EUniversal
UMEI

MARKET ENABLING INTERFACE TO UNLOCK FLEXIBILITY SOLUTIONS FOR COST-EFFECTIVE MANAGEMENT OF SMARTER DISTRIBUTION GRIDS

Deliverable: D6.2

Definition KPI for DEMOs

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Document
D6.2 Definition KPI for DEMOs

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Abbreviations

BUC(s)	Business Use Case(s)
D	Deliverable
DE	Germany
DER	Distributed Energy Resources
DSO(s)	Distribution System Operator(s)
FMO	Flexibility Market Operator
FSP	Flexibility Services Provider
GA	Grant Agreement
HV	High Voltage
KPI(s)	Key Performance Indicator(s)
LV	Low Voltage
MV	Medium Voltage
P2P	Peer to Peer
N. A	Non applicable
P	Producer
PL	Poland
PT	Portugal
RA	Resource Aggregators
RES	Renewable Energy Sources
SO(s)	Specific Objectives(s)
SUC(s)	System Use Case(s)
TSO(s)	Transmission System Operator(s)
UC(s)	Use Case(s)
UMEI	Universal Market Enabling Interface
WP	Work Package

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Executive Summary

The main objective of this deliverable is to identify and define the EUniversal DEMO Key Performance Indicators (KPIs) which will support the monitoring and assessment procedure of the pilot and project activities. In addition, the EUniversal project KPIs, associated with the expected impacts of the call under the European Horizon 2020 programme, are also included.

KPIs serve to evaluate the success and impact of the demonstrators and quantify the overall contribution of EUniversal to the primary goal of enabling a transformative and modular approach, the Universal Market Enabling Interface (UMEI), to couple active system management of the networks with electricity markets that allow for effective provision of flexibility services.

The work from Task 6.2 presented in this deliverable is closely linked to Task 2.2, 'Business use case definition' and Task 2.3 'System Architecture and system use cases' (UC). Furthermore, the work conducted in work packages (WPs) 7, 8 and 9, related to the Portuguese (PT), German (DE) and Polish (PL) pilots, are also key for the development and understanding of this deliverable, as the DEMOs serve to demonstrate and validate the services defined in the project. The structured and reproducible methodology followed to achieve the objective above is depicted in Figure 1.

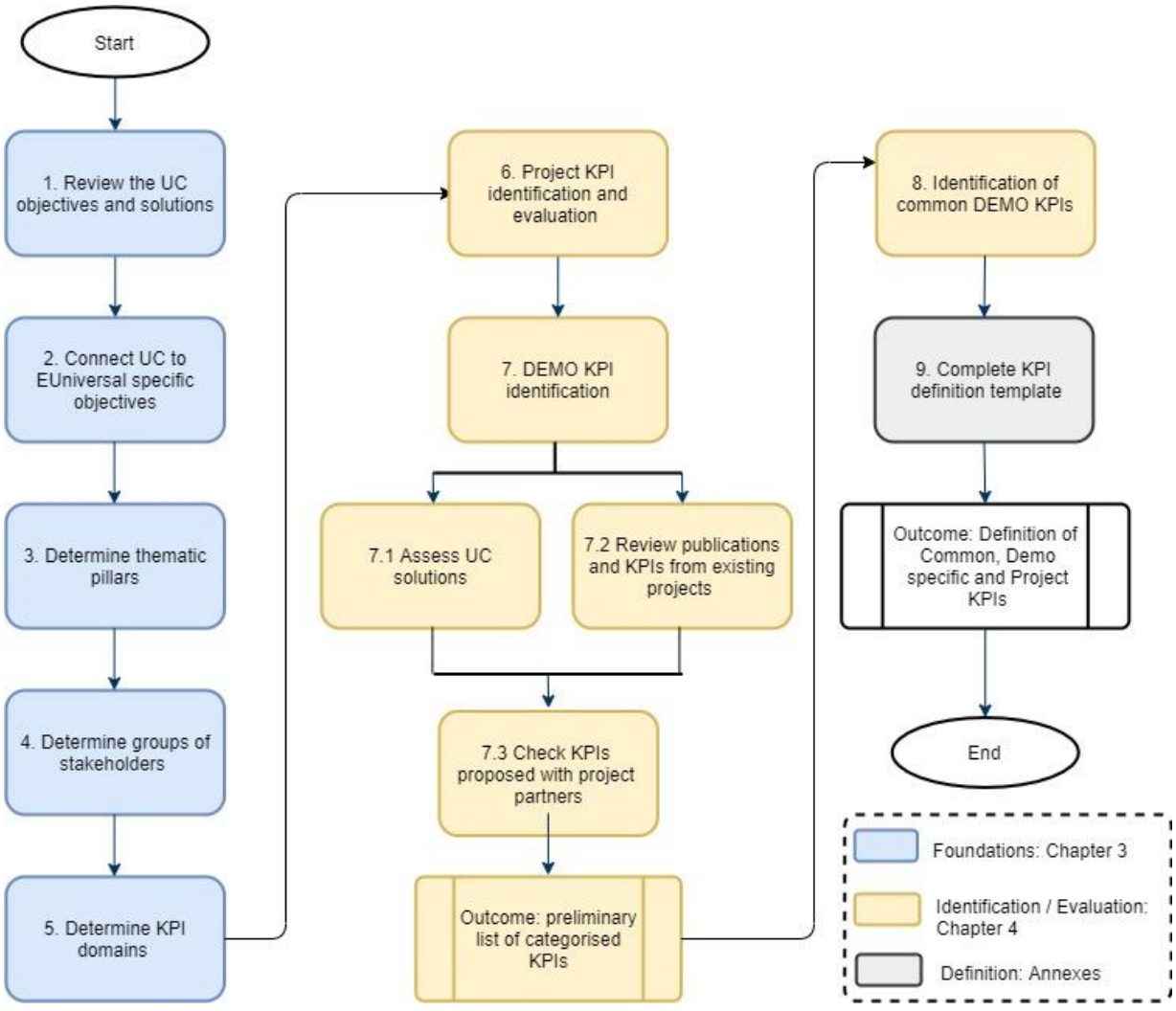


Figure 1. Flow chart presenting the methodology followed in Deliverable 6.2 to identify and define the Key Performance Indicators.

As a result of the steps above, a total of 24 KPIs have been identified for the EUniversal project to enable the evaluation of the project performance. These KPIs can be classified in four domains:

- Technical Domain (19 KPIs) - related to the KPIs measuring the technical performance such as the fulfilment of voltage limits (Polish DEMO).
- Economic Domain (3 KPIs) - related with the KPIs that are measuring the economic and regulatory performance such as the costs of congestion management with flex Market vs Curtailment (German DEMO).
- Environmental Domain (1 KPI) - related to the KPIs measuring the avoided CO_2 emissions from increased Renewable Energy Sources (RES) and Distributed Energy Resource (DER) hosting capacity (Portuguese DEMO).
- Social Domain (1 KPI) - related to the KPI measuring the variation of the resource provider's consumption due to the flexibility services activation, as a way to deliver further information to consumers on how the flexibility provided impacted their consumption, and ultimately their energy bill (Portuguese DEMO).

The KPI domain mapping of the EUniversal project KPIs, common KPIs to at least two DEMOs, and the specific KPIs for the Portuguese, German and Polish DEMO is shown in Table 1.

Table 1. Mapping of the KPIs in EUniversal project KPIs, common KPIs for at least two DEMOs and DEMO-specific KPIs for the Portuguese, German and Polish DEMO

KPI Domain	EUniversal project KPI	Common KPI	DEMO specific KPIs		
			PT DEMO	DE DEMO	PL DEMO
Technical	6	5	/	4	4
Economic	/	/	2	1	/
Environmental	/	/	1	/	/
Social	/	/	1	/	/

To calculate these KPIs, the data included in the KPI definition templates found in Annexes 1-6 has to be collected and used following the calculation methodologies described in such templates. The results and evaluation obtained through the regular monitoring of the KPIs, DEMOs and project activities will be presented in Deliverable 6.3.

1. Introduction

The EUniversal project aims to contribute to the transformation of the electricity grid by overcoming barriers to the **implementation of flexibility services by distribution system operators (DSOs)** through the development of a **Universal Market Enabling Interface (UMEI).** Implementing the UMEI will bring forward an adaptable concept to link active network management with electricity markets that takes the activation needs and coordination requirements with all stakeholders into consideration. The EUniversal Specific Objectives can be found in Chapter 3.

As part of the EUniversal project, demonstrators in three sites in Germany (DE), Portugal (PT) and Poland (PL) will develop and validate the services and project solutions. Key Performance Indicators (KPIs) will serve to evaluate and compare the impact of the DEMOs and the project. KPIs are a compact and meaningful tool to evaluate the development, optimisation, and potential of specific solutions implemented to achieve a use case or a project objective (Pramangioulis et al. 2019).

The main objective of this deliverable is to identify and define the specific KPIs for the project's demonstrators. In addition, D6.2 also aims to present the project KPIs, including the indicators proposed in the Grant Agreement related to the impacts of the EUniversal project and introduce the System Use Cases (SUCs) KPIs, related to the efficiency of the tools used. This report exhaustively defines the KPIs by detailing the key information, calculation methodology, data collection and baseline of each indicator.

These targets are fulfilled in the context of WP6, 'DEMO harmonisation and monitoring,' and T6.2, titled 'Definition of DEMO KPIs and continuous evaluation of the DEMOs.' The efforts of T6.2 are to be presented in two deliverables. The KPIs defined in the D6.2 will allow regular quantitative evaluations and comparisons of the effectiveness and success of the solutions proposed to achieve the UCs and project objectives. Then, D6.3 will present this periodic and continuous evaluation of the DEMO activities based on the KPIs and their main results.

The methodology followed to fulfil the targets previously described has been adapted from the research Pramangioulis et al. (2019) to fit the EUniversal project. The goal has been to follow a step-by-step approach that is structured, reproducible and harmonised among the three DEMOs (Pramangioulis et al. 2019).

Firstly, the foundations needed to conduct the KPI identification efforts are laid out by analysing the DEMOs UC objectives and solutions and linking these UCs to the Specific Objectives (SOs) of the EUniversal project. The SOs are used to determine the thematic pillars. Furthermore, the stakeholder groups of interest and KPI domains (technical, environmental, economic, and social) are established and defined.

Once this initial definition of key parameters and analysis of the UCs and specific EUniversal objectives have been conducted, the KPI identification process begins. The EUniversal project KPIs that were pre-defined in the Grant Agreement (GA) related to the H2020 call impacts are evaluated and the KPIs related to the System Use Cases (SUCs) are presented.

The DEMO partners analysed every UC from the point of view of the stakeholder groups defined, considering every KPI domain. The DEMOs did not only consider technical aspects but also considered other domains to obtain a more holistic result.

In parallel, scientific publications and results from other H2020 projects that also used KPIsas means to monitor and assess the DEMOs were reviewed to learn from previous experience. The EUniversal project also participated in the PlatOne ES-1 intraproject workshop for the 'Flexibility and Retail Market Options for the Distribution Grid' H2020 call, contributing to the KPI breakout session. This enhanced the understanding of the other ES-1 project challenges, timeline and recommendations regarding KPIs.

With all the DEMOs specific KPIs being defined, each demonstrator had to review the other two DEMOs KPIs and evaluate which KPIs could become common to two or three of the DEMOs. This exercise will enable measuring the success of the project as a whole and will allow valuable comparisons, while at the same time simplifying the extensive list of indicators.

The KPIs identified were discussed with the project partners to align and ensure data availability. For all the KPIs identified, a template is filled in containing the information required, calculation methodology, data collection and baseline. The KPI identification and definition process results in a list of KPIs divided into three categories, as shown in Table 2. Each KPI is linked to particular stakeholder group of interest, KPI domains, impact of the call and EUniversal project objective.

Table 2. Types of KPIs included in Deliverable 6.2.

Type of KPI	**Description**
Project KPIs	EUniversal Project KPIs evaluating the impacts of the call and SUC KPIs.
DEMO KPIs - Common KPIs	Common to more than one DEMO allowing for comparison and evaluation of the project's success.
DEMO specific KPIs	Validating the items that each particular DEMO is tackling.

This deliverable is divided into 6 chapters. Chapter 2 describes the methodology followed for the KPI identification and definition in detail. Chapter 3 explains the initial steps that had to be taken to set the foundations for the KPI identification, including the analysis of the DEMOs objectives and solutions proposed. It also presents the connection between the UCs and the overall SOs of the EUniversal project, the classification of the Business Use Cases (BUCs) in thematic pillars, the definition of key stakeholder groups and the selection of the KPI domains.

In addition, Chapters 4 and 5 detail the KPI identification stages, starting with determining the DEMOs specific KPIs, followed by an evaluation of which are common to more than one DEMO and an assessment of the GA KPIs and KPIs related to the SUCs. Finally, the results of the D6.2 are presented in Chapter 5, with a detailed template including all the key information completed for each KPI included in the Annexes. The main conclusions from the deliverable are presented in Chapter 6.

2. Methodology

This chapter aims to describe the methodology followed to fulfil the objectives described in Chapter 1. KPIs have been selected as the means to measure the effectiveness of the solutions proposed to achieve the UCs and EUniversal project objectives. Therefore, analysing the solutions provided in a structured and reproducible manner is key for the development and evaluation of the project. Accordingly, the systematic approach proposed in Pramangioulis et al. (2019) was adapted to suit the needs of the EUniversal project.

Subchapter 2.1 will describe the steps that have been established to define the key parameters and systematically analyse the UCs and EUniversal specific objectives to set the foundations for the KPI identification. Subchapter 2.2 will detail the methodology behind the structured and replicable definition and classification of KPIs. Figure 2 presents an overview of the Key Performance Indicator definition methodological framework followed.

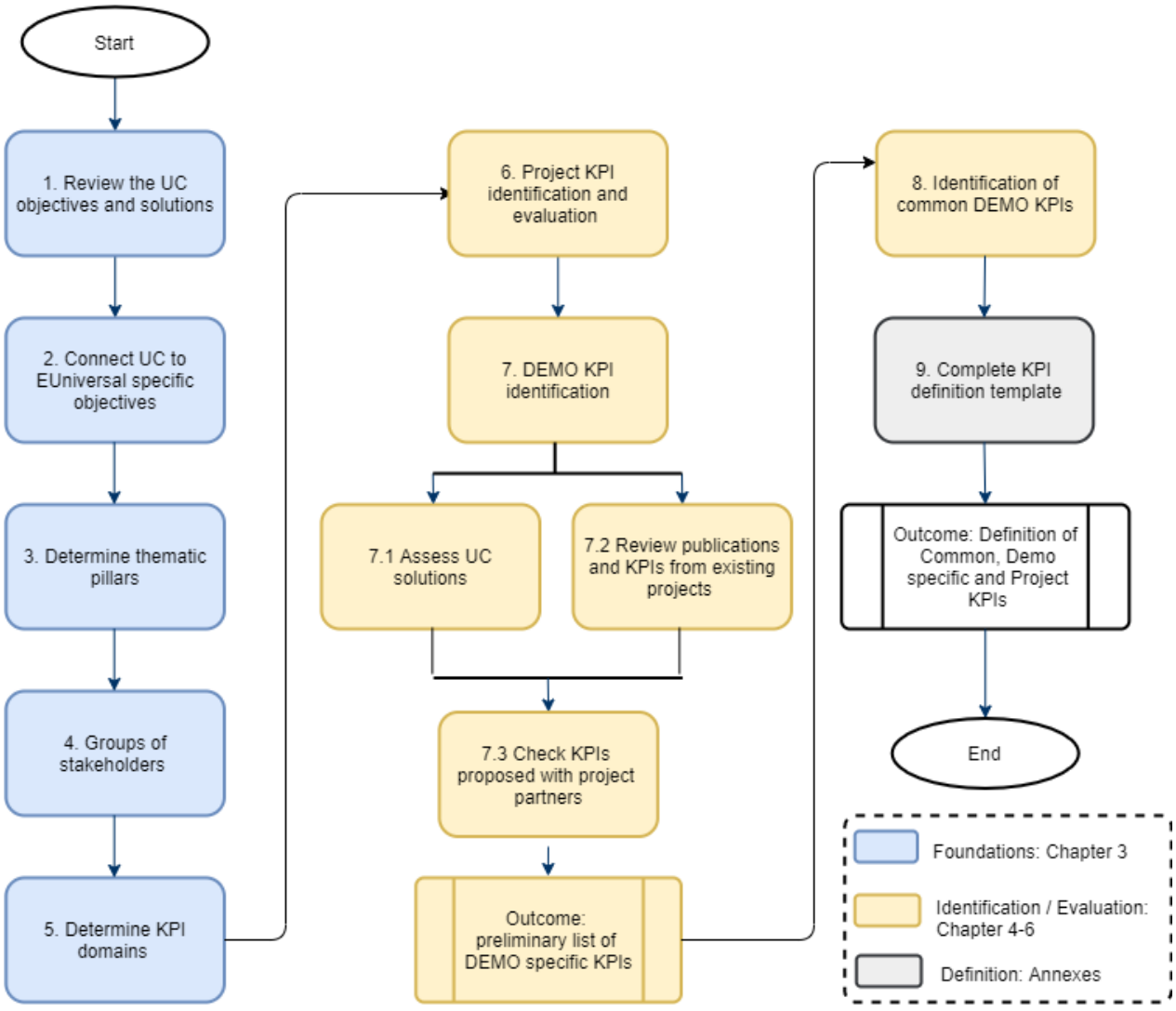


Figure 2. Flow chart presenting the methodology followed to identify and define the Key Performance Indicators.

2.1 Foundations: UC solutions and EUniversal Specific Objectives

This subchapter aims to describe the tasks performed to set a solid basis for the KPI identification and definition. Figure 2 illustrates an overview of the step-by-step methodology followed, situating Steps 1-5 in this subchapter inside the broader methodological framework. The results obtained by conducting these initial steps can be found in Chapter 3.

Step 1: Review the Use Cases (UCs) objectives and solutions.

KPIs aim to quantify and compare the effectiveness of each UC solution proposed. Therefore, the first step is to analyse the UC objectives and list the proposed solutions serving to achieve each Use Case objective.

Step 2: Connect Business Use Cases to the EUniversal specific objectives (SOs).

KPIs not only allow to assess and compare the UC solutions but also serve to assess if the EUniversal project objectives have been fulfilled and to what extent. To do so, the EUniversal specific objectives are reviewed and linked to the relevant Business Use Cases, in an effort to ensure that all the expected objectives are tackled and will be covered when determining the KPIs.

Step 3: The EUniversal SOs have allowed to determine thematic pillars.

The thematic pillars set the first analytical layer for the proposed KPI identification process. This is an effective manner to classify the solutions and make a clear connection to the area that each KPI is expected to evaluate. In contrast to the methodology presented in Pramangioulis et al. (2019), the thematic pillars proposed for this project are not limited to technological solutions. The thematic pillars proposed are linked to the specific objectives of the project and are the following:

- Networks;
- Markets and market mechanisms;
- Investment and business models.

The KPIs related to the thematic pillar `Markets and market mechanisms' and specific to the demonstrators will be introduced in this deliverable. Next to that, KPIs related to this thematic pillar will also be developed in WP5 for specific market mechanisms. In particular, KPIs will be defined to compare alternative distribution tariff designs (as part of T5.2 "Methodology for dynamic distribution grid tariffs") and to analyse different alternative peer to peer (P2P) market designs (as part of "T5.3. Implications for flexibility services and market mechanisms in a peer-to-peer market setting").

Step 4: Definition of the main groups of stakeholders.

The main stakeholder groups are assessed to evaluate the solutions through the perspective of each of these key stakeholders. This enables a more structured identification of KPIs and aims to get a more holistic view of the success and impact of the project. It also seeks to follow a methodology that is structured and reproducible. The main stakeholders' groups are DSOs, Customers, Flexibility Market Operators, Institutions, Producers (Ps) and Resource Aggregators (RAs).

Step 5: Determine KPIs domains

KPI domains or dimensions are defined to support the KPI identification in Step 6. These categories also allow classifying the identified KPIs in groups that monitor similar functions. It also facilitates filtering and finding the KPIs of particular interest for the reader.

Throughout the completion of D6.2, special attention has been given to not limit the scope to KPIs in the technical domain and include economic, environmental, and social KPIs. This allows for a better overview and assessment of the impact of the DEMOs and the project.

2.2 Identification and definition of KPIs

The goal of this subchapter is to detail the methodology followed for the KPI identification and definition process, after having analysed the EUniversal projects specific objectives and UC objectives and solutions, and detailing the key parameters needed. Figure 1 situates the steps in this subchapter, steps 6-8 in the wider methodological context.

Step 6: Project KPI identification: GA and SUC KPIs

In addition to the DEMO KPIs, the project KPIs related to aspects outside of the BUCs are evaluated. These include the KPIs introduced in the GA that relates to the specific impacts to the project and the SUC KPIs related to the efficiency of the tool.

Step 7: DEMO KPI identification

Step 7.1: Assess the UC solutions from the perspective of each stakeholder group and domain.

The UC solutions are assessed following a structured methodology. The UC objectives and solutions have been previously reviewed in the foundation steps 1-3, in which these are studied, connected to the EUniversal Specific Objectives, and classified in thematic pillars.

Firstly, in an orderly manner, a UC solution is chosen. Then, a stakeholder group is selected – e.g., customers, and the UC solution is assessed from the perspective of that actor, according to the different domains (economic, technical, environmental, and social). Then this process is repeated for the rest of the UC solutions. Figure 3 shows the structured methodology followed to methodically identify the DEMO KPIs. This method will result in a preliminary list of KPIs per DEMO.

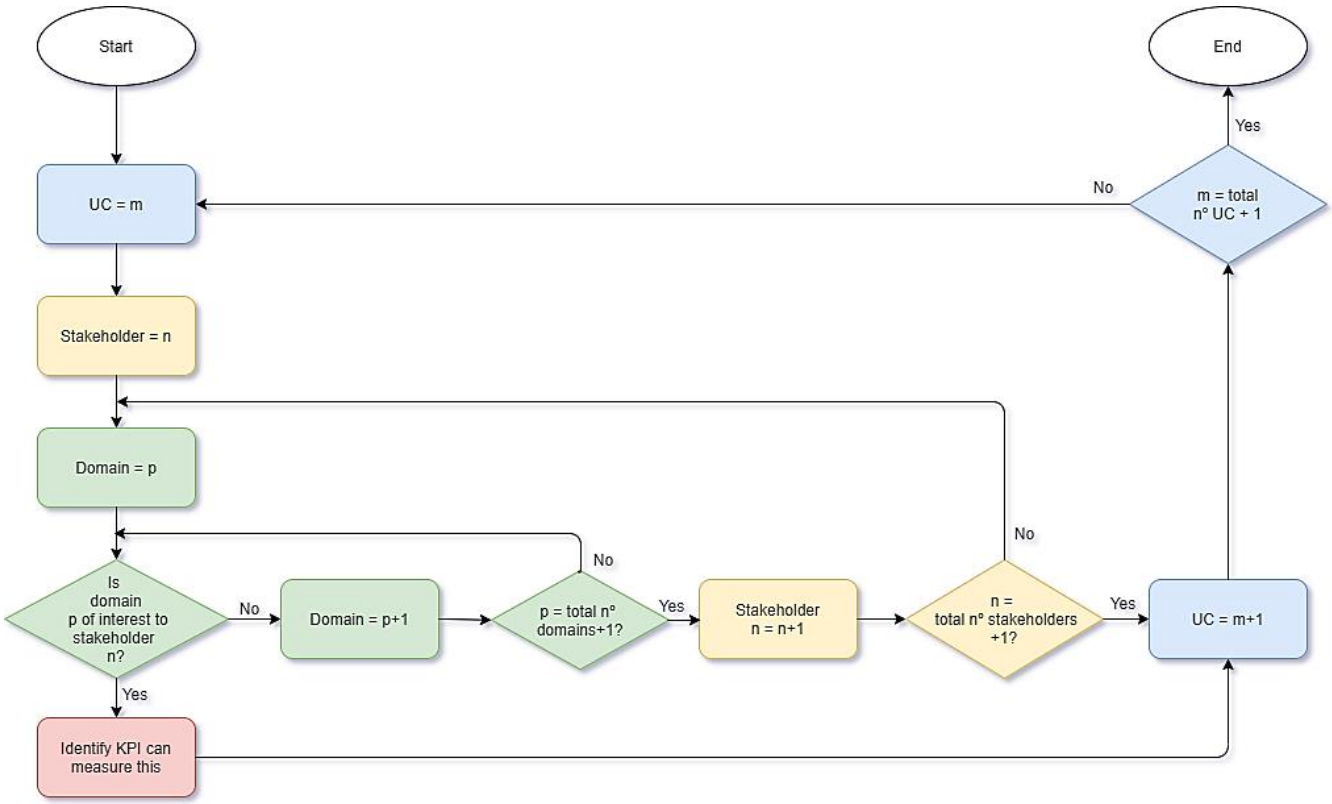


Figure 3. Flowchart representing the structured approach to methodically identify DEMO KPIs from a multi-stakeholder perspective.

For example, UC1 would be assessed from the point of view of stakeholder 1 for each domain (environmental, economic, etc), identifying a KPI for the areas of interest and impact for that stakeholder. Additional considerations such as data availability were also considered when selecting the relevant DEMO KPIs.

Step 7.2: Review of publications and KPIs from existing H2020 projects.

The identification of KPIs is a procedure that is commonly used when assessing research demonstrators. As such, EUniversal took the opportunity to learn from experience and to assess the scientific publications, KPI definition and results from other research projects. The projects and publications that were identified and proved most useful for the project were the following:

1. The publication (Pramangioulis et al. 2019), that contains a detailed methodology.
2. PlatOne D1.2 'Project KPIs definition and measurement methods' was used to incorporate an analogous clear layout and concise summary tables (PlatOne 2020).
3. InteGrid D2.6 'Preparation and Monitoring of Demonstration Activities' (Integrid 2020)
4. UPGRID D1.4 r2 'Report on common KPIs' (UpGrid 2020).
5. CoordiNet D1.6 'List of KPIs: KPI and process of measures,'(Coordinet 2020).

The EUniversal project also benefited from the experience of EUniversal partners from previous projects and collaboration with other current projects. For example, EUniversal participated in the

ES1 workshop, openly discussing with other projects from the H2020 call 'Flexibility and Retail Market Options for the Distribution Grid' H2020 call during the KPI breakout session.

Step 7.3: Check KPI preliminary list with project partners

This preliminary list needs to be iterated before obtaining a final inventory of the EUniversal DEMO KPIs. The stakeholders participating in the DEMO shown in Table 3 are consulted.

Table 3. DEMO project partner types and organisations to iterate the preliminary KPI list with.

The result of the steps up to this stage is a preliminary list of DEMOs' specific KPIs. A table is produced containing the BUCs with their corresponding thematic pillar, and the KPI linked to the key stakeholder group impacted and KPI domain. This table reflects the holistic and reproducible approach followed by the DEMOs in a harmonised manner.

Step 8: Identification of common DEMO KPIs

Once the PL, DE and PT DEMOs have identified the initial DEMO-specific KPIs, each pilot evaluates the KPIs proposed by other demonstrators, to establish which can be common to more than one DEMO. This task will allow to measure the impact and success of the EUniversal project and will enable valuable comparisons, while at the same time simplifying the extensive list of indicators.

Step 9: For each KPI, complete a template of key information.

The template is adapted from the one used in previous projects PlatOne, which is based on the tables used for the Grid4EU project (Grid4EU, 2020). The result of D6.2 is summarised in Chapter **Error! Reference source not found.**, with a complete overview of the KPIs classified by domains. In addition, the filled in templates can be found in the annexes: EUniversal Project KPIs in Annex 1,

Common KPIs in Annex 3, and the DEMO KPIs for the Portuguese, German and Polish demonstrators in Annexes 4, 5 and 6 respectively.

The KPI template contains the following information:

1. KPI Information:
   - KPI Name and ID
   - Strategic Objective (SO) that it was linked to.
   - DEMO(s) where the KPI applies.
   - UC where KPI applies if any: If it related to a specific BUC, SUC or if it is a KPI identified outside the UCs.
   - Owner: Person and company responsible and accountable for single KPI. If the same KPI will be used in different DEMOs, a single owner must be defined, who will be responsible for retrieving the KPI from different DEMOs.
   - KPI description: Description of KPI and rationale for including in project.
   - KPI formula: Precise mathematical formula for calculating KPI, and explanation of the defined formula.
   - Unit of measurements: (i.e. % percentage basis, MW, MWh, etc.)
   - Target / Threshold: Target of KPI relative to defined baseline.
   - Reporting Period: Indicate how often this indicator must be reported (weekly, monthly, yearly).
   - Reporting Audience and Access Rights: To whom will this indicator be reported and access rights. Also, indicate here specific access restrictions (if any): Public / EUniversal / DEMO / Other.
   - Other: Indicate specifics of Reporting Audience and Access Rights if OTHER (please specify) was marked above.

2. KPI Calculation Methodology:
   - KPI Step Methodology ID,
   - Step by step methodology on how to calculate defined KPI
   - Responsible party: Person and Company responsible for a specific step in KPI calculation methodology.

3. KPI Data collection
   - Data: data to collect
   - Data ID: Identification of data requiring collecting, that is later used in formulas for calculating KPI
   - Methodology for data collection: Describe the method by which data is collected.
   - Source/Tools/ Instruments for Data collection
   - Location of Data collection: Where is data measured/located?
   - Frequency of data collection: Indicate how often, when and for how long data is collected.
   - Data collection responsible: Name of person & Company responsible for collecting data.

4. KPI Baseline
   - Source of Baseline Condition: Literature values / Company historical values / Values measured during the project / Other.
   - Details of the Baseline
   - Responsible for Baseline: Name and company

3. Foundations for KPI identification

This Chapter aims to detail the efforts necessary to set a solid basis for the identification and definition of valuable KPIs. The structure of this chapter is depicted in Figure 4. Subchapter 3.1 seeks to examine the BUCs of each DEMO, firstly by reviewing their objectives and solutions (subchapter 3.1.1), then by connecting each of these BUCs to the EUniversal specific objectives and classifying them in thematic pillars based on these objectives (subchapter 3.1.2). Chapter 3.2, assesses the main stakeholder groups that will be impacted by the DEMOs, and Chapter 3.3 defines the KPI domains (technical, economic, environmental, and social), in which the final list of KPIs will be classified.

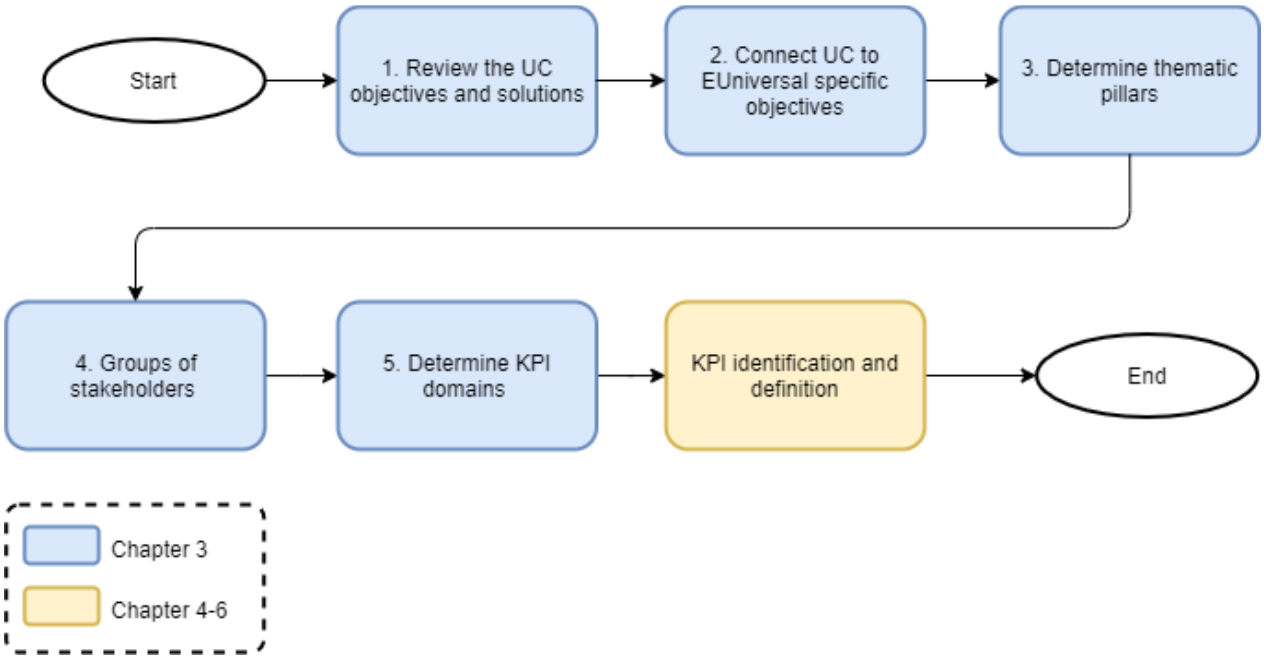


Figure 4. Diagram depicting the methodological framework to set the foundations of the KPI identification and definition process.

3.1 Preliminary analysis

The demonstrators in EUniversal focus on connecting the DSOs network infrastructure to the electricity market, the UMEI. Three demonstrator sites were chosen to test the solution in a range of locations with distinct distribution network topologies, regulatory environments, and national plans. These pilots are located in Portugal, Germany and Poland.

KPIs have been selected as the means to evaluate the impact and success of the demonstrators, as well as the EUniversal project as a whole. This subchapter contains the review and analysis of the DEMOs BUCs objectives and solutions in section 3.1.1, linked to the overall objectives of the project in section 3.1.2.

Reading Deliverable 2.2, 'Business Use Cases to unlock flexibility service provision,' is recommended to get a more complete understanding of this subchapter. Furthermore, for in depth information about each DEMO, the WP7 deliverables focus on the Portuguese DEMO, WP8 on the German DEMO, and WP9 in the Polish DEMO. To provide context, a summarised description of each DEMO has been included below.

Portuguese DEMO

The Portuguese DSO is facing some specific challenges and problems in the grid area under study. In the DEMO, it is intended to analyse how the penetration of copious amounts of distributed energy resources (EV, microgeneration, distributed storage) can support the grid operation in terms of congestion management and voltage control in MV and LV grids. Moreover, it is planned to analyse those problems when they arise due to a contingency. The aim is to solve grid constraints by establishing an exchange between the DSO and aggregators via a flexibility market and thus to make decentralised flexibility solutions accessible for grid services.

Specifically, for the Portuguese DEMO, congestion management and voltage control in MV and LV grids are the key issues to be addressed. The objective is first to anticipate the problems and then to use local flexibility markets to solve them. Regarding the scoping of the DEMO, the day-ahead market (or several days in advance for maintenance actions in the distribution grid) will be considered to solve grid problems identified through forecasting, analysis, and optimization tools. Furthermore, the medium- and long-term flexibility market will be adopted for grid planning and maintenance purposes.

In the Portuguese DEMO, both the NODES and N-SIDE market platforms will be tested in parallel. The NODES platform includes ShortFlex and LongFlex markets (specific NODES terminology) with continuous trading of flexibility across distinct timeframes. The most cost-efficient solution is selected and validated by the DSO to solve the predicted grid congestion. N-SIDE's Local Flexibility Market platform aims to help solve grid problems by offering an auction-based mechanism that facilitates the matching of the DSO's expressed needs with the flexibility service providers (FSPs)/aggregators' offers through an algorithm aiming to maximize the social welfare. It is the intention to test each BUC with each market platform.

Apart from common KPIs that will be used to evaluate all DEMOs, for the Portuguese DEMO it will be calculated KPIs related to the long-term market, since this is the only demonstrator where this type of market will be tested.

German DEMO

The German DSO is investigating the use of flexibility markets in low and medium voltage and their specific challenges. At present, the low-voltage grid is not monitored at all or only to a limited extent. With the increasing number of renewable generation and the addition of new flexible loads, congestions and voltage problems in the grid are becoming more frequent and observability needs to be increased. Therefore, the main objectives of the demonstrator are to increase observability and to develop technical solutions for congestion management and voltage control in the LV-Grid with the help of flexibility markets. It is therefore important to provide accurate forecasts. The implementation is framed by a schedule-based congestion management. The calculations start day ahead and are carried out iteratively until shortly before real time.

In addition to the common KPIs, the measurement of the execution time is therefore an important DEMO specific key indicator that is introduced to be able to keep the intermediate steps of the iteration. Special importance is also attached to the assessment of the economic efficiency of the approach and the correct forecasting of congestions and voltage band violations.

Polish DEMO

The Polish DSO is facing some specific challenges and problems in the grid area under study at all voltage levels. In the medium voltage (MV) grid area, the key issue is congestion management and

voltage control using the flexibility market. In the Polish DEMO, the market platform NODES will be tested with continuous trading in flexibility across distinct timeframes. The most cost-efficient solution is selected and validated by the DSO to solve the predicted grid congestion.

In the low voltage (LV) grid, the problem is the lack of observability. The LV network is not monitored at all or only to a limited extent. With the growing number of RES and the addition of new flexible loads, congestion and voltage problems in the grid are becoming more frequent and observability and controllability should be increased. The Polish DEMO is based on the experience acquired partially in the UPGRID project, in which solutions increasing the observability of the network were tested. Therefore, the main DEMO goals in the area of LV grids are to increase the observability and develop technical solutions for and control voltage using an autonomously managed intelligent secondary substation (flexstation).

Additionally, in the Polish DEMO, flexibility services offered by DSO for 110 kV lines congestion mitigation purposes on the HV level will be tested. The offer is dedicated to the RES energy producers where electricity production is weather dependent. It is applicable for high voltage levels 110kV lines which load capacity is affected by excessive (above connection agreement value) renewable power generation.

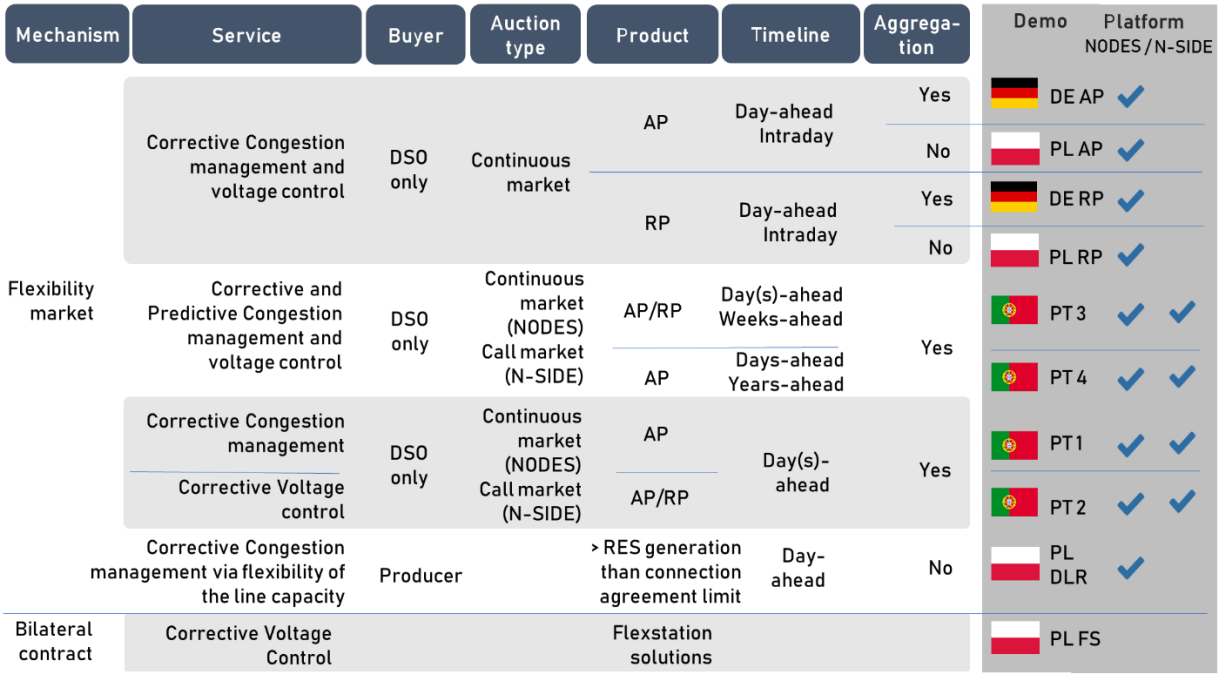
3.1.1 DEMOs BUCs objectives and solutions

For each DEMO, BUCs that specify a set of actions performed by the system to achieve an observable result (ISO/IEC 19505-2:2012) have been developed. Therefore, an in-depth understanding of the UCs is necessary prior to the KPI identification, as KPIs aim to quantify and compare the effectiveness of the solutions proposed for each UC. Consequently, the first step for KPI identification is to review the UCs and proposed solutions.

Figure 5 depicts a detailed overview of BUCs for the three DEMOs. It indicates the market mechanism, flexibility service provided, buyer of the service, auction type, product, timeline, and aggregation. It also indicates whether the platform is supported by NODES or N-SIDE.

Given the project's focus on local flexibility markets, most UCs focus on local flexibility markets. Only the Polish UC on flexstations (PL FS) is using bilateral contracts. On all flexibility markets, the DSO is the only buyer of flexibility. The only exception is the Polish UC on Dynamic Line Rating (PL DLR) where the producer is the buyer. Furthermore, all UCs focus on the delivery of congestion management and/or voltage control grid services through active and reactive power. The auction type specified per UC depends on the type of market platform being used. For NODES this is a continuous market, for N-SIDE this is a call market. In the Portuguese UCs, both market platforms will be used to compare different market approaches and as such to evaluate UMEI for data exchange between multiple markets. With regard to the timing, most UC operates in a day-ahead and/or intra-day time schedule. However, the Portuguese UC PT3 and PT4 are also looking at more medium- and long-term markets (weeks-ahead and years-ahead). Finally, all UCs apart from the Polish UCs allow for aggregation.

Figure 5. Overview of the BUCs for the three DEMOs.



3.1.2 Link UCs to the overall objectives of the project

The next step in the methodology involves indicating which specific UCs will contribute to accomplish each EUniversal Specific Objectives (SOs). This will allow to assess at a later stage in the project if, and to what extent, the EUniversal project objectives have been fulfilled.

Table 4 shows the list of the EUniversal project SOs, which combined, tackle the main goal of the project: the implementation of the Universal Market Enabling Interface (UMEI). In addition, the table indicates the BUCs that will allow to achieve each of these SOs. SO6 will be addressed through simulations of the networks of the three pilots.

Table 4. EUniversal project specific objectives and the corresponding UCs to achieve the SOs.

SO number	SO description	BUC
SO1	To **create a standard, adaptable and modular market-enabling interface** to link smart grids to flexibility markets and to coordinate the actions with commercial parties and system operators.	PT1, PT2, PT3, PT4 DE AP, DE RP PL AP, PL RP, PL DLR

SO2	To increase grid flexibility through the development of **new flexibility services** and tools in a multi-energy system scenario	PT1, PT2, PT3, PT4 DE AP, DE RP PL AP, PL RP, PL DLR, PL FS
SO3	To **incentivise market flexibility** by defining the appropriate market mechanisms to optimise the procurement and activation of new flexibility services for grid operation	PT1, PT2, PT3, PT4 DE AP, DE RP PL AP, PL RP, PL DLR, PL FS
SO4	To optimise **network planning and operation** based on available flexibility both from the grid and market-based services.	PT1, PT2, PT3, PT4 DE AP, DE RP PL AP, PL RP, PL DLR, PL FS
SO5	To **reduce technical restrictions in the operation of the networks** by improving control and observability of the distribution system and further reliance on flexibility services	PT1, PT2, PT3, PT4 DE AP, DE RP PL AP, PL RP, PL DLR, PL FS
SO6	To increase the **resilience of the grids** by implementing adaptive/self-healing schemes for distribution networks, notably in the advent of extreme climate events.	/
SO7	To establish new criteria for network **investment and for operational planning** both in normal and emergency operation - taxonomy, procedures and performance metrics	PT1, PT2, PT3, PT4
SO8	To establish the main pillars of **business model archetypes** for smart grid solutions and for the market-driven flexibility activation considering potential users, value proposition, value chain and profit model.	PT1, PT2, PT3, PT4 DE AP, DE RP PL AP, PL RP
SO9	To reduce the gap between **future scenarios** in which the EUniversal context is expected to operate and current situation by defining a set of long-term vision that clarify the future operating context.	PT3, PT 4 DE AP, DE RP PL AP, PL RP, PL DLR, PL FS
SO10	To enable **collaborative engagement** of the EUniversal ecosystem assessing the interaction between market agents, DSOs and TSOs.	PT1, PT2, PT3, PT4 DE AP, BUC_KPI_2
SO11	To guarantee **replicability and scalability of EUniversal solutions** by analysing technical and non-technical boundaries, including regulation, and to	PT1, PT2, PT3, PT4 DE AP, DE RP

	adapt to the use cases, KPIs and the future scenarios defined.	PL AP, PL RP

The EUniversal SOs are used to define **thematic pillars.** The thematic pillars proposed for this project have been selected to cover the specific EUniversal objectives, without limiting the scope to technical solutions, in contrast to the methodology proposed in (Pramangioulis et al. 2019). Thematic pillars are linked with the BUCs as shown in Table 5.

Table 5. Thematic pillars covering the EUniversal specific objectives.

	Thematic pillar	BUCs
1.	Market: market mechanisms and new flexibility services and tools.	PT1, PT2, PT3, PT4 DE AP, DE RP PL AP, PL RP
2.	Network: network planning and operation to enhance resilience and reduce technical restrictions.	PT1, PT2, PT3, PT4 DE AP, DE RP PL AP, PL RP, PL DLR, PL FS
3.	Investment and business models	PT4

3.2 Stakeholder groups

The objective of defining the key stakeholder groups is to be able to evaluate each solution from the perspective of each of these groups, following a more holistic, structured, and reproducible method. It also ensures that all relevant actors that are involved or may be impacted by the project are considered. By presenting the key stakeholder groups, the parties that are most impacted by each KPI can be highlighted. Chapter **Error! Reference source not found.** summarises D6.2 results, indicating for each DEMO and project KPI identified the key stakeholder groups are concerned.

From the key stakeholders' listed below, the definition of customers and institutions are based on the research paper (Pramangioulis et al. 2019). The DSOs, Flexibility Market Operator, the Resource Aggregators and Producers stakeholders group definitions are aligned with the roles defined EUniversal in the D2.2 (EUniversal D2.2, 2021).

- The DSOs are responsible to operate and manage the distribution electricity grid, with specific responsibilities for flexibility markets added in the project (EUniversal D2.2 2021).
- The Flexibility Market Operator (FMO) as a transparent party is responsible for proving a central service between buyers and sellers to facilitate the communication and

coordination of all processes related to the procurement of capacity and/or energy bids (EUniversal D2.2, 2021).

- The Resource Aggregators (RA) is responsible for aggregating resources for usage by a service provider for energy market services (EUniversal D2.2, 2021).
- The Institutions group which includes policy, law and regulation bodies at the EU, national and local level. This group is responsible for monitoring and enforcing the rules under which the energy market is working. They are also responsible for linking the EU regulations to the institutions at the national level (EUniversal D2.2, 2021).
- Flexibility Service Providers (FSP) offers explicit flexibility services of one resource managed by a Resource Provider or multiple resources aggregated by a Resource Aggregator to system operators, directly via bilateral agreements or through market operators.

    - The Producer (P) is described in this project as a natural or legal person that generates electricity (EUniversal D2.2, 2021).
    - The Customers (or end-users) can have two kinds of roles, the role of a passive user (consumers) or the role of an active user (prosumers). The end-user simply consumes the energy from the electrical grid. The prosumer actively participates in the energy.

While the TSOs may interact with the UMEI interface, the EUniversal project analysis is mainly focused on the DSO level, therefore only the DSOs are being considered for these stakeholders' groups.

3.3 KPI domains

The KPI domains or dimensions are defined to support the KPI identification. These categories also allow to classify the KPIs into groups that monitor similar functions. It facilitates filtering and finding the KPIs of particular interest for the reader. The KPIs categorised by domains can be found in subchapter 5.3.

The domains used on the EUniversal project are the following:

- Technical Domain is related to the KPIs measuring the technical performance such as the fulfilment of voltage limits in the Polish DEMO.
- Economic Domain is related with the KPIs are measuring the economic and regulatory performance such as the costs of congestion management with flex Market vs Curtailment in the German DEMO.
- Environmental Domain includes the KPIs measuring the environmental impact such as the reduction of CO_2 emissions from increased Renewable Energy Sources (RES) and Distributed Energy Resources (DER) hosting capacity in the Portuguese DEMO.
- Social Domain is related to the KPIs measuring the users' degree of satisfaction such as the incentives used by the DSO to motivate the load shifting of energy consumed during the day.

Throughout the completion of the task, an effort was put into not limiting the scope to KPIs in the technical domain, and include economic, environmental, and social KPIs. This allows for a better overview and assessment of the impact of the DEMOs and the project.

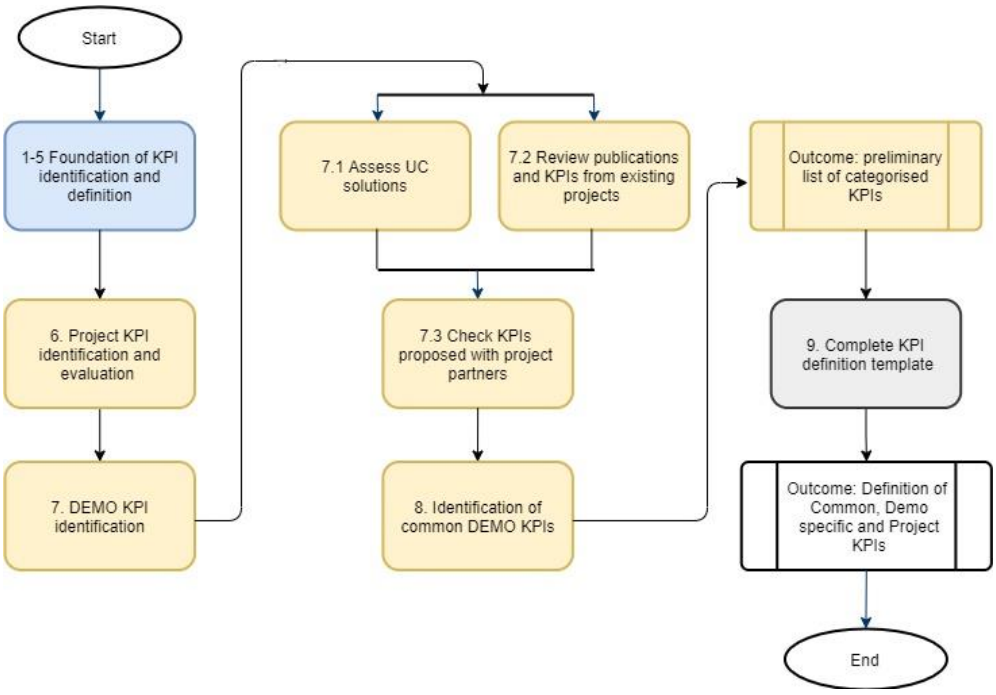
3.4 Conclusions of Chapter 3

Chapter 3 aimed at setting a solid foundation for the KPI identification and definition process. This objective was fulfilled by reviewing the BUCs and EUniversal project specific objectives to ensure that effectiveness and success of every BUC and SO can be quantitatively measured. In addition, key parameters were defined such as the key stakeholder groups that will be impacted. Throughout the completion of the task, there was a focus considering domains that went beyond the technical sphere. This effort resulted in the definition of 3 economic, 1 social and 1 environmental KPIs, as will be explained in more detail in the next chapters.

4. EUniversal Project KPIs

The goal of Chapter 4 is to detail the results of the KPI identification and evaluation process of the EUniversal Project KPIs. Then, Chapter 5 will present the results common and DEMO-specific BUC KPIs. The KPI identification and definition effort is carried out after having analysed the EUniversal project SOs and BUC objectives and solutions, and defined the key parameters needed. Figure 5 depicts a flowchart with the methodological steps followed for the KPI identification and evaluation process detailed in Chapters 4 and 5.

Figure 6. KPI identification and evaluation process situated in the wider methodological context.



A number of EUniversal project KPIs were preidentified in the project design process and presented in the GA. These EUniversal KPIs aim to ensure that the anticipated project impacts are monitored and accomplished. Table 6 presents these impacts, a summary description of what they entail and the key work packages they relate to. These impacts reflect the energy systems need to evolve to integrate increasing capacity, manage new load patterns and integrate market-based flexibility services.

Table 6. Main EUniversal Impacts and summary of what each one entails.

No	Impact Name	Summarised description	WP
1	**Enhance flexibility of distribution grids which are expected to operate in an overall context of**	EUniversal monitors and contributes to the advancement of flexibility provided by diverse technologies and activated by various energy players. The project enables the coordination of flexibility services demonstrated in the DEMOs that cost-effectively solve	WP 2, 3, 4, 5

	50% electricity production from renewables in 2030	network constraints. This enhanced flexibility on the distribution grid will impact the amount the RES that can be integrated and result in avoidance or deferring of unnecessary grid investments.	
2	**Contributions for a well-functioning electricity market which creates business case for stakeholders willing to provide such flexibility and allow to sustain the necessary investments.**	EUniversal brings forward a coordinated approach between the management of the network, the markets and the flexibility provision. New business cases engage more flexibility providers and energy system stakeholders. New flexibility services are standardised and contribute to deal with the grid management and maintenance. These are designed according to the grid needs, technology characteristics and market design considerations.	WP 1, 2, 3, 4, 5
3	**Improve the capability to manage future energy loads including electrical vehicles.**	EUniversal also tackles the short-term repercussions of the presence of new consumers such as EVs. The projects approach aims at managing future new loads by having them participate in the system by trading energy and providing flexibility services. For example, the UMEI can enable smart charging strategies.	WP 4, 5
4	**Guarantee security of supply and the use of flexibility products while integrating large shares of variable renewables avoiding unnecessary investments by solving congestion.**	To ensure energy availability and reliability of the grid, EUniversal will count with strategies such as resilience-driven planning tools, demonstration of predictive/proactive grid management tools for MV and LV networks to predict which hours/days may present technical problems or a distributed control strategy for LV where observability is normally lower. The strategies put forward contribute to avoid significant grid investments.	WP4

To monitor and ensure that the impacts presented in Table 6 are accomplished, the EUniversal project KPIs listed in Table 7 have been formulated. The table below presents which of the impacts each KPI relates to, a preliminary expected amount and the relevant KPI domain. The EUniversal KPIs are thoroughly defined in Annex 1.

Table 7. EUniversal project KPIs linked to their related impact.

EUniversal Project KPIs					
No.	**KPI ID**	**KPI Name**	**Related EUniversal impacts**	**Expected amount**	**Domain**
1	EU_KPI_1	Increased RES and DER hosting capacity	1,2,3	> 50%	Technical
2	EU_KPI_2	Increase of energy storage solutions penetration	1,2,3	Use-case dependent	Technical
3	EU_KPI_3	Percentage of SAIDI and SAIFI improvement using novel methodology for including grid resilience metric in planning and operation of the distribution grid	3,4	~60% compared to scenario without flexibility	Technical
4	EU_KPI_4	Number of standardised flexibility services for distribution grids provided by DERs, storage, microgrids or energy communities	1,2	>6	Technical
5	EU_KPI_5	Distribution grid investment avoidance or deferral due to the use of flexibility	4	>30%	Technical
6	EU_KPI_6	Reinforcement of distribution network resilience	4	~40%	Technical

		and flexibility to extreme events			
7	EU_KPI_7	The power of flexibility activated by energy players	1	/	Technical

The EUniversal KPI 'The power of flexibility activated by energy players' was defined in the GA. This KPI will be measured by the following KPIs: CM 1-3 and PT_KPI 1 and PT_KPI 2 for long-term flexibility. Therefore, it does not appear defined in the annexes as a separate KPI. Moreover, three KPIs related to the SUCs have been identified. Annex 2 presents a summary of the SUCs in Table 18 and a list of the SUC KPIs in

Table 19. The detailed description and definition can be found in Deliverable 2.3.

5. DEMO KPIs

Chapter 5 focuses on the DEMO KPI identification and results, corresponding to step 7 in Figure 6. In step 7.1, each BUC solution is assessed from the perspective of every stakeholder group of interest for every domain identified: technical, economic, environmental and social. The preliminary DEMO KPI list resulting from this exercise and the review of the publications and KPI work from other H2020 projects (step 7.2) is iterated with the project partners to ensure all project participants endorse the KPIs selected (step 7.3).

Chapter 5 is divided in two sections. Subchapter 5.1 presents the common KPIs that will serve to compare and evaluate the success of the project as a whole. Subchapter 5.2 presents the DEMO-specific KPIs, that depict the distinct items that each DEMO validates to be quantitatively evaluated and monitored.

5.1 Common DEMO KPIs

Once the iterated lists of DEMO specific KPIs were obtained, each pilot analysed the other DEMO KPIs, and comprehensive and in-depth discussions resulted in an agreement on what are the common KPIs to more than one DEMO, allowing for a complete evaluation and comparison of the pilots. Table 8 lists the KPIs that are to be monitored by at least two demonstrators, their KPI domain, related impacts, and associated BUC. Most of the common KPIs identified are adopted by the three DEMOs: Portuguese, German, and Polish. The detailed information of the each common KPI identified can be found in Annex 3.

Table 8. Common KPIs to two or three demonstrators, with the related impact, KPI domain and UCs.

No	KPI ID	KPI name	Related EUniversal impact	KPI domain	BUC	DEMOs		
						PT	DE	PL
1	CM_KPI_1	Flexible capacity vs. flexible volume offered ratio	2	Technical	PT1, PT2, PT3, PT4 PL AP, PL RP DE AP, DE RP	x	x	X
2	CM_KPI_2	Flex volume offered by FSP vs. Flex request by DSO	2	Technical	PT1, PT2, PT3, PT4 PL AP, PL RP DE AP, DE RP	x	x	x
3	CM_KPI_3	Flex bids accepted by DSO vs flex volume	2	Technical	PT1, PT2, PT3, PT4 PL AP, PL RP	x	x	x

		delivered by FSP			DE AP, DE RP			
4	CM_KPI_4	Avoided Restrictions	1, 3 & 4	Technical	PT1, PT2, PT3, PT4 DE AP, DE RP	x	x	
5	CM_KPI_5	Voltage Magnitude Prediction Error	4	Technical	PT1, PT2, PT3, PT4 DE AP, DE RP	x	x	

5.2 DEMO specific KPIs

Subchapter 5.2 presents the results from the DEMO-specific KPI identification process. The approach followed to obtain a preliminary list of KPIs was adapted from the research paper (Pramangioulis et al. 2019) to fit the EUniversal project and make it more thorough and suitable for both DEMO and project KPIs. In addition, apart from what is proposed in the study, publications and KPIs defined in other research projects were reviewed to incorporate the expertise and learnings from previous H2020 projects. The deliverables and publications that were found most useful can be found in Chapter 3.1.1.

5.2.1 Portuguese DEMO

Table 9 lists the KPIs identified for the PT demonstrator, indicating the BUC and KPI domain each KPI relates to. It also depicts which of the expected impacts summarised in Table 6 the four KPIs tackle. The detailed templates with the KPI information can be found in Annex 4. Moreover, the WP7 deliverables focus on the distinct aspects of the PT DEMO. Since this is only demonstrator where long-term flexibility markets will be demonstrated, four DEMO-specific KPIs were defined.

The KPI_PT_01 intends to quantify the amount of flexibility the DSO contracts for planning purposes, considering 3 years horizon, deferring grid investment (PT_BUC_04). The KPI_PT_02 will assess what is the proportion between the flexibility reserved, both for planned maintenance and for long term grid planning, and the flexibility activated. The KPI_PT_03 will quantify the variation in CO2 emissions from increased RES and DER hosting capacity assuming that this increase will imply a reduction in the production of electricity from non-renewable sources. The KPI_PT_04 will measure the FSP's absolute variation of electricity consumption. It is intended that the variation will be close to zero, because it is only expected a change in the consumption patterns, shifting consumption periods.

Table 9. DEMO specific KPIs to the PT DEMO, each linked to the relevant related impacts, KPI domains and UCs.

Portuguese DEMO					
No.	**KPI ID**	**KPI Name**	**Related EUniversal impacts**	**KPI Domain**	**Use Case**
1	PT_KPI_01	Amount of flexibility the DSO contracts for planning purposes	1,3,4	Technical	PT4
2	PT_KPI_02	Ratio of flexibility the DSO activates from reserved services	2	Economic	PT3, PT4
3	PT_KPI_03	CO2 emissions from Increased RES and DER hosting capacity	1	Environmental	PT1, PT2, PT3, PT4
4	PT_KPI_04	Energy consumption	2	Social	PT1, PT2, PT3, PT4

5.2.2 German DEMO

Table 10 lists the KPIs identified for the German DEMO, linking them to the relevant UCs and KPI domains. It also presents, which of the expected impacts summarised in Table 6 each KPI tackles. The detailed templates with the information on each KPI can be found in Annex 5. Moreover, the WP8 deliverables focus on the distinct aspects of the German pilot.

The first German DEMO specific metric contains the comparison of flexibility trading with the conventional curtailment of DER in case of congestions in DE_KPI_01 to get an overview of the economic effect of flexibility markets. In addition, since the German DEMO process is intended to be iterative to comply with the Redispatch 2.0 process, the time frame from identifying the technical constraint to finding an optimized solution is measured in DE_KPI_02.

In order to be able to determine the forecast quality, the number of correct and incorrectly predicted congestions are calculated in DE_KPI_03 and DE_KPI_04. And last but not least, the accuracy of the baseline is also evaluated in DE_KPI_05 as it forms the basis for a theoretical curtailment.

Table 10. DEMO specific KPIs to the DE DEMO, each linked to the relevant related impacts, KPI domains and UCs.

German DEMO					
No.	**KPI ID**	**KPI Name**	**Related impact**	**KPI Domain**	**Use Case**
1	DE_KPI_01	Costs of Congestion Management with flex Market vs. Curtailment	1 & 2	Economic	DE AP, DE RP
2	DE_KPI_02	Cycle Time DSO process	4	Technical	DE AP, DE RP
3	DE_KPI_03	Share of correctly forecasted congestions	4	Technical	DE AP, DE RP
4	DE_KPI_04	Share of false positive congestion forecasts	4	Technical	DE AP, DE RP
5	DE_KPI_05	Baseline accuracy	2 & 3	Technical	DE AP, DE RP

5.2.3 Polish DEMO

Table 11 lists the KPIs identified for the PL DEMO, linking them to the relevant BUCs and KPI domains. In addition, it presents, which of the expected impacts summarised in Table 6 each KPI addresses. The detailed templates with the information on each KPI can be found in Annex 6. The WP9 deliverables focus on the distinct aspects of the Polish pilot.

Polish DEMO is the only demonstrator where flexibility services offered by the DSO for 110 kV lines congestion mitigation purposes on High Voltage (HV) level will be tested. The KPI_PL_01 "RES generated energy above connection agreement value" is dedicated to quantifying this BUC (PL_BUC_03).

KPI_PL_02, 03 and 04 are dedicated to PL FS "Voltage Control with the use of flexstation solutions". They are used to quantify the increased observability of the network, ensure of keeping the voltage level in the acceptable range and increase the connection capacity of LV network.

Table 11. DEMO specific KPIs to the PL DEMO, each linked to the relevant related impacts, KPI domains and UCs.

	Polish DEMO				
No.	**KPI ID**	**KPI Name**	**Related impact**	**KPI Domain**	**BUC**
1	PL_KPI_01	RES generated energy above connection agreement value	2	Technical	PL DLR

2	PL_KPI_02	Monitoring information categories	4	Technical	PL FS
3	PL_KPI_03	Increased local PV hosting capacity	4	Technical	PL FS
4	PL_KPI_04	Fulfilment of voltage limits	4	Technical	PL FS

5.3 Results summary

Subchapter 5.3 aims to summarise the KPI identification results of the Task 6.2 in a comprehensive and holistic manner, with the definition and details of the KPIs found in Annexes 2-6. This subchapter contains a complete list of KPIs with the corresponding stakeholder groups of interest, categorised per domain: technical, social, environmental, and economic, in Table 13,

Table 14, Table 15 and Table 16 respectively. Table 12 presents the symbols for each stakeholder group explained above in subchapter 3.2. As mentioned in Chapter 2, KPIs related to the market mechanisms will be found in WP5, and SUC KPIs classification and definition templates will be depicted in D2.3. Nonetheless, all other project and DEMO KPIs are included in this list.

Table 12. Key of stakeholder group icons to include in summary tables of KPIs classified per KPI domain.

Icon	Stakeholder group
	Institutions
	Customers
	DSOs
	Flexibility Market operators
	Producers
	Resource Aggregators

Table 13. Summary table of technical KPIs

Technical KPIs			
DEMO (s)	**KPI ID**	**Name of KPI**	**Relevant stakeholder(s)**
DE DEMO	DE_KPI_2	Cycle Time DSO process	
DE DEMO	DE_KPI_3	Share of correctly forecasted congestions	
DE DEMO	DE_KPI_4	Share of false positive congestion forecasts	
DE DEMO	DE_KPI_5	Baseline accuracy	
PL DEMO	PL_KPI_1	RES generated energy above connection agreement value	
PL DEMO	PL_KPI_2	Monitoring information categories	
PL DEMO	PL_KPI_3	Increased local PV hosting capacity	
PL DEMO	PL_KPI_4	Fulfilment of voltage limits	
PT, DE and PL DEMO	CM_KPI_1	Flexible capacity vs. flexible volume offered ratio	
PT, DE and PL DEMO	CM_KPI_2	Flex volume offered by FSP vs. Flex request by DSO	
PT, DE and PL DEMO	CM_KPI_3	Flex volume delivered by FSP vs. Flex bids accepted by DSO	
PT, DE and PL DEMO	CM_KPI_4	Avoided Restrictions	

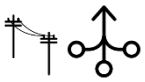
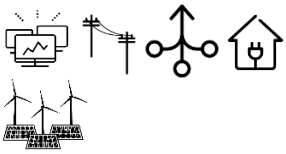
PT, DE and PL DEMO	CM_KPI_5	Voltage Magnitude Prediction Error	
Project KPI	EU_KPI_1	Increased RES and DER hosting capacity	
Project KPI	EU_KPI_2	Increase of energy storage solutions penetration	
Project KPI	EU_KPI_3	Percentage of SAIDI and SAIFI improvement using novel methodology for including grid resilience metric in planning and operation of the distribution grid	
Project KPI	EU_KPI_4	Number of standardised flexibility services for distribution grids provided by DERs, storage, microgrids or energy communities	
Project KPI	EU_KPI_5	Distribution grid investment avoidance or deferral due to the use of flexibility	
Project KPI	EU_KPI_6	The power of flexibility activated by energy players	
Project KPI	EU_KPI_7	Reinforcement of distribution network resilience and flexibility to extreme events	

Table 14. Summary table of social KPIs

Social KPIs			
Demo (s)	**KPI ID**	**Name of KPI**	**Relevant stakeholder(s)**
PT DEMO	PT_KPI_4	Energy consumption	

Table 15. Summary table of economic KPIs

Economic KPIs			
Demo (s)	**KPI ID**	**Name of KPI**	**Relevant stakeholder(s)**
DE DEMO	DE_KPI_1	Cost of Congestion Management with Flex Market Vs Curtailment	
PT DEMO	PT_KPI_1	Amount of flexibility the DSO contracts for planning purposes	
PT DEMO	PT_KPI_2	Ratio of flexibility the DSO activates from reserved services	

Table 16. Summary table of environmental KPIs

Environmental KPIs			
Demo (s)	**KPI ID**	**Name of KPI**	**Relevant stakeholder(s)**
PT DEMO	PT_KPI_3	CO2 emissions from Increased RES and DER hosting capacity	

6. Conclusions

The aim of this deliverable is to present the KPIs indentified and defined for the EUniversal DEMO sites in Portugal, Germany and Poland, as well as the project as a whole. This objective has been fulfilled by following a structured and reproducible methodology that has also been presented in this report. Follow this step-by-step approach has resulted in the identification of 24 KPIs, divided in three categories:

- EUniversal project KPIs: 6 KPIs in the technical domain that serve to evaluate the impacts of the H2020 call.
- DEMO KPIs – common KPIs: 5 KPIs, also classified in the technical domain, common to more than one pilot for comparison and evaluation of the project's success.
- DEMO specific KPIs: 13 KPIs that validate the items each particular demonstrator is tackling.

    - PT DEMO: 4 KPIs, 1 environmental, 2 economic and 1 social KPI.
    - DE DEMO: 5 KPIs, 4 technical and 1 economic KPI.
    - PL DEMO: 4 KPIs, all in the technical domain.

The KPIs identified are defined in detail in the templates found in the annexes. The KPIs defined cover the 11 EUniversal SOs as is presented in Table 17.

Table 17. EUniversal specific objectives linked to the relevant KPIs.

SO number	SO description	KPI ID
SO1	To **create a standard, adaptable and modular market-enabling interface** to link smart grids to flexibility markets and to coordinate the actions with commercial parties and TSOs	PT_KPI_1, PT_KPI_2,
SO2	To increase grid flexibility through the development of **new flexibility services** and tools in a multi-energy system scenario	EU_KPI_1, EU_KPI_4 CM_KPI_1, CM_KPI_2 PT_KPI_1, PT_KPI_2, PT_KPI_3, PT_KPI_4 DE_KPI_2 PL_KPI_1
SO3	To **incentivise market flexibility** by defining the appropriate market mechanisms to optimise the procurement and activation of new flexibility services for grid operation	CM_KPI_1, CM_KPI_2, CM_KPI_3 PT_KPI_1,PT_KPI_2, PT_KPI_4 DE_KPI_1
SO4	To optimise **network planning and operation** based on available flexibility both from the grid and market-based services.	EU_KPI_2, EU_KPI_5, EU_KPI_6 PT_KPI_1, PT_KPI_2, PT_KPI_4

SO5	To **reduce technical restrictions in the operation of the networks** by improving control and observability of the distribution system and further reliance on flexibility services	CM_KPI_4, CM_KPI_5 PT_KPI_1, PT_KPI_2, DE_KPI_3, DE_KPI_4 PL_KPI_2, PL_KPI_3, PL_KPI_5
SO6	To increase the **resilience of the grids** by implementing adaptive/self-healing schemes for distribution networks, notably in the advent of extreme climate events.	EU_KPI_3, EU_KPI_7
SO7	To establish new criteria for network **investment and for operational planning** both in normal and emergency operation - taxonomy, procedures and performance metrics	EU_KPI_2, EU_KPI_5, EU_KPI_6, EU_KPI_7 PT_PT_1, PT_KPI_2, PT_KPI_4
SO8	To establish the main pillars of **business model archetypes** for smart grid solutions and for the market-driven flexibility activation considering potential users, value proposition, value chain and profit model.	DE_KPI_5 PT_KPI_1, PT_KPI_2, PT_KPI_4
SO9	To reduce the gap between **future scenarios** in which the EUniversal context is expected to operate and current situation by defining a set of long-term vision that clarify the future operating context.	PT_KPI_1, PT_KPI_2,
SO10	To enable **collaborative engagement** of the EUniversal ecosystem assessing the interaction between market agents, DSOs and TSOs.	PT_KPI_1, PT_KPI_2, PT_KPI_4
SO11	To guarantee **replicability and scalability of EUniversal solutions** by analysing technical and non-technical boundaries, including regulation, and to adapt to the use cases, KPIs and the future scenarios defined.	PT_KPI_1, PT_KPI_2,

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Annex 1 – EUniversal Project KPIs

Annex 1.1 – EU_KPI_1 – Increased RES an EV hosting capacity

BASIC KPI INFORMATION			
KPI Name	Increased RES and EV hosting capacity	**KPI ID**	EU_KPI_1
Strategic Objective(s)	SO2 - To increase grid flexibility through the development of new flexibility services and tools in a multi-energy system scenario.		
DEMO where KPI applies	All (analysis at project level – Scalability and replicability analysis)		
UC where KPI applies if any	General to project objectives		
KPI Description	This KPI measures the expected increase in distribution network hosting capacity (expressed in kW or MW) for RES and EV integration, enabled by the implementation of new market-based flexibility services as well as advanced tools for improved network long-term and short-term operation planning tools.		
KPI Formula	The KPI is calculated in percentage of additional RES/DER that can be connected to the grid above the Business as Usual (BAU) scenario: $$IHC_{\%} = \frac{HC_{EUniversal} - HC_{BAU}}{HC_{BAU}} . 100\%$$ Where: IHC%: Increase of expected hosting capacity of RES/DER when EUniversal framework are applied with respect to BAU scenario. $HC_{Euniversal}$: additional hosting capacity of RES/DER when EUniversal framework are applied with respect to currently connected generation (kW or MW). HC_{BAU}: additional hosting capacity of RES/DER in BAU scenario applied with respect to currently connected generation (kW or MW).		
Unit of measurement	%		
Target / Thresholds	>50%		

Reporting Period	Yearly
Reporting Audience and Access Rights	Public/EUniversal
OTHER (please specify)	/

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[EU_KPI_1] 1	Define baseline conditions: load conditions, existing generation capacity, grid operational limits (voltage, thermal limits), resources to be considered as a baseline (OLTCs, capacitor banks, DG power factor control, etc.)	Comillas, with contributions from DEMO leaders and WP4 partners (to ensure consistency among operational/planning criteria considered)
[EU_KPI_1] 2	Identify critical buses of the grid and define DG/EV upscaling strategy: locating all additional capacity in the most critical bus would provide a lower bound of this KPI (pessimistic assumption), whereas other allocation criteria would yield higher value of the KPI	Comillas
[EU_KPI_1] 3	Compute baseline HC through simulations	Comillas
[EU_KPI_1] 4	Define grid/flexibility scenarios for HC computation: number and location of flexibility providers, active/reactive power control, available operational tools to support grid operation (e.g. DLR, reconfiguration)	Comillas, with contributions from DEMO leaders and WP4 partners (to ensure consistency among operational/planning criteria considered)
[EU_KPI_1] 5	Define DER scenarios for HC computation: DG/EV sizes, location,	Comillas

	technologies, single phase/three phase connections, etc.	
[EU_KPI_1] 6	Compute HC for each relevant EUniversal scenario through simulations	Comillas
[EU_KPI_1] 7	Calculate KPI value	Comillas

KPI DATA COLLECTION						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Network hosting capacity in BAU scenario	HC_{BAU}	Simulation analyses	NA	NA	Once per grid and scenario	Comillas
Network hosting capacity in EUniversal scenario	$HC_{EUniversal}$	Simulation analyses	NA	NA	Once per grid and scenario	Comillas

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES	COMPANY HISTORICAL VALUES X	VALUES MEASURED DURING THE PROJECT
Details of Baseline	The baseline would be determined through simulations by considering current load and generation conditions.		

	The hosting capacity would be calculated for the more demanding operational scenarios identified in each case (e.g. minimum load and maximum generation, or highest coincident EV charging load). Current DSO operational practices (use of OLTCs, DG power factor control, etc.) and operational criteria (thermal limits, maximum and minimum admissible voltages) will be considered in the baseline. After defining the DG/EV upscaling rules (pessimistic or other), DG/EV penetration levels will be increased until the first network element reaches an operational limit.
Responsible (Name, Company) for Baseline	Comillas, contribution from DEMO leaders

Annex 1.2 – EU_KPI_2 – Increase of energy storage solutions penetration

BASIC KPI INFORMATION			
KPI Name	Increase of energy storage solutions penetration	**KPI ID**	EU_KPI_2
Strategic Objective(s)	SO4 - To optimise network planning and operation based on available flexibility both from the grid and market-based services. SO7 - To establish new criteria for network investment and for operational planning both in normal and emergency operation - taxonomy, procedures and performance metrics		
DEMO where KPI applies	All (analysis at project level – Scalability and replicability analysis)		
UC where KPI applies if any	General to project objectives		
Owner	Comillas in the context of T10.3		

KPI Description	This KPI measures how much storage capacity is used to avoid grid constraints depending on several other parameters (grid characteristics, RES penetration, BESS location, availability from other flexibility sources, etc.).
KPI Formula	The KPI is calculated as the additional storage capacity, both in power (kW) and energy (kWh), needed to avoid grid constraints. $$\Delta SC_{kW/kWh} = SC_{EUniversal} - SC_{BAU}$$ This KPI is not expressed as a percentage of the storage capacity in the BAU as this value will likely be zero in many scenarios. In order to enable comparisons, the storage capacity may be expressed as a percentage of a fixed value such as the peak demand in the area (kW), the transformation capacity of the upstream substation (kWh) or the annual electricity consumption in the area. $$\Delta SC_{\%} = \frac{\Delta SC_{kW/kWh}}{Fixed\ value_{kW/kWh}}$$
Unit of measurement	kW, kWh, %
Target / Thresholds	Use-case dependent
Reporting Period	Could be presented in a yearly basis
Reporting Audience and Access Rights	Public/EUniversal/
OTHER (please specify)	/

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[EU_KPI_2] 1	Define baseline conditions: load conditions, existing generation capacity, grid operational limits (voltage, thermal limits), resources to be considered as a	Comillas, with contributions from DEMO leaders and WP4 partners (to ensure consistency among

	baseline (OLTCs, capacitor banks, DG power factor control, etc.)	operational/planning criteria considered)
[EU_KPI_2] 2	Define baseline storage capacity (if applicable)	Comillas, contribution from DEMO leaders, contribution from T3.3
[EU_KPI_2] 3	Define evaluation scenarios for ΔSC computation: number and location of flexibility providers, active/reactive power control, available operational tools to support grid operation (e.g. DLR, reconfiguration)	Comillas, with contributions from DEMO leaders and WP4 partners (to ensure consistency among operational/planning criteria considered)
[EU_KPI_2] 4	Compute ΔSC for each relevant EUniversal scenario through simulations	Comillas
[EU_KPI_2] 5	Calculate KPI value	Comillas

KPI DATA COLLECTION						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Storage capacity in BAU scenario	SC_{BAU}	DSO systems	NA	NA	Once per grid and scenario	Comillas/ DEMO leaders
Storage capacity in EUniversal scenario	$SC_{EUniversal}$	Simulation analyses	NA	NA	Once per grid and scenario	Comillas
Fixed reference value for storage capacity	$Fixed\ value_{kW/kWh}$	DSO systems	NA	NA	Once per grid and scenario	DEMO leaders/ Comillas

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES	COMPANY HISTORICAL VALUES X	VALUES MEASURED DURING THE PROJECT
Details of Baseline	Existing or expected storage capacity in the grid		
Responsible (Name, Company) for Baseline	Comillas, contribution from DEMO leaders, contribution from T3.3		

Annex 1.3 – EU_KPI_3 – Improvement on distribution network continuity of service

BASIC KPI INFORMATION			
KPI Name	Improvement on distribution network continuity of service	**KPI ID**	EU_KPI_3
Strategic Objective(s)	SO4, SO6, SO7		
DEMO where KPI applies	All (analysis at project level – T4.4)		
UC where KPI applies if any	General to project objectives		
Owner	INESC TEC and CYP		
KPI Description	EUniversal framework aims at improving network reliability and resilience against extreme events, taking advantage of the flexibility of RES and DER and considering improved planning methodologies and new service restoration strategies, allowing the islanded operation.		

KPI Formula	Reliability improvements will be determined though SAIDI, SAIFI and CAIDI and Energy Not Delivered (END). The improvement in SAIDI can be calculated as follows: $$\Delta SAIDI_{\%} = \frac{SAIDI_{EUniversal} - SAIDI_{baseline}}{SAIDI_{baseline}} \cdot 100\%$$ Where, $$SAIDI = \frac{Customer\ Minutes\ of\ Interruption}{Total\ Numver\ of\ Consumers\ Served}\ h/consumer$$ The improvement in SAIFI can be calculated as follows: $$\Delta SAIFI_{\%} = \frac{SAIFI_{EUniversal} - SAIFI_{baseline}}{SAIFI_{baseline}} \cdot 100\%$$ Where, $$SAIFI = \frac{\sum Total\ Number\ of\ Customers\ Interrupted}{Total\ Numver\ of\ Consumers\ Served}\ interruption/consumer$$ The improvement in CAIDI can be calculated as follows: $$\Delta CAIDI_{\%} = \frac{CAIDI_{EUniversal} - CAIDI_{baseline}}{CAIDI_{baseline}} \cdot 100\%$$ Where, $$CAIDI = \frac{\sum Customer\ Minutes\ of\ Interruption}{Total\ Numver\ of\ Consumers\ Interrupted}\ h/\ interruption$$ The improvement in the Energy not supplied (ENS) $$\Delta ENS_{\%} = \frac{ENS_{EUniversal} - ENS_{baseline}}{ENS_{baseline}} \cdot 100\%$$
Unit of measurement	% percentage basis
Target / Thresholds	SAIFI, SAIDI and CAIDI (>20%) ENS (>40%)

Reporting Period	Yearly
Reporting Audience and Access Rights	Public/EUniversal/DEMO
OTHER (please specify)	Indicate specifics of Reporting Audience and Access Rights if OTHER (please specify) was marked above.

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[EU_KPI_3] 1	Define baseline conditions: load conditions, existing generation capacity, grid operational limits (voltage, thermal limits), resources to be considered as a baseline (OLTCs, capacitor banks, DG power factor control, etc.). Collect historical continuity of service indicators (SAIFI, SAIDI, CAIDI) .	CYP with contributions from DEMO leaders and INESC TEC.
[EU_KPI_3] 2	Define baseline for network reliability.	CYP and INESC TEC in the context of T4.4.
[EU_KPI_3] 3	Define evaluation scenarios for reliability analysis: representativeness of the network analysed, number and location of flexibility providers, available operational tools to support grid operation (e.g. DLR, reconfiguration). Perform network reliability analysis.	CYP and INESC TEC in the context of T4.4.
[EU_KPI_3] 4	Compute SAIFI, SAIDI and CAIDI for each relevant EUniversal scenario through simulations.	CYP and INESC TEC in the context of T4.4.
[EU_KPI_2] 5	Calculate KPI value	CYP and INESC TEC in the context of T4.4.

KPI DATA COLLECTION						
Data	**Data ID**	**Methodo-logy for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequen-cy of data collection**	**Data collection responsi ble**
Network reliability indexes baseline (SAIDI, SAIFI, CAIDI)	$SAIDI_{baseline}$ $SAIFI_{baseline}$ $CAIDI_{baseline}$	Simulation analyses	NA	NA	Once per grid and scenario	UCY and INESC TEC
Network reliability indexes EUniver-sal scenario (SAIDI, SAIFI, CAIDI)	$SAIDI_{EUniv}$ $SAIFI_{EUniv}$ $CAIDI_{EUniv}$	Simulation analyses	NA	NA	Once per grid and scenario	UCY and INESC TEC

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES	COMPANY HISTORICAL VALUES x	VALUES MEASURED DURING THE PROJECT
Details of Baseline	The baseline would be determined through simulations by considering current and future load and generation conditions, within the simulation scenario.		
Responsible (Name, Company) for Baseline	UCY and INESC TEC considering the results of the tools obtained in Task 4.4.		

Annex 1.4 – EU_KPI_4 – Number of standardised flexibility services for distribution grids provided by DERs, storage, microgrids or energy communities

BASIC KPI INFORMATION			
KPI Name	Number of standardised flexibility services for distribution grids provided by DERs, storage, microgrids or energy communities	**KPI ID**	EU_KPI_4
Strategic Objective(s)	SO2		
DEMO where KPI applies	All (D2.1 and WP7-9)		
UC where KPI applies if any	General to project objectives		
KPI Description	This KPI measures the number of flexibility services enabled by EUniversal solutions and demonstrated within the 3 pilots.		
KPI Formula	• Number of standardized flexibility services defined within the project (resulting from D2.1) • Number of standardized flexibility services demonstrated in Portuguese DEMO • Number of standardized flexibility services demonstrated in German DEMO • Number of standardized flexibility services demonstrated in Polish DEMO		
Unit of measurement	Absolute value		
Target / Thresholds	>6		
Reporting Period	n.a.		
Reporting Audience and Access Rights	Public/EUniversal/DEMO		

OTHER (please specify)	/

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[EU_KPI_4] 1	Count the number of flexibility services effectively tested in EUniversal project	DEMO leaders

KPI DATA COLLECTION						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Data to collect	N_FlexibilityServices	N.A	N.A	N.A	N.A	DEMO leaders

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES	COMPANY HISTORICAL VALUES	VALUES MEASURED AT START OF PROJECT x
Details of Baseline	Baseline corresponds to the number of flexibility services that could already be implemented at the kick-off of the project. In the case of EUniversal project no implementation of local flexibility trading was in place, so the baseline is null.		
Responsible (Name, Company) for Baseline	DEMO leaders		

Annex 1.5 – EU_KPI_5 – Distribution grid investment avoidance or deferral due to the use of flexibility

BASIC KPI INFORMATION			
KPI Name	Distribution grid investment avoidance or deferral due to the use of flexibility	**KPI ID**	EU_KPI_5
Strategic Objective(s)	SO4, SO7		
DEMO where KPI applies	All (considering the case studies established in T4.4.)		
UC where KPI applies if any	General to project objectives		
KPI Description	The satisfaction of load increase requires an expansion of distribution assets in order to avoid violation of technical operating limits (e.g., overloaded transformers and lines, typically at urban networks, and voltages, typically at rural networks). Network expansion planning considering the connection of DER can defer investments in distribution assets, since load can be satisfied locally up to a certain amount.		
KPI Formula	The present value (PV) of deferred investment is given by: $$PV(\tau) = \frac{IC}{e^{p+\tau}}$$ Where, IC: investment cost, τ: deferral time p: interest rate. The network planning KPI, named as Deferred Distribution Capacity Investment – DDCI, can be calculated as follows **Error! Reference source not found.**: $$DDCI = \frac{NRC_{BAU} - NRC_{EUniversal}}{NRC_{BAU}}$$ Where, NRC_{BAU}: net present value of the network reinforcement cost for the BAU scenario, $NRC_{SENSIBLE}$: net present value of the network reinforcement cost for the EUniversal scenario.		

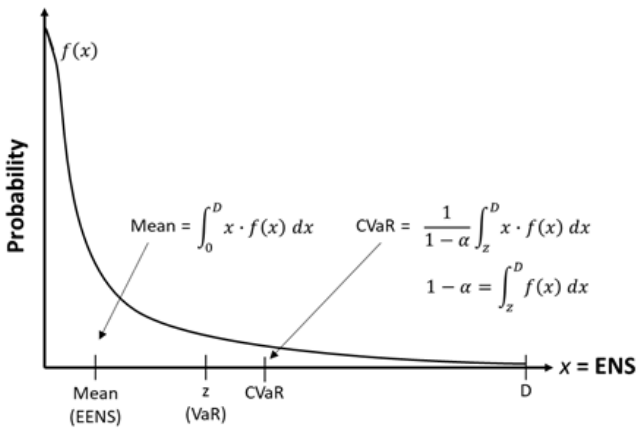
Unit of measurement	% percentage
Target / Thresholds	From 10-20%
Reporting Period	Yearly
Reporting Audience and Access Rights	Public/EUniversal/DEMO
OTHER (please specify)	/

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[EU_KPI_5] 1	Define baseline conditions: load conditions, existing generation capacity, grid operational limits (voltage, thermal limits), resources to be considered as a baseline (OLTCs, capacitor banks, DG power factor control, etc.). Define BAU investment plan for the network.	CYP with contributions from DEMO leaders and INESC TEC.
[EU_KPI_5] 2	Define baseline for network investment	CYP and INESC TEC in the context of T4.4.
[EU_KPI_5] 3	Define evaluation scenarios for investment planning: representativeness of the network analysed, number and location of flexibility providers,	CYP and INESC TEC in the context of T4.4.
[EU_KPI_5] 4	Compute investment deferral by considering participation of flexibility through long-term services.	CYP and INESC TEC in the context of T4.4.
[EU_KPI_5] 5	Calculate KPI value	CYP and INESC TEC in the context of T4.4.

KPI DATA COLLECTION						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
NPC of network reinforcement BAU	NRC_{BAU}	Simulation	NA	NA	Once per grid and scenario	UCY and INESC TEC
NPC of network reinforcement Eunviersal scenario	NRC_{EUniv}	Simulation	NA	NA	Once per grid and scenario	UCY and INESC TEC

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES	COMPANY HISTORICAL VALUES x	VALUES MEASURED AT START OF PROJECT x
Details of Baseline	BAU consists in the distribution network at the reference year with the investments in distributed generation (location and size) within the planning horizon.		
Responsible (Name, Company) for Baseline	INESC TEC and CYP		

Annex 1.6 – EU_KPI_6 – Reinforcement of distribution network resilience and flexibility to extreme events

BASIC KPI INFORMATION			
KPI Name	Reinforcement of distribution network resilience and flexibility to extreme events	**KPI ID**	EU_KPI_7
Strategic Objective(s)	SO6, SO7		
DEMO where KPI applies	All (analysis at project level – T4.4)		
UC where KPI applies if any	General to project objectives		
KPI Description	EUniversal framework aims at improving network reliability and resilience against extreme events, taking advantage of the flexibility of RES and DER and considering improved planning methodologies and new service restoration strategies, allowing the islanded operation. While reliability is a well-established concept and can be measured and benchmarked using the expected, or average, network performance indicators (such as Expected Energy Not Supplied), metrics capable of quantifying the effect of high-impact low-probability events (or "tail risks" as defined in recent literature, such as the 2021 "Climate Resilience" report by IEA) are needed for resilience assessment and quantification. The metrics Value at Risk (VaR), or Conditional Value at Risk (CVaR) are emerging as suitable metrics for resilience purposes, as they are capable of measuring the impacts of the events in the tail of the probability distribution of network performance metrics, such as Energy Not Supplied. The figure below shows an illustration of this concept.  		

KPI Formula	Regarding improvement in network resilience: Resilience improvement will be determined through the conditional value of Expected Energy Not Supplied (CEENS). The improvement in CEENS can be calculated as follows: $$\Delta CEENS_{\%} = \frac{CEENS_{EUniversal} - CEENS_{baseline}}{CEENS_{baseline}} \cdot 100\%$$ where CEENS is calculated as below (as shown in figure above): $$CEENS = \frac{1}{1-a}\int_{z}^{D} f(x)dx$$ where 1-α indicates the size of the considered set of worst cases (usually set to 95%, hence α=5%) and *f(x)* is the probability distribution of energy not supplied
Unit of measurement	% percentage basis
Target / Thresholds	CEENS, >30%
Reporting Period	yearly
Reporting Audience and Access Rights	Public/EUniversal/DEMO
OTHER (please specify)	Indicate specifics of Reporting Audience and Access Rights if OTHER (please specify) was marked above.

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[EU_KPI_7] 1	Define baseline conditions: load conditions, existing generation capacity, grid operational limits (voltage, thermal limits), resources to be considered as a baseline (OLTCs, capacitor banks, DG power factor control, etc.). Collect historical data related to extreme events and continuity of service indicators (SAIFI, SAIDI, CAIDI).	CYP with contributions from DEMO leaders and INESC TEC.
[EU_KPI_7] 2	Define baseline for network resilience.	CYP and INESC TEC in the context of T4.4.
[EU_KPI_7] 3	Define evaluation scenarios for resilience analysis: representativeness of the networks analysed, type of events to be considered, number and location of flexibility providers, available operational tools to support grid operation (e.g. DLR, reconfiguration). Perform network resilience analysis.	CYP and INESC TEC in the context of T4.4.
[EU_KPI_7] 4	Compute resilience metrics EUniversal scenario through simulations.	CYP and INESC TEC in the context of T4.4.
[EU_KPI_7] 5	Calculate KPI value	CYP and INESC TEC in the context of T4.4.

KPI DATA COLLECTION						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Expected Energy Not Supplied	$CEENS_{baseline}$	Simulation	NA	NA	Once per grid and scenario	UCY and INESC TEC

Expected Energy Not Supplied	$CEENS_{Euniversal}$	Simulation	NA	NA	Once per grid and scenario	UCY and INESC TEC

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES n.a	COMPANY HISTORICAL VALUES n.a	VALUES MEASURED DURING THE PROJECT n.a
Details of Baseline	The baseline would be determined through simulations by considering current and future load and generation conditions, within the simulation scenario.		
Responsible (Name, Company) for Baseline	UCY and INESC TEC considering the results of the tools obtained in Task 4.4.		

Annex 2 – System Use Cases KPIs

Table 18. System Use Case summary table

SUC SUMMARY TABLE		
SUC no.	**SUC name**	**Scope and main objective**
1	Grid expansion planning activities considering long-term flexibility services	The main goal of the use case is to identify, characterize and quantify the technical and economic effectiveness of such flexibility services when compared with the traditional grid investments, so as to contract long-term flexibility services as an alternative to the traditional distribution grid investment solutions.
2	Congestion management considering flexibility needs in MV network for planned maintenance	This use case intends to use flexibility services in maintenance operation planning. This will increase the security of operation, considering improved congestion and voltage management capacity, as well as the possibility of operating the network in islanded mode.
3	Coordinating flexibility need identification and mobilization between LV and MV network	The main goal of this system use case is to promote a coordinated operation between MV and LV network, considering the mobilization of both MV and LV flexible resources.
4	Day-ahead congestion management considering flexibility needs in MV network	This use case aims to enable the cost-effective use of market enabled flexibility for solving MV congestion problems, that can arise as a result of the variability of generation and load connected in MV distribution networks.
5	Estimating LV voltage magnitude based on historical data and load forecasts	The objective of this system use case is to provide the most likely state of the network in real time and for the next few hours, relying exclusively on data (measurements) and without resorting to grid topology or electrical characteristics.
6	Day ahead congestion forecasting	Describes the operation of the LV grid day ahead congestion forecasting tool, to be used within the EUniversal German pilot. Output is information on the risk for congestion, per feeder and transformer, day ahead and per quarter hour time step.
7	Voltage control in LV networks based on limited observability and network topology characterization	The main objective of this use case is to present a tool that is capable of not only solving voltage violations, but also offer directions to avoid such

		problems by the establishment of preventive admissible ranges for the consumption/generation.
8	LV flexibility needs assessment for voltage and congestion management	The objective of this use case is to calculate the flexibility required along with its location in the LV network in order to avoid future network issues caused by growth of renewable energy installations and evolution of new consumer loads
9	HV and MV network state forecasting based on load and weather forecasts	The main objective is to determine current and forecasted network power flow for the next 48 hours with a 1h resolution (voltage for each network nodes and power/current for each network branch).
10	HV and MV congestion detection and flexibility needs identification	The main objective is to identify a list of potential flexibility services to eliminate network problems or increase network capacity
11	Congestion management using permissible line capacity based on Dynamic Line Rating (DLR)	The main objective is to identify the available lines capacity as the result of their flexibility (dependency on the weather condition)
12	Minimizing costs linked to DSO flexibility requirements	Compute the optimal bids to contract/submit on the market platform after retrieving the required system and market data by the dedicated optimization algorithm.
13	NODES Market Platform: Short-term flexibility procurement	Processes related to short-term flexibility procurement via the NODES market platform.
14	NODES Market Platform: long-term flexibility procurement	Processes related to long-term flexibility procurement via the NODES market platform.
15	Market Platform SUC (N-SIDE in PT DEMO)	Processes of short and long term flexibility procurement via N-SIDE market platform.
16	DER registration and configuration	Register, model DER & Portfolios/VPP definition & configuration
17	Bidding aggregation	Run optimization process to aggregate flexibilities and submit active/reactive power offers
18	Resources dispatch and monitoring	Dispatch individual resources managed by the FSP, monitor and control the resource delivery in real-time.
19	Baselining	Covers the baselining process managed by the FSP and used as the input of a settlement in order to assess the delivery of the DER

20	Collecting and publishing metering data	Describes the mechanisms and sequences used to retrieve the metering data from the DER and share them to the data consumers
21	DSO data management – German Demonstrator	The scope of this SUC are the communication and data exchange between internal DSO systems and tools in the German DEMO.
22	DSO data exchanges with network tools and internal systems - Portuguese DEMO	The scope of this SUC are the communication and data exchange between internal DSO systems and tools in the Portuguese DEMO.
23	DSO data exchanges with network tools and internal systems – Polish DEMO	The scope of this SUC are the communication and data exchange between internal DSO systems and tools in the Polish DEMO.
24	DSO data exchange (external systems)	The scope of this SUC are the communication and data exchange between DSO, FMO and FSP in the three DEMOs.

Table 19. SUC specific KPI summary table

SUC KPIs			
ID	**Name**	**Description**	**SUC ID**
SUC_KPI_1	Voltage unbalance reduction	This indicator can be used to measure the voltage imbalance reduction.	SUC 7 and SUC 8
SUC_KPI_2	Total Execution time	Measures the function total execution time for evaluating the scalability of the tool.	SUC 3 to SUC 8, SUC 12
SUC_KPI_3	Model accuracy	Measures the accuracy of the model for each flexible asset in case the historical data is provided to fit the model.	SUC 16

Annex 3 – Common KPIs

Annex 3.1 – CM_KPI_1 - Flexible capacity vs. flexible volume offered ratio

BASIC KPI INFORMATION			
KPI Name	Flexible capacity vs. flexible volume offered ratio	**KPI ID**	CM_KPI_1
Strategic Objective(s)	SO2, SO3		
DEMO where KPI applies	PL, DE, PT		
UC where KPI applies if any	PT1, PT2, DE AP, DE RP, PL AP, PL RP		
KPI Description	Assess how much flexibility volume the FSP has been able to expose to the market from the overall flexible capacity registered. The ratio between total registered flexibility capacity and the amount of flexibility that FSP offers via the market platform.		
KPI Formula	$\frac{F_{FSPbid}}{F_{cap}}$ where: F_{cap} Total flexibility capacity registered. F_{FSPbid} Amount of flexibility offered by FSP		
Unit of measure-ment	Percentage [%]		
Target / Thresholds	100%		

Reporting Period	Quarterly
Reporting Audience and Access Rights	EUniversal

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[CM_KPI_1] 1	Determine the total flexibility capacity registered on market platform.	FMO, DSO
[CM_KPI_1] 2	Determine the sum of the FSP's power bids.	FMO, DSO
[CM_KPI_1] 3	Ratio calculation	DSO

KPI DATA COLLECTION						
Data	**Data ID**	**Methodo-logy for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
FSP regis-tered capacity	F_{cap}	Retrieved from market	Flexibility market platform	FMO	15 min	FMO
FSP's flexibility bids	F_{FSPbid}	Retrieved from market	Flexibility market platform	FMO	15 min	FMO

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES n/a	COMPANY HISTORICAL VALUES n/a	VALUES MEASURED DURING THE PROJECT n/a
Details of Baseline	In the DEMO area, the market platform will be used for the first time therefore baseline is not applicable. The aim is to achieve as close as possible to 100%.		
Responsible (Name, Company) for Baseline	n/a		

Annex 3.2 – CM_KPI_2 - Flex volume offered by FSP vs. Flex request by DSO

BASIC KPI INFORMATION			
KPI Name	Flex volume offered by FSP vs. Flex request by DSO	**KPI ID**	CM_KPI_2
Strategic Objective(s)	SO2, SO3		
DEMO where KPI applies	PT, DE, PL		
UC where KPI applies if any	PT1, PT2, DE AP, DE RP, PL AP, PL RP		
KPI Description	Assess to which extent the market has been able to cover the flexibility requests from the grid operators with flexibility offers from the FSPs. The ratio of delivered flexibility and flexibility bid accepted by DSO.		

KPI Formula	$\frac{F_{FSPbid}}{F_{DSO\ request}}$ where: $F_{DSO\ request}$ Amount of flexibility requested by DSO. F_{FSPbid} Amount of flexibility offered by FSP
Unit of measure-ment	Percentage [%]
Target / Thresholds	>100%
Reporting Period	Quarterly
Reporting Audience and Access Rights	EUniversal

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[CM_KPI_2] 1	Determine the flexibility requested by DSO.	FMO, DSO
[CM_KPI_2] 2	Determine the flexibility offered by FSP.	FMO, DSO
[CM_KPI_2] 3	Ratio calculation	DSO

KPI DATA COLLECTION						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collec-tion**	**Frequen-cy of data collection**	**Data collec-tion respon-sible**
Flexibility requested by DSO	$F_{DSO\ request}$	Retrieved from market	Flexibility market platform	FMO	15 min	FMO
Flexibility offered by FSP	F_{FSPbid}	Retrieved from market	Flexibility market platform	FMO	15 min	FMO

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES n/a	COMPANY HISTORICAL VALUES n/a	VALUES MEASURED DURING THE PROJECT n/a
Details of Baseline	In the DEMO area, the market platform will be used for the first time therefore baseline is not applicable. The aim is to achieve as close as possible to 100%.		
Responsible (Name, Company) for Baseline	n/a		

Annex 3.3 – CM_KPI_3 Flex volume delivered by FSP vs. Flex bids accepted by DSO

BASIC KPI INFORMATION			
KPI Name	Flex volume delivered by FSP vs. Flex bids accepted by DSO	**KPI ID**	CM_KPI_03
Strategic Objective(s)	SO3		
DEMO where KPI applies	PL, PT, DE		
UC where KPI applies if any	BUC PL AP, PL RP, DE AP, DE RP, PT 1, PT 2, PT 3, PT4 SUC 22		
KPI Description	Assess if FSP is able to deliver the amount of flexibility which bids before via market platform. The ratio of delivered flexibility and flexibility bid accepted by DSO.		
KPI Formula	$\frac{F_{\text{delivered}}}{F_{\text{bids}}}$ Where: $\boldsymbol{F_{\text{delivered}}}$ is the amount of flexibility which is delivered by FSP as the request of DSO to provide flexibility. $\boldsymbol{F_{\text{bids}}}$ is the amount of flexibility that FSP bids for a particular portfolio to submit in market platform and has been accepted by DSO to be activated.		
Unit of measure-ment	%		
Target / Thresholds	100%		
Reporting Period	quarterly		
Reporting Audience and Access Rights	EUniversal		

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[CM_KPI_03] 1	Determine the sum of the FSP's power bids	FSP
[CM_KPI_03] 2	Determine the actual delivered power adaption by FSP	Meter data operator (as part of DSO); Checked by FSP
[CM_KPI_03] 3	Ratio calculation	DSO; Checked by FSP

KPI DATA COLLECTION						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collect-ion respon-sible**
FSP's flexibility bids	F_{bids}	Retrieved from market	Market platform	Market Platform	For each meter reading period	FSP
FSP flexibility delivery	$F_{\text{delivered}}$	Measurement	Metering System	customers	For each meter reading period	DSO

KPI BASELINE	
Source of Baseline Condition	Values measured at the start of the field test
Details of Baseline	The aim is to achieve as close as possible to 100%.

Responsible (Name, Company) for Baseline	FSP/DSO

Annex 3.4 – CM_KPI_4, Avoided Restrictions

BASIC KPI INFORMATION			
KPI Name	Avoided Restrictions	**KPI ID**	CM_ KPI_4
Strategic Objective(s)	SO2, SO4, SO8		
DEMO where KPI applies	German/Portuguese		
UC where KPI applies if any	PT DEMO: PT 1, PT 2, PT 3, PT4 DE DEMO: BUC DE AP and DE RP		
Owner	DSO		
KPI Description	The fulfilment of voltage limits is a common KPI used to evaluate the power quality and quality of supply of distribution networks. EUniversal project is addressing some actions to be implemented in the DEMO areas which will impact positively in the fulfilment of voltage limits. New voltage regulation capabilities will be implemented by deploying smart devices and tools. Some of these actions regard to the remote management of DER. This KPI will help to assess the contribution of flexibility for grid support. It will be quantified by the voltage and congestion problems that were avoided through the mobilization of flexibility services. Different measures regarding the fulfilment of voltage limits KPI will be calculated: • Voltage Violation Frequency Reduction (reduction of the number of voltage violations in a certain time interval) based on voltage violations registered on the baseline scenario (predicted - Tool) computed with		

	the number of voltage violations registered after the flexibility plans are activated. • Voltage Violation Frequency Reduction (reduction of the number of voltage violations in a certain time interval) based on voltage violations registered (real metering data) computed with the number of voltage violations registered after the flexibility plans are activated. To quantify the congestions avoided, these measures will be calculated: • Congestion Problems Frequency Reduction (reduction of the number of voltage violations in a certain time interval) based on congestions registered on the baseline scenario (predicted - Tool) computed with the number of congestions registered after the flexibility plans are activated. • Congestion Problems Frequency Reduction (reduction of the number of voltage violations in a certain time interval) based on congestions registered (real metering data) computed with the number of congestions registered after the flexibility plans are activated.
KPI Formula	The Power Quality and Quality of Supply KPIs are computed according to the defined quality levels, e.g. in the EN 50160 standard. A KPI is proposed: one based on the number of voltage violations registered. **A voltage violation, ε, is defined as:** $$\varepsilon_{min} = \begin{cases} 1, V < V_{min} \\ 0, \text{Otherwise} \end{cases}, \text{and } \varepsilon_{max} = \begin{cases} 1, V > V_{max} \\ 0, \text{Otherwise} \end{cases}$$ Where ε_{min} represents an undervoltage, ε_{max} an overvoltage, and V_{max} and V_{min} are the upper and lower voltage limits considered for the KPI computation, respectively. Given this, the voltage violations number, n, for the operation period T, is given by: $$n = \sum_{t=1}^{I} \varepsilon_i$$ A c**ongestion problem,** δ, is defined as: $$\delta = \begin{cases} 1, I > I_{rating} \\ 0, \text{Otherwise} \end{cases}$$

	Where δ represents an overload, and I_{rating} the upper operational limits, for each asset, considered for the KPI computation, respectively. Given this, the congestion violations number, n, for the operation period T, is given by: $$n = \sum_{t=1}^{T} \delta_t$$ • Violation Frequency Reduction (VFR_{Tool}) -Tool $$VFR_{Tool} = \frac{n_{\text{baseline}} - n_{LVC}}{n_{\text{baseline}}} \times 100\%$$ Where n_{baseline} is the number of violations (registered in each asset) in the baseline scenario and n_{LVC} is the number of violations (registered in each asset) with the tool application. • Violation Frequency Reduction (VFR_{Real}) -Real $$VFR_{Real} = \frac{n_{\text{real}} - n_{LVC}}{n_{\text{real}}} \times 100\%$$ Where n_{real} is the number of violations (registered in each asset) andn_{LVC} is the number of violations (registered in each asset) with the tool application.
Unit of measurement	% percentage
Target / Thresholds	100%
Reporting Period	Indicate how often this indicator must be reported (weekly, monthly, yearly) two months
Reporting Audience and Access Rights	EUniversal
OTHER (please specify)	/

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[CM_ KPI_4] 1	Collection of measurements from the SM infrastructure, for the grid field test period.	DSO
[CM_ KPI_4] 2	Computation of the voltage violations and congestions number.	INESC TEC
[CM_ KPI_4] 3	KPI computation	INESC TEC

KPI DATA COLLECTION						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Smart meter data	I, V	DSO Internal systems	DSO Internal systems	DSO Internal storage	15 min average data values	DSO
Predicted congestions	N_{LVC-I}	State Estimation + Power Flow	Grid Tools	DSO System	15 min average data values	INESC-TEC/VITO
Predicted Voltage violations	N_{LVC-V}	Data driven state estimator	Grid Tools	DSO System	15 min average data values	INESC-TEC/VITO

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES	COMPANY HISTORICAL VALUES	VALUES MEASURED DURING THE PROJECT
Details of Baseline	In the DEMO area, the market platform will be used for the first time therefore baseline is not applicable. The aim is to achieve as close as possible to 100%.		
Responsible (Name, Company) for Baseline	DSO		

Annex 3.5 – CM_KPI_5, Voltage Magnitude Prediction Error

BASIC KPI INFORMATION			
KPI Name	Voltage Magnitude Prediction Error	**KPI ID**	CM_KPI_5
Strategic Objective(s)	SO2, SO4, SO8		
DEMO where KPI applies	Portugal, Germany		
UC where KPI applies if any	PT DEMO: PT 1, PT 2, PT 3, PT4 DE DEMO: BUC DE AP & DE RP SUC5		
Owner	E-Redes		

KPI Description	Computation of voltage violation magnitude estimated based on the baseline scenario (predicted) and the real voltage magnitude registered. Determines the accuracy of the algorithm to perform state estimations. The performance and dispersion are evaluated for voltage magnitude. Two indicators are calculated: MAE (Voltage magnitudes Mean Absolute Error (MAE) and MAD (Voltage magnitudes Maximum Absolute Deviation (MAD)
KPI Formula	$$MAE = \frac{1}{N \cdot T} \sum_{n=0}^{N} \sum_{t=0}^{T} \left\lvert z_{n,t} - x_{n,t} \right\rvert$$ $$MAD = \max \left\lvert z_{n,t} - x_{n,t} \right\rvert, n = 0, \dots, N, t = 0, \dots T$$ where: • N is the number of estimation points • T is the size of the testing period • $z_{n,t}$ is the real measurement at point n for the period t $x_{n,t}$ is the estimated measurement at point n for the period t
Unit of measurement	[V]
Target / Thresholds	MAE (Voltage magnitudes Mean Absolute Error (MAE) : 0V MAD (Voltage magnitudes Maximum Absolute Deviation (MAD): 0V
Reporting Period	Two months
Reporting Audience and Access Rights	EUniversal
OTHER (please specify)	/

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**

[CM_KPI_5] 1	Measurements are gathered from the smart meters included in the estimation during the testing period. **N.B.** The processes of gathering the real values of the estimated quantities is part of the state estimation process already since it uses historical data to infer the real-time state of the network.	DSO
[CM_KPI_5] 2	The state estimator executes a real-time state estimation (voltage magnitudes) every 15 minutes.	INESC TEC,
[CM_KPI_5] 3	Computation of the MAE and MAD for voltage magnitude estimations.	INESC TEC,

KPI DATA COLLECTION						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Voltage magnitudes	$z_{n,t}$	Smart meters gather measurements and send data infrastructure	SM infrastructure	DSO Data Platform	15-minute discretised data is sent to the historical database every 24 hours	DSO SM infrastructure

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES	COMPANY HISTORICAL VALUES	VALUES MEASURED DURING THE PROJECT
Details of Baseline	In the DEMO area, the market platform will be used for the first time therefore baseline is not applicable. The aim is to achieve as close as possible to 100%.		

Responsible (Name, Company) for Baseline	n.a

Annex 4 – Portuguese DEMO KPIs

Annex 4.1 – PT_KPI_1 – Amount of flexibility the DSO reserves for planning purposes

BASIC KPI INFORMATION			
KPI Name	Amount of flexibility the DSO reserves for planning purposes	**KPI ID**	PT_KPI_1
Strategic Objective(s)	SO1, SO2, SO3, SO4, SO5, SO7, SO8, SO9, SO10, SO11		
DEMO where KPI applies	Portugal		
UC where KPI applies if any	PT 1, SUC1		
Owner	E-REDES		
KPI Description	Total amount of flexibility reserved for planning purposes during the entire DEMO		
KPI Formula	$$TFA_{LT} = \sum_{t=0}^{T} P_{flex,t}$$ Where: • TFA_{LT} – Total flexibility (active power) reserved for grid planning purposes from FSP that was available in the network, for the period *T*. • $P_{flex,t}$ – Total flexibility (active power) reserved for grid planning purposes from FSP available in the network, at each instant *t*.		
Unit of measurement	kW		
Target / Thresholds	>0 kW		
Reporting Period	Yearly		

Reporting Audience and Access Rights	EUniversal
OTHER (please specify)	/

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[PT_KPI_1] 1	Extract all trade confirmations of reserved flex. services	E-REDES
[PT_KPI_1] 2	KPI Computation	E-REDES

KPI DATA COLLECTION						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Trade confirmation list of reserved flexibility service	$P_{flex,t}$	Store data of reserved bids	UMEI	UMEI	For each reservation	DSO, FMO

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES	COMPANY HISTORICAL VALUES	VALUES MEASURED DURING THE PROJECT
Details of Baseline	N.A. (no flex contracts before EUniversal).		

Responsible (Name, Company) for Baseline	N.A

Annex 4.2 – PT_KPI_2 – Ratio of activated reserved flexibility

BASIC KPI INFORMATION			
KPI Name	Ratio of activated reserved flexibility	**KPI ID**	PT_KPI_02
Strategic Objective(s)	SO1, SO2, SO3, SO4, SO5, SO7, SO8, SO9, SO10, SO11		
DEMO where KPI applies	Portugal		
UC where KPI applies if any	PT 3 and PT 4 SUC01, SUC 03		
Owner	E-Redes		
KPI Description	Percentage of the total flexibility reserved that is activated used to manage operation for both active and reactive power		
KPI Formula	In the Long Term Flexibility market, flexibility is reserved and the DSO must pay a reservation fee. It is important to be aware if this flexibility, in the short term flexibility market will be actually activated. 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, is defined as: $$FARR_{P\%} = \frac{\sum_{t=0}^{T} P_{\text{flex,Activated}_t}}{\sum_{t=0}^{T} P_{\text{reserved}_t}} \times 100\%$$ Where: • $FARR_{P\%}$ - Percentage of the total flexibility (Active power) from FSP reserved in the network that was activated for grid management purposes, for the period T; • Pflex,Activatedt – Total flexibility from FSPs reserved that is activated in the network at each time instant. t used for grid management purposes (Active		

	power); • P_{reserved_t} – Total flexibility from FSP reserved in the network at each time instant t (Active power). $$FARR_{Q\,\%} = \frac{\sum_{t=0}^{T} Q_{\text{flex,Activated}_t}}{\sum_{t=0}^{T} Q_{\text{reserved}_t}} \times 100\%$$ Where: • $FARR_{Q\,\%}$ - Percentage of the total flexibility (Reactive power) from FSP reserved in the network that was activated for grid management purposes, for the period T; • Qflex,Activatedt – Total flexibility from FSPs reserved that is activated in the network at each time instant t used for grid management purposes (Reactive power); • Qreservedt – Total flexibility from FSP reserved in the network at each time instant t (Reactive power).
Unit of measurement	%
Target / Thresholds	100%
Reporting Period	Semester
Reporting Audience and Access Rights	EUniversal
OTHER (please specify)	/

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[PT_KPI_02]1	Extract all trade confirmations of reserved flex. Services (active and reactive power)	E-REDES

[PT_KPI_02] 2	Extract all trade confirmations of activated flex. Services (active and reactive power)	E-REDES
[PT_KPI_02] 3	KPI computation	INESC TEC

KPI DATA COLLECTION						
Data	**Data ID**	**Methodo-logy for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collec-tion**	**Frequen-cy of data collection**	**Data collection responsible**
Trade confirmation list of reserved flexibility service (active power)	P_{reserved_t}	Store data of reserved bids	UMEI	UMEI	For each reservation	DSO, FMO
Activation list of flexibility services (active power)	Q_{reserved_t}	Store data of activated bids	UMEI	UMEI	For each activation	DSO, FMO
Trade confirmation list of reserved flexibility service (reactive power)	$P_{\text{activated}_t}$	Store data of reserved bids	UMEI	UMEI	For each activation	DSO, FMO
Activation list of flexibility services (reactive power)	$Q_{\text{activated}_t}$	Store data of activated bids	UMEI	UMEI	For each activation	DSO, FMO

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES	COMPANY HISTORICAL VALUES	VALUES MEASURED DURING THE PROJECT
Details of Baseline	N.A. (no long term flexibility contracts before EUniversal).		
Responsible (Name, Company) for Baseline	N.A		

Annex 4.3 – PT_KPI_3 – Avoided CO_2 emissions from increased RES and DER hosting capacity (depends on EU_KPI_1)

BASIC KPI INFORMATION			
KPI Name	Avoided CO_2 emissions from increased RES and DER hosting capacity (depends on EU_KPI_1)	**KPI ID**	PT_KPI_3
Strategic Objective(s)	SO2 (in line with EU_KPI_1)		
DEMO where KPI applies	Portugal		
UC where KPI applies if any	General to project objectives (in line with EU_KPI_1)		
Owner	E-Redes		
KPI Description	Avoided CO_2 emissions from increased RES and DER hosting capacity that would otherwise be emitted by the thermal power plants.		
KPI Formula	The avoided CO_2 emissions KPI is defined as:		

	$Avoided\ CO_2\ emissions = EF_{RES} \times [IHC_{RES} \times h_{RES}] + EF_{DER} \times [+ IHC_{DER} \times h_{DER}]$, considering $$IHC_{RES} = HC_{RES;EUniversal} - HC_{RES;BAU}$$ $$IHC_{DER} = HC_{DER;EUniversal} - HC_{DER;BAU}$$ Where: • EF_{RES} – Annual emission factor from the Portuguese thermal power plants (tCO_2/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 (tCO_2/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)
Unit of measurement	tCO_2
Target / Thresholds	Not applicable
Reporting Period	Yearly
Reporting Audience and Access Rights	EUniversal

OTHER (please specify)	/

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[PT_KPI_3] 1	Collect from EU_KPI_1 the hosting capacities of RES and DER when EUniversal framework are applied with respect to currently connected generation ($HC_{RES;EUniversal}$ and $HC_{DER;EUniversal}$) and in BAU scenario ($HC_{RES;BAU}$ and $HC_{DER;BAU}$).	E-Redes
[PT_KPI_3] 2	Increased hosting capacity of RES and DER computation (IHC_{RES} and IHC_{DER})	E-Redes
[PT_KPI_3] 3	Collect the average number of electricity generation hours of RES (h_{RES}), from the Transmission System Operator website (excel file).	E-Redes
[PT_KPI_3] 4	Computation of the annual emission factor from the thermal power plants and the overall energy mix (EF_{RES} and EF_{DER}), using information from the Transmission System Operator (excel file)	E-Redes
[PT_KPI_3] 5	Avoided CO_2 emissions computation	E-Redes

KPI DATA COLLECTION						
Data	**Data ID**	**Methodo-logy for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collect-ion respon-sible**
Additional hosting capacity of RES	$HC_{RES;EUniversal}$	from EU_KPI_1	from EU_KPI_1	from EU_KPI_1	from EU_KPI_1	from EU_KPI_1

when EUniversal framework is applied						
Additional hosting capacity of RES in BAU scenario	$HC_{RES;BAU}$	from EU_KPI_1	from EU_KPI_1	from EU_KPI_1	from EU_KPI_1	from EU_KPI_1
Additional hosting capacity of DER when EUniversal framework is applied	$HC_{DER;EUniversal}$	from EU_KPI_1	from EU_KPI_1	from EU_KPI_1	from EU_KPI_1	from EU_KPI_1
Additional hosting capacity of DER in BAU scenario	$HC_{DER;BAU}$	from EU_KPI_1	from EU_KPI_1	from EU_KPI_1	from EU_KPI_1	from EU_KPI_1
Average number of electricity generation hours of RES	h_{RES}	Download of the excel file from the Transmission System Operator website	Transmission System Operator website	Excel file	Yearly	E-Redes
Reference number for electricity generation hours of DER in Portugal	h_{DER}	n/a	n/a (Reference number for electricity generation hours of DER in Portugal)	n/a (Reference number for electricity generation hours of DER in Portugal)	One shot	E-Redes
Annual emission factor from the Portuguese thermal	EF_{RES}	Download of the excel file from the Transmission System	Transmission System Operator website	Excel file	Yearly	E-Redes

power plants		Operator website				
Annual emission factor from the Portu-guese energ y mix	EF_{DER}	Download of the excel file from the Transmissio n System Operator website	Transmission System Operator website	Excel file	Yearly	E-Redes

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES n/a	COMPANY HISTORICAL VALUES n/a	VALUES MEASURED DURING THE PROJECT n/a
Details of Baseline	CO_2 emissions will only be calculated after the EUniversal framework is applied, by comparing it to the hosting capacity in BAU scenario.		
Responsible (Name, Company) for Baseline	n/a		

Annex 4.4 – PT_KPI_4 – Energy consumption

BASIC KPI INFORMATION			
KPI Name	Energy consumption	**KPI ID**	PT_KPI_4
Strategic Objective(s)	SO2, S04, SO7, S08, SO10		
DEMO where KPI applies	Portugal		
UC where KPI applies if any	PT 1, PT 2, PT 3 and PT 4		

KPI Description	Variation of resource provider's consumption due to the flexibility services activation by voltage
KPI Formula	The resource provider's consumption (RPC) KPI is defined as: $$RPC_{LV} = \frac{\sum_{n=1}^{N}\sum_{t=0}^{T} RPC_{LV;f} - \sum_{n=1}^{N}\sum_{t=0}^{T} RPC_{LV;i}}{N}$$ $$RPC_{MV} = \frac{\sum_{n=1}^{N}\sum_{t=0}^{T} RPC_{MV;f} - \sum_{n=1}^{N}\sum_{t=0}^{T} RPC_{MV;i}}{N}$$ Where: • RPC_{LV} – variation of resource provider's consumption before and after the flexibility service activation, by low voltage consumers • $RPC_{LV;f}$ – resource provider's consumption after flexibility services activation, for the period T and for N low voltage consumers, for a given month • $RPC_{LV;i}$– resource provider's consumption before flexibility services activation, for the period T and for N low voltage consumers, for the homologous month of a previous year without flexibility services activation • RPC_{MV} – variation of resource provider's consumption before and after the flexibility service activation, by medium voltage consumers • $RPC_{ML;f}$ – resource provider's consumption after flexibility services activation, for the period T and for N medium voltage consumers • $RPC_{ML;i}$– resource provider's consumption before flexibility services activation, for the period T and for N medium voltage consumers
Unit of measurement	MWh
Target / Thresholds	0 MWh
Reporting Period	Yearly
Reporting Audience and Access Rights	EUniversal
OTHER (please specify)	/

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[PT_KPI_4] 1	Collection of the resource provider's consumption after the flexibility service activation from the smart meter infrastructure, for each period *T* and for all the low voltage consumers, for a given month	E-Redes
[PT_KPI_4] 2	Collection of the resource provider's consumption after the flexibility service activation from the smart meter infrastructure, for each period *T* and for all the medium voltage consumers, for a given month	E-Redes
[PT_KPI_4] 3	Collection of the resource provider's consumption before the flexibility service activation from the smart meter infrastructure, for each period *T* and for all the low voltage consumers, for the homologous month of the previous year	E-Redes
[PT_KPI_4] 4	Collection of the resource provider's consumption before the flexibility service activation from the smart meter infrastructure, for each period *T* and for all the medium voltage consumers, for the homologous month of the previous year	E-Redes
[PT_KPI_4] 5	Collection of the total number of low voltage consumers involved	E-Redes
[PT_KPI_4] 6	Collection of the total number of medium voltage consumers involved	E-Redes
[PT_KPI_4] 7	RPC LV Computation	E-Redes
[PT_KPI_4] 8	RPC MV Computation	E-Redes

KPI DATA COLLECTION						
Data	**Data ID**	**Methodo-logy for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequenc y of data collection**	**Data collection respon-sible**
Resource provider's co nsumption aft er flexibility services activation (low voltage)	$RCP_{LV;f}$	Collection of smart meter measure-ments that are stored at data platform	Smart Meter Data (SMD)	Data platform	Monthly	E-Redes
Resource provider's co nsumption aft er flexibility services activation (Medium voltage)	$RCP_{MV;f}$	Collection of smart meter measure-ments that are stored at data platform	Smart Meter Data (SMD)	Data platform	Monthly	E-Redes
Resource provider's co nsumption be fore flexibility services activation (low voltage)	$RCP_{LV;i}$	Collection of historical information from smart metering data	Smart Meter Data (SMD)	Data platform	One shot	E-Redes
Resource provider's co nsumption be fore flexibility services activation (medium voltage)	$RCP_{MV;i}$	Collection of historical information from smart metering data	Smart Meter Data (SMD)	Data platform	One shot	E-Redes

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES n/a	COMPANY HISTORICAL VALUES Smart Meter Data (SMD)	VALUES MEASURED DURING THE PROJECT n/a
Details of Baseline	Historical information from Smart Meter Data ($RCP_{LV;I}$ and $RCP_{MV;i}$)		
Responsible (Name, Company) for Baseline	E-Redes		

Annex 5 – German DEMO KPIs

Annex 5.1 – DE_KPI_1 – Costs of Congestion Management with flexibility market vs. Curtailment

BASIC KPI INFORMATION			
KPI Name	Costs of Congestion Management with flexibility market vs. Curtailment	**KPI ID**	DE_KPI_01
Strategic Objective(s)	SO3		
DEMO where KPI applies	German		
UC where KPI applies if any	BUC DE AP		
KPI Description	Demonstrate the economic value of the market process. Relates the cost for of traded flexibility on the market with the costs of curtailment		
KPI Formula	$\frac{C_{FM}}{C_C}\ 100$ Where: C_{FM} are the cost for the traded flexibility on the market Cc are the costs for curtailment measures		
Unit of measure-ment	%		
Target / Thresholds	Costs for congestion management and curtailment should be less with demonstrator or at least not higher		
Reporting Period	quarterly		

Reporting Audience and Access Rights	DEMO

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[DE_KPI_01] 1	Sum up costs for the traded market-based flexibility[1]	FMO
[DE_KPI_01] 2	Determine an approximation for curtailment prices	DSO
[DE_KPI_01] 3	Estimate sum of curtailed energy and calculate total costs	DSO
[DE_KPI_01] 4	Determine ratio of market-based flexibility to curtailment	DSO

KPI DATA COLLECTION						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsi-ble**
Costs of alternati-vely to market curtailed energy	c_C	Research on past curtailment costs multiplied by the required curtailment energy	Flexibility Market	DSO System	For reporting period	FMO
Costs for traded flexibility	c_{FM}	Determine flexibilities traded on the	Flexibility Market	Market Platform	For reporting period	FMO

on the market		market; sum up the costs				

KPI BASELINE	
Source of Baseline Condition	Values measured at the start of the field test
Details of Baseline	Baseline are determined by the curtailment costs which are directly included in the KPI; The aim is to achieve a more cost-efficient result with the flexibility market solution than with curtailment
Responsible (Name, Company) for Baseline	DSO

Annex 5.2 – DE_KPI_2 – Cycle Time DSO process

BASIC KPI INFORMATION			
KPI Name	Cycle Time DSO process	**KPI ID**	DE_KPI_02
Strategic Objective(s)	SO2		
DEMO where KPI applies	German		
UC where KPI applies if any	DE AP, DE RP, SUC 15		
KPI Description	Calculation of the amount of time between information input (***Ti***) and finalized output to the market (□₀). The DSO update process needs to be done in a certain time to be able to react adequately to the grid situation.		

KPI Formula	$\boldsymbol{d = T_o - T_i}$ where: $\boldsymbol{T_i}$ is the time of information input $\boldsymbol{T_o}$ is the time of finalized output/order to the market
Unit of measure-ment	seconds/minutes
Target / Thresholds	5minutes
Reporting Period	weekly
Reporting Audience and Access Rights	EUniversal/DEMO
OTHER **(please specify)**	For developing KPI can be divided into minor KPI for each step

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[DE_KPI_02] 1	Trigger Calculation process and start of timekeeping	DSO in cooperation with technology provider
[DE_KPI_02] 2	Successive execution of program parts and data exchange	DSO
[DE_KPI_02] 3	Display results in the GUI	DSO

[DE_KPI_02] 4	Offer/execute market options and end of timing	DSO

KPI DATA COLLECTION						
Data	**Data ID**	**Methodo-logy for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Execu-tion time	*d*	Timing of DSO process	DSO System	DSO Platform	For each calculation iteration	DSO + technology providers

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES n.a	COMPANY HISTORICAL VALUES n.a	VALUES MEASURED DURING THE PROJECT n.a
Details of Baseline	A total time of less than 5 minutes should be achieved; This time value results on the one hand from empirical values from the EU-Sysflex project, on the other hand it allows to reliably derive measures within the market periods of 15min.		
Responsible (Name, Company) for Baseline	DSO + Technology partners		

Annex 5.3 – DE_KPI_03: Share of correctly forecasted congestions & DE_KPI_04: Share of false positive congestion forecast

BASIC KPI INFORMATION			
KPI Name	DE-03: Share of correctly forecasted congestions DE-04: Share of false positive congestion forecasts	**KPI ID**	DE_KPI_03 DE_KPI_04
Strategic Objective(s)	SO5		
DEMO where KPI applies	German		
UC where KPI applies if any	DE AP, DE RP, SUC 7		
KPI Description	DE-04: The ratio of the correctly forecasted congestions versus all congestions that occurred or would have occurred without curative DSO action. DE-05: The ratio of the incorrectly forecasted congestions versus the total number of congestions forecasted.		
KPI Formula	**<u>DE_KPI_3:</u>** $\mathbf{C_{fc,c}/C_o}$ Where: $\mathbf{C_{fc,c}}$ is the number of congestions correctly forecasted, so excluding the false positive congestions forecasts. $\mathbf{C_o}$ is the 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). **<u>DE_KPI_4:</u>** $\mathbf{C_{fc,f}/C_{fc}}$		

	Where: $C_{fc,f}$ is the 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} is the total number of congestions forecasted.
Unit of measure-ment	[%]
Target / Thresholds	DE_KPI_3: 100% DE_KPI_4: 50% All congestions need to be correctly detected in the day ahead congestion forecast, as to ensure that the DSO has adequate time to take action to avoid all congestions. False negatives should not occur. False positives are acceptable, but their share should be as small as possible.
Reporting Period	monthly
Reporting Audience and Access Rights	EUniversal/DEMO

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[DE_KPI_3] 1	During German pilot, the day ahead forecast is generated on a daily basis. The forecast results are stored: per grid, per quarter hour the congestion risk and whether the congestion risk exceeds the detection threshold.	VITO
[DE_KPI_3] 2	Voltage and current measurements are collected in the German pilot on the relevant loactions where	Mitnetz Strom

	congestions can occur (feeder head, feeder end, locations with high PV connections) and stored.	
[DE_KPI_3] 3	Any activations of flexible devices which are altered or caused by LV congestion management actions are logged and quantified. (delta P per quarter hour, which is translated into the delta V/delta I realized per quarter hour)	Market platform In cooperation with DSO & VITO
[DE_KPI_3] 4	Per feeder and per quarter hour, following categorization is applied: • true negative: no congestion forecasted, no congestion occured • false negative: no congestion forecasted, congestion occured • true positive: congestion forecasted, load on the grid corrected for the flexibility activations would have caused congestion • false postive: congestion forecasted, load on the grid corrected for the flexibility activations would not have caused congestion	VITO
[DE_KPI_3] 5	The results from step 4 are aggregated into $\mathbf{C_{fc,c}}$, $\mathbf{C_o}$, $\mathbf{C_{fc,f}}$ and $\mathbf{C_{fc}}$ and the KPI's are calculated.	VITO

KPI DATA COLLECTION						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Congestion forecast result	Forecasted congestions C_f	Results of SUC 07	Day ahead congestion forecasting tool	Prob. State estimation algorithm (SUC07)	Daily	VITO + Mitnetz Strom

Measured or indicated congestions	C_0	Collection of metering data	Feeder head and street box measurements	Metering Database	Every 15min	Mitnetz Strom

KPI BASELINE	
Source of Baseline Condition	Values measured during field test
Details of Baseline	Comparison of result from SUC7 and the real measured values
Responsible (Name, Company) for Baseline	VITO and Mitnetz

Annex 5.4 – KPI_DE_05, Baseline accuracy

BASIC KPI INFORMATION			
KPI Name	Baseline accuracy	**KPI ID**	DE_KPI_05
Strategic Objective(s)	SO8		
DEMO where KPI applies	German		
UC where KPI applies if any	BUC DE AP, DE RP, SUC 29		

KPI Description	Assess the accuracy of the computed baseline compared to the energy/power consumer/injected into the grid (when no dispatch)
KPI Formula	Mean Absolute Error (MAE): $$MAE = \frac{1}{n}\sum|e_t|$$ Root Mean Squared Error (RMSE): $$RMSE = \sqrt{\frac{1}{n}\sum e_t^2}$$ With: - t as settlement period - n as number of settlement periods considered - e as the error, difference between the baseline value and the energy/power measurement (when no dispatch). -
Unit of measure-ment	KW, KWh (or % if scaled to the measurement)
Target / Thresholds	0
Reporting Period	daily
Reporting Audience and Access Rights	DE DEMO

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**

[DE_KPI_05] 1	Create Baseline per portfolio	FSP
[DE_KPI_05] 2	Measure resources without dispatch	Meter data operator (as part of DSO role)
[DE_KPI_05] 3	Calculate the MAE and RMSE for the considered time-steps and portfolios	DSO/FSP

KPI DATA COLLECTION						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Baseline of flexibility resources	F_B	Forecast	FSP	Market Platform	daily on ¼ hourly bases	FSP
Measure Resources without dispatch	F_M	Measurement	Power Measurement	Metering System	on ¼ hourly bases	DSO
Error of baseline value and measure-ment	$e = F_B - F_M$	Calculation	-	Market Platform + Metering System	daily	DSO+FSP

KPI BASELINE	
Source of Baseline Condition	Values measured at the beginning of the field test

Details of Baseline	Error should be close to zero; Practical values are coordinated after final measurement setup
Responsible (Name, Company) for Baseline	FSP+DSO

Annex 6 – Polish DEMO KPIs

Annex 6.1 – PL_KPI_1 – RES energy enlargement

BASIC KPI INFORMATION			
KPI Name	RES energy enlargement	**KPI ID**	PL_KPI_1
Strategic Objective(s)	SO2		
DEMO where KPI applies	PL		
UC where KPI applies if any	PL DLR		
KPI Description	RES generated energy above connection agreement value.		
KPI Formula	$$\text{PL KP1} = \frac{\Delta A_Y}{A_T - \Delta A_Y}$$ Total yearly production: $$A_T = \sum_{i=1}^{8760} A_{hi}$$ Total yearly production above connection agreement: $$\Delta A_Y = \sum_{i=1}^{8760} \Delta A_{hi}$$ $$\Delta A_{hi} = A_{hi} - A_{CA} \text{ if } A_{hi} > A_{CA}$$ $$\Delta A_{hi} = 0 \quad \text{if } A_{hi} < A_{CA}$$ ΔA_Y = Total yearly production above connection agreement A_T = Total yearly production A_{hi} = hourly production [MWh] ΔA_{hi} = hourly production above connection agreement A_{CA} = production according to connection agreement [MWh]		
Unit of measurement	%		

Target / Thresholds	120%
Reporting Period	Yearly
Reporting Audience and Access Rights	EUniversal

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[PL_KPI_1] 1	Collect metering data: Generation hourly profile for each Producer (Wind Farm)	DSO
[PL_KPI_1] 2	Compare with connection agreement value	DSO
[PL_KPI_1] 3	Calculate PL KPI_1 acc formula	DSO

KPI DATA COLLECTION						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Hourly production	A_{hi}	AMI	Smart meter	Wind Farm connection point	Monthly	DSO

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES n/a	COMPANY HISTORICAL VALUES n/a	VALUES MEASURED DURING THE PROJECT n/a

Details of Baseline	In the DEMO area, this service will be used for the first time therefore baseline is not applicable.
Responsible (Name, Company) for Baseline	DSO

Annex 6.2 – PL_KPI_2 – Monitoring Information Categories

BASIC KPI INFORMATION			
KPI Name	Monitoring Information Categories	**KPI ID**	PL_KPI_2
Strategic Objective(s)	SO5		
DEMO where KPI applies	PL		
UC where KPI applies if any	PL FS		
KPI Description	Monitoring data volume is an indication of the increase of data amount for new monitored currents, powers, or voltages in primary substations, secondary substations, or customer level. One of the main objectives of EUniversal project is the integration of measurement data for low voltage network control tools, for supporting state estimation and power flow algorithms, or for the congestion's management		

KPI Formula	$$MIC(\%) = \frac{MD_{Flex} - MD_{BAU}}{MD_{BAU}}$$ where: MD_{BAU} Total monitored data according to the count criterion in BAU scenario. MD_{Flex} Total monitored data according to the count criterion in flexibility scenario.
Unit of measurement	% percentage
Target / Thresholds	200%
Reporting Period	Once at end of the project
Reporting Audience and Access Rights	EUniversal

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[PL_KPI_2] 1	Consolidation of the table of information categories for the following equipment: • Smart meters, data concentrators, based nodes and RTU. • Advanced LV supervisors (SS). • DER controllers, in BAU scenario	DSO
[PL_KPI_2] 2	Consolidation of the table of information categories for the following equipment: • Smart meters, data concentrators, based nodes and RTU. • Advanced LV supervisors (SS). • DER controllers, in flexibility scenario	DSO

	KPI DATA COLLECTION					
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Total monitored data in BAU scenario	MD_{BAU}	Filling the monitored data (yes/no) column before EUniversal and count each case	DEMO equipment inventory	Based on companions	once	DSO
Total monitored data in flexibility scenario	MD_{Flex}	Filling the monitored data (yes/no) column after EUniversal and count each case	DEMO equipment inventory	Based on companions	once	DSO

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES -	COMPANY HISTORICAL VALUES -	VALUES MEASURED DURING THE PROJECT X
Details of Baseline	Total monitored data according to the count criterion in the BAU scenario will be defined at the beginning of field tests		
Responsible (Name, Company) for Baseline	DSO		

Annex 6.3 – PL_KPI_3 – Increased local PV hosting capacity

BASIC KPI INFORMATION			
KPI Name	Increased local PV hosting capacity	**KPI ID**	PL_KPI_3
Strategic Objective(s)	SO5		
DEMO where KPI applies	Polish		
UC where KPI applies if any	PL FS		
KPI Description	Flexible substations will allow for increased RES and DER hosting capacity		
KPI Formula	$\frac{P_{max}}{P_0}$ P_{max} = Maximum technically allowable PV installation capacity calculated with the presence of the flexible substation P_0 = Total PV capacity installed before flexible substation.		
Unit of measurement	%		
Target / Thresholds	130%		
Reporting Period	Once at the end of the project		
Reporting Audience and Access Rights	EUniversal		

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[PL_KPI_3] 1	Collect and summarize the installation power of all PV in the LV network supplied by the planned flexstation	DSO
[PL_KPI_3] 2	The power flow calculation of the maximum allowable PV capacity in the presence of the control feature of the flexible substation	DSO
[PL_KPI_3] 3	Calculate PL KPI_3 acc formula	DSO

KPI DATA COLLECTION						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Total PV capacity installed	P_0	manually	Inventory list of the PV installation connected to the grid	LV network supplied by FS	once	DSO

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES -	COMPANY HISTORICAL VALUES -	VALUES MEASURED DURING THE PROJECT **X**
Details of Baseline	Total PV capacity installed before flexible substation. will be defined at the beginning of field tests		

Responsible (Name, Company) for Baseline	DSO

Annex 6.4 – PL_KPI_4 – Fulfilment of voltage limits

BASIC KPI INFORMATION			
KPI Name	Fulfillment of voltage limits	**KPI ID**	PL_KPI_4
Strategic Objective(s)	SO5		
DEMO where KPI applies	PL		
UC where KPI applies if any	PL FS		
KPI Description	The fulfillment of voltage limits is a common KPI used to evaluate the power quality and quality of supply of distribution networks. EUniversal project is addressing some actions to be implemented in the DEMO areas which will impact positively in the fulfillment of voltage limits. New voltage regulation capabilities will be implemented by deploying smart devices and tools. Some of these actions regard to the remote management of DER.		
KPI Formula	$$V(\%) = \frac{V_{BAU} - V_{Flex}}{V_{BAU}}$$ where: V_{BAU} The 95% percentage voltage value during the monitoring period in a selected critical point in the LV network for the BAU scenario. V_{Flex} The 95% percentage voltage value during the monitoring period in a selected critical point in the LV network for flexibility scenario.		
Unit of measurement	%		

Target / Thresholds	2,5 %
Reporting Period	Once at the end of the project
Reporting Audience and Access Rights	EUniversal

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID	**Step**	**Responsible**
[PL_KPI_4] 1	Collect V95% values in a selected critical point in the LV network for the BAU scenario.	DSO
[PL_KPI_4] 2	Collect V95% values in a selected critical point in the LV network for a flexibility scenario.	DSO
[PL_KPI_4] 3	Calculate PL KPI_4 acc formula	DSO

KPI DATA COLLECTION						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/ Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Voltage value for the BAU scenario	V_{BAU}	Analysis of data from AMI	Smart Meters	AMI	15 min average data values	DSO
Voltage value for flexibility scenario	V_{Flex}	Analysis of data from AMI	Smart Meters	AMI	15 min average data values	DSO

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES -	COMPANY HISTORICAL VALUES -	VALUES MEASURED DURING THE PROJECT X
Details of Baseline	The 95% percentage voltage value during the monitoring period in a selected critical point in the LV network will be measured after flexible substation installation with automatic control disabled		
Responsible (Name, Company) for Baseline	DSO		