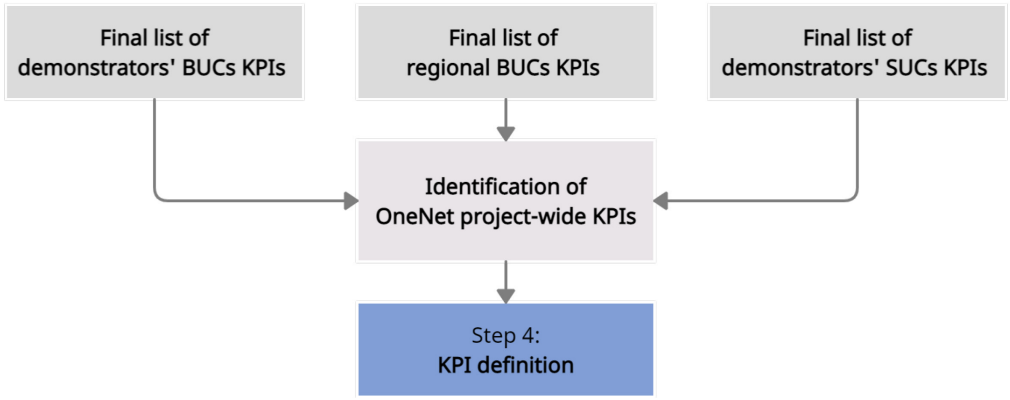

Figure 2.4 – Identification process for OneNet project-wide KPIs

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2.3 Step 3: KPI Harmonisation

The OneNet project is characterised by a large number of demonstrators (15) situated in different countries[4]; the multiplicity of demonstrators, partners involved, and countries encompassed by the OneNet project led to a great variety of initiatives (both BUCs and SUCs) that differ in terms of objectives and activities. Consequently, the corresponding KPIs for assessing the performances of BUCs and SUCs show great diversity; however, common points can be identified among the demonstrators. Figure 2.5 depicts the methodology that has been applied to identify the harmonised set of KPIs, which general definition applies to the whole OneNet demonstration activities. This methodology has been applied to demonstrators' BUCs considering the comprehensiveness of the description of the demonstration initiatives embraced; hence, harmonising the KPIs for BUCs has been considered of utmost relevance for the OneNet project scope. SUCs generally have a technical perspective and cover specific aspects of the demonstration activity; therefore, similarities among SUCs defined by demonstration initiatives that cover different activities, sites, and actors are generally scarce.

Section 5 describes the harmonisation process and presents the outcome obtained by applying the methodology depicted in Figure 2.5 to the OneNet project.

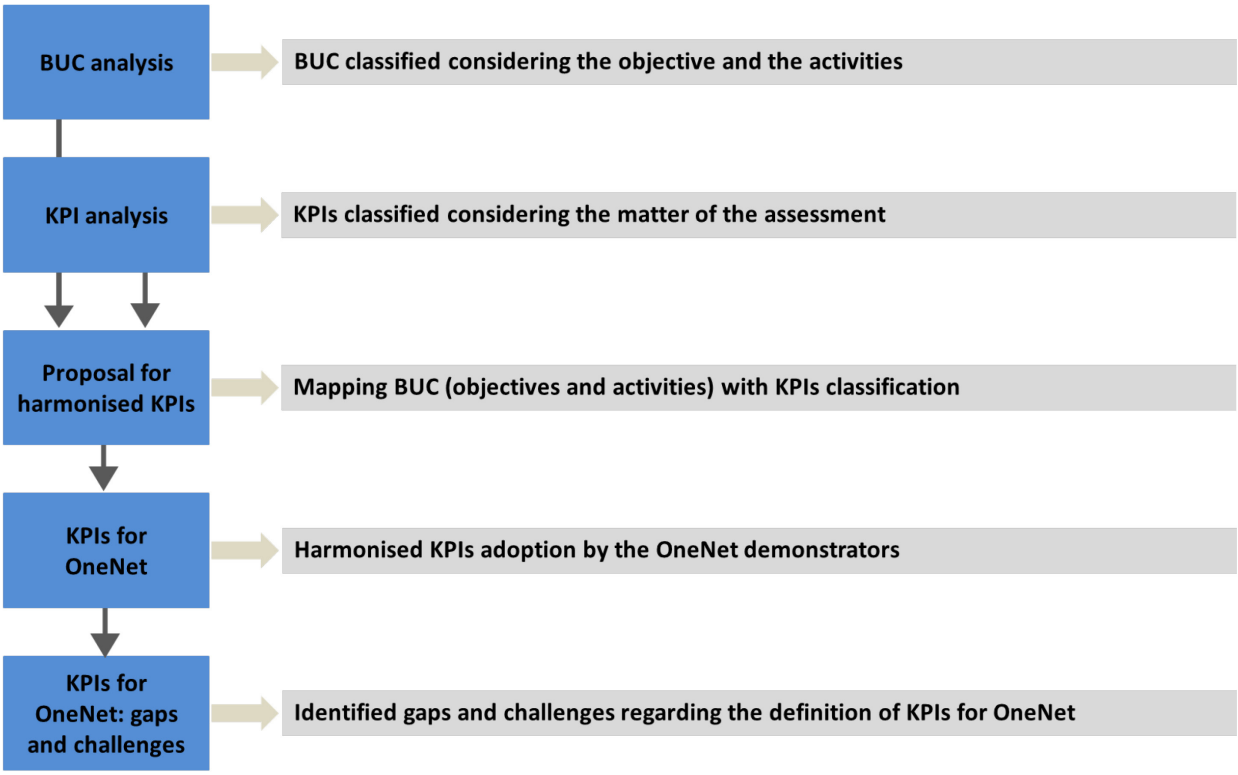

Figure 2.5 – Methodology developed and applied for harmonizing the KPI definition within the OneNet project

[4]Updated information is available at: https://cordis.europa.eu/search?q=contenttype%3D%27project%27%20AND%20programme%2Fcode%3D%27LC-SC3-ES-5-2018-2020

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2.4 Step 4: KPI Definition

The KPI definition includes several aspects that provide a comprehensive description of the indicators that aim to assess the performance achieved through the demonstration activities. Table 2.1 shows an example of the template used to complete the definition of the OneNet KPIs, which is organised into two main sections:

- The **KPI Definition section** includes the general KPI information such as the identifier (ID), name, domain, category, description, related BUCs and objectives, etc. Furthermore, information concerning the KPI calculation includes formula, variables, unit of measurement, baseline, calculation methodology, and gaps and challenges for the KPI calculation and quantification.
- The **KPI Data collection section** includes relevant information on the necessary data to be collected during the demonstration to calculate the KPIs.

Since the information collected is preliminary, the KPI templates are not published at this stage of the OneNet project.

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Table 2.1 - Example of the template used for OneNet KPIs definition

KPI definition template (Demo KPIs)		
	KPI DEFINITION SECTION	
General Information	**1. KPI ID**	KPI_E4
	2. KPI Demo ID	EU_BUC_KPI_01
	3. Name	Cost variation
	4. KPI domain	Economic
	5. KPI category	CAPEX and OPEX
	6. Description	Compare the cost for flexibility with the avoided cost (Cost of the flexibility solution VS alternative grid solution).
	7. OneNet Cluster	Central (WP27)
	8. OneNet Demonstrator	DEMO00
	9. Related BUC(s)	CECL-EU-01; CECL-EU-02
	10. Link with other projects	CoordiNet, InterFlex, EU-SysFlex,
	11. KPI responsible	Partner00
	12. General comments	This KPI allows estimating the economic performances of the activities carried out within the corresponding BUCs which objective is resorting flexibility to solve network congestions.
Calculation information	**13. Formula**	$Cost_{variation} = \frac{Cost_{flex}}{Cost_{Sub}} \cdot 100$
	14. Variables	$Cost_{Sub}$: Avoided exceeding subscription cost [€] $Cost_{flex}$: Cost of flexibility [€]
	15. Unit of measurement	%
	16. KPI baseline explanation	The baseline for the calculation of this KPI is the scenario in which the congestions are solved using traditional network reinforcement designed using the deterministic fit and forget approach
	17. KPI baseline source	Values measured at the start of the project and complimented with simulations
	18. Baseline responsible	Partner00
	19. KPI target value	Costs reduced by 50% with respect to the baseline
	20. Calculation methodology	The KPI will be calculated using historical data and simulations to evaluate the costs corresponding to the baseline and to the project scenario.

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	21. Gaps and challenges for KPI definition and quantification	The definition of this KPI for the corresponding BUCs is fundamental for assessing the BUC's economic sustainability. The assessment of the KPI requires knowledge of the current situation, the corresponding data collection, and the development of the simulation tools. Data collection is affected by uncertainty related to the future scenarios in the project horizon. It is not easy to quantify the cost of flexibility because it depends on the providers and the procurement method.

KPI DATA COLLECTION SECTION

BUC	Data ID	Data Description	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible
CECL-EU-01	EU_CF_01	$Cost_{flex}$	Inventory list and simulation environment	Input data manually, simulation to determine the value to be used for the KPI calculation	DEMO00 Capital City – site 1	Monthly Starting at the beginning of the project, then updated monthly	M1-M16	Partner00
CECL-EU-01	EU_CS_01	$Cost_{Sub}$	Inventory list and simulation environment	Input data manually, simulation to determine the value to be used for the KPI calculation	DEMO00 Capital City – site 1	Monthly Starting at the beginning of the project, then updated monthly	M1-M16	Partner01

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3 European projects' review concerning relevant KPIs

The identification of the OneNet KPIs is based on the project review procedure described in section 2.1. As a result, from the project review, 83 KPIs from CoordiNet, EUniversal, EU-SysFlex, InterFlex, and SmartNet projects are considered relevant for the KPI identification process of the OneNet project. As stated in section 2.1, the KPIs are selected for each of the surveyed projects based on their potential link with the OneNet BUC and SUC objectives. For example, the selected KPIs quantify and compare the effectiveness of use cases focused on developing market platforms to acquire system services such as congestion management, voltage control, balancing services.

Furthermore, these KPIs are categorised into four domains; most of them (62) are technical KPIs, while 17 belong to the economic domain, 6 to the environmental, and 4 to the social domain. The categorised lists of KPIs are presented in this chapter, describing each KPI by its ID, category, name, description, formula, variables, and unit of measurement.

The technical KPIs are listed in section 3.1, the economic KPIs in section 3.2, the environmental KPIs in section 3.3, and the societal KPIs in section 3.4.

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3.1 Economic KPIs from European projects' review

Table 3.1 shows the categorised list of KPIs resulting from reviewing the relevant European projects. This list is focused on the economic domain.

Table 3.1 – Categorised list of KPIs from European projects' review - Economic domain

KPI_ID	KPI Category	KPI Name	KPI description	Formula	Variables	Unit
KPI_E1	Redispatch Cost	Cost of counteractions needed based on the activated flexibility	The cost of emergency actions to re-dispatch some resources to solve real congestions and voltage violations in the grid. They can be caused by the partial activation of accepted bids or by the activation of non-accepted bids (flexibility requested to be activated even if the market did not select the related bid).	$Cost_{rdispatch} = \sum_{t=1}^{T}\sum_{i=1}^{I} E_{i,t}^{rdisp}\lambda_{i,t}^{mFRR\ bid}$	$E_{i,t}^{rdisp}$: Redispatch energy of ith flexible resource at time t (kWh). $\lambda_{i,t}^{mFRR\ bid}$: Price of bids submitted to mFRR market of the ith flexible resource at time t (€/kWh). I: Set of flexible resources. T:Set of time periods.	€
KPI_E2	CAPEX and OPEX	OPEX - Operational Expenditures	This indicator calculates the recurrent costs required to operate and maintain the installed equipment.	$OPEX_{recurrent_{cost}} = \sum_{t=1}^{T}\sum_{rc=1}^{RC} Rcost_{rc,t}$	$Rcost_{rc,t}$: Recurrent cost at time t (€). RC: Set of recurrent cost. T: Set of time periods.	€
KPI_E3	CAPEX and OPEX	OPEX for service procurement	This indicator measures the cost of services procurement.	$OPEX_{service_{proc.}} = \sum_{t=1}^{T}\sum_{i=1}^{I}\left(P_{i,t}^{AS}C_{i,t}^{PAS} + E_{i,t}^{AS}C_{i,t}^{EAS}\right)$	$P_{i,t}^{AS}, C_{i,t}^{PAS}$: Reserved capacity (kW) and cost of reserved capacity (€/kW) for ancillary services of ith flexible resource at time t. $E_{i,t}^{AS}, C_{i,t}^{PAS}$: Provided energy (kWh) and energy cost (€/kWh) for ancillary services of ith unit at time t. I: Set of flexible resources. T: Set of time periods.	€
KPI_E4	CAPEX and OPEX	Cost of R&I solution VS alternative grid solution	Comparison between the CAPEX of the research and innovation (R&I) solution with the investment costs required to apply alternative solutions annually	$Cost_{variation} = \frac{CAPEX_{BAU} - CAPEX_{R\&I}}{CAPEX_{BAU}}$	$CAPEX_{BAU}$: CAPEX of Business-as-Usual scenario [€]. $CAPEX_{R\&I}$: CAPEX of R&I scenario [€].	%
KPI_E5	Ancillary services	Average cost per service for the examined period	The indicator measures the average cost for providing ancillary services in the different markets. This indicator is used to measure the average cost of the reserved capacity and provided energy.	$C_{AS} = \frac{\sum_{i=1}^{I}\sum_{t=1}^{T}\left[\left(P_{AS,i,t}\right)\cdot\left(c_{AS,i,t}\right)\right]}{\sum_{i=1}^{I}\left(P_{AS,i,t}\right)}$	$P_{AS,i,t}$: Reserved capacity for service procurement of ith flexible resources at time t (kW). $c_{AS,i,t}$: Cost of reserved capacity for service procurement of ith flexible resources at time t (€/kW). I: Set of flexible resources. T: Examined period.	€/kW
KPI_E6	Ancillary services	Total mFRR cost	This metric includes the total balancing cost of the market defined in the R&I project. The energy activated is remunerated at the nodal price resulting from the clearing process. The mFRR activations in the balancing market aim to solve the network imbalance and avoid congestions predicted in advance for the next time step.	$mFRR_{upward} = \min\{mFRR_{min,} - \min[negative\ imbalance(t1 \div t2)]\cdot k_{mFRR}\}$ $mFRR_{downward} = \max\{-mFRR_{min,} - \max[positive\ imbalance(t1 \div t2)]\cdot k_{mFRR}\}$	$t1, t2$: Generic time instants. $mFRR_{min}, mFRR_{max}$: Minimum and maximum amount of reserve (MW). k_{aFRR}: Coverage factor (€/MW).	€

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KPI_E7	Ancillary services	Total aFRR cost	This is the cost of re-balancing the system after the mFRR market. In this case, the bids submitted to the market are ordered according to a system-wide merit order and the resulting price will be applied as marginal price (off-line simulation of aFRR market). At each balancing market session, the aFRR total needs (downward and upward) are calculated for the next time steps. The calculation of the aFRR cost based on the actual aFRR activations and cleared price.	$aFRR_{upward} = \min\{aFRR_{min,} - \min[negative\ imbalance(t1 \div t2)] \cdot k_{aFRR}\}$ $aFRR_{downward} = \max\{-aFRR_{min,} - \max[positive\ imbalance(t1 \div t2)] \cdot k_{aFRR}\}$	$t1, t2$: Generic time instants (MW). $aFRR_{min}, aFRR_{max}$: Minimum/maximum amount of reserve. k_{aFRR}: Coverage factor (€/MW).	€
KPI_E8	Ancillary services	Costs of Congestion Management with flexibility market vs Curtailment	Relates the cost of traded flexibility on the market with the costs of curtailment	$C_{\%} = \frac{C_{FM}}{C_C} \cdot 100$	$C_{\%}$: Costs of Congestion Management with flexibility market vs. Curtailment (%). C_{FM}: Cost for the traded flexibility on the market (€). C_C: Costs for curtailment measures (€).	%
KPI_E9	Ancillary services	Cost of the energy distributed thanks to islanding	This KPI applies to Use Cases where Island mode is activated in case of an outage. It represents how much (in costs of interruption) could be saved from a DSO planning methods point of view when energy sources (or storage) inside Island mode supply customers without significant time of the outage.	$EnergyIslanded_{EUR} = R \cdot \sum_{i=1}^{N} \int_{T_{start(i)}}^{T_{end(i)}} P_{LCi}(t)dt$	$EnergyIslanded_{EUR}$: Energy distributed in islanding mode (€). $P_{LCi}(t)$: Load curve of the islanded grid (kW). $T_{start(i)}$: Beginning of the islanding. $T_{end(i)}$: End of the islanding. N : Number of the islanding trials. R: Ratio €/MWh used in planning tools by the DSO.	€
KPI_E10	Investment deferral	Distribution grid investment avoidance or deferral due to the use of flexibility	Distribution grid investment avoidance or deferral due to the use of flexibility.	$DDCI = \frac{NPV_{BAU} - NPV_{EUniversal}}{NPV_{BAU}} \cdot 100$	$DDCI$: Deferred Distribution Capacity Investment NPV_{BAU}: Net present value of the network reinforcement cost for the BAU scenario (€). $NPV_{EUniversal}$: Net present value of the network reinforcement cost for the SENSIBLE scenario (€). The present value (PV) of deferred investment is given by: $NPV(\tau)\frac{IC}{e^{p+\tau}}$ IC: Investment cost (€). τ: Deferral time (€). p: Interest rate.	%
KPI_E11	Market indicators	Volume of transactions (Energy)	This indicator measures the volume of transactions in kWh depending on the provided service. This indicator will be used to measure the volume of offered and cleared bids for each service.	$VT_E = \sum_T \sum_I E_{i,t}$	VT_E: Volume of transaction considering energy (kWh). $E_{i,t}$: Volume offered or cleared energy by the i-th flexible resource at time t (kWh). I: Set of flexible resources. T: Examined period.	kWh
KPI_E12	Market indicators	Volume of transactions (Power)	This indicator measures the volume of transactions in kW depending on the provided service. This indicator will be used to measure the volume of offered and cleared bids for each service.	$VT_P = \sum_T \sum_I P_{i,t}$	VT_P: Volume of transaction considering active power (kW). $P_{i,t}$: Volume offered or cleared capacity by the ith flexible resource at time t (kW). I: Set of flexible resources. T: Examined period.	kW
KPI_E13	Market indicators	Number of transactions	This indicator measures the number of transactions. This indicator will be used to measure the number of offered and cleared bids for each service.	$N_T = \sum_T n_{Bids,t}$	$n_{Bids,t}$: Number of offered or cleared bids at time t (kW or kWh). T: Examined period.	–
KPI_E14	CAPEX and OPEX	ICT costs	The term ICT cost comprises the communications and information technologies, including the aggregation and market clearing process software. Only those ICT costs directly related to the implementation of each coordination scheme are considered.	$ICT_{cost} = \sum_{i=1}^{N_c} c_i$	ICT_{cost}: Cost of ICT (€). c_i: Generic ith cost directly related to each coordination scheme. N_c: Overall number of cost items.	€

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KPI_E15	CAPEX and OPEX	Cost of R&I solution VS alternative grid solution	Compare the cost for flexibility with avoided exceeding subscription cost.	$Cost_{variation} = \frac{Cost_{flex}}{Cost_{Sub}} \cdot 100$	$Cost_{Sub}$: Avoided exceeding subscription cost (€). $Cost_{flex}$: Cost of flexibility (€).	%
KPI_E16	Ancillary services	Average cost per service for the examined period	The indicator measures the average cost for providing ancillary services in the different markets. This indicator is used to measure the average cost of the reserved capacity and provided energy.	$C_{AS} = \frac{\sum_{i=1}^{I}\sum_{t=1}^{T}\left[\left(C_{AS,i,t}\right)\cdot\left(c_{EAS,i,t}\right)\right]}{\sum_{i=1}^{I}\left(E_{AS,i,t}\right)}$	$E_{AS,i,t}$: Provided energy for service procurement of ith flexible resources at time t (kWh). $c_{EAS,i,t}$: energy cost for service procurement of ith flexible resources at time t (€/kWh). I: set of flexible resources. T: examined period.	€/kWh

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3.2 Technical KPIs from European projects' review

Table 3.2 shows the categorised list of KPIs resulting from the review of the relevant European projects. This list is focused on the technical domain.

Table 3.2 – Categorised list of KPIs from European projects' review - Technical domain

KPI_ID	KPI Category	KPI Name	KPI description	Formula	Variables	Unit
KPI_T1	Flexibility indicator	Estimation of the increment of reactive power flexibility for the network operators (TSO and DSO)	The increment of reactive power flexibility regulation will depend on the technical features of wind generators and electronic equipment and the regulatory changes allowing the provision of this service with the proposed market to benefit from the existing distribution grid flexibility.	$IRPF = \frac{RPF_{R\&I} - RPF_{BaU}}{RPF_{BaU}} \cdot 100$ where: $RPF = \sum_{i=1}^{I} Q.\Delta t$	$IRPF$: Increment of Reactive Power Flexibility (%) RPF_{BaU}: Reactive power flexibility of Business as Usual scenario (kVArh). $RPF_{R\&I}$: Reactive power flexibility of R& I scenario (kVArh). Δt : examined period (h). I: set of flexibility provides. Q: Reactive power that is provided (kVAr).	%
KPI_T2	Grid security and operation quality	Capacity increase with active management	The indicator measures the percentage difference, or in other words, percentage increase, in Capacity (Apparent Power) as a result of using market Platform and products proposed by the project. The active and reactive power increase at the primary substation is considered.	$\Delta C_{AP_{\%}} = \frac{Cap_{R\&I} - Cap_{BaU}}{Cap_{BaU}} \cdot 100$	$\Delta C_{RP}\%$: Variation of active power capability (%). Cap_{BaU} : Apparent power capacity of Business as Usual scenario (MVA). $Cap_{R\&I}$: Apparent power capacity of R&I scenario (MVA).	%
KPI_T2bis	Grid security and operation quality	Capacity increase with reactive management	The indicator measures the percentage difference, or in other words, percentage increase, in Capacity (Apparent Power) as a result of using market Platform and products proposed by the project. The active and reactive power increase at the primary substation is considered.	$\Delta C_{RP_{\%}} = \frac{Cap_{R\&I} - Cap_{BaU}}{Cap_{BaU}} \cdot 100$	$\Delta C_{RP}\%$: Variation of reactive power capability (%). Cap_{BaU} : Apparent power capacity of Business as Usual scenario (MVA). $Cap_{R\&I}$: Apparent power capacity of R&I scenario (MVA).	%
KPI_T3	Grid security and operation quality	Peak load demand reduction	This indicator measures the maximum percentage decrease of peak load demand in an area by a flexibility provider resource.	$\Delta PeakLoad = \frac{PeakLoad_{BaU} - PeakLoad_{R\&I}}{PeakLoad_{BaU}} \cdot 100$	$\Delta PeakLoad$: Peak load demand reduction (%). $PeakLoad_{BaU}$: Peak load of Business as Usual scenario (MW). $PeakLoad_{R\&I}$: Peak load of R&I scenario (MW).	%
KPI_T4	Renewable energy generation	Increase RES and DER hosting capacity	This indicator measures the potential increase of hosting capacity for DERs with Innovative grid services compared to the baseline situation where no "smart" actions are performed on the network. The indicator gives a statement about the additional DERs that can be installed in the network thanks to innovative grid services without the need for conventional reinforcements (i.e. new grid lines).	$HC_{\%} = \frac{HC_{R\&I} - HC_{BaU}}{HC_{BaU}} \cdot 100$	$HC_{\%}$: Increase RES and DER hosting capacity (%). HC_{BaU} : Hosting Capacity of Business as Usual scenario (kW). $HC_{R\&I}$: Hosting Capacity of Research and innovation scenario (kW).	%
KPI_T5	Forecast indicators	Accuracy of the RES production forecast calculated 1 hour in advance	Accuracy of the RES production forecast calculated 1 hour in advance	$RES_{FA_{1h}} = \frac{\left\lvert \frac{FC_{RES_{prod}} - RL_{RES_{prod}}}{RL_{RES_{prod}}} \right\rvert}{N \cdot RES_{cap}} \cdot 100$	$RES_{FA_{1h}}$: Accuracy of the RES production forecast calculated 1 hour in advance (%). $FC_{RES_{prod}}$: RES production estimated 1h in advance (MW). $RL_{RES_{prod}}$: Real RES production (MW). N: Number of available data points. RES_{cap} : installed capacity of RES (MW).	%

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KPI_T6	Forecast indicators	Accuracy of the RES production forecast calculated 24 hours in advance	Accuracy of the RES production forecast calculated 24 hours in advance	$RES_{FA_{24h}} = \frac{\left\lvert \frac{FC_{RES_{prod}} - RL_{RES_{prod}}}{RL_{RES_{prod}}} \right\rvert}{N \cdot RES_{cap}} \cdot 100$	$RES_{FA_{1h}}$: Accuracy of the RES production forecast calculated 24 hours in advance (%). $FC_{RES_{prod}}$: RES production estimated 24h in advance (MW) $RL_{RES_{prod}}$: Real RES production (MW) N: Number of available data points RES_{cap} : Installed capacity of RES (MW)	%
KPI_T7	Forecast indicators	Forecast quality	Error in the power exchange forecast	$NMAE = \frac{MAE}{Pnom} \cdot 100$ $Where: \quad MAE = \sum \lvert F - M \rvert$	MAE : Mean absolute error of forecast (kW). $NMAE$: Normalized mean absolute error of forecast (%). F : Forecasted Value (kW). M : Measured value (kW). $Pnom$: Installed power(kW).	%
KPI_T8	Flexibility indicators	Ratio of activated reserved flexibility (active power)	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, defined as the percentage of the total flexibility reserved from FSPs that is activated to manage the grid operation without technical constraints.	$FARR_{P\%} = \frac{\sum_{t=0}^{T} P_{flex,Activated_t}}{\sum_{t=o}^{T} P_{reserved_t}} \cdot 100$	$FARR_{P\%}$: Percentage of the total flexibility (Active power) from FSP reserved in the network that was activated for grid management purposes, for the period T (%). $P_{flex,Activated_t}$: Total flexibility from FSPs reserved that is activated in the network at each time instant t used for grid management purposes (Active power) (kW). $P_{reserved_t}$: Total flexibility from FSP reserved in the network at each time instant t (Active power). (kW).	%
KPI_T8bis	Flexibility indicators	Ratio of activated reserved flexibility (reactive power)	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, defined as the percentage of the total flexibility reserved from FSPs that is activated to manage the grid operation without technical constraints.	$FARR_{Q\%} = \frac{\sum_{t=0}^{T} Q_{flex,Activated_t}}{\sum_{t=o}^{T} Q_{reserved_t}} \cdot 100$	$FARR_{Q\%}$: Percentage of the total flexibility (Reactive power) from FSP reserved in the network that was activated for grid management purposes, for the period T (%). $Q_{flex,Activated_t}$: Total flexibility from FSPs reserved that is activated in the network at each time instant t used for grid management purposes (Reactive power) (kVAr). $Q_{reserved_t}$: Total flexibility from FSP reserved in the network at each time instant t (Reactive power) (kVAr).	%
KPI_T9	Forecast indicators	Accuracy of load forecast calculated 1 hour in advance	Accuracy of load forecast calculated 1 hour in advance	$Load_{FA_{1h}} = \frac{\left\lvert \frac{FC_{load} - RL_{load}}{RL_{load}} \right\rvert}{N} . 100$	$Load_{FA_{1h}}$: Accuracy of load forecast calculated 1 hour in advance (%) FC_{load} : Load estimated 1h in advance (MW). RL_{load} : Real load (MW). N: Number of available data points.	%
KPI_T10	Forecast indicators	Accuracy of load forecast calculated 24 hours in advance	Accuracy of load forecast calculated 24 hours in advance	$Load_{FA_{24h}} = \frac{\left\lvert \frac{FC_{load} - RL_{load}}{RL_{load}} \right\rvert}{N} \cdot 100$	$Load_{FA_{24h}}$: Accuracy of load forecast calculated 24 hours in advance FC_{load}: load estimated 24 hours in advance (MW). RL_{load}: real load (MW). N: number of available data points.	%
KPI_T11	Forecast indicators	Share of correctly forecasted congestions	Share of correctly forecasted congestions	$CFC_{\%} = \frac{C_{fc,c}}{C_o} \cdot 100$	$CFC_{\%}$: share of correctly forecasted congestions [%] $C_{fc,c}$**:** Number of congestions correctly forecasted, so excluding the false positive congestions forecasts. C_o**:** Number of situations where analysis of the measurements indicate that congestion occurred or would have occurred if no curative actions by the DSO were taken (i.e., flexibility used).	%
KPI_T12	Forecast indicators	Share of false positive congestion forecasts	Share of false-positive congestion forecasts	$FFC_{\%} = \frac{C_{fc,c}}{C_{fc}} \cdot 100$	$FFC_{\%}$: share of correctly forecasted congestions [%] $C_{fc,c}$**:** Number of false positive congestion forecasts, so congestions forecasted where analysis of the measurements indicate that no congestion would have occurred, even if no curative actions by the DSO were taken (I.e., flexibility used)**.** C_{fc}**:** Total number of congestions forecasted.	%

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KPI_T13	Forecast indicators	Flexibility service reliability	Flexibility service reliability	$MSE = \frac{1}{T}\sqrt{\sum_{t=1}^{T}\left(P_{R,t} - P_{B_v,t}\right)^2}$	MSE: Mean square error t : One of the T time periods considered. P_R : Realized power exchanged (kW). P_{B_v} : Power accepted (or validated) from the bid on the Market (kW).	kW
KPI_T14	Forecast indicator	Baseline accuracy	Baseline accuracy, according to the following metrics: Mean Absolute Error (MAE) Root Mean Squared Error (RMSE)	$MAE = \frac{1}{n}\sum\lvert e_t\rvert$ $RMSE = \sqrt{\frac{1}{n}\sum {e_t}^2}$	$RMSE$: root mean square error (kW or kWh) MAE: mean absolute error (kW or kWh) t : settlement period n : number of settlement period considered e_t: the error, difference between the baseline value and the energy/power measurement (when no dispatch) (kW or kWh)	kW or kWh
KPI_T15	Voltage indicators	Voltage variation rate	Voltage variation	$R\delta_v = \frac{\delta_{v\_R\&I} - \delta_{v_{BaU}}}{\delta_{v_{BaU}}} \cdot 100$ $\delta_v = \frac{\sqrt{\sum_{t=1}^{T}\sum_{n=1}^{N}\left(V_{n,t} - V_{n,nom}\right)^2}}{N.T}$	$R\delta_v$: Voltage variation rate $\delta_{v\_R\&I}$: Voltage deviation for the R&I scenario (%). $\delta_{v_{BaU}}$: Voltage deviation for the BaU scenario (%). T : Examined period. N: Number of nodes under consideration. $V_{n,t}$: Voltage on node n at time period t (V or pu). $V_{n,nom}$: Nominal voltage on node n (V or pu).	%
KPI_T16	Voltage indicators	Line Voltage profile deviation	Line Voltage profile deviation. From the cumulative Distribution Function of $\Delta V(t)$ it can be calculated the 5th and 95th percentile of $\Delta V(t)$ % or rather $\Delta V(t)_{(5\%)}$ and $\Delta V(t)_{(95\%)}$, that is the value for which 95% of all voltage line measurements fall below or above.	$\Delta V(t) = \lvert V^*(t) - 1\rvert$ Where $V^*(t)$ is the normalized voltage profile, obtained as follows: $V^*(t) = \frac{V(t)}{V_n}$	$\Delta V(t)$: Line Voltage profile deviation (p.u.) $V(t)$: Voltage profile (p.u.) V_n : Nominal voltage value (p.u.)	p.u.
KPI_T17	Voltage indicators	Criticalities Reduction Index	Criticalities Reduction Index	$CRI = \frac{N_{cr_{BaU}} - N_{cr\_R\&I}}{N_{cr_{BaU}}} \cdot 100$	CRI: Criticalities Reduction Index $N_{cr_{BaU}}$: Number of criticalities when applying Business as Usual solution. $N_{cr\_R\&I}$: Number of criticalities when applying R&I solution.	%
KPI_T18	Islanding indicators	Islanding duration index	Islanding duration index	$I_{cap} = \frac{\sum_{i=1}^{N} D_{isl_i}}{\sum_{i=1}^{N} D_{req,i}} \cdot 100$	I_{cap}: Islanding duration index (%) D_{isl_i} : Duration of a single islanding (h) $D_{req,i}$: Required duration of an islanding, after an Intentional or unintentional disconnection from the grid (h). N: Number of disconnections.	%
KPI_T19	Islanding indicators	Delivered energy in a controlled island	Delivered energy in a controlled island	$E_{isl} = E_{FSP} + E_{gen}$	E_{isl}: Delivered energy in a controlled island E_{FSP}: Energy provided by the FSP during the island (kWh). E_{gen} : Energy provided by other generators connected to the island (kWh).	kWh
KPI_T20	Islanding indicators	Maximum power (non-transient) in controlled island	Maximum power (non-transient) in controlled island	$P_{max,isl} = \max(P_{FSP} + P_{gen})$	$P_{max,isl}$: Maximum power (non-transient) in controlled island (kW) P_{FSP} : Power injected to the grid by the FSP (kW). P_{gen} : Power produced by the other generators connected to the island (kW).	kW
KPI_T21	Flexibility indicators	Potential Offered flexibility	Potential Offered flexibility (Power)	$P_{Flex_{PO}} = \sum_{i=1}^{I}\sum_{t=1}^{T} P_{flex_{PO_{i,t}}}$	$P_{flex_{PO_{i,t}}}$: Amount of power send from the ith flexible resource at time t to offer flexibility for sale. It contains the potential flexibility that is available to the market platform (MW or kW). T: Examined period. I: Set of flexible resources.	kW or MW

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KPI_T21bis	Flexibility indicators	Potential Offered flexibility	Potential Offered flexibility (Energy)	$E_{Flex_{PO}} = \sum_{i=1}^{I}\sum_{t=1}^{T} E_{flex_{PO_{i,t}}}$	$E_{flex_{PO_{i,t}}}$: Amount of energy send from the i-th flexible resource at time t to offer flexibility for sale. It contains the potential flexibility that is available to the market platform (MWh or kWh). T: Examined period. I: Set of flexible resources.	kWh or MWh
KPI_T22	Flexibility indicators	Flexibility	Available Flexibility	$Flexibility_{\%} = \frac{\sum P_{Available_{Flexibility}}}{\sum P_{Total_{in_{Area}}}} \cdot 100$	$Flexibility_{\%}$: Percentage of available flexible power with respect to the available in reporting period (%). $\sum P_{Available_{Flexibility}}$: Power of available flexibility in reporting period (MW). $\sum P_{Total_{in_{Area}}}$: Total power in MW used in DEMO grid segment (MW)	%
KPI_T23	Flexibility indicators	Requested flexibility (Power)	Requested flexibility (Power)	$P_{Flex_R} = \sum_{t=1}^{T} P_{flex_{R_t}}$	P_{Flex_R}: Requested flexibility (Power) (kW). $P_{flex_{R_t}}$: The amount of power requested by the DSO/TSO to solve their forecasted constraints at a time T (kW).	kW
KPI_T23bis	Flexibility indicators	Requested flexibility (Energy)	Requested flexibility (Energy)	$E_{Flex_R} = \sum_{t=1}^{T} E_{flex_{R_t}}$	E_{Flex_R}: Requested flexibility (Energy) (kWh) $E_{flex_{R_t}}$: The amount of energy requested by the DSO/TSO in order to solve their forecasted constraints at a time T [MWh or kWh]. T: Examined period.	kWh
KPI_T24	Flexibility indicators	Flexible capacity vs flexible volume offered ratio	Flexible capacity vs flexible volume offered ratio	$F_C = \frac{F_{FSPbid}}{F_{cap}} \cdot 100$	F_C: Flexible capacity vs. flexible volume offered ratio (%). F_{cap}: Total flexibility capacity registered (kW). F_{FSPbid}: Amount of flexibility offered by FSP (kW).	%
KPI_T25	Flexibility indicators	Flex volume offered by FSP vs Flex request by DSO	Flex volume offered by FSP vs Flex request by DSO	$F_V = \frac{F_{FSPbid}}{F_{DSO\ request}} \cdot 100$	F_V: Flex volume offered by FSP vs. Flex request by DSO (%) $F_{DSO\ request}$: Amount of flexibility requested by DSO (kW). F_{FSPbid} : Amount of flexibility offered by FSP (kWh)	%
KPI_T26	Flexibility indicators	Flex volume delivered by FSP vs Flex bids accepted by DSO	Flex volume delivered by FSP vs Flex bids accepted by DSO	$F_D = \frac{F_{delivered}}{F_{bids}} \cdot 100$	F_D: Flex volume delivered by FSP vs. Flex bids accepted by DSO (%). $F_{delivered}$: Amount of flexibility which is delivered by FSP as the request of DSO to provide flexibility (kW). F_{bids} **:** Amount of flexibility that FSP bids for a particular portfolio to submit in the market platform and has been accepted by DSO to be activated (kW).	%
KPI_T27	Flexibility indicators	Type of flexibility providers per demo	Type of flexibility providers per demo	$TFP = \frac{N_{leverage_{technology}}}{N_{target_{technology}}} \cdot 100$	TFP: Type of flexibility providers per demo (%) $N_{leverage_{technology}}$: Number of different types of technologies utilized during the demo. $N_{target_{technology}}$: Number of different types of technologies available in the region of the demo.	%
KPI_T28	Renewable energy generation	RES energy increase	RES energy increase	$PLKP1 = \frac{\Delta A_Y}{A_T - \Delta A_Y}$ $A_T = \sum_{i=1}^{8760} A_{hi}$ $\Delta A_Y = \sum_{i=1}^{8760} \Delta A_{hi}$ $\Delta A_{hi} = A_{hi-}A_{CA}\ if\ A_{hi} > A_{CA}$ $\Delta A_{hi} = 0\ if\ A_{hi} < A_{CA}$	$PLKP1$: RES energy increase (kWh) ΔA_Y : Total yearly production above connection agreement (kWh). A_T :Total yearly production (kWh). A_{hi} : Hourly production (kWh). ΔA_{hi} : Hourly production above connection agreement (kWh). A_{CA} = Production according to connection agreement (kWh).	kWh

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KPI_T29	Market indicators	Reactive power market utilization factor	Reactive power market utilization factor	$MUQ = \frac{\sum h}{T_{test\ period}}.100$	MUQ: Reactive power market utilization factor (%) $\sum h$: Number of hours that the market is being used to compensate the reactive power. $T_{test\ period}$: Duration of the test period.	%
KPI_T30	Market indicators	Total activation time of a product	Total activation time of a product	$Total_{act} = \sum_{N} t_{act_n}$	$Total_{act}$: Total activation time of a product (h). t_{act_n}: Duration of the nth product activation (h). N : Times of activation.	h
KPI_T31	Market indicators	Number of products per demo	Number of products per demo	$NPD = \frac{nP_{tested}}{nP_{targeted}} \cdot 100\%$	NPD: Number of products per demo (%). nP_{tested}: number of products tested in the BUC. $nP_{targeted}$: number of products initially targeted for the BUC.	%
KPI_T32	Market indicators	Ratio of forwarded flexibility bids	Ratio of forwarded flexibility bids	$FBF = \frac{Bids_{forwarded}}{Bids_{total}}.100\%$	FBF: Ratio of forwarded flexibility bids (%). $Bids_{forwarded}$: Volume of bids forwarded from a LV DSO (HV DSO) market to an MW DSO (Balancing) market (MWh). $Bids_{total}$: Volume of bids in LV DSO (HV DSO) market (MWh).	%
KPI_T33	ICT performance	Total Computational Runtime variation	Total Computational Runtime variation	$\Delta RT = \frac{RT_{reference} - RT_{cs}}{RT_{reference}} \cdot 100$ Where $RT = T_{final} - T_{initial}$	ΔRT: Total Computational Runtime variation (%) RT: Total Computational Runtime (s) $T_{initial}$: Time at the end of running the algorithm (s). T_{final} : Time at the beginning of running the algorithm (s). $RT_{reference}$: Running time of reference algorithm (s). RT_{cs} : Running time of Coordination Scheme algorithm (s).	%
KPI_T34	ICT performance	Data reliability ratio	Data reliability ratio	$DRR = \sum_{T} \frac{n_{reliable}}{n_{recieved}} \cdot 100$	DRR: Data reliability ratio (%) $n_{reliable}$: Amount of reliable data that received over period T. $n_{recieved}$: Amount of data that received over period T.	%
KPI_T35	ICT performance	Availability of the communication infrastructure	Availability of the communication infrastructure	$AV_{\%} = \frac{T_{com}}{T_{op}} \cdot 100$	$AV_{\%}$: Availability of the communication infrastructure (%) T_{com} : Total duration in which all the communication platform is working correctly as defined in the demonstration specification (s). T_{op} : Total operational time of the aggregator during the test carried out (s).	%
KPI_T36	ICT performance	Monitoring information categories	Monitoring information categories	$MIC = \frac{MD_{Flex} - MD_{BAU}}{MD_{BAU}} \cdot 100$	MIC: Monitoring information categories (%) MD_{BAU} : Total monitored data according with the count criterion in BAU scenario. MD_{Flex} : Total monitored data according with the count criterion in R&I scenario.	%
KPI_T37	ICT performance	Cycle time DSO process	Cycle time DSO process	$d = T_0 - T_i$	d: Cycle time DSO process (s) T_i : Time of the information input (s) T_0 : Time of finalized output/order to the market (s)	s
KPI_T38	Grid security and operation quality	TIEPI - Equivalent interruption time related to the installed capacity	TIEPI - Equivalent interruption time related to the installed capacity	$TIEPl_i = \frac{Pl_i \cdot H_i}{Pl_{total}}$	$TIEPI_i$- Equivalent interruption time related to the installed capacity i-th (s) Pl_i: Installed Power of the MV/LV secondary substations of the DSO plus the power contracted affected by the interruption i-th (kVA). H_i: Time of supply disruption that affects the power Pl_i (s). Pl_{total} : Total power installed in the MV/LV secondary substation of the distributor plus the power contracted (kVA).	s
KPI_T39	Flexibility indicators	Availability of the service provision	Availability of the service provision	$SPR = \frac{TPS}{TPS + TRS} \cdot 100$	SPR: Availability of the service provision (%) $TPS(min)$: The time duration in which the aggregator correctly provides the scheduled services (s). $TRS\ (min)$: The period of the time during which the aggregator should have provided some services but fails to do so for different technical reasons (s).	%

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KPI_T40	Flexibility indicators	Flexibility services re-dispatch success rate	Flexibility services re-dispatch success rate	$SRR = \frac{T_{redispatch\_suc}}{T_{redipatch\_act}} \cdot 100$	SRR: Flexibility services re-dispatch success rate (%) $T_{redispatch\_suc}$: Time duration in which the short-term control succeeds in re-allocating the capacities and services to available resources or units during unexpected operational events (s). $T_{redipatch\_act}$: Total operational time during which unexpected events occur and services re-dispatch is technically possible (i.e. the corresponding function of the short-term control is activated) (s).	%
KPI_T41	Grid security and operation quality	Improvement on distribution network continuity of service	Reliability improvement determined by System Average Interruption Duration Index (SAIDI)	$\Delta SAIDI\% = \frac{SAIDI_{EUniversal} - SAIDI_{baseline}}{SAIDI_{baseline}} \cdot 100$	Where: $SAIDI = \frac{\sum Costumer\ Minutes\ of\ Interruption}{Total\ Number\ of\ Costumers\ Served}\ h/costumer$	%
KPI_T41bis	Grid security and operation quality	Improvement on distribution network continuity of service	Reliability improvement determined by System Average Interruption Frequency Index (SAIFI)	$\Delta SAIFI\% = \frac{SAIFI_{EUniversal} - SAIFI_{baseline}}{SAIFI_{baseline}} \cdot 100$	Where: $SAIFI = \frac{\sum Total\ Number\ of\ Costumers\ Interrupted}{Total\ Number\ of\ Costumers\ Served}\ interruption/costumer$	%
KPI_T41ter	Grid security and operation quality	Improvement on distribution network continuity of service	Reliability improvement determined by Customer Average Interruption Duration Index (CAIDI)	$\Delta CAIDI\% = \frac{CAIDI_{EUniversal} - CAIDI_{baseline}}{CAIDI_{baseline}} \cdot 100$	Where: $CAIDI = \frac{\sum Costumer\ Minutes\ of\ Interruption}{Total\ Number\ of\ Costumers\ Interrupted}\ h/costumer$	%
KPI_T41quater	Grid security and operation quality	Improvement on distribution network continuity of service	Reliability improvement determined by non-served energy	$\Delta ENS\% = \frac{ENS_{R\&I} - ENS_{baseline}}{ENS_{baseline}} \cdot 100$	$\Delta ENS\%$: Improvement on distribution network continuity of service (%) $ENS_{R\&I}$: Non served energy (estimated) after the adoption of the R&I solution (kWh) $ENS_{baseline}$: Non served energy (estimated) in the baseline scenario (kWh)	%
KPI_T42	Grid security and operation quality	Reinforcement of distribution network resilience and flexibility to extreme events	Reinforcement of distribution network resilience and flexibility to extreme events Resilience improvement determined through the conditional value of Expected Energy Not Supplied.	$\Delta CEENS\% = \frac{CEENS_{R\&I} - CEENS_{baseline}}{CEENS_{baseline}} \cdot 100$ Where: $CEENS = \frac{1}{1-a}\int_{Z}^{D} f(x)dx$	$\Delta CEENS\%$: variation of the Expected Energy Not Supplied (CEENS) (%). $CEENS_{R\&I}$: CEENS after the adoption of the R&I solution (kWh) $CEENS_{baseline}$: CEENS in the baseline scenario (kWh) $1-a$: Indicates the size of the considered set of worst cases (usually set to 95%, hence α=5%) $f(x)$: Probability distribution of energy not supplied.	%
KPI_T43	Grid security and operation quality	Avoided technical restrictions	Avoided technical restrictions	$ATR_{\%} = \frac{N_{TR_{Flex}}}{N_{TR}} \cdot 100$	$ATR_{\%}$: Share of avoided technical restrictions (%). N_{TR}: Total number of forecasted technical restrictions. $N_{TR_{Flex}}$: Total number of technical restrictions solved through activation of flexibility services.	%
KPI_T44	Flexibility Indicator	Deviation between accepted and actual activated mFRR	Deviation between accepted and actual activated mFRR	$\delta E = E_{i,t}^{Actual} - E_{i,t}^{mFRR}$	δE: Deviation between accepted and actual activated mFRR (kWh). $E_{i,t}^{Actual}$: Actual activated energy of the ith flexible resources at time t (kWh). $E_{i,t}^{mFRR}$: Market activated activation of the ith flexible resources at time t (kWh) For each period, t, the positive values will be added on the one hand, and the values will be added on the other hand.	kWh

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KPI_T45	Grid security and operation quality	Compliance of existing services provision by new assets to SO's requirements	Meet TSO need in adjustment of schedule (active power adjustment error): the aggregated need of schedule adjustment from TSO needs to be segregated for adjusting the schedule of single units; therefore, the accuracy of optimization is important. See if the adjustment of single units (Pu) result in correct adjustment at TSO-DSO-interface.	$\Delta P_s = P_{TDI} - P_U$	ΔP_s: Compliance of existing services provision by new assets to SO's requirements (MW). P_U : Active power adjustment of single units (MW). P_{TDI}: Active power adjustment at TSO-DSO-interface (MW).	MW
KPI_T45bis	Grid security and operation quality	Compliance of existing services provision by new assets to SO's requirements	Meet TSO need in adjustment of reactive power (Reactive Power Adjustment error).	$\Delta Q_s = Q_{TDI} - Q_U$	ΔQ_s: Compliance of existing services provision by new assets to SO's requirements (MVAr). Q_U : Reactive power adjustment of single units (MW). Q_{TDI}: Reactive power adjustment at TSO-DSO-interface (MW).	MVAr
KPIT45ter	Grid security and operation quality	Compliance of existing services provision by new assets to SO's requirements	Meet TSO need in adjustment of voltage (Voltage Adjustment error).	$\Delta U_s = U_{TDI} - U_U$	ΔU_s: Compliance of existing services provision by new assets to SO's requirements (V). U_U *:* Voltage adjustment of single units (v). U_{TDI} : Voltage adjustment at TSO-DSO interface (v).	V
KPI_T46	Grid security and operation quality	Grid efficiency	Grid efficiency	$\eta = \frac{P_0}{P_W} \cdot 100$	η: Grid efficiency (%). P_W: The losses without using adjustment stated in optimization (MW). P_0: Losses using adjustment (MW).	%
KPI_T47	Network connectivity	Increased grid connections	Increased grid connections	$IGC = \frac{FCIGC}{SL} \cdot 100$	IGC: Increased grid connections (%) $FCIGC$: Feasible connection of increased grid connection (MW). SL : Subscription level (MW).	%
KPI_T48	Grid security and operation quality	Variation in the imbalances in participation of RES in energy markets	Variation in the imbalances in participation of RES in energy markets	$\Delta_{Imabalance} = \frac{Imb_{vpp} - Imb_{single\ unit}}{Imb_{vpp}} \cdot 100$	$\Delta_{Imabalance}$: Variation in the imbalances in participation of RES in energy markets (%). Imb: Stand for the imbalances (in MWh) of a given RES unit in both participation scenario.	%

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3.3 Environmental KPIs from European projects' review

Table 3.3 shows the categorised list of KPIs resulting from the review of the relevant European projects. This list is focused on the environmental domain.

Table 3.3 – Categorised list of KPIs from European projects' review - Environmental domain

KPI_ID	KPI Category	KPI Name	KPI description	Formula	Variables	Unit
KPI_EV1	Renewable generation	Reduction in RES curtailment	This indicator measures the reduction in the amount of energy from Renewable Energy Sources (RES) that is not injected into the grid (even though it is available) due to operational limits of the grid, such as voltage violations or congestions.	$RE_{RES} = \frac{E_{RES_{BaU}} - E_{RES_{R\&I}}}{E_{RES_{Bau}}} \cdot 100$	RE_{RES}: Reduction in RES curtailment (%) $E_{RES_{R\&I}}$: RES curtailment for the R&I scenario (kWh). $E_{RES_{BaU}}$: RES curtailment for the BaU scenario (kWh).	%
KPI_EV1bis	Renewable generation	Reduction in RES curtailment	This indicator measures the reduction in the amount of energy from Renewable Energy Sources (RES) that is not injected into the grid (even though it is available) due to operational limits of the grid, such as voltage violations or congestions.	$E_{RES} = \sum_{i=1}^{I}\sum_{t=1}^{T}(E_{i,t}^{prod} - E_{i,t}^{inj})$	E_{RES}: Reduction in RES curtailment (kWh) I: Set of RES facilities under consideration. T: Set of time intervals of the period under consideration, excluding periods of scheduled maintenance and outages. $E_{i,t}^{prod}$: Available energy production of the ith RES facility at period t (kWh). $E_{i,t}^{inj}$: Injected energy of the ith RES facility at the period t (kWh).	kWh
KPI_EV2	GHG emissions	Share of fossil-based activated energy	This indicator measures the ratio of activated energy bids that are fossil-fuel-based with respect to the total amount of offered energy bids.	$SFE = \sum_{T} \frac{fossil\_act\_bids_t}{total\_energy\_bids_t} \cdot 100$	SFE: Share of fossil-based activated energy (%) $fossil\_act\_bids_t$: fossils-fuel-based activated energy bids at time t (kWh). $total\_energy\_bids_t$: Total amount of offered energy bids at time t (kWh). T : examined period.	%
KPI_EV3	GHG emissions	CO2 emissions savings	The achieved savings in CO2 emissions can be calculated from the difference between dispatched power of conventional generators and Combined Heat and Power (CHP) plants before and after SmartNet market is dispatched, and the CO2-emissions factors for the different technologies.	$ED_{CO_2} = \sum_{i}[(B_i - A_i) \cdot EmissionFactor_i]$ $A_i = nomP_i \cdot activePowerInjection_i$ $B_i = phyP_i$ $i: device$	ED_{CO_2}: CO2 emissions savings (Ton) A_i : Dispatch of all conventional and CHP power plants before SmartNet market (MWh) B_i : Dispatch of all conventional and CHP power plants after SmartNet market (MWh) The CO_2 emission factor is assumed to be 0.2015 ton/MWh for the Combined Cycle Gas Turbines (CCGT) and CHP plants and 0.3388 ton/MWh for the coal power plants.	Ton

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KPI_EV4	GHG emissions	Avoided CO2 emissions from increased RES and DER hosting capacity	Avoided CO2 emissions from increased RES and DER hosting capacity that the thermal power plants would otherwise emit.	$A_{CO_2} = (EF_{RES} \cdot IHC_{RES} \cdot h_{RES}) + (EF_{DER} \cdot IHC_{DER} \cdot h_{DER})$ $IHC_{RES} = HC_{RES;EUniversal} - HC_{RES;BAU}$ $IHC_{DER} = HC_{DER;EUniversal} - HC_{DER;BAU}$	A_{CO_2}: Avoided CO_2 emissions from increased RES and DER hosting capacity (tCO2) EF_{RES}: Annual emission factor from the Portuguese thermal power plants (tCO2/GWh). IHC_{RES} : Increased hosting capacity of RES (kW or MW). h_{RES} : Average number of electricity generation hours of RES, considering the Portuguese energy mix in a given year (h). EF_{DER} : Annual emission factor from the Portuguese energy mix (tCO2/GWh). IHC_{DER} : Increased hosting capacity of DER (kW or MW). h_{DER} : Reference number for electricity generation hours of DER in Portugal, in a given year (1,500 h). $HC_{RES;EUniversal}$: Additional hosting capacity of RES when EUniversal framework is applied with respect to currently connected generation (kW or MW) (from EU_KPI_1). $HC_{RES;BAU}$: Additional hosting capacity of RES in BAU scenario applied with respect to currently connected generation (kW or MW) (from EU_KPI_1). $HC_{DER;EUniversal}$: Additional hosting capacity of DER when EUniversal framework is applied with respect to currently connected generation (kW or MW) (from EU_KPI_1). $HC_{DER;BAU}$: Additional hosting capacity of DER in BAU scenario applied with respect to currently connected generation (kW or MW) (from EU_KPI_1).	tCO2
KPI_EV5	GHG emissions	Greenhouse Gas (GHG) emissions	This KPI aims to illustrate the reduction of carbon emissions by utilizing the project tools related to the supply of cheap renewable energy to consumers.	$GHG = \sum_h CEC_h L_h$ $L_n = \sum_{n \in N} l_n^h$	GHG: Greenhouse Gas (GHG) emissions (tCO_2) CEC_h: The Carbon Emission Coefficient during each time interval h of the period under study; it must reflect the carbon emissions of the respective generation, facilities and will be significantly lower when RES generation has a greater share in the total production than fossil fuel-based generation (tCO2/kWh). L_h : The total load across all users $n \in N$ during each time interval h of the period under study (kWh). H: The set of time intervals of the period under study. N: The set of customers under study.	tCO2

3.4 Societal KPIs from European projects' review

Table 3.4 shows the categorised list of KPIs resulting from the review of the relevant European projects. This list is focused on the environmental domain.

Table 3.4 – Categorised list of KPIs from European projects' review - Societal domain

KPI_ID	KPI Category	KPI Name	KPI description	Formula	Variables	Measurement Unit
KPI_S1	Customers indicators	Customer acceptance ratio	This indicator calculates the percentage of customers who accepted their participation in the demo in relation to the total number of customers who were contacted to participate in the demo. This indicator will be used to evaluate the customer engagement plan.	$R = \frac{N_{accept}}{N_{total}} \cdot 100$	R: Customer acceptance ratio (%) N_{accept}: Customers participate in the demo. N_{total}: Customer contacted to participate in the demo.	%
KPI_S2	Customers indicators	Customer recruitment	Measure whether demos are managing to recruit enough customer bases to attain demo objectives. This KPI measures if customers are prone to be more active in the new system, which will impact how new solutions will be designed in a commercialization phase. A prerequisite for this is that they are willing to take part in the first place.	$CR\% = \frac{CR_{successful}}{CR_{required}} \cdot 100$	$CR\%$: Percentage of the required customer base that the use case was able to recruit (%). $CR_{successful}$: Number of customers (installed capacity, energy volume) actually recruited. $CR_{required}$: Number of customers (installed capacity, energy volume) needed to obtain enough flexibility in the demo in order to verify use cases.	%
KPI_S3	Customers indicators	Active participation	This indicator measures the percentage of customers actively participating in the CoordiNet demo with respect to the total customers that accepted the participation. This indicator will be used to evaluate the customer engagement plan.	$R = \frac{N_{active}}{N_{accept}} \cdot 100$	R: Active participation (%) N_{active}: Customers actively participating in the demo N_{accept}: Customers accepted to participate in the demo	%
KPI_S4	Load indicators	Increase in the amount of load capacity participating in DR	This indicator measures the increase in the amount of load that participates in demand response to offer flexibility to system operators as a result of using market platforms and products.	$ILCP = \frac{LCP_{R\ \&I} - LCP_{Bau}}{LCP_{Bau}} \cdot 100$ where $LCP = \frac{\sum_{i=1}^{I}\sum_{t=1}^{T} P_{i,t}^{DR}}{\sum_{i=1}^{I}\sum_{t=1}^{T} P_{i,t}} \cdot 100$	$ILCP$: Increase in the amount of load capacity participating in DR (%). $LCP_{R\ \&I}$: Load capacity participation for the R&I scenario (%). LCP_{BaU}: Load capacity participation for the BaU scenario (%). I: set of loads participate in demand response. T: set of time intervals of the period under consideration. $P_{i,t}^{DR}$: Amount of power capacity of the i^{th} load at period t. that participate in demand response (kW). $P_{i,t}$P: Consumption of the i^{th} load at period t (kW).	%

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4 OneNet BUC, SUC, and Regional BUCs KPIs

As described in section 2, the identification process for the OneNet KPIs relies on the list of KPIs obtained as the outcome of the project review reported in section 3. The scope of this chapter is to list the KPIs identified by the OneNet demonstrators to assess the OneNet BUCs, SUCs, and regional BUCs. The procedure for this identification is depicted in Figure 4.1 and follows the below steps:

- **Step 2.1**. Adoption of the definition of the KPIs from project review. The OneNet demonstrators adopt several KPI definitions from the list obtained from the project review.
- **Step 2.2**. Particularisation of the KPI definitions from the project review. Some of the KPIs selected by the OneNet demonstrators are based on the definitions from the project review. However, the corresponding definitions are tailored to fit the OneNet demonstration needs.
- **Step 2.3.** Proposal of novel KPIs. Demonstrators' leaders propose novel KPIs not included in the list obtained from the project review. The new KPIs are proposed to cover the peculiarities of the demonstration activities and measure the corresponding performances.
- **Step 2.4.** Adoption of the KPIs. The final list of KPIs identified for OneNet demonstrators' BUC, SUCs, and regional BUCs included KPI definitions adopted from other projects, KPIs which definition is modified to satisfy the OneNet needs, and novel KPIs proposed by the OneNet project.

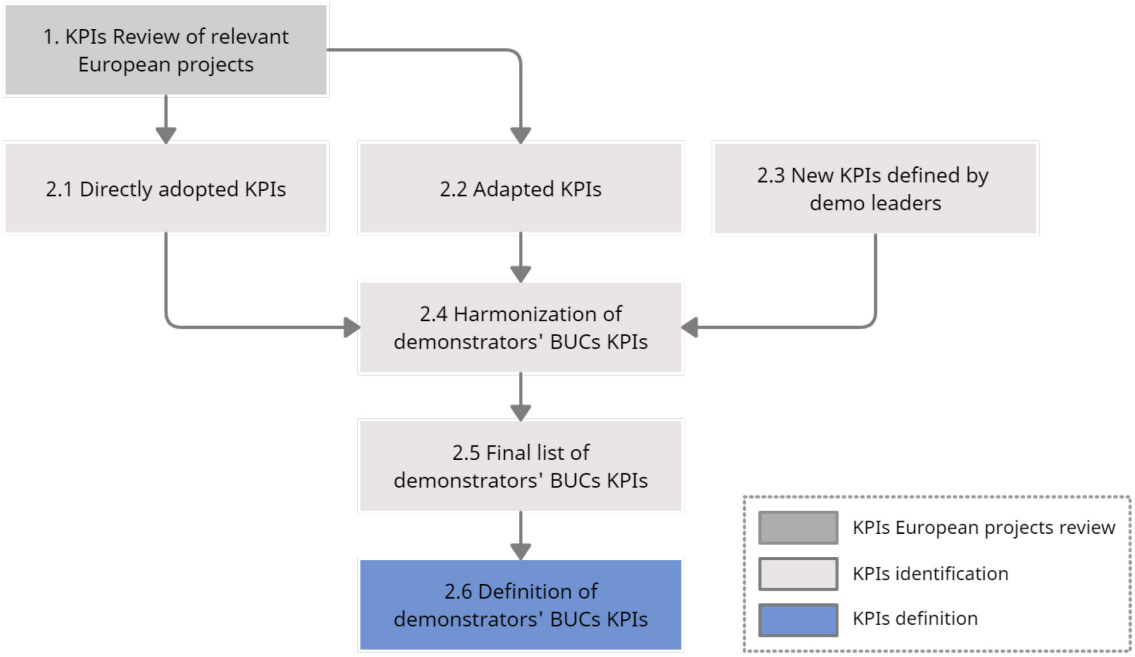

Figure 4.1 – Identification process of demonstrators' BUCs KPIs

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This section provides an overview of the result of the identification and definition process for the BUCs, SUCs, and regional BUCs KPIs of the OneNet demonstrators. KPI definition and selection followed the procedure described in section 2. This section describes the BUCs and SUCs of demonstrators considering their grouping in regional clusters: Northern, Southern, Western, Eastern.

This subsection also recalls a brief presentation of the demonstrators' BUCs, SUCs, and regional BUCs; more detailed information can be found in OneNet Deliverable 2.3 [21] and OneNet Deliverable 5.1 [22]. We need to declare that the maturity level of the reported Demo BUCs, SUCs, and the corresponding KPIs reflects the progress conducted up to M15 of the project (December 2021). Any further upgrades, refinements or redefinitions will be available in the future deliverables of the WPs 7-10.

4.1 OneNet Project KPIs

The OneNet project aims to contribute to the integration of all the actors in the electricity network across the countries, creating the conditions for a synergistic operation that optimizes the overall energy management while creating an open and fair market structure. The OneNet activities are based on three main pillars:

- Definition of a common market design for Europe,
- Definition of a common IT Architecture and common IT Interfaces,
- Verification of the proposed solutions in large field tests.

The first pillar encompasses the definition of standardised product and key parameters for grid services, the definition of procedures to coordinate the actors creating a market environment, and the promotion of the procurement of services by TSOs and DSOs from the resources connected in the TSO and DSO networks. The second pillar regards the creation of an architecture defined as an interoperable network of platforms that fits the market requirements, the provision of universal access for market participants in the EU regardless of their geographical point of connection. The third pillar concerns the development of the demonstration activities by the field tests where the demonstrators implement the solutions developed by the first and second pillars.

The three pillars of the OneNet project activities lead to the achievement of the OneNet strategic object of developing an open and flexible architecture to transform the existing European electricity system, which is often managed in a fragmented country- or area-level way, into a pan-European smarter and more efficient one, where market and network technical operations are reciprocally coordinated closer to real-time i) among them, ii) across different countries iii) while maximizing the consumer capabilities to participate in an open market structure. Correspondingly, the OneNet project has the operational objectives of:

1) Developing innovative market structure;
2) Upscaling, adapting, validating and testing the OneNet architecture;
3) Removing barriers to the commercial use of the innovative market structure;

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In line with the overarching OneNet project objectives, the OneNet demonstrators proposed a broad set of KPIs (99 in total) that aim to quantify the performances of the demonstration activities. Each KPI represents a measurable quantity defined to assess the achievement of the demonstration's activity objectives, and in turn, the OneNet project goals. The significant number of demonstrators (15) in the OneNet projects led to the great variety of demonstration activities, which differ in terms of goal, actors involved, activity addressed, and local conditions. This great variety is beneficial from the research and innovation perspective since it allows to devise and test different aspects concerning the TSO-DSO-consumer coordination and explore different paths for achieving the OneNet project goals.

The diversity of the demonstration activities is also reflected in the large number of adopted KPIs able to cover the different aspects of the TSO-DSO-customers coordination from different perspectives (e.g., economic, technical, societal, environmental, market). In total, the OneNet Consortium adopted 100 KPIs to assess the proposed demonstrators BUCs, SUCs, and regional BUCs. From Table 4.1 to Table 4.10, the complete list of the KPIs adopted by the OneNet demonstrators is provided, highlighting the corresponding appraised BUCs and SUCs and classifying them into 10 categories:

- General descriptive KPIs (Table 4.1)

  The general descriptive indicators represent KPIs that describe generic aspects of a demonstration activity in the context of the TSO-DSO-Customer coordination. The general descriptive indicators adopted in the OneNet project are listed in Table 4.1.
- Economic KPIs (Table 4.2)

  The economic indicators represent KPIs able to capture the economic aspects related to the demonstration activities in the context of the TSO-DSO-Customer coordination. The general descriptive indicators adopted in the OneNet project are listed in Table 4.2.
- Environmental and societal KPIs (Table 4.3)

  The environmental and societal indicators represent KPIs able to capture the externalities related to the demonstration activities in the context of the TSO-DSO-Customer coordination. The environmental and social indicators adopted in the OneNet project are listed in Table 4.3.
- Market performance KPIs (Table 4.4)

  The market performance indicators aim to assess the outcome of the market development and testing addressed in the demonstration activities in the context of the TSO-DSO-Customer coordination. The market performance indicators adopted in the OneNet project are listed in Table 4.4.
- Congestion management performance KPIs (Table 4.5)

  The congestion management indicators aim to assess the performances of the use cases dealing with the development and testing of congestion management procedures in the demonstration activities in the context of the TSO-DSO-Customer coordination. The congestion management performance indicators adopted in the OneNet project are listed in Table 4.5.

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- Voltage control performance KPIs (Table 4.6)

  The voltage control indicators aim to assess the performances of the use cases dealing with the development and testing of voltage control procedures in the demonstration activities in the context of the TSO-DSO-Customer coordination. The voltage control performance indicators adopted in the OneNet project are listed in Table 4.6.
- Balancing performance KPIs (Table 4.7)

  The balancing indicators aim to assess the performances of the use cases dealing with the development and testing of balancing procedures in the demonstration activities in the context of the TSO-DSO-Customer coordination. The balancing performance indicators adopted in the OneNet project are listed in Table 4.7.
- Data processing performance KPIs (Table 4.8)

  The data processing indicators aim to assess the performances of the use cases dealing with the development and testing of data processing procedures in the demonstration activities in the context of the TSO-DSO-Customer coordination. The data processing performance indicators adopted in the OneNet project are listed in Table 4.8.
- Network operation performance KPIs (Table 4.9)

  The network operation performance indicators aim to assess the performances of the use cases dealing with the development and testing of solutions that affect the network operation procedures in the demonstration activities in the context of the TSO-DSO-Customer coordination. The network operation performance indicators adopted in the OneNet project are listed in Table 4.9.
- Prequalification process performance KPIs (Table 4.10)
- The prequalification process indicators aim to assess the performances of the use cases dealing with the development and testing of prequalification procedures in the demonstration activities in the context of the TSO-DSO-Customer coordination. The prequalification performance indicators adopted in the OneNet project are listed in Table 4.10.

The detailed description of the KPIs definitions adopted by each demonstrator is provided in sections 4.2 (Northern cluster), 4.3 (Southern cluster), 4.4 (Western cluster), 4.5 (Eastern cluster), and 4.6 (OneNet Regional BUCs).

The identifiers (ID) adopted in this document for the OneNet BUCs and SUCs is defined as follows:

- The first segment, formed by 4 letters, identifies the OneNet cluster:
  - NOCL: Northern cluster,
  - SOCL: Southern cluster,
  - WECL: Western cluster,
  - EACL: Eastern cluster

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- The second segment, formed by 2 letters, if present, represent the relevant country; if not present, it means that the BUC, SUC identifiers refer to the entire cluster. The countries are identified as follows:
    - CY: Cyprus,
    - GR: Greece,
    - FR: France,
    - PT: Portugal,
    - ES: Spain,
    - CZ: Czech Republic,
    - HU: Hungary,
    - PL: Poland,
    - SL: Slovenia.
- The third segment, formed by 3 letters, indicates whether the identifier refers to a BUC or a SUC:
    - BUC: Business Use Case,
    - SUC: System Use Case.
- The fourth segment, formed by 2 digits, represent the cardinal number that enumerates the sequence of BUCs and SUCs corresponding to the relevant OneNet demonstrator or cluster.

For clarity, the identifier NOCL-BUC-01 represents the first BUC of the Northern cluster, while EACL-CZ-SUC-02 indicates the second SUC of the Czech demonstrator.

The identifiers (ID) adopted for the OneNet KPIs are two depending on the process followed for identifying and defining each KPI. The KPIs denoted with the ID “KPI_H00” are those KPIs considered of interest for the harmonisation process described in section 5. The definitions proposed in this report for those KPIs represent the outcome of the harmonisation process addressed as OneNet Task 2.4 activity. Occasionally, an additional letter is present on the right side of the last digit of the identifier; it denotes that the corresponding KPI defines a family of indicators that deal with the same measurable aspect but exploit different quantifiable quantities. This approach has been adopted to achieve a comfortable level of harmonisation among the KPIs definitions by preserving an adequate granularity level to satisfy each demonstrator's peculiarities.

The KPIs denoted with the ID “KPI_N00” are those KPIs that have not been part of the harmonisation process; the definition proposed in this report for those KPIs represent the outcome of the bilateral exchange that involved OneNet Task 2.4 core team and the proponent demonstrators.

Generally, both KPI classes (KPI_H00 and KPI_N00) have been defined starting from the definitions available from project review (described in section 2) or a novel OneNet internal proposal. The KPIs adopted by each demonstrator have to be considered a preliminary list; any changes in terms of KPI definition and adoption may occur during future project activities. The refinement of the KPI list adopted by each demonstrator represents

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an activity that interests future OneNet Tasks, and that will be addressed by the cluster WPs. Not all KPIs discussed during the OneNet Task 2.4 activities have been adopted by the OneNet demonstrators; therefore, the continuity of the KPI numbering is not guaranteed in this report.

Table 4.1 – General descriptive KPIs adopted by the OneNet demonstrators

KPI_ID	KPI Name	BUCs	SUCs
KPI_H01	Number of service providers enrolled in the demonstration exercise	NOCL-BUC-01; WECL-FR-BUC-01	
KPI_H02	Active participation	WECL-ES-BUC-01; WECL-ES-BUC-02; EACL-HU-BUC-01; EACL-HU-BUC-02	
KPI_N03	Number of FSPs participating in more than one country	NOCL-BUC-01	
KPI_N04	Number of conflicts resulting from flexibility product activation	NOCL-BUC-01	
KPI_N35	Increase in availability of flexibility		EACL-CZ-SUC-02
KPI_N47	Increase in flexibility providers (units)		EACL-CZ-SUC-01
KPI_N48	FSP acceptance	WECL-BUC-01	

Table 4.2 – Economic KPIs adopted by the OneNet demonstrators

KPI_ID	KPI Name	BUCs	SUCs
KPI_H03	Cost effectiveness	WECL-ES-BUC-01; WECL-ES-BUC-02	WECL-ES-SUC-01
KPI_H04	ICT costs	WECL-PT-BUC-01; WECL-PT-BUC-02; WECL-PT-BUC-03; WECL-ES-BUC-01; WECL-ES-BUC-02	WECL-ES-SUC-01

Table 4.3 – Environmental and societal KPIs adopted by the OneNet demonstrators

KPI_ID	KPI Name	BUCs	SUCs
KPI_H05	Reduction in RES curtailment	WECL-PT-BUC-01; WECL-PT-BUC-02; WECL-PT-BUC-03	WECL-PT-SUC-02
KPI_H06	Ease of access	EACL-PL-BUC-01;	
KPI_N29	Load Curtailment	WECL-PT-BUC-01; WECL-PT-BUC-02	

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Table 4.4 – Market performance KPIs adopted by the OneNet demonstrators

KPI_ID	KPI Name	BUCs	SUCs
KPI_H07	Number of transactions	WECL-ES-BUC-01; WECL-ES-BUC-02	WECL-ES-SUC-01
KPI_H08	Bid statistics (Bid Min, Max, Average values)	EACL-HU-BUC-01; EACL-HU-BUC-02	
KPI_H09A	Volume of transactions (Power)	WECL-ES-BUC-01; WECL-ES-BUC-02	WECL-ES-SUC-01
KPI_H09B	Volume of transactions – cleared bids (P or Q Availability)	NOCL-BUC-01	NOCL-SUC-05
KPI_H09D	Volume of transactions – cleared bids (P or Q Activation) (Energy)	NOCL-BUC-01	NOCL-SUC-05
KPI_H10	Flex volume offered by FSP vs Flex request by DSO	EACL-PL-BUC-03	
KPI_H11	Number of products per demo	WECL-ES-BUC-01; WECL-ES-BUC-02	
KPI_N01	Number of implemented cross-border products	NOCL-BUC-01	
KPI_N02	Number of implemented joint products	NOCL-BUC-01	
KPI_N40	Volume of total monetized flexibility	EACL-SL-BUC-01; EACL-SL-BUC-02	
KPI_N05	Ratio of successful bid		NOCL-SUC-01
KPI_N10	Product number		NOCL-SUC-04
KPI_N11	The rate of the secondary contract to the requested one		NOCL-SUC-06
KPI_N43	Success of local flexibility market platform test		

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Table 4.5 – Congestion management performance KPIs adopted by the OneNet demonstrators

KPI_ID	KPI Name	BUCs	SUCs
KPI_H12	Number of avoided technical restrictions (congestions)	NOCL-BUC-01; WECL-PT-BUC-01; WECL-PT-BUC-02; EACL-HU-BUC-02; EACL-PL-BUC-03; EACL-SL-BUC-01;	
KPI_H13	Congestion reduction (magnitude)	WECL-ES-BUC-01; WECL-ES-BUC-02	
KPI_H14A	Available Flexibility	WECL-ES-BUC-01; WECL-ES-BUC-02; EACL-CZ-BUC-01	WECL-ES-SUC-01
KPI_H15A	Requested flexibility (Power)	WECL-PT-BUC-01; WECL-PT-BUC-02; EACL-PL-BUC-03	WECL-PT-SUC-02
KPI_H16C	Ratio of activated reserved flexibility	EACL-HU-BUC-01; EACL-HU-BUC-02	
KPI_H23A	Power exchange deviation	WECL-ES-SUC-01; WECL-ES-BUC-02; EACL-PL-BUC-03	
KPI_H23B	Energy exchange deviation	EACL-PL-BUC-03	
KPI_H23C	Flexibility volume delivered by FSP (in power) vs Flex bids selected to be activated	EACL-PL-BUC-03	
KPI_H23D	Flexibility volume delivered by FSP (in energy) vs Flex bids selected to be activated	EACL-PL-BUC-03	
KPI_H23E	Deviation of the FSP response compared to the awarded bids		SOCL-CY-SUC-03
KPI_N16	Overloading	SOCL-CY-BUC-01; SOCL-CY-BUC-02	SOCL-CY-SUC-04;
KPI_N27	Total power of avoided congestions through flexibility activation	WECL-PT-BUC-01; WECL-PT-BUC-02	WECL-PT-SUC-02
KPI_N31	Nº of congestions/violations on DSO network		WECL-PT-SUC-06
KPI_N32	Nº of congestions/violations on TSO network		WECL-PT-SUC-06
KPI_N39	Volume of activated Flexibility services	EACL-SL-BUC-01; EACL-SL-BUC-02	

Table 4.6 – Voltage control performance KPIs adopted by the OneNet demonstrators

KPI_ID	KPI Name	BUCs	SUCs
KPI_H17	Number of avoided technical restrictions (voltage violations)	EACL-HU-BUC-01; EACL-PL-BUC-03; EACL-SL-BUC-02;	
KPI_N17	Improvement of voltage limits violations	SOCL-CY-BUC-02	SOCL-CY-SUC-04

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Table 4.7 - Balancing performance KPIs adopted by the OneNet demonstrators

KPI_ID	KPI Name	BUCs	SUCs
KPI_H18A	Volume of balancing service offers for UP reserves	SOCL-CY-BUC-01; EACL-PL-BUC-02	
KPI_H18B	Volume of balancing service offers for UP reserves transferred to BM	EACL-PL-BUC-02	
KPI_H18C	Volume of accepted balancing service offers for UP reserves	EACL-PL-BUC-02	
KPI_H18D	Volume of balancing service offers for DOWN reserves	EACL-PL-BUC-02	
KPI_H18E	Volume of balancing service offers for DOWN reserves transferred to BM	EACL-PL-BUC-02	
KPI_H18F	Volume of accepted balancing service offers for DOWN reserves	EACL-PL-BUC-02	
KPI_H18G	Volume of balancing energy offers	EACL-PL-BUC-02	
KPI_H18H	Volume of balancing energy offers transferred to the BM	EACL-PL-BUC-02	
KPI_H18I	Volume of accepted balancing energy offers	EACL-PL-BUC-02	
KPI_H19A	Number of DER available for BSPs	SOCL-CY-BUC-01; EACL-PL-BUC-04	
KPI_H19B	The percentage of resources available for balancing services	EACL-PL-BUC-04	
KPI_H19C	Total capacity of DER available for BSP	EACL-PL-BUC-04	
KPI_N14	Rate of Change of Frequency improvement (ROCOFI)	SOCL-CY-BUC-01	
KPI_N15	Improvement of Frequency Nadir	SOCL-CY-BUC-01	

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Table 4.8 – Data processing performance KPIs adopted by the OneNet demonstrators

KPI_ID	KPI Name	BUCs	SUCs
KPI_H20A	Accuracy of the RES production forecast calculated T hours in advance	WECL-PT-BUC-03; SOCL-GR-BUC-01	SOCL-GR-SUC-01
KPI_H20B	Accuracy of load forecast calculated T hours in advance	WECL-PT-BUC-03; WECL-ES-BUC-01; WECL-ES-BUC-02; SOCL-GR-BUC-01	
KPI_H21A	Share of correctly forecasted congestions	SOCL-GR-BUC-01; EACL-HU-BUC-01; EACL-HU-BUC-02	SOCL-GR-BUC-04
KPI_H21B	Share of false positive and negative congestion forecasts	WECL-PT-BUC-01; WECL-PT-BUC-02	WECL-PT-SUC-02
KPI_N28	Maximum ratio of false-positive and negative congestion forecasts	WECL-PT-BUC-01; WECL-PT-BUC-02	
KPI_N06	Accuracy of flexibility prediction		NOCL-SUC-01
KPI_N07	Activation delay		NOCL-SUC-02; NOCL-SUC-09
KPI_N08	Level of automation of SUC process steps		NOCL-SUC-05
KPI_N09	Verification method accuracy		NOCL-SUC-03
KPI_N12	Speed of grid qualification algorithm		NOCL-SUC-07
KPI_N13	Speed of bid optimisation algorithm		NOCL-SUC-08
KPI_N21	Voltage magnitude and angle error		SOCL-CY-SUC-01
KPI_N22	Calculated limits deviation		SOCL-CY-SUC-02
KPI_N23	Number of successfully predicted hazardous power system regimes and cyber threats	SOCL-BUC-01	SOCL-GR-SUC-04; SOCL-GR-SUC-05; SOCL-GR-SUC-06; SOCL-GR-SUC-08
KPI_N24	Number of successfully predicted severe weather conditions	SOCL-GR-BUC-01; SOCL-GR-BUC-02; SOCL-BUC-01	SOCL-GR-SUC-05, SOCL-GR-SUC-06
KPI_N26	Tracked flexibility	WECL-FR-BUC-01	WECL-FR-SUC-01
KPI_N33	Improvement of the forecast		WECL-PT-SUC-07; WECL-PT-SUC-08
KPI_N36	Average runtime of aggregated network offer algorithm		EACL-PL-SUC-02
KPI_N37	Average runtime of automatic grid impact assessment algorithm		EACL-PL-SUC-02; EACL-PL-SUC-03
KPI_N38	Average runtime of merit order list algorithm		EACL-PL-SUC-03
KPI_N41	Average time needed for prequalification of a unit		EACL-SL-SUC-01; EACL-SL-SUC-02
KPI_N42	Percentage of instances where alignment process was necessary		EACL-SL-SUC-05
KPI_N44	Active power flow forecast quality - day-ahead /intra-day	SOCL-GR-BUC-01	SOCL-GR-BUC-04
KPI_N45	Total Computational Runtime		EACL-HU-SUC-01
KPI_N49	Average Processing Time	WECL-BUC-01	
KPI_N52	Data retrieval successful	EACL -BUC-01	
KPI_N53	Data retrieval delay	EACL -BUC-01	
KPI_N54	Data reliability ratio	EACL -BUC-01	

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Table 4.9 – Network operation performance KPIs adopted by the OneNet demonstrators

KPI_ID	KPI Name	BUCs	SUCs
KPI_N18	Reduction of energy losses	SOCL-CY-BUC-02	SOCL-CY-SUC-04
KPI_N19	Reduction of loading asymmetries – Maximum and Average Current Phase Factor (MCPUF and ACPUF)	SOCL-CY-BUC-02	SOCL-CY-SUC-04
KPI_N20	Power factor (PF) improvement	SOCL-CY-BUC-02	
KPI_N30	Comparison of the rated short circuit current of the circuit breakers for the 63kV and maximum short circuit value registered for the series under analysis		WECL-PT-BUC-08
KPI_N25	Comparison between the Isc max forecasted for the 63kV by the planning and the maximum short circuit value registered for the series under analysis		WECL-PT-BUC-08

Table 4.10 – Prequalification process performance KPIs adopted by the OneNet demonstrators

KPI_ID	KPI Name	BUCs	SUCs
KPI_H22A	Percentage of successfully prequalified FSPs	NOCL-BUC-01; EACL-PL-BUC-01;	EACL-SL-SUC-01; EACL-SL-SUC-02
KPI_H22B	Percentage of successfully prequalified FSPAs	EACL-PL-BUC-01;	
KPI_H22C	Number of certified DERs	EACL-PL-BUC-01;	
KPI_H22D	Capacity of certified DERs	EACL-PL-BUC-01;	
KPI_H22E	Volume of flexibility by prequalified units		EACL-SL-SUC-01; EACL-SL-SUC-02
KPI_N34	Successful ending of prequalification process		WECL-PT-SUC-01
KPI_N46	Nº prequalification process that needs additional information		WECL-PT-SUC-01
KPI_N50	Cross SO Prequalification Acceptance	WECL-BUC-01	
KPI_N51	Need for additional information for cross SO Prequalification	WECL-BUC-01	

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4.2 Northern Cluster demonstrators' KPIs

The OneNet Northern Cluster is formed by the demonstrators in four countries: Finland, Estonia, Latvia, and Lithuania. The Northern Demonstrator is an integrated effort by multiple TSOs and DSOs to enable market-driven flexibility uptake by these networks in a coordinated way through multiple markets where liquidity can be reached due to scope or existing trading volumes. Through the Northern Cluster demonstration, the OneNet project shows mapping and management of network needs in multiple use cases over multiple networks. This cluster focuses on joint and shared mechanisms to be used by multiple networks and, therefore, demonstrates the scalability and contribution towards a pan-European solution. Cross-border joint use cases are defined; therefore, country-specific market models coincide.

The key developments in the Northern Cluster relate to new mechanisms for flexibility procurement, namely flexibility register and TSO & DSO coordination platform (T&D CP). A flexibility register is needed for the qualification and management of market parties and assets. This register is also used for settlement and verification, data sharing and access management as well as forecasting and visualization and enabling secondary market.

The T&D CP has three main tasks: first, to ensure that flexibility activations do not cause congestions in any network level, i.e. setting continuously (from prequalification to activation) constraints on the flexibility bids to complete grid prequalification (considering thermal limits, voltage requirements). Second, to prioritize flexibility bids/activations that are not only economical but also technically cost-effective. Finally, the third task is to maximize the use of flexibility by doing value stacking, i.e. to find the most optimal mix of available flexibilities to be activated by running optimisation algorithm based on socio-economic value.

The OneNet Northern cluster demonstrator envisions the definition of a market architecture that applies to all the demonstrators in the belonging countries. Therefore, all the countries involved in the Northern demonstrator are to implement the same market architecture, the countries interested in the development of the demonstrators are Finland, Estonia, Latvia, and Lithuania. The market architecture of the Northern demo includes the design of new markets for flexibility procurement.

Northern Cluster is procuring flexibility for congestion management, balancing and voltage control services. Relevant products have been defined and for the Northern Cluster are NRT-P-E (Near Real-Time Active Energy), ST-P-E (Short Term Active Energy), LT-P-C/E (Long Term Active Capacity/Energy), ST-P-C (Short Term Active Capacity), LT-Q-C (Long Term Reactive Capacity), NRT-Q-E (Near Real-Time Reactive Energy).

4.2.1 Northern Cluster demonstrators' BUCs KPIs

The Northern cluster developed one BUC in the context of OneNet. Table 4.11 summarises the key information regarding the Northern BUC [21].

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The Northern Cluster BUC describes the flexibility process starting from FSP contracting the end-customers to prequalification, procurement, activation, delivery and monitoring, verification and settlement. The business use case can be applied in the provision and procurement of balancing, network congestion management and voltage control services. This BUC introduces a flexibility register for sharing flexibility resource information and a T&D CP platform for the grid impact assessment and optimisation. These platforms will have a role in the management of flexibility resources and procurement related data and joint TSO/DSO coordination and network impact assessment.

Table 4.11 - NOCL-BUC-01 BUC overview

BUC ID	NOCL-BUC-01
BUC Name	Northern flexibility market
Scope	Regional, enabling multiple operators, coordination of the system operators
Objectives	○ Develop a seamless end-to-end process for market-based flexibility utilization for grid services; ○ Lower the entry barrier for flexibility by simplifying the process for flexibility service providers; and ○ Ensure availability of short-term flexibility from multiple sources.
Services	Service agnostic[5]
Type of coordination	Market-based TSO-DSO coordination

The KPIs proposed for assessing the NOCL-BUC-01 BUC are listed in Table 4.12.

[5] Products are identified in OneNet Deliverable 2.2 . The defined products are defined to address most of the services listed for frequency control, congestion management and voltage control.

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Table 4.12 – KPIs adopted by the Northern Demonstrator BUCs

BUC_ID	KPI_ID	Reference to KPI BUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
NOCL-BUC-01	KPI_H01	NOCL_BUC_KPI_01	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}	N_{FSP} : Number of FSPs	-
NOCL-BUC-01	KPI_H09B	NOCL_BUC_KPI_02	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.	$VT_{CAV} = \sum_{T}\sum_{I} P_{i,t}$	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
NOCL-BUC-01	KPI_H09D	NOCL_BUC_KPI_03	Volume of transactions – cleared bids (P or Q Activation) (Energy)	This indicator measures the volume of cleared bids.	$VT_{CAC} = \sum_{T}\sum_{I} E_{i,t}$	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
NOCL-BUC-01	KPI_N01	NOCL_BUC_KPI_04	Number of implemented cross border products	This KPI is valid for the BUCs that aim to harmonise the definition and process of Flexibility products among system operators in different countries. The overall BUC performance of this aim can be measured considering the number of implemented products that can trade beyond one country (cross border products).	$N_{P,CB}$	$N_{P,CB}$: Number of implemented cross border products	-
NOCL-BUC-01	KPI_N02	NOCL_BUC_KPI_05	Number of implemented joint products	This KPI is valid for the BUCs that aim to harmonise the definition and process of Flexibility products among system operators in different countries. The overall BUC performance of this aim can be measured considering the number of implemented products that can be traded beyond one system operator (joint products).	$N_{P,I}$	$N_{P,I}$: Number of implemented joint products	-
NOCL-BUC-01	KPI_N03	NOCL_BUC_KPI_06	Number of FSPs participating in more than one country	This KPI is valid for the BUCs that aim to harmonise the definition and process of Flexibility products among system operators in different countries. The overall BUC performance of this aim can be measured considering the enhanced possibility of FSPs' participation in the flexibility market beyond the home country.	$N_{FSP,CB}$	$N_{FSP,CB}$: Number of FSPs that participate in market beyond their original country.	-
NOCL-BUC-01	KPI_N04	NOCL_BUC_KPI_07	Number of conflicts resulting from flexibility product activation	In the uncoordinated way of flexibility activation in the existing market, activation of flexibility products by one SO may lead to conflicts (e.g. new congestions) in another SO grid area. One of the aims of this BUC is to avoid any such conflicts by performing the grid qualification process in prequalification, procurement, and activation phases. This indicator measures the performance of this aim.	N_C	N_C : Number of conflicts resulting from flexibility product activation.	-
NOCL-BUC-01	KPI_H22A	NOCL_BUC_KPI_08	Percentage of successfully prequalified FSPs	This indicator presents the percentage of flexibility services providers in the demo that are successfully prequalified against the number of FSPs only registered on the flexibility platform	$K_{FSP} = \frac{N_{FSP\,preq}}{N_{FSP\,reg}} \cdot 100$	K_{FSP} : Indicator showing the percentage of flexibility service providers that are successfully prequalified against number of flexibility services providers only registered on the flexibility platform. $N_{FSP\,preq}$: number of flexibility service providers that are succesfully prequalified. $N_{FSP\,reg}$: number of flexibility service providers registered on the flexibility platform.	%

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NOCL-BUC-01	KPI_H12	NOCL_BUC_KPI_09	Number of avoided technical restrictions (congestions)	Avoided congestions thanks to the measures implemented in the demo	$ATR_{\%} = \frac{N_{TR_{Flex}}}{N_{TR}} \cdot 100$	$ATR_{\%}$: Share of avoided technical restrictions (congestions) N_{TR}: Total number of expected technical restrictions $N_{TR_{Flex}}$: Total number of technical restrictions solved through activation of flexibility services	%

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4.2.2 Northern Cluster demonstrators' SUCs KPIs

Based on the Northern Cluster BUC, several SUCs are proposed. SUCs are developed based on the functionalities of the flexibility register, market operator (MO) and TSO & DSO coordination platform (T&D CP) for the flexibility procurement process.

Table 4.13, Table 4.14, Table 4.15, Table 4.16, Table 4.17, Table 4.18, Table 4.19, Table 4.20, Table 4.21, and Table 4.22 present the SUCs proposed for the Northern demonstrator. Table 4.23 reports the KPIs selected to assess the Northern demonstrator's SUCs.

Table 4.13 - NOCL-SUC-01

Name SUC	Preparation to flexibility trading
SUC ID	NOCL-SUC-01
Objectives	Enable the preparation of FSPs and their resources for flexibility trading in the context of OneNet Northern demonstration scope. Prequalification process is a prerequisite for the following process steps of multilateral flexibility trading and coordinated flexibility procurement by system operators.
Narrative	To prepare an FSP for flexibility trading, firstly, its contracted resources must be managed in the flexibility register. This information makes it possible for the FSP to start prequalifying its resources. This use case also includes the steps for registering new products sent by the market operator, registration of the FSP and the SO flexibility need. These are needed later by the overall processes including flexibility trading and TSO-DSO coordination.
Steps	After these steps the resource information can be registered by the FSP, which initiates the prequalification process. Information is sent to the TSO & DSO coordination platform (T&D CP) for grid impact assessment for which the results are stored in the FR. Next, the resource or a group of resources is prequalified as products by comparing their characteristics to the product requirements. In some cases, the product prequalification is confirmed by the market operator or system operator. Again, these results are stored in the flexibility register and shared with parties when needed.
Related BUCs	NOCL-BUC-01

Table 4.14 - NOCL-SUC-02

Name SUC	Procurement and delivery support
SUC ID	NOCL-SUC-02
Objectives	Enable the FSPs to efficiently offer their resources on different markets and the SOs to procure and monitor the flexibilities in the context of the OneNet Northern demonstration scope. This process is a prerequisite for the settlement and verification phases.
Narrative	In the procurement phase, the role of the flexibility register is to support the MO and T&D CP by sharing relevant information and receiving the outcome of the procurement to later enable the verification and settlement. The flexibility register is also used to provide real-time visibility for the SOs regarding the activated flexibility.
Steps	Flexibility (capacity and energy) procurement
Related BUCs	NOCL-BUC-01

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Table 4.15 - NOCL-SUC-03

Name SUC	Flexibility Register Verification and settlement
SUC ID	NOCL-SUC-03
Objectives	Enable quantifying the delivered flexibility volumes and support the financial and imbalance settlement based on the results in the context of the OneNet Northern demonstration scope.
Narrative	One of the core functionalities of the flexibility register is to conduct the verification and settlement of the flexibility bids being traded. Verification means the quantification of the delivered flexibility. This is done by gathering metering data and comparing it to either a calculated baseline or predefined plans. The product in question specifies which method is to be used. After the verification, the results are shared with parties involved in the trades. In some cases, the flexibility register can also determine the remuneration and penalties if these are described within the product specification. The flexibility register also communicates possible adjustments to BRPs' balance position to the Imbalance Settlement Responsible.
Steps	Verification and settlement
Related BUCs	NOCL-BUC-01

Table 4.16 - NOCL-SUC-04

Name SUC	Add New Product
SUC ID	NOCL-SUC-04
Objectives	Creating a new product in the market
Narrative	To have any trade between a flexibility provider (FSP) and system operator (SO), a market needs to offer, at least, the flexibility product. Here the process of adding a product to a market will be reviewed. In this SUC it is considered that the process starts from the need for a system operator. When a SO needs any type of flexibility, it contacts market operators (MO) to find which product is suitable for its need. If there is no product, which is suitable for the need of the SO, it needs to define the product properties and send it to MO. Here, the MO will decide whether it wants to offer this product in its market or not. If the MO wants to offer the product, it will publish the description and inform the flexibility register to start the prequalification process.
Steps	MO steps in add new product
Related BUCs	NOCL-BUC-01

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Table 4.17 - NOCL-SUC-05

Name SUC	Procurement
SUC ID	NOCL-SUC-05
Objectives	Product procurement in the market
Narrative	The procurement process of flexibility products in a market can be divided into four main processes: opening the market, trading, matching, and closing the market. In the opening scenario, the market will be open, and the availability of trading will be informed to all relevant parties. In trading, flexibility service providers submit their bids and system operators publish their purchasing need. In the matching scenario, the market operator in cooperation with the TSO & DSO coordination platform match the bid and offer and find the optimum solution. finally, the market operator informs the results to the relevant parties in the closing scenario.
Steps	Opening of the procurement process Trading Matching Closing Settlement
Related BUCs	NOCL-BUC-01

Table 4.18 - NOCL-SUC-06

Name SUC	Secondary Trading
SUC ID	NOCL-SUC-06
Objectives	Replacing FSP, which failed to provide flexibility
Narrative	When an FSP, which have a bidding contract for providing a flexibility product for the future, realizes that it cannot fulfil the contract, it can inform and ask the market operator to find a replacement for it. This process is called secondary trading and it is quite similar to the normal trading, but the process is triggered by sending a request from the FSP, which is not capable to fulfil the contract.
Steps	MO steps in New Product prequalification
Related BUCs	NOCL-BUC-01

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Table 4.19 - NOCL-SUC-07

Name SUC	Grid Qualification of Resource
SUC ID	NOCL-SUC-07
Objectives	Tool and algorithm developed to facilitate multilateral flexibility market through improved TSO-DSO coordination, also enabling cross-border marketplace. The objective of grid impact assessment is to avoid congestions by setting restrictions on the activation of flexibilities which would cause congestion in grids.
Narrative	Grid qualification of a flexibility resource may take place in prequalification, procurement, and activation phases. Grid impact assessment is the central activity of grid qualification process. Two alternatives are possible in each phase. First, the concerned SO identifies grid restrictions (constraints) by itself and provide the results to the coordination platform. The second alternative is that restrictions are calculated by TSO-DSO Coordination Platform. For the second alternative, a dedicated algorithm is needed which calculates the grid restrictions based on input information (depending on the phase – flexibility needs, and resource information or flexibility bid or flexibility activation request; and grid information either as grid model, grid topology or simple grid constraints). If both alternatives are applied to the same resource, these need to be merged into a single result by updating the algorithm. The impact assessment is a continuous process. In the prequalification phase normally structural congestions should be considered, while in the procurement and activation phases also dynamic congestions. Resource Provider's consent is needed by TSO-DSO Coordination Platform to have access to private information like Resource Information and Flexibility Bid.
Steps	Grid qualification of resource in prequalification phase Grid qualification of resource in procurement phase Grid qualification of resource in activation phase
Related BUCs	NOCL-BUC-01

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Table 4.20 - NOCL-SUC-08

SUC ID	NOCL-SUC-08
Objectives	Tool and algorithm developed for ranking and optimizing flexibility bids to facilitate multilateral flexibility market through improved TSO-DSO coordination, also enabling cross-border marketplace.
Narrative	An algorithm performs bid ranking and bid optimization processes. Grid model or grid topology or grid constraints are needed as input for the algorithm. Bid ranking means listing the flexibility bids for each product according to their economic value. Ranking should not be based on the price but on the 'relative price' which takes into account grid information, i.e., total costs for the System Operator(s). Several merit order lists can be produced if the ranking depends on the availability of a bid for different services. This step is repeated continuously. Inserting purchase offers as input into the algorithm enables to perform bid optimization. Optimizing means matching flexibility bids and purchase offers in the most economical way which considers synergies (value-stacking). This step is repeated continuously. Bids for balancing need to be shared with the relevant EU platform (MARI, PICASSO). If bids were meanwhile activated for congestion management purposes, it should be possible to withdraw the respective bids from EU platform.
Steps	Bid ranking
Related BUCs	NOCL-BUC-01

Table 4.21 - NOCL-SUC-09

Name SUC	Bid Selection for Activation
SUC ID	NOCL-SUC-09
Objectives	Tool developed for flexibility activation to facilitate multilateral flexibility market through improved TSO-DSO coordination, also enabling cross-border marketplace.
Narrative	Bids not to be activated directly after matching of bids and offers by Market Operator should first pass grid impact assessment and optimization. Flexibility activation requests were collected from system operators in the optimization process and will be forwarded to selected FSPs. FSPs send back to TSO-DSO Coordination Platform confirmation about receiving the activation request as well as confirmation about actual activation. Counter Action is needed if activation of FSPs would cause imbalance in the system. Three alternative options are possible: TSO-DSO Coordination Platform selects the bid automatically for counter action, System Operator sends information to coordination platform about whether counter action should be taken, or no action for counter action is taken by coordination platform.
Steps	Bid selection
Related BUCs	NOCL-BUC-01

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Table 4.22 - NOCL-SUC-10

Name SUC	Flexibility call for tender opening
SUC ID	NOCL-SUC-10
Objectives	Facilitate coordinated trading by centralizing information about active calls for tender.
Narrative	A call for tender of flexibility services relies on specific products and can cover in addition to product specifications specific periods (week ahead, day ahead, intraday, etc.), location, quantity. The call for tender is initiated by the System Operator who needs the flexibility. Information about all calls is collected and stored centrally at TSO-DSO Coordination Platform and made available to concerned market operators and system operators. Call for tender applies to all one-time auctions (e.g., long-term procurement), regular auctions (e.g., mFRR) and continuous bidding (e.g., bids from intraday market). In case of regular and continuous trading the call is opened only once for all subsequent delivery periods.
Steps	FCT opening
Related BUCs	NOCL-BUC-01

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Table 4.23 – KPIs adopted by the Northern Demonstrator SUCs

SUC ID	KPI_ID	Reference to KPI SUC template	KPI Name	KPI description	Formula	Variables	Unit or measurement
NOCL-SUC-01	KPI_N05	NO_SUC_KPI_01	Ratio of successful bid	This indicator measures the performance of the FSP bid preparation process and price estimation. The number of times that FSP bids are selected (call-off bid) compared to the total number of bids that FSP offered.	$NSB_{\%} = \frac{n_{co}}{n_T} \cdot 100$	$NSB_{\%}$: Ratio of successful bid (%) n_{co} : Number of call-off (successful) bid n_T: Total number of bids	%
NOCL-SUC-01	KPI_N06	NO_SUC_KPI_02	Accuracy of flexibility prediction	This indicator illustrates the accuracy of the FSP process in predicting the available flexibility. For this purpose, it measures the average deviation of activated flexibility resources compared to the bid.	$AFP_{\%} = \sum_{k=1}^{n} \frac{P_{ac,k} - P_{bid,k}}{P_{bid,k}} \cdot 100$	$AFP_{\%}$: Accuracy of flexibility prediction (%) $P_{ac,k}$: Power of activated flexibility in *k*th trade (kW) $P_{bid,k}$: Power of bided flexibility for *k*th trade (kW) n: number of trades	%
NOCL-SUC-02; NOCL-SUC-09	KPI_N07	NO_SUC_KPI_03	Activation delay	The activation speed of the flexibility resource is one of the essential aspects defined in the product specification. The activation time depends on the nature of the resource and the performance of all platforms, connection of the FSP and the control methodology. This indicator measures the total activation time for the aggregated resource. i.e. how long it takes after SO requests for activation until the resource updates its behaviour.	$AD = Mean(T_{ac} - t_{re})$	AD: Activation delay (min) T_{ac}: the time that flexibility resource adopts the requested change (min) t_{re} : the time that SO requested for activation of a flexibility product (min)	min
NOCL-SUC-05	KPI_N08	NO_SUC_KPI_04	Level of automation of SUC process steps	The flexibility register facilitates preparing FSPs and their resources before the market phase can start. This process has many steps, many of which might require manual tasks from different parties. The aim of the process definitions has been to automatize these processes.	$LA_{\%} = \frac{N_{p,a}}{N_p} \cdot 100$	$LA_{\%}$: level of automation $N_{p,a}$:number of automatized process steps N_p : number of process steps	%
NOCL-SUC-03;	KPI_N09	NO_SUC_KPI_05	Verification method accuracy	The aim is to assess the accuracy of the reference value (e.g., computed baseline) compared to the energy/power consumer/injected into the grid, when no flexibility activation was conducted	$MAE = \frac{1}{n}\sum\lvert e_t\rvert$ $RMSE = \sqrt{\frac{1}{n}\sum e_t^2}$	t : settlement period n : number of settlement period considered e : The error, difference between the baseline value and the energy/power measurement (when no dispatch) (MW or MWh)	MW or MWh
NOCL-SUC-04;	KPI_N10	NO_SUC_KPI_06	Product number	The goal is to avoid defining the new product while the existing one can be used to satisfy the SO need. Therefore, the lower number of products while covering all needs of SOs is an indicator for a less complex market.	n_p	n_p: Number of flexibility products traded in the market	–
NOCL-SUC-05	KPI_H09B	NO_SUC_KPI_07	Volume of transactions – cleared bids (P or Q Availability)	This indicator measures the volume of cleared bids. This indicator measures the volume of transactions depending on the provided service.	$VT_{CAV} = \sum_{T}\sum_{I} P_{i,t}$	VT_{CAV}: Volume of transaction considering active power (MW or MVA). $P_{i,t}$: Volume cleared availability (capacity) bids by the ith flexible resource at time t (MW or MVA). I: Set of flexible resources. T: Examined period.	MW or MVA

NOCL-SUC-05	KPI_H09D	NO_SUC_KPI_08	Volume of transactions – cleared bids (P or Q Activation) (Energy)	This indicator measures the volume of cleared bids. This indicator measures the volume of offered activation bids depending on the provided service.	$VT_{CAC} = \sum_{T}\sum_{I} E_{i,t}$	VT_{CAC}: Volume of transaction considering P·T or Q·T (MWh or MVAh). $E_{i,t}$: Volume cleared activation bids by the ith flexible resource at time t (MWh or MVAh). I: Set of flexible resources. T: Examined period.	MWh or MVAh
NOCL-SUC-06	KPI_N11	NO_SUC_KPI_09	The rate of the secondary contract to the requested one	The aim is to find a replacement for flexibility contracts when the provider cannot keep the commitment. The ideal situation is to find a replacement instead of all FSPs that failed to provide.	$RC = \frac{n_{SC}}{n_{FC}}$	RC: rate of the secondary contract to the requested one n_{SC}: Number of contracts in the secondary market n_{FC}: Number of contracts that failed to keep the commitment.	–
NOCL-SUC-07	KPI_N12	NO_SUC_KPI_10	Speed of grid qualification algorithm	Grid qualification algorithm should deliver the results as soon as required.	$SGQ = \frac{t_p}{t_a}$	SGQ: Speed of grid qualification algorithm t_p : planned time for results' delivery (s) t_a: actual time of results' delivery (s)	–
NOCL-SUC-08	KPI_N13	NO_SUC_KPI_11	Speed of Bid optimisation algorithm	Bid optimisation algorithm should deliver the results as soon as required.	$SBO = \frac{t_p}{t_a}$	SBO: Speed of Bid optimisation algorithm t_p : planned time for results' delivery (s) t_a : actual time of results' delivery (s)	–

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4.3 Southern Cluster demonstrators' KPIs

The Cypriot and Greek demonstrators form the Southern cluster. The objective of the Southern Demonstrator is to devise, develop, implement and evaluate two pilot projects in Greece and Cyprus dealing, in compliance with the OneNet overall architecture with balancing and congestion management challenges that system operators face in the clean energy era. The results aim to provide recommendations for future market reforms in the region and harmonise a pan-EU electricity market. The primary activity of the Greek demonstrator is the improvement of the procedures for congestion management resolution. The Greek demonstrator focuses on the technical-based TSO-DSO coordination based on the existing market architecture. The Cypriot demonstrator aims to provide an effective collaboration framework for the TSO-DSO-Consumer value chain and the energy market by developing an active balancing and congestion management platform. The Cypriot demonstrator includes the definition of a market-based TSO-DSO coordination. The TSO and the DSO participate in the Cypriot market architecture to procure the products to address congestion management, frequency control, power quality, system adequacy, and voltage control.

4.3.1 Cypriot demonstrators' BUCs KPIs

The BUCs for the Cypriot demonstrator, part of the Southern Cluster, are focused on active power flexibility, reactive power flexibility, and power quality. The Cypriot OneNet demonstrator aims to:

- Provide an effective collaboration framework between TSO, DSO, Consumer, and Energy Markets;
- Develop the active balancing and congestion management platform to enable the active coordination of distribution grids;
- Allow aggregators and prosumers to provide active power, reactive power and power quality flexibility services to the power grid;
- Enable a higher penetration of RES without risking the stability and integrity of the system;
- Use the OneNet system to facilitate coordination between the TSO-DSO and the Market Operator.

A set of KPIs is defined for the two BUCs to assess the effectiveness of the Cyprus demonstration and evaluate to what extent the objectives mentioned above are fulfilled. The KPIs are related to voltage, frequency, congestion management and power quality.

The Cypriot demonstrator proposes two BUCs which's key information is provided in Table 4.24 and Table 4.25. The KPIs proposed by the Cypriot demonstrator's BUCs are listed in Table 4.26.

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Table 4.24 - SOCL-CY-01 BUC overview

BUC ID	SOCL-CY-BUC-01
BUC Name	Active power flexibility
Scope	Enhance of active power flexibility (i.e., ramping, droop control and power regulation) through the use of distributed flexible resources (energy storage and PV systems)
Objectives	○ Maintain frequency stability; and ○ Demonstrate congestion management for maintaining capacity limits of the grid.
Services	Inertia, aFRR, mFRR and corrective active power management for CM
Type of coordination	Market-based TSO-DSO coordination

Table 4.25 - SOCL-CY-BUC-02 BUC overview

BUC ID	SOCL-CY-BUC-02
BUC Name	Reactive power flexibility and power quality
Scope	Enhancement of reactive power flexibility and power quality (i.e., voltage support, congestion management, phase balancing) through the use of distributed flexible resources (energy storage and PV systems)
Objectives	○ Maintain voltage stability; ○ Demonstrate congestion management for maintaining capacity limits of the grid; ○ Achieve power quality enhancement.
Services	Corrective reactive power management for voltage control and congestion management
Type of coordination	Market-based TSO-DSO coordination

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Table 4.26 – List of KPIs for BUCs in the Southern Cluster - Cyprus

BUC ID	KPI_ID	Reference to KPI BUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
SOCL-CY-BUC-01	KPI_N14	CY_BUC_KPI_01	Rate of Change of Frequency improvement	This indicator considers the maximum rate of frequency change (in Hz/s) after an intense disturbance on system balancing. The indicator provides the improvement on the maximum ROCOF (ROCOFI) of the Research and Innovation (R&I) scenario where FSPs provide fast frequency responses compared to the Business as Usual (BaU) scenario where FSPs do not provide frequency support.	$ROCOFI = \frac{ROCOF_{R\&I} - ROCOF_{BaU}}{ROCOF_{BaU}} \cdot 100$	$ROCOFI$: Rate of Change of Frequency improvement (%) $ROCOF_x$: for each scenario $x \in \{R\&I, BaU\}$ is given by $ROCOF_x = \max_k \left(\frac{f(k)-f(k-1)}{\Delta t}\right)$ (Hz/s)	%
SOCL-CY-BUC-01	KPI_N15	CY_BUC_KPI_02	Improvement of Frequency Nadir	This indicator shows the improvement of the frequency nadir, which is the minimum point that the frequency reaches (in Hz) after an intense disturbance on system balancing.	$FNadirI = \frac{FreqNadir_{R\&I} - FreqNadir_{BAU}}{FreqNadir_{BAU}} \cdot 100$	$FNadirI:$ Improvement of Frequency Nadir (%) $FreqNadir_x$ for each scenario $x \in \{R\&I, BaU\}$ is given by $FreqNadir_x = \min [f_x(k)]\ x \in \{R\&I, BAU\}$ (Hz)	%
SOCL-CY-BUC-01; SOCL-CY-BUC-02	KPI_N16	CY_BUC_KPI_03	Overloading	This indicator provides information for the maximum overloading conditions that occurs at the distribution grid	$TL_i = \frac{\lvert TL_{R\&I} - TL_{BAU}\rvert}{TL_{BAU}} \cdot 100$	TL_i: overloading of the i-th element (%) where the TL_x for each scenario $x \in \{R\&I, BaU\}$ is given by, $TL_x = \frac{\max(S(k))}{S_n}$ $x \in \{R\&I, BAU\}$ (pu)	%
SOCL-CY-BUC-02	KPI_N17	CY_BUC_KPI_04	Improvement on voltage limits violations	This indicator provides information for the distribution grid's maximum over/under-voltage conditions in terms of intensity and duration. The indicator provides the improvement, of the Maximum Upper Voltage Violation Intensity ($MUVVI_i$) and the Maximum Lower Voltage Violation Intensity ($MLVVI_i$), between the Research and Innovation (R&I) scenario and the Business as Usual (BaU) scenario for the grid under examination.	The Maximum Upper and Lower Voltage Intensity improvement ($MUVVI_i$ and $MLVVI_i$) between the R&I and the BaU scenario are calculated according to, $MUVVI = \frac{MUVVI_{R\&I} - MUVVI_{BaU}}{MUVVI_{BaU}} \cdot 100$ and $MLVVI = \frac{MLVVI_{R\&I} - MLVVI_{BaU}}{MLVVI_{BaU}} \cdot 100$	$MUVVI:$ Improvement of Maximum Upper Voltage Violation Intensity (%) $MLVVI:$ Improvement of Maximum Lower Voltage Violation Intensity (%) where the maximum upper/lower voltage violation intensity $MUVVI_x$ and $MLVVI_x$ for each scenario $x \in \{R\&I, BaU\}$ is given by, $MUVVI_x = \max_j \left(\sum_k UVV_j(k) \cdot (V_j(k) - V_{max})T_s\right)$ (V), $MLVVI_x = \max_j \left(\sum_k LVV_j(k) \cdot (V_{min} - V_j(k))T_s\right)$ (V), where j ∈ $\{1, \dots, N\}$ and represents all the voltage buses of the distribution grid under examination.	%
SOCL-CY-BUC-02	KPI_N18	CY_BUC_KPI_05	Reduction of Energy Losses	This indicator provides information for the energy losses of the distribution grid for the selected operational scenarios. The indicator provides the Energy Losses reduction (REL) between the Research and Innovation (R&I) scenario where local FSPs provides flexibility services to the distribution grid and the Business as Usual (BaU) scenario where no flexibility services are provided.	The energy losses reduction between the R&I and the BaU scenario is calculated according to, $REL = \frac{EL_{BaU} - EL_{R\&I}}{EL_{BaU}} \cdot 100$	REL: Reduction of Energy Losses (%) where the energy losses EL_x for each scenario $x \in \{R\&I, BaU\}$ are given by, $EL_x = \frac{Total\ Energy\ Losses_x}{Total\ Load\ Energy_x} \cdot 100$ (%)	%

SOCL-CY-BUC-02	KPI_N19	CY_BUC_KPI_06	Reduction of Loading asymmetries–Maximum and Average Current Phase Unbalanced Factor (MCPUFR and ACPUFR)	This indicator provides information about the loading asymmetry between the three phases (Current Phase Unbalanced Factor) at the substation level (either primary or secondary substation), before (BaU) and after (R&I) the provision of local flexibility services for power quality enhancement by the local FSPs. The average and the maximum improvement will be considered for the examined period. The reduction of loading asymmetries is measured according to the maximum and average Current Phase Unbalance Factor reduction (*MCPUFR* and *ACPUFR*, respectively) between the R&I and the BaU.	$MCPUFR = \frac{\max_k(CPUF_{BaU}(k)) - \max_k(CPUF_{R\&I}(k))}{\max_k(CPUF_{BaU}(k))} \cdot 100$ $ACPUFR = \frac{\text{average}_k(CPUF_{BaU}(k)) - \text{average}_k(CPUF_{R\&I}(k))}{\text{average}_k(CPUF_{BaU}(k))} \cdot 100$	$MCPUFR$: Maximum Current Phase Unbalance Factor Reduction (%) $ACPUFR$: Average Current Phase Unbalance Factor Reduction (%) where the Current Phase Unbalanced Factor $CPUF_x$ for each scenario $x \in \{R\&I, BaU\}$ are given by, $CPUF_x(k) = \frac{\lvert I^0(k)\rvert + \lvert I^N(k)\rvert}{\lvert I^P(k)\rvert} \cdot 100$	%
SOCL-CY-BUC-02	KPI_N20	CY_BUC_KPI_07	Power factor (PFI) improvement	This indicator shows the improvement of the power factor value in different nodes of the distribution grid. It should be noted that the minimum value of the power factor over a period of time is considered in the calculation of this indicator.	$PFI = \frac{PF_{R\&I} - PF_{BAU}}{PF_{BAU}} . 100$	PFI: Power Factor Improvement (%) between the R&I and the BaU scenario, where the PF_x for each scenario $x \in \{R\&I, BaU\}$ is given by, $PF_x = \min\left[\frac{P(k)}{\sqrt{P(k)^2 + Q(k)^2}}\right] \quad x \in \{R\&I, BAU\}$	%
SOCL-CY-BUC-01	KPI_H19A	CY_BUC_KPI_08	Number of DER available for BSPs	Total number of certified DERs prequalified to provide balancing services available for BSPs	N_{DER_av}	N_{DER_av} : Number of available DER prequalified for balancing services	–
SOCL-CY-BUC-01	KPI_H18A	CY_BUC_KPI_09	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.	$VBS_{UP} = \sum_{n=1}^{N} aFRR(FP)_{U,n} + \sum_{m=1}^{M} mFRR(FP)_{U,m} + \sum_{k=1}^{K} RR(FP)_{U,k}$	VBS_{UP}: Volume of balancing service offers for UP reserves (aFRR, mFRR, RR) (kW) $\text{aFRR(FP)}_{\text{U,n}}$: Automatic Frequency restoration reserve (up-reserve) of unit n submitted to the flexibility platform (kW) $\text{mFRR(FP)}_{\text{U,m}}$: Manual Frequency restoration reserve (up-reserve) of unit m submitted to the flexibility platform (kW) $\text{RR(FP)}_{\text{U,k}}$: Replacement Reserve (up-reserve) of unit k submitted to the flexibility platform (kW)	kW

4.3.2 Cypriot demonstrators' SUCs KPIs

The SUC developed in the Cypriot demonstrator will be included in the Active Balancing Congestion Management platform for the TSO and the DSO (ABCM-T and ABCM-D). There are four different SUCs developed in the Cypriot demonstration related to the monitoring of the transmission and distribution systems, the prequalification of bids provided by the distributed energy sources, the evaluation of the FSPs response after the provision of ancillary services, and the optimal coordination of the FSP for the provision of ancillary services. For all the SUCs, relative KPIs are defined to assess the SUCs performance in the testing phase. The SUCs details are provided in Table 4.27, Table 4.28, Table 4.29, Table 4.30, while Table 4.31 shows the corresponding KPIs.

Table 4.27 - SOCL-CY-SUC-01

Name SUC	Real Monitoring of the grid
SUC ID	SOCL-CY-SUC-01
Objectives	○ Provide fast, accurate, and reliable visualization of the Cyprus power system operating condition (transmission level) ○ Enhance the situational awareness of the TSO
Narrative	This SUC deals with the monitoring schemes that will be used for obtaining in real time the operating condition of the transmission and distribution system. The monitoring system of the transmission grid will run to the ABCM-T platform and to the ABCM-D platform for the distribution grid. The real time monitoring system will provide in real time crucial information to the TSO such as: voltage phasors of all the buses, line loadings, frequency, and rate of change of frequency (ROCOF). In the case of the distribution grid the real time monitoring scheme will provide to the DSO the node voltages and line loadings.
Steps	○ Real time monitoring of the transmission grid operating condition ○ Real time monitoring of the distribution grid operating condition
Related BUCs	SOCL-CY-BUC-01; SOCL-CY-BUC-02

Table 4.28 - SOCL-CY-SUC-02

Name SUC	Prequalification of the location-based limit of each market product
SUC ID	SOCL-CY-SUC-02
Objectives	○ Provide fast, accurate, and reliable visualization of the Cyprus distribution grid ○ Enhance the situational awareness of the DSO
Narrative	This SUC deals with the calculation of certain operational limits in consecutive time intervals (before the clearing of the market) that should be respected by the TSO and local DSO market when the market is cleared. This SUC will be included both in the ABCM-T and ABCM-D platform and will be helpful for both operators for maintaining the operation of the grid in admissible limits
Steps	Prequalification of operational limits
Related BUCs	SOCL-CY-BUC-01; SOCL-CY-BUC-02

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Table 4.29 - SOCL-CY-SUC-03

Name SUC	Evaluation of the Flexible Services Providers response
SUC ID	SOCL-CY-SUC-03
Objectives	○ Real time grid assessment of the transmission and distribution grid operating condition ○ Evaluation of the response of the FSPs according to the awarded bids cleared by the corresponding market
Narrative	This SUC will use available monitoring information (from SCADA, smart meters, PMUs) to evaluate the response of the FSPs located at the transmission and the distribution grid after the provision of grid services. The objective of the SUC is to determine if the response of the FSPs corresponds to the awarded bids cleared by the TSO and local DSO market respectively.
Steps	Assessment of FSPs response
Related BUCs	SOCL-CY-BUC-01; SOCL-CY-BUC-02

Table 4.30 - SOCL-CY-SUC-04

Name SUC	Coordination of the distributed flexible resources
SUC ID	SOCL-CY-SUC-04
Objectives	○ Coordinate (on-line) the available flexible resources according to the grid operating conditions ○ Relieve congestions and achieve an efficient, stable and high-quality operation of the power grid by coordinating the flexibility resource located in the distribution grid
Narrative	This system use case (SUC) allows the DSO to online coordinate the flexible resources connected to the distribution grid to achieve the stable, efficient and high-quality operation of the power grid. In this coordination scheme, the flexibility services related to the location-based awarded bids cleared by the local DSO market and the real-time grid operating conditions are considered to maintain an appropriate operation of the distribution grid by the DSO.
Steps	The market operator publishes the cleared awarded bids. Monitoring of the grid operation conditions Coordination of FSPs Provision of grid services by the FSPs
Related BUCs	SOCL-CY-BUC-01; SOCL-CY-BUC-02

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Table 4.31 – KPIs adopted by the Cypriot Demonstrator SUCs

SUC ID	KPI_ID	Reference to KPI SUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
SOCL-CY-SUC-01	KPI_N21	CY_SUC_KPI_01	Voltage magnitude and angle error	This indicator provides information about the estimation accuracy of the real-time monitoring scheme. It is calculated as the difference between the actual and the estimated voltage and angle (provided by the monitoring scheme).	$V_{error} = \sum_{i=1}^{N} \lvert V_{act}^{i} - V_{est}^{i} \rvert$ $\theta_{error} = \sum_{i=1}^{N} \lvert \theta_{act}^{i} - \theta_{est}^{i} \rvert$	$V_{error}, \theta_{error}$: Estimation error of the voltage magnitude (kV) and angle (degrees) respectively *N:* Number of buses in the system. $V_{act}^{i}, \theta_{act}^{i}$: Actual voltage magnitude (kV) and voltage angle (degrees) respectively of the *i-th* bus. $V_{est}^{i}, \theta_{est}^{i}$: Estimated voltage magnitude (kV) and voltage angle (degrees) respectively of the *i-th* bus.	kV and degrees (°)
SOCL-CY-SUC-02	KPI_N22	CY_SUC_KPI_02	Calculated limits deviation	This indicator provides information about the calculation accuracy of the limits extracted from the SUC. As an indicator for the accuracy, the deviation (in percentage) that the calculated limits have from the actual limits in the HV/MV and MV/LV interface is adopted.	$LD = max\left[\frac{\lvert L_{act}(k) - L_{cal}(k) \rvert}{L_{act}(k)} . 100\right]$	LD: Maximum deviation of the calculated operational limits from the actual ones for a specific time interval (%) $L_{act}(k)$: Actual operational limits of the HV/MV or MV/LV interface that the system has at the k^{th} sample (kV) or (kA) $L_{cal}(k)$: Calculated operational limits of the HV/MV or MV/LV interface extracted by the SUC for the k^{th} sample (kV) or (kA). These operational limits are calculated a certain time interval before the k^{th} sample.	%
SOCL-CY-SUC-03	KPI_H23E	CY_SUC_KPI_03	Deviation of the FSP response compared to the awarded bids	This indicator assesses if the response of the FSPs corresponds to the awarded bids by the market. The indicator provides a percentage of how much each FSP response is in line with its market obligation.	$\Delta P_{max} = \max_{k}\left(\frac{P_{FSPi}(k) - P^{*}(k)}{P^{*}(k)}\right) \cdot 100$ $\Delta P_{mean} = \text{mean}_{k}\left(\frac{P_{FSPi}(k) - P^{*}(k)}{P^{*}(k)}\right) \cdot 100$	$\Delta P_{max}, \Delta P_{mean}$: Maximum and mean value of the power deviation (ΔP) (kW or kVAr). The same formula is applied for reactive power as well to determine the ΔQ_{max} and ΔQ_{mean} indicators. P^{*}, Q^{*}: Active (kW) and reactive (kVAr) power that an FSP should provide according to the awarded market bids. Any deviation from these values is recorded as deviation of the FSPs response.	%
SOCL-CY-SUC-04	KPI_N16	CY_SUC_KPI_04	Overloading	This indicator provides information for the duration and intensity of the overloading conditions at the distribution grid.	$TL_i = \frac{\lvert TL_{R\&I} - TL_{BAU} \rvert}{TL_{BAU}} \cdot 100$	TL_i: overloading of the i-th element (%) where the TL_x for each scenario $x \in \{R\&I, BaU\}$ is given by, $TL_x = \frac{\max(S(k))}{S_n} \quad x \in \{R\&I, BAU\}$ (pu)	%
SOCL-CY-SUC-04	KPI_N17	CY_SUC_KPI_05	Improvement of voltage limits violations	This indicator provides information for the duration and the intensity of the over/under-voltage conditions at the distribution grid. The Maximum Upper and Lower Voltage Intensity improvement (*MUVVI* and *MLVVI*) between the R&I and the BaU scenario are of interest.	$MUVVI = \frac{MUVVI_{R\&I} - MUVVI_{BaU}}{MUVVI_{BaU}} \cdot 100$ and $MLVVI = \frac{MLVVI_{R\&I} - MLVVI_{BaU}}{MLVVI_{BaU}} \cdot 100$	*MUVVI:* Improvement of Maximum Upper Voltage Violation Intensity (%) *MLVVI:* Improvement of Maximum Lower Voltage Violation Intensity (%) where the maximum upper/lower voltage violation intensity $MUVVI_x$ and $MLVVI_x$ for each scenario $x \in \{R\&I, BaU\}$ is given by, $MUVVI_x = \max_{j}\left(\sum_k UVV_j(k) \cdot (V_j(k) - V_{max})T_s\right)$ (V), $MLVVI_x = \max_{j}\left(\sum_k LVV_j(k) \cdot (V_{min} - V_j(k))T_s\right)$ (V), where j $\in \{1, \dots, N\}$ and represents all the voltage buses of the distribution grid under examination.	%
SOCL-CY-SUC-04	KPI_N18	CY_SUC_KPI_06	Reduction of energy losses	This indicator assesses the energy losses and the efficiency of the distribution grid.	The energy losses reduction between the R&I and the BaU scenario is calculated according to, $REL = \frac{EL_{BaU} - EL_{R\&I}}{EL_{BaU}} \cdot 100$	REL: Reduction of Energy Losses (%) where the energy losses EL_x for each scenario $x \in \{R\&I, BaU\}$ are given by, $EL_x = \frac{Total\ Energy\ Losses_x}{Total\ Load\ Energy_x} \cdot 100$ (%)	%

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SOCL-CY-SUC-04	KPI_N19	CY_SUC_KPI_07	Reduction of loading asymmetries – Maximum and Average Current Phase Factor	This indicator provides information about the loading asymmetry among the three phases for the distribution grid.	The reduction of loading asymmetries is measured according to the maximum and average Current Phase Unbalance Factor reduction (*MCPUF$_r$* and *ACPUF$_r$* respectively) between the R&I and the BaU scenario is calculated according to, $MCPUFR = \frac{\max_k(CPUF_{BaU}(k)) - \max_k(CPUF_{R\&I}(k))}{\max_k(CPUF_{BaU}(k))} \cdot 100$ and $ACPUFR = \frac{\text{average}_k(CPUF_{BaU}(k)) - \text{average}_k(CPUF_{R\&I}(k))}{\text{average}_k(CPUF_{BaU}(k))} \cdot 100$	$MCPUFR$: Maximum Current Phase Unbalance Factor Reduction (%) $ACPUFR$: Average Current Phase Unbalance Factor Reduction (%) where the Current Phase Unbalanced Factor *CPUF$_x$* for each scenario $x \in \{R\&I, BaU\}$ are given by, $CPUF_x(k) = \frac{\lvert I^0(k)\rvert + \lvert I^N(k)\rvert}{\lvert I^P(k)\rvert} \cdot 100$	%

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4.3.3 Greek demonstrators' BUCs KPIs

One of the main objectives of the Greek demonstrator is to enhance power system resilience in the new era of high-RES penetrated power systems through the development of an "F-channel" platform. This platform increases grid operators' observability by using advanced techniques based on artificial intelligence (AI). This capability offers enhanced severe weather condition management and active power management for operators in all the different voltage levels, providing a holistic and robust solution for the planning and operation of the power system.

Table 4.32 and

Table 4.33 provide an overview of the key elements of the BUCs proposed for the Greek demonstrators. The list of KPIs adopted to assess the Greek BUCs is available in Table 4.34.

Table 4.32 - SOCL-GR-BUC-01 BUC overview

BUC ID	SOCL-GR-BUC-01
BUC Name	Enhanced Active/Reactive Power Management for TSO-DSO coordination
Scope	Achieve enhanced identification of the available flexibility resources, focused on a DSO voltage level, as well as enhanced identification of the power system flexibility needs, focused on a TSO voltage level grid. This identification will be on a longer time span and wider geographical scope than the one being utilised today, through a sequence of DSO and TSO grid simulations backed up by AI based calculation engines.
Objectives	○ Maintain frequency stability; ○ Demonstrate improved load flow and contingency monitoring and predictions; ○ Facilitate predictive congestion management for maintaining secure and stable power system operation; ○ Achieve cost-effective operation of the system; ○ Implement early warning on hazardous power system regimes; ○ Demonstrate better FSPs planning and managing flexibility resources; ○ Demonstrate better energy predictions and power system state predictions; ○ Achieve improved identification of the available flexibility resources on all power system levels; and ○ Achieve improved prediction of the system flexibility needs.
Services	mFRR, RR, predictive active power products for CM and predictive reactive power products for VC
Type of coordination	Technical based TSO-DSO coordination

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Table 4.33 - SOCL-GR-BUC-02 BUC overview

BUC ID	SOCL-GR-BUC-02
BUC Name	Enhanced severe weather condition management and outage management for TSO, DSO and micro grid operator
Scope	Ensure that the SO can operate the power system more efficiently and preserve it from running into dangerous topological or operational states by enhanced severe weather condition management using predictive maintenance algorithms and enhanced storm and icing predictions.
Objectives	○ Facilitate predictive maintenance and outage management; ○ Achieve enhanced severe weather condition management; ○ Demonstrate outage management optimization for increased system adequacy; ○ Implement early warning on a potentially hazardous power system topology and regimes; and ○ Avoid damages caused by severe weather conditions.
Services	Service agnostic
Type of coordination	Technical based TSO-DSO coordination

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Table 4.34 – List of KPIs for BUCs in the Southern Cluster - Greece

BUC ID	KPI_ID	Reference to KPI BUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
SOCL-GR-BUC-01	KPI_H20A	GR_BUC_KPI_01	Accuracy of the RES production forecast calculated 24 hours in advance	The accuracy of power production prediction largely affects the performance of the DSO and TSO in using flexibility services. The KPI reflects on the accuracy of DSO and TSO flexibility providers production predictions by calculating the ratio and volume of expected and actual power production.	$RES_{FA_{24h}} = \frac{1}{N}\left(\sum_{t=1}^{N}\left\lvert\frac{FC_{RES_{prod,t}} - RL_{RES_{prod,t}}}{RL_{RES_{prod,t}}}\right\rvert\right)\cdot 100$	$RES_{FA_{24h}}$: Accuracy of the RES production forecast calculated 24 hours in advance (%) $FC_{RES_{prod}}$: RES production estimated 24h in advance (MW) $RL_{RES_{prod}}$: Real RES production (MW) N: Number of available data points	%
SOCL-GR-BUC-01	KPI_H20B	GR_BUC_KPI_02	Accuracy of load forecast calculated 24 hours in advance	The accuracy of demand prediction largely affects the performance of the DSO and TSO in using flexibility services. The KPI reflects on the accuracy of DSO and TSO flexibility demand predictions by calculating the ratio and volume of expected and actual flexibility service needs.	$Load_{FA_{24h}} = \frac{1}{N}\left(\sum_{t=1}^{N}\left\lvert\frac{FC_{load,t} - RL_{load,t}}{RL_{load,t}}\right\rvert\right)\cdot 100$	$Load_{FA_{24h}}$: Accuracy of load forecast calculated 24 hours in advance (%) FC_{load}: load estimated 24 hours in advance (MW). RL_{load}: real load (MW). N: number of available data points.	%
SOCL-GR-BUC-01	KPI_N44	GR_BUC_KPI_03	Active power flow forecast quality - day-ahead /intra-day	Active power flow forecast quality - day-ahead /intra-day	$qd(t) = m(t) - s_d(t)$ $qi(t) = m(t) - s_i(t)$	$qd(t)$: Active power flow forecast quality day-ahead (kW) $qi(t)$: Active power flow forecast quality intraday (kW) $m(t)$: Measured active power flow (kW) $s_d(t)$: Day ahead scheduled active power flow (kW) $s_i(t)$: Intraday scheduled active power flow (kW)	kW
SOCL-GR-BUC-01	KPI_H21A	GR_BUC_KPI_04	Share of correctly forecasted congestions	Share of correctly forecasted contingencies (network congestions)	$CFC_{\%} = \frac{C_{fc,c}}{C_o}\cdot 100$	$CFC_{\%}$: Share of correctly forecasted congestions (%) $C_{fc,c}$: 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).	%
SOCL-GR-BUC-01 SOCL-GR-BUC-02	KPI_N23	GR_BUC_KPI_05	Number of successfully predicted hazardous power system regimes and cyber threats	Rate of early warning on hazardous power system regimes. This indicator shows how efficient is the identification of the hazardous power system state and how much in advance, time-wise, it is given.	$CFC_{\%} = \frac{C_{fc,c}}{C_o}\cdot 100$	$CFC_{\%}$: Share of successfully predicted hazardous power system regimes and cyber threats (%) $C_{fc,c}$: Number of hazardous power system regimes correctly forecasted. C_o: Number of situations where analysis of the measurements indicate that hazardous power system regimes occurred or would have occurred if no curative actions by the DSO/TSO were taken (i.e., flexibility used).	%

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SOCL-GR-BUC-01 SOCL-GR-BUC-02	KPI_N24	GR_BUC_KPI_06	Number of successfully predicted severe weather conditions	It is very important to have as much as possible precise information on the grid reliability. The appearance of ice or storms can cause unplanned outages and severe damages in the grid, influencing the power system flexibility needs and the possibility of the transmission system and distribution system to guarantee the supply.	$CFC_{\%} = \frac{C_{fc,c}}{C_o} \cdot 100$	$CFC_{\%}$: Share of successfully predicted severe weather conditions (%) $C_{fc,c}$: Number of the severe weather conditions correctly forecasted. C_o: Number of situations where weather data analysis indicate that severe weather conditions occurred.	%

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4.3.4 Greek demonstrators' SUCs KPIs

The SUCs developed for the Greek Demonstrator comprises of 6 SUCs, which aim at improving prediction of production and consumption for DSO and microgrids, managing the point of interests (POI) for operators, simulating aggregation capabilities with different granularity, improving congestion management capabilities, offering predictive maintenance for extreme weather conditions, and managing outages efficiently. For all the SUCs, corresponding KPIs are defined to assess the SUCs performance in the testing phase. The Greek SUCs are functionally oriented, dealing with the future app advanced features that will be utilized through predefined scenarios. KPIs dedicated to other SUCs are also influenced by those features, and therefore, those SUCs will be indirectly assessed through them. An overview of the SUCs is provided in Table 4.35 – Table 4.39, while in Table 4.42, the corresponding KPIs are shown.

Table 4.35 - SOCL-GR-SUC-01

Name SUC	Improved production and consumption prediction for DSO and microgrid voltage levels
SUC ID	SOCL-GR-SUC-01
Objectives	○ Frequency stability ○ Cost-effective operation of the system ○ Better FSPs planning and managing flexibility resources. ○ Better energy predictions and power system state predictions ○ Improved identification of the available flexibility resources on all power system levels. ○ Improved prediction of the system flexibility needs.
Narrative	Improved production and consumption prediction for DSO and microgrid voltage levels that will allow for better identification of the available flexibility resources.
Steps	Provision of the weather forecast Forecast of the energy demand, generation and the transfer capacities
Related BUCs	SOCL-GR-BUC-01

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Table 4.36 - SOCL-GR-SUC-03

Name SUC	Change View - different aggregation level simulations
SUC ID	SOCL-GR-SUC-03
Objectives	○ Frequency stability ○ Load flow and contingency monitoring and predictions ○ Predictive congestion management for maintaining secure and stable power system operation ○ Cost-effective operation of the system ○ Early warning on a hazardous power system regimes, ○ Better FSPs planning and managing flexibility resources. ○ Better energy predictions and power system state predictions ○ Improved identification of the available flexibility resources on all power system levels. ○ Improved prediction of the system flexibility needs.
Narrative	User defined domain of DSO/Microgrid and TSO voltage level area of interest for which simulation of a power production, consumption and load flow (contingency analysis) is being performed.
Steps	Provision of the weather forecast Forecast of the energy demand, generation and the transfer capacities Update of the individual grid model Identification of the potential flexibility resources Forwarding of the information to the potential flexibility resources Confirmation of the reception of the information
Related BUCs	SOCL-GR-BUC-01

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Table 4.37 - SOCL-GR-SUC-04

Name SUC	Improved congestion management process on TSO and RSC side
SUC ID	SOCL-GR-SUC-04
Objectives	○ Frequency stability ○ Load flow and contingency monitoring and predictions ○ Predictive congestion management for maintaining secure and stable power system operation ○ Cost-effective operation of the system ○ Early warning on a hazardous power system regime ○ Better FSPs planning and managing flexibility resources ○ Better energy predictions and power system state predictions ○ Improved identification of the available flexibility resources on all power system levels. ○ Improved prediction of the system flexibility needs.
Narrative	Improved power system state estimation in order to better predict system flexibility needs, with the wider geographical observability and longer “look into the future”. through improved predictions and forecasting efficiency from increased spatial resolution NWPs and AI integration and its presentation with the improved observability on a higher operational control and monitoring levels, including regional, RSC level.
Steps	Provision of the weather forecast Forecast of the energy demand, generation and the transfer capacities Update of the individual grid model Identification of the potential flexibility resources Forwarding of the information to the potential flexibility resources Confirmation of the reception of the information
Related BUCs	SOCL-GR-BUC-01

Table 4.38 - SOCL-GR-SUC-05

Name SUC	Storm and Icing predictive maintenance process in TSO, DSO grid and local microgrid
SUC ID	SOCL-GR-SUC-05
Objectives	○ Predictive congestion management for maintaining secure and stable power system operation ○ Cost-effective operation of the system ○ Early warning on a hazardous power system regime
Narrative	Identification of the severe weather conditions that can cause tripping of the lines or DG outages and as a consequence partial or full blackout in the region of interest.
Steps	Provision of the weather forecast Forecast of the energy demand, generation and the transfer capacities Update of the individual grid model Identification of the severe system states Identification of the potential solutions Sending the information of interest Confirmation of the reception of the information
Related BUCs	SOCL-GR-BUC-02

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Table 4.39 - SOCL-GR-SUC-06

Name SUC	Outage management process in TSO/DSO grid and local micro grid
SUC ID	SOCL-GR-SUC-06
Objectives	○ Predictive congestion management for maintaining secure and stable power system operation ○ Cost-effective operation of the system ○ Early warning on a hazardous power system regime
Narrative	DSO/TSO grid, local microgrid outage management that considers improved predictions and forecasting efficiency from increased spatial resolution NWPs and AI integration.
Steps	Provision of the weather forecast Forecast of the energy demand, generation and the transfer capacities Update of the individual grid model Identification of the severe system states Identification of the potential solutions Sending the information of interest Confirmation of the reception of the information
Related BUCs	SOCL-GR-BUC-02

Table 4.40 - SOCL-GR-SUC-07

Name SUC	Improved frequency control on TSO side
SUC ID	SOCL-GR-SUC-07
Objectives	○ Frequency stability; ○ Load flow and contingency monitoring and predictions; ○ Predictive congestion management for maintaining secure and stable power system operation; ○ Cost-effective operation of the system; ○ Early warning on the hazardous power system regimes; ○ Better FSPs planning and managing flexibility resources; ○ Better energy predictions and power system state predictions; ○ Improved identification of the available flexibility resources on all power system levels; ○ Improved prediction of the system flexibility needs.
Narrative	The use case considers the situation in which the imbalance of such proportions is noticed in the system that the frequency stability of it may be endangered, which requires the immediate action, composed of the optimal identification and activation of the available flexibility resources that could mitigate the consequences of such an event. Active power flexibility products provided within this use case will enhance the frequency stability, relieve the congestions in the system and enable a cost-effective operation of the system, while exploiting the flexible sources through mFRR and RR.
Steps	Provision of the weather forecast Forecast of the energy demand, generation and the transfer capacities Update of the individual grid model Identification of the potential flexibility resources Forwarding of the information to the potential flexibility resources Confirmation of the reception of the information
Related BUCs	SOCL-GR-BUC-01

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Table 4.41 - SOCL-GR-SUC-08

Name SUC	Improved Voltage control on DSO and TSO side
SUC ID	SOCL-GR-SUC-08
Objectives	○ Voltage stability; ○ Load flow and contingency monitoring and predictions; ○ Predictive congestion management for maintaining secure and stable power system operation; ○ Cost-effective operation of the system; ○ Early warning on the hazardous power system regimes; ○ Better FSPs planning and managing flexibility resources; ○ Better energy predictions and power system state predictions; ○ Improved identification of the available flexibility resources on all power system levels; ○ Improved prediction of the system flexibility needs.
Narrative	The use case considers the situation in which the potential over- or undervoltage are identified, predicted well up front, with the enough time remaining for the proper reaction, enhanced by the AI solutions offered by the proposed platform. As such events can easily slip into the voltage instability of the system, it is necessary for the appropriate system operator to coordinate the relevant FSPs in order to provide the needed reactive power flexibility, with the FSPs connected both to the DSO grid levels and the TSO grid levels (mainly through the transformers with the TAP change option).
Steps	Provision of the weather forecast Forecast of the energy demand, generation and the transfer capacities Update of the individual grid model Identification of the potential flexibility resources Forwarding of the information to the potential flexibility resources Confirmation of the reception of the information
Related BUCs	SOCL-GR-BUC-01

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Table 4.42 – KPIs adopted by the Greek Demonstrator SUCs

SUC ID	KPI_ID	Reference to KPI SUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
SOCL-GR-SUC-01	KPI_H20A	GR_SUC_KPI_01	Accuracy of the RES production forecast calculated 24 hours in advance	The accuracy of power production prediction largely affects the performance of the DSO and TSO in using flexibility services. The KPI reflects the accuracy of DSO and TSO flexibility providers production predictions by calculating the ratio and volume of expected and actual power production.	$RES_{FA_{24h}} = \frac{\left\lvert\frac{FC_{RES_{prod}} - RL_{RES_{prod}}}{RL_{RES_{prod}}}\right\rvert}{N} \cdot 100$	$RES_{FA_{24h}}$: Accuracy of the RES production forecast calculated 24 hours in advance (%) $FC_{RES_{prod}}$: RES production estimated 24 hours in advance (MW). $RL_{RES_{prod}}$: Real RES production (MW). N: Number of available data points.	%
SOCL-GR-SUC-01	KPI_H20B	GR_SUC_KPI_02	Accuracy of load forecast calculated 24 hours in advance	The accuracy of demand prediction largely affects the performance of the DSO and TSO in using flexibility services. The KPI reflects the accuracy of DSO and TSO flexibility demand predictions by calculating the ratio and volume of expected and actual flexibility service needs.	$LO_{FA_{24h}} = \frac{\left\lvert\frac{FC_{load} - RL_{load}}{RL_{load}}\right\rvert}{N} \cdot 100$	$LO_{FA_{24h}}$: Accuracy of load forecast calculated 24 hours in advance (%) FC_{load}: Load estimated 24 hours in advance (MW). RL_{load}: Real load (MW). N: Number of available data points.	%
SOCL-GR-SUC-04	KPI_N44	GR_SUC_KPI_03	Active power flow forecast quality - day-ahead /intra-day	Active power flow forecast quality - day-ahead /intraday	$qd(t) = m(t) - s_d(t)$ $qi(t) = m(t) - s_i(t)$	$qd(t)$: Active power flow forecast quality day-ahead (kW) $qi(t)$: Active power flow forecast quality intraday (kW) $m(t)$: Measured active power flow (kW) $s_d(t)$: Day ahead scheduled active power flow (kW) $s_i(t)$: Intraday scheduled active power flow (kW)	kW
SOCL-GR-SUC-04	KPI_H21A	GR_SUC_KPI_04	Share of correctly forecasted congestions	Share of correctly forecasted contingencies (network congestions)	$CFC_{\%} = \frac{C_{fc,c}}{C_o} \cdot 100$	$CFC_{\%}$: Share of correctly forecasted congestions (%) $C_{fc,c}$: 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).	%
SOCL-GR-SUC-04 SOCL-GR-SUC-05 SOCL-GR-SUC-06 SOCL-GR-SUC-08	KPI_N23	GR_SUC_KPI_05	Number of successfully predicted hazardous power system regimes and cyber threats	Early warning on a hazardous power system regimes rate. This indicator shows how efficient is the identification of the hazardous power system state and how much in advance, time-wise, it is given.	$CFC_{\%} = \frac{C_{fc,c}}{C_o} \cdot 100$	$CFC_{\%}$: Share of successfully predicted hazardous power system regimes and cyber threats (%) $C_{fc,c}$: Number of hazardous power system regimes correctly forecasted. C_o: Number of situations where analysis of the measurements indicate that hazardous power system regimes occurred or would have occurred if no curative actions by the DSO/TSO were taken (i.e., flexibility used).	%

SOCL-GR-SUC-05 SOCL-GR-SUC-06	KPI_N24	GR_SUC_KPI_06	Number of successfully predicted severe weather conditions	It is very important to have as much as possible precise information on the grid reliability. The appearance of ice or storms can cause unplanned outages and severe damages in the grid, influencing the power system flexibility needs and the possibility of the transmission system and distribution system to guarantee the supply.	$CFC_{\%} = \frac{C_{fc,c}}{C_o} \cdot 100$	$CFC_{\%}$: Share of successfully predicted severe weather conditions (%) $C_{fc,c}$: Number of the severe weather conditions correctly forecasted. C_o: Number of situations where analysis of the weather data indicate that severe weather conditions occurred.	%

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4.4 Western Cluster demonstrators' KPIs

The Western cluster includes 3 countries (Portugal, Spain and France). It has the objective of implementing a wide range of flexibility mechanisms, namely addressing DSO and TSO needs, including coordination between market mechanisms and the planning and real-time operation of the grids. Among the main goals to be achieved, increasing the share of renewables in energy generation and anticipating operating scenarios are relevant priorities.

The French demonstrator focuses on the interactions between the TSO and the DSO due to the already existing market architecture. One of the activities of the OneNet French demonstrator, the System for Traceability of Renewable Activations (STAR), aims to track the activation of power generation curtailments, while the Tunnel of Warranty (TOW) aims to ensure that the resource activation in one system operator's network does not negatively affect other system operator's network.

The Portuguese demonstrator focuses on defining the principles and the information exchange needed to procure flexibility and address operational planning activities, particularly congestion management.

The Spanish demonstrator develops and tests a local market model to unlock the flexibility of the resources connected to the distribution system to contribute to congestion management at the distribution level.

4.4.1 French demonstrators' BUCs KPIs

The OneNet French Demonstration is focused on two business use cases: the implementation of STAR and the study on innovative ways for TSO-DSO information exchange for DER activation (TOW).

The STAR is a monitoring platform that allows sharing relevant information for the settlement but not directly undertaking it. The use case STAR aims to build a shared ledger to simplify and optimise the management of renewable production curtailments by covering the entire life cycle of a flexibility offer, from the formulation of offers to the monitoring of their activation invoicing.

The French demonstration also studies innovative ways of TSO-DSO information exchange in the context of DER activation. When a TSO or DSO activates flexibilities on its networks (such as renewable curtailments), it can generate contingencies on the other system operator's network (i.e. congestion or voltage constraints). With the foreseen extensive use of flexibilities close to real-time, system operators will not have the possibility to perform ad hoc security analysis for every flexibility activation demand, this is the aim of the study to come up with methods to assess which flexibilities are "safe" to activate. For now, the discussions on this topic between the TSO and the DSO are still at a very early stage and a work on common definitions and vision is still to be achieved. As it is an exploratory subject, these future discussions could modify the objectives and therefore the results of this study, both in terms of substance and form (for instance the inclusion of simulations or not). For

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now, in order to keep open the results' form and all possible directions that could emerge from this effort, it has been chosen not to define KPIs related to the WECL-FR-BUC-02 BUC.

Table 4.43 and Table 4.44 provide an overview on the key elements of the BUCs proposed for the French demonstrator. Table 4.45 reports the KPIs identified and defined for assessing the French demonstrator's BUCs.

Table 4.43 - WECL-FR-BUC-01 BUC overview

BUC ID	WECL-FR-BUC-01
BUC Name	Improved monitoring of flexibility for congestion management
Scope	Simplify and optimize the management of renewable production curtailments
Objectives	○ Simplify and optimize the management of renewable production curtailments, by covering the entire life cycle of a flexibility offer, from the formulation of offers to the control of their activations for invoicing using blockchain technology; and ○ Build a platform enabling such objectives and test it for each participating entity on a chosen area of the French network.
Services	Corrective active power management for CM
Type of coordination	Technical based TSO-DSO coordination

Table 4.44 - WECL-FR-BUC-02 BUC overview

BUC ID	WECL-FR-BUC-02
BUC Name	Improved TSO-DSO information exchange for DER activation
Scope	Enhanced information exchange between TSO and DSO: When a TSO or DSO activates flexibilities on its networks (such as renewable curtailments), it can generate contingencies on the other system operator's network (i.e., congestion or voltage constraints). With the foreseen extensive use of flexibilities close to real-time, system operators will not have the possibility to perform ad hoc security analysis for every flexibility activation demand. One of the solutions that could be considered is having the TSO and DSO to agree in advance on a constraint envelope within which the controls sent to the flexibilities must be kept in check so that it can be guaranteed that activations are safe for each other and that can be used without further prior approval, the so-called "shared DSO/TSO congestion management in case of activation of distributed flexibility"
Objectives	○ Improve the information exchange between TSO and DSO in the context of local DER flexibility activation; ○ Carry out studies on the management of the constraints between DSO and TSO in case of activation of a flexibility; and ○ Develop a method that would guarantee that the activation of curtailment by one TSO or DSO will not trigger other constraints on one or another network.
Services	Service agnostic
Type of coordination	Technical based TSO-DSO coordination

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Table 4.45 - List of KPIs for BUCs in the Western Cluster - France

BUC ID	KPI_ID	Reference to KPI BUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
WECL-FR-BUC-01	KPI_H01	FR_BUC_KPI_01	Service provider involved	Number of producers involved in the demonstrator	Not applicable	Nb_{FSP}: number of service provider involved in the demonstrator	–
WECL-FR-BUC-01	KPI_N26	FR_BUC_KPI_02	Tracked flexibility	Number of tracked flexibility activations	Not applicable	NAa_{Flex}: Number of tracked flexibility activations	–

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4.4.2 French demonstrators' SUCs KPIs

The French demonstration defined two SUCs related to the WECL-FR-BUC-01 BUC that aims to improve the monitoring of flexibility activations using the STAR platform. Both SUCs describe what is expected from the platform to be developed in terms of information sharing and rights between the TSO, DSO and producers. The WECL-FR-SUC-01 SUC provides these requirements when an automated activation is issued from the TSO, whereas the WECL-FR-SUC-02 focuses on the case when the DSO sends a manual order.

Table 4.46 and Table 4.47 summarise the French demonstrator's SUCs, while the list of selected KPIs to evaluate them is provided in Table 4.48.

Table 4.46 - WECL-FR-SUC-01

Name SUC	STAR – TSO automated activation
SUC ID	WECL-FR-SUC-01
Objectives	Faced with the challenges of the energy transition, ENEDIS and RTE are experimenting with new technological solutions to integrate new flexibility levers to manage congestions on their networks. The BUC WECL-FR-BUC-01 related to this SUC aims to simplify and optimize the management of renewable production curtailments, by covering the entire life cycle of a flexibility offer, from the formulation of offers to the control of their activations for invoicing. The final goal is to build a platform based on the blockchain technology, enabling such objectives and test it for each participating entity on a chosen area of the French network. This system use case particularly highlights the information to be tracked and processed to follow in order to meet the BUC WECL-FR-BUC-01 objective in the case where the TSO automatically activates flexibilities in a context of congestion management.
Narrative	In order to simplify and optimize the management of renewable production curtailments building the STAR platform, we have to define the information exchanges and processes needed to perform the related BUC's traceability objectives in the case of TSO automated activations.
Steps	This SUC highlights the needed information and processes between TSO, DSO, FSP and producers in the case of TSO automated activations for the four following phases: ○ Market phase ○ Monitoring and Activation ○ Measurement and settlement ○ Platform consultation
Related BUCs	WECL-FR-BUC-01

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Table 4.47 - WECL-FR-SUC-02

Name SUC	STAR – DSO manual activation
SUC ID	WECL-FR-SUC-02
Objectives	Faced with the challenges of the energy transition, ENEDIS and RTE are experimenting with new technological solutions to integrate new flexibility levers to manage congestions on their networks. The business use case WECL-FR-BUC-01 related to this SUC aims to simplify and optimize the management of renewable production curtailments, by covering the entire life cycle of a flexibility offer, from the formulation of offers to the control of their activations for invoicing. The final goal is to build a platform based on the blockchain technology, enabling such objectives and test it for each participating entity on a chosen area of the French network. This system use case particularly highlights the information to be tracked and processes to follow in order to meet the BUC WECL-FR-BUC-01 objective in the case where the DSO manually activates flexibilities in a context of congestion management.
Narrative	In order to simplify and optimize the management of renewable production curtailments building the STAR platform, we have to define the information exchanges and processes needed to perform the related BUC's traceability objectives in the case of DSO manual activations.
Steps	This SUC highlights the needed information and processes between TSO, DSO, FSP and producers in the case of DSO manual activations for the four following phases: ○ Market phase ○ Monitoring and Activation ○ Measurement and settlement ○ Platform consultation
Related BUCs	WECL-FR-BUC-01

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Table 4.48 – KPIs adopted by the French Demonstrator SUCs

SUC ID	KPI_ID	Reference to KPI SUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
WECL-FR-SUC-01	KPI_N26	FR_SUC_KPI_01	Tracked flexibility	Number of tracked flexibility activations automatically triggered	Not applicable	NAa_{Flex}: Number of tracked flexibility activations	_
WECL-FR-SUC-01	KPI_N26	FR_SUC_KPI_02	Tracked flexibility	Number of tracked flexibility activations manually triggered	Not applicable	NAa_{Flex}: Number of tracked flexibility activations	_

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4.4.3 Portuguese demonstrators' BUCs KPIs

The OneNet Portuguese demonstrator aims to specify the exchanges of information between system operators to enable flexibility provision and improve their operational planning.

For the Business Use Cases related to flexibility (WECL-PT-BUC-01 and WECL-PT-BUC-02), the ASM report [6] stages were considered as the necessary steps in defining the process upon which coordination should be carried out between TSO and DSO. Except for the settlement process, all stages were considered since the goal is to focus on the information exchange.

For the Business Use Case related to operational planning (WECL-PT-BUC-03), the operational processes of the DSO and TSO that can be improved with the exchange of information between network operators are considered, such as the generation and load forecast, the maintenance plans and the short-circuit level forecast.

Table 4.49, Table 4.50, and Table 4.51 provide an overview of the key elements of the BUCs proposed for the Portuguese demonstrator. Table 4.52 provides the list of the KPIs that have been identified and defined for assessing the Portuguese demonstrators' BUCs.

Table 4.49 - WECL-PT-BUC-01 BUC overview

BUC ID	WECL-PT-BUC-01
BUC Name	Exchange of Information for Congestion Management – Short Term
Scope	Description in detail of each process phase of the ASM report, stating what information should be exchanged and what rules should be established between DSO and TSO in order to procure congestion management products for short-term (intraday, day-ahead)
Objectives	○ Design and detail each process phase of ASM report so that it can serve as a basis for future developments; ○ Coordination of the use of flexibility for different voltage levels; ○ Identify what information should be shared between DSO and TSO for each of the flexibility procurement process phases for short term congestion management, namely for the technical selection and validation of the bids by the relevant system operator; and ○ Develop information exchange mechanisms to enable market-based procurement of flexibility products.
Services	Predictive active power management for CM
Type of coordination	Technical based TSO-DSO coordination

[6] The Active System Management report is a position paper written by CEDEC, E.DSO, ENTSOE, EURELETTRIC, GEODE that discusses an integrated approach to active system management with focus on TSO – DSO coordination in congestion management and balancing [23].

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Table 4.50 - WECL-PT-BUC-02 BUC overview

BUC ID	WECL-PT-BUC-02
BUC Name	Exchange of Information for Congestion Management – Long Term
Scope	Description of each process phase of the ASM report, stating what information should be exchanged and what rules should be established between DSO and TSO in order to procure congestion management products for long-term (more than annually)
Objectives	○ Design and detail each process phase of ASM report so that it can serve as a basis for future developments; ○ Coordination of the use of flexibility for different voltage levels; ○ Identify what information should be shared between DSO and TSO for each of the flexibility procurement process phases for long terms congestion management, namely for the technical selection and validation of the bids by the relevant system operator; and ○ Develop information exchange mechanisms to enable market-based procurement of flexibility products.
Services	Predictive active power management for CM
Type of coordination	Technical based TSO-DSO coordination

Table 4.51 - WECL-PT-BUC-03 BUC overview

BUC ID	WECL-PT-BUC-03
BUC Name	Exchange of information for operational planning
Scope	Definition and description of the TSO and DSO information exchange, aiming to improve and facilitate long-term to short-term operational planning for both networks.
Objectives	○ Identify the scheduled/forecasted information exchanged between DSO and TSO in order to improve programming of DSO operation; ○ Identify the scheduled/forecasted information exchanged between DSO and TSO in order to improve programming of TSO operation; ○ Anticipate and solve distribution grid constraints; ○ Anticipate and solve transmission grid constraints; and ○ Develop information exchange mechanisms to share the identified information.
Services	Service agnostic
Type of coordination	Technical based TSO-DSO coordination

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Table 4.52 - List of KPIs for BUCs in the Western Cluster - Portugal

BUC ID	KPI_ID	Reference to KPI BUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
WECL-PT-BUC-01; WECL-PT-BUC-02; WECL-PT-BUC-03	KPI_H04	PT_BUC_KPI_01	ICT costs	The term ICT cost comprises the communications and information technologies directly related to the implementation of the communication infrastructures between DSO and TSO.	$ICT_{cost} = \sum_{i=1}^{N_c} c_i$	ICT_{cost}: cost of ICT (€) c_i: generic i-th cost directly related to information exchange (€) Nc: overall number of cost items per BUC	€
WECL-PT-BUC-03	KPI_H20A	PT_BUC_KPI_02	Accuracy of the RES production forecast calculated 24 hours in advance	Evaluate the forecast quality after the information exchange between DSO and TSO, measuring the error before and after the information exchange. It is a day-ahead forecast with a granularity of fifteen minutes.	$RES_{FA_{24h}} = \frac{1}{N}\left(\sum_{t=1}^{N}\left\lvert\frac{FC_{RES_{prod,t}} - RL_{RES_{prod,t}}}{RL_{RES_{prod,t}}}\right\rvert\right)\cdot 100$	$RES_{FA_{24h}}$: Accuracy of the RES production forecast calculated 24 hours in advance (%) $FC_{RES_{prod}}$: RES production estimated 24h in advance (MW) $RL_{RES_{prod}}$: Real RES production (MW) N: Number of available data points	%
WECL-PT-BUC-03	KPI_H20B	PT_BUC_KPI_03	Accuracy of load forecast calculated 24 hours in advance	Evaluate the forecast quality after the information exchange between DSO and TSO, measuring the error before and after the information exchange. It is a day-ahead forecast with a granularity of fifteen minutes.	$Load_{FA_{24h}} = \frac{1}{N}\left(\sum_{t=1}^{N}\left\lvert\frac{FC_{load,t} - RL_{load,t}}{RL_{load,t}}\right\rvert\right)\cdot 100$	$Load_{FA_{24h}}$: Accuracy of load forecast calculated 24 hours in advance (%) FC_{load}: load estimated 24 hours in advance (MW). RL_{load}: real load (MW). N: number of available data points.	%
WECL-PT-BUC-01; WECL-PT-BUC-02	KPI_N27	PT_BUC_KPI_04	Total power of avoided congestions through flexibility activation.	The difference of the total amount of power of the congestions (overloaded elements) in the grid for all periods of observation between the scenarios without flexibility activation (before BUC implementation) and with flexibility activation (after BUC implementation) by DSO and TSO action.	$TPAC = \sum_{t=1}^{T}\left(\sum_{i=0}^{M}{}_{before\ BUC}(P_{i,t} - P_i^{max}) - \sum_{k=0}^{N}{}_{after\ BUC}(P_{k,t} - P_k^{max})\right)$	$TPAC$: Total power of avoided congestions through flexibility activation (kW) M, N: number of overloaded elements in scenario without and with flexibility activation respectively. T: number of time intervals the entire period under consideration (e.g. for one day 24 intervals of 1 hour or 96 intervals of 15 minutes). $P_{i,t}, P_{k,t}$: power-flow in overloaded network element i or k for time interval t, respectively for the scenario without and with flexibility activation (kW). P_i^{max}, P_k^{max} : maximum power for network element i or k without it being overloaded, respectively for the scenario without and with flexibility activation (kW).	kW
WECL-PT-BUC-01; WECL-PT-BUC-02	KPI_H12	PT_BUC_KPI_05	Number of avoided technical restrictions.	Ratio between the number of avoided congestions (overloaded elements) in the grid for all periods of observation scenarios with flexibility activation (after BUC implementation) by DSO and/or TSO action and the total number of expected restrictions.	$ATR_{\%} = \frac{N_{TR_{Flex}}}{N_{TR}}\cdot 100$	$ATR_{\%}$: Share of avoided technical restrictions (%). N_{TR}: Total number of expected technical restrictions $N_{TR_{Flex}}$: Total number of technical restrictions solved through activation of flexibility services	%

WECL-PT-BUC-01; WECL-PT-BUC-02	KPI_H21B	PT_BUC_KPI_06	Share of false positive and negative congestion forecasts	The ratio of the incorrectly forecasted congestions versus the total number of congestions forecasted.	$FFC_{\%} = \frac{C_{fc,c}}{C_{fc}} \cdot 100$	$FFC_{\%}$: Share of false positive and negative congestion forecasts (%) ***Cfc,f:*** is the number of false positive and negative congestion forecasts, so congestions forecasted where analysis of the measurements indicate that no congestion would have occurred, even if no curative actions by the DSO and TSO were taken (I.e., flexibility used). ***Cfc****:* is the total number of congestions forecasted.	%
WECL-PT-BUC-01; WECL-PT-BUC-02	KPI_N28	PT_BUC_KPI_07	Maximum ratio of false-positive and negative congestion forecasts	The maximum ratio of the incorrectly forecasted power congestions versus the total power of congestions forecasted.	$FFC_{\%} = Max\left(\frac{P_{fc,c}}{P_{fc}} \cdot 100\right)$	$FFC_{\%}$: Maximum ratio of false positive and negative congestion forecasts (%) ***Pfc,f:*** is the amount of power of false positive and negative congestion forecasts, so congestions forecasted where analysis of the measurements indicate that no congestion would have occurred, even if no curative actions by the DSO and TSO were taken (I.e., flexibility used). ***Pfc****:* is the total amount of power of congestions forecasted.	%
WECL-PT-BUC-01; WECL-PT-BUC-02	KPI_H15A	PT_BUC_KPI_08	Requested flexibility	This indicator measures the amount of flexibility requested by the DSO or TSO for ancillary services from all the flexible resources of the portfolio.	$P_{Flex_R} = \sum_{t=1}^{T} P_{flex_{R_t}}$	P_{Flex_R}: Requested flexibility (Power) (kW or MW) $P_{flex_{R_t}}$: The amount of power requested by the DSO/TSO in order to solve their forecasted constraints at a time T (kW or MW) T: examined period	kW or MW
WECL-PT-BUC-01; WECL-PT-BUC-02	KPI_N29	PT_BUC_KPI_09	Load Curtailment	Load energy avoided curtailment in transmission or distribution grid before and after BUC implementation.	$E_{Load} = \sum_{i=1}^{I}\sum_{t=1}^{T}\left(Load_{i,t}^{before\ flexibility} - Load_{i,t}^{after\ flexibility}\right)$	E_{Load}: Load Curtailment (kWh or MWh) I: set of Load facilities under consideration T: set of time intervals of period under consideration excluding periods of scheduled maintenance and outages $Load_{i,t}^{before\ flexibility}$: Load curtailed before flexibility activation of the i_{th} consumer at period t (kWh or MWh) $Load_{i,t}^{after\ flexibility}$: Load curtailed after flexibility activation of the i_{th} consumer at the period t (kWh or MWh)	kWh or MWh

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WECL-PT-BUC-01; WECL-PT-BUC-02; WECL-PT-BUC-03	KPI_H05	PT_BUC_KPI_10	Reduction in RES curtailment	This indicator measures the reduction in the amount of energy from Renewable Energy Sources (RES) that is not injected into the grid (even though it is available) due to operational limits of the grid, such as voltage violations or congestions.	$E_{RES} = \sum_{i=1}^{I} \sum_{t=1}^{T} \left(E_{i,t}^{prod} - E_{i,t}^{inj}\right)$	E_{RES}: Reduction in RES curtailment (MWh) I: Set of RES facilities under consideration. T: Set of time intervals of period under consideration excluding periods of scheduled maintenance and outages. $E_{i,t}^{prod}$: Available energy production of the i^{th} RES facility at period t (kWh or MWh). $E_{i,t}^{inj}$: Injected energy of the ith RES facility at the period t (kWh or MWh).	kWh or MWh

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4.4.4 Portuguese demonstrators' SUCs KPIs

The use cases were approached from a business intent but considering a time horizon perspective since different tools and needs are required when a long or short-term analysis is being carried out. In this sense, eight system use cases were defined, which distinguish different time horizons where needed and replicates as common SUCs the activities common to both WECL-PT-BUC-01 and WECL-PT-BUC-02. Moreover, three of those are dedicated to WECL-PT-BUC-03. Table 4.53 summarises the SUCs, the corresponding designation and BUCs.

Since KPIs are metrics that help measure the progress and the performance of the Business and System Use Cases, the Portuguese Demo partners agreed that it would only make sense to define KPIs for Business and System Use Cases that will be developed.

As described in section 3.2.4 of the Deliverable 9.1, from the extensive list of SUCs that have been described, for demonstration purposes, the Portuguese demonstration effort in this project only allows the development of the following SUCs: SUC01, SUC02, SUC06, SUC07 and SUC08. As such, no KPIs were defined for SUCs 03, 04 and 05, as these are not planned to be developed.

Table 4.53 presents the correspondence among the BUCs and SUCs proposed for the Portuguese demonstrator. Table 4.54, Table 4.55, Table 4.56, Table 4.57, Table 4.58, Table 4.59, Table 4.60, and Table 4.61 resume the key elements of the SUCs proposed for the Portuguese demonstrator, while Table 4.62 reports the KPIs that have been identified and defined for assessing the Portuguese demonstrator's SUCs.

Table 4.53 - Summary of System Use Cases and corresponding BUCs

SUCs IDs	SUC Designation	Ref. BUC
WECL-PT-SUC-01	Evaluation of the Product & Grid pre-qualification requirements	WECL-PT-BUC-01; WECL-PT-BUC-02
WECL-PT-SUC-02	Day-Ahead & Intraday Flexibility needs	WECL-PT-BUC-01
WECL-PT-SUC-03	Long-term Flexibility needs	WECL-PT-BUC-02
WECL-PT-SUC-04	Selection of Bids	WECL-PT-BUC-01; WECL-PT-BUC-02
WECL-PT-SUC-05	Evaluate Grid Constraints	WECL-PT-BUC-01; WECL-PT-BUC-02
WECL-PT-SUC-06	Maintenance plans information exchange	WECL-PT-BUC-03
WECL-PT-SUC-07	Consumption and generation forecast information exchange	WECL-PT-BUC-03
WECL-PT-SUC-08	Short-circuit levels information exchange	WECL-PT-BUC-03

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Table 4.54 - WECL-PT-SUC-01

Name SUC	Evaluation of the Product & Grid prequalification requirements
SUC ID	WECL-PT-SUC-01
Objectives	○ Demonstrate that it is feasible to implement these system processes efficiently and within the expected timeframe. ○ Enable FSPs and their resources for flexibility markets, since Prequalification phase is necessary for the following phases that we will approach. ○ List of requirements for product prequalification for DSO and TSO. ○ Ensure coordination between system operators for all scenarios. ○ Receive and send data between system operators in a secure manner.
Narrative	This SUC is divided into two different processes; the product and the grid evaluation processes. For each process we describe each step, where we address which requirements are mandatory and which are informative to prequalify an FSP. We also separate the processes for DSO and TSO when necessary. For product evaluation, it is identified which mandatory and informative requirements, such as mode of activation, minimum quantity to deliver, locational information, etc., are required to evaluate whether the unit can (technically) deliver the product it wants to sell/deliver. For Grid evaluation, in prequalification phase, a grid impact assessment is evaluated. In order to do this evaluation, it is defined what kind of grid data is the most appropriate: Comprehensive grid data -selecting the most efficient combination of flexibilities and switching of topology. Partial grid data -using essentially the sensitivities of flexibilities, e.g., Traffic lights system Simple Rule – Empirical selection. Within the scope of this SUC, real-world implementation of technologies enabling the exchange of data about product and grid prequalification is foreseen. This implementation is supported by work done in previous H2020 projects.
Steps	Prequalification for FSPs connected to Distribution Grid Prequalification for FSPs connected to Transmission Grid
Related BUCs	WECL-PT-BUC-01; WECL-PT-BUC-02

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Table 4.55 - WECL-PT-SUC-02

Name SUC	Day-Ahead & Intraday Flexibility needs
SUC ID	WECL-PT-SUC-02
Objectives	○ Demonstrate that it is feasible to implement these system processes efficiently and within the expected timeframe. ○ Identify potential network constrains and planning of the grid operation for the next day/hours considering the load and generation forecasts ○ Promote the participation of flexible resources connected at all voltage levels grids in distribution and transmission networks operation ○ Ensure coordination between system operators for all scenarios. ○ Receive and send data between system operators in a secure manner.
Narrative	This SUC focuses on the steps that system operators should perform to plan and forecast their grid utilization. This SUC supports the coordination between DSO and TSO so that they can determine how much flexibility they will need to acquire, for a short-term timeframe. The coordination is needed to prevent congestions in the distribution and transmission grids due to activation of active power flexibilities for the needs DSO and TSO. This coordination process starts day-ahead and ends intraday, after the opening of the intraday flexibility market. In this SUC is described the steps that system operators should go through in order to identify potential network restrictions for the next day and intraday and to understand the amount of flexibility they will need to solve their needs and constraints. The steps needed to identify the amount of flexibility required address the following aspects, such as the grid layout, weather forecasts, information on the flexible assets. Within the scope of this SUC, real-world implementation of technologies enabling the exchange of data about planning, forecast and the amount of flexibility needed is foreseen. This implementation is supported by work done in previous H2020 projects.
Steps	○ Day-Ahead & Intraday Flexibility needs for DSO ○ Day-Ahead & Intraday Flexibility needs for TSO ○ Day-Ahead & Intraday Flexibility needs for DSO within OneNet System ○ Day-Ahead & Intraday Flexibility needs for TSO within OneNet System
Related BUCs	WECL-PT-BUC-01

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Table 4.56 - WECL-PT-SUC-03

Name SUC	Long-term Flexibility needs
SUC ID	WECL-PT-SUC-03
Objectives	○ Demonstrate that it is feasible to implement these system processes efficiently and within the expected timeframe. ○ Cover grid investment needs through flexibility services. ○ Anticipate technical problems arisen as a consequence of planned action on the distribution grid for some years in advance, considering the load and generation forecast as well as the schedule for the planned interventions on the grid. ○ Improve network operation security during maintenance actions, using flexibility to minimize the risk of reduced redundancy. ○ Ensure coordination between system operators for all scenarios. ○ Receive and send data between system operators in a secure manner.
Narrative	This SUC is focused on the steps that system operators should perform to plan and forecast their grid utilization. This SUC supports the coordination between DSO and TSO so that they can determine how much flexibility they will need to acquire, for a long-term timeframe. The coordination is needed to anticipate technical problems, improve network operation security, and avoid investments in the distribution and transmission grids with the activation of active power flexibilities. In this SUC is described the steps, such as a probabilistic power flow checking and forecasting of possible congestion areas, that system operators should go through considering the possibility of reserving flexibility services for congestion management years in advance. Within the scope of this SUC, real-world implementation of technologies enabling the exchange of data about planning, forecast and the amount of flexibility needed is foreseen. This implementation is supported by work done in previous H2020 projects.
Steps	○ Long-term Flexibility needs for DSO ○ Long-term Flexibility needs for TSO
Related BUCs	WECL-PT-BUC-02

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Table 4.57 - WECL-PT-SUC-04

Name SUC	Selection of Bids
SUC ID	WECL-PT-SUC-04
Objectives	○ Demonstrate that it is feasible to implement these system processes efficiently and within the expected timeframe. ○ Ensure that the solution provided by the flexibility activation through the market mechanisms will not create additional problems from a technical point of view. ○ Ensure coordination between system operators for all scenarios. ○ Receive and send data between system operators in a secure manner
Narrative	This SUC focuses on the steps that system operators should perform to select bids from FSP's. After the system operators have identified the amount of flexibility, they need to solve their needs and possible constraints, FPS offers bids can cover the amount of flexibility identified. In this SUC is described which bid parameters, such as flexibility direction, possibility for aggregation, etc., is addressed in order to select what bids can solve system operators needs and constraints considering the impact of each bid on both the operator's network and the neighbouring operator's network. In addition to the parameters of the bids, another aspect to consider when selecting bids is the coordination between DSO and TSO markets, namely the coordination in forwarding bids from the DSO market to the TSO market and vice versa. Furthermore, it is described which parameters are addressed in order to select which bids can and cannot be acquired and the merit order list (MOL) of the previous acquired bids. After the selection of the bids, based on the requirements described above, a merit order list (MOL) of the acquired bids is defined. Within the scope of this SUC, real-world implementation of technologies enabling the exchange of data about the bids that need to be analysed by the operator they are connected to and the bids that are forwarded from one network operator to another. This implementation is supported by work done in previous H2020 projects.
Steps	Selecting Bids
Related BUCs	WECL-PT-BUC-01; WECL-PT-BUC-02

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Table 4.58 - WECL-PT-SUC-05

Name SUC	Evaluate grid constraints
SUC ID	WECL-PT-SUC-05
Objectives	○ Demonstrate that it is feasible to implement these system processes efficiently and within the expected timeframe. ○ Ensure that the solution provided by the flexibility activation through the market mechanisms will not create additional problems from a grid point of view. ○ Ensure coordination between system operators for all scenarios. ○ Receive and send data between system operators in a secure manner.
Narrative	This SUC is focused on the steps that system operators should take to accept and validate the acquired bids in the market phase. This SUC supports the coordination between DSO and TSO in the market and activation phase. To avoid the acceptation and the activation of bids results in new constraints, the system operator to which the resource is connected should make a check of the state of its network in order to be sure that the activation does not cause any future problems. In this SUC it is described which parameters are addressed and analysed in order to validate the activation of the accepted bids in the market phase. To do this, the grid data used by system operators should be as up to date as possible to ensure that the bids that will be activated will not bring consequences. The dynamic grid constraints evaluation is a continuous process, during the market and activation phases. Within the scope of this SUC, real-world implementation of technologies enabling the exchange of data about the bids that are located in another system operator's network and may or may not be activated. This implementation is supported by work done in previous H2020 projects.
Steps	Evaluate grid constraints
Related BUCs	WECL-PT-BUC-01; WECL-PT-BUC-02

Table 4.59 - WECL-PT-SUC-06

Name SUC	Maintenance plans information exchange
SUC ID	WECL-PT-SUC-06
Objectives	○ Anticipate grid constraints due to maintenance works scheduled ○ Have an updated view of the maintenance plans defined by TSO and DSO from long-term until close to real-time.
Narrative	This SUC describes the processes of the exchange of maintenance plans from long-term until short-term planning, that affect the power flows between the transmission and distribution networks. An accurate definition of the maintenance plans is crucial for the operational activities of different stakeholder like consumers and grid operators. The maintenance work plans should be defined between distribution and transmission operators in an annual basis (long-term). This SUC has as objective to keep tracking the schedule of the maintenance works and update them when needed, by exchanging more detailed information during different timeframes (medium-term until close to real-time). This implementation is supported by work done in previous H2020 projects.
Steps	○ Year-ahead works programming ○ Monthly-ahead, Weekly-ahead or on event update of maintenance plans
Related BUCs	WECL-PT-BUC-03

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Table 4.60 - WECL-PT-SUC-07

Name SUC	Consumption and generation forecast information exchange
SUC ID	WECL-PT-SUC-07
Objectives	○ Improve TSO and DSO forecast processes by considering each other's generation and load forecasts. ○ Improve programming of TSO and DSO operation activities. ○ Contribute to the improvement of the forecast of technical constraints.
Narrative	This SUC presents the information exchanged between TSO and DSO regarding load and generation forecast in short-term. The load and generation forecasts should be aggregated by node level in interface TSO/DSO and could be disaggregated concerning their technology/type. The forecast of load and generation is essential to the operational planning of network in order to ensure a secure operation of the grid and warrant the security of supply. This information can be used by the operators to foresee grid constraints. This SUC explores the exchange of this information between operators in order to improve their planning activities, in short-term. The generation forecast should be disaggregated by technology type (Solar, Wind, Hydro, CHP, among others). The load forecast can also be exchanged in a disaggregated way by distinguishing different type of consumers (residential, industrial, etc.). This information should be exchanged day-ahead between operators, taking into consideration the market clearance results. This data exchange is to be exchanged every 24h. The data shall include the forecast the next 72h with a granularity of 15 minutes.
Steps	Exchange forecasts of disaggregated generation and load
Related BUCs	WECL-PT-BUC-01; WECL-PT-BUC-03

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Table 4.61 - WECL-PT-SUC-08

Name SUC	Short-circuit levels information exchange
SUC ID	WECL-PT-SUC-08
Objectives	○ Improve TSO and DSO grid planning by considering each other's short-circuit contributions in the TSO/DSO interface ○ Improve security of operation and quality of service
Narrative	This SUC presents the processes and information exchanged between TSO and DSO regarding short-circuit levels (three-phase short-circuits) foreseen in the EHV/HV substations in the short-term (day-ahead). The short-circuit levels is one of the most important operational security parameters and for that reason is crucial to monitor it. With the increase of the DERs the grid operators have the necessity to monitor the short-circuit levels closely throughout a shorter period (ideally daily). In the EHV/HV substations, located in the interface TSO/DSO, it is relevant to consider the active contributions for the short circuit power that comes from either transmission or distribution networks. For that reason, in this SUC is established the process to compute and exchange the complete short-circuit power in the interface nodes (EHV/HV substations) that could be used for operational planning purposes. The active contributions from transmission and distribution assets are specific and taken into consideration for the short-circuit power in different stages. The fault type under this SUC will focus only in the three-phase symmetrical short-circuit transient. For the day-ahead forecast of the short-circuit level in the interface, firstly TSO computes the short-circuit power only considering the contributions from its grid. Then these values are exchanged with the DSO in order to complete the final value of the short-circuit power for each EHV/HV substation, by adding the contribution from the distribution assets to it. The process finishes when both operators have the final value for the short-circuit levels in the TSO/DSO interface. Independently of the different topological arrangements of each country, the calculation of the short-circuit powers should follow a similar approach that is proposed in this BUC.
Steps	○ Short-circuit power definition at bay level considering TSO information ○ Short-circuit power definition at bay level considering TSO and DSO information
Related BUCs	WECL-PT-BUC-03

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Table 4.62 – KPIs adopted by the Portuguese Demonstrator SUCs

SUC ID	KPI_ID	Reference to KPI SUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
WECL-PT-SUC-02	KPI_N27	PT_SUC_KPI_01	Total power of avoided congestions through flexibility activation.	The difference of the total amount of power of the congestions (overloaded elements) in the grid for all periods of observation between the scenarios without flexibility activation (before BUC implementation) and with flexibility activation (after BUC implementation) by DSO and/or TSO action.	$TPAC = \sum_{t=1}^{T}\left(\sum_{i=0}^{M}{}_{before\ BUC}(P_{i,t} - P_i^{max}) - \sum_{k=0}^{N}{}_{after\ BUC}(P_{k,t} - P_k^{max})\right)$	$TPAC$: Total power of avoided congestions through flexibility activation (kW) M, N: number of overloaded elements in scenario without and with flexibility activation respectively. T: number of time intervals the entire period under consideration (e.g. for one day 24 intervals of 1 hour or 96 intervals of 15 minutes). $P_{i,t}, P_{k,t}$: power-flow in overloaded network element i or k for time interval t, respectively for the scenario without and with flexibility activation (kW). P_i^{max}, P_k^{max} : maximum power for network element i or k without it being overloaded, respectively for the scenario without and with flexibility activation (kW).	kW
WECL-PT-SUC-02	KPI_H21B	PT_SUC_KPI_02	Share of false positive and negative congestion forecasts	The ratio of the incorrectly forecasted congestions versus the total number of congestions forecasted.	$FFC_{\%} = \frac{C_{fc,f}}{C_{fc}} \cdot 100$	$FFC_{\%}$: Share of false positive and negative congestion forecasts (%) **Cfc,f:** is the number of false positive and negative congestion forecasts, so congestions forecasted where analysis of the measurements indicate that no congestion would have occurred, even if no curative actions by the DSO and TSO were taken (I.e., flexibility used). **Cfc:** is the total number of congestions forecasted.	%
WECL-PT-SUC-02	KPI_N28	PT_SUC_KPI_03	Maximum share of false positive and negative congestion forecasts	The maximum ratio of the incorrectly forecasted power congestions versus the total power of congestions forecasted.	$FFC_{\%} = Max\left(\frac{P_{fc,c}}{P_{fc}} \cdot 100\right)$	$FFC_{\%}$: Maximum share of false positive and negative congestion forecasts (%) **Pfc,f:** is the amount of power of false positive and negative congestion forecasts, so congestions forecasted where analysis of the measurements indicate that no congestion would have occurred, even if no curative actions by the DSO and TSO were taken (I.e., flexibility used). **Pfc:** is the total amount of power of congestions forecasted.	%
WECL-PT-SUC-02	KPI_H15A	PT_SUC_KPI_04	Requested flexibility	This indicator measures the amount of flexibility requested by the DSO or TSO for ancillary services from all the flexible resources of the portfolio.	$Flex_R = \sum_{T} P_{flex_{R_t}}$	$Flex_R$: Requested flexibility (kW or MW) $P_{flex_{R_t}}$: The amount of power requested by the DSO/TSO in order to solve their forecasted constraints at a time T (kW or MW) T: examined period	kW or MW

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WECL-PT-SUC-02	KPI_H05	PT_SUC_KPI_05	Curtailed RES (MWh/day)	RES accumulated energy curtailed in transmission or distribution grid before and after BUC implementation.	$E_{RES} = \sum_{i=1}^{I}\sum_{t=1}^{T}(E_{i,t}^{prod} - E_{i,t}^{inj})$	E_{RES}: Curtailed RES (MWh/day) I: set of RES facilities under consideration T: set of time intervals of period under consideration excluding periods of scheduled maintenance and outages $E_{i,t}^{prod}$: available energy production of the i-th RES facility at period t (kWh or MWh) $E_{i,t}^{inj}$: injected energy of the i-th RES facility at the period t (kWh or MWh)	kWh or MWh
WECL-PT-SUC-08	KPI_N25	PT_SUC_KPI_06	Comparison between the Isc max forecasted for the 63kV by the planning and the maximum short circuit value registered for the series under analysis	Deviation between the maximum planning estimated value of Isc (iscmax) and the maximum value effectively forecasted (MAX(Isc)) in a D-1 timeframe	$e = iscmax - MAX(I_{sc})$	e: deviation between the maximum planning estimated value of Isc (iscmax) and the maximum value effectively forecasted (MAX(Isc)) in a D-1 timeframe (A) iscmax: maximum planning estimated value of Isc (A) $\mathrm{MAX(I_{sc})}$: maximum value effectively forecasted in the D-1 (A)	A
WECL-PT-SUC-08	KPI_N30	PT_SUC_KPI_07	Comparison of the rated short circuit current of the circuit breakers for the 63kV and maximum short circuit value registered for the series under analysis	Deviation between the breaker limit Isc 63kVlim and the maximum value effectively forecasted (MAX(Isc)) in a D-1 timeframe	$\sigma = I_{sc}\ 63kVlim - MAX\ (I_{sc}\ )$	σ: deviation between the breaker limit Isc 63kVlim and the maximum value effectively forecasted (MAX(Isc)) in a D-1 timeframe (A) $\mathrm{I_{sc}\ 63kVlim}$: circuit breaker short circuit limit (A) $\mathrm{MAX\ (I_{sc}\ )}$: maximum value effectively forecasted in the D-1 (A)	A
WECL-PT-SUC-06	KPI_N31	PT_SUC_KPI_08	Nº of congestions/violations on DSO network	Anticipate distribution grids constraints because of scheduled maintenance actions.	$CAD_{\%} = \frac{\#congestion\ avoided}{\#congestion\ forcasetd} \cdot 100$	$CA_{\%}$: Nº of congestions/violations on DSO network (%) *# congestions avoided*: number of congestions avoided through the implementation of predictive actions resulting from the maintenance works information exchange *# congestions forecasted*: number of congestions correctly forecasted, so excluding the false positive congestions forecasts.	%
WECL-PT-SUC-06	KPI_N32	PT_SUC_KPI_09	Nº of congestions/violations on TSO network	Anticipate transmission grids constraints because of scheduled maintenance actions.	$CAT_{\%} = \frac{\#congestion\ avoided}{\#congestion\ forcasetd} \cdot 100$	$CAT_{\%}$: Nº of congestions/violations on TSO network (%) *# congestions avoided*: number of congestions avoided through the implementation of predictive actions resulting from the maintenance works information exchange *# congestions forecasted*: number of congestions correctly forecasted, so excluding the false positive congestions forecasts.	%
WECL-PT-SUC-07; WECL-PT-SUC-08	KPI_N33	PT_SUC_KPI_10	Improvement of the Forecast	This indicator measures the increase in forecast accuracy after the information exchange	$IF_{\%} = \frac{\%accuracy_{after\ information\ exchange}}{\%accuracy_{before\ information\ exchange}} \cdot 100$	IF: Improvement of the Forecast (%) % accuracy (after information exchange): forecast accuracy when extra data from information exchange between TSO and DSO is used in forecast (%) % accuracy (before information exchange): forecast accuracy when no data is exchanged between TSO and DSO (%)	%

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WECL-PT-SUC-01	KPI_N34	PT_SUC_KPI_11	Successful ending of Prequalification Process	This indicator measures the percentage of prequalification processes approved	$SPP_{\%} = \frac{Successful}{TPP} \cdot 100$	$SPP_{\%}$: successful Prequalification Processes (%) Successful: number of successful prequalification processes TPP: Total number of Prequalification process	%
WECL-PT-SUC-01	KPI_N46	PT_SUC_KPI_12	Nº Prequalification process that needs additional information	This indicator measures the percentage of prequalification processes that require additional information.	$PPA_{\%} = \frac{NPPA}{TPP} \cdot 100$	$PPA_{\%}$: Prequalification Processes that needs additional information (%) $NPPA$: Prequalification Process that needs additional information Nº Prequalification process that needs additional information TPP: Total number of Prequalification process	%

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4.4.5 Spanish demonstrators' BUCs KPIs

The OneNet Spanish demonstrator aims at unlocking the flexibility of the resources connected to the distribution system to contribute to congestion management at the distribution level. Local markets in which the DSO is the only buyer of the flexibility services, and the FSPs are the sellers, are tested. A local market platform (LMP) is developed and used by DSOs, MO and FSPs to enable the trading of flexibility products, two BUCs have been defined.

Table 4.63 and Table 4.64 summarise the key elements of the Spanish demonstrator's BUCs, while Table 4.65 presents the list of selected KPIs to evaluate them.

Table 4.63 - WECL-ES-BUC-01 BUC overview

BUC ID	WECL-ES-BUC-01
BUC Name	Long-term congestion management
Scope	Ensure that the DSO can procure flexibility in advance to solve specific local system loading issues on the distribution system thus deferring/eliminating the need for traditional system upgrades.
Objectives	○ Apply market procedures to obtain flexibility services attending DSO requirements; ○ Demonstrate that long term agreements are suitable amongst different available DERs; ○ Implement flexibility provision/usage through a market platform; and ○ Use consumer's demand-response in efficient flexibility services.
Services	Predictive active power management for CM
Type of coordination	Market-based DSO coordination

Table 4.64 - WECL-ES-BUC-02 BUC overview

BUC ID	WECL-ES-BUC-02
BUC Name	Short-term congestion management
Scope	Demonstration of the short-term local congestion management procurement of local flexibility by the DSO. Flexibility providers at both LV and MV will be able to participate. Two-time frame markets will be considered: Day ahead and intraday.
Objectives	○ Apply market procedures to obtain flexibility services attending short term DSO requirements; ○ Implement flexibility provision/usage through a market platform; and ○ Use consumer's demand-response in efficient flexibility services.
Services	Corrective and predictive active power management for CM
Type of coordination	Market-based DSO coordination

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Table 4.65 - List of KPIs for BUCs in the Western Cluster - Spain

BUC ID	KPI_ID	Reference to KPI BUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
WECL-ES-BUC-01; WECL-ES-BUC-02	KPI_H03	ES_BUC_KPI_01	Cost-effectiveness	Compare the cost for flexibility with avoided traditional grid cost (Cost of the flexibility solution against traditional solution).	$Cost_{effectiveness} = \frac{Cost_{flex}}{Cost_{Sub}} \cdot 100$	$Cost_{effectiveness}$: Cost effectiveness (%) $Cost_{Sub}$: Avoided traditional solution cost (€/MWh) $Cost_{flex}$: Cost of flexibility (€/MWh)	%
WECL-ES-BUC-01; WECL-ES-BUC-02	KPI_H04	ES_BUC_KPI_02	ICT costs	The term ICT cost comprises the information and communication technologies necessaries for DSO-MO-FSP coordination through platforms to develop new local markets.	$ICT_{cost} = \sum_{i=1}^{N_c} c_i$	ICT_{cost}: cost of ICT (€) c_i: generic ith cost directly related new local market implementation (€) Nc: overall number of cost items	€
WECL-ES-BUC-01; WECL-ES-BUC-02	KPI_H14A	ES_BUC_KPI_03	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.	$Flexibility_{\%} = \frac{\sum P_{Available_{Flexibility}}}{\sum P_{Total_{in_{Area}}}} \cdot 100$	$Flexibility_{\%}$: 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)	%
WECL-ES-BUC-01; WECL-ES-BUC-02	KPI_H20B	ES_BUC_KPI_04	Accuracy of load forecast	Accuracy of load forecast calculated T hour in advance.	$Load_{FA_{T,h}} = \frac{1}{N}\left(\sum_{t=1}^{N}\left\lvert\frac{FC_{load,t} - RL_{load,t}}{RL_{load,t}}\right\rvert\right).100$	$Load_{FA_{T,h}}$: Accuracy of load forecast calculated T hour in advance (%) FC_{load} : Load estimated T hours in advance (MW) RL_{load} : Real load (MW) N: Number of available data points	%
WECL-ES-BUC-01; WECL-ES-BUC-02	KPI_H23A	ES_BUC_KPI_05	Power exchange deviation	Tracking error between a set-point requested by the SO and the measure.	$P_{Deviation} = \frac{\lvert P_{accepted} - P_{activacted}\rvert}{P_{accepted}} \cdot 100$	$P_{Deviation}$: Power exchange deviation (%) $P_{accepted}$: accepted (contracted) power (kW) $P_{activacted}$: activated flexibility power (kW)	%
WECL-ES-BUC-01; WECL-ES-BUC-02	KPI_H13A	ES_BUC_KPI_06	Congestion reduction (magnitude)	This indicator measures the percentage decrease of load demand in the requested asset by a flexibility provider resource.	$CR = \frac{AL_{initial} - AL_{final}}{AL_{initial}} \cdot 100$	CR: Congestion reduction (%) $AL_{initial}$: asset load before delivering flexibility (initial asset load (kW)). AL_{final}: asset load a during delivery of flexibility (final asset load (kW)).	%
WECL-ES-BUC-01; WECL-ES-BUC-02	KPI_H09A	ES_BUC_KPI_07	Volume of transactions (Power)	This indicator measures the volume of transactions in kW. This indicator will be used to measure the volume of transactions (cleared bids) during the examined period T for each product.	$VT_P = \sum_T \sum_I P_{i,t}$	VT_P: Volume of transaction considering active power (kW) $P_{i,t}$: Volume offered or cleared capacity by the i-th flexible resource at time t (kW) I: Set of flexible resources. T: Examined period.	kW
WECL-ES-BUC-01; WECL-ES-BUC-02	KPI_H07	ES_BUC_KPI_08	Number of transactions	This indicator measures the number of transactions. This indicator will be used to measure the number of offered and cleared bids for each product.	$N_T = \sum_T n_{Bids,t}$	$n_{Bids,t}$: Number of offered or cleared bids at time t T: Examined period	–

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WECL-ES-BUC-01; WECL-ES-BUC-02	KPI_H11	ES_BUC_KPI_09	Number of products per demo	This indicator measures the percentage of products tested in the demos with respect to the number of products initially targeted by the demos.	$NPD = \frac{nP_{tested}}{nP_{targeted}} \cdot 100$	NPD: Number of products per demo (%) nP_{tested}: number of products tested in the BUC. $nP_{targeted}$: number of products initially targeted for the BUC.	%
WECL-ES-BUC-01; WECL-ES-BUC-02	KPI_H02	ES_BUC_KPI_10	Active participation	This indicator measures the percentage of customers actively participating in the demo with respect to the total customers that accepted the participation. This indicator will be used to evaluate the customer engagement plan.	$R = \frac{N_{active}}{N_{accept}} \cdot 100$	R: Active participation (%) N_{active}: Customers actively participating in the demo N_{accept}: Customers accepted to participate in the demo	%

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4.4.6 Spanish demonstrators' SUCs KPIs

Besides the two BUCs described in section 4.4.5, the Spanish demonstration has also designed one SUC, the Local Market Platform. This SUC serves both WECL-ES-BUC-01 and WECL-ES-BUC-02 BUCs and describes the platform that will be developed to enable the procurement of local flexibility by the Spanish DSOs, the communications among the different actors in the demonstration, the storage of information with regards to FSP pre-qualification and qualification, as well as the market-clearing for the different markets and products to be tested.

Table 4.66 summarises the key elements of the Spanish demonstrator's SUC, while the list of selected KPIs to evaluate it is provided in Table 4.67.

Table 4.66 - WECL-ES-SUC-01

Name SUC	Local Market Platform
SUC ID	WECL-ES-SUC-01
Objectives	○ Enable local flexibility procurement by DSOs ○ Open market sessions at the request of the DSO ○ Collect bids from market participants ○ Clear the local flexibility markets ○ Communicate market results to stakeholders
Narrative	This SUC describes the Local Market Platform, a system responsible for receiving the DSO needs on market sessions for flexibility procurement, the bids from FSPs, for the market-clearing and for the communication of market results to different stakeholders. The market platform will be the main information exchange enabler and will also act as a Flexibility Resource Register, as proposed by the Active System Management (ASM) report.
Steps	Flexibility Resource Register Market Request Market Session
Related BUCs	WECL-ES-BUC-01, WECL-ES-BUC-02

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Table 4.67 – KPIs adopted by the Spanish Demonstrator SUCs

SUC ID	KPI_ID	Reference to KPI SUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
WECL-ES-SUC-01	KPI_H03	ES_SUC_KPI_01	Cost-effectiveness	Compare the cost for flexibility with avoided traditional grid cost (Cost of the flexibility solution against traditional solution).	$Cost_{effectiveness} = \frac{Cost_{flex}}{Cost_{Sub}} \cdot 100$	$Cost_{effectiveness}$: Cost effectiveness (%) $Cost_{Sub}$: Avoided traditional solution cost (€/MWh) $Cost_{flex}$: Cost of flexibility (€/MWh)	%
WECL-ES-SUC-01	KPI_H04	ES_SUC_KPI_02	ICT costs	The term ICT cost comprises the information and communication technologies necessaries for DSO-MO-FSP coordination through platforms to develop new local markets.	$ICT_{cost} = \sum_{i=1}^{N_c} c_i$	ICT_{cost}: cost of ICT (€) c_i: generic i-th cost directly related new local market implementation (€) Nc: overall number of cost items	€
WECL-ES-SUC-01	KPI_H14A	ES_SUC_KPI_03	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.	$Flexibility_{\%} = \frac{\sum P_{Available_{Flexibility}}}{\sum P_{Total_{in_{Area}}}} \cdot 100$	$Flexibility_{\%}$: Percentage of available flexible power with respect to the total demand at a specific grid segment in reporting period (kW) $\sum P_{Available_{Flexibility}}$: Power in MW of available flexibility at a specific grid segment in reporting period (kW) $\sum P_{Total_{in_{Area}}}$: Total power demand in MW at DEMO grid segment (kW)	%
WECL-ES-SUC-01	KPI_H23A	ES_SUC_KPI_04	Power exchange deviation	Tracking error between a set-point requested by the SO and the measure.	$P_{Deviation} = \frac{\lvert P_{accepted} - P_{activacted} \rvert}{P_{accepted}} \cdot 100$	$P_{Deviation}$: Power exchange deviation (%) $P_{accepted}$: accepted (contracted) power (kW) $P_{activacted}$: activated flexibility power (kW)	%
WECL-ES-SUC-01	KPI_H09A	ES_SUC_KPI_05	Volume of transactions (Power)	This indicator measures the volume of transactions in kW. This indicator will be used to measure the volume of transactions (cleared bids) during the examined period T for each product.	$VT_P = \sum_T \sum_I P_{i,t}$	VT_P: Volume of transaction considering active power (kW) $P_{i,t}$: Volume offered or cleared capacity by the ith flexible resource at time t (kW). I: Set of flexible resources. T: Examined period.	kW
WECL-ES-SUC-01	KPI_H07	ES_SUC_KPI_06	Number of transactions	This indicator measures the number of transactions. This indicator will be used to measure the number of offered and cleared bids for each product.	$N_T = \sum_T n_{Bids,t}$	$n_{Bids,t}$: Number of offered or cleared bids at time t T: Examined period.	–

4.5 Eastern Cluster demonstrators' KPIs

The Eastern cluster comprises four demonstrator countries: Slovenia, Czech Republic, Poland, and Hungary. The Eastern cluster develops and extends capabilities of existing flexibility market platforms for TSO and DSO system services. The Polish demonstrator focuses on the market-based TSO-DSO coordination, while the Slovenian, Hungarian, and Czech demonstrators focus mainly on the DSO-Customer coordination.

The demonstrator in the Czech Republic focuses on creating a new market platform for non-frequency services and defining those services as standard products. The Hungarian demonstrator investigates P and Q control for DSO congestion management, voltage control, and TSO-DSO coordination through information exchange. The Polish demonstrator has the primary objective to enable the resources connected to the distribution level to support the system operation of both DSO and TSO. According to market-based coordination, a digital platform to procure the services for balancing, congestion management, and voltage control is to be developed and tested. The Slovenian demonstrator addresses several use cases regarding using the resources connected at the distribution level to defer and avoid grid reinforcements; hence, an interoperable marketplace for flexibility enablement, the optimisation of ancillary services procurement, and TSO-DSO coordination are to be developed.

4.5.1 Czech demonstrators' BUCs KPIs

The Czech Republic demonstrator aims to create a new market platform for non-frequency services and define those services as a standard product, which all actors can offer at the distribution level (DER, BESS, and DSR) in line with a TSO-DSO-Consumers coordination scheme. The market platform developed by the Czech Republic demonstrator concerns only non-frequency services for the DSO. However, the TSO is part of the market processes of the developed platform in terms of service evaluation, procurement process and safe and reliable grid operation. The TSO-DSO data exchange is integrated into the new platform proposed by the Czech demonstrator. The procurement of other than non-frequency grid services is out of the scope of this exercise, but the scheme can be enhanced to enable procurement of flexibility capacities to TSO as well.

The Czech Republic demonstrator is reflected in the platform's design to accommodate three types of non-frequency services. The process corresponding to each service is described separately for the platform implementation. At the end of the preparatory phase, the platform will allow an exchange between DSOs and FSPs, in other words to process, each of the BUCs. The test of the services is out of the scope of the Czech demonstrator, which scope is to produce a new platform for non-frequency services. For this reason, it is considered not reasonable to produce KPIs related to the test of services since it is out of scope.

Table 4.68, Table 4.69, and Table 4.70 report the Czech Republic demonstrator's BUCs; the corresponding list of the KPIs is available in Table 4.71.

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Table 4.68 - EACL-CZ-BUC-01 BUC overview

BUC ID	EACL-CZ-BUC-01
BUC Name	Nodal area congestion management
Scope	Describe an interaction amongst FSPs (aggregators/other flexibility providers), DSOs and IT platform in terms of provision of given service (Nodal area congestion management)
Objectives	Identify relevant ways of service procurement to address local congestion management in the distribution networks. The test is expected to deliver knowledge on how to specify bids/offer (data format for bid announcement, specific parameters of bid, transparent market environment, activation of flexibility).
Services	Predictive active power management for CM
Type of coordination	Market-based DSO coordination

Table 4.69 - EACL-CZ-BUC-02 BUC overview

BUC ID	EACL-CZ-BUC-02
BUC Name	Reactive power overflow management
Scope	Describe an interaction amongst FSPs (aggregators/other flexibility providers), DSOs and IT platform in terms of provision of given service (Reactive power overflow management)
Objectives	Identify relevant ways of service procurement to control flow of reactive power between TSO and DSO in order to keep reactive power flows in given limits. The test is expected to deliver knowledge on how to specify bids/offer (data format for bid announcement, specific parameters of bid, transparent market environment).
Services	Predictive reactive power management for VC
Type of coordination	Market-based DSO coordination

Table 4.70 - EACL-CZ-BUC-03 BUC overview

BUC ID	EACL-CZ-BUC-03
BUC Name	Voltage Control
Scope	Describe an interaction amongst FSPs (aggregators/other flexibility providers), DSOs and IT platform in terms of provision of given service (Voltage control)
Objectives	Identify relevant ways of service procurement to address voltage issues in the distribution networks through reactive power. The test is expected to deliver knowledge on how to specify bids/offer (data format for bid announcement, specific parameters of bid, transparent market environment).
Services	Predictive reactive power management for VC
Type of coordination	Market-based DSO coordination

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Table 4.71 - List of KPIs for BUCs in the Eastern Cluster – Czech Republic

BUC ID	KPI_ID	KPI_BN	KPI Name	KPI description	Formula	Variables	Unit of measurement
EACL-CZ-BUC-01	KPI_H14A	CZ_BUC_KPI_01	Increase of active power-based flexibility	The BUC tests flexibility providers' ability (aggregator) to collect and offer DSOs active power-based flexibility to control load in relevant nodal areas. The flexibility is managed through charging management of EV charging poles.	$Flexibility_{\%} = \frac{\sum PAP}{\sum PTA} \cdot 100$	$Flexibility_{\%}$: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)	%

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4.5.2 Czech demonstrators' SUCs KPIs

The SUCs proposed by the Czech demonstrator deal with the non-frequency services and the traffic light system. The SUCs and the related KPIs aim to demonstrate the system's ability to allow relevant data exchange interactions needed for reporting of planned/unplanned outages, procured/delivered services, and delivery of information on bids/offers. The system has to deal with specific requirements for the system when it comes to non-frequency services as they have different parameters for activation and procurement procedure.

Table 4.72 and Table 4.73 reports the Czech Republic demonstrator's SUCs; the corresponding KPIs are listed in Table 4.74.

Table 4.72 - EACL-CZ-SUC-01

Name SUC	Non-frequency services
SUC ID	EACL-CZ-SUC-01
Objectives	Enable the procurement of non-frequency services for DSO to address the grid related issues
Narrative	The newly created IT environment shall cover activities related to procurement of non-frequency services. The system shall: ○ accommodate different types of non-frequency services ○ enable DSOs to procure non-frequency services in a way that fits to needs of operation of distribution grid ○ allow access for FSP/units to the platform in order to provide non-frequency services ○ enable via traffic light system availability for activation of relevant resources
Steps	Administration module Market module non-frequency services Availability for activation of relevant resources (via traffic light system)

Table 4.73 - EACL-CZ-SUC-02

Name SUC	Traffic light system
SUC ID	EACL-CZ-SUC-02
Objectives	○ Enable notification of unavailability of DSO to other market participants ○ Allowing safe and reliable operation of distribution grid
Narrative	In order to notify properly grid unavailability, the traffic light system shall enable: ○ registration of all participants FSP/DSO/TSO into the system (database includes also reserved capacity of FSP, location and other details) ○ DSO to report and announce outages (interruptions) / planned outages ○ FSP to report day ahead contracted capacities (for DSO to consider load in given nodal areas)
Steps	Administration module Outages/planned outages announcement FSP – contracted capacities of Ancillary services

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Table 4.74 – KPIs adopted by the Czech Demonstrator SUCs

SUC ID	KPI_ID	Reference to KPI SUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
EACL-CZ-SUC-01	KPI_N47	CZ_SUC_KPI_01	Increase in flexibility providers (units)	Implementation of IT market platform will enable an increased number of participants (units) in providing flexibility. Recently only major resources are involved in case flexibility is needed as DSOs are not aware of the potential of smaller aggregated resources and thus, this potential is not known and used. IT platform will make this potential available and enable the participation of new resources in the market.	$\mathrm{INFFP} = \frac{N_{FSP}(platform)}{N_{FSP}} \cdot 100$	INFFP: Increase in flexibility providers (units) (%) $number\ of\ FSP$: number of flexibility providers eligible according to recent conditions $number\ of\ FSP\ (platform)$: number of providers for aggregated flexibility after implementation of market platform	%
EACL-CZ-SUC-02	KPI_N35	CZ_SUC_KPI_02	Increase in availability of flexibility	Implementation of the traffic light scheme will enable swift sharing of data on planned outages to aggregators – this represent added value, especially if the maintenance is finished before the scheduled date (planned deadline). As this information was not previously available, the advantage lies mainly in enhancing the provision of the aggregator's flexibility, more effective utilization of flexibility and unlocking the full potential of their flexibility portfolio.	$IAF = \frac{FP}{\mathrm{FPS}} \cdot 100$	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)	%

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4.5.3 Hungarian demonstrators' BUCs KPIs

A significant new capacity is expected to be connected to the medium-voltage distribution network in Hungary, which will cause a burden on the voltage management of distribution networks. Hungarian medium-voltage overhead line networks are characterized by long feeders and relatively small line ampacities, making them prone to contingencies. It is important to reduce the grid constraints to increase the integration of large-scale and small-scale flexibility resources.

The main primary assets in the demonstration are medium voltage distribution lines (mainly 20 kV overhead lines), high voltage to medium voltage transformers (120 kV/20 kV), high voltage lines (120 kV overhead lines) and high voltage to high voltage (220 kV/120 kV and 400 kV/120 kV) transformers. The availability of these assets determines the availability of the offered services across the grid.

Two solutions are proposed for the Hungarian demonstrator: the functional extension of a national flexibility platform and the development of an expert system to maximise the value offered by assets providing flexibility. The solution includes the definition of new products with related use cases, product and grid prequalification process, and operation optimisation. The solutions will be demonstrated in the service area of MVM and E.ON DSOs to test their scalability.

These markets will introduce a new player in the form of flexibility providers; these entities are similar to aggregators but are able to activate services based on their locations and are expected to involve smaller customers in the cooperation. Flexibility providers will be able to offer their services to the TSO (mostly balancing and frequency services) and to the DSO (mostly non-frequency, like congestion management, voltage control), which necessitates a certain level of cooperation. The flexibility providers are expected to bring flexibility, provided by various resources (e.g. ~300 MW control range of existing aggregators, demand-side, storage and solar photovoltaic plants) to the market. In the project, the capabilities of this platform will be compared to European benchmarks to identify the most valuable functionalities that could drive the development of the extensions.

The extensions will focus on four areas: definition of new potential standardised flexibility services, elaboration of the related product and grid prequalification processes, the conceptualisation of location-based service activation and the coordination of access to local and system-level services. The extensions are planned to be gradually introduced and demonstrated.

Table 4.75 and Table 4.76 present the BUCs defined for the Hungarian demonstrator, namely, the MV feeder voltage control and the HV/MV transformer overload. Table 4.77 shows the Hungarian demonstrator's KPIs defined to assess the impact of the BUCs quantitatively.

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Table 4.75 - EACL-HU-BUC-01 BUC overview

BUC ID	EACL-HU-BUC-01
BUC Name	MV feeder voltage control
Scope	Increasing renewable penetration causes the violation of standard voltage bands on MV lines. The main scope of EACL-HU-BUC-01 is to mitigate voltage variations of MV feeders by activating flexibility services.
Objectives	○ Keep actual voltage values of MV feeders within the standard bands.
Services	Predictive active and reactive power management for VC
Type of coordination	Market-based DSO coordination

Table 4.76 - EACL-HU-BUC-02 BUC overview

BUC ID	EACL-HU-BUC-02
BUC Name	HV/MV transformer overload
Scope	Increasing renewable penetration causes overloading of HV/MV transformers. The main scope of EACL-HU-BUC-02 is to mitigate the overloading of HV/MV transformers by activating flexibility services.
Objectives	○ Avoid overloading of HV/MV transformers in all operational states of the power system.
Services	Predictive active and reactive power management for VC
Type of coordination	Market-based DSO coordination

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Table 4.77 - List of KPIs for BUCs in the Eastern Cluster – Hungary

BUC ID	KPI_ID	Reference to KPI BUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
EACL-HU-BUC-01; EACL-HU-BUC-02	KPI_H02	HU_BUC_PI_01	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.	$\text{KPI\_H02} = \frac{N_{active}}{N_{accept}} \cdot 100$	KPI_H02: Active participation (%) N_{active}: Customers actively participating in the demo exercise N_{accept}: Number of service providers enrolled in the demonstration exercise (KPI_H01)	%
EACL-HU-BUC-02	KPI_H12	HU_BUC_PI_02	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 solutions developed by the demonstration activities.	$ATR_{\%} = \frac{N_{TR_{Flex}}}{N_{TR}} \cdot 100$	$ATR_{\%}$: 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	%
EACL-HU-BUC-01; EACL-HU-BUC-02	KPI_H16	HU_BUC_PI_03	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.	$FARR_{P\%} = \frac{\sum_{t=0}^{T} P_{flex,Activated_t}}{\sum_{t=0}^{T} P_{reserved_t}} \cdot 100$ $FARR_{Q\%} = \frac{\sum_{t=0}^{T} Q_{flex,Activated_t}}{\sum_{t=0}^{T} Q_{reserved_t}} \cdot 100$	$FARR_{P\%}$: 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); $P_{reserved_t}$: Total flexibility from FSP reserved in the network at each time instant t (Active power) (kW). The same applied to reactive power Q (kVAr).	%
EACL-HU-BUC-01	KPI_H17	HU_BUC_PI_04	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.	$ATR_{\%} = \frac{N_{TR_{Flex}}}{N_{TR}} \cdot 100$	$ATR_{\%}$: 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	%
EACL-HU-BUC-01; EACL-HU-BUC-02	KPI_H08	HU_BUC_PI_05	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.	$B_m = min\{bid\ set\}$ $B_M = max\{bid\ set\}$ $B_A = average\{bid\ set\}$	Minimal (B_m), maximal (B_M) and average (B_A) prices of the auctions given a certain period T of observation. The calculation concern active power (P) capacity auctions, active power (P) activations (energy) auctions, reactive power (Q) capacity auctions, and reactive power (Q) activations.	€/kW, or €/kWh €/kVAr, or €/kVArh
EACL-HU-BUC-01; EACL-HU-BUC-02	KPI_H21A	HU_BUC_PI_06	Share of correctly forecasted contingencies	The “Effectiveness of the event forecasting” KPI aims to assess the forecasting tools' performance in predicting specific circumstances.	$CFC_{\%} = \frac{C_{fc,c}}{C_o} \cdot 100$	$CFC_{\%}$: 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).	%

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4.5.4 Hungarian demonstrators' SUCs KPIs

The SUCs proposed for the Hungarian demonstrator deal with prequalification, forecasting, and procurement. The aim is to develop the methodologies to enable product and grid prequalification, allow the DSO to determine the volume and spatial temporal location of flexibility needs, and collect the supply bid in the order book to address then market clearing. Table 4.78, Table 4.79, and Table 4.80 present the Hungarian demonstrator's SUCs, Table 4.81 shows the corresponding KPIs.

Table 4.78 - EACL-HU-SUC-01

Name SUC	Prequalification
SUC ID	EACL-HU-SUC-01
Objectives	Product and grid prequalification
Narrative	Product and grid prequalification
Steps	Prequalification Request Product and grid prequalification Approval of prequalification Prequalification Results
Related BUCs	EACL-HU-BUC-01, EACL-HU-BUC-02

Table 4.79 - EACL-HU-SUC-02

Name SUC	Forecasting
SUC ID	EACL-HU-SUC-02
Objectives	Forecast of flexibility needs
Narrative	DSO determines the volume and spatial temporal location of flexibility needs
Steps	DSO receives data for modelling flexibility needs DSO determines flexibility needs DSO informs TSO on flexibility needs DSO delivers flexibility needs
Related BUCs	EACL-HU-BUC-01, EACL-HU-BUC-02

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Table 4.80 - EACL-HU-SUC-03

Name SUC	Procurement
SUC ID	EACL-HU-SUC-03
Objectives	Procurement of bids
Narrative	Collection of supply bid in the order book, market clearing in week ahead and day ahead.
Steps	DSO receives data for modelling flexibility needs DSO determines flexibility needs DSO informs TSO on flexibility needs DSO delivers flexibility needs Flexibility market opening, DSO needs announced FSPs submit bids D-1 FSP bid prequalification FSP bids delivered Clearing Announcement
Related BUCs	EACL-HU-BUC-01, EACL-HU-BUC-02

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Table 4.81 – KPIs adopted by the Hungarian Demonstrator SUCs

SUC ID	KPI_ID	Reference to KPI SUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
EACL-HU-SUC-01	KPI_N45	HU_SUC_KPI_01	Total Computational Runtime	This indicator measures the execution time of market clearance under different coordination schemes.	$RT = T_{final} - T_{initial}$	RT: Total Computational Runtime (s) $T_{initial}$: Time at the end of running the algorithm (s). T_{final} : Time at the beginning of running the algorithm (s).	s

4.5.5 Polish demonstrators' BUCs KPIs

The Polish demo focuses on testing the possibility of using market-based flexibility by DSOs and TSOs to increase the efficiency, security and reliability of power systems. As part of the project, technical solutions will be defined, tested and demonstrated in real conditions, allowing to test the services provided by flexibility resources, which in the future can be used to support network management by Operators and can bring tangible benefits. Activities focus on the design and implementation of a flexibility services market platform, which will be used to test the provision of products based on active power management for balancing, limitation management and voltage control services.

Currently, there is no market for flexibility services in Poland, and DSOs do not purchase flexibility services and products. The TSO has access to standard balancing products on the dedicated balancing market, but the requirements for participation in this market prevent small service providers from participating in the balancing market. A new approach to balancing services provision by flexible service providers is being developed in the Polish demonstrator. The main idea is to enable small and medium-sized customers connected to the DSO's network to provide day-ahead market balancing services to TSO. The customer will be able to provide standard balancing products like FRR, RR, etc. to TSO alone or with the help of an aggregator. It is assumed that balancing auctions will be organized by PSE on a continuous basis (daily) to support the continuous process of balancing the power system.

A new service dedicated to DSO needs will be tested during the project for congestion management and voltage control based on active power management. The same product will be used in the day ahead and medium/long term time frame. The DSO will acquire those services in the event-driven approach, which means the auction will be only called when the need for such services is identified. The day-ahead market may be a result of the change in the forecast or some events that result from the network reconfiguration. Medium/long-term auction will be used for the planned works scheduled by the DSO. In that case, the DSO will pay first for the capacity and then, after activation, for energy (if this will be still needed). The auction will be called a few weeks ahead, and the activation will take place in the day-ahead timeframe. The project will also develop methods of coordinating activities between TSO-DSO to optimize the process of obtaining services.

Table 4.82, Table 4.83, Table 4.84, Table 4.85 present the four Polish demonstrator's BUCs. Table 4.86 shows the KPIs for the BUCs of the Polish pilot.

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Table 4.82 - EACL-PL-BUC-01 BUC overview

BUC ID	EACL-PL-BUC-01
BUC Name	Prequalification of resources provided by FSPs to support flexibility services in the Polish demonstration
Scope	The description of prequalification of resources (DER) to participate in the flexibility market represented by Flexibility Platform (FP)
Objectives	○ Register DER in the Flexibility Register, which will enable the submission of bids on FP and participation in the flexibility market.
Services	Service agnostic
Type of coordination	Market-based TSO-DSO coordination

Table 4.83 - EACL-PL-BUC-02 BUC overview

BUC ID	EACL-PL-BUC-02
BUC Name	Managing flexibility delivered by DER to provide balancing services to TSO
Scope	Bring the flexibility provided by resources connected to the distribution network (Low and Medium voltage, LV/MV) in the form of active power and/or active energy to the polish TSO balancing market.
Objectives	○ Ensure that the energy system is balanced and frequency is kept within the permitted range; ○ Open a balancing market for resources connected to the distribution network (LV/MV); ○ Develop rules for coordination between TSO and DSO when using flexibility services; and ○ Create revenue opportunities for market participants for providing balancing services in the form of balancing capacity products and balancing energy.
Services	aFRR, mFRR, RR
Type of coordination	Market-based TSO-DSO coordination

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Table 4.84 - EACL-PL-BUC-03 BUC overview

BUC ID	EACL-PL-BUC-03
BUC Name	Event-driven Active Power Management for Congestion Management and voltage control by the DSO
Scope	The scope of this BUC covers the use by the distribution system operator (DSO) of the service providers' active power capabilities to eliminate congestion and voltage violations in the distribution network. The services would be purchased using an IT Flexibility platform on market condition.
Objectives	○ Elimination of congestion in the distribution network using active power; ○ Elimination of voltage violations in the distribution MV and LV network, using active power; and ○ Coordination of TSO and DSO activities in the field of congestion management and voltage control.
Services	Predictive active power management for CM and VC
Type of coordination	Market-based TSO-DSO coordination

Table 4.85 - EACL-PL-BUC-04 BUC overview

BUC ID	EACL-PL-BUC-04
BUC Name	Balancing Service Provider on the Flexibility Platform
Scope	Introduction of BSP, linking it with FSP or FSPA, creation of a scheduling unit and its prequalification for the Balancing Market
Objectives	○ Enable pre-qualified FSP and FSPA resources to provide balancing services in the balancing market via BSP.
Services	aFRR, mFRR, RR
Type of coordination	Market-based TSO-DSO coordination

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Table 4.86 - List of KPIs for BUCs in the Eastern Cluster – Poland

BUC ID	KPI_ID	Reference to KPI BUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
EACL-PL-BUC-01;	KPI_H06	PL_BUC_KPI_01	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	Questionnaire	Range [0,10] where 0 means the worst case; 10 means the best case
EACL-PL-BUC-01;	KPI_H22A	PL_BUC_KPI_02	Percentage of successfully prequalified FSPs	This indicator presents the percentage of flexibility services providers in the demo that are successfully prequalified against the number of FSPs only registered on the flexibility platform	$K_{FSP} = \frac{N_{FSP\,preq}}{N_{FSP\,reg}} \cdot 100$	K_{FSP} : Indicator showing the percentage of flexibility service providers that are successfully prequalified against number of flexibility services providers only registered on the flexibility platform (%) $N_{FSP\,preq}$ – number of flexibility service providers that are successfully prequalified $N_{FSP\,reg}$ – number of flexibility service providers registered on the flexibility platform	%
EACL-PL-BUC-01;	KPI_H22B	PL_BUC_KPI_03	Percentage of successfully prequalified FSPAs	This indicator presents the percentage of flexibility services providers being aggregators in the demo that are successfully prequalified against the number of FSPAs only registered on the flexibility platform	$K_{FSPA} = \frac{N_{FSPA\,preq}}{N_{FSPA\,req}} . 100$	K_{FSPA} : indicator showing the percentage of flexibility services providers being aggregator that are successfully 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.	%
EACL-PL-BUC-01;	KPI_H22C	PL_BUC_KPI_04	Number or certified DERs	Total number of DERs representing certified resourced on the flexibility platform	$N_{DER,cer}$	$N_{DER,cer}$: Number of certified DERs	_
EACL-PL-BUC-01;	KPI_H22D	PL_BUC_KPI_05	Capacity of certified DERs	Total capacity of certified DERs	$P_{DER\_cer} = \sum_{i=1}^{I} P_{DER\_cer,i}$	$P_{DER_{cer}}$: Capacity of certified DERs (kW) $P_{DER,i}$: certified amount of kW of $DER, i-th$ (kW)	kW
EACL-PL-BUC-02	KPI_H18A	PL_BUC_KPI_06	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	$VBS_{UP} = \sum_{n=1}^{N} \mathrm{aFRR(FP)_{U,n}} + \sum_{m=1}^{M} \mathrm{mFRR(FP)_{U,m}} + \sum_{k=1}^{K} \mathrm{RR(FP)_{U,k}}$ Sum of capacity reserves products direction UP (aFRR_up, mFRR_up, RR_up) offered by BSPs on the flexibility platform	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) $\mathrm{RR(FP)_{U,k}}$: Replacement Reserve (up-reserve) of unit k submitted to the flexibility platform (kW)	kW

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EACL-PL-BUC-02	KPI_H18B	PL_BUC_KPI_07	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	$VBS_{UP-BM} = \sum_{n=1}^{N} \mathrm{aFRR(FP,BM)}_{U,\mathrm{n}} + \sum_{m=1}^{M} \mathrm{mFRR(FP,BM)}_{U,\mathrm{m}} + \sum_{k=1}^{K} \mathrm{RR(FP,BM)}_{U,\mathrm{k}}$	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
EACL-PL-BUC-02	KPI_H18C	PL_BUC_KPI_08	Volume of accepted balancing service offers for UP reserves	Volume of balancing services offers for UP reserves (aFRR, mFRR, RR) from flexibility platform accepted on the Balancing Market. Sum of capacity reserves products direction UP (aFRR_up, mFRR_up, RR_up) accepted on the Balancing Market.	$VBS_{UP-A} = \sum_{n=1}^{N} \mathrm{aFRR(BM)}_{\mathrm{U,n}} + \sum_{m=1}^{M} \mathrm{mFRR(BM)}_{\mathrm{U,m}} + \sum_{k=1}^{K} \mathrm{RR(BM)}_{\mathrm{U,k}}$	VBS_{UP-A}: Volume of accepted balancing service offers for UP reserves (kW) $\mathrm{aFRR(BM)}_{\mathrm{U,n}}$: Automatic Frequency restoration reserve (up-reserve) of unit n accepted on the Balancing Market (kW) $\mathrm{mFRR(BM)}_{\mathrm{U,m}}$: Manual Frequency restoration reserve (up-reserve) of unit m accepted on the Balancing Market (kW) $\mathrm{RR(BM)}_{\mathrm{U,k}}$: Replacement Reserve (up-reserve) of unit k accepted on the Balancing Market (kW)	kW
EACL-PL-BUC-02	KPI_H18D	PL_BUC_KPI_09	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.	$VBS_{DO} = \sum_{n=1}^{N} \mathrm{aFRR(FP)}_{D,\mathrm{n}} + \sum_{m=1}^{M} \mathrm{mFRR(FP)}_{D,\mathrm{m}} + \sum_{k=1}^{K} \mathrm{RR(FP)}_{D,\mathrm{k}}$	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
EACL-PL-BUC-02	KPI_H18E	PL_BUC_KPI_10	Volume of balancing service offers for DOWN reserves transferred to BM	Volume of balancing service offers for DOWN reserves (aFRR, mFRR, RR) transferred by the flexibility platform to the Balancing Market. Sum of capacity reserves products direction DOWN (aFRR_down, mFRR_down, RR_down) transferred by the flexibility platform to the Balancing Market.	$VBS_{DO-BM} = \sum_{n=1}^{N} \mathrm{aFRR(FP,BM)}_{D,\mathrm{n}} + \sum_{m=1}^{M} \mathrm{mFRR(FP,BM)}_{D,\mathrm{m}} + \sum_{k=1}^{K} \mathrm{RR(FP,BM)}_{\mathrm{D,k}}$	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)	kW
EACL-PL-BUC-02	KPI_H18F	PL_BUC_KPI_11	Volume of accepted balancing service offers for DOWN reserves	Volume of balancing services offers for DOWN reserves (aFRR, mFRR, RR) from the flexibility platform accepted on the Balancing Market. Sum of capacity reserves products direction DOWN (aFRR_down, mFRR_down, RR_down) accepted on the Balancing Market.	$VBS_{DO-A} = \sum_{n=1}^{N} \mathrm{aFRR(BM)}_{D,\mathrm{n}} + \sum_{m=1}^{M} \mathrm{mFRR(BM)}_{D,\mathrm{m}} + \sum_{k=1}^{K} \mathrm{RR(BM)}_{\mathrm{D,k}}$	VBS_{DO-A}: Volume of accepted balancing service offers for DOWN reserves (kW) $\mathrm{aFRR(BM)}_{D,\mathrm{n}}$: Automatic Frequency restoration reserve (down-reserve) of unit n accepted on the Balancing Market (kW) $\mathrm{mFRR(BM)}_{D,\mathrm{m}}$: Manual Frequency restoration reserve (down-reserve) of unit m accepted on the Balancing Market (kW) $\mathrm{RR(BM)}_{D,\mathrm{k}}$: Replacement Reserve (up-reserve) of unit k accepted on the Balancing Market (kW)	kW

EACL-PL-BUC-02	KPI_H18G	PL_BUC_KPI_12	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.	$V_{BE} = \sum_{i=1}^{I} E\,(FP)_i$	V_{BE}: Volume of balancing energy offers (kWh) $E(FP)_i$: Balancing energy offered by unit i-th on the flexibility platform (kWh)	kWh
EACL-PL-BUC-02	KPI_H18H	PL_BUC_KPI_13	Volume of balancing energy offers transferred to the BM	Volume of balancing energy offers transferred by the flexibility platform to the Balancing Market	$V_{BE-BM} = \sum_{i=1}^{I} E\,(FP, BM)_i$ Sum of balancing energy transferred by the flexibility platform to the Balancing Market	V_{BE-BM}: Volume of balancing energy offers transferred to the BM (kW) $E(FP, BM)_i$: Balancing energy of unit i-th transferred by the flexibility platform to the Balancing Market (kWh)	kWh
EACL-PL-BUC-02	KPI_H18I	PL_BUC_KPI_14	Volume of accepted balancing energy offers	Volume of balancing energy from the flexibility platform accepted on the Balancing Market	$V_{BEA} = \sum_{i=1}^{I} E\,(BM)_i$ Sum of balancing energy accepted on the Balancing Market	V_{BEA}: Volume of accepted balancing energy offers (kWh) $E(BM)_i$: Balancing energy of unit i-th accepted on the Balancing Market (kWh)	kWh
EACL-PL-BUC-03	KPI_H15A	PL_BUC_KPI_15	Requested flexibility (Power)	This indicator measures the amount of flexibility requested by DSO on the market Platform for congestion management and voltage control services to solve identified issues in the DSO network.	$P_{Flex_R} = \sum_{t=1}^{T} P_{flex_{R_t}}$	P_{Flex_R}: Requested flexibility (Power) (kW) $P_{flex_{R_t}}$: The amount of power requested by the DSO on the market platform for congestion management and voltage control services at time t (kW) T: examined period	kW
EACL-PL-BUC-03	KPI_H10	PL_BUC_KPI_16	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	$ARF_{\%} = \frac{\sum_i \frac{F_{FSP\_bid_i}}{F_{FSP\_req_i}}}{N_{req}} \cdot 100$	$ARF_{\%}$: Flex volume offered by FSP vs. Flex request by DSO (%) $F_{FSP\_bid_i}$- The amount of flexibility (kW) offered by FSPs for a particular (i) auction $F_{DSO\_req_i}$ – The amount of flexibility (kW) requested by DSO for a particular (i) auction N_{req} – total number of auctions called by DSO at given period	%
EACL-PL-BUC-03	KPI_H23A	PL_BUC_KPI_17B	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)	$P_{Deviation} = \frac{\lvert P_{accepted} - P_{activacted} \rvert}{P_{accepted}} \cdot 100$	$P_{Deviation}$: Power exchange deviation (%) $P_{accepted}$: accepted (contracted) power (kW) $P_{activacted}$: activated flexibility power (kW)	%
EACL-PL-BUC-03	KPI_H23B	PL_BUC_KPI_18B	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)	$E_{Deviation} = \frac{\lvert E_{accepted} - E_{activacted} \rvert}{E_{accepted}} \cdot 100$	$E_{Deviation}$: Energy exchange deviation (%) $E_{accepted}$: accepted (contracted) energy (kWh) $E_{activacted}$: activated flexibility energy (kWh)	%
EACL-PL-BUC-03	KPI_H23C	PL_BUC_KPI_17	Flexibility volume delivered by FSP (in power) vs Flex bids selected to be activated	The average ratio of delivered flexibility in terms of power by FSPs and the power flexibility bids requested by DSO at a given period This KPI considers the FSP reliability calculating the KPI for the whole demo period and all auctions considering all involved FSP.	$FVD_{P\%} = \frac{\sum_{j=1}^{N_{FSP}} \sum_{i=1}^{N_{req}} \frac{P_{delivered\,i,j}}{P_{accepted\_bids\,i,j}}}{N_{req}} \cdot 100$	$FVD_{\%}$: Flexibility volume delivered by FSP (in power) vs. Flex bids selected to be activated (%) $P_{delivered_{i,j}}$: the amount of flexibility (kW) which is delivered the j-th FSPs as the request of DSO for a particular i-th auction $P_{accepted\_bids_{i,j}}$: the amount of flexibility (kW) that the j-th FSP bids and has been selected to be activated for a particular i-th auction N_{req}: total number of auctions called by DSO at given period N_{FSP}: total number of FSPs	%

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EACL-PL-BUC-03	KPI_H23D	PL_BUC_KPI_18	Flexibility volume delivered by FSP (in energy) vs Flex bids selected to be activated	The average ratio of delivered flexibility in terms of energy by FSPs and the energy flexibility bids requested by DSO at given period T. This KPI considers the FSP reliability calculating the KPI for the whole demo period (T) and all auctions considering all involved FSP.	$FVD_{E\%} = \frac{\sum_{j=1}^{N_{FSP}} \sum_{i=1}^{N_{req}} \frac{E_{delivered_{i,j}}}{E_{accepted\_bids_{i,j}}}}{N_{req}} \cdot 100$	$FVD_{E\%}$: Flexibility volume delivered by FSP (in energy) vs. Flex bids selected to be activated (kWh) $E_{delivered_{i,j}}$: the amount of flexibility (kWh) which is delivered the j-th FSPs as the request of DSO for a particular i-th auction $E_{accepted\_bids_{i,j}}$: the amount of flexibility (kWh) that the j-th FSP bids and has been selected to be activated for a particular i-th auction N_{req}: total number of auctions called by DSO at given period N_{FSP}: total number of FSPs	%
EACL-PL-BUC-03	KPI_H12	PL_BUC_KPI_22A	Number of avoided technical restrictions (congestions)	Avoided congestions thanks to the measures implemented in the demo	$ATR_{\%} = \frac{N_{TR_{Flex}}}{N_{TR}} \cdot 100$	$ATR_{\%}$: share Number of avoided technical restrictions (congestions) (%) N_{TR}: Total number of expected technical restrictions $N_{TR_{Flex}}$: Total number of technical restrictions solved through activation of flexibility services	%
EACL-PL-BUC-03	KPI_H17	PL_BUC_KPI_22**B**	Number of avoided technical restrictions (voltage violations)	Avoided voltage problems thanks to the measures implemented in the demo	$ATR_{\%} = \frac{N_{TR_{Flex}}}{N_{TR}} \cdot 100$	$ATR_{\%}$: share Number of avoided technical restrictions (voltage violations) (%) N_{TR}: Total number of expected technical restrictions $N_{TR_{Flex}}$: Total number of technical restrictions solved through activation of flexibility services	%
EACL-PL-BUC-04	KPI_H19A	PL_BUC_KPI_19	Number of DER available for BSPs	Total number of certified DERs prequalified to provide balancing services available for BSPs	N_{DER_av}	N_{DER_av} : Number of available DER prequalified for balancing services	–
EACL-PL-BUC-04	KPI_H19B	PL_BUC_KPI_20	The 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	$K_{BAL} = \frac{N_{DER\_BAL}}{N_{DER\_ALL}}.100$	K_{BAL} : 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 (%) $N_{DER_{BAL}}$: Number of resources represented by the number of DERs, prequalified to provide balancing services $N_{DER_{ALL}}$: Total number of resources represented by the number of DERs certified on the Flexibility Platform	%
EACL-PL-BUC-04	KPI_H19C	PL_BUC_KPI_21	Total capacity of DER available for BSP	Total capacity of certified DERs ready to provide balancing services available for BSPs. Amount of kW of resources prequalified to provide balancing services.	$TP_{DER-BSP} = \sum_{i=1}^{I} P_{DER\_av,i}$	$TP_{DER-BSP}$: Total capacity of DER available for BSP (kW) $P_{DER,i}$: Available amount of kW of DER, i to provide balancing services (kW)	kW

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4.5.6 Polish demonstrators' SUCs KPIs

The SUCs proposed for the Polish demonstrator deal with the prequalification of resources, the process of bidding for day-ahead balancing, congestion management, and voltage control. The prequalification of resources aims to register the DERs and their flexibility potential in the Flexibility Register, which will enable the submission of bids and participation in the flexibility market. The SUCs concerning the bidding process aim to enable the procurement of the bids for day-ahead services delivered on the Balancing Market and for the Congestion Management and Voltage Control services. Table 4.87, Table 4.88, and Table 4.89 present the four Polish demonstrator's SUCs. Table 4.90 shows the KPIs for the SUCs of the Polish pilot.

Table 4.87 - EACL-PL-SUC-01

Name SUC	Prequalification of resources
SUC ID	EACL-PL-SUC-01
Objectives	To register Distributed Energy Resource (DER) and its flexibility potential by Flexibility Service Provider (FSP) in the Flexibility Register, which will enable submission of bids on the FP and participation in the flexibility market.
Narrative	This use case describes the prequalification process on the FP, which consists of: ○ market prequalification (registration and assessment of a new FSP on the FP) ○ certification of DER (registration and assessment of a new unit by FSP) ○ product prequalification and/or static grid prequalification (registration and assessment of a new potential by FSP in response to a certain product available of the FP) ○ This use case covers all obligatory steps for an FSP to participate in the flexibility market through FP
Steps	Market prequalification Certification of DER Product and/or static grid prequalification
Related BUCs	EACL-PL-BUC-01

Table 4.88 - EACL-PL-SUC-02

Name SUC	Bidding for day-ahead balancing services
SUC ID	EACL-PL-SUC-02
Objectives	To procure bids for day-ahead services delivered on the Balancing Market (BM)
Narrative	This use case describes bidding process for day-ahead balancing services on the FP.
Steps	Initiation of day-ahead auctions by TSO on the FP Procurement of bids from BSPs Creation of an aggregated network offer Grid impact assessment Bids forwarding to the Balancing Market Activation
Related BUCs	EACL-PL-BUC-02

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Table 4.89 - EACL-PL-SUC-03

Name SUC	Bidding for Congestion Management and Voltage Control services
SUC ID	EACL-PL-SUC-03
Objectives	To procure bids for CM and VC services
Narrative	This use case describes bidding process for mid-term and day-ahead CM and VC services on the FP.
Steps	Initiation of auctions by DSO on the FP Procurement of bids from FSPs Grid impact assessment Creation of a merit order list Activation
Related BUCs	EACL-PL-BUC-03

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Table 4.90 – KPIs adopted by the Polish Demonstrator SUCs

SUC ID	KPI_ID	Reference to KPI SUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
EACL-PL-SUC-02	KPI_N36	PL_SUC_KPI_01	Average runtime of aggregated network offer algorithm	This KPI evaluates how long it takes to create Aggregated Network Offer.	$AR_{OA} = \frac{\sum_i runtime}{number\_of\_calls}$	AR_{OA}: Average runtime of aggregated network offer algorithm *(s)* *Runtime (s)* *number_of_calls*	s
EACL-PL-SUC-02; EACL-PL-SUC-03	KPI_N37	PL_SUC_KPI_02	Average runtime of automatic grid impact assessment algorithm	Duration of compiling Automatic Grid Impact Assessment algorithm for Day-ahead and Congestion Management and Voltage Control auctions This KPI evaluates how long it takes to compile Automatic Grid Assessment algorithm from collected offers	$AR_{IA} = \frac{\sum_i runtime}{number\_of\_calls}$	AR_{IA}: Average runtime of automatic grid impact assessment algorithm *(s)* *Runtime (s)* *number_of_calls*	s
EACL-PL-SUC-03	KPI_N38	PL_SUC_KPI_03	Average runtime of merit order list algorithm	Duration of compiling Merit Order List algorithm	$AR_{MO} = \frac{\sum_i runtime}{number\_of\_calls}$	AR_{MO}*: Average runtime of merit order list algorithm (s)* *Runtime (s)* *number_of_calls*	s

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4.5.7 Slovenian demonstrators' BUCs KPIs

The Eastern cluster develops the capabilities of the flexibility market platforms, with the Slovenian demonstrator focusing on activating resources connected at the distribution level to defer investments in grid reinforcements or avoid these classical investments altogether. Two business use cases have been defined to fulfil this objective that address congestion management and voltage control in distribution grids under market conditions. Currently, the flexibility market on the DSO level is not established. The idea is to gather a number of household customers connected to the same DSO substation. Customers that own either a heat pump or PV power plants are of interest since their flexibility potential. These devices are summoned into balance groups; the aggregated flexibility is used to off-load the local grid.

Table 4.91 and Table 4.92 provide an overview of the BUCs adopted by the Slovenian demonstrator; 4 KPIs are defined to assess the success of the business use cases quantitatively. These KPIs measure how many activations successfully managed to avoid congestion, the volume activated, and assess the performance of the activation platform. Table 4.93 lists the Slovenian demonstrator's BUCs KPIs.

Table 4.91 - EACL-SL-BUC-01 BUC overview

BUC ID	EACL-SL-BUC-01
BUC Name	Congestion management in distribution grids under market conditions
Scope	Demonstrate effectiveness and appropriateness of flexibility services for the congestion management of a distribution grid, under market conditions. The flexibility tested with this BUC can also be utilized for mFRR at the balancing market. This BUC will validate a process in which managing flexibility in the distribution grid (e.g., switching of heat pumps) can prevent that distribution grid to overreach its physical limits (e.g., transformer overheating, line congestion). It will also verify information exchange between all stakeholders in this process enabling data as well as communication interoperability, under flexibility market conditions.
Objectives	○ Deferral of grid reinforcement investments (defer or avoid secondary substation replacement); ○ Improve security of supply; ○ Validate demand response mechanism to prevent congestion in the distribution grid; and ○ Test flexibility products to prevent congestion in the distribution grid under market conditions.
Services	Corrective active power management for CM
Type of coordination	Market-based DSO coordination

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Table 4.92 - EACL-SL-BUC-02 BUC overview

BUC ID	EACL-SL-BUC-02
BUC Name	Voltage control in distribution grids under market conditions
Scope	An increased number of household solar power plants causes voltage increase on LV voltage substations. Integrated smart inverters have advanced power controlling functions and with adjusting the output of active power, they may be used as voltage reduction devices. Using Volt-Watt method, we would properly design the control parameters in the PV inverters. With this control method, voltage violation would be mitigated and the power curtailment would be evenly distributed among the PV power plants. The flexibility tested with this BUC can also be utilised for mFRR at the balancing market. This BUC will validate a process in which managing flexibility in the distribution grid (e.g., mitigating active power of the PV plants and charging household battery systems with excess energy) can prevent that distribution grid overreaches its physical limits (e.g., voltage increase, transformer overheating, line congestion). It will also verify information exchange between all stakeholders in this process enabling data as well as communication interoperability, under flexibility market conditions.
Objectives	○ Deferral of grid reinforcement investments (defer or avoid secondary substation replacement); ○ Improve security of supply; ○ Validate demand response mechanism to prevent voltage increase in the distribution grid; and ○ Test flexibility products to prevent voltage increase in the distribution grid under market conditions.
Services	Corrective active power management for VC
Type of coordination	Market-based DSO coordination

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Table 4.93 - List of KPIs for BUCs in the Eastern Cluster – Slovenia

BUC ID	KPI_ID	Reference to KPI BUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
EACL-SL-BUC-01;	KPI_H12	SL_BUC_KPI_01	Number of successfully avoided congestions during the demonstration period.	DSO will estimate the number of avoided congestions and will compare it to the number of all congestions to calculate the success rate of activations.	$KC_{succ} = \frac{NumC_{succ}}{NumC_{all}} \cdot 100$	KC_{succ}: indicator showing percentage of successfully avoided congestions (%) $NumC_{succ}$: number of successfuly avoided congestions $NumC_{all}$: number of all expected congestions	%
EACL-SL-BUC-01; EACL-SL-BUC-02	KPI_N39	SL_BUC_KPI_02	Volume of activated Flexibility services	Validate demand response mechanism to prevent congestion in the distribution grid. The total volume of needed and provided energy will be calculated and displayed.	$K_{succ} = \frac{Vol_{del}}{Vol_{need}} \cdot 100$	K_{succ}: indicator showing percentage of successfully delivered energy (%) Vol_{del}: volume of delivered energy Vol_{need}: volume of needed energy	%
EACL-SL-BUC-02;	KPI_H17	SL_BUC_KPI_04	Number of successfully avoided voltage increases during the demonstration period.	DSO will estimate the number of avoided voltage increases and will compare it to the number of all voltage drops to calculate the success rate of activations.	$KV_{succ} = \frac{NumV_{succ}}{NumV_{all}} \cdot 100$	KV_{succ}: indicator showing percentage of successfully avoided voltage increases (%) $NumV_{succ}$: number of successfully avoided voltage increases $NumV_{all}$: number of all expected voltage increases	%
EACL-SL-BUC-01; EACL-SL-BUC-02	KPI_N40	SL_BUC_KPI_03	Volume of total monetized flexibility	Can be calculated from an arbitrary period (week, month, demonstration)	$CostSUM = \sum Pay_{aggr}$	$CostSUM$: sum of all payments for delivered flexibility to aggregators (€) Pay_{aggr}: individual payment for flexibility to aggregator (€)	€

4.5.8 Slovenian demonstrators' SUCs KPIs

Based on the BUCs presented in section 4.5.7, five system use cases are established for the Slovenian demonstrator. The SUCs are namely grid and product prequalification, bidding, activation, and settlement. Table 4.94, Table 4.95, Table 4.96, Table 4.97 present the SUCs and Table 4.99 lists the 8 KPIs defined to assess the SUCs, and present a shot description, the formula, variables and unit of measurement.

Grid prequalification involves validating the existence of a flexibility resource registered and its impact on the distribution grid. In the product prequalification, the FSP sends the prequalification request to the Flexibility Market Operator (FMO), who forwards the request to the DSO that is the one that has defined the requirements that each local flexibility product should meet. The DSO runs the tests and calculations and informs the FMO about the decision, which stores the information and notifies the FSP. Then, the FMO sends the request for bids collected from the FSPs, to later inform the DSO, FSPs, TSO, and flexibility register about the bids selected. DSOs activate these bids by sending a signal to the FSPs, that activate the resources informing all relevant parties. Finally, the volume of delivered power is calculated and confirmed and the invoice is sent.

Table 4.94 - EACL-SL-SUC-01

Name SUC	Grid Prequalification
SUC ID	EACL-SL-SUC-01
Objectives	○ Validate prequalification mechanism for various flexibility sources ○ Prequalify numerous flexibility sources. ○ Improve the security of supply through a transparent and easy process
Narrative	Due to excessive and increasing energy consumption, existing MV/LV secondary substations occasionally becomes thermally overloaded and power lines congested. Demand response services can be utilized to decrease the duration or even prevent overloads of the distribution grid components. In particular, switching off the heat pumps in one substation area can be used to reduce the transformer load during peak hours. This use case describes the process of prequalification for units planned for use in support demand response services.
Steps	Grid Prequalification with DSO Grid Prequalification without DSO
Related BUCs	EACL-SL-BUC-01

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Table 4.95 - EACL-SL-SUC-02

Name SUC	Product Prequalification
SUC ID	EACL-SL-SUC-02
Objectives	○ Deferral of grid reinforcement investments (defer or avoid secondary substation replacement). ○ Improve security of supply. ○ Validate demand response mechanism to prevent congestion in the distribution grid. ○ Test flexibility products to prevent congestion in the distribution grid under market conditions.
Narrative	Due to excessive and increasing energy consumption, existing MV/LV secondary substations occasionally becomes thermally overloaded and power lines congested. Demand response services can be utilized to decrease duration or even prevent overloads of the distribution grid components. In particular, switching off the heat pumps in one substation area can be used to reduce the transformer load during peak hours.
Steps	Product Prequalification
Related BUCs	EACL-SL-BUC-01

Table 4.96 - EACL-SL-SUC-03

Name SUC	Bidding
SUC ID	EACL-SL-SUC-03
Objectives	○ Deferral of grid reinforcement investments (defer or avoid secondary substation replacement). ○ Improve security of supply. ○ Organize a marketplace with fair competition between aggregators
Narrative	Demonstrate effectiveness and appropriateness of flexibility services for the congestion management of a distribution grid, under market conditions. The flexibility tested with this BUC can also be utilized for mFRR at the balancing market. This BUC will validate a process for bidding flexibility in the distribution grid. It will also verify information exchange between all stakeholders in this process enabling data as well as communication interoperability, under flexibility market conditions.
Steps	Bidding
Related BUCs	EACL-SL-BUC-01

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Table 4.97 - EACL-SL-SUC-04

Name SUC	Activation
SUC ID	EACL-SL-SUC-04
Objectives	○ Deferral of grid reinforcement investments (defer or avoid secondary substation replacement). ○ Improve security of supply. ○ Organize a marketplace with fair competition between aggregators
Narrative	Demonstrate effectiveness and appropriateness of flexibility services for the congestion management of a distribution grid, under market conditions. The flexibility tested with this BUC can also be utilized for mFRR at the balancing market. This BUC will validate an activation of flexibility resources in distribution grid. It will also verify information exchange between all stakeholders in this process enabling data as well as communication interoperability, under flexibility market conditions.
Steps	Activation
Related BUCs	EACL-SL-BUC-01

Table 4.98 - EACL-SL-SUC-05

Name SUC	Settlement
SUC ID	EACL-SL-SUC-05
Objectives	○ Deferral of grid reinforcement investments (defer or avoid secondary substation replacement). ○ Improve security of supply. ○ Validate demand response mechanism to prevent congestion in the distribution grid. ○ Monetize activated flexibility so that the FSP receives reimbursement.
Narrative	Demonstrate effectiveness and appropriateness of flexibility services for the congestion management of a distribution grid, under market conditions. The flexibility tested with this BUC can also be utilized for mFRR at the balancing market. This BUC will validate a process of monetizing activated flexibility It will also verify information exchange between all stakeholders in this process, enabling data as well as communication interoperability, under flexibility market conditions.
Steps	Settlement
Related BUCs	EACL-SL-BUC-01

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Table 4.99 – KPIs adopted by the Slovenian Demonstrator SUCs

SUC ID	KPI_ID	KPI_BN	KPI Name	KPI description	Formula	Variables	Unit of measurement
EACL-SL-SUC-01; EACL-SL-SUC-02	KPI_H22A	SL_SUC_KPI_01	A number of successfully prequalified units	With this KPI, a total number of prequalified units is measured.	$N_{units} = SUM\ (list\ of\ units\ names)$	N_{units}: total number of prequalified units	_
EACL-SL-SUC-01; EACL-SL-SUC-02	KPI_H22E	SL_SUC_KPI_02	Volume of flexibility by prequalified units	The volume of prequalified flexibility is measured with this KPI.	$FL_{units} = SUM\ (list\ of\ units\ flexibility)$	FL_{units}: total quantity of prequalified flexibility	kW
EACL-SL-SUC-01; EACL-SL-SUC-02	KPI_N41	SL_SUC_KPI_03	Average time needed for prequalification of a unit	Unit prequalification has to be fast. That is why the averaged time for prequalification is calculated with this KPI.	$ATime = \frac{\sum_1^{N_{units}} T_i}{N_{units}}$	$ATime$: average time needed to prequalify a unit (days) N_{units}: total number of prequalified units T_i: Days needed to prequalify an individual unit	days
EACL-SL-SUC-05	KPI_N42	SL_SUC_KPI_04	Percentage of instances where alignment process was necessary	This KPI estimates how many occasions an alignment process was necessary after an activation compared to the number of all activations	$AUT\_AL_{succ} = \left(1 - \frac{M_{AL_{num}}}{ACT_{num}}\right) \cdot 100$	$\mathrm{AUT_{AL_{succ}}}$: indicator showing percentage of f successful automatic alignment process (%) $\mathrm{M_{AL_{num}}}$: number of manual alignments needed after activation $\mathrm{ACT_{num}}$: number of all activations	%
EACL-SL-SUC-01; EACL-SL-SUC-02	KPI_N43	SL_SUC_KPI_05	Success of local flexibility market platform test	Validate demand response mechanism to prevent congestion in the distribution grid. Test flexibility products to prevent congestion in the distribution grid under market conditions.	$Platform\_test = \begin{cases} Success\ (if\ all\ test\ are\ OK) \\ Fail\ (if\ all\ tests\ are\ not\ OK) \end{cases}$	Platform_test	_

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4.6 KPIs for the OneNet Regional BUCs

A central objective of the OneNet project is the development of an interoperable network of platforms with near to real-time multi-country operation. The regional business use case concept (regional BUC) aims to promote cooperation between countries at a demonstration cluster level. A regional BUC comprises multi-country cross-border scenarios in which the different clustered countries foresee the exchange of information between themselves through the technical solutions developed throughout the project. These use cases are refined by discussing the different country needs and how they could use a pan-European system to connect and allow for different systems to exchange valuable information to improve, amongst others, network operation. This action allows demonstrating the scalability and interoperability of the OneNet projects by taking advantage of the unprecedented number of European level demonstrations that compose the project.

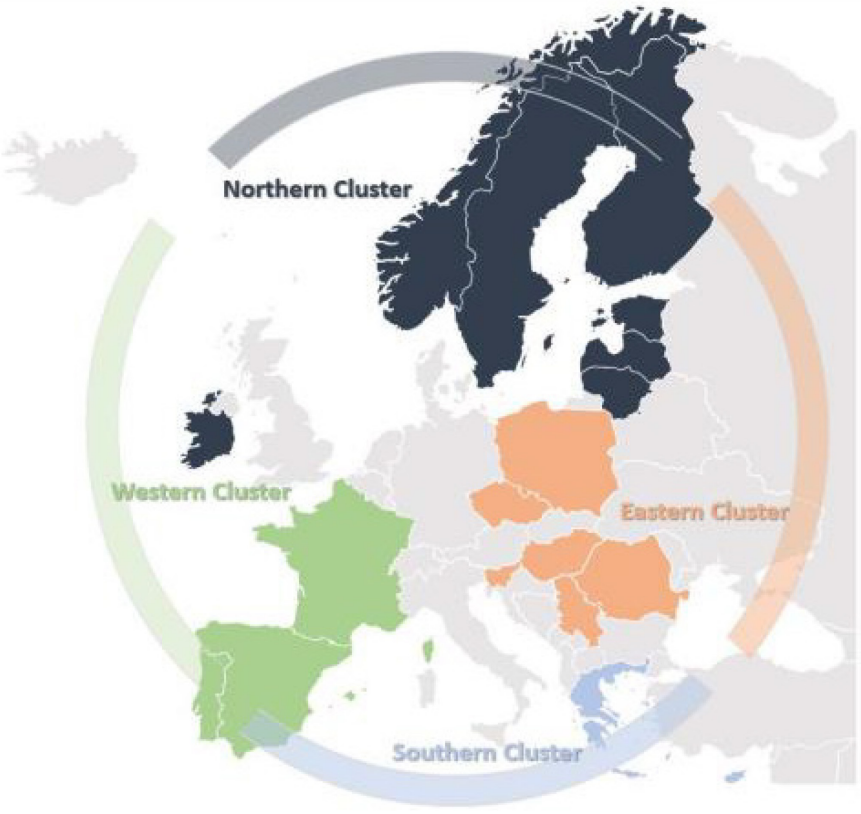

Figure 4.2 - OneNet project demonstration clusters

The 4 clusters that compose the OneNet demonstrations (Northern, Southern, Western, and Eastern) developed the regional BUCs; however, as the Northern cluster is undertaking a regional, or cross-border, approach since the beginning of the demonstration efforts, the cooperation between countries within this cluster is already explicit in the BUCs and SUCs presented in section 4.2. For the remaining 3 clusters, 3 regional BUCs are developed following the IEC 62559-2 template for the specific foreseen interactions. This deliverable reflects the status of the regional BUCs development reached at month 15 of the OneNet project (December 2021).

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4.6.1 Northern cluster OneNet regional BUCs KPIs

The Northern cluster develops a single demonstration activity that includes the countries belonging to the cluster. Therefore, the BUC in section 4.2.1 describes a regional system BUC; for the sake of brevity, the information already reported in section 4.2.1 is not again reported in this section. The overview of the Northern cluster BUC is available in Table 4.11, while the related KPIs are in Table 4.12.

4.6.2 Southern cluster OneNet regional BUCs KPIs

The Southern Regional BUC aims to enhance regional cooperation by providing early warnings regarding potentially hazardous weather conditions and cyber threats. This objective is pursued by exchanging information about cyber security and severe weather condition forecasts between the Greek and Cypriot demo. Predictive maintenance algorithms and enhanced storm predictions are developed under Greek BUC to prevent the system from running into dangerous topological or operational states. In addition, information exchange and an early warning system for potentially hazardous weather conditions and cyber threats with TSO and DSO from Cyprus will be introduced to avoid dangerous power system regimes that could damage the critical infrastructure. The main foreseen functionalities related to this particular business case are as follows:

- Regional storm predictive operations and maintenance process in TSO and DSO grid.
- Cyber security and protection of the vital infrastructure.

Table 4.100 provides an overview of the Southern Cluster Regional BUC while the corresponding KPIs in Table 4.101.

Table 4.100 - Southern Cluster Regional BUC overview

BUC ID	SOCL-BUC-01
BUC Name	Regional critical infrastructure security awareness information exchange
Scope	Regional cooperation and information exchange about cyber security and severe weather condition forecasts.
Objectives	○ Cyber Security; ○ Critical infrastructure protection and avoidance of damages caused by severe weather conditions and cyber-attacks; ○ Predictive maintenance and outage management; ○ Enhanced severe weather condition management; and ○ Early warning on a potentially hazardous power system topology and regimes.
Countries	Cyprus, Greece

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Table 4.101 - List of KPIs for BUCs in the Southern Cluster – Regional BUC

BUC ID	KPI_ID	Reference to KPI BUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
SOCL-BUC-01	KPI_N23	SOCL_BUC_KPI_01	Number of successfully predicted severe weather conditions	Early warning on a hazardous power system regimes rate. This indicator shows how efficient is the identification of the hazardous power system state and how much in advance, time-wise, it is given.	$CFC_{\%} = \frac{C_{fc,c}}{C_o} \cdot 100$	$CFC_{\%}$: successfully predicted severe weather conditions (%) ***Cfc,c:*** is the number of hazardous power system regimes correctly forecasted. ***Co:*** is the number of situations where analysis of the measurements indicate that hazardous power system regimes occurred or would have occurred if no curative actions by the DSO/TSO were taken (i.e., flexibility used).	%
SOCL-BUC-01	KPI_N24	SOCL_BUC_KPI_02	Number of successfully exchanged information on hazardous power system regimes and cyber threats	It is crucial to have as much as possible precise information on the grid reliability. The appearance of ice or storm can cause unplanned outages and severe damages in the grid, directly influencing the power system flexibility needs and the possibility of the transmission system and distribution system to serve those needs.	$CFC_{\%} = \frac{C_{fc,c}}{C_o} \cdot 100$	$CFC_{\%}$: successfully exchanged information on hazardous power system regimes and cyber threats (%) ***Cfc,c:*** is the number of the severe weather conditions correctly forecasted. ***Co:*** is the number of situations where analysis of the weather data indicate that severe weather conditions occurred.	%

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4.6.3 Western cluster OneNet Regional BUCs KPIs

The objective behind the definition of a Western cluster regional BUC is to promote the interaction and exchange of information among all demo countries in the Western Cluster while contributing to the development of cross-border solutions in line with the OneNet project objectives.

The Regional BUC defined by the Western Cluster is named “Cluster Preparatory Phase: Cross-SO grid pre-qualification”. This BUC describes how an FSP can be pre-qualified to provide the service to the SO they are connected to and to another SO. In this context, this BUC aims to go beyond the TSO-DSO coordination scope, allowing that an FSP connected to one SO can be pre-qualified to a neighbouring SO if this type of flexibility provision is physically possible. This type of cross-SO pre-qualification could be useful, for instance, in places where two DSOs are directly connected (e.g. i-DE and UFD in Madrid, Spain) or possibly close to two countries' borders (given that the interconnection characteristics allow for flexibility provision).

More than actually pre-qualifying resources for the cross-SO or cross-border flexibility provision, this Regional BUC aims to allow the necessary information exchange between SOs so that the pre-qualifications occur. For this purpose, firstly, a harmonization of minimum data for pre-qualification will be done, additional data, however, can always be requested by the pre-qualifying SO. It is important to ensure that all SOs agree on the most relevant data when pre-qualifying an FSP connected to another network. Secondly, the necessary data exchange processes have to be in place so SOs can conclude the pre-qualification in an efficient and timely manner. For that, the demonstration of this BUC will count on the OneNet System, a pan-European network of platforms being developed to integrate the local platforms developed in the project.

Table 4.102 provides an overview of the Western Cluster Regional BUC, while the corresponding KPIs are available in Table 4.103.

Table 4.102 - Western Cluster Regional BUC overview

BUC ID	WECL-BUC-01
BUC Name	Cluster Preparatory Phase: Cross-SO grid pre-qualification
Scope	Regional Use Case, enabling coordination among market and system operators of the Western Cluster through OneNet System for the harmonization of the preparatory phase based on the experience of the system and market operators from the three countries in the cluster.
Objectives	○ Design the Pre-qualification process phase of ASM report among the Cluster so that it can serve as a basis for future developments; ○ Design the Flexibility Resource Register requirements among the Western Cluster; ○ Exchange information for the Grid Pre-qualification through OneNet System; and ○ Facilitate the entry of FSPs into the various flexibility markets within the Western Cluster.
Countries	Portugal, Spain, France

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Table 4.103 - List of KPIs for BUCs in the Western Cluster – Regional BUC

BUC ID	KPI_ID	Reference to KPI BUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
WECL-BUC-01	KPI_N48	WECL_BUC_KPI_01	FSP acceptance	This indicator calculates the percentage of FSPs accepted their participation in the joint cross border SO prequalification with the total amount of FSPs contacted to participate in the BUC. This indicator will be used to evaluate the FSP engagement plan.	$\mathrm{A} = \frac{N_{accept}}{N_{total}} \cdot 100$	A: FSP acceptance (%) $\boldsymbol{N_{accept}}$: Customers that agreed on a potential cross-SO prequalification (integer) $\boldsymbol{N_{total}}$: Customers contacted (integer)	%
WECL-BUC-01	KPI_N49	WECL_BUC_KPI_02	Average Processing Time	This indicator measures the execution time of the prequalification process.	$\mathrm{APT} = \frac{\sum_i T_i^{final} - T_i^{initial}}{i}$	APT: Average Processing Time (s) T_i^{final}: time at the end of the process for the prequalification request *i-th* (timestamp) $T_i^{initial}$: time at the beginning of running the algorithm for the prequalification request *i* (timestamp)	s
WECL-BUC-01	KPI_N50	WECL_BUC_KPI_03	Cross SO Prequalification Acceptance	This indicator calculates the percentage of Cross SO Prequalification accepted	$\mathrm{Acc.} = \frac{\sum Accepted}{\sum Forwared} \cdot 100$	$Acc.$: Ratio of accepted prequalification requests (%) $\sum Accepted$: total number of accepted cross-SO prequalification requests (integer) $\sum Forwared$: total number of cross-SO prequalification requests (integer)	%
WECL-BUC-01	KPI_N51	WECL_BUC_KPI_04	Need for additional information for cross SO Prequalification	This indicator calculates the percentage of Cross SO Prequalification that needs additional information beyond the harmonized requirements	$\mathrm{AIR} = \frac{\sum InfoRequest}{\sum Forwared} \cdot 100$	*AIR*: Ratio of cross-SO prequalification requests that required a bilateral request for more information, apart that one established in the general BUC. (%) $\sum InfoRequest$: Total number of cross-SO prequalification requests that required a bilateral request for more information, apart that one established in the general BUC. (integer) $\sum Forwared$: total number of cross-SO prequalification requests (integer)	%

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4.6.4 Eastern cluster OneNet Regional BUCs KPIs

The regional BUC defined by the Eastern cluster describes the process of sharing the key flexibility and balancing market data that characterizes each national demonstration. The data are aggregated using the same principles and presented to the OneNet system uniquely for all the demos. It allows the national flexibility markets to be compared.

The business use case defines how an external entity can retrieve market data from national market platforms through the OneNet system, in a standardised way and in a standardised data format. The Eastern cluster regional BUC provides preliminary information to be exchanged through the OneNet system.

Table 4.104 provides an overview of the Eastern Cluster Regional BUC, while the corresponding KPIs are listed in Table 4.105.

Table 4.104 - Eastern Cluster Regional BUC overview

BUC ID	EACL-BUC-01
BUC Name	Flexibility market data aggregation
Scope	Sharing aggregated data on individual national flexibility platforms via the OneNet system
Objectives	Defining and preparing key data on the results of national flexibility markets. Rules for sharing data through the OneNet system, by registered users of the OneNet system
Countries	Czech Republic, Hungary, Poland, Slovenia

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Table 4.105 - List of KPIs for BUCs in the Eastern Cluster – Regional BUC

BUC ID	KPI_ID	Reference to KPI BUC template	KPI Name	KPI description	Formula	Variables	Unit of measurement
EACL -BUC-01	KPI_N52	EA_BUC_KPI_01	Data retrieval successful	When a registered OneNet user sends a request for data retrieval, this request can be successful or not. This KPI is used to validate system functionality.	Not applicable	Not applicable	Pass/Fail
EACL -BUC-01	KPI_N53	EA_BUC_KPI_02	Data retrieval delay	The time interval between sending the request and receiving the response.	$\bar{d} = \sum_{k=1}^{N} d_k$	$\bar{d}$: average delay (s); d_k: delay of the k-th trial (s) N: number of trials	s
EACL -BUC-01	KPI_N54	EA_BUC_KPI_03	Data reliability ratio	To prove the reliability of the retrieved data.	$DRR = \sum_{T} \frac{n_{reliable}}{n_{recieved}} \cdot 100$	DRR: Data reliability ratio (%) $n_{reliable}$: Amount of reliable data that received over period T. $n_{recieved}$: Amount of data that received over period T.	%

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5 Harmonising the OneNet KPIs

Considering the research and innovation projects in the field of the TSO – DSO – Consumer coordination dealing with large-scale demonstrations of innovative grid services through demand response, storage and small-scale (RES) generation, the OneNet project is characterised by a large number of demonstrators (15) situated in different countries[7]. As highlighted in section 4, under the final goal of the OneNet project, the multiplicity of demonstrators, partners involved, and countries encompassed by the OneNet project led to a great variety of initiatives (both BUCs and SUCs) that differ in terms of objectives and activities. Consequently, the corresponding KPIs to be adopted for assessing the performances of BUCs and SUCs are characterised by great diversity; however, common points can be identified. Figure 5.1 depicts the methodology applied to identify a harmonised set of KPIs, which general definition applies to the whole OneNet demonstration activities. This methodology is applied to demonstrators' BUCs considering the comprehensiveness of the description of the demonstration initiatives embraced; hence, harmonising the KPI for BUCs has been considered of utmost relevance for the OneNet project scope. SUCs generally cover specific aspects of the demonstration activity from a technical perspective; therefore, one can consider SUCs as demonstrators' specific; similarities among SUCs defined by demonstration initiatives that cover different activities, sites, and actors are generally scarce. The harmonisation of KPIs for BUCs has also been beneficial for the definition of the KPIs for the regional BUCs; as one can see from 4.6, the regional BUCs also adopted some harmonised KPIs.

As shown in Figure 5.1, the methodology is formed by four main steps; in the first step (BUC analysis) the demonstrators' BUCs are analysed to point out objectives and activities addressed; in Figure 5.1, the BUC categories identified during the OneNet Task 2.4 activities are reported. In the second step (KPI analysis), the preliminary list of KPIs proposed by the demonstrators is analysed to identify the similarities existing among the aspects of the demonstration activities under assessment within each demonstrator. This activity allows classifying the proposed KPIs in categories depending on the assessment matter; in Figure 5.1, the KPI categories identified during the OneNet Task 2.4 activities are reported. The third step (proposal for common KPIs) relies on the outcome of the first and second steps. The BUCs are mapped with respect to the KPI classification to identify the existing similarities among BUCs and point out, on the one hand, the aspects that are commonly assessed, and on the other hand, the gaps that each demonstrator may have in terms of aspects under assessment. This activity relies on the rationale that similar BUCs should have a common set of KPIs. As a result, a set of KPIs was proposed for adoption to each demonstrator. In the fourth step, the demonstrators analyse the proposed list of KPIs to assess the applicability to the KPIs definitions. The set of harmonised KPIs is then defined on the basis of the feedback received from the demonstrators.

The methodology depicted in Figure 5.1 is an iterative process involving multiple interactions between the Task 2.4 core team and the demonstrators' representatives. In fact, in steps nº1 and nº2, Task 2.4 received inputs from demonstrators. In steps nº3 and nº4 Task 2.4, the demonstrators actively collaborated in cluster workshops and bilateral

[7]Updated information is available at: https://cordis.europa.eu/search?q=contenttype%3D%27project%27%20AND%20programme%2Fcode%3D%27LC-SC3-ES-5-2018-2020

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exchanges to achieve a common view on the definition of the harmonised KPIs to be adopted within the OneNet project. In the last step (nº5), the gaps identified and challenges faced during the KPI identification and definition process are analysed to provide recommendations and lessons learnt to support future OneNet tasks. This section reports the outcome of the harmonization process undertaken within the OneNet project following the methodology in Figure 5.1.

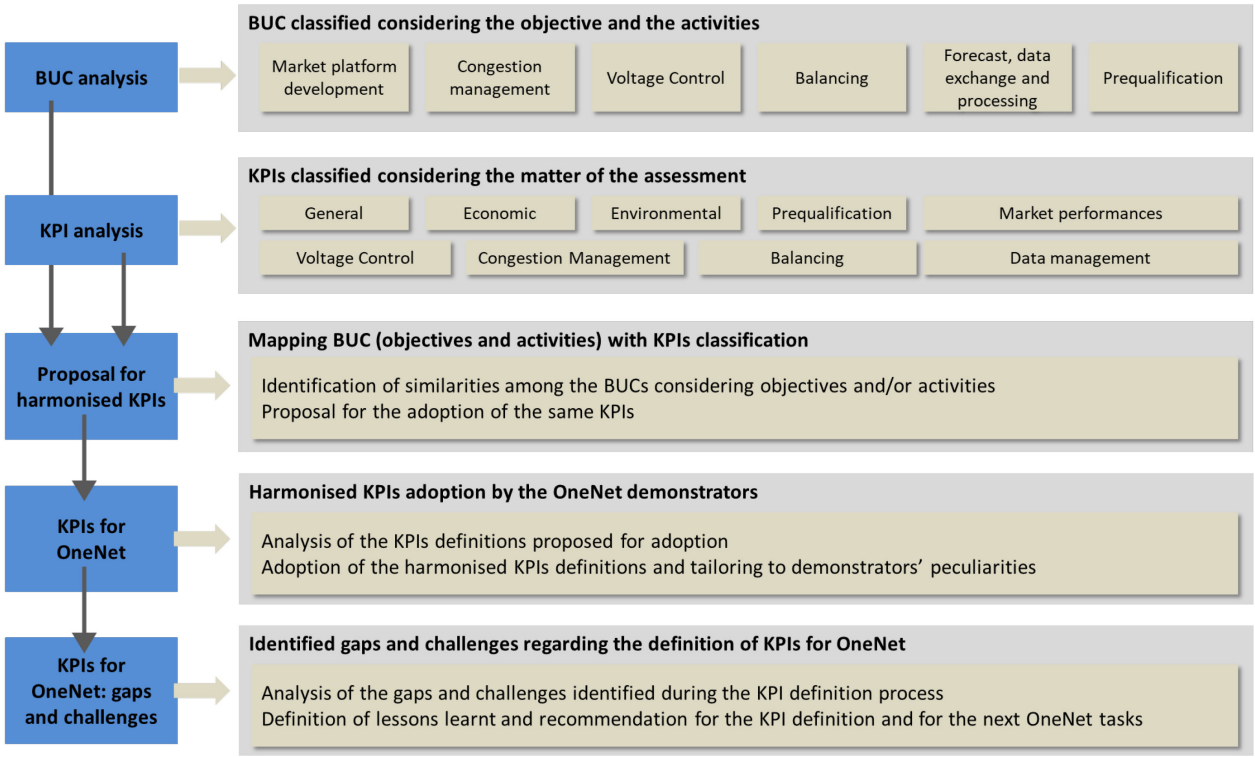

Figure 5.1 – Methodology developed and applied for harmonizing the KPI definition within the OneNet project

5.1 Step 1: BUC analysis

According to the methodology in Figure 5.1, the BUCs proposed by the OneNet demonstrators are analysed considering the objective and the concerning activities. The analysis of the BUCs proposed by the demonstrators allows to group them according to the main activities addressed. Considering all the BUCs proposed by each OneNet demonstrator, Table 5.1 re-clusters the OneNet demonstrators according to the main activities addressed in the proposed BUCs. The classification is not exclusive; the same BUC can belong to more than one class depending on the scope of the activities encompassed. As shown by Table 5.1, the categories adopted are:

- Market platform development;
- Congestion management;
- Voltage control;
- Balancing;
- Forecasting, data processing and exchange;
- Prequalification

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Table 5.1 - OneNet demonstrators BUCs re-clustered according to the BUC objective and activities addressed

Country's demonstrator	BUC	Market platform development	Congestion management	Voltage control	Balancing	Forecasting, data processing and exchange	Prequalification
North	NOCL-BUC-01	■	■				
Cyprus	SOCL-CY-BUC-01	■	■	■	■		
	SOCL-CY-BUC-02	■		■			
Greece	SOCL GR-BUC-01		■	■		■	
	SOCL GR-BUC-02					■	
France	WECL-FR-BUC-01		■			■	
	WECL-FR-BUC-02		■			■	
Portugal	WECL-PT-BUC-01		■			■	
	WECL-PT-BUC-02		■			■	
	WECL-PT-BUC-03					■	
Spain	WECL-ES-BUC-01	■	■			■	
	WECL-ES-BUC-02	■	■			■	
Czech Republic	EACL-CZ-BUC-01	■	■			■	
	EACL-CZ-BUC-02	■		■		■	
Hungary	EACL-HU-BUC-01	■		■			
	EACL-HU-BUC-02	■	■				
Poland	EACL-PL-BUC-01						■
	EACL-PL-BUC-02	■			■		
	EACL-PL-BUC-03	■	■	■			
	EACL-PL-BUC-04	■			■		
Slovenia	EACL-SL-BUC-01	■	■				
	EACL-SL-BUC-02	■		■			

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5.2 Step 2: KPI analysis

As described in Section 2, the KPIs considered by the OneNet activities are gathered from the review of the KPIs adopted by similar research and innovation projects and the definition of brand new KPIs as proposed by the demonstrators. This section presents the mapping of all OneNet demonstrators' BUCs with these KPIs; the aim is to find similarities between KPIs dealing with the assessment of the same aspect to harmonize the KPI definitions at the project level. Considering the whole set of KPIs (both gathered and proposed) adopted by the OneNet demonstrators, 9 classes can be considered to group the harmonized KPIs:

1. General KPIs
2. Economic KPIs
3. Environmental and social KPIs
4. Prequalification KPIs
5. Market platform KPIs
6. Congestion management KPIs
7. Voltage control KPIs
8. Balancing KPIs
9. Data processing KPIs

In total, 32 harmonised KPIs definition are adopted in the OneNet project.

5.3 Step 3 and 4: formulation of the harmonised definition for KPIs

As depicted in Figure 5.1, steps nº3 and nº4 leverage the output of steps nº1 and nº2 to formulate the harmonised definition for KPIs to be adopted within the OneNet project. Steps nº 3 and nº 4 concern an iterative process involving the demonstrators' representatives to reach common formulations for the harmonized definition of KPIs. In this process, the requirements, expectations, and constraints that characterise each demonstrator have been considered to achieve a general definition that all demonstrators could apply by particularising only some aspects. For simplicity, the result of steps nº3 and nº4 are jointly discussed in this section. This section only mentions the harmonised definition of KPIs, i.e., those that cover aspects under assessment on more than one demonstrator or of particular interest for the OneNet project objectives.

5.3.1 General descriptive indicators

The general descriptive indicators represent KPIs that appraise generic aspects of a demonstration activity in the context of the TSO-DSO-Customer coordination. The general descriptive indicators adopted in the OneNet project are:

- KPI_H01: Number of service providers enrolled in the demonstration exercise;
- KPI_H02: Active participation in the demonstration exercise.

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The definitions of the harmonised KPIs KPI_H01 and KPI_H02 are reported in Table 5.2.

Table 5.2 – Harmonized definition of general descriptive indicators

KPI_ID	KPI Name	KPI description	Formula	Variables	Unit of measurement
KPI_H01	Number of service providers enrolled in the demonstration exercise	This KPI aims to assess the audience of the demonstration activity. To quantify this aspect, the KPI is defined in general terms as the number of service providers enrolled in the demonstration exercise.	not applicable	n_{FSP} = Number of FSP	–
KPI_H02	Active participation in the demonstration exercise	This KPI aims to quantify the performance of the demonstrators in terms of actively engaging the service providers enrolled in the demonstration exercise. This KPI represents a step further than the KPI_H01.	$KPI\_H02 = \frac{N_{active}}{N_{accept}} \cdot 100$	KPI_H02: Active participation in the demonstration exercise (%) N_{active}: Customers actively participating in the demo exercise N_{accept}: Number of service providers enrolled in the demonstration exercise (KPI_H01)	%

Due to the variety of the demonstration objective and activities, the methodology to calculate KPI_H01 is based on different inclusion criteria; however, the KPI core definition is preserved. Table 5.3 reports the tailored definitions adopted by the OneNet demonstrators considering the respective peculiarities.

Table 5.3 – Declination of the KPI_H01 definition adopted by the OneNet demonstrators

Description	Formula	Variable	Unit of measurement
Number of FSP joining the platform	not applicable	n_{FSP} = Number of FSPs	–
Number of flexibility service providers involved in the service	not applicable	n_{FSP} = Number of FSPs	–
Total number of certified DERs prequalified to provide balancing services available for BSPs	not applicable	N_{DER_av} = Number of available DER prequalified for balancing services	–

The indicator KPI_H02 measures the percentage of customers actively participating in the demo with respect to the number of service providers enrolled in the demonstration exercise. It represents an indicator obtained from KPI_H01. KPI_H02 coincides with the indicator KPI_S03 from the project review belonging to the societal domain (Table 3.4).

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Table 5.4 provides an overview of the adoption of the general descriptive indicators by the OneNet demonstrators. Green cells highlight the BUCs that adopt the harmonized definition of these KPIs, while the empty cells correspond to the BUCs for which that indicator is not adopted.

Table 5.4 – General indicators adoption by the OneNet project

	BUC	KPI_H01	KPI_H02
North	**NOCL-BUC-01**		
Cyprus	**SOCL-CY-BUC-01**		
	SOCL-CY-BUC-02		
Greece	**SOCL GR-BUC-01**		
	SOCL GR-BUC-02		
France	**WECL-FR-BUC-01**		
	WECL-FR-BUC-02		
Portugal	**WECL-PT-BUC-01**		
	WECL-PT-BUC-02		
	WECL-PT-BUC-03		
Spain	**WECL-ES-BUC-01**		
	WECL-ES-BUC-02		
Czech Republic	**EACL-CZ-BUC-01**		
	EACL-CZ-BUC-02		
Hungary	**EACL-HU-BUC-01**		
	EACL-HU-BUC-02		
Poland	**EACL-PL-BUC-01**		
	EACL-PL-BUC-02		
	EACL-PL-BUC-03		
	EACL-PL-BUC-04		
Slovenia	**EACL-SL-BUC-01**		
	EACL-SL-BUC-02		

5.3.2 Economic indicators

The economic indicators represent KPIs able to capture the economic aspects related to the demonstration activities in the context of the TSO-DSO-Customer coordination. The general descriptive indicators adopted in the OneNet project are:

- KPI_H03: Cost-effectiveness;
- KPI_H04: ICT costs.

The definitions of the harmonised KPIs KPI_H03 and KPI_H04 are reported in Table 5.5.

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Table 5.5 - Harmonized definition of the economic indicators

KPI_ID	KPI Name	KPI description	Formula	Variables	Unit of measurement
KPI_H03	Cost-effectiveness	Compare the cost for flexibility with the avoided traditional grid cost	$Cost_{effectiveness} = \frac{Cost_{flex}}{Cost_{Sub}} \cdot 100$	$Cost_{effectiveness}$: Cost-effectiveness (%) $Cost_{Sub}$: Avoided traditional solution cost (€) $Cost_{flex}$: Cost of flexibility (€)	%
KPI_H04	ICT costs	The term ICT cost comprises the communications and information technologies, including the aggregation and market clearing process software. Only those ICT costs directly related to the implementation of the ICT scheme are considered.	$ICT_{cost} = \sum_{i=1}^{N_c} c_i$	ICT_{cost}: cost of ICT (€) c_i: generic ith cost directly related to each coordination scheme (€) Nc: overall number of cost items	€

The cost-effectiveness indicator (KPI_H03) and the ICT cost indicator (KPI_H04) are based respectively on the definition of the indicators from project review KPI_E15 and KPI_E14 reported in Table 3.1.

Table 5.6 provides the overview of the adoption of the economic indicators in the OneNet project. The green cells highlight the BUCs that adopt the harmonized definition, while the empty cells correspond to the BUCs for which those indicators are not adopted.

Table 5.6 - Economic indicators adoption in the OneNet project

	BUC	KPI_H03	KPI_H04
North	**NOCL-BUC-01**		
Cyprus	**SOCL-CY-BUC-01**		
	SOCL-CY-BUC-02		
Greece	**SOCL GR-BUC-01**		
	SOCL GR-BUC-02		
France	**WECL-FR-BUC-01**		
	WECL-FR-BUC-02		
Portugal	**WECL-PT-BUC-01**		
	WECL-PT-BUC-02		
	WECL-PT-BUC-03		
Spain	**WECL-ES-BUC-01**		
	WECL-ES-BUC-02		
Czech Republic	**EACL-CZ-BUC-01**		
	EACL-CZ-BUC-02		
Hungary	**EACL-HU-BUC-01**		
	EACL-HU-BUC-02		
Poland	**EACL-PL-BUC-01**		
	EACL-PL-BUC-02		
	EACL-PL-BUC-03		
	EACL-PL-BUC-04		
Slovenia	**EACL-SL-BUC-01**		
	EACL-SL-BUC-02		

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5.3.3 Environmental and social indicators

The environmental and social indicators represent KPIs able to capture the externalities related to the demonstration activities in the context of the TSO-DSO-Customer coordination. The environmental and social indicators adopted in the OneNet project are:

- KPI_H05: Reduction in RES curtailment;
- KPI_H06: Ease of access.

The definitions of the harmonised KPIs KPI_H03 and KPI_H04 are reported in Table 5.7.

Table 5.7 - Harmonized definition of the environmental and social indicators

KPI_ID	KPI Name	KPI description	Formula	Variables	Unit of measurement
KPI_H05	Reduction in RES curtailment	This indicator measures the reduction in the amount of energy from Renewable Energy Sources (RES) that is not injected into the grid (even though it is available) due to operational limits of the grid, such as voltage violations or congestions.	$E_{RES} = \sum_{i=1}^{I}\sum_{t=1}^{T}(E_{i,t}^{prod} - E_{i,t}^{inj})$	E_{RES}: Reduction in RES curtailment (kWh or MWh) I: Set of RES facilities under consideration. T: Set of time intervals of the period under consideration excluding periods of scheduled maintenance and outages. $E_{i,t}^{prod}$: Available energy production of the ith RES facility at period t (kWh or MWh). $E_{i,t}^{inj}$: Injected energy of the ith RES facility at the period t (kWh or MWh).	kWh or MWh
KPI_H06	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	Questionnaire	Range [0,10] where 0 means the worst case; 10 means the best case

The Reduction in RES curtailment (KPI_H05) is based on the indicator KPI_ EV1bis in Table 3.3, while KPI_H06 is based on a proposal from the OneNet demonstrators.

Table 5.8 provides the overview of the adoption of the economic indicators in the OneNet project. The green cells highlight the BUCs that adopt the harmonized definition, while the empty cells correspond to the BUCs for which those indicators are not adopted.

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Table 5.8 - Environmental and social indicators adoption in the OneNet project

	BUC	KPI_H05	KPI_H06
North	**NOCL-BUC-01**		
Cyprus	**SOCL-CY-BUC-01**		
	SOCL-CY-BUC-02		
Greece	**SOCL GR-BUC-01**		
	SOCL GR-BUC-02		
France	**WECL-FR-BUC-01**		
	WECL-FR-BUC-02		
Portugal	**WECL-PT-BUC-01**		
	WECL-PT-BUC-02		
	WECL-PT-BUC-03		
Spain	**WECL-ES-BUC-01**		
	WECL-ES-BUC-02		
Czech Republic	**EACL-CZ-BUC-01**		
	EACL-CZ-BUC-02		
Hungary	**EACL-HU-BUC-01**		
	EACL-HU-BUC-02		
Poland	**EACL-PL-BUC-01**		
	EACL-PL-BUC-02		
	EACL-PL-BUC-03		
	EACL-PL-BUC-04		
Slovenia	**EACL-SL-BUC-01**		
	EACL-SL-BUC-02		

5.3.4 Market performance indicators

The market performance indicators aim to assess the outcome of the market development and testing addressed in the demonstration activities in the context of the TSO-DSO-Customer coordination. The market performance indicators adopted in the OneNet project are:

- KPI_H07: Number of transactions;
- KPI_H08: Bid statistics;
- KPI_H09: Market volumes (traded energy or capacity);
- KPI_H10: Average ratio of offered flexibility by FSPs and flexibility requested by SO at a given period;
- KPI_H11: Bid success ratio;
- KPI_H11: Number of products per demo.

The definitions of the harmonised market performance indicators are reported in Table 5.9.

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Table 5.9 - Harmonized definition of the market performance indicators

KPI_ID	KPI Name	KPI description	Formula	Variables	Unit of measurement
KPI_H07	Number of transactions	This indicator measures the number of transactions. This indicator measures the number of cleared bids, for each product, for example.	$N_T = \sum_T n_{Bids,t}$	$n_{Bids,t}$: Number of offered or cleared bids at time t. T: Examined period.	–
KPI_H08	Bid statistics	Minimal, maximal and average prices of a class of auctions given a certain period T of observation.	$B_m = min\{bid\ set\}$ $B_M = max\{bid\ set\}$ $B_A = average\{bid\ set\}$	Minimal (B_m), maximal (B_M) and average (B_A) prices of the auctions given a certain period T of observation. The calculation concern active power (P) capacity auctions, active power (P) activations (energy) auctions, reactive power (Q) capacity auctions, and reactive power (Q) activations.	€/kW, or €/kWh €/kVAr, or €/kVArh
KPI_H09A	Volume of transactions – offered bids (P or Q Availability)	This indicator measures the volume of offered availability bids.	$VT_{OAV} = \sum_T \sum_I P_{i,t}$	VT_{OAV}: Volume of transaction considering active or reactive power (kW or kVAr) $P_{i,t}$: Volume offered availability (capacity) by the i-th flexible resource at time t (kW or kVAr). I: Set of flexible resources. T: Examined period.	kW or kVAr

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KPI_H09B	Volume of transactions – cleared bids (P or Q Availability)	This indicator measures the volume of cleared availability bids.	$VT_{CAV} = \sum_{T}\sum_{I} P_{i,t}$	VT_{CAV}: Volume of transaction considering active or reactive power (kW or kVAr). $P_{i,t}$: Volume cleared availability (capacity) bids by the i-th flexible resource at time t (kW or kVAr). I: Set of flexible resources. T: Examined period	kW or kVAr
KPI_H09C	Volume of transactions – offered bids (P or Q Activation) (Energy)	This indicator measures the volume of offered activation bids.	$VT_{OAC} = \sum_{T}\sum_{I} E_{i,t}$	V_{OAC}: Volume of transaction considering P·T or Q·T (kWh or kVArh) $E_{i,t}$: Volume offered activation bids by the i-th flexible resource at time t (kWh or kVArh). I: Set of flexible resources T: Examined period	kWh or kVArh
KPI_H09D	Volume of transactions – cleared bids (P or Q Activation) (Energy)	This indicator measures the volume of offered cleared bids.	$VT_{CAC} = \sum_{T}\sum_{I} E_{i,t}$	V_{CAC}: Volume of transaction considering P·T or Q·T (kWh or kVArh) $E_{i,t}$: Volume cleared activation bids by the i-th flexible resource at time t (kWh or kVArh). I: Set of flexible resources T: Examined period	kWh or kVArh
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	$ARF_{\%} = \frac{\sum_i \frac{F_{FSP\_bid_i}}{F_{FSP\_req_i}}}{N_{req}} \cdot 100$	$ARF_{\%}$: Flex volume offered by FSP vs Flex request by DSO (%) $F_{FSP\_bid_i}$- The amount of flexibility (kW or kVAr) offered by FSPs for a particular (i-th) auction $F_{DSO\_req_i}$ – The amount of flexibility (kW or kVAr) requested by DSO for a particular (i-th) auction N_{req} – total number of auctions called by DSO at a given period	%

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KPI_H11	Number of products per demo	This indicator measures the percentage of products tested in the demos with respect to the number of products initially targeted by the demos.	$NPD = \frac{nP_{tested}}{nP_{targeted}} \cdot 100$	NPD: Number of products per demo (%) nP_{tested}: number of products tested in the BUC. $nP_{targeted}$: number of products initially targeted for the BUC.	%

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The Number of transactions (KPI_H07) is based on the indicator KPI_ E13 in Table 3.1; the KPIs KPI_H09 are based on KPI_E12 and KPI_E11 in Table 3.1, KPI_H10 is based on the KPI_T25 while KPI_H11 is based on KPI_T31 both reported in Table 3.2.

Table 5.10 provides the overview of the adoption of the economic indicators in the OneNet project. The green cells highlight the BUCs that adopt the harmonized definition, while the empty cells correspond to the BUCs for which those indicators are not adopted.

Table 5.10 - Market indicators adoption in the OneNet project

		KPI_H07	KPI_H08	KPI_H09	KPI_H10	KPI_H11
North	NOCL-BUC-01					
Cyprus	SOCL-CY-BUC-01					
	SOCL-CY-BUC-02					
Greece	SOCL GR-BUC-01					
	SOCL GR-BUC-02					
France	WECL-FR-BUC-01					
	WECL-FR-BUC-02					
Portugal	WECL-PT-BUC-01					
	WECL-PT-BUC-02					
	WECL-PT-BUC-03					
Spain	WECL-ES-BUC-01					
	WECL-ES-BUC-02					
Czech Republic	EACL-CZ-BUC-01					
	EACL-CZ-BUC-02					
Hungary	EACL-HU-BUC-01					
	EACL-HU-BUC-02					
Poland	EACL-PL-BUC-01					
	EACL-PL-BUC-02					
	EACL-PL-BUC-03					
	EACL-PL-BUC-04					
Slovenia	EACL-SL-BUC-01					
	EACL-SL-BUC-02					

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5.3.5 Congestion management indicators

The congestion management indicators aim to assess the performances of the use cases dealing with the development and testing of congestion management procedures in the demonstration activities in the context of the TSO-DSO-Customer coordination. The congestion management performance indicators adopted in the OneNet project are:

- KPI_H12: Contingencies reduction (reduced network congestions);
- KPI_H13: Load shape indicator;
- KPI_H14: Available flexibility (Availability, Activation);
- KPI_H15: Requested flexibility (Availability, Activation);
- KPI_H16A: Volume of activated flexibility (Activation);
- KPI_H16B: Volume of cleared flexibility (Availability, Activation);
- KPI_H23A: Power exchange deviation.

The definitions of the harmonised market performance indicators are reported in Table 5.11.

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Table 5.11 - Harmonized definition of the congestion management performance indicators

KPI_ID	KPI Name	KPI description	Formula	Variables	Unit of measurement
KPI_H12	Contingency reduction (reduced network congestions)	Number of avoided technical restrictions (congestions) Avoided congestions thanks to the measures implemented in the demo.	$ATR_{\%} = \frac{N_{TR_{Flex}}}{N_{TR}} \cdot 100$	$ATR_{\%}$: Contingencies reduction (share of avoided congestions) (%) N_{TR}: Total number of expected technical restrictions $N_{TR_{Flex}}$: Total number of technical restrictions solved through activation of flexibility services	%
KPI_H13	Congestion reduction (magnitude)	This indicator measures the percentage decrease of load demand in an asset by a flexibility provider resource.	$CR = \frac{AL_{initial} - AL_{final}}{AL_{initial}} \cdot 100$	CR: Congestion reduction (%) $AL_{initial}$: asset load before delivering flexibility (initial asset load (kW)). AL_{final}: asset load a during delivery of flexibility (final asset load (kW)).	%
KPI_H14A	Available flexibility (Availability)	Available flexible power	$Flexibility_{\%} = \frac{\sum P_{Available_{Flexibility}}}{\sum P_{Total_{in_{Area}}}} \cdot 100$	$Flexibility_{\%}$: Percentage of available flexible power with respect to the potential amount available in the reporting period (%) $\sum P_{Available_{Flexibility}}$: Power of available flexibility in the reporting period (kW) $\sum P_{Total_{in_{Area}}}$: Total power in DEMO grid segment (registered) (kW)	%
KPI_H15A	Requested flexibility (Power)	Requested power flexibility	$P_{Flex_R} = \sum_{t=1}^{T} P_{flex_{R_t}}$	P_{Flex_R}: Requested flexibility (Power) (kW) $P_{flex_{R_t}}$: The amount of power requested by the DSO on the market platform for congestion management and voltage control services at time t (kW) T: examined period	kW

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KPI_H16	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, defined as the percentage of the total flexibility reserved from FSPs that is activated to manage the grid operation without technical constraints.	$FARR_{P\%} = \frac{\sum_{t=0}^{T} P_{flex,Activated_t}}{\sum_{t=o}^{T} P_{reserved_t}} \cdot 100$ $FARR_{Q\%} = \frac{\sum_{t=0}^{T} Q_{flex,Activated_t}}{\sum_{t=o}^{T} Q_{reserved_t}} \cdot 100$	$FARR_{P\%}$: 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); $P_{reserved_t}$: 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_H23A	Power exchange deviation	Tracking error between the power set-point requested by the SO and the measure	$P_{Deviation} = \frac{\lvert P_{accepted} - P_{activacted} \rvert}{P_{accepted}} \cdot 100$	$P_{Deviation}$: 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	$E_{Deviation} = \frac{\lvert E_{accepted} - E_{activacted} \rvert}{E_{accepted}} \cdot 100$	$E_{Deviation}$: Energy exchange deviation (%) $E_{accepted}$: accepted (contracted) energy (kWh) $E_{activacted}$: activated flexibility energy (kWh)	%

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KPI_H23C	Flexibility volume delivered by FSP (in power) vs Flex bids selected to be activated	The average ratio of delivered flexibility in terms of power by FSPs and the power flexibility bids requested by DSO at a given period This KPI considers the FSP reliability calculating the KPI for the whole demo period and all auctions considering all involved FSP.	$FVD_{P\%} = \frac{\sum_{j=1}^{N_{FSP}} \sum_{i=1}^{N_{req}} \frac{P_{delivered\,i,j}}{P_{accepted\_bids\,i,j}}}{N_{req}} \cdot 100$	$FVD_{\%}$: Flexibility volume delivered by FSP (in power) vs Flex bids selected to be activated (%) $P_{delivered_{i,j}}$: the amount of flexibility (kW) which is delivered the j-th FSPs as the request of DSO for a particular i-th auction $P_{accepted\_bids_{i,j}}$: the amount of flexibility (kW) that the j-th FSP bids and that has been selected to be activated for a particular i-th auction N_{req}: total number of auctions called by DSO at given period N_{FSP}: total number of FSPs	%
KPI_H23D	Flexibility volume delivered by FSP (in energy) vs Flex bids selected to be activated	The average ratio of delivered flexibility in terms of energy by FSPs and the energy flexibility bids requested by DSO at given period T. This KPI considers the FSP reliability calculating the KPI for the whole demo period (T) and all auctions considering all involved FSP.	$FVD_{E\%} = \frac{\sum_{j=1}^{N_{FSP}} \sum_{i=1}^{N_{req}} \frac{E_{delivered\,i,j}}{E_{accepted\_bids\,i,j}}}{N_{req}} \cdot 100$	$FVD_{E\%}$: Flexibility volume delivered by FSP (in energy) vs. Flex bids selected to be activated (kWh) $E_{delivered_{i,j}}$: the amount of flexibility (kWh) which is delivered the j-th FSPs as the request of DSO for a particular i-th auction $E_{accepted\_bids_{i,j}}$: the amount of flexibility (kWh) that the j-th FSP bids and that has been selected to be activated for a particular i-th auction N_{req}: total number of auctions called by DSO at a given period N_{FSP}: total number of FSPs	%

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It is worth noting that KPI_H12, KPI_H14, and KPI_H15 are respectively based on the KPIs KPI_T43, KPI_T22, and KPI_T23 in Table 3.2 while KPI_H16 is based on KPI_ E11 from Table 3.1. The OneNet demonstrators proposed the series of KPI_H23A.

Table 5.12 provides the overview of the congestion management performance indicators adoption in the OneNet project. The green cells highlight the BUCs that adopt the harmonized definition, while the empty cells correspond to the BUCs for which those indicators are not adopted.

Table 5.12 - Congestion Management performance indicator adoption in OneNet BUCs

		KPI_H12	KPI_H13	KPI_H14	KPI_H15	KPI_H16	KPI_H23A
North	**NOCL-BUC-01**						
Cyprus	**SOCL-CY-BUC-01**						
	SOCL-CY-BUC-02						
Greece	**SOCL GR-BUC-01**						
	SOCL GR-BUC-02						
France	**WECL-FR-BUC-01**						
	WECL-FR-BUC-02						
Portugal	**WECL-PT-BUC-01**						
	WECL-PT-BUC-02						
	WECL-PT-BUC-03						
Spain	**WECL-ES-BUC-01**						
	WECL-ES-BUC-02						
Czech Republic	**EACL-CZ-BUC-01**						
	EACL-CZ-BUC-02						
Hungary	**EACL-HU-BUC-01**						
	EACL-HU-BUC-02						
Poland	**EACL-PL-BUC-01**						
	EACL-PL-BUC-02						
	EACL-PL-BUC-03						
	EACL-PL-BUC-04						
Slovenia	**EACL-SL-BUC-01**						
	EACL-SL-BUC-02						

5.3.6 Voltage control indicators

The voltage control indicators aim to assess the performances of the use cases dealing with the development and testing of voltage control procedures in the demonstration activities in the context of the TSO-DSO-Customer coordination. The voltage control performance indicators adopted in the OneNet project is:

- KPI_H17: Contingencies reduction (reduced voltages violations).

The definitions of the harmonised market performance indicators are reported in Table 5.13.

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Table 5.13 - Harmonized definition of the voltage control performance indicators

KPI_ID	KPI Name	KPI description	Formula	Variables	Unit of measurement
KPI_H17	Avoided technical restrictions (voltage violations)	Avoided contingencies (voltage violations) thanks to the measures implemented in the demonstrator	$ATR_{\%} = \frac{N_{TR_{Flex}}}{N_{TR}} \cdot 100$	$ATR_{\%}$: share of avoided technical restrictions (voltage violations) (%) N_{TR}: Total number of expected technical restrictions $N_{TR_{Flex}}$: Total number of technical restrictions solved through activation of flexibility services	%

KPI_H17 is based on the definition of KPI_T43 from the project review available in Table 3.2.

Table 5.14 provides the overview of the voltage control performance indicators adoption in the OneNet project. The green cells highlight the BUCs that adopt the harmonized definition, while the empty cells correspond to the BUCs for which that indicator is not adopted.

Table 5.14 - Voltage control performance indicator adoption in OneNet BUCs

		KPI_H17
North	**NOCL-BUC-01**	
Cyprus	**SOCL-CY-BUC-01**	
	SOCL-CY-BUC-02	
Greece	**SOCL GR-BUC-01**	
	SOCL GR-BUC-02	
France	**WECL-FR-BUC-01**	
	WECL-FR-BUC-02	
Portugal	**WECL-PT-BUC-01**	
	WECL-PT-BUC-02	
	WECL-PT-BUC-03	
Spain	**WECL-ES-BUC-01**	
	WECL-ES-BUC-02	
Czech Republic	**EACL-CZ-BUC-01**	
	EACL-CZ-BUC-02	
Hungary	**EACL-HU-BUC-01**	
	EACL-HU-BUC-02	
Poland	**EACL-PL-BUC-01**	
	EACL-PL-BUC-02	
	EACL-PL-BUC-03	
	EACL-PL-BUC-04	
Slovenia	**EACL-SL-BUC-01**	
	EACL-SL-BUC-02	

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5.3.7 Balancing indicators

The balancing indicators aim to assess the performances of the use cases dealing with the development and testing of balancing procedures in the demonstration activities in the context of the TSO-DSO-Customer coordination. The balancing performance indicators adopted in the OneNet project are:

- KPI_H18: Volume of balancing service offers for UP or DOWN reserves;
- KPI_H19A: Number of DER available for BSPs.

The definitions of the harmonised balancing performance indicators are reported in Table 5.15.

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Table 5.15 - Harmonized definition of the balancing performance indicators

KPI_ID	KPI Name	KPI description	Formula	Variables	Unit of measurement
KPI_H18A	Volume of balancing service offers for UP reserves	Volume of balancing service offers for UP or DOWN 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.	$VBS_{UP} = \sum_{n=1}^{N} \mathrm{aFRR(FP)_{U,n}} + \sum_{m=1}^{M} \mathrm{mFRR(FP)_{U,m}} + \sum_{k=1}^{K} \mathrm{RR(FP)_{U,k}}$	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) $\mathrm{RR(FP)_{U,k}}$: Replacement Reserve (up-reserve) of unit k submitted to the flexibility platform (kW)	kW
KPI_H18D	Volume of balancing service offers for DOWN reserves	Volume of balancing service offers for DOWN reserves (aFRR, mFRR, RR) submitted to the flexibility platform by BSPs from the distribution network. Sum of capacity reserves products direction DOWN (aFRR_down, mFRR_down, RR_down) offered by BSPs on the flexibility platform.	$VBS_{DO} = \sum_{n=1}^{N} \mathrm{aFRR(FP)_{D,n}} + \sum_{m=1}^{M} \mathrm{mFRR(FP)_{D,m}} + \sum_{k=1}^{K} \mathrm{RR(FP)_{D,k}}$	VBS_{DO}: Volume of balancing service offers for DOWN reserves (kW) $\mathrm{aFRR(FP)_{D,n}}$: Automatic Frequency restoration reserve (down-reserve) of unit n submitted to the flexibility platform (kW) $\mathrm{mFRR(FP)_{D,m}}$: Manual Frequency restoration reserve (down-reserve) of unit m submitted to the flexibility platform (kW) $\mathrm{RR(FP)_{D,k}}$: Replacement Reserve (down-reserve) of unit k submitted to the flexibility platform (kW)	kW
KPI_H19A	Number of DERs available for BSPs	Total number of certified DERs prequalified to provide balancing services available for BSPs	N_{DER_av}	N_{DER_av} : Number of available DER prequalified for balancing services	–

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Table 5.16 provides the overview of the balancing performance indicators adoption in the OneNet project. The green cells highlight the BUCs that adopt the harmonized definition, while the empty cells correspond to the BUCs for which those indicators are not adopted.

Table 5.16 - Balancing performance indicator adoption in OneNet BUCs

		KPI_H18A	KPI_H18D	KPI_H19A
North	**NOCL-BUC-01**			
Cyprus	**SOCL-CY-BUC-01**			
	SOCL-CY-BUC-02			
Greece	**SOCL GR-BUC-01**			
	SOCL GR-BUC-02			
France	**WECL-FR-BUC-01**			
	WECL-FR-BUC-02			
Portugal	**WECL-PT-BUC-01**			
	WECL-PT-BUC-02			
	WECL-PT-BUC-03			
Spain	**WECL-ES-BUC-01**			
	WECL-ES-BUC-02			
Czech Republic	**EACL-CZ-BUC-01**			
	EACL-CZ-BUC-02			
Hungary	**EACL-HU-BUC-01**			
	EACL-HU-BUC-02			
Poland	**EACL-PL-BUC-01**			
	EACL-PL-BUC-02			
	EACL-PL-BUC-03			
	EACL-PL-BUC-04			
Slovenia	**EACL-SL-BUC-01**			
	EACL-SL-BUC-02			

5.3.8 Data processing indicators

The data processing indicators aim to assess the performances of the use cases dealing with the development and testing of data processing procedures in the demonstration activities in the context of the TSO-DSO-Customer coordination. The data processing performance indicators adopted in the OneNet project are:

- KPI_H20: Energy production or consumption prediction error;
- KPI_H21: Effectiveness of the event forecasting.

The definitions of the harmonised data processing performance indicators are reported in Table 5.17.

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Table 5.17 - Harmonized definition of the data processing performance indicators

KPI_ID	KPI Name	KPI description	Formula	Variables	Unit of measurement
KPI_H20A	Accuracy of the RES production forecast calculated T hours in advance	Accuracy of the RES production forecast calculated T hours in advance	$RES_{FA_T} = \frac{1}{N}\left(\sum_{t=1}^{N}\left\lvert\frac{FC_{RES_{prod,t}} - RL_{RES_{prod,t}}}{RL_{RES_{prod,t}}}\right\rvert\right)\cdot 100$	RES_{FA_T}: Accuracy of the RES production forecast calculated T hours in advance (%) $FC_{RES_{prod}}$: RES production estimated 24h in advance (MW) $RL_{RES_{prod}}$: Real RES production (MW) N: Number of available data points T: number of hours in advance for the forecasted data calculation	%
KPI_H20B	Accuracy of load forecast calculated T hour in advance	Accuracy of load forecast calculated T hour in advance	$Load_{FA_T} = \frac{1}{N}\left(\sum_{t=1}^{N}\left\lvert\frac{FC_{load,t} - RL_{load,t}}{RL_{load,t}}\right\rvert\right)\cdot 100$	$Load_{FA_T}$: Accuracy of load forecast calculated T hour in advance (%) FC_{load} : Load estimated 1h in advance (MW). RL_{load} : Real load (MW). N: Number of available data points. T: number of hours in advance for the forecasted data calculation	%
KPI_H21A	Share of correctly forecasted contingencies	Share of correctly forecasted contingencies	$CFC_{\%} = \frac{C_{fc,c}}{C_o}\cdot 100$	$CFC_{\%}$: 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_H21B	Share of false positive congestion contingencies	Share of false positive congestion contingencies	$FFC_{\%} = \frac{C_{fc,c}}{C_{fc}}\cdot 100$	$FFC_{\%}$: Share of false positive congestion contingencies (%) $C_{fc,c}$**:** Number of false positive contingencies forecasts, so contingencies forecasted where analysis of the measurements indicate that no contingencies would have occurred, even if no curative actions by the SO were taken (I.e., flexibility used)**.** C_{fc}**:** Total number of contingencies forecasted.	%

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KPI_H20A and KPI_H20B are based on the definitions of KPI_T06 and KPI_T09 available in Table 3.2, while KPI_H21A and KPI_H21B rely on KPI_T11 and KPI_T12 defined in Table 3.2.

Table 5.18 provides the overview of the balancing performance indicators adoption in the OneNet project. The green cells highlight the BUCs that adopt the harmonized definition, while the empty cells correspond to the BUCs for which those indicators are not adopted.

Table 5.18 – Data processing performance indicator adoption in OneNet BUCs

		KPI_H20A	KPI_H20B	KPI_H21A	KPI_H21B
North	**NOCL-BUC-01**				
Cyprus	**SOCL-CY-BUC-01**				
	SOCL-CY-BUC-02				
Greece	**SOCL GR-BUC-01**				
	SOCL GR-BUC-02				
France	**WECL-FR-BUC-01**				
	WECL-FR-BUC-02				
Portugal	**WECL-PT-BUC-01**				
	WECL-PT-BUC-02				
	WECL-PT-BUC-03				
Spain	**WECL-ES-BUC-01**				
	WECL-ES-BUC-02				
Czech Republic	**EACL-CZ-BUC-01**				
	EACL-CZ-BUC-02				
Hungary	**EACL-HU-BUC-01**				
	EACL-HU-BUC-02				
Poland	**EACL-PL-BUC-01**				
	EACL-PL-BUC-02				
	EACL-PL-BUC-03				
	EACL-PL-BUC-04				
Slovenia	**EACL-SL-BUC-01**				
	EACL-SL-BUC-02				

5.3.9 Prequalification process indicators

The prequalification process indicators aim to assess the performances of the use cases dealing with the development and testing of prequalification procedures in the demonstration activities in the context of the TSO-DSO-Customer coordination. The prequalification performance indicator adopted in the OneNet project is:

- KPI_H22A: Percentage of successfully prequalified FSPs.

The definition of the harmonised data processing performance indicator is reported in Table 5.19.

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Table 5.19 - Harmonized definition of the prequalification performance indicators

KPI_ID	KPI Name	KPI description	Formula	Variables	Unit of measurement
KPI_H22A	Percentage of successfully prequalified FSPs	This indicator presents the percentage of flexibility services providers in the demo that are successfully prequalified against the number of FSPs only registered on the flexibility platform	$K_{FSP} = \frac{N_{FSP_{preq}}}{N_{FSP_{reg}}} \cdot 100$	K_{FSP} : Indicator showing the percentage of flexibility service providers that are successfully prequalified against the number of flexibility services providers only registered on the flexibility platform (%) $N_{FSP\,preq}$: number of flexibility service providers that are successfully prequalified. $N_{FSP\,reg}$: number of flexibility service providers registered on the flexibility platform.	%

Table 5.20 provides the overview of the prequalification performance indicators adoption in the OneNet project. The green cells highlight the BUCs that adopt the harmonized definition, while the empty cells correspond to the BUCs for which that indicator is not adopted.

Table 5.20 – Prequalification process performance indicator adoption in OneNet BUCs

	BUCs	KPI_H22A
North	**NOCL-BUC-01**	
Cyprus	**SOCL-CY-BUC-01**	
	SOCL-CY-BUC-02	
Greece	**SOCL GR-BUC-01**	
	SOCL GR-BUC-02	
France	**WECL-FR-BUC-01**	
	WECL-FR-BUC-02	
Portugal	**WECL-PT-BUC-01**	
	WECL-PT-BUC-02	
	WECL-PT-BUC-03	
Spain	**WECL-ES-BUC-01**	
	WECL-ES-BUC-02	
Czech Republic	**EACL-CZ-BUC-01**	
	EACL-CZ-BUC-02	
Hungary	**EACL-HU-BUC-01**	
	EACL-HU-BUC-02	
Poland	**EACL-PL-BUC-01**	
	EACL-PL-BUC-02	
	EACL-PL-BUC-03	
	EACL-PL-BUC-04	
Slovenia	**EACL-SL-BUC-01**	
	EACL-SL-BUC-02	

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5.4 KPI definition for the OneNet project, gaps and challenges

The identification and definition of KPIs for the OneNet project described in this report encountered and addressed several challenges that are analysed in this section. These challenges are mainly related to the peculiarities of the OneNet project in terms of project size, diversity of the demonstration goals and activities, the actual status of development, local demonstrators' characteristics, and the innovative nature of the demonstration activities.

The OneNet project is the largest research and innovation project in the field of the TSO – DSO – Customer coordination dealing with large-scale demonstrations of innovative grid services through demand response, storage and small-scale (RES) generation. The OneNet project consists of a large number of demonstrators (15) situated in different countries and more than 70 parties involved[8]. The dimension of the OneNet project represents a critical aspect for the KPIs identification and definition since the great number of interactions required to achieve consensus among the internal stakeholders. The process described in section 2 required a significant number of interactions with a consequent high burden in terms of time required and quantity of information to be gathered and processed. This challenge was addressed by facilitating the sharing of the proposals among the demonstrators; however, future OneNet tasks dealing with KPIs can further improve the level of adoption and harmonisation of the defined KPIs among the demonstrators in the consortium. It is advisable to devise activities aimed at achieving the consensus among many demonstrators considering in advance the challenges related to the size of the problem. The use of top-down approaches based on tailored proposals formulated as the outcome of an in-depth analysis of the characteristics of every single demonstrator's activity may reduce the burden related to the interactions to be addressed.

Besides the significant number of demonstrators, the OneNet project is also characterised by a great diversity of demonstration activities. Each OneNet demonstrator addresses different aspects of the TSO–DSO–Customer coordination leading to a great diversity of BUCs and SUCs. On the one hand, it allows the OneNet project to provide a comprehensive analysis of the real-world challenges related to the innovative TSO–DSO–Customer coordination schemes; on the other hand, it represents a challenge for the definition of a unique set of KPIs that applies to all demonstrators. As highlighted in section 5.3, only a small number of KPIs are commonly adopted by more demonstrators. This outcome is due to the diversity of the demonstration goals and activities. However, considering the whole set of KPIs adopted at the project level, multiple aspects concerning the TSO–DSO–Customer coordination are assessed; therefore, the great diversity among the demonstrators favours the OneNet project in providing a manifold contribution to the evolution of the European electricity system.

The definition of KPIs to be adopted by more demonstrators requires achieving consensus on the matter of assessment, the quantified quantity, the calculation formula, and the measurement methodologies and

[5] The OneNet project partners are listed at: https://onenet-project.eu/partners/

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procedures. Considering the size of the OneNet project and the diversity of the demonstrators, the challenge of achieving this consensus was addressed with multiple interactions and a collaborative approach that allowed devising shared methodologies for calculating the KPIs adopted by the demonstrators. This process was favoured by the harmonisation approach described in this section, which provides a high-level definition for the KPIs to be tailored according to each demonstrators' needs. An example of this approach is KPI_H21 (RES forecast error), which's general definition leaves each demonstrator the prerogative of deciding the time window length for the forecast. However, except for this parameter to be set according to each demonstrator's peculiarity, the methodology and formula for calculation are shared among all the relevant demonstrators.

The diversity existing among the OneNet demonstrators influences the comparability of the same KPI calculated in two different demonstrators. Local conditions may affect the obtained results; the KPI value obtained by one demonstrator could be considered inadequate in the context of another demonstrator. This challenge especially relates to costs, since the differences existing among the countries involved in the OneNet project, the cost occurred in different countries may be not comparable. Outclassing these challenges, each demonstrator needs to define a dedicated baseline and target value to grant self-consistency to the result of the demonstration activity allowing a meaningful assessment. Ensuring the comparability of the demo result also requires considering the obtained KPI values and surrounding aspects that allow building a comprehensive picture of the demonstrator's activity.

OneNet Task 2.4 aims to support the OneNet demonstrators in defining the KPIs; this task had its horizon in the period when the demonstrators BUCs and SUCs were still under development. For this reason, the set of KPIs defined and described in this report is preliminary and reflects the progress conducted up to M15 of the project (December 2021). Any further upgrades, refinements or redefinitions will be available in the future deliverables of the WPs 7-11. The definition of the KPIs worth assessing the performance of the demonstrators' activities is a crucial task that should be embedded in the BUC and SUC definition process. KPIs assess the demonstrators' goals achievement; therefore, the KPIs have to reflect the demonstrator's ambitions and expectations. Future OneNet tasks dealing with the assessment of demonstration performances should refine the preliminary definition of KPIs reported in this document to reflect the progress of project activities. Moreover, further efforts are required to complete the methodology for data gathering and KPI calculation by achieving the highest level of harmonisation among the OneNet demonstrators.

The OneNet project deals with the definition of innovative solutions for TSO-DSO-Customer coordination, market architectures, and FSP service provision. The lack of historical information, knowledge, and experience represents a challenge for the KPI definition and calculation. The main challenge due to the lack of a generally recognised benchmark especially relates to the definition of KPIs for the markets since the corresponding BUCs demonstrate novel market structures and new flexibility products; therefore, it is challenging to define meaningful KPIs and the corresponding baseline and target value to indicate the successfulness of the project

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activities. Moreover, some BUCs and SUCs proposed by the OneNet demonstrators deal with innovative processes in which proof-of-concept is itself represented by their design within the OneNet project. Therefore, quantitative KPIs cannot be defined to evaluate these use cases. Moreover, some KPIs require involving factors that are external from the demonstration activities (e.g. the avoided cost of traditional network reinforcement), which makes the calculation process challenging since it requires a deep knowledge of the demonstration area, historical information on current practices, the definition of a complex methodology, the adoption of acceptable assumptions and simplifications.

The variety of activities, local peculiarities, and the differences among the actors involved make clear that a single solution for assessing the project results will not well perform. Therefore, the definition of the KPIs has to consider the peculiarities and propose general definitions that can be tailored to fit local objectives and peculiarities by preserving generality. For clarity, since the differences among different contexts, a different baseline can be required for the same KPI. The same reasoning applies to target values. Hence, performance assessment has to consider the context peculiarities. On the contrary, the KPI definition and calculation methodology have to be harmonised considering the different contexts to ensure result comparability.

Demonstration activities concerning the coordinated provision of services at the system and local levels develop and test innovative solutions that have to be embedded within the power system. The surrounding context influences the performance achieved by the demonstration activities. In turn, the effects of the developed and tested innovative solutions cross the demonstration's border and impact the power system functioning. It is challenging to capture the extent of this mutual influence by the KPIs values calculated in the context of the demonstration activities. While the effects that the surrounding power system has on the demonstration activities can be captured by analysis of the local context and quantified through baseline and target values, the quantification of the impacts generated by the developed innovative solution requires a more complex analysis (e.g. SRA, Social Cost-Benefit Analysis, Multi-Criteria Analysis). Assessing the impact of the developed and tested innovative solutions on the power system requires considering the system perspective to complement the quantification of results based on KPIs defined from the demonstrators' perspective.

In conclusion, the KPIs identification and definition described in this report highlighted the great variety of activities ongoing within the OneNet project. This variety, and the differences among demonstrators due to the local peculiarities and the different actors involved, make it clear that the definition of the KPIs has to consider the peculiarities of each demonstrator and propose general definitions that, on the one hand, achieve the highest consensus, while on the other hand, can be tailored to fit with local objectives and peculiarities. Moreover, the great diversity of the demonstration activities addressed led to the definition of a set of KPIs able to embrace a wide variety of aspects concerning the TSO–DSO–Customer coordination.

This report represents the first attempt of the OneNet project regarding the definition of measurable indicators to quantify the demonstrators' performances. Future OneNet Tasks will rely on this preliminary

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proposal and deal with KPI definitions refinement, OneNet demonstrators' alignment, set of common KPIs enrichment, and the finalisation of the methodologies for data gathering and KPI calculation. Those actions are necessary to ease the analysis of the results of the different cluster demonstrations to extract conclusions for EU implementation, including the related supportive policies to enable TSOs-DSOs-Customers to procure standardized system products in a coordinated manner through interoperable platforms.

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6 Methodology for scalability and replicability analysis

As mentioned in section 2, one of Task 2.4 goals is to define the methodology to perform the Scalability and Replicability Analysis (SRA). The SRA aims to assess the effect of the implementation of the proposed solutions on a larger scale or under different contexts. This analysis will be carried out in Task 11.4 of the OneNet project. Therefore, the methodology proposed herein needs to meet the requirements and conditions set in the Description of Actions (DoA) for Task 11.4.

The description of Task 11.4 states that the SRA methodology should rely on the SGAM to determine the topics or layers to address. Nonetheless, the DoA does not prescribe any specific approach, either qualitative (e.g. desk research, surveys) or quantitative (e.g. simulations). The SRA methodology presented hereafter was proposed considering this, together with the task duration of 12 months, the available resources, and their distribution among partners.

Figure 6.1 provides an overview of the methodological framework proposed to perform the SRA in Task 11.4. This SRA approach will be essentially qualitative with two main types of input data sources: i) desk research to identify and analyse relevant SRA results from previous EU projects and ii) feedback from partners and project stakeholders on SRA results and gaps.

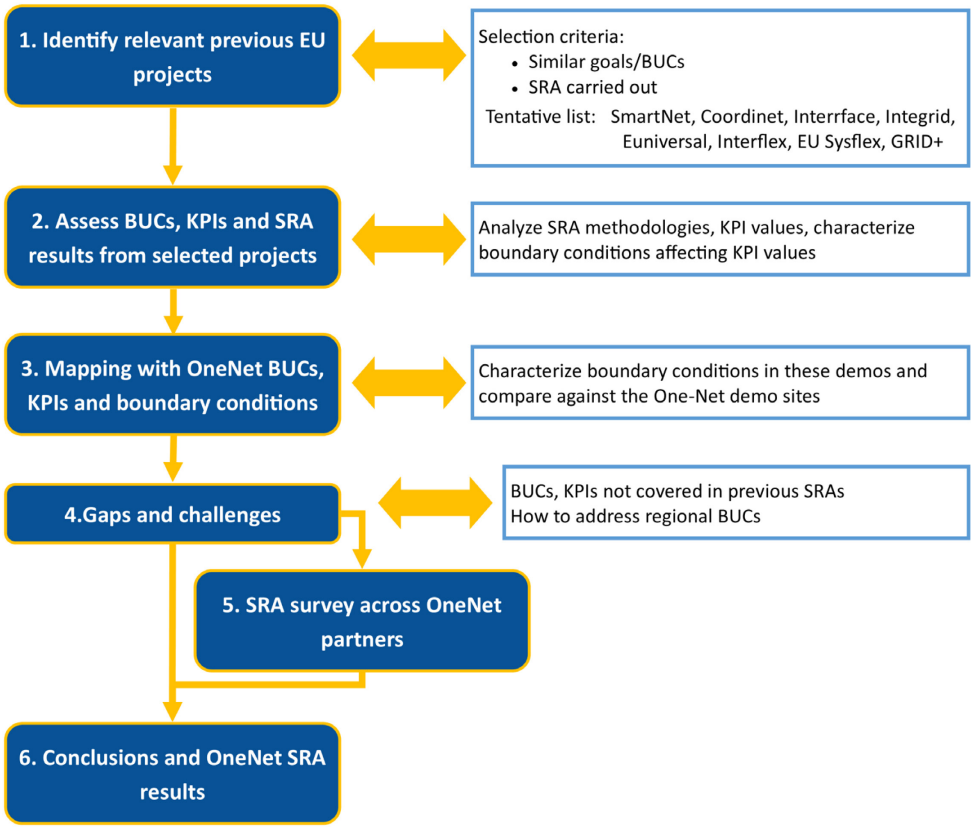

Figure 6.1 - Overview of the SRA methodology

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Each of these steps is described in further detail below. It is important to note that, despite its representation, these steps will not be necessarily fully sequential, as feedback loops may exist between them.

1. **Identification of previous relevant EU projects**. First, a selection of key past or ongoing projects to be analysed in further detail will be made. This selection will identify what projects test similar use cases and/or measure comparable KPIs. Among these, particular attention will be paid to those projects that performed some form of SRA or implementation roadmap.

   Some of the projects to explore further have already been preliminary identified. These include, among others: SmartNet, CoordiNet, INTERRFACE, CROSSBOW, Integrid, EUniversal, Interflex, EU-Sysflex, GRID+. The information is planned to be mostly collected from publicly available reports, but also benefitting from the fact that many OneNet partners have been involved in some of these projects, and through contacts within the corresponding consortiums of these projects in case reports are not available the time of performing the OneNet SRA.

2. **Assess information from selected projects.** For every selected project, the relevant information will be analysed in detail. The key aspects evaluated include i) the use cases tested and their implementation (e.g. time horizon for flexibility procurement and activation, flexibility products definition, coordination schemes, market sequence, etc.), ii) the SRA methodology and scope (e.g. the dimensions considered, i.e. functional, market and regulation, economic, social, etc.) iii) the definition of KPIs and the numerical values obtained both from demo activities and SRA studies, and iv) the boundary conditions affecting the KPI values obtained (e.g. grid characteristics, types and number of participating FSPs).

3. **Mapping relevant projects against OneNet demos**. The characterization of the previous projects obtained in the previous step is now compared systematically against the characteristics of OneNet's use cases and demo sites. This step aims to assess how comparable or applicable the conclusions of previous SRAs and demos are to the OneNet demonstrators. Differences and similarities on all the aforementioned factors will be analysed to extrapolate past results to OneNet contexts.

4. **Identify existing gaps and challenges.** The initial desk, together with the previous step, should allow detecting specific gaps and challenges for assessing OneNet solutions scalability and replicability. These may include particularities of some BUCs not covered in previous projects, missing quantification of certain KPIs, or, something that is likely to happen due to its being very OneNet specific, the fact that regional use cases have not been evaluated in past projects.

5. **Survey among OneNet partners and stakeholders.** In this step, ad-hoc surveys addressing key OneNet partners, particularly those involved in the demos and cluster, will be prepared and carried out. The aims of these surveys will be i) to validate the results obtained so far and ii) to fill in the gaps identified in the previous step. In addition, if deemed useful and possible, surveys or other means of consultation

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will be carried out among stakeholders external to the consortium either online or during specific events, e.g. GRIFOn meetings, project events, etc.

6. **Conclusions and OneNet SRA results.** Lastly, the results and lessons learnt from all the previous steps will be collected to draw the final conclusions and SRA results to be included in deliverable D11.4 by M34 of the project.

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7 Conclusions

The OneNet project aims to foster the conditions for a new generation of grid services that fully exploit demand response, storage, and distributed generation, creating at the same time fair, transparent, and open conditions for the consumer. This goal is pursued by proposing new markets, products, services, and a unique IT architecture characterised by innovative mechanisms of platform federation. The OneNet project involves 15 European countries pursuing regional cross-border cooperation among demonstrators to create a base of knowledge on the proposed solutions.

The OneNet project considers flexibility and digitalisation as the key resources and enablers for the evolution of the electricity system by addressing flexibility market unlocking, TSO-DSO cooperation enhancement, RES integration, improvement of the network operation, and stabilisation of future grid connection costs. The innovation that the OneNet project aims to bring relies on the proposal for an integrated marketplace for system services, the promotion of a consumer-centric approach, and the definition of an integrated data and platform architecture. These innovations are sought through the harmonisation of product parameters for system services (both at the cross-regional and cross SO levels), the participation of the flexibility sources to the network operation, and the creation of the conditions for interoperability and openness data management architecture.

Within OneNet Task 2.4, Deliverable 2.4 contributes to the OneNet project by defining the KPIs and the methodology for scalability and replicability analysis to assess the impacts of the OneNet solutions. This Deliverable describes the collaborative process undertaken to identify and define the KPIs for assessing the performances of the OneNet demonstrators' activities. The harmonisation of the KPI definitions to reach project-wide KPIs and the devised methodology for scalability and replicability will allow evaluating the impacts of the OneNet solutions on a European scale. Moreover, in this Deliverable, the gaps and challenges concerning the KPI definitions and the scalability and replicability analysis are identified to provide recommendations to address the upcoming OneNet Tasks. In fact, the outcome of Task 2.4 represents the input for OneNet Task 11.4.

This Deliverable describes the methodology adopted to identify and define the KPIs for the OneNet project. The KPIs defined cover demonstrators' BUCs, demonstrators' SUCs, and OneNet Regional BUCs. These KPIs measure the impact of the innovative solutions proposed and implemented by the OneNet demonstrators. An extensive project review is carried out to identify the relevant KPIs adopted by European projects similar to OneNet (i.e., CoordiNet, EUniversal, EU-SysFlex, InterFlex, and SmartNet). The most suitable KPIs for OneNet are selected based on their applicability to the features and objectives of the OneNet demonstrators to pave the way for monitoring their performance. In total, 83 KPIs from the project review were considered relevant and classified into four domains (i.e., economic, technical, environmental, and social) to support the KPI identification.

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The list of KPIs obtained as a result of the project review represents the input of the iterative process that actively involved the OneNet demonstrators' representatives in identifying and defining the KPIs to be adopted in the OneNet project. The KPIs for the demonstrators' BUCs, SUCs, and regional BUCs are defined starting from the definitions proposed by the list obtained from the project review. Several of the adopted KPIs definitions are directly adopted from the KPI project review list; other KPIs adopted by the OneNet demonstrators come from the project review, but the definitions are tailored to the OneNet demonstrators' needs. Moreover, the OneNet demonstrators also defined novel KPIs to address the peculiarities and objectives of each demonstrator.

This Deliverable presents the definition adopted for the KPIs to assess the OneNet BUCs, SUCs, and regional BUCs; the OneNet demonstrators finally adopted a broad set of KPIs (99 in total) to quantify the performances of the demonstration activities, and in turn, the OneNet project goals.

The great number of demonstrators in the OneNet projects led to a great variety of goals, actors involved, activity addressed, and local conditions. This great variety is beneficial from the research and innovation perspective since it allows to devise and test different aspects concerning the TSO-DSO-Customers coordination and explore different paths for achieving the OneNet project goals. This variety is reflected in the significant number of KPIs, which allows assessing the project results from different perspectives. The KPIs adopted by the OneNet demonstrators are classified into 10 categories that include general descriptive aspects, economic impacts, environmental and societal impacts, market performance, congestion management performance, voltage control performance, balancing performance, data processing performance, network operation performance, and prequalification process performance.

This result is obtained through cooperation with demonstrators involved in identifying and harmonising the KPIs definitions. The OneNet BUCs, SUCs, and regional BUCs are analysed to identify similarities in the objectives and activities addressed. This harmonization process allowed reaching consensus on the definition of the common KPIs considering the peculiarities of each demonstrator.

The process of identification and definition of KPIs allowed to point out a set of challenges mainly related to the peculiarities of the OneNet project in terms of project size, diversity of the demonstration goals and activities, the actual status of development, local demonstrators' characteristics, and the innovative nature of the demonstration activities.

The size of the OneNet project represents a critical aspect addressed by facilitating the sharing of the proposals among the demonstrators; however, future OneNet tasks dealing with KPIs can further improve the level of adoption and harmonisation of the defined KPIs among the OneNet demonstrators. The OneNet project is also characterized by a great diversity of demonstration activities that represent a challenge for defining a set of KPIs that applies to all demonstrators. The multiple interactions and the collaborative approach allowed devising shared definitions for calculating the KPIs adopted by the demonstrators. The diversity existing among the OneNet demonstrators influences the comparability of the same KPI calculated in different demonstrators.

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Ensuring the comparability of the demonstration results requires a dedicated baseline and target value to grant self-consistency and to consider the obtained KPI values and surrounding aspects that allow building a comprehensive picture of the demonstrator's activity.

The lack of historical information, knowledge, and experience represents a challenge for defining and calculating the KPIs related to markets and flexibility products. The main challenge due to the lack of a generally recognised benchmark especially relates to BUCs on novel market structures and new flexibility products.

The KPIs identification and definition described in this report highlighted the great variety of activities ongoing within the OneNet project. The variety of activities, local peculiarities, and the differences among the actors involved make clear that a single solution will not well perform for assessing the project results. Therefore, the definition of the KPIs has to consider the peculiarities and propose general definitions that can be tailored to fit local objectives and peculiarities by preserving generality. Since the differences among different contexts, a different baseline can be required for the same KPI. The same reasoning applies to target values. Hence, performance assessment has to consider the context peculiarities. On the contrary, the KPI definition and calculation methodology have to be harmonised to ensure comparability across different contexts.

Demonstration activities concerning the coordinated provision of services at the system and local levels develop and test innovative solutions that have to be embedded within the power system. The surrounding context influences the performance achieved by the demonstration activities. The effects of the developed and tested innovative solutions cross the demonstrators' border and impact the power system functioning. It is challenging to capture the extent of this mutual influence by the KPIs values calculated in the context of the demonstration activities. While the effects that the surrounding power system has on the demonstration activities can be captured by analysis of the local context and quantified through baseline and target values, the quantification of the impacts generated by the developed innovative solution requires a more complex analysis (e.g. SRA, Social Cost-Benefit Analysis, Multi-Criteria Analysis). Assessing the impact of the developed and tested innovative solutions on the power system requires considering the system perspective to complement the quantification of results based on KPIs defined from the demonstrators' perspective.

This Deliverable also presents the Scalability and Replicability Analysis methodology devised for the OneNet project based on best practices on the EU level. The SRA aims to assess the effect of implementing the proposed solutions on a larger scale or under a different context. The proposed SRA to be used in OneNet is based on the best practices proposed by the BRIDGE task force and will be essentially qualitative with two main types of input data sources: desk research to identify and analyse relevant SRA results from previous EU projects and feedback from partners and project stakeholders on SRA results and gaps. The devised SRA relies on six steps: identification of previous relevant EU projects, assessment of the information from selected projects, mapping relevant projects against OneNet demos, identification of the existing gaps and challenges, information gathering from the OneNet partners and stakeholders, formulation of the OneNet SRA results.

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In conclusion, this Deliverable represents the first attempt of the OneNet project regarding the definition of indicators to quantify the demonstrators' performances and the definition of the methodology to address the scalability and replicability analysis. Future OneNet Tasks will rely on this preliminary proposal and deal with KPI definitions refinement, OneNet demonstrators' alignment, enrichment of the set of common KPIs, finalization of the methodologies for data gathering and KPI calculation, and will apply the proposed scalability and replicability methodology.

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