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Report on the selection of KPIs for the demonstrations

D10.1

EU-SysFlex

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EXECUTIVE SUMMARY

The EU-SysFlex project seeks to enable the European power system to utilise efficient, coordinated flexibilities in order to integrate at least 50% of electricity coming from renewable energy sources (RES-E). In order to reach at least 50% RES-E on a European scale, it will be necessary to integrate increasing levels of variable non-synchronous renewable technologies(vRES), such as wind and solar. Transitioning from power systems which have traditionally been dominated by large synchronous generating units to systems with high levels of variable non-synchronous renewable technologies results in challenging the safe and reliable operation of power systems. Addressing these challenges is at the core of the EU-SysFlex project, mainly by demonstrating in the field, and on a large scale the capabilities and complementarity of several technical and digital solutions, but also by addressing the business, market and regulation changes necessary to their development. The overall objective of integrating over 50% RES therefore relies on several fields of expertise, from data management to real time balancing, the results of which will feed in Work Package 10 of the project and the proposal of a roadmap for Europe.

The Work Package 10 of the EU-SysFlex European project has several main objectives, the first of which is the definition of Key Performance Indicators (KPIs) for the industrial scale demonstrations at the centre of the project, carrying out a Scalability and Replicability Analysis (SRA) of the results from the demonstrations and, by also integrating the results of the market studies and data management solutions, finally providing a roadmap for development and deployment of innovative services needed by Power System Operators to support the integration of variable renewable sources, storage and flexible demand technologies. Within this Work Package, Task 10.1 deals with technical, economic and regulatory flexibility analyses. The first part of this Task, Sub-Task 10.1.1, identifies the Key Performance Indicators for the demonstrations. Based on these KPIs, data will be collected during the demonstrations and several assessments will be done at a later stage in the project: the technical energy analysis, the scalability, and replicability analysis.
The main output of T10.1.1 is D10.1 – *Report on the selection of KPIs for the demonstrations*. This document collects the selected KPIs for monitoring the EU-SysFlex demonstrations. It contains KPI definitions, formulas that will enable their evaluation in T10.1.2 – *Technical Energy Analysis* - later in the project.

A literature review was initially done on the KPIs used in other smart grid projects in Europe, that took place in the past few years in order to analyse the lessons learned. It turns out that past projects often use the EEGI framework as a basis for KPIs development, this framework being superseded by the ETIP-SNET framework in 2017. A tentative use of the ETIP-SNET framework was done at the beginning of the EU-SysFlex project, which turned down to be too generic. Decision was made to make a distinction between project-related indicators, that capture the overall and transverse outputs of the EU-SysFlex project, and demo-related KPIs, that are specific to each demonstration. The former will be dealt within T10.2 (Roadmap) whereas the latter are the main focus of this document.

The demo-related KPIs are aiming at proving the success of the services trialled, qualify their performance and reliability. The approach followed several steps. First of all, a structured template was created for defining each KPI and providing a calculation methodology. KPIs were selected through bottom-up proposals from demonstrations

leaders and several iterations. A typology of KPIs was then proposed in order to classify the KPIs into main categories and identify those common to several demos.

The KPIs defined in the various demonstrations can be grouped in several categories (Figure 1):

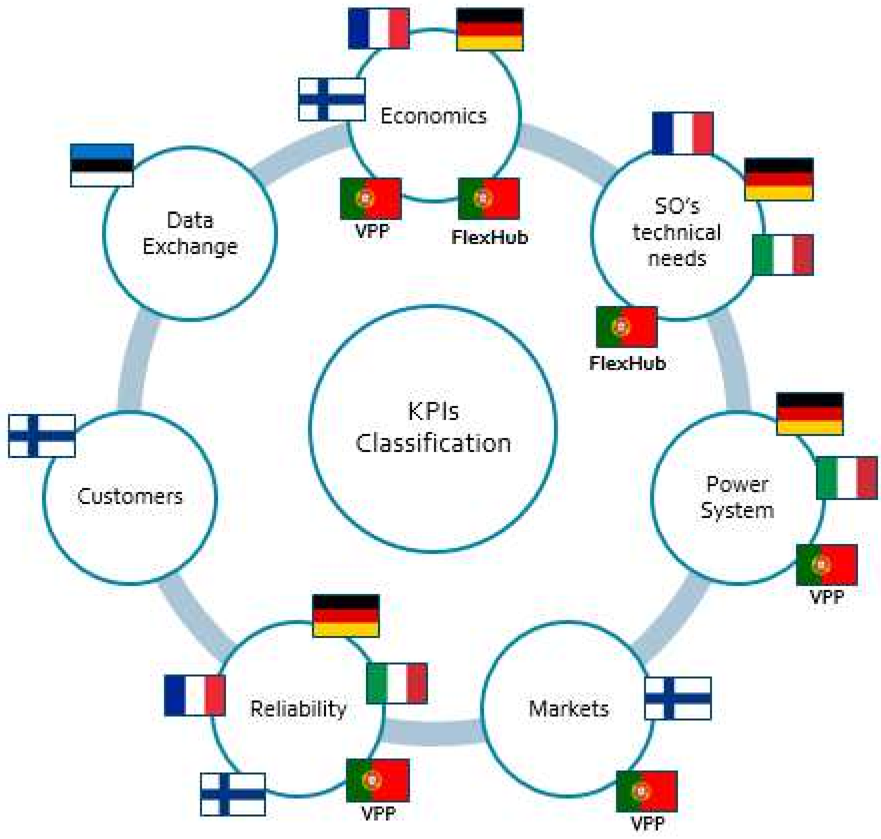

FIGURE 1: MAIN CATEGORIES OF KPIS

- economic impacts of the solutions;
- meeting system operators' technical needs in terms of flexibility service provision (frequency regulation, voltage control, congestion management, …);
- impacts on the power system and in particular on the distribution grid where congestion must be avoided when providing flexibility services from distributed resources;
- market aspects;
- reliability;
- customers' acceptance;
- data exchange.

Not all demonstrations cover all categories. For example, economic impacts are not measured in the Italian demonstration since solutions for congestions management are not regulated/remunerated in the current Italian regulatory framework.

The entire list of KPIs defined by the various demonstrations is summarized per categories and demonstrations in the two following tables.

	Finland	Italy	Germany	Portugal Flexhub	Portugal VPP	France
Economic impacts						
Increase in revenue of the flexibility provider	X			X	X	X
Decrease in cost for flexibility service provision	X		X			
Cost sharing between TSO and DSO for congestion management				X		
Opportunity cost of providing a flexibility service				X		
Meet SO's needs						
Compliance of existing services provision by new assets to SO's requirements			X			X
Tracking error between a set-point requested by the SO and the measure		X		X		
Increase in flexibility service provision capability		X		X		
Compliance of new services provision (e.g. FFR) to SO's requirements						X
Impacts on the power system						
Line voltage profiles		X				
Hosting capacity variation		X				
Grid efficiency			X			
Impacts on markets						
Reactive power market utilization factor	X					
Variation in the imbalances in participation of RES in energy markets					X	
Reliability						
Availability of the flexibility services	X		X		X	
Availability of the aggregation platform	X					
Availability of the communication infrastructure		X				
Forecast quality		X	X		X	X
Flexibility services re-dispatch success rate						X
Impacts on customers						
Customers' acceptance	X					

TABLE 1: PROPOSED KPIS FOR THE WP6 (FINLAND, ITALY, GERMANY), WP7 (PORTUGAL_FLEXHUB, PORTUGAL_VPP) AND WP8 (FRANCE) DEMONSTRATIONS

#	KPI	Data Exchange (WP9)				
		Affordable tool	Flexibility platform	Cross-Border exchange of flexibility services		
		(A)	(B)	(C)	(D)	(E)
				Elering + Energinet	Elering + ESO	Elering + ENTSO-E
1. Global KPIs						
1.1	Easy access to own data	■		■	■	■
1.2	Sharing information related to participation in flexibility market	■	■			■
1.3	Energy services and applications benefiting from data exchange	■	■	■	■	■
2. Non-functional KPIs – (from BUCs)						
2.1	Delivery/Implementation	■	■	■	■	■
2.2	Expected flexibility	■				
2.3	Deliverability of flexibility service at time step t	■				
2.4	Duration of flexibility delivery	■				
2.5	Performance – messaging latency	■	■	■	■	■
2.6	User satisfaction	■				
2.7	Open Source		■	■	■	■
2.8	Connectivity	■	■	■	■	■
3. KPIs related to System Use cases – functional KPIs (from SUCs)						
3.1	Collect energy data	■	■	■	■	■
3.2	Transfer energy data	■	■	■	■	■
3.3	Provide list of suppliers and ESCOs		■	■	■	■
3.4	Manage flexibility bids	■	■			
3.5	Manage flexibility activations	■	■			
3.6	Verify and settle activated flexibilities	■	■			
3.7	Manage users' requests	■	■	■	■	■
3.8	Notify customers	■	■	■	■	■
3.9	Manage authorizations (permissions)	■	■	■	■	■
3.10	Authenticate data users	■	■	■	■	■
3.11	Manage security logs	■	■	■	■	■
3.12	Calculate flexibility baseline	■	■			
3.13	Predict flexibility availability	■	■			
3.14	Process massive data					

#	KPI	Data Exchange (WP9)				
		Affordable tool	Flexibility platform	Cross-Border exchange of flexibility services		
		(A)	(B)	(C)	(D)	(E)
				Elering + Energinet	Elering + ESO	Elering + ENTSO-E
3.15	Manage sub-meter data					
3.16	Exchange data between DER and SCADA					
3.17	Anonymize data					
3.18	Aggregate energy data					
3.19	Integrate new data source					
3.20	Integrate new application					
3.21	Detect data breaches					
3.22	Erase and rectify personal data					

TABLE 2: PROPOSED KPIS FOR THE DATA EXCHANGE DEMONSTRATION (WP9)

1. INTRODUCTION

The H2020 EU-SysFlex European project aims at demonstrating innovative flexibility solutions for the electrical system and at studying the large-scale deployment of the latter considering the integration of more than 50% RES at the horizon 2030. These flexibility solutions include technical options, system control and data transfer enhancement.

The Work Package 10 of the project has several main objectives such as defining Key Performance Indicators (KPIs) for the demonstrations, carrying out a Scalability and Replicability Analysis (SRA) of the results from the demonstrations and, integrating also the results from the market and economic studies as well as the data management solutions, finally providing a roadmap for development and deployment of innovative system services needed by Power System Operators to support the integration of variable renewable sources, storage and flexible demand technologies. Within this Work Package, Task 10.1 deals with technical, economic and regulatory flexibility analyses. The first part of this Task, Sub-Task 10.1.1, concerns the identification of the Key Performance Indicators for the demonstrations. Based on these KPIs, data will be collected during the demonstrations and several assessments will be done at a later stage in the project: the technical energy analysis, the scalability, and replicability analysis.

The main output of T10.1.1 is D10.1 – *Report on the selection of KPIs for the demonstrations*. This document collects the selected KPIs for monitoring the EU-SysFlex demonstrations. It contains KPI definitions, formulas that will enable their evaluation in T10.1.2 – *Technical Energy Analysis* - later in the project.

The establishment of the list of KPIs has mainly involved the partners involved in the demonstrations as well as EDF, VITO and Imperial College. The EU-partners contributing to Sub-Task 10.1.1 were:
<u>A core group composed of:</u> EDF R&D, Imperial College London, VITO, EirGrid, ESADE.
<u>Partners leading the demonstrations:</u>

- Germany: Innogy; Mitnetz;
- Finland: Helen; Helen Electricity Network; VTT;
- Italy: ENEL; EDIS; RSE;
- Portugal: InescTec; EDP;
- France: EDF;
- Data exchange: Elering; Enoco; AKKA.

As part of the work on KPIs, a milestone report was delivered after six months and consisted in a preliminary shared list of KPIs between demonstration leaders and all partners working in WP10.

2. LITERATURE REVIEW ON KPIS

The EU-SysFlex project carried out a literature review on the KPIs, that were used in other smart grids projects in Europe that took place in the past few years and analyzed the lessons learned and how these KPIs could be used and adapted to the features and objectives of the EU-SysFlex demonstrations in order to pave the way for enabling a robust and feasible monitoring of their performance.

The list of past projects analyzed within the EU-SysFlex project are listed in the §7 - References. It comprises

- deliverables on KPIs from several European Projects:
  - Grid+ (2011-2014) - *Supporting the development of the European Electricity Grids Initiative* (EEGI);
  - ADVANCED (2012-2014) -*Active Demand Value ANd Consumers Experience Discovery*. The project focused on spreading active demand and knowledge of its benefits throughout Europe, assessing its impact on consumers and the energy network;
  - IDE4L (2013-2016) - *Ideal grid for all*. The project aimed at defining, developing and demonstrating distribution network automation, IT systems and applications for active network management;
  - EvolvDSO (2013-2016) aiming at developing the methodologies and tools for new and evolving DSO roles for efficient distributed renewable technology sources integration in distribution networks;
  - DISCERN (2013-2016) - *Distributed intelligence for Cost-Effective and Reliable Distribution Network Operation*. The project aimed at assessing the optimal level of intelligence required for distribution networks and at determining if replicable technological options may be deployed in a cost effective manner;
  - Grid4EU (2011-2016) that consisted of six demonstrators and tested the potential of smart grids in areas such as renewable energy integration, electric vehicle development, grid automation, energy storage, energy efficiency and load reduction;
  - IGREENGrid (2013-2016) - *IntegratinG Renewables in the EuropEaN Electricity Grid*. The project focused on increasing the hosting capacity for Distributed Renewable Energy Sources (DRES) in power distribution grids without compromising the reliability or jeopardizing the quality of supply;
  - UPGRID (2015-2017) that tested solutions to enable active demand and distributed generation flexible integration, through a fully controllable distribution grid;
- Reports on the ETIP-SNET roadmap (2016) and implementation plan (2017).

One of the lessons learned from the literature review shows that past projects often use the EEGI framework as a basis for KPIs development, this framework being superseded by the ETIP-SNET framework in 2017. The European Electricity Grid Initiative (EEGI) was one of the European Industrial Initiatives under the Strategic Energy Technologies Plan (SET-PLAN) and proposed a 9-year European Research, Development and Demonstration (RD&D) programme to accelerate innovation and the development of the electricity networks of the future in Europe. EEGI's objectives were the base of the EEGI Roadmap 2013-22 and Implementation Plan 2013-2022. The Final 10 year ETIP SNET R&I roadmap covering 2017-26 is the update and a extension of the previous EEGI roadmap 2013-2022: the specified research and innovation (R&I) activities cover a scope larger than the electricity system, encompassing interactions with the gas and heat networks and focusing on the integration of energy storage technologies into the power system. The ETIP SNET R&I Implementation Plan 2017-2020 is itself based upon the ETIP-SNET R&I roadmap.

In the ETIP-SNET approach, three levels of KPIs are used, each level having a specific management goal of the Research and Innovation Roadmap. These KPIs are not only oriented to evaluate the results of R&I project, but also to estimate their contribution to achieve EU goals: i) Overarching KPIs, ii) Specific KPIs, and iii) Project KPIs. The Overarching KPIs consist of a limited set of network and system performance indicators which are intended to provide a very high level of understanding of the benefits that would be achieved by European R&I projects and will be evaluated at a system level. Next in line, the Specific KPIs provide an overview of other specific technical parameters relevant for power system operators in order to reliably achieve their overarching goals. Finally, the Project KPIs are proposed by each R&I project of the ETIP-SNET Roadmap. The results from the Project KPIs are used to evaluate the Overarching and the Specific KPIs.

A tentative use of the ETIP-SNET framework was done at the beginning of the EU-SysFlex project and helped produce a preliminary list of KPIs after 6 months. However, this approach turned out to be too general and difficult to use by the demonstration leaders. For example, the KPI “Increased hosting capacity for flexibility”, or “level of distributed RES contributing to ancillary services”, are indirectly and partially tested in all the demonstrations of the EU-SysFlex project. Further simulations and evaluations at system level will be required to address these KPIs.

Decision was therfore made to make a distinction between project-related KPIs that capture the main outputs of the overall EU-SysFlex project and demo-related KPIs that are specific to the demonstrators. The former will be dealt within T10.2 (Roadmap) whereas the latter are the main focus of this document. They are aiming at proving the success of the services trialled, qualify their performance and reliability and were defined using a bottom-up approach.

3. WHY USE KPIS

Key Performance Indicators (KPIs) evaluate the success of a demonstration at reaching targets. Often success is the mere achievement of a given goal (e.g. availability of a list of suppliers and service providers through a data exchange platform, customer satisfaction, etc.), and sometimes success is defined in terms of a measurable value that demonstrates how effectively a demonstration is achieving key objectives. There are therefore two categories of measurements for KPIs: quantitative and qualitative.

In principle, whenever a KPI is quantitative, it measures an improvement against a baseline (Figure 2) considering:

- a reference date;
- the baseline: in our case, the electrical system without EU-SysFlex innovations;
- and the situation when EU-SysFlex innovations are implemented.

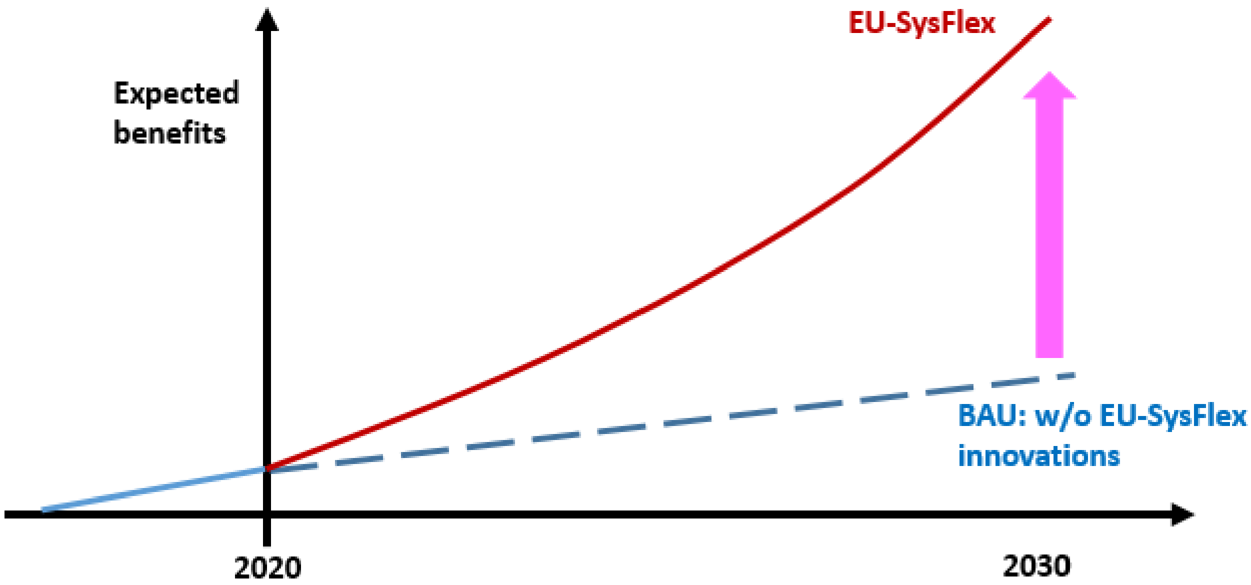

FIGURE 2: A KPI AIMS AT MEASURING AN IMPROVEMENT AGAINST A BASELINE

However, it is not always possible or easy to define a baseline especially when the service provided is a new service. For example, the provision of fast frequency response is tested in the French demonstration[1] whereas the French TSO has not yet requested this service and therefore the grid code contains no prescription regarding the provision of this service.

Selecting the right KPIs for EU-SysFlex demonstrations depends on the demonstration considered and which aspect is tracked. Accordingly, defining the right KPIs relies upon a good understanding of what is important to the demonstration. Each demo will therefore use different KPIs to measure the success based on their specific goals

[1] All demonstrations will be described in §4 with their overall objectives to understand what will be tested an therefore be captured by KPIs.

and targets. The Key Performance Indicators defined for EU-SysFlex demonstrations are designed to cover several aspects and aim to answer the following questions:

- Do the proposed flexibility services meet SOs' needs?
- What are their impacts on the power system?
- What are the improvement needed in terms of data exchange between TSOs (cross-border), between TSO and DSO or between a data exchange platform and customers?
- How reliable are the services provided?
- What is the customers' acceptance?
- Do the demonstrations have measurable economic impacts?

The approach followed several steps. First of all, a structured template was created for defining each KPI and providing a calculation methodology. KPIs were selected through bottom-up proposals from demonstrations leaders and several iterations. A typology of KPIs was then proposed in order to classify the KPIs into main categories and identify those common to several demos.

4. DETAILS OF EU-SYSFLEX DEMO-RELATED KPIS

This paragraph describes in detail, demonstration per demonstration, the list of proposed EU-SysFlex KPIs, with the detailed definition and applicable formulae. These indicators are specific to each demonstration though some of them may be common to different demonstrations (see §5). In this case, the measurement methodologies, baseline conditions, and data to be collected will differ from one demonstration to another. For some of the KPIs, the description is incomplete at that stage, in particular the definition of target values, or the description of the calculation method may be missing. In order not to leave room for interpretation, these KPIs will be finalized at a later stage of the project when the details of the related use cases will be clarified.

4.1 FINLAND

4.1.1 DESCRIPTION OF THE DEMONSTRATION

In the Nordic electricity system, the amount of variable renewable energy capacity is rapidly increasing and more flexibilities and applicable solutions are needed for ensuring the electrical system stability. The Finnish demonstration, located in Helsinki, is testing a novel approach where distributed low-voltage resources are aggregated to be traded by a retailer on TSO's existing market places and for DSO's balancing needs (Figure 3).
The demonstration will include the development of i) an energy management system for the aggregation, ii) of a forecasting tool to estimate the availability of flexible capacity from manifold small resources (customer scale batteries, industrial scale BESS, EV infrastructures, electric heating loads via home automation system, electric heating loads via automatic meter reading (AMR) meters, a PV power plant), iii) and of a mechanism for optimizing the reactive power procurement in the DSO market place.

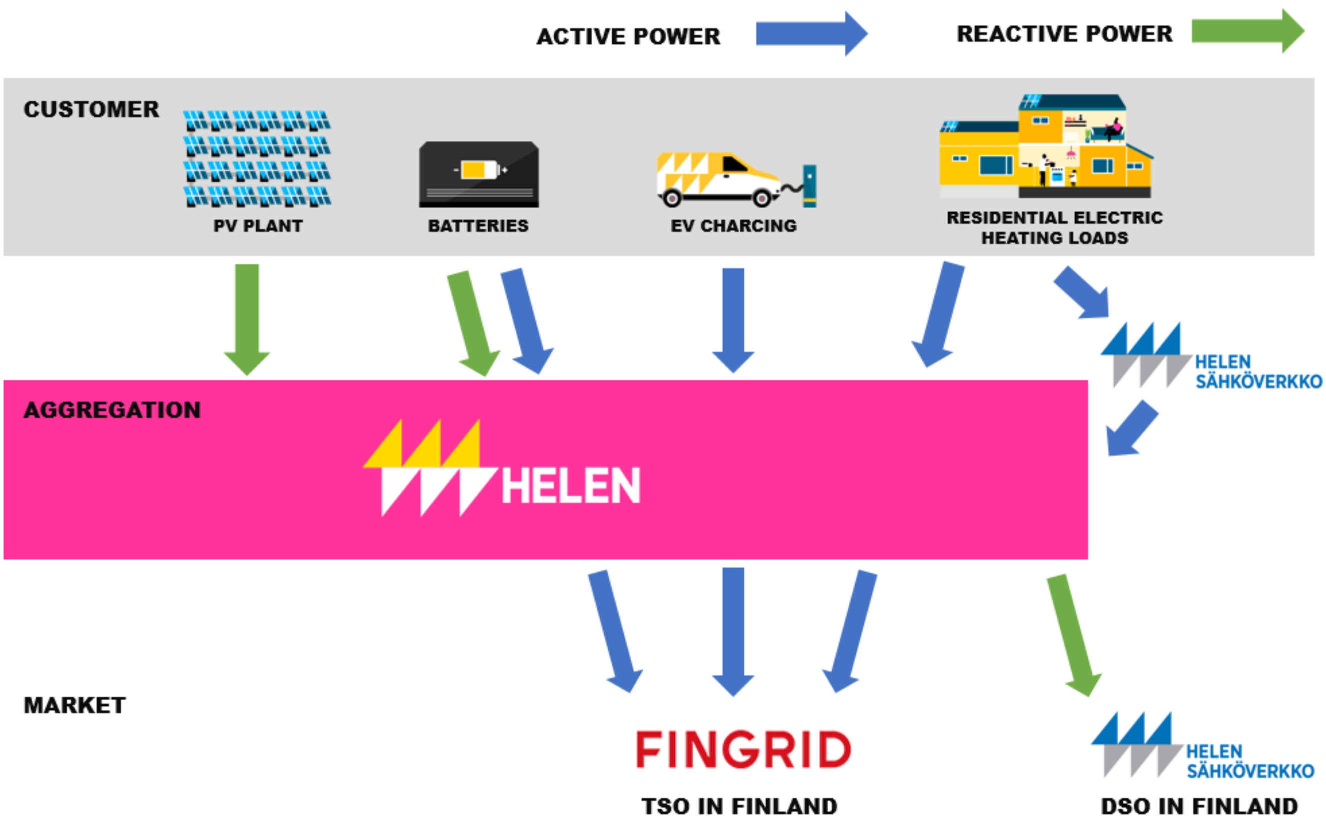

FIGURE 3: THE FINNISH DEMONSTRATION AIMS AT AGGREGATING DISTRIBUTED LOW-VOLTAGE RESOURCES TO BE TRADED BY A RETAILER ON TSO'S EXISTING MARKET PLACES AND FOR DSO'S BALANCING NEEDS

The Finnish demonstration will test the following services:

- active power flexibility provision to support FCR-N;
- active power flexibility provision to support mFRR/RR;
- reactive power flexibility provision to support voltage control.

4.1.2 KEY PERFORMANCE INDICATORS

KPI n°1	
KPI name	**Increase in revenue of the flexibility service provider**
Main objective	Calculation of the total increase in revenue by providing new services with a specific set of resources compared to the BaU services and resources.
KPI Description	The revenue is calculated by multiplying the provided power by the price of the service summed over a set of resources and a set of markets/services.
Unit	€
Formula	$R = \sum_{s \in S} \sum_{a \in A} \sum_{t=1}^{T} \boldsymbol{P}_{s,a,t} \cdot \boldsymbol{\pi}_{s,a,t}$ where: S is the set of available markets/services A is the set of available resources t is one of the T time periods considered $\boldsymbol{P}$ is the realized power exchanged π is the price
Target value	Estimated costs of operating the flexibility
Baseline scenario	Operating with the existing pre-EU-SysFlex capacities
Smart-Grid scenarios	With EU-SysFlex innovations. Horizon: demo period Operating the resources on other markets, or on a combination of markets.

KPI n°2	
KPI name	**Decrease in penalties for going out of the PQ window**
Main objective	Estimate the value of the market that is being developed in the project for the DSO

KPI Description	Calculating the cost of being out of the PQ window with and without the market support. The costs consist of two parts which are related (when being out of the window) to the 1) reactive power, 2) reactive energy.
Unit	%
Formula	$\frac{C_{hmarket} - C_h}{C_h}$ The invoicing period is a month and the measurement data is hourly PQ data. Only those hours exceeding the PQ limits are taken into account, however, during a month, the 50 highest exceeding hours are free of charge and out of consideration. For those hours of interest, the costs include 1) the cost of reactive power and 2) the cost of reactive energy. $C = C_{power} + C_{energy}$ For power cost: For those *k* hours exceeding the PQ limits, the 51st highest absolute value of Q determines the cost of power. $C_{power} = c_{power} * Q_{51st\,max}$ For energy cost: For those *(k-50)* hours exceeding the PQ limit are taken into account, the exceeding reactive energy is the penalized energy. $C_{energy} = c_{energy} * \sum_{51}^{k} \lvert \Delta Q \rvert$ Where: C_h is the cost for deviating from the allowed Q band when operating BaU $C_{hmarket}$ is the cost for deviating from the allowed Q band when Q market is used C_{power} is the cost for reactive power C_{energy} is the cost for reactive energy k is the number of hours when exceeding the PQ limits during a month ΔQ is the amount of reactive power exceeding the PQ limits during an hour
Target value	Less than zero

Baseline scenario	w/o EU-SysFlex (compensators)
Smart-Grid scenario	with EU-SysFlex innovations. Horizon: demo period

KPI n°3	
KPI name	**Reactive power market utilization factor**
Main objective	The goal is to measure the need for such a market and estimate the value for the aggregator
KPI Description	Calculation of the number of hours that the market is being used to compensate the reactive power during the test period
Unit	%
Formula	$\frac{\sum \boldsymbol{h}}{\boldsymbol{T_{test\ period}}} \cdot \mathbf{100}\ \%$ Where: $\sum \boldsymbol{h}$ is number of hours that the market is being used to compensate the reactive power $\boldsymbol{T_{test\ period}}$ is the duration of the test period
Target value	>0
Baseline scenario	No baseline
Smart-Grid scenario	with EU-SysFlex innovations. Horizon: demo period

KPI n°4	
KPI name	**Flexibility service reliability**
Main objective	Difference between the offered bids and the realized power exchanges.
KPI Description	The mean squared error (MSE) between the bid power exchanges and the realized ones. This error includes forecasting errors, but also the other sources of errors in the system (e.g. communication failures, asset owner overriding the command, …)
Unit	MW
Formula	$MSE = \frac{1}{T}\sqrt{\sum_{\boldsymbol{t=1}}^{\boldsymbol{T}}(P_{R,t} - P_{B_v,t})^2}$ Where: t is one of the T time periods considered $\boldsymbol{P_R}$ is the realized power exchanged

	P_{B_v} is the power accepted (or validated) from the bid on the market
Target value	Towards 0.
Baseline scenario	No baseline
Smart-Grid scenario	with EU-SysFlex innovations. Horizon: demo period

KPI n°5	
KPI name	**Reliability of the aggregation platform**
Main objective	The goal is to measure how reliably the platform delivers and receives information
KPI Description	Calculating the hours that the communication is travelling through the platform
Unit	%
Formula	$\boldsymbol{AV}[\%] = \frac{\boldsymbol{T_{com}}}{\boldsymbol{T_{op}}} \times \mathbf{100}\%$ Where: $\boldsymbol{T_{com}}$ [s] is the total duration in which all the aggregation platform is working correctly as defined in the demonstration specifications. $\boldsymbol{T_{op}}$ [s] is the total operational time of the aggregator during the tests carried out.
Target value	$\boldsymbol{AV}[\%] > x\%$, as good as possible
Baseline scenario	No baseline
Smart-Grid scenario	With EU-SysFlex. Horizon: demo period

KPI n°6	
KPI name	**Customer acceptance**
Main objective	The goal is to have an attractive service that encourages the customers to give permission to use their resources (eg. electricity loads or battery storages) by the aggregator/utility company
KPI Description	Measuring how well customers will engage to take part in grid stabilization. KPI can additionally be supported by conducting an interview with a defined group of customers, eg. key customers.
Unit	%
Formula	$\frac{\boldsymbol{accepted\ contracts}}{\boldsymbol{offered\ contracts}} \cdot \mathbf{100}\%$
Target value	15% – 25%

Baseline scenario	No baseline
Smart-Grid scenario	With EU-SysFlex innovations. Horizon: demo period

4.2 ITALY

4.2.1 DESCRIPTION OF THE DEMONSTRATION

The Italian demonstration site is located in the area of Forlì-Cesena (Emilia Romagna) in an area which is characterized by a strong penetration of renewable generation (mainly PV) along with a low consumption (back-feeding phenomena from MV to HV observed several times). The demonstrator itself will test and validate the provision of ancillary services (e.g. voltage and congestion management) to the transmission grid by resources connected to the MV distribution network, taking into account transmission grid and distribution network mutual needs and constraints. Prior to the beginning of the EU-SysFlex project, e-distribuzione implemented here an advanced MV network control system, which is used for local voltage and current control. The system carries out network state estimation automatically, optimisation calculations and sends control commands to the available resources, comprising the OLTC of the HV/MV transformer.

The distributed resources that will be used are composed of a 1 MVA/1 MWh storage system, 4 PV generators (which can be regulated in reactive power), an on-Load Tap Changer (OLTC) at the HV/MV substation, 2 STATCOMs (1 for each busbar). All are interfaced to the DSO SCADA, which includes a tool of state estimation that collects forecast data and network state information (Figure 4). Each resource is involved within the regulation service after performing a distribution network optimization. This allows to:

- Perform normal operation of the system when no set point is requested by the TSO (the optimization, respecting the network constraints, can achieve other goals like the losses reduction).
- Reach a desired reactive power exchange in the primary substation (set points of the resources are used to reach the desired reactive power at Primary Substation respecting network constraints).

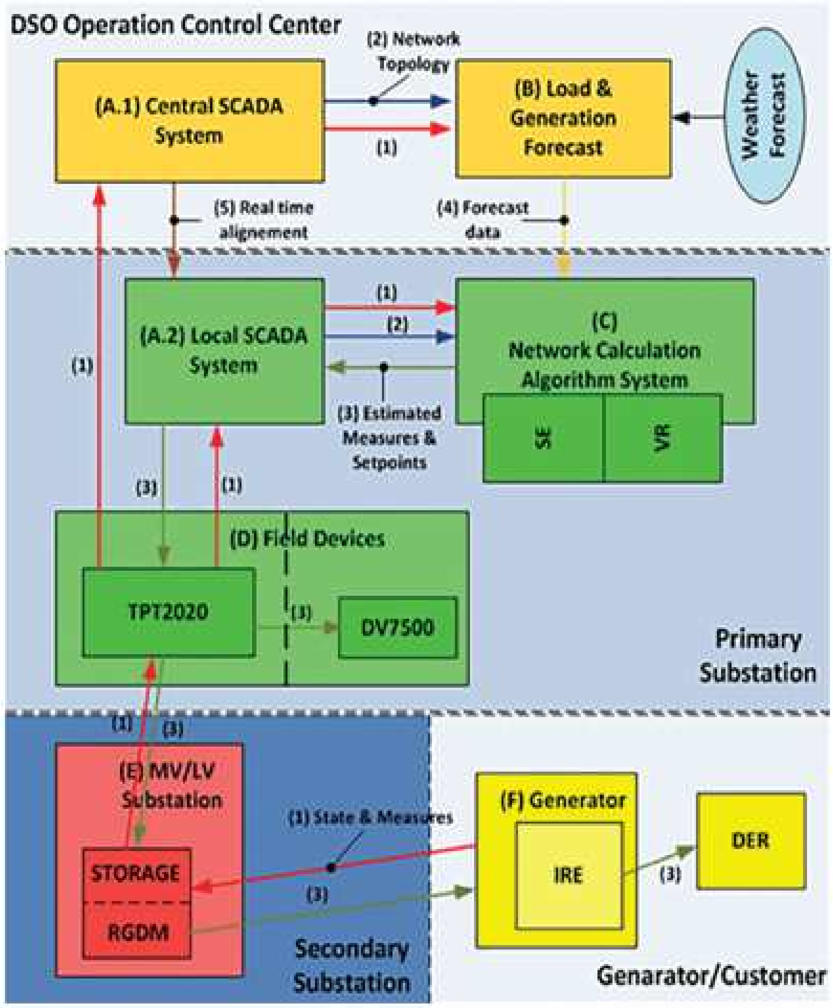

FIGURE 4: ARCHITECTURE OF THE ITALIAN DEMONSTRATION

The main features of the demonstration include i) the improvement of data exchange between the DSO and TSO and of the forecasting system in order to increase the observability, ii) the modulation of active and reactive power at Primary Substation in order to allow the TSO to guarantee the secure operation of the electrical system. Reactive power will be modulated by the DSO by means of different types of resources (STATCOM, inverters of PV plants) whereas the modulation of the Active Power will be simulated.

The Italian demonstration will aim at establishing the proof of concept for the provision of:

- active power flexibilities from the distribution grid to the Transmission Network Operator in real-time to support mFRR/RR and congestion management.
- reactive power flexibilities at Primary Substation interface for voltage control and congestion management in real-time (performed by the Distribution System Operator through suitable optimization processes, exploiting reactive power flexibilities connected to its network).

4.2.2 KEY PERFORMANCE INDICATORS

KPI n°1	
KPI name	**Tracking error measured at TN_O/DN_O interface [%]**
Main objective	
KPI Description	Error between Reactive Power Set-point requested by TN_O $\boldsymbol{Q}^*(\boldsymbol{t})$ and the Reactive Power measure at TN_O/DN_O interface $\boldsymbol{Q}(\boldsymbol{t})$
Unit	%
Formula	$$\boldsymbol{e}_{\boldsymbol{TSO/DSO}}(\boldsymbol{t}) = \frac{\lvert\boldsymbol{Q}(\boldsymbol{t}) - \boldsymbol{Q}^*(\boldsymbol{t})\rvert}{\boldsymbol{Q}^*(\boldsymbol{t})}$$ From the CDF (Cumulative Distribution Function) of $\boldsymbol{e}_{\boldsymbol{TSO/DSO}}(\boldsymbol{t})$ it can be calculated the 5th and 95th percentile of $\boldsymbol{e}_{\boldsymbol{TSO/DSO}}(\boldsymbol{t})$, or rather $\boldsymbol{e}_{\boldsymbol{TSO/DSO}}(\boldsymbol{t})_{(5\%)}$ and $\boldsymbol{e}_{\boldsymbol{TSO/DSO}}(\boldsymbol{t})_{(95\%)}$, that is the value for which 95% of all measurements fall below or above.
Target Value	0
Baseline scenarios	TBD it is not foreseen a baseline scenario
Smart-Grid scenarios	Optimization functionalities fully operating

KPI n°2	
KPI name	**Tracking error measured at DER interface [%]**
Main objective	
KPI Description	Error between Reactive Power Set-point requested by DN_O $\boldsymbol{Q}^*(\boldsymbol{t})$ and the Reactive Power measure at DN_O/DER interface $\boldsymbol{Q}(\boldsymbol{t})$
Unit	%
Formula	$$\boldsymbol{e}_{\boldsymbol{DER}}(\boldsymbol{t}) = \frac{\lvert\boldsymbol{Q}(\boldsymbol{t}) - \boldsymbol{Q}^*(\boldsymbol{t})\rvert}{\boldsymbol{Q}^*(\boldsymbol{t})}$$ From the CDF (Cumulative Distribution Function) of $\boldsymbol{e}_{\boldsymbol{DER}}(\boldsymbol{t})$ it can be calculated the 5th and 95th percentile of $\boldsymbol{e}_{\boldsymbol{DER}}(\boldsymbol{t})$ or rather $\boldsymbol{e}_{\boldsymbol{DER}}(\boldsymbol{t})_{5\%)}$ and $\boldsymbol{e}_{\boldsymbol{DER}}(\boldsymbol{t})_{(95\%)}$, that is the value for which 95% of all measurements fall below or above
Target Value	0
Baseline scenarios	TBD it is not foreseen a baseline scenario
Smart-Grid scenarios	Optimization functionalities fully operating

KPI n°3	
KPI name	**Tracking error Monitoring at STATCOM interface [%]**
Main objective	
KPI Description	Error between Reactive Power Set-point requested by DN_O $\boldsymbol{Q}^*(\boldsymbol{t})$ and the Reactive Power measure at DN_O/STATCOM Interface $\boldsymbol{Q}(\boldsymbol{t})$
Unit	%
Formula	$$e_{STATCOM}(t) = \frac{\lvert Q(t) - Q^*(t)\rvert}{Q^*(t)}$$ From the CDF (Cumulative Distribution Function) of $e_{STATCOM}(t)$ it can be calculated the 5th and 95th percentile of $e_{STATCOM}(t)$%, or rather $e_{STATCOM}(t)_{(5\%)}$ and $e_{STATCOM}(t)_{(95\%)}$, that is the value for which 95% of all measurements fall below or above.
Target Value	0
Baseline scenarios	TBD it is not foreseen a baseline scenario
Smart-Grid scenarios	Optimization functionalities fully operating

KPI n°4	
KPI name	**Tracking error Monitoring at storage interface [%]**
Main objective	
KPI Description	Error between Reactive Power Set-point requested by DN_O $\boldsymbol{Q}^*(\boldsymbol{t})$ and the Reactive Power measure at DN_O/BESS interface $\boldsymbol{Q}(\boldsymbol{t})$
Unit	%
Formula	$$e_{BESS}(t) = \frac{\lvert Q(t) - Q^*(t)\rvert}{Q^*(t)}$$ From the CDF (Cumulative Distribution Function) of $e_{BESS}(t)$ it can be calculated the 5th and 95th percentile of $e_{BESS}(t)$%, or rather $e_{BESS}(t)_{(5\%)}$ and $e_{BESS}(t)_{(95\%)}$, that is the value for which 95% of all measurements fall below or above.
Target Value	0
Baseline scenarios	TBD it is not foreseen a baseline scenario
Smart-Grid scenarios	Optimization functionalities fully operating

KPI n°5	
KPI name	**Increase in active power capability at primary substation**
Main objective	
KPI Description	Increase in active power capability at primary substation.
Unit	%
Formula	$$\Delta C_{AP}\% = \frac{\sum_t(\Delta P_{SG} - \Delta P_{base})}{\sum_t \Delta P_{base}} \cdot 100\%$$ where: - ΔP_{base} is the active power capability at primary substation for baseline scenario, expressed as a time-function - ΔP_{SG} is the active power capability at primary substation for Smart Grid scenario, expressed as a time-function - $\Delta C_{AP}\%$ is the variation of active power capability expressed in percentage
Target	$\Delta C_{AP}\% > 0$
Baseline scenarios	1. No optimization functionalities; OLTC and curtailment only; no local flexibility market; 2. Optimization functionalities fully operating; OLTC and flexibility market; non-operating BESS
Smart-Grid scenarios	1. Optimization functionalities fully operating; OLTC and BESS; flexibility market 2. Optimization functionalities fully operating; OLTC and flexibility market; BESS operating

KPI n°6	
KPI name	**Increase in reactive power capability at primary substation**
Main objective	Increase in reactive power capability at primary substation.
KPI Description	
Unit	%
Formula	$$\Delta C_{RP}\% = \frac{\sum_t(\Delta Q_{SG} - \Delta Q_{base})}{\sum_t \Delta Q_{base}} \cdot 100\%$$ where: - ΔQ_{base} is the reactive power capability at primary substation for baseline scenario, expressed as a time-function - ΔQ_{SG} is the reactive power capability at primary substation for Smart Grid scenario, expressed as a time-function $\Delta C_{RP}\%$ is the variation of reactive power capability expressed in percentage
Target Value	$\Delta C_{RP}\% > 0$
Baseline scenarios	1. No optimization functionalities; OLTC only; fixed reactive power capability for DERs

	2. Optimization functionalities fully operating; OLTC operating; variable reactive power capability for DERs; non-operating BESS and STATCOM
Smart-Grid scenarios	**1.** Optimization functionalities fully operating; OLTC, BESS and STATCOM operating; variable reactive power capability for DERs **2.** Optimization functionalities fully operating; OLTC operating; variable reactive power capability for DERs; BESS and STATCOM operating

KPI n°7	
KPI name	**Line voltage profiles**
Main objective	Power Quality improvements (in this case voltage quality) [%]
KPI Description	
Unit	%
Formula	$\boldsymbol{\Delta V(t) = \lvert V^*(t) - 1\rvert}$ Where $\boldsymbol{V^*(t)}$ is the normalized voltage profile, obtained as follows: $\boldsymbol{V^*(t) = \frac{V(t)}{V_n}}$ • $\boldsymbol{V(t)}$ is the voltage profile • Vn is the nominal voltage value From the CDF (Cumulative Distribution Function) of $\boldsymbol{\Delta V(t)}$ it can be calculated the 5_{th} and 95_{th} percentile of $\boldsymbol{\Delta V(t)}$%, or rather $\boldsymbol{\Delta V(t)}_{(5\%)}$ and $\boldsymbol{\Delta V(t)}_{(95\%)}$, that is the value for which 95% of all voltage line measurements fall below or above.
Target Value	**0**
Baseline scenarios	BAU scenario: No optimization functionalities
Smart-Grid scenarios	Optimization functionalities fully operating

KPI n°8	
KPI name	**Hosting Capacity variation**
Main objective	Smart Grid solutions allow better network operations resulting in an increase in HC. This may drive to a higher penetration of DERs and, consequently, to a potentially higher participation to ancillary services provision
KPI Description	
Unit	%
Formula	$\Delta HC\% = \frac{HC_{SG} - HC_{base}}{HC_{base}} \cdot 100\%$ where: - $\boldsymbol{HC_{base}}$ is the network hosting capacity for baseline scenario

	- HC_{SG} is the network hosting capacity for Smart Grid scenario - $\Delta HC\%$ is the variation of the network hosting capacity expressed in percentage
Target Value	$\Delta HC\% > 0$
Baseline scenario	No optimization functionalities; OLTC and curtailment only;
Smart-Grid scenario	Optimization functionalities fully operating; OLTC, BESS, STATCOM operating; flexibility market

KPI n°9	
KPI name	**Availability of the communication infrastructure**
Main objective	Ensure highest connectivity It should be assessed for each specific service and in relationship to their latencies. It's also necessary to refer to the analysis which will be made on WP5 to use more specific KPIs related to TLC matters.
KPI Description	
Unit	%
Formula	$$\frac{MTBF}{MTBF + MTTR}$$ Where MTBF is generally specified in the units of hours. One year has 24*365 = 8760 hours. In general, hardware MTBFs are in the range of 100,000 hours or more and software MTBFs are in the range of 10,000 to 50,000 hours. MTBF (Mean Time Between Failure) is the measure of failure rate. MTTR (Mean Time to Repair) represents the average time required to detect, troubleshoot, obtain replacement parts and service personnel, and restore product functionality. Availability improvement is gained significantly faster by decreasing MTTR than by increasing MTBF. Increasing k times MTBF is equivalent with decreasing k MTTR.
Target value	
Baseline scenario	
Smart-Grid scenario	

KPI n°10	
KPI name	**PV Forecast Quality**

Main objective	MAE – mean absolute error of PV plants [kW]
KPI Description	
Unit	kW
Formula	$$MAE = \sum \lvert F - M \rvert$$ Where F is Forecast value and M is measured value of Power, of each PV plant
Target value	As close as possible to 0
Baseline scenario	BAU scenario: AS-IS algorithms based on weather forecast from external provider
Smart-Grid scenario	EU-Sysflex approach: improvements of algorithms and weather forecast fully operating

KPI n°11	
KPI name	**PV Normalized Forecast Quality**
Main objective	NMAE – normalized mean absolute error of PV plants [%]
KPI Description	
Unit	
Formula	$$NMAE = \frac{MAE}{Pnom}$$ Where *Pnom* is nominal Power of Power Plant
Target value	As close as possible to 0
Baseline scenario	BAU scenario: AS-IS algorithms based on weather forecast from external provider
Smart-Grid scenario	EU-Sysflex approach: improvements of algorithms and weather forecast fully operating

4.3 GERMANY

4.3.1 DESCRIPTION OF THE DEMONSTRATION

The German demonstration is located in the east of Germany in the South of Brandenburg, in the West and South of Saxony and in the South of Saxony-Anhalt. The high share of RES in the northern and eastern part of Germany already causes congestions in the transmission and distribution grids and substantial ReDispatch (schedule adjustments) measures are necessary. As a matter of fact, the ReDispatch potential in the transmission grid reached its limits due to the minimum capacity of conventional power plants. It makes it necessary to move to more efficient congestion management processes with a good coordination of actions between TSOs and DSOs.
Without a proper coordination, congestion management by the DSO could lead to the feed-in curtailment of RES in the distribution grid as an emergency measure, which might be counteracting the action done by the TSO.
Requirements of reactive power management will also increase in the future, caused by high share of volatile feed-in and intended reliable energy supply.

The demonstration itself aims at enabling the provision of active and reactive power flexibility range to the TSO (50Hertz) from decentralized resources connected to the HV distribution grid of MITNETZ STROM to support congestion management and voltage control at the interface grid node with the transmission system in a system with a high share of RES. The portion of distribution grid considered in the demo includes over 30 retailers with more than 1.500 generation units and comprises 16 TSO/DSO interfaces with 40 transformers and 372 HV/MV substations, thereof 97 infeed of RES. The main innovations foreseen of the demonstration will consist in:

- co-optimising the grid in active and reactive power management using scheduled grid asset utilisation, and forecasted infeed and load;
- automating the conversion of the optimisation result into a control signal sent to generation sites for reactive power management purposes;
- integrating RES in a schedule-based congestion management process.

This will imply:

- **Forecasting P and Q** by providing specific load profiles for each grid node: For a precise forecast, specific grid information will be needed (geographic coordination of generation sites, weather forecast, installed capacity of generation, historical measurements of load and generation).
- **Improving data management and transfer between DSO and TSO** to increase observability. This will mean dealing with the process of receiving data, translating data formats and sending data to calculation modules.
- **Performing losses optimization for congestion management and local voltage control in the distribution grid**: The tasks of congestion management and voltage control in the distribution grid will be executed even when no demand of TSO is received. This optimization becomes a subordinated condition if the TSO sends a demand for active or reactive power
- **Enabling Provision of Active Power by the DSO to the TSO for congestion management**. The coordination process starts day ahead and ends intraday 2 hours before activation of flexibility.

- **Enabling Provision of Reactive Power by the DSO to the TSO**. In this case, a coordination is needed to prevent voltage failure in the DSO-grid due to the activation of the flexibility. The coordination process starts day ahead and ends with the activation of flexibility via sending an operation signal by DSO.

4.3.2 KEY PERFORMANCE INDICATORS

KPI n°1	
KPI name	Decrease in costs for congestion management
Main objective	
KPI Description	Costs for congestion management and curtailment should be less with demonstrator or at least not higher
Unit	%
Formula	details how to measure which cost-components are unclear
Target value	
Baseline scenario	w/o EU-SysFlex innovations
Smart-Grid scenario	with EU-SysFlex innovations

KPI n°2	
KPI name	**Intraday update process duration**
Main objective	the intraday update process needs to be done in a certain time (for developing KPI can be divided into minor KPI for each step)
KPI Description	Calculation of the amount of time between information input ($\boldsymbol{T_i}$) and finalized adjusted schedule ($\boldsymbol{T_s}$)
Unit	s
Formula	$\boldsymbol{d = T_s - T_i}$ where: $\boldsymbol{T_i}$ is the time of information input $\boldsymbol{T_s}$ is the time of finalized adjusted schedule
Target value	5 minutes
Baseline scenario	
Smart-Grid scenario	

KPI n°3	
KPI name	**Keeping deadlines of the day ahead process**
Main objective	
KPI Description	The day ahead process begins and ends at certain times, plus there are different times in this process for information exchange, all these times have to be met
Unit	Y or N
Formula	met deadline yes or no no deviation
Target value	
Baseline scenario	
Smart-Grid scenario	

KPI n°4	
KPI name	**Meet TSO need in adjustment of schedule (active power adjustment error)**
Main objective	the aggregated need of schedule adjustment from TSO needs to be segregated for adjusting the schedule of single units, therefore the accuracy of optimization is important
KPI Description	in field-test, see if the adjustment of single units ($\boldsymbol{P_u}$) result in correct adjustment at TSO-DSO-interface ($\boldsymbol{P_{TDI}}$)
Unit	MW
Formula	$$\Delta \boldsymbol{P_S} = \boldsymbol{P_{TDI}} - \boldsymbol{P_u}$$ Where $\boldsymbol{P_u}$ is the active power adjustment of single units [MW] $\boldsymbol{P_{TDI}}$ is the active power adjustment at TSO-DSO-interface [MW]
Target value	$\Delta \boldsymbol{P_S} \leq value$
Baseline scenario	
Smart-Grid scenario	

KPI n°5	
KPI name	**Meet TSO need in adjustment of reactive power (Reactive Power Adjustment error)**
Main objective	same as for active power, but within close to real time adjustment

KPI Description	in field-test, see if the adjustment of single units ($\boldsymbol{Q_u}$) result in correct adjustment at TSO-DSO-interface ($\boldsymbol{Q_{TDI}}$)
Unit	MVaR
Formula	$$\Delta \boldsymbol{Q_S} = \boldsymbol{Q_{TDI}} - \boldsymbol{Q_u}$$ Where $\boldsymbol{P_u}$ is the reactive power adjustment of single units [MVaR] $\boldsymbol{P_{TDI}}$ is the reactive power adjustment at TSO-DSO-interface [MVaR]
Target value	$\Delta \boldsymbol{Q_S} \leq value$
Baseline scenario	
Smart-Grid scenario	

KPI n°6	
KPI name	**Meet TSO need in adjustment of voltage (Voltage Adjustment error)**
Main objective	same as reactive power, but voltage value
KPI Description	
Unit	V
Formula	$$\Delta \boldsymbol{U_S} = \boldsymbol{U_{TDI}} - \boldsymbol{U_u}$$ Where $\boldsymbol{U_u}$ is the voltage adjustment of single units [V] $\boldsymbol{U_{TDI}}$ is the voltage adjustment at TSO-DSO-interface [V]
Target value	$\Delta U \leq value$
Baseline scenario	
Smart-Grid scenario	

KPI n°7	
KPI name	**meet TSO need in delivering data**
Main objective	Needed data for demonstrator must be included in amount, accuracy and detail (e.g. sensitivity of each TSO-DSO-interface and interdependence between each TSO-DSO-interface
KPI Description	
Unit	Y or N
Formula	yes or no for each information needed (under discussion with TSO 50Hz)
Target value	Every needed information included

Baseline scenario	
Smart-Grid scenario	

KPI n°8	
KPI name	**Grid efficiency** $= 1 - \frac{P_o}{P_w}$
Main objective	standard use case of demonstrator is optimizing grid for most efficient operation, considering needs of connected parties including TSO
KPI Description	comparing losses without using adjustments stated in optimization (P_w) and with using these (P_o)
Unit	%
Formula	$$\eta = \frac{P_o}{P_w}$$ Where P_w represents the losses without using adjustments stated in optimization P_o represents the losses using adjustments
Target value	
Baseline scenario	
Smart-Grid scenario	

KPI n°9	
KPI name	**Percentage of scheduled flexibility**
Main objective	to prevent curtailment you need a planning process to address the needed amount of flexibility for congestion management in a schedule
KPI Description	ratio between scheduled flexibility (F_s) and the sum of scheduled adjustment and curtailment (F_c)
Unit	%
Formula	$$f = \frac{F_s}{(F_s + F_c)}$$ Where F_s is the scheduled flexibility F_c is the sum of scheduled adjustment and curtailment
Target value	

Baseline scenario	
Smart-Grid scenario	

KPI n°10	
KPI name	**Active power flow forecast quality – day-ahead**
Main objective	an accurate forecast is needed for a satisfactory planning process in congestion management; quality of adjusted schedule at 10pm for the next day
KPI Description	difference between measured ($m(t)$) and day ahead scheduled ($s_d(t)$) active power flow
Unit	MW
Formula	$qd(t) = m(t) - s_d(t)$ Where $m(t)$ is the measured active power flow $s_d(t)$ is the day ahead scheduled active power flow
Target value	
Baseline scenario	
Smart-Grid scenario	

KPI n°11	
KPI name	**Active power flow forecast quality – intraday**
Main objective	an accurate forecast is needed for a satisfactory planning process in congestion management; quality of schedule 2h before measurement
KPI Description	difference between measured ($m(t)$) and intraday scheduled ($s_i(t)$) active power flow can also be quadratic average or mean value of multiple deviations
Unit	MW
Formula	$qi(t) = m(t) - s_i(t)$ Where $m(t)$ is the measured active power flow $s_i(t)$ is the intraday scheduled active power flow
Target value	less than x MW as aggregated value less than 0.x MW as segregated value
Baseline scenario	

Smart-Grid scenario	

4.4 PORTUGAL: FLEXHUB

4.4.1 DESCRIPTION OF THE DEMONSTRATION

An increasing share of RES is expected in the Portuguese grid. The re-dispatch potential in the transmission grid will soon reach its limits due to the closure of conventional thermal plants and the increment of distributed generation. This will increase the needs of using distributed resources to provide both active and reactive power management, and new flexible mechanisms need to be designed. This in turns increases the need of strong TSO-DSO coordination to provide these services without causing additional problems to the distribution grids. In addition, the traditional passive nature of the distribution grid is evolving and the latter is becoming more dynamic and complex, which should be properly modelled and considered by the TSO for both voltage and frequency disturbance analysis.

The FlexHub Portuguese demonstration will be developed at the distribution grid connected to Frades primary substation. Frades is a 20 MW TSO/DSO substation located at the north of Portugal, with 40 transformers that provide service to about 8000 grid connection points, 90 MW of installed RES (larger than the grid consumption), and 2 distribution high/medium voltage (HV/MV) secondary substations (Vila da Ponte & Caniçada). Flexibilities come from 46 MW of wind active power, with reactive power ranging between -50 Mvar and +50 Mvar. represents a very simplified architecture of the FlexHub. It uses the updated grid configuration and the real and forecasted active and reactive power flows from DSO information systems, and the bids from the market agents, to provide the flexibility services described in the following sections, and summarized in Figure 5. Figure 6 represents the communications among the different stakeholders in the local reactive power market.

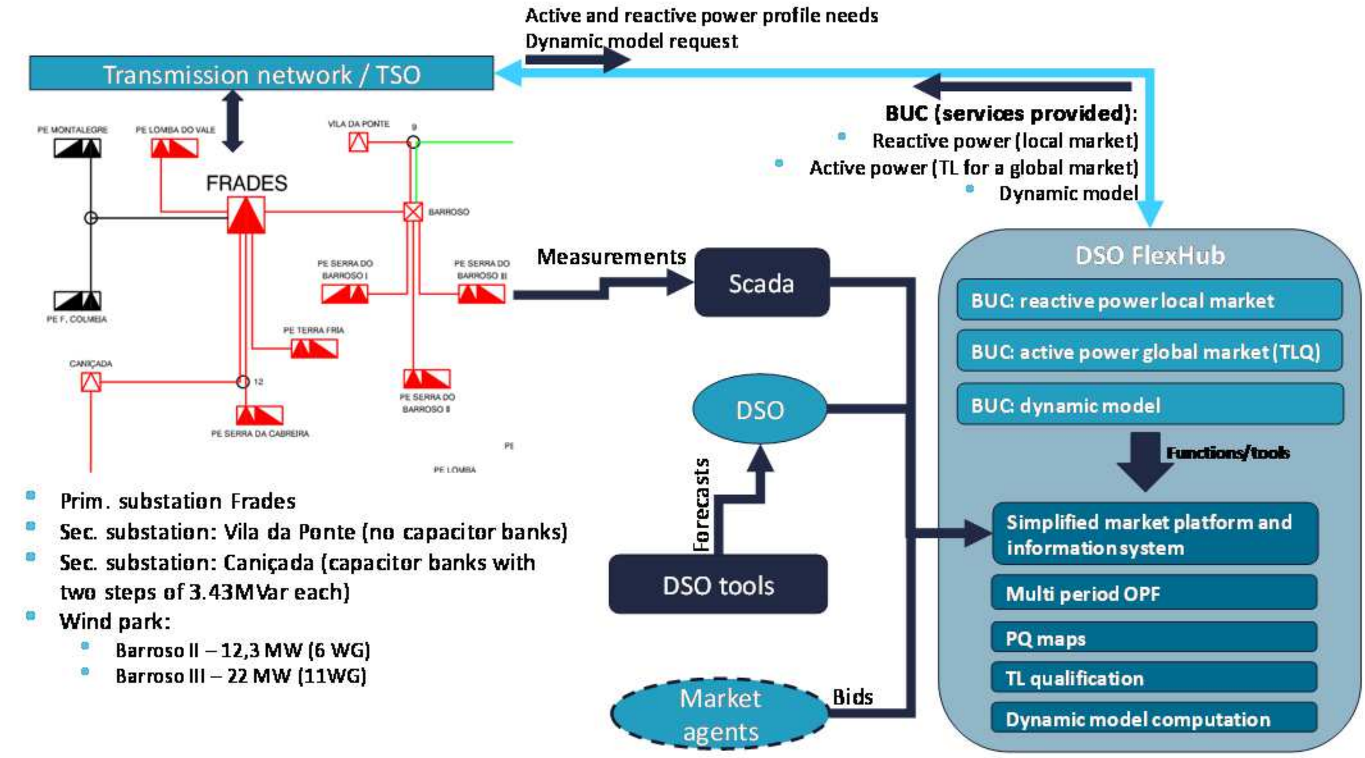

FIGURE 5: CONCEPT AND ARCHITECTURE DRAFT OF THE FLEXHUB DEMONSTRATION [SOURCE: EDP]

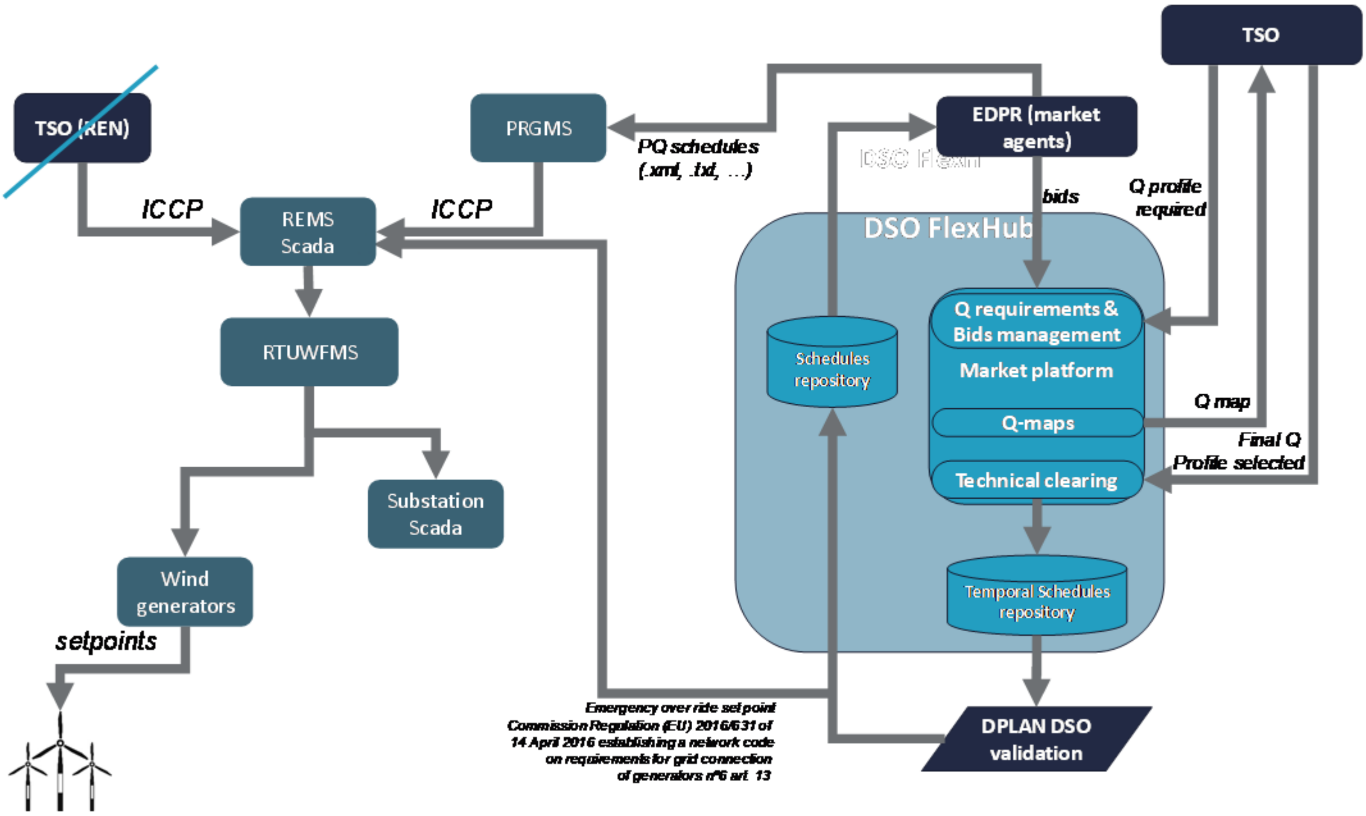

FIGURE 6: COMMUNICATIONS IN THE FLEXHUB LOCAL REACTIVE POWER MARKET [SOURCE: EDP]

The Portuguese FlexHub demonstration provides a flexibility market oriented platform to the DSO to help providing active and reactive power to the TSO, as well as a better dynamic characterization of the DSO grid. It aims at addressing several barriers linked to high RES penetration in 2030 and has several innovative aspects:

- Local market for reactive power provision to TSO from the DSO grid using distribution grid resources in a close to real time intraday market ;
- Redesign of the Replacement Reserve (RR) Market as a close to real-time intraday market with a traffic light qualification system to validate the activation of bids of active power to TSO that involve resources from the DSO grid;
- Equivalent Dynamic Model of the DSO grid for voltage and frequency disturbance analysis. The DSO will send the distribution network dynamic model to the TSO for operation and planning purposes

The main contributions of the FlexHub are:

- A new innovative local market design to provide reactive power from resources connected to the distribution grid, to compensate for the decrease of the resources currently providing this service. The proposed market increases the temporal granularity with respect to many other current market's structures, decreasing the product time-duration, as well as allowing bids closer to the market gate closure. It also combines an extended delivery time with complex bids, designed according to the expected participating resources, to facilitate the adaptation of the cleared schedules to the real operating constraints of the new assets providing the service. Finally, the market designed also provides additional flexibility to the market agents, since they can correct future previously scheduled positions by participating themselves to adjust their previous positions to their future availability, strategy or needs.
- A new innovative market design to provide active power from resources connected to both the transmission and distribution grids. This market is a redesign of the current restoration reserve (RR) market, with increased temporal granularity (as for the previous case), reducing the time-duration of the products. It also increases the delivery horizon, so that in combination with complex bids (designed according to the resources that could provide the service) it helps market agents to adapt the clearing schedules to the real operating constraints of their assets. Finally, the market designed also provides additional flexibility to the market agents, since they can also participate to correct previously scheduled positions according to their future availability, strategy or needs.
- A new simplified equivalent dynamic model of the whole distribution grid for frequency and voltage disturbances at the TSO/DSO connection point, to provide a more realistic dynamic behavior of the grid. The increasing penetration of distributed resources is transforming the distribution grid into more complex and dynamic structures with larger impact on the transmission grid dynamics, so these models would contribute to improve TSO dynamic analysis. The proposed model allows to include a larger diversity of distributed generation technologies than existing approaches.
- A new platform that promotes the interaction and coordination between TSO and DSO for enhanced system operation.

4.4.2 KEY PERFORMANCE INDICATORS

KPI n°1	
KPI name	**Bidding price estimation of providing reactive power**
Main objective	The objective is estimating the cost or price of providing reactive power from the wind generator available in the FlexHub demonstration. This estimation could also provide some insight for other assets types, as well as helping to assess this system service.
KPI Description	Bidding price estimation, based on the costs of providing the service.
Unit	€/MVARh
Formula	Calculations could consider fixed and variable costs, and in general depend on the asset considered, see for example "A Model for Reactive Power Pricing and Dispatch of Distributed Generation", H. Haghighat; S. Kennedy.
Target value	No target
Baseline scenario	Currently reactive power should be inside a regulated range near zero and penalties are applied if this range is exceed.
Smart-Grid scenario	FlexHub reactive power market will allow to provide other reactive power values, suitable for the TSO, and outside the range mentioned.

KPI n°2	
KPI name	**Service cost of providing reactive power.**
Main objective	Bids are used to provide the TSO reactive power request. However, guaranteeing that no DSO grid constraints are violated, may also imply some resources usage. The objective of this KPI is to assess the service cost and its allocation between TSO and DSO according their respective resources usage.
KPI Description	The OPF market clearing will provide the service cost. By clearing without TSO reactive power requirements, the cost of the resources used by the DSO alone can be estimated.
Unit	€/MVARh and %
Formula	As described two OPF must be run and costs subtracted.
Target value	No target
Baseline scenario	No TSO reactive profile requested.
Smart-Grid scenario	TSO reactive profile requested.

KPI n°3	
KPI name	**Bidding price estimation of providing active power**
Main objective	The objective is to estimate a reasonable price for the wind power generators to participate in the new active power reserve market proposed. This cost could be estimated by assessing the energy opportunity costs with past data.
KPI Description	Bidding price estimation of providing active power in the proposed extended tertiary reserve market.
Unit	€/MWh
Formula	Cost-benefit analysis considering energy and reserve historical market prices, forecasted generation profiles, and other technical issues could be used.
Target value	No target.
Baseline scenario	No participation in replacement reserve services

Smart-Grid scenario	Participating in the extended replacement reserve service

KPI n°4	
KPI name	**Estimation of the increment of reactive power flexibility for the network operators (TSO and DSO).**
Main objective	Assessment of the increased reactive power regulation that can be provided from the assets in the DSO grid with the proposed market and corresponding regulation, for the demonstration assets.
KPI Description	The increment of reactive power regulation will depend on the technical features of wind generators and electronic equipment, but also on the regulatory changes allowing the provision of this service with the proposed market, to benefit from the existing distribution grid flexibility.
Unit	MVARh
Formula	$\sum_{assets}(Q.T),\ st\ grid\ constraints$ (reactive power by time)
Target value	No target
Baseline scenario	Without reactive power market (BAU)
Smart-Grid scenario	With the proposed reactive power market

KPI n°5	
KPI name	**Estimation of the increment of active power flexibility for the TSO**
Main objective	Assess the increment of active power regulation that can be provided from the assets of the FlexHub demonstration.
KPI Description	The increment of active power regulation will depend on the technical features of the wind generators and their electronic equipment, and on the opportunity cost of providing this service.
Unit	MWh
Formula	$\sum_{assets}(P.T),\ st\ grid\ constraints$ (active power by time)
Target value	No target
Baseline scenario	Without replacement reserve market participation (BAU)
Smart-Grid scenario	With the participation in the proposed active power market

KPI n°6	
KPI name	**Error in the reactive power provision service**
Main objective	Assess the difference between the requested reactive power and the reactive power finally provided.
KPI Description	Due to non-continuous regulations, losses, grid constraints, etc, it becomes of interest assessing the error of providing the reactive power hypothetically requested by the TSO.
Unit	%
Formula	$(Provided\_Q - Req\_Q)/Req\_Q$
Target value	Null error
Baseline scenario	Ideal performance

Smart-Grid scenario	Real performance

KPI n°7	
KPI name	**Error in the active power provision service**
Main objective	Assess the difference between the requested active power and the active power finally provided.
KPI Description	Due to non-continuous regulations, losses, grid constraints, etc, it becomes of interest assessing the error providing the active power hypothetically requested by the TSO.
Unit	%
Formula	$(Provided\_P - Req\_P)/Req\_P$
Target value	Null error
Baseline scenario	Ideal performance
Smart-Grid scenario	Real performance

KPI n°8	
KPI name	**Execution time of the Q market clearing process**
Main objective	The computational processes involved are complex and it is difficult to forecast the time required. The objective is to assess this time to test the feasibility of such a service, or the need of especial computational resources.
KPI Description	The whole process will be simulated under different conditions to test the execution times and assess the feasibility of the proposal, the need of special requirements to comply with initially proposed time-periods, or the need of enlarging these times.
Unit	s
Formula	Measured time of the whole process execution
Target value	Below the delivery time period (15 min)
Baseline scenario	Ideal performance
Smart-Grid scenario	Real performance

KPI n°9	
KPI name	**Execution time of TLQ process for the P market participation**
Main objective	The computational processes involved are complex and it is difficult to forecast the time required. The objective is to assess this time to test the feasibility of such a service, or the need of especial computational resources.
KPI Description	The whole process will be simulated under different conditions to test the execution times and assess the feasibility of the proposal, the need of special requirements to comply with initially proposed time-periods, or the need of enlarging these times.
Unit	s
Formula	Measured time of the whole process execution
Target value	Below the delivery time period (15 min)
Baseline scenario	Ideal performance

Smart-Grid scenario	Real performance

KPI n°10	
KPI name	**Network secure operation margins while delivering reactive power**
Main objective	The objective is to test how the resources activation respect the secure operation margins while making a more efficient usage of the grid.
KPI Description	Different simulations may allow to see how the service is differently provided when the grid margins security coefficients vary, pushing the grid closer to the grid constraints violation.
Unit	%
Formula	An average measure of how the grid constraints are violated will have to be designed, by comparing the resulting line flows and voltage nodes with their margins.
Target value	No target
Baseline scenario	No flexhub reactive power market
Smart-Grid scenario	With the flexhub reactive power market

KPI n°11	
KPI name	**Network secure operation margins while delivering active power**
Main objective	The objective is to test how the resources activation respect the secure operation margins while making a more efficient usage of the grid.
KPI Description	Different simulations may allow to see how the service is differently provided when the grid margins security coefficients vary, pushing the grid closer to the grid constraints violation.
Unit	%
Formula	An average measure of how the grid constraints are violated will have to be designed, by measuring, for each constraint line flow and voltage node, how far they are from their limits.
Target value	No target
Baseline scenario	Without replacement reserve market participation (BAU)
Smart-Grid scenario	With the participation in the proposed active power market

KPI n°12	
KPI name	**Modelling error of the dynamic model BUC**
Main objective	The objective is to assess the errors between the real grid behavior and the behavior as represented by the simplified dynamic model
KPI Description	Since the model is a simplified representation of the distribution grid, this KPI is to determine how well the proposed model is performing in terms of errors. Different performance test will need to be designed to see how the models performs.
Unit	%
Formula	Error of the model performance under frequency or voltage disturbances.
Target value	No error

Baseline scenario	Ideal model performance
Smart-Grid scenario	Real model performance

KPI n°13	
KPI name	**Benefit of a dynamic model vs a static resistive model**
Main objective	The objective is to qualitatively assess the benefits of using a dynamic representation of the distribution grid, instead of a conventional resistive model, for the TSO dynamic analysis.
KPI Description	Since dynamic analysis should have a good dynamic representation of the whole grid, the dynamic model BUC tries to improve the static models traditionally used by for the distribution grids. A better dynamic representation of these grids should improve the quality of the models the TSO uses for dynamic analysis. This KPI tries to qualitatively assess these benefits.
Unit	Qualitative assessment
Formula	List of benefits and drawbacks of such approach
Target value	No target
Baseline scenario	The distribution grid is represented with a static resistive model
Smart-Grid scenario	The distribution grid is represented with the equivalent dynamic model

4.5 PORTUGAL: VPP

4.5.1 DESCRIPTION OF THE DEMONSTRATION

The demonstration is located in the north of Portugal and consists in a Virtual Power Plant that will provide multi-services for coordination of centralised flexibilities (large-scale storage and RES power plants) and will participate in the wholesale and ancillary services markets. The equipment used comprise a variable speed pump storage Hydro Plant (756 MW), the wind park Alto da Coutada (115 MW, 57 turbines), the wind Park Falperra (50 MW, 25 turbines) and resources connected to the transmission grid.

The demonstration aims at developing a power dispatch optimizer that will support a new balancing area concept, help decrease in the imbalances in participation of RES in energy markets, maximize the profit in Wind Parks operation, by reducing O&M expenses and therefore increase the revenue brought about by using a VPP, as opposed to the individual operation of the units. The forecasts accuracy of price and resource availability will be increased.

The demonstration has several innovative aspects:

- Real-time management of the storage and generation portfolio: based on mathematical models including short term balancing operations;
- Integrating forecasting modules for prices, energy supply and demand;
- Market bidding suite for the different markets, respecting long term strategies for storage management.

4.5.2 KEY PERFORMANCE INDICATORS

KPI n°1	
KPI name	**Increase in revenue of the flexibility service provider (Overall economic performance of delivery via a VPP)**
Main objective	Assess total revenue increase
KPI Description	Calculation of the increase in revenue (from all services provision) brought about by using a VPP (as opposed to the individual operation and dispatch of units)
Unit	%
Formula	$$\Delta_{revenue} = \frac{Rev_{VPP} - \sum_{n=1}^{N} Rev_{Unit\,n}}{\sum_{n=1}^{N} Rev_{Unit\,n}} \cdot 100\%$$
Target Value	> 0
Baseline scenarios	Wind Parks without feed-in tariffs and going individually to the energy markets. The hydro power plant (VNIII) not belonging to a balancing area and go individually to the market.
Smart-Grid scenarios	With EU-SysFlex innovation. Aggregated (WP + VNIII) to the energy markets and the VPP as a balancing area.

KPI n°2	
KPI name	**Maximizing the profit in Wind Parks operation, by reducing O&M expenses**
Main objective	Assess the benefit (profit) allowed by the use of a wind park control optimization tool developed by Siemens.
KPI Description	Through Siemens optimization tool, detailed models for the WP will be used, allowing an optimized control and costs reduction
Unit	€
Formula	$$\Delta_{profit} = \frac{Profit_{Opt\,tool} - Profit_{baseline}}{Profit_{baseline}} \cdot 100\%$$
Target Value	> 0
Baseline scenarios	No
Smart-Grid scenarios	Demo period

KPI n°3	
KPI name	**Variation in the imbalances in participation of RES in energy markets**
Main objective	Assess the variation on the imbalances due to the VPP innovation

KPI Description	Two scenarios are compared: one in which RES reach the market through a VPP and another in which RES participate as a single unit
Unit	% (MWh)
Formula	$$\Delta_{Imabalance}=\frac{Imb_{VPP}-Imb_{single\ unit}}{Imb_{VPP}}\cdot 100\%$$ "Imb" stand for the imbalances (in MWh) of a given RES unit in both participation scenarios
Target Value	< 0
Baseline scenarios	Wind Parks without feed-in tariffs and going individually to the energy markets. The hydro power plant (VNIII) not belonging to a balancing area and go individually to the market.
Smart-Grid scenarios	With EU-SysFlex innovation. Aggregated (WP + VNIII) to the energy markets and the VPP as a balancing area.

KPI n°4	
KPI name	**Market price forecasts quality**
Main objective	Determine the accuracy of the new VPP price forecasting tools
KPI Description	Comparison of forecasted and actual prices in the intra-day, day ahead and ancillary services markets
Unit	% (€)
Formula	Forecast error: deviation between the actual market price for a given moment t (day, hour) and the forecasted price, as percentage of the actual value. $$\varepsilon_{mkt\ prices}(t)=\frac{p_{actual}(t)-p_{estimated}(t)}{p_{estimated}(t)}\cdot 100\ \%$$
Target Value	The target value should be higher than the reference taken from the current forecasting tools from EDP's trading unit (to be determined)
Baseline scenarios	No
Smart-Grid scenarios	Demo period

KPI n°5	
KPI name	**Quality of forecasts of available Renewable Energy Sources (RES) power and water level of pumped storage plants**

Main objective	Determine the accuracy of the new VPP forecasting tools for RES availability and water level at hydro power plants.
KPI Description	Comparison of forecasted and actual available power from RES
Unit	% (MW)
Formula	$\varepsilon_{RES\ Power}(t) = \frac{P_{actual}(t) - P_{estimated}(t)}{P_{estimated}(t)} \cdot 100\ \%$
Target Value	The target value should be higher than the reference taken from the current forecasting tools from EDP's trading unit (to be determined)
Baseline scenarios	No
Smart-Grid scenarios	Demo period

KPI n°6	
KPI name	**Services dispatch success rate**
Main objective	Determine the VPP response success rate due to TSO requests.
KPI Description	Evaluate the response of the generation units to the market requests or TSO.
Unit	% (MW)
Formula	$SR = \frac{Positive\ responses}{Total\ responses} * 100\%$
Target Value	> 95%
Baseline scenarios	No
Smart-Grid scenarios	Demo period

4.6 FRANCE

4.6.1 DESCRIPTION OF THE DEMONSTRATION

The concept of multi-resources aggregation for multi-services provision is proposed in the French demonstration of the EU-SysFlex project. The demonstrator comprises a wind farm built and operated by Enercon connected to the public distribution grid and resources implemented at the EDF Concept Grid facility (Figure 7), which is a private distribution grid dedicated to the test and validation of smart grid equipment, systems and functions. The portfolio of resources is composed of a 12-MW wind farm, a 2.3- MW/1h lithium-ion battery system, some photovoltaic panels and a variable load test bench, combined with power amplifiers. All the resources will be controlled remotely through a newly developped IEC-61850-based and hardware-agnostic communication platform, which helps to ensure the interoperability and replicability of the demonstrated solutions. The detailed description of the French demonstration can be found in the D8.1 public report of the project, which is available online.

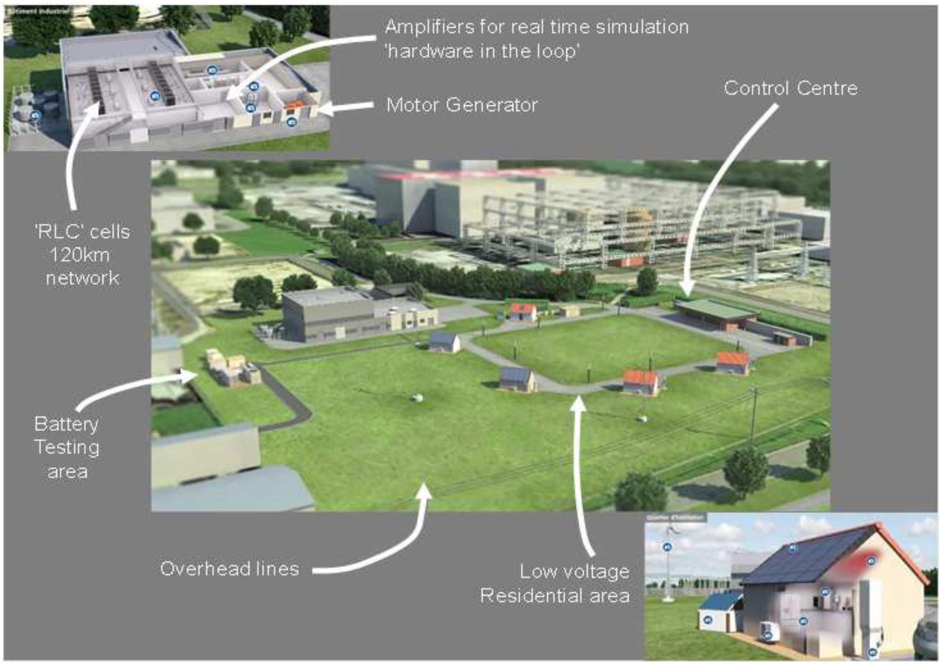

FIGURE 7: EDF CONCEPT GRID: A REAL NETWORK SPANNING FROM THE PRIMARY SUBSTATION UP TO THE METER AND END-CUSTOMER

The main objectives of the demonstration are:

- to demonstrate the technical feasibility of performing optimal management and coordinated control of the multi-resources aggregator to provide multi-services to the power system, by taking into account renewable generation forecasts, market prices, services remunerations, etc.;
- to assess the performances of different services and flexibility solutions that can be procured from the aggregator by considering the power system's needs and grid codes' requirement.

The multi-service operation will be achieved using a dedicated two-level supervisory control (Figure 8). First, a remote supervision will perform day-ahead scheduling of services allocation to maximize profitability while satisfying different constraints (e.g. battery state of charge) and requests from the system operators. It will also make intraday adjustments of the schedule in order to limit the impact of the deviations due notably to RES forecast errors and take appropriate actions if any contingency occurs. Secondly, local controllers of each resource will autonomously manage the execution of the optimized schedule in real time.

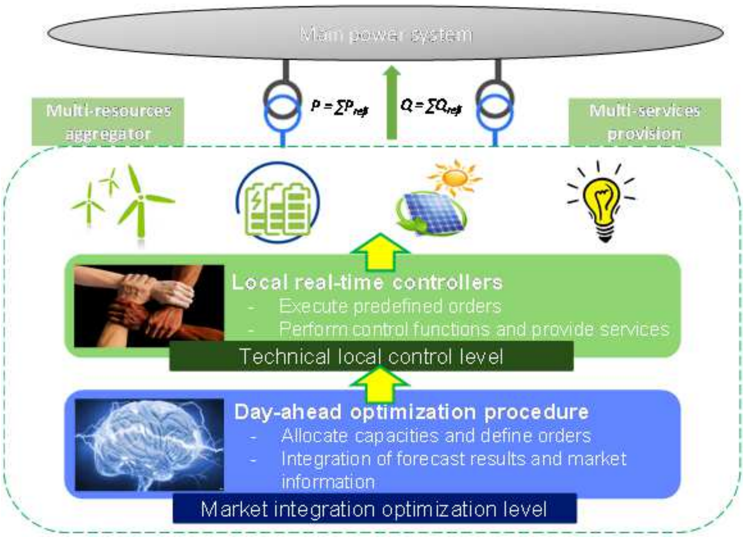

FIGURE 8: GENERAL OPERATING PRINCIPLE OF THE MULTI-RESOURCES MULTI-SERVICES DEMONSTRATOR

The French demonstration will test the following services:

- Frequency support services: FCR, FRR and FFR;
- Flexibility solutions: ramp-rate control / smoothing, peak shaving;
- Reactive power services: local voltage support, dynamic reactive response;
- Energy arbitrage by the aggregator as a whole.

4.6.2 KEY PERFORMANCE INDICATORS

KPI n°1	
KPI name	**Increase in revenue of the flexibility service provider (multi-resources aggregator for multi- services provision)**
Main objective	Assess the increase in revenue due to the use of an optimization procedure based on determinist or stochastic approaches within the scheduler.
KPI Description	In a context of aggregation of various assets, the use of an optimizer will help maximize the revenue of the aggregator when providing multi-services by taking account generation forecasts, market prices, service remunerations, etc. This will encourage new players to participate in ancillary service markets.
Unit	%
Formula	$IR[\%] = \frac{G_{EUSysFlex} - G_{BaU}}{G_{BaU}} \times 100\%$ Where: $G_{EUSysFlex}$ [€] is the measured or simulated aggregator revenue when EU-SysFlex solutions are applied (while the WP8 demonstrator is operated with the scheduler developed).

	G_{BaU} [€] is the simulated aggregator revenue in the BaU (Business as Usual) scenario (without optimal use and economic dispatch of the aggregator's assets).
Target value	no target
Baseline scenario	w/o SysFlex innovation: assets aggregated without optimization
Smart-Grid scenario	with EU-SysFlex innovation. Horizon: demo period

KPI n°2	
KPI name	**Compliance of existing services provision to SO's requirements**
Main objective	Evaluate the performances and reliability of the services provided by the aggregator corresponding to the existing products in the current ancillary services market or grid codes of continental Europe.
KPI Description	The WP8 demonstrator will provide multi-services to the power system. The idea is to analyse the performance and reliability of some of the services corresponding to the existing products in the current system, such as FCR, aFRR and voltage controls. The current and updated ENTSO-E grid codes, although initially defined for the qualification and performance control of the services provided by conventional generators, will be used as references for this KPI evaluation. Suggestions on methods adaption could be given to assess the performance of the corresponding services procured from renewables or storage according to the experimental results analyses and field tests feedback.
Unit	Y or N
Formula	Detailed description of the TSO requirement, performance measurement approaches as well as the performance control formula for the different existing services can be found in the ENSTO-E guideline and in the French / German grid codes. These approaches will be applied firstly to assess this KPI.
Target value	SO's prescriptions
Baseline scenario	
Smart-Grid scenario	

KPI n°3	
KPI name	**Compliance of "new" services provision to SO's set points**
Main objective	Evaluate the performances and reliability of the services provided by the aggregator which do not yet exist in the current ancillary services market or required by the grid codes of continental Europe.
KPI Description	The WP8 demonstrator will provide multi-services to the power system. The idea is to analyse the performance and reliability of some "new" services that could be provided by the aggregator, such as FFR and flexibility solutions (ramp rate control or peak shaving). These services have not been required in the current continental grid codes and could be of good interest and potential in the future. The performance measurement methods may be defined at a later stage through discussions with the system operators. Suggestions can also be given according to the experimental results analyses.
Unit	-
Formula	Some updated grid codes (Ireland, UK, etc.) including fast frequency response requirement could be used as reference documents.
Target value	
Baseline scenario	
Smart-Grid scenario	

KPI n°4	
KPI name	**Availability of service provision**
Main objective	Evaluate the performance of all the developed control modules as well as of the global communication infrastructure and assess the capacity of the whole aggregator to participate in multi-services provision.
KPI Description	It is important to ensure the effective participation of the aggregator in different services as scheduled to guarantee the revenue income for the operator. This KPI allows to measure the global performance of all the solutions as well as control modules developed to operate the demonstrator and can be assessed by the percentage of time during which the programmed services are delivered as expected with required performance.
Unit	%
Formula	$SPR[\%] = \frac{TPS}{TPS + TRS} \times 100\%$ Where:

	TPS [min] is the time duration in which the aggregator provides correctly the scheduled services. TRS [min] is the period of time during which the aggregator should have provided some services but fails to do so for different technical reasons.
Target value	
Baseline scenario	
Smart-Grid scenario	

KPI n°5	
KPI name	**Availability of the communication infrastructure**
Main objective	Evaluate the performance of the communication infrastructure and the IT solutions applied in the WP8 demonstration.
KPI Description	To ensure the interoperability and scalability of the WP8 demonstrator, a new full IEC 61850 based and hardware-agnostic R&D software and communication platform is developed. The availability of this ICT (Information and Communication Technology) infrastructure and interface is essential to ensure the constant exchanges between the centralised control and all the assets, so as to guarantee a proper functioning of the aggregator and its full services delivery capacity. This availability can be measured in percentage of the time during which the communication infrastructure is working as expected.
Unit	%
Formula	$AV[\%] = \frac{T_{com}}{T_{op}} \times 100\%$ Where: T_{com} [s] is the total duration in which all the communication platform is working correctly as defined in the demonstration specifications. T_{op} [s] is the total operational time of the aggregator during the tests carried out.
Target value	as close to 100% as possible
Baseline scenario	no baseline
Smart-Grid scenario	

KPI n°6	
KPI name	**VRES Generation forecast quality**
Main objective	Evaluate the quality of the forecast methods and tools considering real measurement of the wind and PV generation.
KPI Description	The performance of generation forecasting will be a key factor for the multi-resources aggregator's operation and will have significant impacts on the quality of the services provided by variable renewables as well as on the market integration possibility of those services. This KPI can be determined by different indexes such as MAPE, RMSE, sMAPE, etc. The proposed approach is to use the RMSE (root-mean-square error) for performance evaluation.
Unit	%
Formula	$$FO[\%] = \frac{1}{P_{nom}} \sqrt{\frac{\sum_{t=1}^{T}(Forecast_t - Generation_t)^2}{T}} \times 100\%$$ Where: $Forecast_t$ [kW] is the wind or PV generation forecast at each time step t. $Generation_t$ [kW] is the measured wind or PV generation produced at each time step t. T [min] is the considered total period. P_{nom} is the installed capacity of the wind or PV farm.
Target value	It should be noted that the forecast perimeter in WP8 is at the level of a local production site for only demonstration purpose. Therefore the forecast error estimation cannot be compared with the value expected at regional or national levels.
Baseline scenario	
Smart-Grid scenario	

KPI n°7	
KPI name	**Services re-dispatch success rate (availability)**
Main objective	Evaluate the performance of the developed short-term control module regarding its capability of services re-dispatch.
KPI Description	One of the functionalities of the short-term control is to re-dispatch the allocation of services during unexpected operational events (e.g. loss of one unit, unavailability of a variable resource, etc.) to make sure that the programmed services can be delivered constantly with limited impact on the expected performance of service provision. The proper functioning of the short-term

	control can be assessed using the re-dispatch success rate, which is determined by considering the percentage of time during which the services re-allocation is successful when it is needed and technically possible.
Unit	%
Formula	$SRR[\%] = \frac{T_{redispatch\_suc}}{T_{redispatch\_act}} \times 100\%$ Where: $T_{redispatch\_suc}$ [s] is the time duration in which the short-term control succeeds in re-allocating the capacities and services to available resources or units during unexpected operational events. $T_{redispatch\_act}$ [s] is the total operational time during which unexpected events occur and services re-dispatch is technically possible (i.e. the corresponding function of the short-term control is activated).
Target value	
Baseline scenario	
Smart-Grid scenario	

4.7 DATA EXCHANGE (WP9)

4.7.1 DESCRIPTION OF THE DEMONSTRATION

Several demonstrations focus on different aspects of data management, including cross-border communication between data exchange platforms and with different stakeholders in order to facilitate cross-border exchange of flexibility services. The main objectives of these demonstrations can be summarized as follows:

- Affordable tool (demonstration A): Development of a tool for flexibility aggregators in order to enable an affordable access-to-market to small distributed flexibility sources. An interface between this tool and a data exchange platform referred to in task 9.3 will be developed.
- Flexibility platform (demonstration B): Develop a software application for flexibility trading market places to support TSO-DSO data exchanges for the effective supply of flexibility services from all sources connected to both the distribution grid and transmission grid. The application focusses on data exchanges between flexibility providers (including aggregators) and flexibility users (system operators). An interface between this software and a data exchange platform referred to in task 9.3 will be developed.
- Cross-border data exchange (demonstrations C, D and E): Development of a customer-centric cross-border data exchange model for flexible market design serving all stakeholders (TSOs, DSOs, suppliers, generators, consumers flexibility providers, ESCOs, etc.). The aim is not to develop a single data exchange platform but ensure the interoperability of different solutions. This Cross-border exchange of data will be tested:
    - (C): between data exchange platforms located in Estonia (Elering) and in Denmark (Energinet);

- (D): between a data exchange platform located in Estonia (Elering) and customers located in the distribution grid of ESO in Lithuania;
- (E): between a data exchange platform in Estonia (Elering), the ENTSO-E's platform in Brussels and a third party like aggregator (in country to be selected).

The demonstrations of WP9 will test recommendations from WP5 aiming at ensuring the scalability of data exchanges in particular concerning the requirements related to cyber security, data privacy, performance, procedures for handling massive flows of data, and functionalities. Functionalities are described in more than 20 system use cases in task 5.2.

4.7.2 KEY PERFORMANCE INDICATORS

In the following table, the green color in the cells means that KPIs are only assessed for the related demonstrations. For some of the KPIs, the units and target values are not defined yet. This will bedone at a later stage in the project.

<table>
<tr><th rowspan="4">#</th><th rowspan="4">KPI</th><th colspan="5">DEMONSTRATIONS</th></tr>
<tr><th>Affordable tool</th><th>Flexibility platform</th><th colspan="3">Cross-Border exchange of flexibility services</th></tr>
<tr><th>(A)</th><th>(B)</th><th>(C)</th><th>(D)</th><th>(E)</th></tr>
<tr><th></th><th></th><th>Elering + Energinet</th><th>Elering + ESO</th><th>Elering + ENTSO-E</th></tr>
<tr><td colspan="7">1. Global KPIs (project level KPIs)</td></tr>
<tr><td>1.1</td><td>KPI name: Easy access to own data
KPI description: Increase in number of European consumers (both individuals and organizations) that can access their electricity meter data (i.e. from all metering points, incl. from sub-meters) through a single access point no later than on the following day
Unit: %
Target value: At least [90] percent of European consumers in 2030</td><td style="background:#92d050"></td><td></td><td style="background:#92d050"></td><td style="background:#92d050"></td><td style="background:#92d050"></td></tr>
<tr><td>1.2</td><td>KPI name: Sharing information related to participation in flexibility market
KPI description: Increase in availability of all flexibilities to all concerned TSOs and DSOs as a result of sharing information related to participation in flexibility markets
Unit: %
Target value: At least [90] percent of all flexibilities in Europe are available to all concerned TSOs and DSOs by [2030]</td><td style="background:#92d050"></td><td style="background:#92d050"></td><td></td><td></td><td style="background:#92d050"></td></tr>
</table>

#	KPI	DEMONSTRATIONS				
		Affordable tool	Flexibility platform	Cross-Border exchange of flexibility services		
		(A)	(B)	(C)	(D)	(E)
				Elering + Energinet	Elering + ESO	Elering + ENTSO-E
1.3	KPI name: Energy services and applications benefiting from data exchange KPI description: Increase in number of metering points and applications connected by European data exchange model Unit: # Target value: European data exchange model connecting at least 100 million metering points and 1000 applications by [2020] and […] million metering points and […] applications by [2030]					
2. Non-functional KPIs – (from BUCs)						
2.1	KPI name: Delivery/Implementation KPI description: Application has been delivered into an environment available to partners for testing Unit: tbd Target value: tbd					
2.2	KPI name: Expected flexibility KPI description: it should be possible to calculate within some relative precision (p), actual flexibility available when a command is issued. This must take into account time delays in communication and variability in available flexibility Unit: relative precision (p) for flexibility availability Target value:					

#	KPI	DEMONSTRATIONS				
		Affordable tool	Flexibility platform	Cross-Border exchange of flexibility services		
		(A)	(B)	(C)	(D)	(E)
				Elering + Energinet	Elering + ESO	Elering + ENTSO-E
2.3	KPI name: Deliverability of flexibility service at time step t KPI description: the loads, or a percentage (p) of the loads, will turn off within some time (t) after the command to turn off is given. Unit: tbd Target value: tbd					
2.4	KPI name: duration of flexibility delivery KPI description: the loads will remain off for the duration promised by the flexibility provider. Unit: tbd Target value: tbd					
2.5	KPI name: Performance – messaging latency KPI Description: Exchange of date. Received by requesting party in due time Unit: Y or N Target value: Yes					
2.6	KPI name: User satisfaction KPI description: survey on the satisfaction of small distributed flexibility sources (consumers/generators) contributing to the aggregated flexibility Unit: tbd Target value: tbd					
2.7	KPI name: Open Source KPI Description: will the developments be open-source? share of open source components in the platform Unit: Y or N Target value: Yes or a percentage (For the flexibility platform, 80% of components used open-source components)					

#	KPI	DEMONSTRATIONS				
		Affordable tool	Flexibility platform	Cross-Border exchange of flexibility services		
		(A)	(B)	(C)	(D)	(E)
				Elering + Energinet	Elering + ESO	Elering + ENTSO-E
2.8	KPI name: Connectivity KPI Description: the flexibility platform (DEP) can receive information from Estfeed DEP and send information to Estfeed DEP Unit: Y or N Target value: Yes					
3. KPIs related to System Use cases – functional KPIs (from SUCs)						
3.1	KPI name: Collect energy data KPI description: N° of data hubs (existing and new data hubs) to be used for collecting the different types of energy data in the demos Unit: # data hubs Target value: at least 6 data hubs					
3.2	KPI name: Transfer energy data KPI description: Data exchange platform capable to transfer different types of data Unit: Y or N Target value: Yes					
3.3	KPI name: Provide list of suppliers and ESCOs KPI description: List of suppliers and service providers is available through the data exchange platform. List of aggregators is available through the flexibility platform Unit: Y or N Target value: Yes					
3.4	KPI name: Manage flexibility bids KPI description: Effective flexibility prequalification and bidding processes supported by 'single flexibility platform' Unit: Y or N Target value: Yes					

#	KPI	DEMONSTRATIONS				
		Affordable tool	Flexibility platform	Cross-Border exchange of flexibility services		
		(A)	(B)	(C)	(D)	(E)
				Elering + Energinet	Elering + ESO	Elering + ENTSO-E
3.5	KPI name: Manage flexibility activations KPI description: Effective flexibility activation process supported by one 'single flexibility platform' Unit: Y or N Target value: Yes					
3.6	KPI name: Verify and settle activated flexibilities KPI description: Effective verification and settlement processes supported by 'single flexibility platform' Unit: Y or N Target value: Yes					
3.7	KPI name: Manage users' requests KPI description: *SUC not developed yet* Unit: tbd Target value: tbd					
3.8	KPI name: Notify customers KPI description: *SUC not developed yet (*GDPR compliance must be ensured.) Unit: tbd Target value: tbd					
3.9	KPI name: Manage authorizations (permissions) KPI description: Personal and other sensitive data can be exchanged based on data owner's consent (authorization). Authorization can be issued on data exchange platform. GDPR compliance must be ensured. Unit: Y or N Target value: Yes					

#	KPI	DEMONSTRATIONS				
		Affordable tool	Flexibility platform	Cross-Border exchange of flexibility services		
		(A)	(B)	(C)	(D)	(E)
				Elering + Energinet	Elering + ESO	Elering + ENTSO-E
3.10	KPI name: Authenticate data users KPI Description: Data users need to be authenticated on data exchange platform before having access to personal and other sensitive data. Representation rights can be given on data exchange platform. GDPR compliance must be ensured. Unit: Y or N Target value: Y					
3.11	KPI name: Manage security logs KPI Description: Data owner, application and data source can access logs related to data exchange and authorizations on data exchange platform. GDPR compliance must be ensured. Unit: Y or N Target value: Yes					
3.12	KPI name: Calculate flexibility baseline KPI description: Effective flexibility calculation process supported by 'single flexibility platform' Unit: Y or N Target value: Yes					
3.13	KPI name: Predict flexibility availability KPI description: Effective flexibility prediction processes supported by 'single flexibility platform' Unit: Y or N Target value: Yes					
3.14	KPI name: Process massive data KPI description: *SUC not developed yet* Unit: tbd Target value: tbd					

#	KPI	DEMONSTRATIONS				
		Affordable tool	Flexibility platform	Cross-Border exchange of flexibility services		
		(A)	(B)	(C)	(D)	(E)
				Elering + Energinet	Elering + ESO	Elering + ENTSO-E
3.15	KPI name: Manage sub-meter data KPI description: Effective sub-meter data management processes supported by data exchange platform Unit: Y or N Target value: Yes					
3.16	KPI name: Exchange data between DER and SCADA KPI description: Effective data exchange processes between DER resources and network operators supported by data exchange platform and flexibility platform Unit: Y or N Target value: Yes					
3.17	KPI name: Anonymize data KPI Description: *SUC not developed yet* Unit: tbd Target value: tbd					
3.18	KPI name: Aggregate energy data KPI Description: *SUC not developed yet* Unit: tbd Target value: tbd					
3.19	KPI name: Integrate new data source KPI Description: *SUC not developed yet* Unit: tbd Target value: tbd					
3.20	KPI name: Integrate new application KPI Description: *SUC not developed yet* Unit: tbd Target value: tbd					

#	KPI	DEMONSTRATIONS				
		Affordable tool	Flexibility platform	Cross-Border exchange of flexibility services		
		(A)	(B)	(C)	(D)	(E)
				Elering + Energinet	Elering + ESO	Elering + ENTSO-E
3.21	Detect data breaches KPI Description: *SUC not developed yet* (GDPR compliance must be ensured.) Unit: tbd Target value: tbd					
3.22	Erase and rectify personal data KPI Description: Effective erasure and rectification processes of personal data supported by data exchange platform. GDPR compliance must be ensured. Unit: Y or N Target value: Yes					

5. CLASSIFICATION OF KPIS

The KPIs defined in the various demonstrations and detailed in the previous chapter can be grouped in several categories. These categories answer the main questions that were raised in §3:

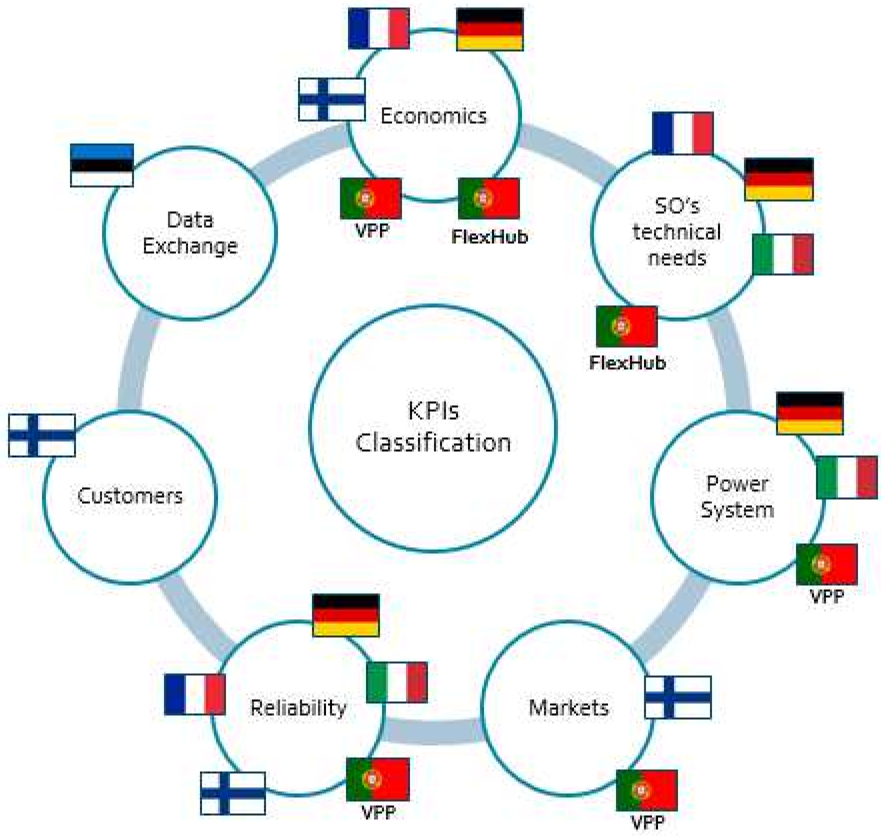

FIGURE 9: MAIN CATEGORIES OF KPIS

- The first category of indicators evaluates the economic impacts of the solutions. These are not impacts at the system level but rather local impacts such as the increase in revenue for the flexibility provider (measured in Finland, France, Portugal_Flexhub and Portugal_VPP), the decrease in cost for flexibility service provision (Germany, Finland), …
  - increase in revenue of the flexibility provider (measured in Finland, France, Portugal_Flexhub and Portugal_VPP);
  - decrease in cost for flexibility service provision (Germany, Finland);
  - cost sharing between TSO and DSO for congestion management (Portugal_Flexhub);
  - opportunity cost of providing a flexibility service (Portugal_Flexhub).
- The second category of indicators evaluate the progress of the solution towards the primary objectives of the project: meeting system operators' technical needs in terms of flexibility service provision (frequency regulation, voltage control, congestion management, …). In this category, the KPIs mainly measure the compliance to SO's requirements of existing services provision with new assets or of new services provision:

  - Compliance of existing services provision by new assets to SO's requirements (Germany, France);
  - Tracking error between a set-point requested by the SO and the measure (Italy, Portugal_Flexhub);
  - Increase in flexibility service provision capability (Italy, Portugal_Flexhub);
  - Compliance of new services provision (e.g. FFR) to SO's requirements (France);
- The third category addresses the impacts on the power system and in particular on the distribution grid where congestion must be avoided when providing flexibility services from distributed resources:
  - Line voltage profiles (Italy);
  - Hosting capacity variation (Italy);
  - Grid efficiency (Germany);
- The fourth category addresses market aspects:
  - Reactive power market utilization factor (Finland);
  - Variation in the imbalances in participation of RES in energy markets (Portugal_VPP).
- The fifth category evaluate the reliability and especially the availability of the services provided or of sub-systems (forecast, communication infrastructure). The latter may shed light on the former.
  - Availability of the flexibility services (Finland, Germany, Portugal_VPP);
  - Performance of aggregator in providing flexibility (data exchange demo A);
  - Availability of sub-systems
    - Availability of the aggregation platform (Finland)
    - Availability of the communication infrastructure (Italy);
    - Forecast quality (Italy, Germany, Portugal_VPP, France);
    - Flexibility services re-dispatch success rate (France).
- The sixth category deals with customers' acceptance in the Finnish demo and in one of the data exchange demos:
  - Customers' acceptance (Finland);
  - Customers' satisfaction contributing to aggregated flexibility (data exchange demo A).
- Finally, the last category deals with KPIs related to the data exchange demonstrations.

As can be seen on Figure 9, not all demonstrations address all categories. At the moment, For example, economic impacts are not measured in the Italian demonstration since solutions for congestions management are not regulated/remunerated in the current Italian regulatory framework. The impact on customers is measured in Finland where there is an aggregation of distributed flexibilities that can be customer-based but not in other demonstrations where there are no direct links with customers.

The entire list of KPIs is summarized per categories and demonstrations in the two following tables.

	Finland	Italy	Germany	Portugal Flexhub	Portugal VPP	France
Economic impacts						
Increase in revenue of the flexibility provider	■			■	■	■
Decrease in cost for flexibility service provision	■		■			
Cost sharing between TSO and DSO for congestion management				■		
Opportunity cost of providing a flexibility service				■		
Meet SO's needs						
Compliance of existing services provision by new assets to SO's requirements			■			■
Tracking error between a set-point requested by the SO and the measure		■		■		
Increase in flexibility service provision capability		■		■		
Compliance of new services provision (e.g. FFR) to SO's requirements						■
Impacts on the power system						
Line voltage profiles		■				
Hosting capacity variation		■				
Grid efficiency			■			
Impacts on markets						
Reactive power market utilization factor	■					
Variation in the imbalances in participation of RES in energy markets					■	
Reliability						
Availability of the flexibility services	■		■		■	
Availability of the aggregation platform	■					
Availability of the communication infrastructure		■				
Forecast quality		■	■		■	■
Flexibility services re-dispatch success rate						■
Impacts on customers						
Customers' acceptance	■					

TABLE 3: PROPOSED KPIS FOR THE WP6 (FINLAND, ITALY, GERMANY), WP7 (PORTUGAL_FLEXHUB, PORTUGAL_VPP) AND WP8 (FRANCE) DEMONSTRATIONS

#	KPI	Data Exchange (WP9)				
		Affordable tool	Flexibility platform	Cross-Border exchange of flexibility services		
		(A)	(B)	(C)	(D)	(E)
				Elering + Energinet	Elering + ESO	Elering + ENTSO-E
1. Global KPIs						
1.1	Easy access to own data					
1.2	Sharing information related to participation in flexibility market					
1.3	Energy services and applications benefiting from data exchange					
2. Non-functional KPIs – (BUCs)						
2.1	Delivery/Implementation					
2.2	Expected flexibility					
2.3	Deliverability of flexibility service at time step t					
2.4	Duration of flexibility delivery					
2.5	Performance – messaging latency					
2.6	User satisfaction					
2.7	Open Source					
2.8	Connectivity					
3. KPIs related to System Use cases – functional KPIs (SUCs)						
3.1	Collect energy data					
3.2	Transfer energy data					
3.3	Provide list of suppliers and ESCOs					
3.4	Manage flexibility bids					
3.5	Manage flexibility activations					
3.6	Verify and settle activated flexibilities					
3.7	Manage users' requests					
3.8	Notify customers					
3.9	Manage authorizations (permissions)					
3.10	Authenticate data users					
3.11	Manage security logs					
3.12	Calculate flexibility baseline					
3.13	Predict flexibility availability					
3.14	Process massive data					
3.15	Manage sub-meter data					

#	KPI	Data Exchange (WP9)				
		Affordable tool	Flexibility platform	Cross-Border exchange of flexibility services		
		(A)	(B)	(C)	(D)	(E)
				Elering + Energinet	Elering + ESO	Elering + ENTSO-E
3.16	Exchange data between DER and SCADA					
3.17	Anonymize data					
3.18	Aggregate energy data					
3.19	Integrate new data source					
3.20	Integrate new application					
3.21	Detect data breaches					
3.22	Erase and rectify personal data					

TABLE 4: PROPOSED KPIS FOR THE DATA EXCHANGE DEMONSTRATION (WP9)

6. FOLLOW-UP OF THE WORK

This document presents the lists of KPIs defined for each demonstration in the EU-SysFlex Project. A work on project-related indicators started also in 2018, to extend the present work on demo KPIs to higher level indicators concerning not the demonstrations only, but the whole project and its overarching objective of integrating over 50% RES in the European power system. Project-related indicators or KPIs will cover the main results of the EU-SysFlex project and feed the roadmap for flexibility at the end of the project. They are out of the scope of this document and have not been finalized yet because more time was needed to have a better understanding of the global challenges (further to the demonstrations) and of long-track results in transverse WPs. Besides, the ETIP-SNET framework mentioned in §2 and used in past smart-grid projects will be used as a basis for project-related KPIs development so that the contribution of the EU-SysFlex project to the EU objectives can be evaluated.

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